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Analysis of the influence of false twist integrated into a high speed drafting system of an air jet spinning machine

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Abstract

Air jet spinning is an emerging technology, already well established in the textile market. The commercial success increased over the last decades and intensified the research and innovation approach in the field of air jet spinning machines. The requirements for establishing air spun yarn in the textile market include high yarn quality, high production speeds and high material yield during the process.

The concept and the quality of the integrated drafting system of an air jet spinning machine is one of the responsible parts to influence the named requirements. Moreover, the drafting system directly influences the regularity of fibre motion during the transportation to the spinning nozzle. In this case, the fibres need to deal with challenges like highly increasing velocities of the roller pairs and resulting air turbulences which cause misaligned fibres at the main draft zone.

False twist is a well-known principle in the textile process technology. False twist is used to stabilize the spinning stability, to create special effects on yarn structure or to impact the spinning process in general.

Based on the principles of false twist, the aim of this work is to use the characteristics of false twist in the drafting system of an air jet spinning machine to improve the fibre motion during drafting. The PhD thesis presents the use of the principles of false twist implementation into the drafting system to influence the fibre control during high speed drafting for air jet spinning machines. Therefore, two prototypes were developed, tested, and evaluated by their impact for the fibre motion through the drafting system. A dynamic false twist device which can insert false twist individually set by torque and velocity into the drafted fibre bundle is used. Moreover, a video analysis tool was developed to measure the fibre motion.

Resumen

La hilatura por chorro de aire o neumática es una tecnología emergente, actualmente bien establecida en el mercado textil. Su éxito comercial ha aumentado en las últimas décadas y ha intensificado el enfoque de la investigación y la innovación en el campo de las máquinas de hilar por aire. Los requisitos para consolidar la hilatura por aire en el mercado textil incluyen una alta calidad del hilo, altas velocidades de producción y un alto rendimiento del material durante el proceso.

El concepto y la calidad del tren de estiraje integrado de una máquina de hilar por chorro de aire es uno de los aspectos más influyentes en los requisitos mencionados. Además, el sistema de estiraje influye directamente en la regularidad del movimiento de las fibras durante el transporte a la boquilla de hilatura de la tobera neumática. En este caso, las fibras tienen que enfrentarse a inconvenientes como el aumento de la velocidad de los pares de rodillos y las turbulencias de aire resultantes, que provocan la desalineación de las fibras en la zona de estiraje principal.

La falsa torsión es un principio bien conocido en la tecnología del proceso textil. Se utiliza para estabilizar la formación del hilo, para crear efectos especiales en la estructura del hilo o para influir en el proceso de hilatura en general.

Basándose en los principios de la falsa torsión, el objetivo de este trabajo es utilizar las características de la falsa torsión en el sistema de estiraje de una máquina de hilar por chorro de aire para mejorar el movimiento y recorrido de las fibras durante el estiraje. Esta tesis doctoral presenta el uso de los principios de la falsa torsión en el sistema de estiraje para mejorar el control de la fibra durante el estiraje de alta velocidad para máquinas de hilatura neumática. Por lo tanto, se ha desarrollado, probado y evaluado el impacto en el movimiento de la fibra en su recorrido durante a través del sistema de estiraje de dos prototipos funcionales. Además, se ha desarrollado una herramienta de análisis de vídeo para medir el movimiento de la fibra. En la parte teórica se ha desarrollado un análisis de control de integración de falsa torsión en un tren de estiraje de fibras, lo que ha simplificado la predicción de los movimientos de las fibras. Los análisis teóricos condujeron a un mejor conocimiento del movimiento de la fibra dentro de un sistema de estiraje de alta velocidad.

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1. Introduction

The industrial production of short staple yarn is dating back to the 18th century with the development of "Spinning Jenny" from Hargreaves in 1764 and the "Water-Frame" from Arkwright in 1769. However, the idea of using two rollers to draft a fibre bundle was already invented by J. Wyatt and L. Paul in 1738 [Weber, 1993, p.1, Baines, 1835, p. 139].

The "Lewis Paul's spinning machine" is the first patented invention which presents the drafting principle for spinning. The patent consists besides of using a roller drafting system, also of a principle for spinning yarn.

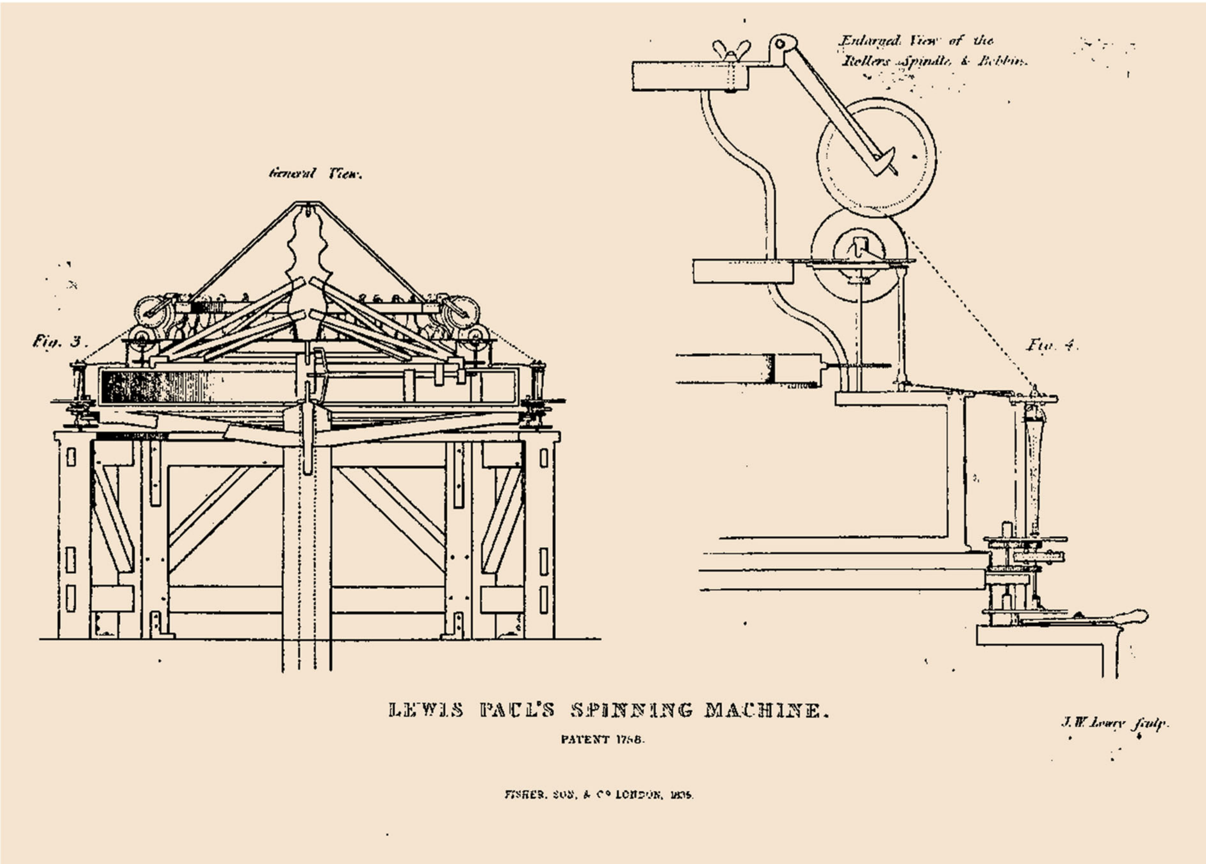


Figure 1 Patent drawing of "Lewis Paul's Spinning Machine" 1738

After the implementation of the industrial ring spinning machine in Great Britain and the industrialisation of Europe, other mechanical short staple spinning methods like open end rotor spinning and pneumatical short spinning methods like air jet spinning have been invented. Still, the ring spinning principle defends its position as worldwide most processing spinning system.

The air jet spinning technology is by far the youngest and the fastest spinning technology. However, high speeds require special solutions. The specialty of this technology is also its weak spot - the high speed. Since other spinning technologies never had the need to care about what high production speeds would require because of their mechanical limitations. For example, ring spinning is mechanically limited due to the centrifugal force of the yarn balloon around the spindle and the friction forces of the traveller on the ring [Klein, 2014, p.72]. Rotor spinning is limited by the centrifugal force of the rotor – higher rotational speed of the rotor would interfere with the mass of the rotor [Ernst, 2014, p. 26]. Since air jet spinning has no mechanical rotational parts during the yarn formation, it still has rotational parts at the drafting – this is the weak spot.

The drafting quality is responsible for the yarn evenness. Due to steadily increasing production speed, new challenges and requirements occur for the drafting system and always gives room for improvement and new developments. [Weber, 1993, p.4]

Drafting a fibre bundle is a well-known principle in different spinning technologies and machines along the textile process chain. They can differ by task, structure, draft-folds and productivity. Table 1 presents a basic overview of the variety in drafting.

Table 1 Basic overview of machines using drafting

Drafting system	**Draw frame**	**Roving frame**	**Ring spinning**	**Air jet spinning**
Drafting folds	4 – 11 folds	5 – 20 folds	8 – 80 folds	180 – 220 folds
Drafting speed	Up to 1000 m/min	Up to 25 m/min	Up to 25 m/min	Up to 450 m/min
Draft auxiliaries	Cot roller	Cot roller, apron pair, condensers	Cot roller, apron pair, condensers	Cot roller, apron pair, condensers

The aim of this work is to investigate the influence of false twist insertion at the high-speed drafting unit of an air jet spinning machine. A regular drafting unit consists of 3 or 4 roller pairs which rotate in different surface speeds to draft the delivered fibre material. Condensers and aprons help to keep the fibres in line of the drafting system and guide them until the fibres reach the point of yarn formation by twisting them and frictional forces hold the fibres together. That works if the surface speeds of the rollers do not interfere with the guidance of the fibres. In case of high drafting speeds, where the surface speed of the rollers reaches high velocities, it results in air turbulences around the rollers. Those air turbulences hinder the fibres by entering the clamping lines of the roller pairs uniformly and the yarn formation creates uneven yarn or may lead to interruptions of the spinning process.

Over the last decades, efforts have been taken to investigate this challenge and to find solutions. There are different points of view about how to approach this challenge. Some studies deal with the fibre motion at drafting units in general. This includes research in the field of fluid dynamics to learn more about the occurring air flows at the roller surfaces and their interference for the fibre flow. Particle Image Velocimetry- Analysis and Laser-Doppler method helped to understand the creation of the interfering air flows and fibre velocities in an experimental way [Weber, 1993, p. 11, Bergada, 2007].

Theoretical approaches with modelling and simulation of the interfering air flows and their impact on the fibre flow complement those studies.

Nevertheless, the simulation of fibre motion, influenced by the sum of all aerodynamic and mechanical forces is only a mathematical approach and represents not the actual fibre motion of all fibres yet. The actual behaviour of fibres moving through a drafting unit (or any other place where fibres move) still differs from the theory and challenges mathematicians until today [Beyreuther, 2007, p. 189/190, Schulte-Südhoff, 2015, p. 25, 28].

Here, another point of investigation takes place. Not the theoretical fibre motion stays in focus during the research, but the development of auxiliaries which could improve the fibre guidance through the drafting process is analysed. Those auxiliaries can create false twist on different levels. As theoretical attempt, those levels are tested with a control system using the signal input-output principle. As validation, experiments in spinning in combination with image processing from a high-speed-video is developed and used.

2. The state of art

2.1 Air jet spinning

2.1.1 Historical development of air jet spinning

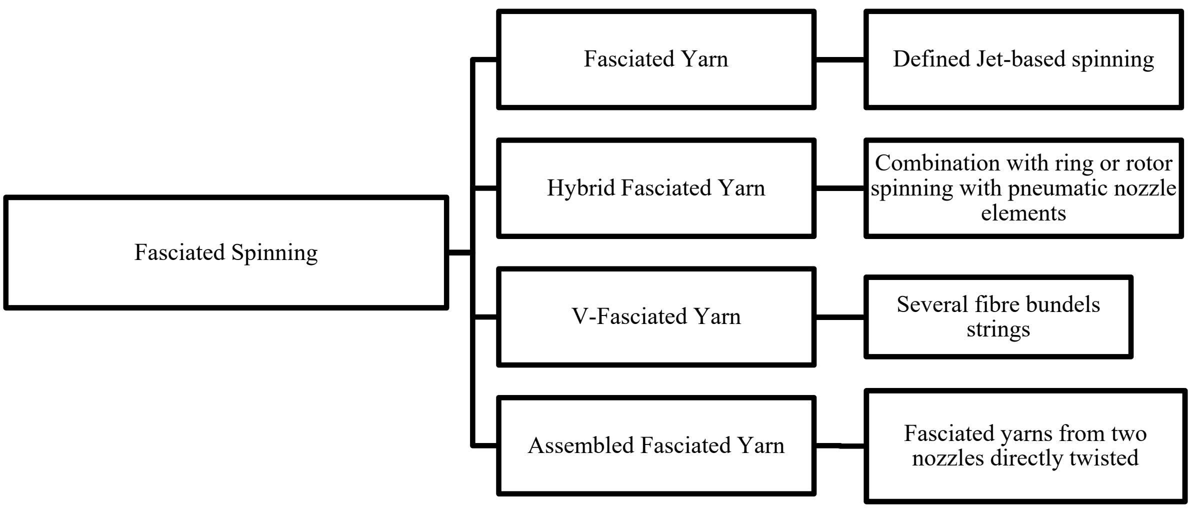
"A spinning system in which air is used to insert twist. Two technologies manufactured by Muratec are the MJS and the MVS (Vortex) systems" (definition by Textile Encyclopedia Cottonworks.com)

Considering the market requirements for faster production speeds and higher machine efficiency, regular spinning methods reach their limits. Conventional spinning processes are mechanical based methods where rotational machine parts are responsible for the yarn formation process by twist insertion. They all have a physical speed limitation because of centrifugal force and durability of the machine parts. Examples are ring spinning (spindle, traveler), rotor spinning (opening roller, rotor) or friction spinning (perforated roller pair) [Klein, 2014, p. 72, Ernst, 2014, p.26].

These limitations led to the idea of using air for twist insertion to produce yarn. The first mention of an air-based spinning process is the patent by Götzfried from 1955. Since then, several attempts to develop a stable spinning process using air have been made.

Table 2 gives an overview of the early air-based twist spinning methods, machines, and company names, constituted from the 1990's. At that time, yarn spun with air was so-called "fasciated yarn" [Schwabe, 1991].

Table 2 Overview Fasciated Spinning from 1991 (Source: based on Schwabe, 1991)



Under the name "fasciated spinning" not only todays known jet-based spinning principles are clustered. Also, the niche products of hybrid-, assembled- and V-fasciated yarns include air-based spinning methods.

However, only one machine manufacturer reached an industrial impact with its air-based spinning machines at that time. The Japanese company Murata Machinery Inc. invested successfully into the development of air jet spinning processes and owns the highest market share worldwide until today. An overview of today's market situation of air jet machine manufacturers is outlined in the following sub-chapter.

Although the idea of yarn formation with air was first invented by Götzfried in 1955 and several methods have been tried to implement at the market, the main industrial yarn production with air began in the late 1990's (Götzfried 1959, 1960, Göbbels, 1984). Table 3 gives a rough overview of the timeline of developments. Here, two main developments of air jet spinning occurred on the market – false twist and real twist – and two manufacturers are presented, Rieter and Murata.

Table 3 Timeline of developments in air jet spinning (source based on: Weide, 2004, p. 5)

Twist type	Fibre bundle	Timeline of developments
Real twist	connected	MVS Rieter J26 Vortex III 870
False twist	connected	Götzfried Murata MJS
Real twist	Open-end	Götzfried Vortex PF- 1
		1960 → 1970 → 1980 → 1990 → 2000 → 2010

In 1982, at the American Textile Machinery Exhibition, Murata Machinery Inc. introduced the *Murata Jet Spinner*, the MJS 801. It was the first air jet spinning machine with two air jet nozzles to create opposed vortices to spin yarn. The yarn formation results of repeating vibration of the fibre bundle along the longitudinal axe of the yarn and using false twist, created by the opposed vortices of the nozzles [Göbbels, 1984, Weide, 2004 p.10]. Due to the lack of tenacity of the produced yarns and the limitation of only processing blends and man-made fibres, but not 100 % cotton, the machine was not successful in the market.

Although, Murata modified the machine by implementing a 4-roller drafting system with the MJS 802 in the late 1980's which could reach a delivery speed up to 210 m/min, the two-nozzle jet spinning method could not entirely stand the high demands of the market. Therefore, it only holds a subordinated role at the market today. Still, the false twist-based air jet spinning method will be presented further in a sub-chapter.

Murata revised their concept of air jet spinning and invented the *Murata Vortex Spinning* method, the MVS. The first machine was exhibited at the OSAKA International Textile Machinery Show in 1997 under the name MVS 810. A 4-roller drafting system in combination with a single air-nozzle builds the base of the concept. The nozzle spins the yarn with real twist by combining parallel inserted fibres with wrapping fibres, created by a single vortex inside the nozzle. This concept allows the machine to produce yarn with higher tenacity due to the higher number of wrapping fibres with a delivery speed up to 400 m/min, and to process 100 % cotton.

This concept of air jet spinning reached a satisfied impact in the market and several machine generations followed. Table 4 lists the main MVS machine generations with their improvements and add-ons until now [based: Günaydin, 2017].

Table 4 Overview MVS machine generations (Source: Günaydin, 2017)

Year	Machine name	Max. delivery speed [m/min]	Improvement
1997	MVS 810 (T)	400	Yarn tenacity (T =twin)
2003	MVS 861	450	Coarse yarn possible; optimised winding tension, splicing possible
2011	MVS 870	500	Higher production speed
2015	MVS III 870	500	Polymaster to spin 100 % PES

The company Rieter, based in Switzerland, entered the air jet machine market at a later date. They introduced their first air jet spinning machine in 2008. The J10 is based on the same air jet technology as MVS but differs from construction and design. It can reach a delivery speed of 450 m/min. Since the first entry, new machine generations followed like J20 and J26 in 2011 and 2015 which differ in terms by increasing the spindle number, possible delivery speed and the possibility of processing polyester [Eldessouki, 2015, p. 1827, Oxenham, 2016].

2.1.2 Market share of air jet spinning

The production of yarn has a long history and will remain its important state in the nearest future. As long as there is a need for clothing and with the increase of the world population it is even presumed the total world production of yarn will increase [Gherzi, 2012, 2016, Rieter Briefing, 2015]. Figure 2 below shows the total yarn production in 2014 and the expected total yarn production in 2020, separated into the three main yarn production types as short staple, long staple, and filaments. The presumed yarn production in short staple spinning with 46 % remains high, considering the presumed increase of the yarn production in total.

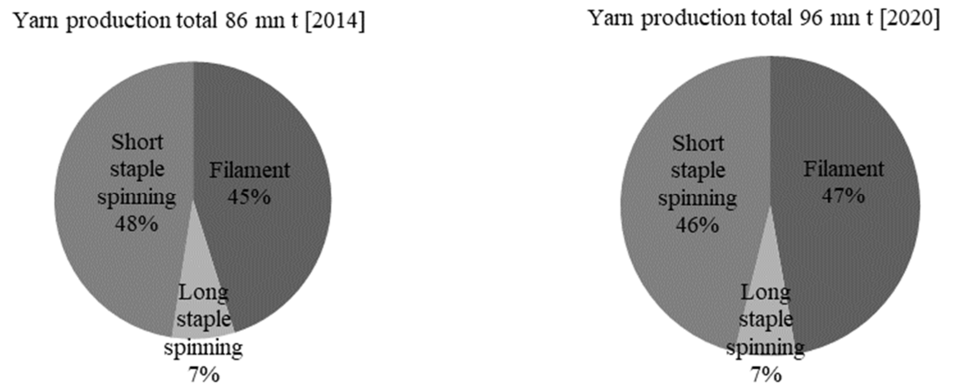


Figure 2 Left: Total yarn production 2014, right: Presumed total yarn production 2020 (Source: based on Gherzi, 2012, 2016)

Taking into account the fact of an increase of the total yarn production, the question of market shares of the single short staple spinning concepts appears. Over the centuries several spinning technologies were developed. Nevertheless, only three technologies remain their status in the commercially used spinning industry. Air jet spinning is the youngest and most promising spinning technology, considering its market growth over the years.

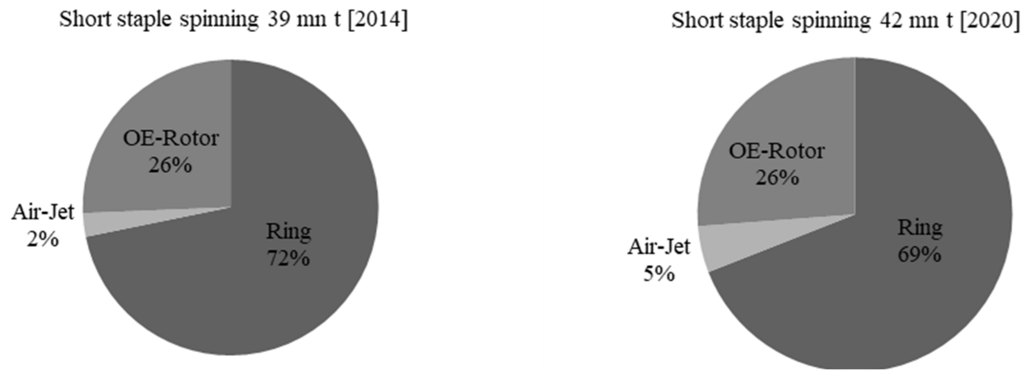


Figure 3 Total yarn production 2014 and presumed total yarn production 2020 worldwide (source based on: Gherzi, 2016)

Figure 3 below shows the market shares of ring spinning, rotor spinning and air jet spinning with the background of the total short staple spun yarn, produced in 2014 and the forecast for 2020. It shows a major increase in the air jet spun yarn production while the total short staple spun yarn production worldwide increases.

This global increase of air jet spun yarn production is even more noticeable considering the growth of air jet spun yarn over the years. The figure 4 shows the development of increasing air jet yarn production over the last 10 years [based on: Gherzi 2012, 2016].

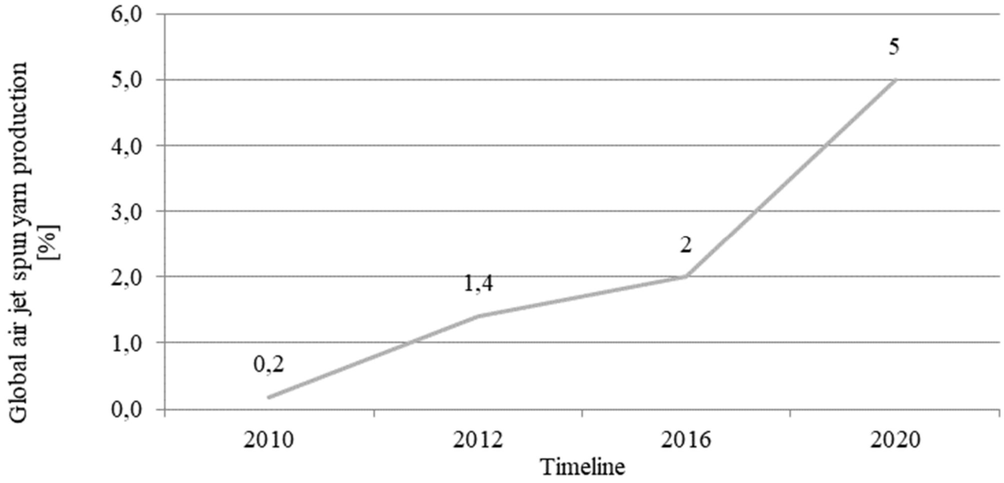


Figure 4 Development of air jet yarn production (Source: based on Gherzi, 2012, 2016)

This development of the global increase of air jet spun yarn production is mainly seen in the possibility for higher yarn quality and higher yarn finesses.

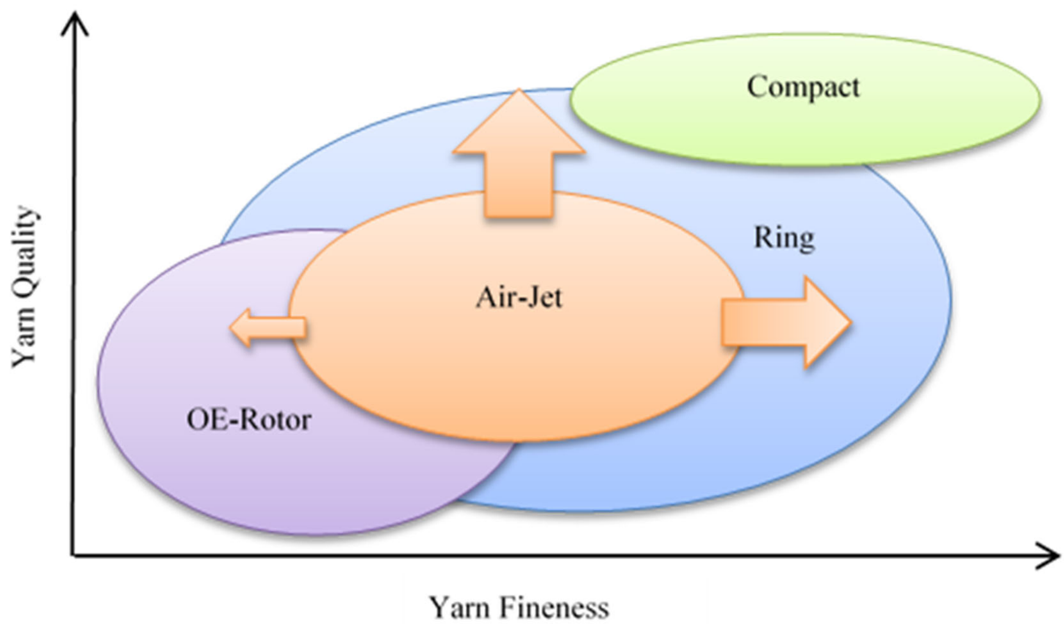


Figure 5 Expected growth of air-jet yarn production (based on: Povel, 2012)

The figure 5 visualizes this expected development in comparison to ring, compact and rotor yarn production, which gives air jet spinning the future competitive role against ring yarn [based on: Povel, 2012]

2.1.3 False twist air jet spinning technology

Although the false twist air jet spinning technology holds a small market share compared to real twist air jet spinning, the concept is presented in detail here. Considering the use of false twist during the yarn formation process, it can give another point of view for the understanding of *false twist* itself which is the investigated subject of this thesis. Nevertheless, the concept of false twist is explained separately in detail in chapter 2.3.

As mentioned in the previous chapter, the company Murata Machinery Inc. presented the first false twist-air-jet-spinning machine (Murata Jet Spinning) in the market in 1981. The machine consists of a 3 over 3 roller drafting system, two air jet nozzles, a take up roller pair and a yarn package build unit (seen in figure 6, based on: Stalder, 2014).

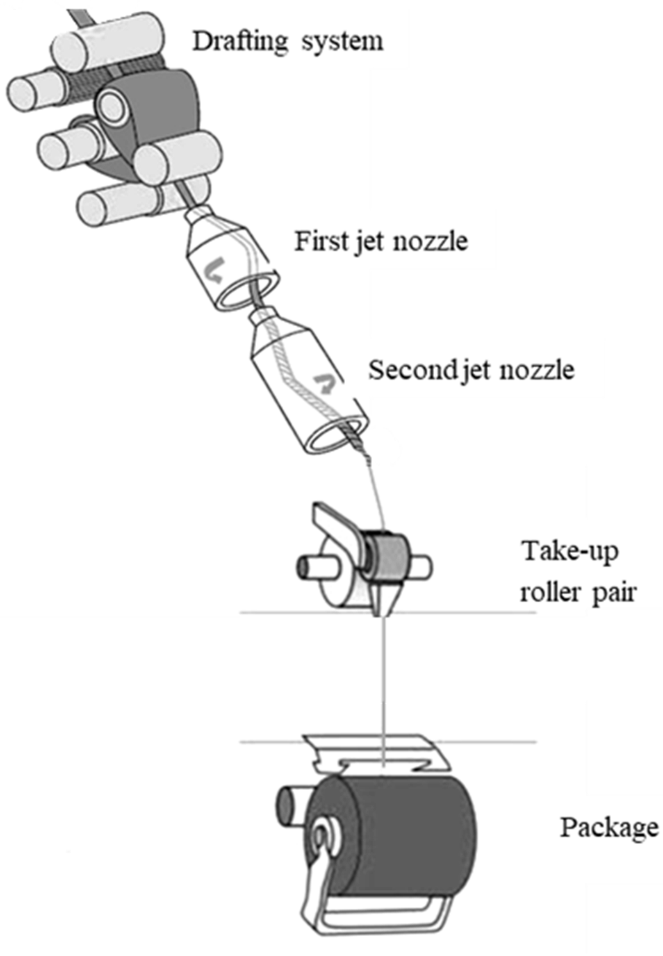


Figure 6 Principle of Murata Jet Spinning (Stalder, 2014)

The spinning process starts with the delivery of a fibre ribbon into the drafting unit. The roller pairs transport the ribbon with increasing rotation speed from roller pair to roller pair to reach the draft fold for the final yarn count. Aprons help to guide floating fibres through drafting system. It follows the 2-nozzle-system where compressed air is inserted through four tangential boreholes each to create vortices inside. The drafted fibre bundle is twisted and untwisted by passing the two nozzles, where airflow rotates in two different directions. During the untwist step, edge fibres leaving the fibre bundle with one fibre end and wrap around the core fibres which were not fully caught by the vortex. The actual false twist appears at the second nozzle. Friction forces of the fibres are responsible to create enough tenacity for the yarn formation process [Günyadin, 2017].

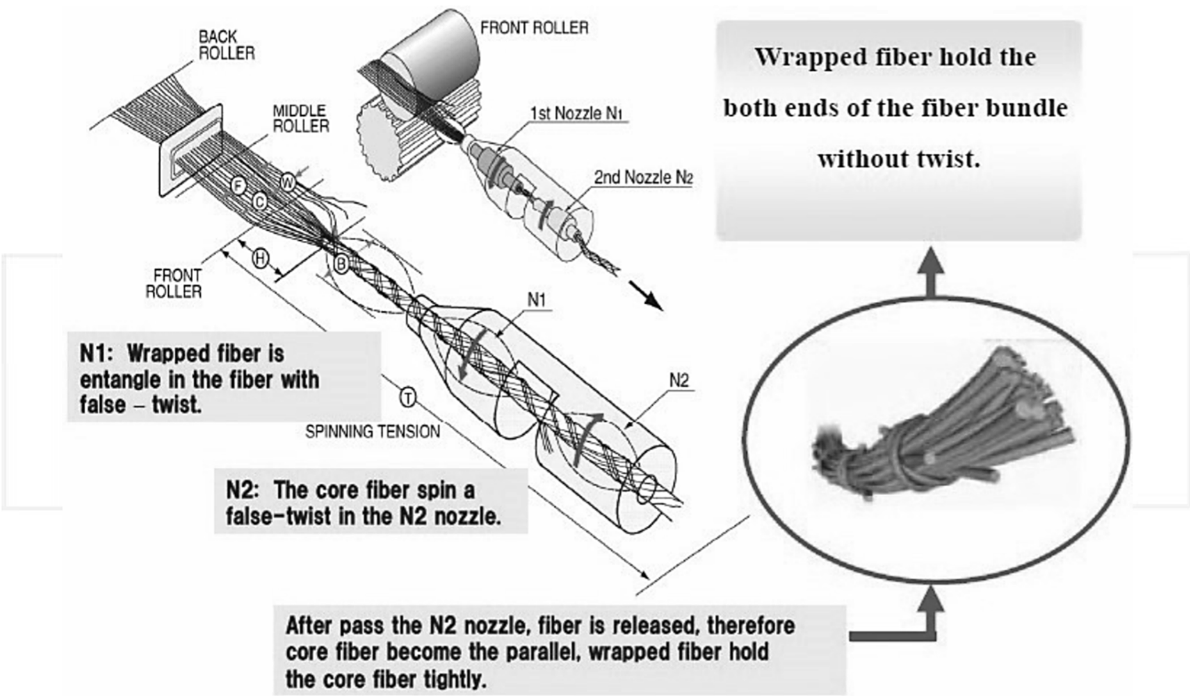


Figure 7 Detailed principle of Murata Jet Spinning (Günaydin, 2017)

For better understanding of the false twist effect, the twist and untwist steps and the appearance of wrapping edge fibres are presented in the figure 8. The diagram is based on a cartesian coordinate system, where the two twist directions are visualized as Z-twist and S-twist and represent the twist distribution in thread line.

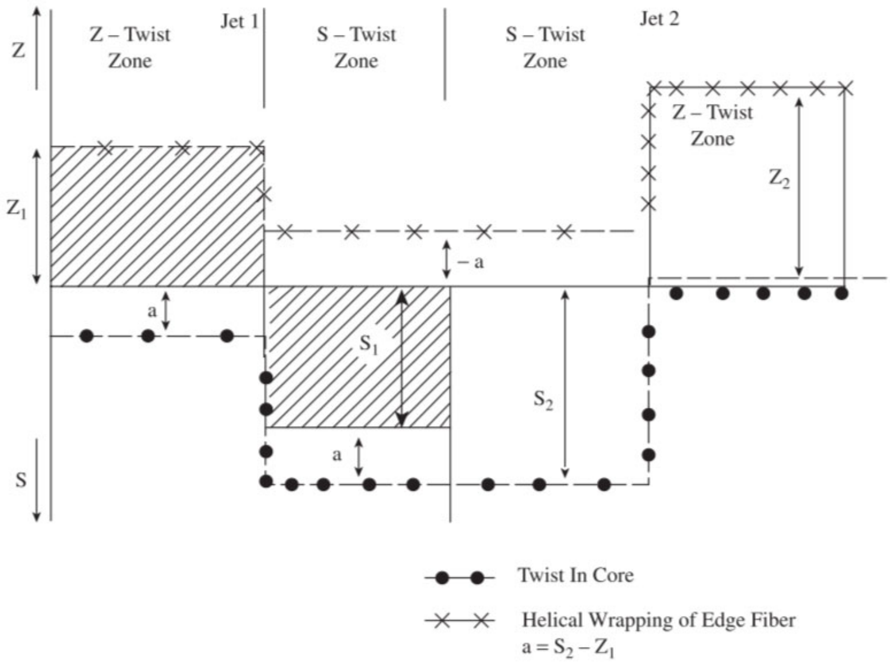


Figure 8 Twist distribution development of Murata Jet Spinning (Lawrence, 2003)

"The solid lines represent the false-twisting actions of the jets [nozzles], and the dotted and dashed lines show the twist in the core [of the fibre bundle] and the helical wraps of the edge fibers. […] As the core moves through jet [nozzle] 1 and into jet 2 [nozzle], its twist increases to S_2 until it enters the Z-twist zone of jet [nozzle] 2. Here, the S_2 twist in the core is removed by the opposing twist Z_2, leaving an untwisted core of parallel fibers. The helical wrap of the edge fibers around the core is initially equal to Z_1 and, in the S-twisting zone, it is reduced to -a before increasing to Z_2." [citation: Lawrence, p. 311].

The challenge stays in the interfering airflows at the last roller pair of the drawing system. High rotation speed at the rollers causes misalignment of edge fibres before entering the first nozzle. That results in lack of enough wrapping fibres to reach tenacity for the yarn [Lawrence, p. 312].

This challenge leads to the main limitation of this concept in processability. Consequently, this concept has low flexibility of the delivered material. Only man-made fibres or blends with < 50 % cotton can be used. Especially carded cotton cannot be processed because of the short fibre content and uneven fibre length [Wulfhorst 1986, Murugan 2003, Göbbels 1984].

2.1.4 Real twist air jet spinning technology

In 1997 at the Osaka International Textile Machinery Show, Murata presented the first real-twist-air-jet spinning machine Murata Vortex Spinning (MVS). Several more machine types followed over the last years. The newest machine is Vortex III 870, which was presented at ITMA 2016 in Milano.

It runs with 500 m/min with a mechanical total draft up to 380-fold for fine yarns. The specialty of this machine is the workability of 100 % polyester with the help of special additive [Oxenham 2016, Stalder 2014, Karnan 2006].

The spinning process starts in general with the delivery of a sliver into a 4-over4-roller high-speed drafting system of the air jet spinning machine. The use of aprons provides the control of the fibre feed speed. When the drafted fibre bundle reaches the nip of the delivery roller, the following nozzle sucks the parallel lying fibres of the fibre bundle inside, where the spindle forms the yarn. After the yarn formation process a winding device takes off the yarn and forms a package. A yarn cleaner provides a continuous quality and signalizes in case of a yarn break.

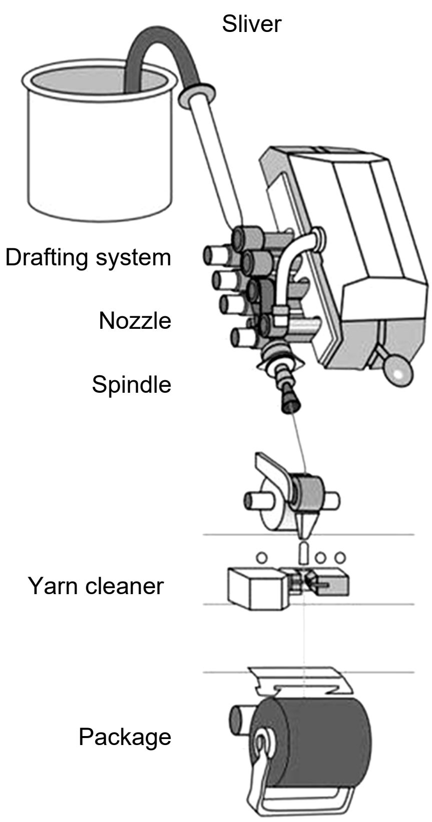


Figure 9 Principle of Murata Vortex Spinning (Stalder, 2014)

The main principle of the yarn formation inside the nozzle is an interaction of two airflow types, inserted by compressed air. Firstly, the axial airflow, which is generated near the fibre entry of the spinning nozzle. It produces a negative pressure which generates a certain vacuum inside the nozzle chamber. This axial airflow sucks fibres inside the spinning nozzle and transports them further through the cone channel [hollow spindle]. The second airflow, the tangential airflow, is generated by forcing the compressed air through tangential boreholes [jet orifice]. This tangential airflow rotates around the cone [hollow spindle].

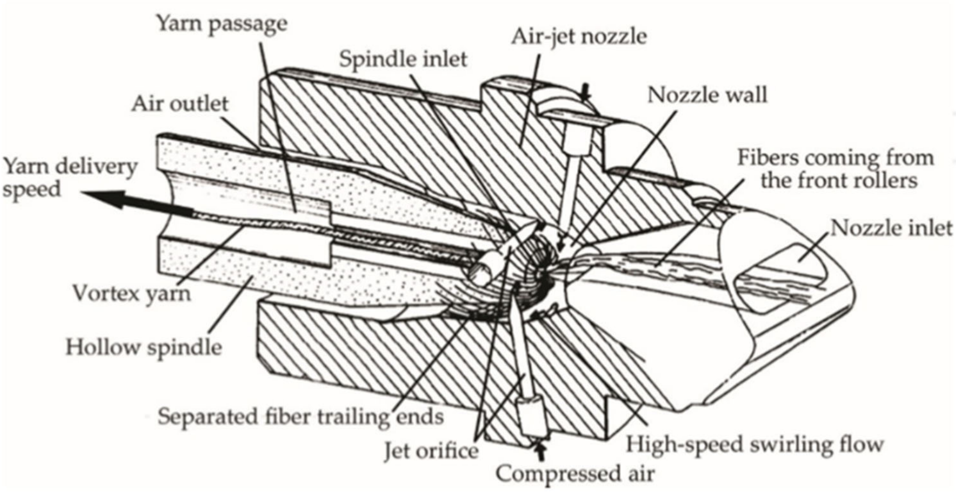


Figure 10 Cross-sectional view of the spinning nozzle (Lawrence, 2003)

During the fibre feed a certain amount of fibre ends split off from the main parallel fibre flow and get caught by the rotating air flow and wrap around the cone tip. Because of the constant fibre feed through the cone channel those wrapped fibres get laid down over the parallel main fibre strand. A needle after the fibre entry guides the delivered fibres in a defined angle to the top of the cone and behaves like a twist stop to prevents the propagation of twist [patent US 5528895].

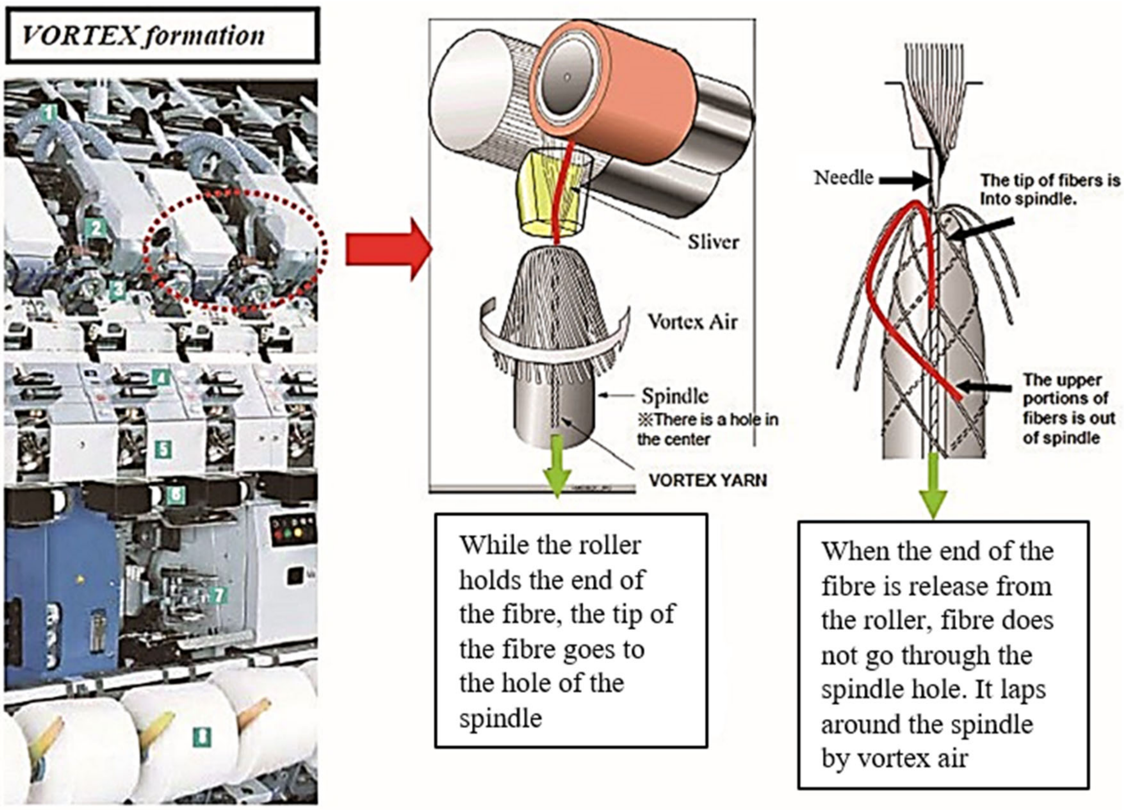


Figure 11 MVS yarn formation (Günaydin, 2017)

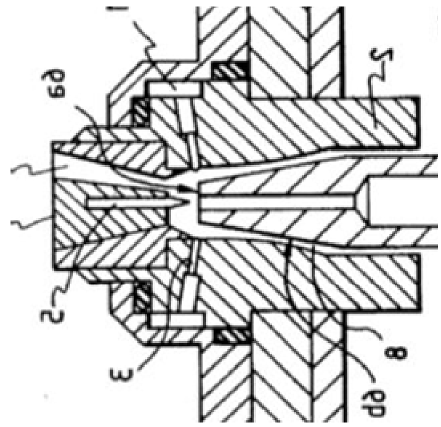


Figure 12 Technical drawing Murata nozzle (Patent US5528895)

Single fibres, especially short fibres, which neither are in the parallel main fibre bundle nor at the yarn surface as wrapping fibres, bypass the cone and are lost. This occurring fibre loss is relatively high by processing 100 % cotton (up to 10 % or even more). To reduce the number of lost fibres several parameters are important, such as the distance from the nip of the delivery roller to the nozzle entry, the pressure of the compressed air and the evenness of the drafting process [Stalder 2014, Ziegler 2009, Karnan 2006].

In 2008, the company Rieter Machine Works Ltd. launched their first real-twist-air-jet spinning machine J10. The newest machine J26 was presented at ITMA 2015 in Milano. It can also reach 500 m/min production speed and has a total draft up to 220-fold (technological) or 317-fold (mechanical). Main innovation on this machine is the polyester attachment P26, which allows the production of 100 % polyester by infusing distilled water as additive during the yarn formation [Oxenham, 2016].

The main principle of the yarn formation at a Rieter air jet spinning machine stays equal to the machines from Murata. The only apparent difference between the two is the guidance element of the needle inside the nozzle is replaced by a defined fibre guidance edge, which also behaves like a twist stop [patent EP 1335050 B1].

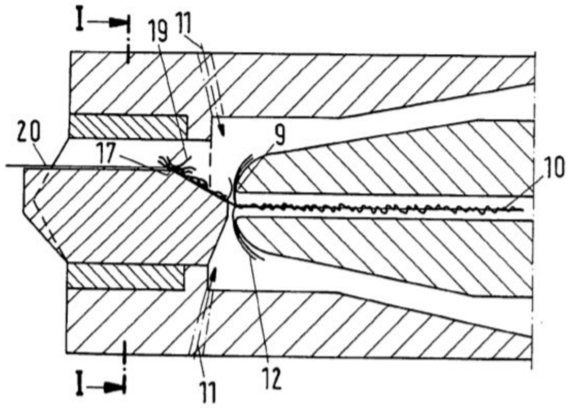


Figure 13 Technical drawing Rieter nozzle (Patent EP 1335050 B1)

Another company known for short staple spinning machines, the company Saurer (former Schlafhorst) holds a patent for an air jet nozzle. Here, the needle or the guidance edge is replaced by tweezers, like a two-needle solution.

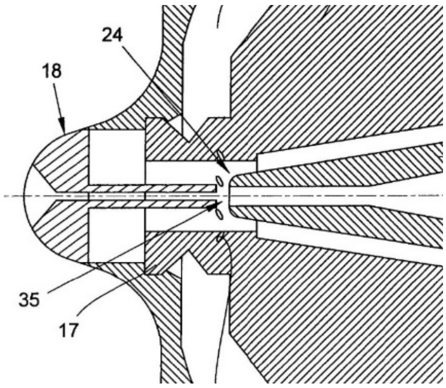


Figure 14 Technical drawing Saurer nozzle (Patent DE 102008006379 A1)

In Barcelona, at the ITMA 2019, the company Saurer launched a new Air-Spinning machine called “Autoairo” and widened their portfolio in short staple spinning machines. The market feedback classified the launch as a “game changer” in air spinning, which emphasises the growth and stimulates the demand of air spinning technology in the market. The unique autonomous spindle with individual drives of the Autoairo is an innovation compared to the market competitors Murata and Rieter. This creates the opportunity for present developments regarding integrated intelligence and digital control possibilities (based on press releases 2019).

In connection to the release of the Autoairo machine, several patents appeared to underline the innovation aspects of the third supplier of air spinning machines. The single drive concept for individual driven spinning positions including the drafting system is presented in the figure below in 2019.

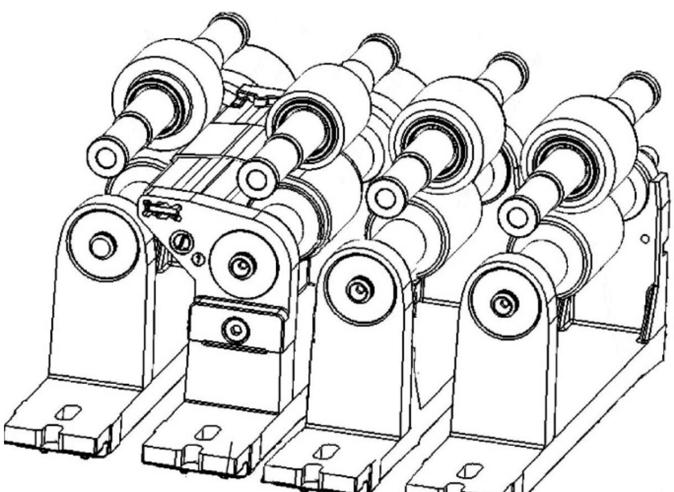


Figure 15 Single drive drafting system (patent: DE 10 2019 110 881 A1)

2.2 Short-staple spinning technologies

This chapter gives an overview of the most important short staple spinning technologies and their historical and market-related classification. Furthermore, the different yarn structures are presented and compared to air jet spun yarn.

2.2.1 Ring Spinning

"Spinning machine for the continuous spinning of staple yarn equipped with a drafting system for drafting the roving, in which by interaction of the spindle with the ring traveler on the spinning ring the fibers are twisted into yarn and wound on a bobbin." (DIN ISO 16875:2006-04)

Ring spinning is a conventional spinning technology which was first invented in America in 1828. It defends its position as the most widespread spinning technology with 28 million tons yarn per year (status 2014) [Gherzi 2015, Stalder 2003, Klein 2014]. The whole ring spinning process includes three stations with roving, spinning, and winding. The roving process is necessary to produce the pre-yarn which is delivered afterwards into the ring spinning machine. The process of roving production is explained in the following chapter separately.

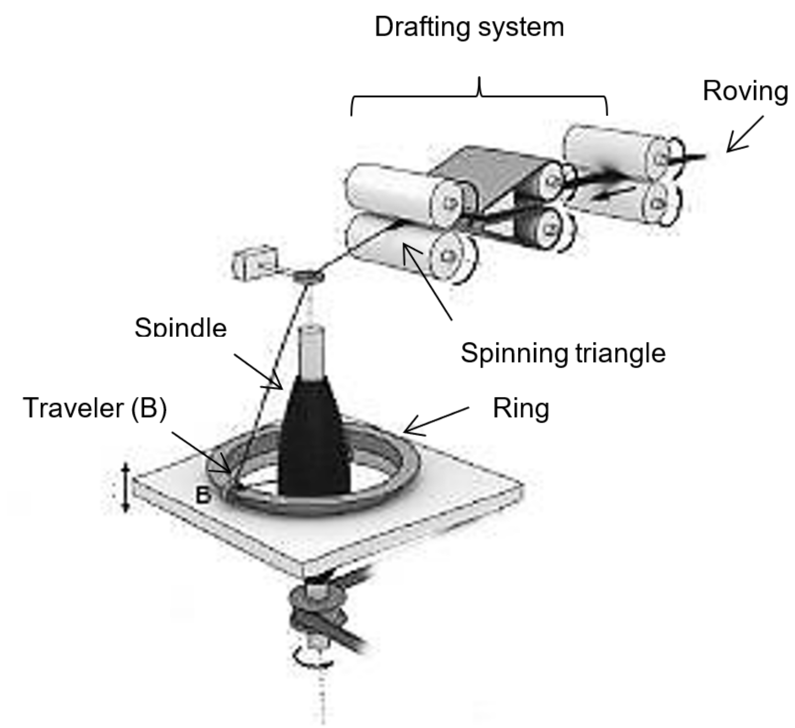


Figure 16 Principle of ring spinning (Lehmann, 2011)

The spinning process at the ring spinning machine starts with a 3-over-3 drafting unit where the roving gets drafted until the actual finesse for the yarn is reached and winded on the cone. Aprons and rubber coated upper rollers are used to control the fibres through the drafting process. The yarn tenacity is created by twist insertion from the rotating spindle and the traveler (1 twist/rotation). The inserted twist propagates until the nip of the last front roller where it forms a spinning triangle. The width of the spinning triangle is an important indicator for the yarn quality and spinning stability [Klein 2014, Lawrence, 2003]. The role of the spinning triangle is explained further in chapter 2.2.1.2.

Ring spinning machines at the market shows an average spindle speed of 18000 rpm with an average production speed of 25 m/min. This relatively low production rate of ring spinning can be explained by two factors. Firstly, the rotation of the traveler on the ring is subject to occurring friction forces of high contact pressure, which generates considerable heat. Secondly, the occurring yarn tension challenges the spinning triangle zone at high spindle speeds [Klein, 2014]. This is explained more in detail in a separate chapter (2.2.1.2).

Although the named limitations, ring spinning defends its status at the market. Ring spinning can produce a wide range of possible yarn finesses and materials. Process modifications like compact-, Siro- and core spun yarn give a high flexibility in yarn structures with high qualities [Stalder 2003, Klein 2014]. Ring spinning is even considered setting standards for other yarn technologies and is generally accepted as best yarn quality [Soe, 2004].

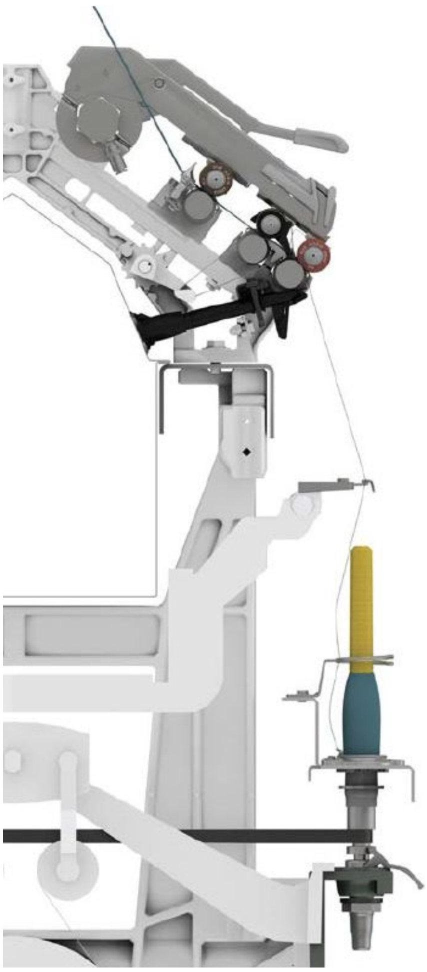


Figure 17 Sideview from a ring spindle (Rieter Brochure G36, accessed 24.08.2016)

2.2.1.1 Roving frame production

"A roving is a continuous fibrous strand drafted from a sliver and a cohesion by either inserting a small amount of twist […]. It is drafted and twisted to spun into a yarn." [Lawrence, 2003, p.262]

The roving frame machine produces pre-yarn for the ring spinning process. This intermediate step before the actual ring spinning process is necessary because to three main reasons.

Firstly, draw frame slivers consists of too many fibres in cross-section which would require much higher draft at the ring spinning unit by using it directly. The drafting unit of a ring spinning machine is not capable of that high draft creating suitable resulting yarn quality. Secondly, the transportation of draw frame sliver material out of the can to feed it to the drafting unit would cause a break of the sliver. The distance from the can to the drafting unit is too long and the tare weight of the thick sliver would pull it apart, since there is no twist at the sliver. There are attempts to eliminate the roving production step like "RingCan" from Suessen, but this technique could not reach a high customer feedback yet [Ben Hassen, 2003, Wulfhorst, 2012, p.110]. Thirdly, the use of sliver cans would require more space than roving bobbins.

The principle of roving production is similar to ring spinning. The roving frame machine consists of a drafting system, rotating spindles with guidance elements, the flyer, to create twist. The produced roving is winded on a bobbin (seen figure 18, Lawrence, 2003, p. 265).

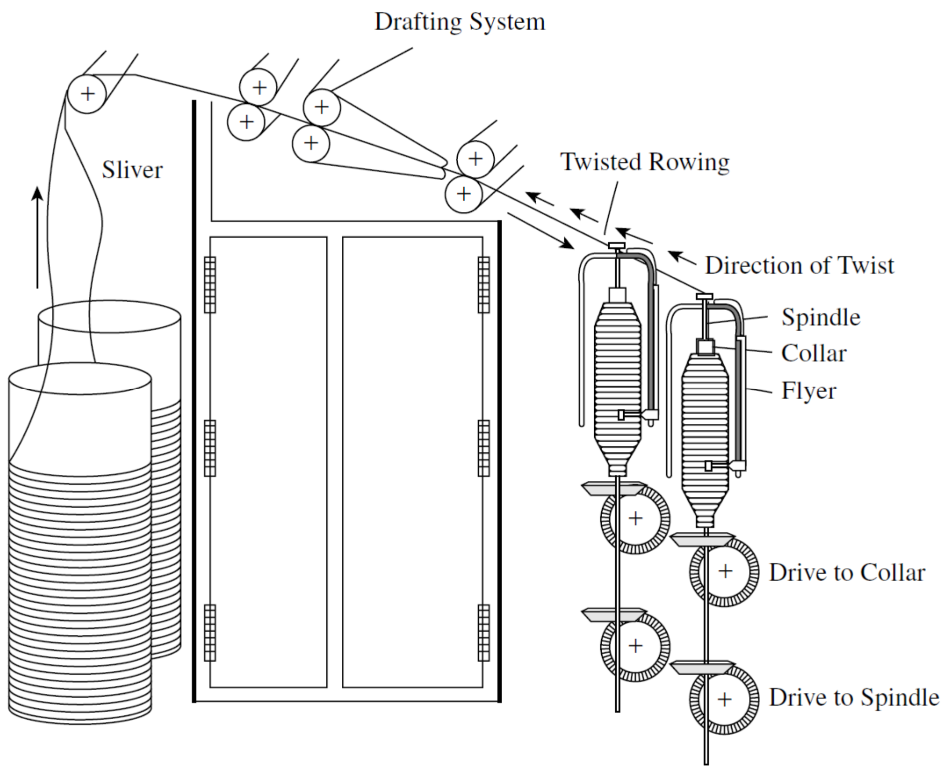


Figure 18 Basic features of a roving frame machine (Lawrence, 2003, p. 265)

The process of roving production starts with the delivery of a sliver, which is inserted into the drafting system of the roving frame machine. The drafting system, mainly a 3 over 3 roller system, drafts the delivered sliver up to the final roving count. The draft can be set between 5 to 20-folds. The number of fibres in cross-section in a roving ranges around 2500 fibres, which results in low tenacity of the roving. To overcome this fact, protective twist is implemented into the roving to increase the fibre-fibre friction and guarantee enough tenacity for the next process step in ring spinning.

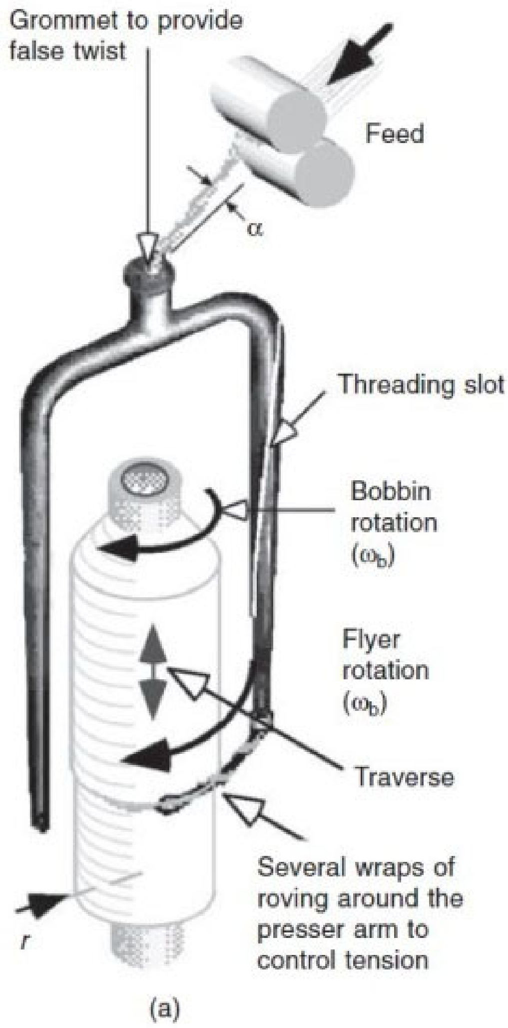


Figure 19 Principle of roving production (Lord, 2003, p. 170)

The twist insertion takes place at the spindle in combination with the flyer and produces twist between 25-70 twists per meter. In figure 19, the roving production is shown in detail. The twist is created by the rotating flyer and the rotating bobbin on the spindle (ω_b). The twist continues up the length of roving through the threading lot until the last roller pair of the drafting system, where it forms a spinning triangle. The width of the spinning triangle (α) is one important factor driving the spinning performance and the roving quality. The roving is wrapped 2-3 times around the pressure arm of the flyer to ensure the tension. To provide a stable fibre bundle during the roving process, it runs through the grommet at the top of the flyer. Special surface structures at the grommet implement false twist into the roving to increase the stability of the roving. To guarantee a uniform winding of the roving on the bobbin, the spindle traverses up and down [Klein, 2014, p.58].

2.2.1.2 Influence of spinning triangle

In the roving process as well as in ring spinning, the twist propagates up the yarn/roving length until it reaches the nip of the front roller pair, where the delivered fibres form a triangular shape, the so-called spinning triangle. It is considered as one of the most sensible areas in ring spinning as well as in roving production. The fibres in the spinning triangle are neither controlled anymore by the drafting system with the pressure of the roller pairs nor by the resulting fibre-fibre-friction caused by twisting them around each other. The shape of the spinning triangle is responsible for the number of breakages, unevenness and yarn hairiness [Carrisoni, 2002, p.51, Lawrence, 2003, p. 278-288].

After the roving is drafted, the fibres leave the controlled area of the drafting rollers. Because of aerodynamic fluctuations at the last roller pair single fibres may not integrated into the leaving fibre bundle which forms the yarn. The inserted twist from the rotating spindle cannot reach exactly the nip of the roller pair. Figure 20 shows the principle of the spinning triangle. The principle in sketch a shows a small spinning triangle compared to sketch b. In sketch a, the twist almost reaches the nip of the roller pair. Consequently, the risk of losing edge fibres is limited.

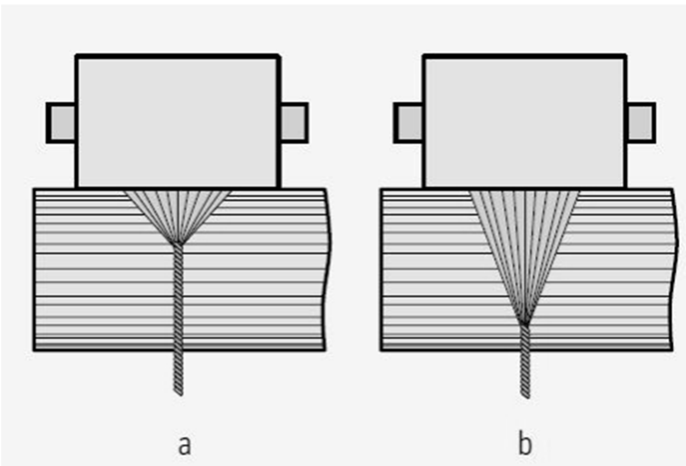


Figure 20 Principle of spinning triangle (Klein, 2014, p. 62)

Improvements regarding to decrease length and width of the spinning triangle is possible by using condensers in the drafting system, increase the yarn twist or yarn tension value and by optimizing the overhang of the top roller of the roller pair [Klein, 2014, p. 62). This directly effects the appearance of the yarn which results in different hairiness and surface structures. In figure 21 the principle of the spinning triangle and the resulting yarn, as a SEM image is shown [Carissoni, 2002, p.52]. On the left side a regular ring yarn, produced with a wide spinning triangle shows high hairiness. On the right side of the figure a yarn with low hairiness, produced with a small spinning triangle, is shown. This degree of fibre migration into the yarn influences the production stability in the downstream processes like knitting or weavin [Lawrence, 2003, p. 278-288].

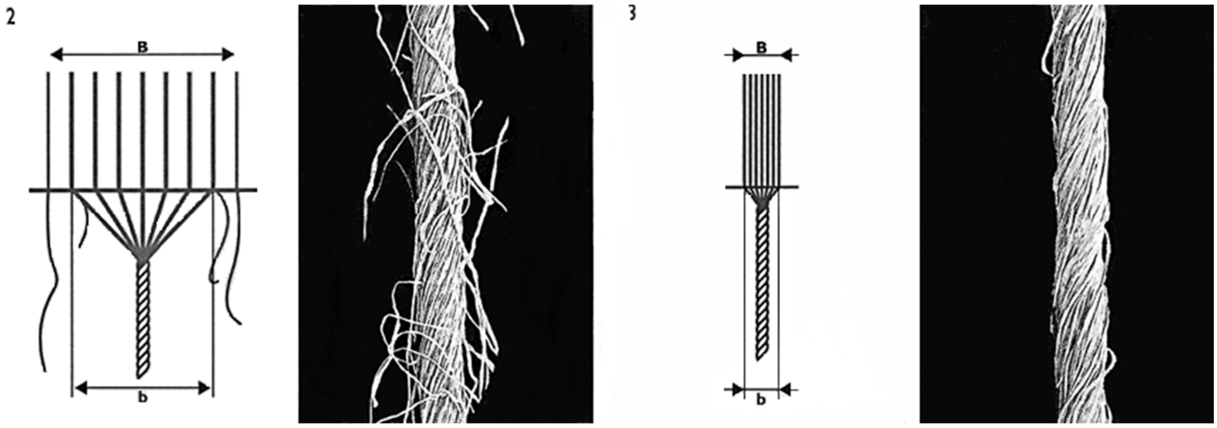


Figure 21 Principle of spinning triangle and influence for fibre migration (Carrisoni, 2002, p. 52)

To overcome the problem of the wide spinning triangle, a modification of the classic ring spinning was developed, which is presented in the next chapter – the compact spinning.

In air jet spinning there is no spinning triangle like it can be found in ring or roving spinning. Since the twist insertion takes place inside the spinning nozzle, the twist does not propagate until the nip of the last roller pair and does not form a spinning triangle in a conventional way. Still, the regularity of delivering the fibres from the nip of the last roller pair into the nozzle is a crucial point for the quality of the spinning stability as well as for the yarn quality and is analyzed further in this thesis.

2.2.1.3 Compact Spinning Modification

The compact or condensed spinning is a modification of the classic ring spinning technology. The delivered fibre bundle from the drafting system is pneumatically compacted or condensed at the last roller pair to decrease the width of the spinning triangle.

At ITMA 1999, four different machine manufacturers presented their compact spinning systems (Rieter, Suessen, Zinser, MAL) [2003, Kumar]. The differences of each system are shown in table 5.

Table 5 The Compacting Systems in Ring Spinning (Lawrence, 2003, p. 288)

Manufacturer	**Trade names**	**Basic features**
Rieter Machine Works Ltd.	Com4Spin	4-over-3 double apron drafting system with perforated bottom front roller and two top rollers drafted ribbon compacted by air suction through bottom front roller
Spindelfabrik Suessen	EliTe	3-over-3 double drafting system with additional roller and special lattice apron, moving around slotted, air suction tube (*tubular profile*) for compaction of drafted ribbon
Zinser Textilmaschinen GmbH	Air-Com-Tex 700	4-over-4 double apron drafting system with perforated apron circulating around top front roller drafted ribbon in front zone compacted by suction through perforated apron
Maschinen-und Anlagenbau Leisnig GmbH	P4	4-over-4 double apron drafting system with perforated apron circulating around bottom front rollers drafted ribbon in front zone compacted by suction through perforated apron

The solution of the company Rieter shows that the bottom roller of the last roller pair is perforated and pneumatically connected. The air flow inside the bottom roller creates a certain sub-atmospheric pressure. A suction slot at the surface of the bottom roller leads the fibres over the perforated roller and produces the desired condensation of the fibre bundle [Klein, 2014, p. 57].

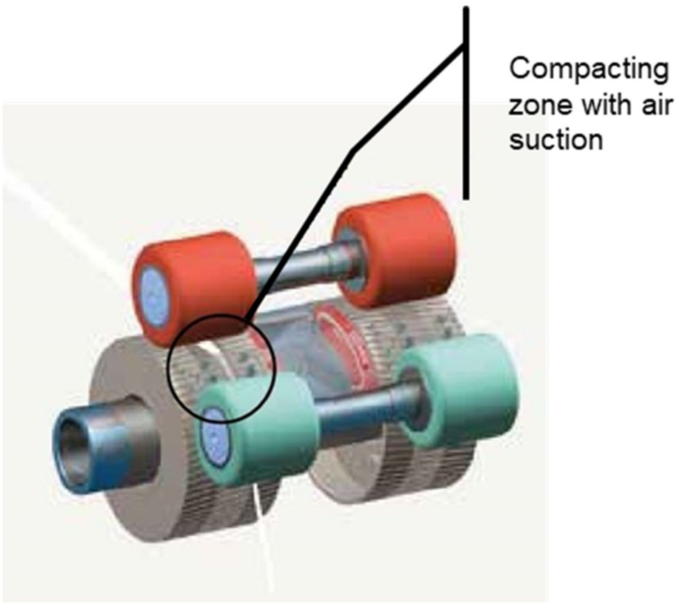


Figure 22 Compact system of Rieter Com4 Spin (Klein, 2014, p. 57)

The air suction inside the bottom roller prevents edge fibres moving uncontrolled on the sides of the spinning triangle. Even the integration of short fibres is improved which result in less fibre fly and waste. In figure 23 this effect is shown, where the spinning triangle width WS is reduced. This leads to lower hairiness, higher yarn tenacity and yarn elongation, compared to conventional ring spinning. These properties effect the downstream processes as fabric production and fabric appearance positively [2014, Klein, p. 57, Lawrence 2003].

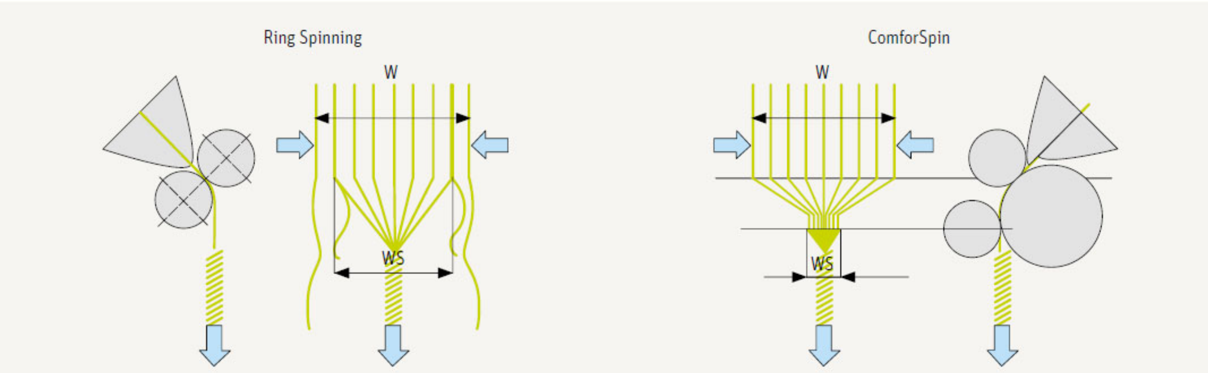


Figure 23 Principle of difference from ring to compact spinning regarding the spinning triangle (Klein, 2014, p. 57)

In figure 24 the comparison of the spinning triangles of a conventional ring spinning machine and compact spinning machine is shown [Lawrence, 2003, p. 286].

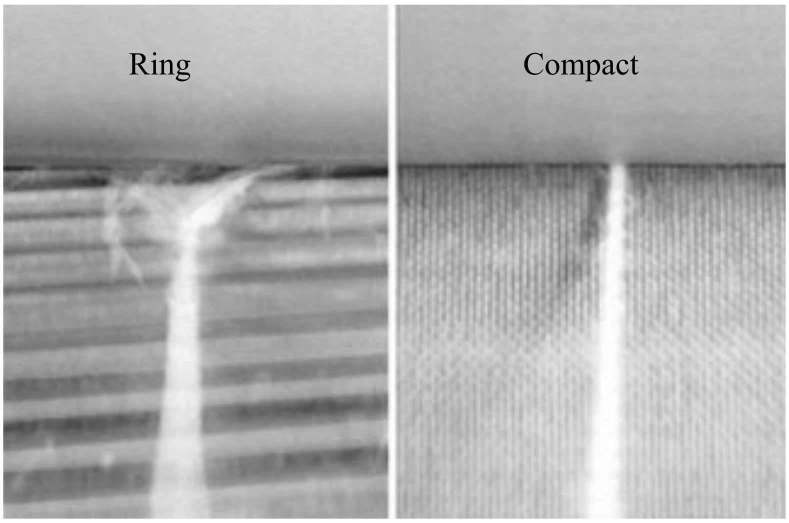


Figure 24 Difference of the spinning triangle from ring to compact yarn (Lawrence, 2003, p. 286 Secondary source)

By incorporating edge fibres during the process of yarn formation, the strength of the spinning triangle takes one-third of the yarn strength. Therefore, the spinning triangle is a potential weak spot for the spinning stability. The innovation of compact spinning is an example where especially fine yarn counts and yarn with low twist levels can benefit from incorporating edge fibres [Lawrence, 2003, p. 287].

2.2.2 Rotor Spinning technology

"Machine in which the assembly of the individual fibres and the insertion of real twist are affected by the rotor. The fibres are separated from the feed stock and are conveyed to the rotor where they are continuously deposited on the collection surface. By rotation of the rotor the fibres are twisted into yarn which is progressively withdrawn through the navel." [DIN ISO 6173]

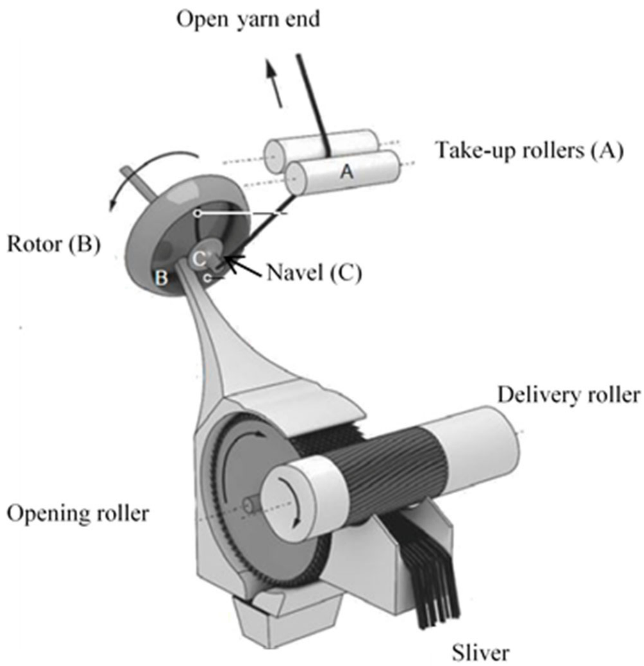


Figure 25 Principle of rotor spinning (Lehmann, 2011, p. 143)

Since its first introduction in 1967, the open-end rotor spinning process plays another important role at the international spinning machine industry. Although, the rotor spinning works without a roller drafting unit, its high market share should be noticed since the yarn appearance can serve as comparison [Gherzi, 2016].

To produce rotor yarn, a sliver is delivered over a delivery roller into the spinning unit. An opening roller disintegrates the sliver into single fibres and leads them through a fibre channel into the rotor. The teethed opening roller causes simultaneously a cleaning of the delivered material by combing out trash particles and short fibres. With the combination of airflow and centrifugal force the fibres continuously slide into the rotor groove where they form a fibre bundle with the thickness of the final yarn. The end of the fibre bundle is connected by twist to a rotating open yarn end and a navel guides the yarn out of the spinning area. The inserted twist propagates until the nip of the take-up rollers and the spun yarn is winded up [Lehmann, 2011, p. 143 f].

The surface of the navel has a huge impact on the spinning stability and the yarn quality. Different surface designs can temporary create a specific false twist into the yarn. This effect leads to specific character of the yarn surface and the yarn quality.

Another spinning auxiliary is located between the navel and the take-up rollers (not seen at figure 8). The torque-stop generates a change of direction of the yarn of about 30 %. This redirection hinders the twist to propagate further and increases the point of yarn formation inside the rotor groove. This torque-stop has a positive effect for the spinning stability [Trommer, 1995, p.160].

Rotor spinning provides his market share with its ability in high productivity, the variety of useable spinning auxiliaries like different rotor or navel types and the specific yarn structure. Rotor spinning is with its production of mostly coarse to middle coarse yarns in most cases not a direct opponent to air jet spinning. [Oxenham, 2016, Trommer, 199]).

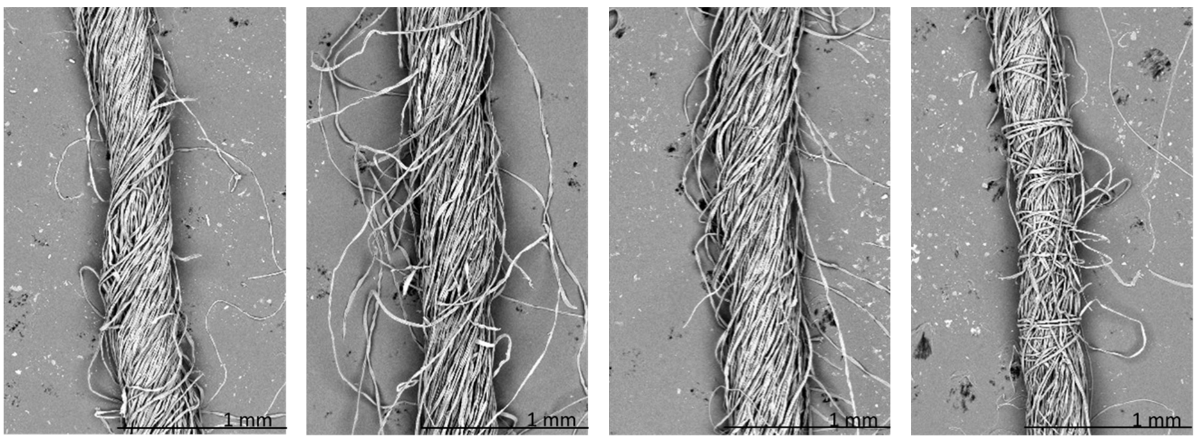
2.2.3 Comparison of yarn structure and its influence for the processability

Each yarn technology has its ideal field of application. Regarding efficiency, yarn properties and yarn appearance in a fabric or any other final product, raw material, fibre length and yarn count, the yarn type is selected. Even the process steps in the textile chain which follow the spinning process have special requirements to the yarn. The yarn structure plays a significant role for the yarn properties. The amount and the distribution of twist and the (non-) parallel position and integration of single fibres in the yarn structure influence yarn properties like tenacity, elongation, evenness as well as hairiness of the yarn.

Furthermore, depending on the yarn structure the fabric has different pilling and dying behaviour and washing resistance. This subchapter gives a brief introduction into the different yarn structures and their impact for the textile chain [Schwippl, 2014].

Table 6 SEM images of Nm25 yarns with magnification x50

Real twist air jet yarn	Ring yarn	Compact yarn	Rotor yarn



In table 6, SEM images of different yarn types are shown. The yarn count is Nm25 and the magnification of the images is x50. Each picture shows the special characteristics of each yarn type. The air jet yarn has parallel fibres in the core and wrapped fibres at the shell. Ring yarn shows a uniformly distributed twist and noticeable hairiness. The compact yarn appears like ring yarn but with a significant reduce of hairiness. And the rotor yarn is characterized by the non-uniformly distributed twist and the horizontal (rectangular to yarn axis) wrapper fibres.

The table 7 shows the main differences in yarn structure arising from the used spinning process considering fibre disposition and the effect of the fibre orientation for the yarn appearance [based on: Klein, 2014, p. 50]

Table 7 Differences of the yarn structure and fibre disposition (Klein, 2014, p. 50)

	Ring yarn	Compact yarn	Rotor yarn	Air jet yarn
Fibre disposition				
In the core:	parallel, helical	parallel, helical	less parallel, helical	parallel without twist
In the sheath:	parallel, helical	parallel, helical	more random, less twisted	20 % of fibres twisted around core in spirals
Fibre Orientation				
Parallelism:	good	very good	medium	good
Compactness:	compact	very compact, round	open	compact
Handle:	soft	soft	hard	medium to hard
Hairiness:	noticeable	low	medium	low to medium
Stiffness:	low	low	high	fairly high

The unique yarn structures have an impact on the yarn quality and fabric quality. The highest yarn tenacity can be found at compact and ring yarns because of the uniformly distributed twist through the whole yarn cross-section. Rotor yarn has the lowest tenacity because of the random twist in the sheath. The partly twisted air jet yarn shows tenacities between ring and rotor yarns regarding its fibre type and number of short fibres. This effect is shown in the next figure from Rieter. It gives an overview of the relative yarn strength [%] regarding used fibre length, material type and spinning process. The elongation values depend on the yarn count and fibre type.

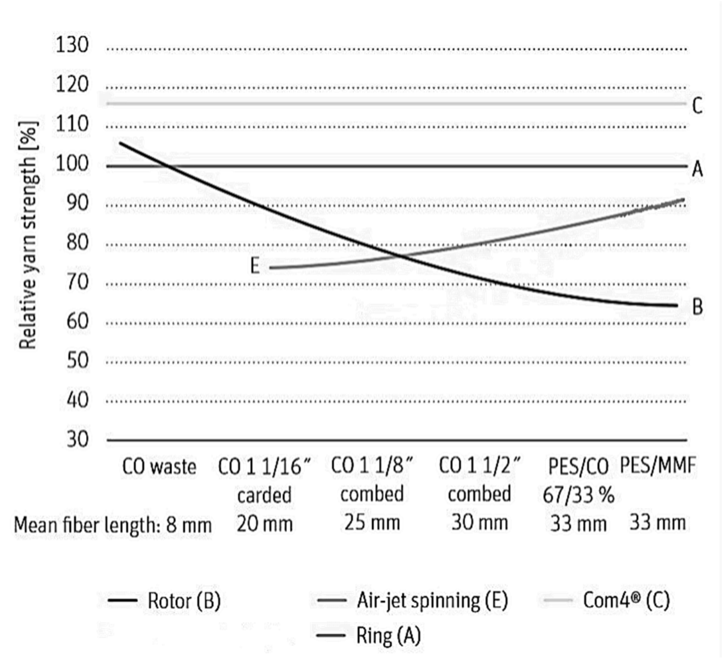


Figure 26 Overview relative yarn strength related to the yarn type (Stalder, 2014, p. 55)

The yarn evenness is a yarn quality which cannot be compared directly. The yarn structure has a significant impact on the appearance of the yarn evenness. Ring yarn shows the most even yarn evenness (lowest CV%) regarding yarn lengths < 1 m. Due to the number of wrapping fibres, air jet yarn appears less even than uniformly distributed helical fibres of ring or compact yarn. This results in 15 to 20 % higher CVm%-values, compared to ring yarn. Nevertheless, the total mass variation over longer yarn lengths shows better results with the air jet spinning technology.

Especially, the yarn evenness appearance in a fabric differs to the results of the yarn itself [2012, Povel, Schwippl, 2014]. The H-value of hairiness shows a significant decrease of 25 % with air jet yarns. The S3-value reaches even a 75 % reduction, compared to ring yarns [Stalder 2014, Povel 2012].

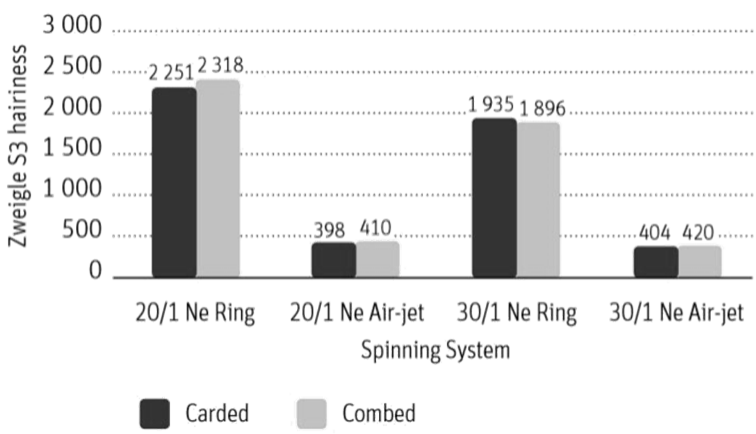


Figure 27 Comparison hairiness ring to air jet yarn (Stalder, 2014, p. 47)

The low hairiness of air jet yarn comes with other positive effects like high abrasion and washing resistance and high pilling resistance of a fabric. Processing air jet yarn in knitting or weaving results in less fibre fly and dust values. Data from the company Murata shows a significant reduction of lint shedding and higher pilling resistance after 15 minutes using air jet yarn compared to ring yarn (seen in figures 28, 29) [Stalder, 2014].

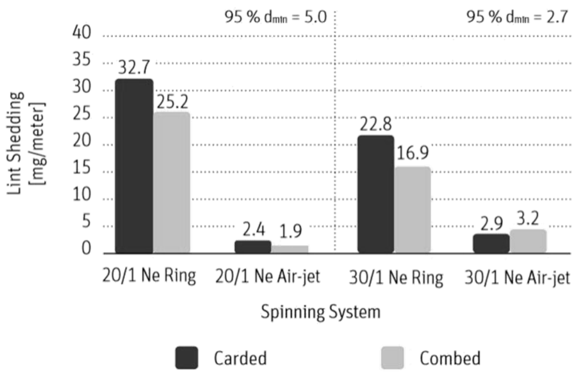


Figure 28 Comparison lint shedding ring to air jet system (Stalder, 2014, p. 48)

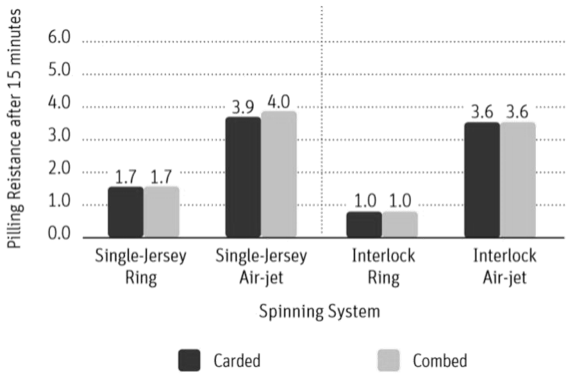


Figure 29 Comparison pilling resistance ring to air jet yarn (Stalder, 2014, p. 48)

The special core-shell structure of air -jet yarn has a positive effect on the finishing behaviour. Due to the parallel laying fibres in the core, 10 to 15 % less dye is necessary with the same dye result. The parallel laying fibres work as a capillary effect [Gresser, 2011].

The range of possible yarn counts for air jet yarn, compared to rotor and ring yarn is shown in the figure 30. Since ring spinning can process with a high flexibility, especially in fine yarn counts, rotor spinning produces mainly coarse yarn counts. Air jet spinning takes its place in the middle fine to fine yarn count range [Stalder, 2014].

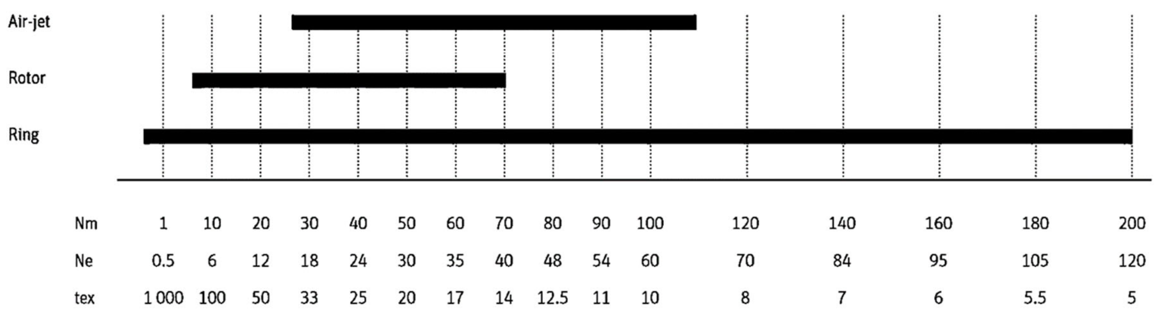


Figure 30 Possible yarn count range of air jet, rotor, and ring yarn (Stalder, 2014, p. 54)

Considering the possible yarn count range, the figure 31 shows the production rates of the different spinning methods regarding the spun yarn count. The line A represents ring spinning, line B rotor spinning and line D air jet spinning. It shows clearly that air jet spinning is the spinning method of choice for high productivity in the yarn count range of Nm25 -Nm74 [Stalder, 2014].

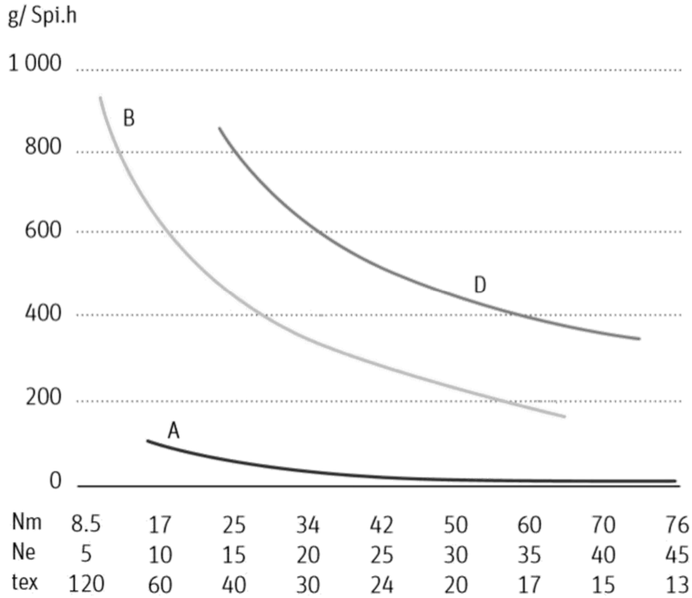


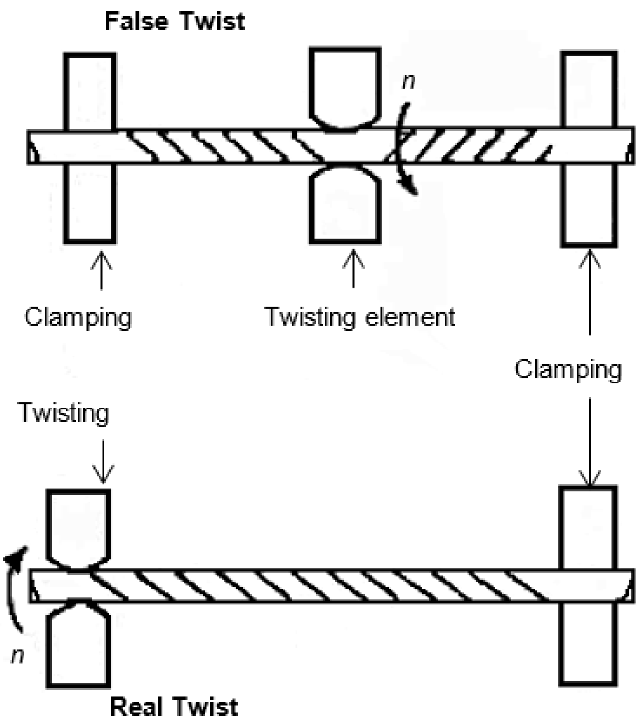
Figure 31 Comparison of productivity related to the spinning method (Stalder, 2014, p. 55)

2.3 Principle of false twist

"False twist takes place in a textile process where twists are only locally present and if they can be disintegrated by themselves immediately at the next process-step. That means, that the twist is only at one (or more) defined place(s) of a process if it is disintegrated afterwards." [Schwabe, 2009].

The main task of twist insertion is the consolidating of a fibre bundle. The fibre friction itself is too low to create a permanent grip of the single fibres in a fibre bundle. Furthermore, twist can produce special yarn effects and has an important role for the development of new spinning technologies (Schwabe, 2009, p. 1). In general, there are two types of twist insertion in textile processes. Depending on the spinning technology and the process step of yarn formation, real and/or false twist is used. (Schwabe, 1977)

The definition above of false twist gives a basic explanation of what false twist is. However, there is not only "the" false twist, but many stages of false twist and its application fields. In figure 32, a scheme shows the difference of real and false twist with a stationary yarn. The term "stationary yarn" represents a yarn which is clamped at bot yarn ends.



$$\sum \vec{n} = 0 \quad (1)$$

$$\sum \vec{n} = \vec{n} \quad (2)$$

Figure 32 Principle of stationary false and real twist

By inserting real twist at one yarn end, it propagates until the nip of the clamping point and the total number of twists in the yarn stays equal the number of twists which was inserted (2). That twist can only be cancelled by reversed twist.

By inserting twist in the middle of a stationary yarn, the twist propagates from the twisting element in different directions until the nip of the two clamping points (1). That means, on one side of the twisting element is S-twist and on the other side is Z-twist. In total, the number of twists is zero. The twist cancels itself after removing the twisting element.

In textile processes, the false twist insertion is mainly a dynamic process. That means, the clamping point are replaced with moving objects as roller pairs. The scheme in figure 33 shows the principle the false twist insertion between two rotating roller pairs over time [Lawrence 2003, p. 31).

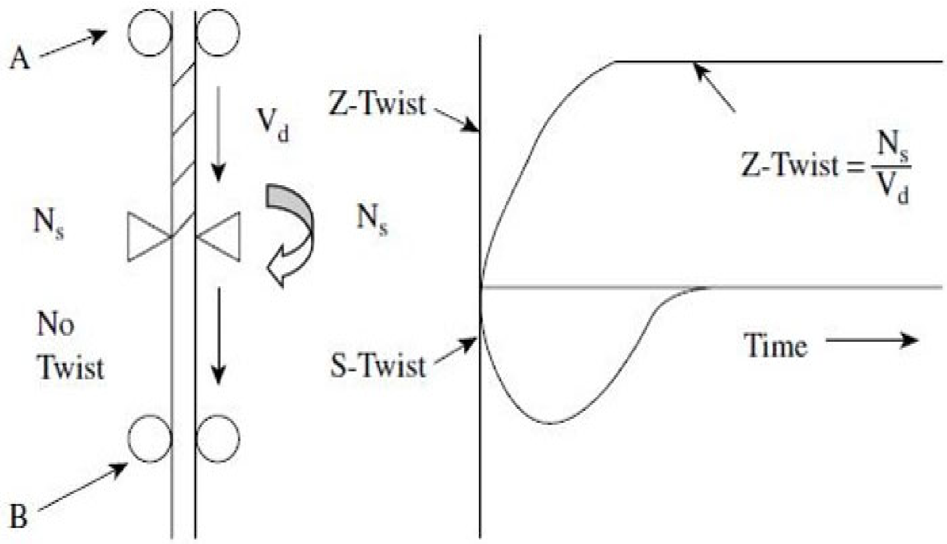


Figure 33 Principle of dynamic false twist and its related twist distribution over time (Lawrence, 2003, p. 31)

Here, the false twist insertion takes place at the same time the yarn is transported by the roller pairs A and B with the speed V_d. After passing the roller pair A, where the yarn enters the false twist insertion field, twist is generated (Z-twist) by a twisting element N_s. After leaving the twisting element, in combination with the generated velocity during the transportation by roller pair B, the previous S-twist disappears. The twist is only "at one defined place and it is disintegrated afterwards" (Schwabe, 2009).

The disintegration of twist afterwards can be influenced by using an alternating twisting element. In this case the part-timed twist changes its direction from Z- to S-twist repeatedly. The scheme in the figure 34 displays the twist direction change and their disintegrations over time, based on the explained principle [Lawrence, 2003, p.31]

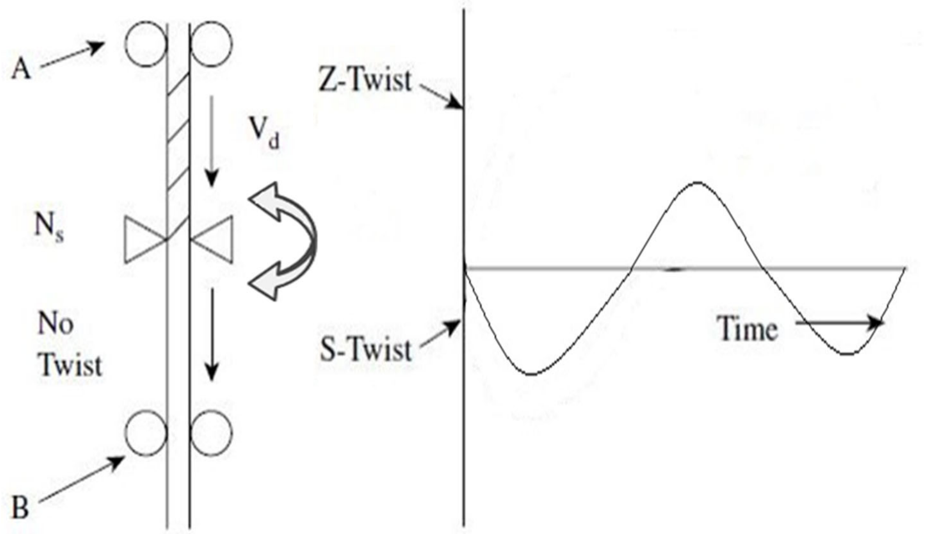


Figure 34 Principle of alternating false twist insertion and its related twist distribution over time

There are different false twist processes for a defined aim and different types of false twist. Even combinations of false twists are possible and may predict more application possibilities in the future. The flowchart in Fig. 35 gives an overview of the used different false twist types and ways of insertion. Those boxes are only a few examples for the widely ranged types and application of false twist. This time-limited and locally present twist can be a passive reaction to its environment or an active mechanical action. It can be inserted deliberately or not. The active false twist insertion can be divided again, into direct and indirect false twist.

It can be divided even further: There are simple false twist $\boldsymbol{T_f} = \frac{\boldsymbol{n}}{\boldsymbol{v}}$, double false twist $\boldsymbol{T_f} = \boldsymbol{2} \cdot \frac{\boldsymbol{n}}{\boldsymbol{v}}$ and numerous false twist $\boldsymbol{T_f} = \frac{\boldsymbol{D_R}}{\boldsymbol{d_F}} \cdot \frac{\boldsymbol{n}}{\boldsymbol{v}}$ [Schwabe, 2009, p.8/Oxenham, 1995]

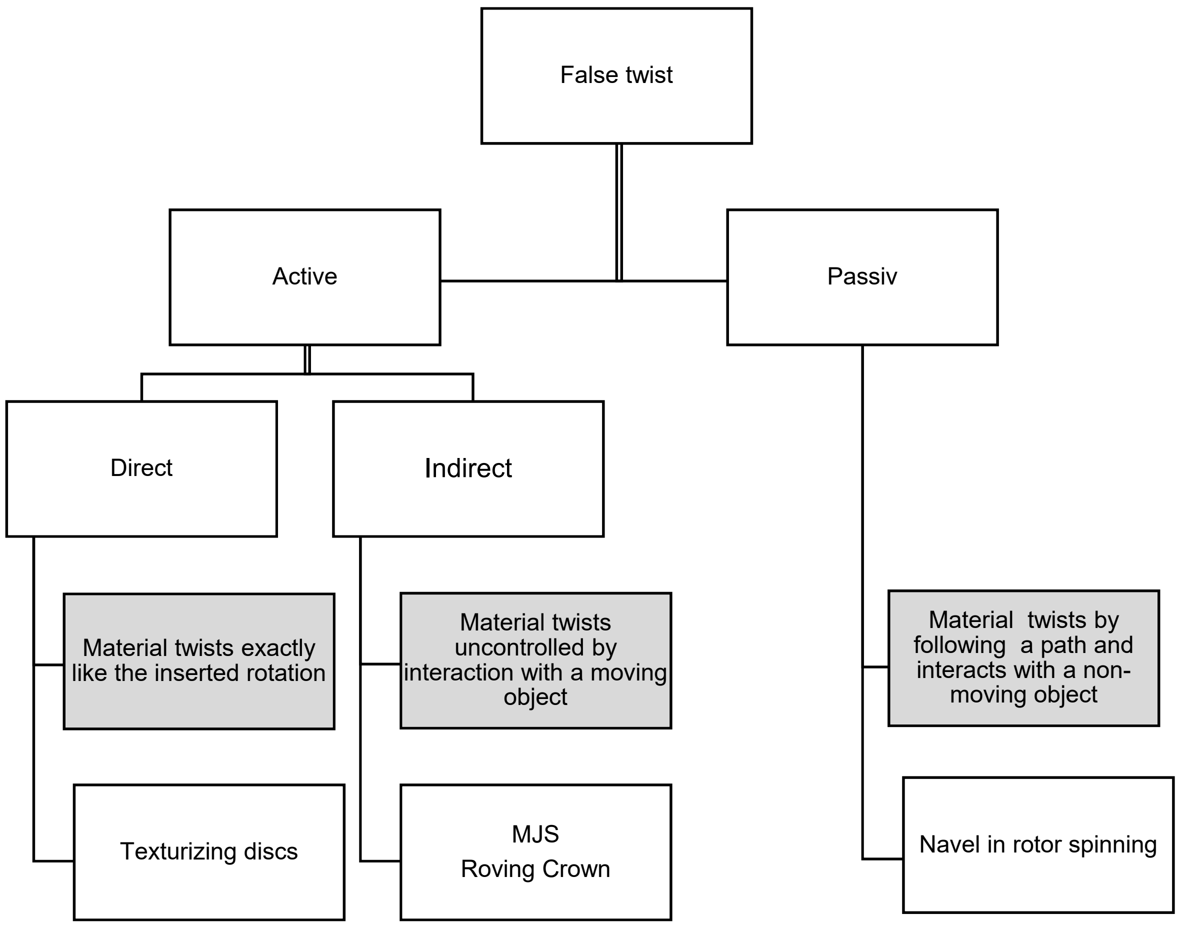


Figure 35 Overview/Tree of false twist types

Used cases for the application of false twist can be different. Some applications are aimed to create special yarn structures or to increase the spinning stability to reduce end-breakages.

For example, in texturing filaments, twist is actively inserted by stacks of discs. The filaments bypass the discs, and the shape and structure of the filaments is rearranged by the path of the discs. The filaments leave the discs in a stressed condition which causes the filaments to texture themselves and get crimped by thermal fixation, just after releasing the stress and create a bulky wavy structure (Lord, 2003, p. 63).

An example for the active indirect false twist insertion is the Murata Jet Spinning (MJS). It is also known as "false twist air-jet spinning" which indicates the importance of false twist in the process of spinning. Here, two countered air jet streams twist and untwist the yarn during the spinning process. The resulting yarn tenacity appears through fibre-fibre-friction and single fibre ends which are wrapped around the other fibres. The process is explained more in detail in chapter 2.1.3.

The third method to apply false twist is a passive interaction of fibres with a non-moving object. This object creates a spatial diversion or torque. This passive interaction takes place at the surface of the navel in rotor spinning. Here, the surface of a spun strand slides along a structured object which shifts the twist and increases it for a period. That creates a combination of real and false twist at the weak spots of the processes and the strand is temporarily strengthened. In rotor spinning, the passive effect of false twist can have a major effect on yarn character. If the navel is more structured by grooves, the friction between the yarn surface and the navel increases which creates a more bulky and hairy yarn (Lord, 2003, p. 63, 169, 194).

The table 8 gives an overview of the mentioned examples and even more and where to find them.

Table 8 Overview of false twist applications and examples with references

Active		Passive
Direct	Indirect	
Filament texturizing *(Lawrence, 2003, p.20)* *(Lord, 2003, p.13, 92)*	Yarn Splicing *(Lord, 2003, p.56)*	Rotor Navel *(Lawrence, 2003, p.298)* *(Lord, 2003, p.194)*
Bobtex *(Bobkowitcz, 1971)* *(Lawrence, 2003, p.316)*	MJS *(Lawrence, 2003, p.309,274)* *(Lord, 2003, p.263)* *(Karnan, 2006)*	Roving Crown *(Lord, 2003, p.169)* *(Klein, 2014, p.64)*
	Repco self-twist-spinning *(Lawrence, 2003, p.274, 302)*	Hollow Spindle (partly) *(Lawrence, 2003, p.315)* *(Lord, 2003, p.270)*

It should be noted that in some parts of spinning processes, low AND high real twist levels are required. In the case of higher production speeds, the twist factor should be as low as possible during the constant torque movements. Nevertheless, higher twist levels are required to reach enough tenacity during the yarn production. Higher real twist insertion determines the twist factor which restricts possible higher take-up speeds. A solution would be the use of inserting real and false twist. That can be realized by partly inserted high twist level to guarantee tensile strength for the spinning stability. However, this high twist level is restricted on that area without interfering the final yarn twist [1977 Schwabe].

In 1993, Miao made a mathematical attempt to explain false twist. He described false twist as an example of time-dependent twisting systems. Here, he pointed out that twist distribution at high-speeds differ to those of "regular" speeds. The fibre travelling speed could surpass the twist propagation speed, so that the false twisting zone would be shifted to the after-twister zone on false twist spinning systems. [Miao, 1993].

2.4 Drafting systems

Definition Draft: *"draft V attenuation of the fibre bundle seized between two pairs of rollers by drafting off at increased speed, expressed by the ratio between the delivery speed V_{Ex} and the feedspeed V_E, or between the no. of fibres in cross-section of the fibre bundle and the no. of fibres in cross-section in the following yarn formation process step […] (based on DIN ISO 16875)*

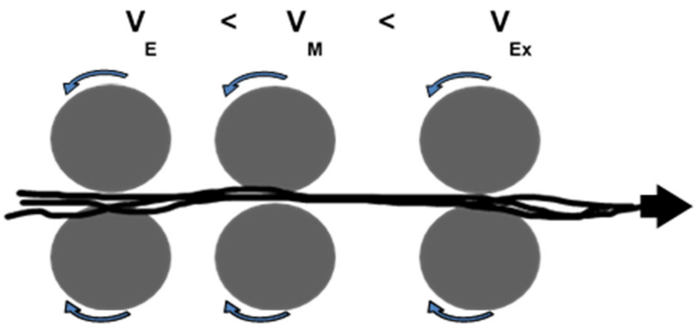


Figure 36 Basic principle of drafting

In figure 36 the general principle of drafting is shown. The increase of the of the velocities of the roller pairs from roller pair at the entry (V_E) to the roller pair exit (V_E) results in the drafting of the clamped fibre bundle in an ideal drafting process, the number of fibres in cross-section decreases uniformly by this process because of the increasing velocities. With the reduction of fibres in cross-section, the diameter of the bundle automatically decreases, which defines the fineness of the fibre bundle. This attenuation can be explained by the fold of draft (Klein, Vol. 1, 2014, p. 43):

$$Attenuation = Draft \times \frac{100}{100 - p} \qquad (3)$$

p defines the fibre loss percentage during the drafting process.

2.4.1 Regular drafting systems

This chapter presents three regular drafting systems and their position in the spinning chain. They differ to each other by task, machine, structure, draft-folds, and productivity. Firstly, the basic principles of a conventional drafting unit of a draw frame machine are presented. Secondly, the drafting units of a roving frame machine and a ring (and compact) spinning machine are explained. A presentation of a high-speed drafting system of an air jet spinning machine follows in detail in the next chapter 2.4.2. For each drafting system, the main tasks and influencing parameters or machine parts are explained.

2.4.1.1 Drafting in draw frame machines

"Draw frame textile machinery consisting of a delivery unit employed to straighten and parallelize the fibres by drafting, to homogenize the sliver by means of doubling and to blend and dedust the fibres" (DIN ISO 21485)

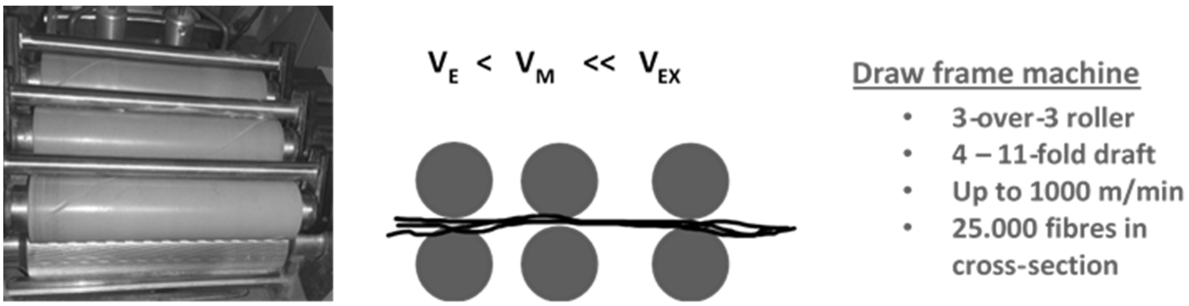


Figure 37 Overview drafting system of a draw frame machine

The draw frame machine takes part in the spinning preparation. The task of a draw frame machine is to homogenize the sliver by doubling several slivers and drafting them. Slivers from the carding machine or already drafted slivers are processed. This process leads to improvements in the sliver quality by equalizing the sliver and removing dust. Another possibility is blending several sliver qualities or colors (Klein, Vol. 3, 2014, p. 46). High drafting speeds come along with high risks of faults drafts and irregularities of the sliver [Cherif, 2001, p. 2]. State of the art draw frame machines have an autolevelling feature that detects and eliminates irregularities in the sliver automatically by adjusting the velocities of the drafting rollers. Therefor higher production speeds up to 1000 m/min are possible.

Examples in the industry are the RSB-D 24 by Rieter Machinery Ltd. with a 4-over-3- roller-drafting system and the Trützschler draw frame machine TD10 with a 4 over 3 roller drafting system [Source: Trützschler – draw frames, pdf, accessed 25.11.2018].

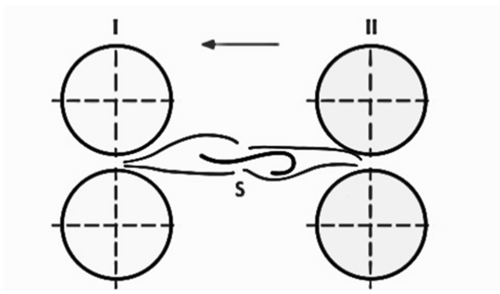
Figure 38 Principle of a Trützschler draw frame machine and its drafting arrangement

The number of draw frame passages of a sliver is responsible for the final sliver quality. In ring spinning mainly 2 passages of drawing is used [Klein, 2014, Vol.1, p. 29]. For air jet spinning, where high sliver qualities are required, 3 passages are usual [Stalder, 2014, Vol.6, p.36]. Furthermore, an integrated draw frame (IDF) is a possibility for reaching high qualities and reduce process steps and costs [Fibre2fashion, 2017, p.116-117]

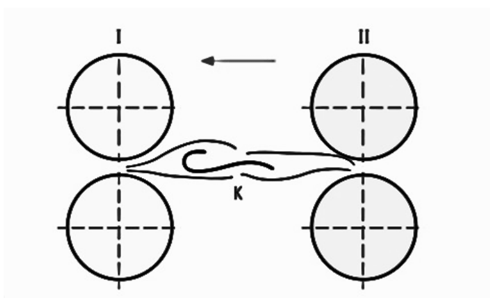
Another aspect of the importance of the number of draw frame passages is the fibre position and orientation in the sliver. In 1949, W. E. Morton and R. J. Summers analyzed the fibre distribution in a carded sliver and clustered them in four categories [Weber, 1993, p. 9ff]. Depending on the fibre ends position, they are categorized as: [Klein, 2014, Vol. 1, p.28].

Table 9 Categories of fibre orientation in a sliver (Klein, 2014, p.28)

1.) Trailing hooks (around 50 %)



2.) Leading hooks (around 15 %)



3.) Doubled hooks (around 15 %)
4.) No hooks (around 20 %)

The draw frame machine removes partly the trailing hooks and parallelize the fibres in the sliver. Regarding the number of draw frame passages, more trailing hooks or more leading hooks can be found in the sliver and influence the quality of the final yarn. For rotor spinning, the existence of the hooks is subordinate since the sliver is opened into single fibres during processing. For ring and air jet yarn the number of passages is significant, since the position of fibres as trailing or leading hooks is directly transferred to the final yarn [Weber, 1993, p. 10, Klein, 2014, Vol.1, p.29, Stalder, 2014, Vol. 6, p.36].

2.4.1.2 Drafting in roving frame machines

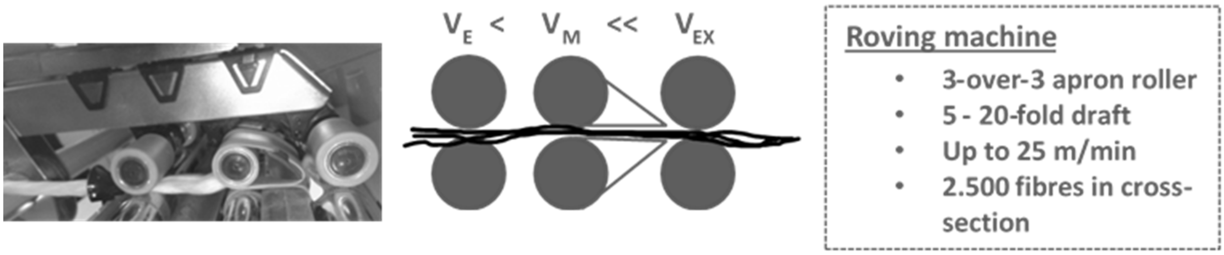


Figure 39 Overview drafting system of a roving frame machine

The roving frame machine produces rovings for the ring spinning process. The standard drafting arrangement for roving machines is the 3-over-3 roller pair with an integrated double-apron system at the second roller pair. The aprons increase the fibre guidance through the drafting process. Additionally, three condensers control the width of the fibre strand at corresponding points in the drafting unit (marked in orange) [Klein, 2014, Vol.3, p. 60, Carrisoni, 2002, p. 46].

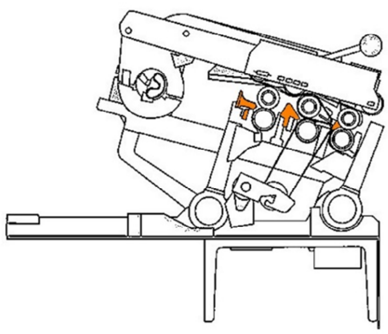


Figure 40 Sideview drafting system (Klein, 2014, p.)

At the sliver feed entry of the drafting system, a trumpet condenser can be fixed on a traversing bar to improve the lifetime of the following cots. Another condenser is placed just before the double apron arrangement to guide the fibre bundle. At the main draft zone, where the fibres exit the guidance of the double apron arrangement and before they are clamped at the front roller pair, a “flying condenser” is placed to control the fibre bundle width and to prevent fibres from spreading. This third condenser is not fixed it can move with the whole width of the fibre bundle.

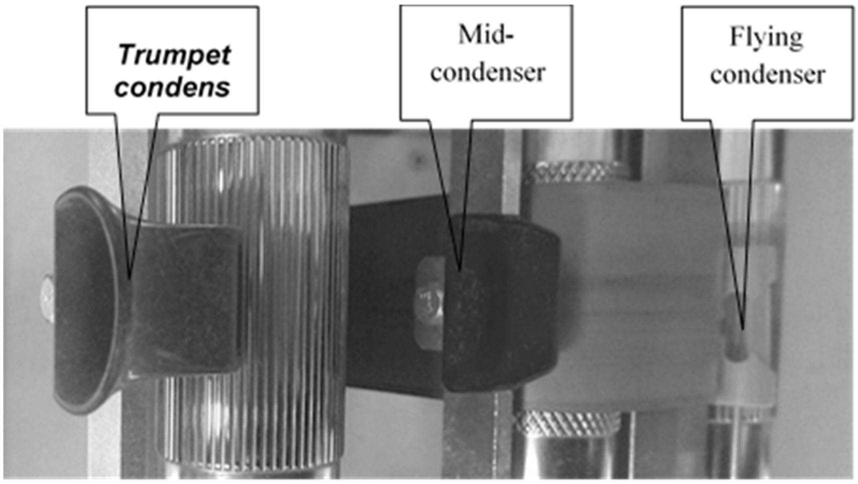


Figure 41 Top view of condenser arrangement in drafting system

Although the use of condensers, spreading fibres in the drafting system and loosing fibres as fibre fly is still a challenge. The combination of the optimal condensers, roller distances and top roller pressures and hardness of the cots and aprons influence the performance of the drafting system of the roving frame. The risk of spreading edge fibres during the drafting process can cause a wide spinning triangle which results in fibre fly and high hairiness values of the roving [Klein, 2014, Vol.3, p. 61, Lord, 2003, p. 173].

2.4.1.3 Drafting in ring spinning machines

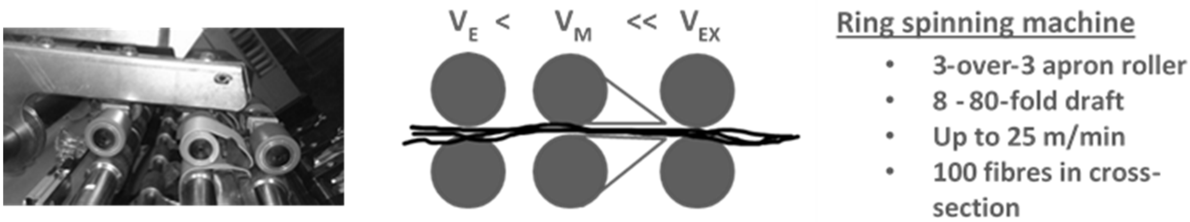


Figure 42 Overview drafting system of ring spinning machine

The conventional drafting system for short-staple in ring spinning is the 3-over-3 roller drafting unit with a double apron arrangement. A trumpet condenser at the entry of the drafting system guides the roving to the middle of the first roller pair. Another condenser is absent in a conventional drafting system of a ring spinning machine.

The absence of condensers is explainable with the use of a roving as delivery material. The roving has a protective twist which reduces the possibility of spreading fibres. Another aspect to explain the positive impact of the protective twist, is the nearly round cross-section of the roving. During drafting, the fibre ribbon is pressed by the rotation roller pairs, which causes a spatial deformation into a nearly flat cross-section.

Consequently, the risk of losing edge fibres or spreading fibres increases by a flat cross-section. The protective twist of the roving during the drafting in a ring spinning machine decreases this risk. Nevertheless, the protective twist must be set correctly. Otherwise, the twist can be too high for the drafting process in the ring spinning machine, or too low, that the friction forces do not hold the fibre strand together and the roving can break, or faults draft occurs [Klein, 2014, Vol.1, p. 47, Vol. 3, p.63].

The maximum draft can be set up to 80-folds, which is higher than in a draw frame or roving frame machine, but still a regular drafting fold. Examples for ring spinning machines in the industry are Zinser 351 and the Rieter G32.

Since the number of fibres in the drafting system of a ring spinning machine steadily decreases, aprons are used in the main draft zone to improve the guidance. Another aspect is the overlap or underlap of the top rollers to the bottom rollers to improve the guidance of the fibres during the drafting [Klein, 2014, Vol. 3, p.17].

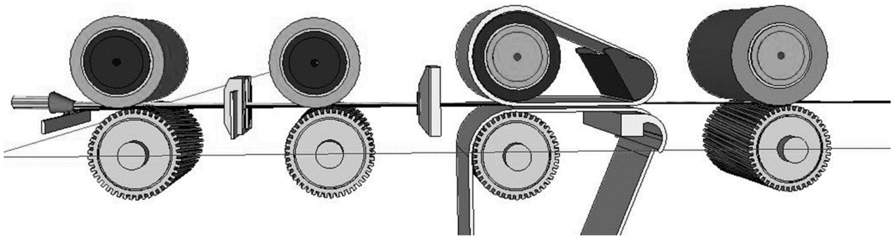
The company Rieter replaces in their compact spinning system the front bottom roller with a perforated bottom roller with an attached air-suction. More details of the compact spinning method can be found in chapter 2.2.1.3.

2.4.2 High-speed drafting system

In this thesis, the term "high-speed drafting" is used when the total draft for a spinning system is higher than 100-fold. High- speed draft requires other spinning auxiliaries and adjusted geometries of the drafting unit for a regular fibre transportation. This chapter contents the challenges of high-speed drafting systems, especially of air jet spinning machines and presents inventions to face them.

The application of high-speed drafting units is only possible if the following spinning technology can process the delivered fibres in time. Since the spinning technologies ring- and compact spinning are limited by the spindle speed and rotor spinning does not require a drafting unit, the only remaining spinning technology is air jet spinning. The production speed of conventional spinning technologies like ring or rotor spinning is partly limited by the degradation of parts subject to wear and partly by occurring spinning tensions.

Since in air jet spinning the main spinning process takes part with rotational airflow inside the nozzle, there is almost no comparable mechanical degradation like in the conventional spinning processes. Less spinning tension gives the opportunity of high-speed spinning which results in the necessity of a high-speed drafting system to deliver the fibres in time.



V_E < V_{M1} < V_{M2} <<< V_{Ex}

Pre-draft Mid-draft Main draft Total draft

Figure 43 Principle of high-speed drafting

High speed drafting folds are the result of high rotating speeds of the transporting roller pairs. The velocity of the roller pairs increases from roller pair to roller pair by processing the fibre bundle. This high velocity is particularly noticeable at the last roller pair, the delivery roller pair. Here, the velocity is equal to the production speed to deliver the fibre material in time for the spinning process. This leads to high fibre acceleration in the main draft zone. The challenge stays in the control of the fibre motion in the main draft zone during high fibre acceleration and caused interreferences during the drafting process [Taylor, 1954, Cherif, 2001, p. 36]

2.4.2.1 Challenges for high speed drafting

Regular drafting systems must fulfill either the challenge of high speed, or of high draft. Draw frame drafting systems work with high-speeds up to 1000 m/min, but with a low draft, related to the high number of fibres in cross-section with up to 25.000. Roving frame drafting systems work with relative low speeds and mid-high drafts, related to decrease the number of fibres in cross-section from around 25.000 down to 2.500. Ring drafting systems work with low speeds and relative high drafts related to the low number of fibres in cross-section to reach the final yarn count.

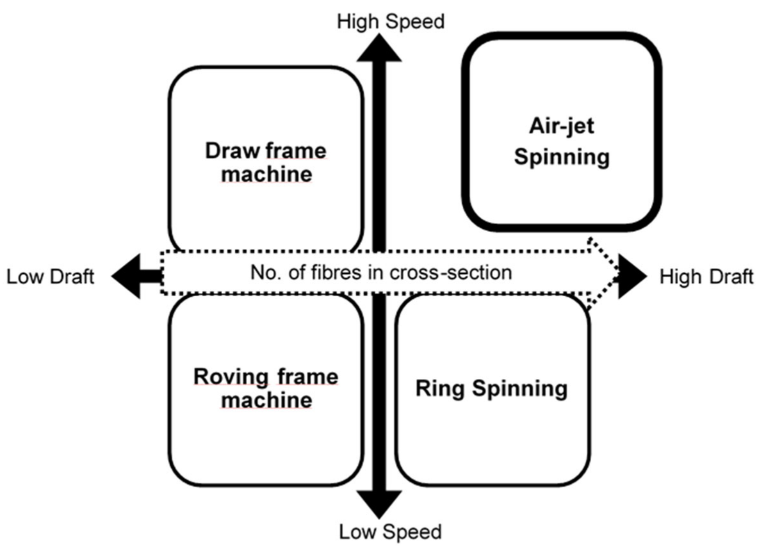


Figure 44 Relation between draft, speed and fibres in cross-section related to the used drafting system

Consequently, the challenge of the drafting system in air jet spinning is the combination of high draft folds and high production speed with a high reduction of fibres in cross-section during the drafting process. The thesis deals with this challenge and presents developments and innovations with their related limitations.

2.4.2.2 Drafting unit in air jet spinning

Since in air jet spinning the fed fibre material consists of a sliver with up to 25.000 fibres in cross-section, a high-speed drafting is necessary to reach the final yarn count with around 100 fibres in cross-section. That means, the required fibres in cross-section of the final yarn are only 0.04 % from the delivered sliver material. The drafting unit of an air jet spinning machine consists of a four over four roller arrangement with a double apron system to reach the high drafting folds.

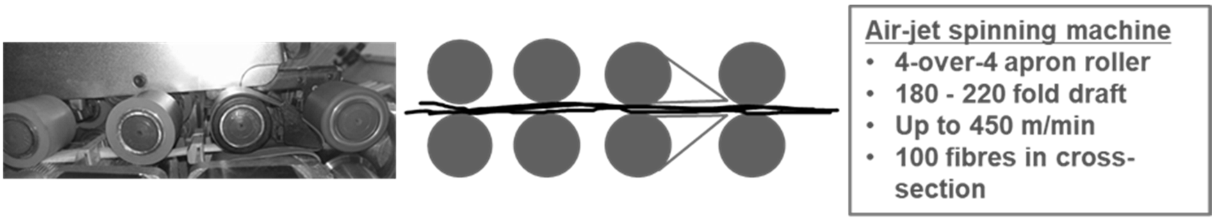


Figure 45 Overview of the drafting system of air-jet spinning

In the datasheet of the MVS III 870, the company Murata claims a maximum main draft up to 80-fold possible [Murata Inc.]. The company Rieter gives the information of maximum 60-fold at the main draft of their drafting system for the air jet spinning machine [Stalder, 2014].

At a high-speed drafting system several fluid dynamic problems appear with increasing speed which limits the possible production speed. The drafting system must deliver the right amount of fibres in the same time as the nozzle creates the yarn. Here, the main problem is that conventional drafting systems are not constructed for high speed. Especially in the main drafting zone high surface speeds of the roller pairs are necessary to deliver the fibres to the nozzle entry. If the delivery roller pair rotates in high speed, air flow appears at the inlet of the drafting rollers which causes misalignment of some fibres. Mechanical degradation like high abrasion and thermal resistance of the roller pairs is another challenge for the high-speed drafting system and should be mentioned (Chennoth 2007, Bergada, 2007). Figure 46 shows the principle of misaligned fibres. Figure 47 shows massive air flow turbulences, created by the counter-rotating drafting rollers. Both figures display the delivery roller pair where the velocity of the rollers reach their maximum.

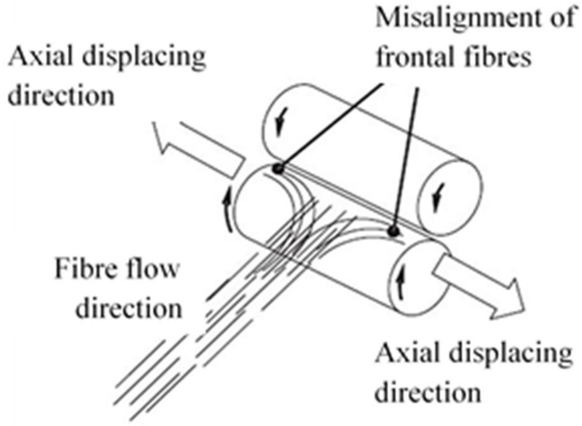


Figure 46 Principle of misalignment fibres in high speed drafting (source: Bergada, 2007)

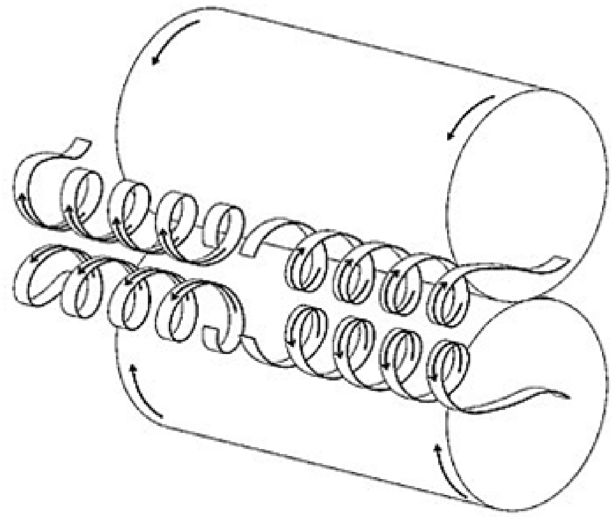
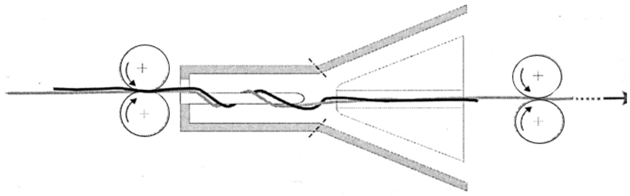


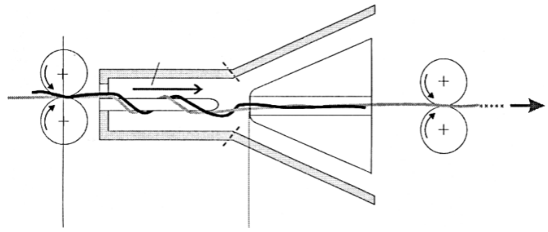
Figure 47 Principle of occurring air flow turbulences during high speed drafting (source: Bergada, 2007)

The misaligned fibres at the main draft zone play a crucial role for the resulting yarn quality and consequently for the reachable production speed. The amount and quality of parallel laying fibres in the main draft zone are responsible for the position of fibres entering the spinning nozzle. The fibres enter the nozzle only because of a slight air suction, generated by the vacuum inside the nozzle. If fibres are not parallelly laid in the fibre bundle after passing the nip of the last roller pair, they can produce irregularities in the yarn or get lost as fibre waste.

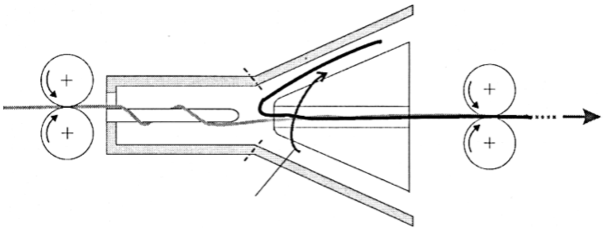
The figure 48 shows schematically the influence of the fibre position after leaving the main draft zone for the yarn formation process. Directly after leaving the nip of the last roller pair, the fibres enter the spinning nozzle. Depending on the position of the fibre in the loose fibre bundle, a single fibre is processed at the spinning cone as parallel fibre, wrapping fibre or fibre waste. Here, the spinning distance, the distance between the clamping point of the last roller to the cone tip, is crucial. If the fibre is hanging too lose at the surface of the fibre bundle without strong fibre-to-fibre friction, the fibre is lost as waste. That happens especially with short fibres. The position of parallel fibres in the core appears when they are in the middle of the fibre bundle. The position of wrapping fibres at the shell appears mainly when they are with one fibre end stuck in the yarn and the other fibre end can be caught by the rotational vortex and become a wrapping fibre [2004, Weide, p. 51-63].



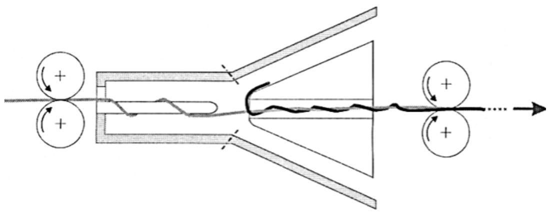
Formation of parallel fibres



Formation of parallel fibres with marked spinning distance



Formation start of wrapping fibres



Formation end of wrapping fibres

Figure 48 Yarn formation process clustered by parallel and wrapping fibres (based on: Weide, 2004, p. 60, 61)

Fibres which are folded, or transverse to the other parallel laying fibres do not integrate uniformly into the yarn formation process and decrease the spinning stability and cause waste or may even produce uneven yarn. The figure 49 underlines the role of the position of the fibres in the main draft zone before leaving the drafting system and the challenge of misaligned fibres.

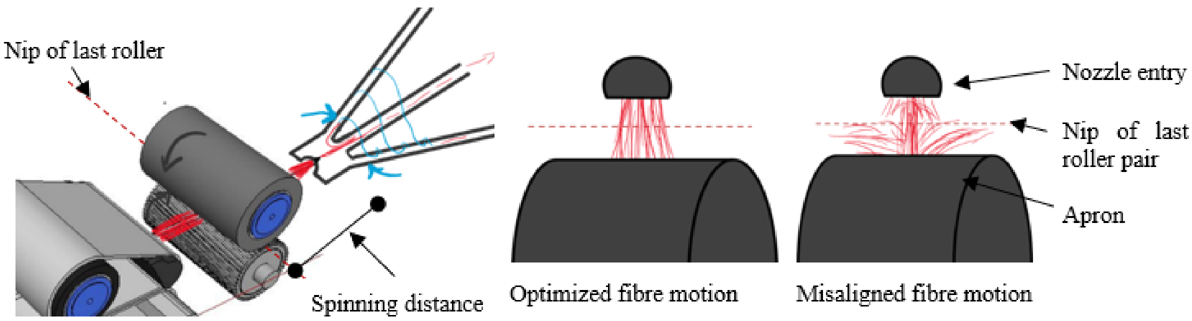


Figure 49 Schematic principle of the influence of the fibre position for the yarn formation process

2.4.2.3 Concepts for fibre transportation in high-speed drafting systems

Over the last few years, research has been carried out to analyse those airflows, which are responsible for losing peripheral fibres during the drafting process and for creating uneven yarn qualities. The goal of those research works is to understand the occurring air flow dynamics and solve the problems they create. Some of the innovations try to improve the machine parts and parameters directly, so that the interfering airflows at the roller pairs decrease (Bergada 2006, 2007, Karnan 2006, Aslan 2009, Wischnowski 2015, Schulte-Südhoff 2015). Other developments "accept" the occurring axial airflows and try to improve the fibre guidance in general – an indirect solution (Wehrli and Mondgenast, 2004, Stahlecker and Schoch, 2004, Deno et al, 2006, Weide et al, 2014).

Table 10 and Table 11 give a selected overview about the research of high-speed spinning and –drafting and their solutions to increase the fibre guidance at the drafting system.

Table 10 Latest research on high speed spinning and -drafting and main developments found

Year	Author	Main development	Consequences
2003	Ben Hassen & Sakli	4-over-4 roller pair high speed drafting for sliver-to-yarn ring spinning; shaped condensers and draft distances	No roving production step; yarn evenness increases
2007	Bergada et al	Analysis of axial airflow at inlet rollers -perforated and not perforated-	Perforated inlet rollers with internal suction increases yarn quality
2007	Heitmann & Gericke	Modification of top apron composition	Less pressure necessary and longer lifetime of aprons
2008	Aslan et al	Modification of roving drafting unit with 5-over-5 roller pair high speed and high modular structure	Increase of yarn quality in comparison to standard 3-over-3 roller pair
2010	Biermann	Separate and individual parts for drafting units	Quick and flexible change of drafting parts
2015	Schulte-Südhoff	Air evacuation at bottom roller; arrangement of aprons; condenser at main draft	Increase of fibre guidance and yarn quality

It can be seen that the listed research in table 10 and 11 is not narrowed to drafting systems for air jet spinning. Some of the developments have their application in drafting systems of roving or ring spinning. The additional involvement of other technologies could be helpful for further investigations.

Table 11 Latest patents and developments regarding fibre loss at high-speed drafting

Year	Author	Main development	Consequences/Claims
2004	Wehrli & Mondgenast	Condenser at nip of main drafting roller pair to reduce fibre loss	Increase of yarn quality
2004	Stahlecker & Schoch	Special arrangement of double apron with several add-ons like air-suction at nip	Decrease of axial airflow at roller pairs
2005	Ota	Gaps at both sides of upper rubber roller	Prevents axial airflow and degradation of yarn quality
2006	Deno et al	Detailed texture of bottom roller surface	Higher grip of fibres through the drafting
2012	Ota et al	Special roller cot geometry	Prevents axial airflow
2014	Griesshammer et al	Pneumatic spiral false twist device at preliminary drafting zone	Comprising fibre bundle through the drafting unit
2014	Weide et al	Mechanical device to insert false twist in sliver in the drafting zone	Higher compaction of sliver during drafting and increase of yarn quality
2016	Mori, H.	Pneumatic suction device between nip of main drafting roller pair and spinning device	Reduce fibre fly between start/stop of machine

The following sub-chapters present patents which claim to improve the drafting performance with a compaction of fibres in the main draft zone more in detail. Some of the here presented solutions or ideas are already state of the art for the manufacturers.

2.4.2.3.1 Compaction with false twist

Year	Patent No.	Owner	Title	Content
2014	DE 10 2012 023 985 A1	Saurer Germany GmbH & Co.KG	Luftspinnvorrichtung	False twist device

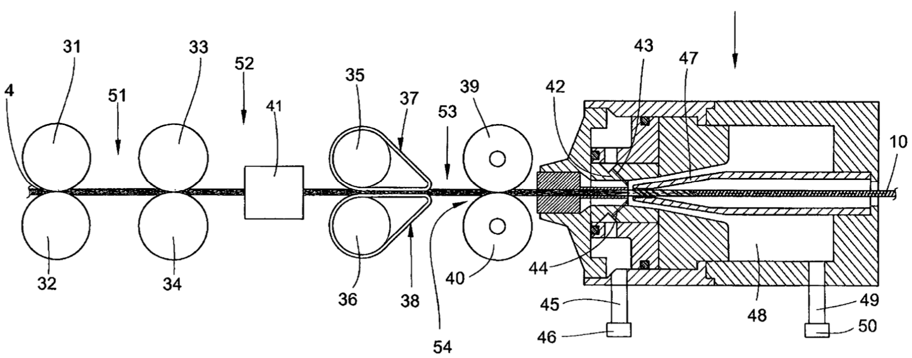


Figure 50 Patent drawing of compaction with false twist (DE102012023085A1)

The patent builds the base for the mechanical false twist device in this thesis. The aim is to increase the fibre-fibre-friction in the drafted fibre bundle in the main draft zone by inserting false twist with an alternating rotational device at the pre-draft. The patent claims to realise this aim with a pneumatic device (figure 50) to create alternating vortices (claim [0019]) or with a mechanical device with the help of a rotational tube (claim [0018]).

2.4.2.3.2. Mechanical compaction with condenser

Year	Patent No.	Owner	Title	Content
2004	DE10252631A1	Maschinenfabrik Rieter AG	Spinnmaschine mit Verdichtungseinrichtung	Condenser at delivery roller pair

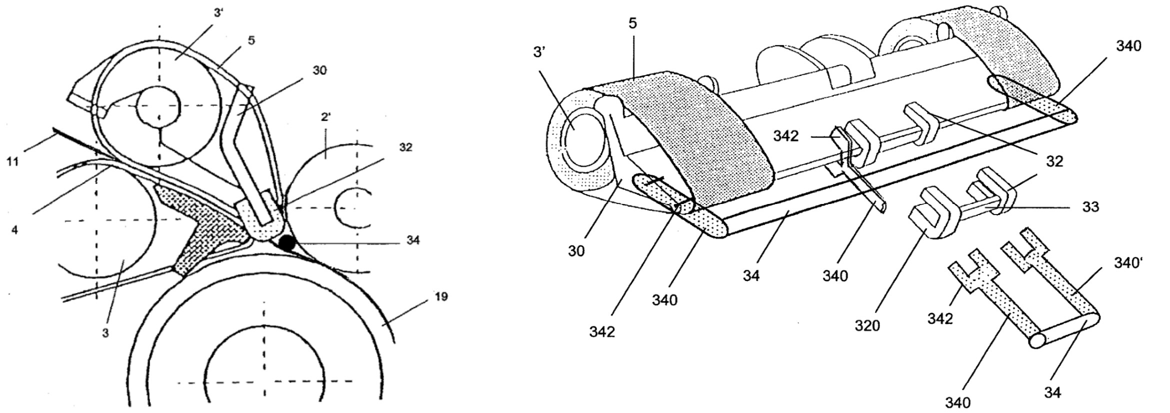


Figure 51 Patent drawings of a mechanical compaction (DE1025263A1)

One part of the patent describes a condenser-like device at the main draft zone between the apron roller and the delivery roller pair. A bar is implemented at the cradle top to hold the misaligned fibres down and improve the guidance of the fibres through the nip of the delivery roller pair. The patent claims by using the bar to decrease fibre fly and improve the yarn evenness.

Year	Patent No.	Owner	Title	Content
2014	WO14037773A2	Maschinenfabrik Rieter AG	Spinnmaschine mit Drallelement	Spiral False Twist Device at preliminary drafting zone

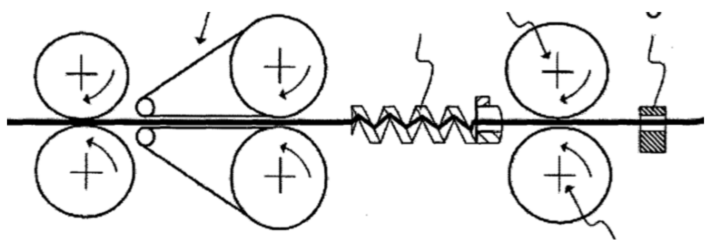


Figure 52 Patent drawing of a mechanical compaction with false twist (WO14037773A2)

Another type of condenser is presented in this patent for a drafting system of a roving frame machine. The patent describes a false twist insertion at a pre-draft zone by using a spiral guidance element. The spiral guides the fibre bundlethrough the drafting system and travers the fibre bundle parallely. The patent claims to prevent false drafts and to restrain thin places in the delivered sliver material.

2.4.2.3.3. Pneumatic compaction with air-suction or perforated rollers

Year	Patent No.	Owner	Title	Content
2013	WO002013138875A1	D-A-Dinko Bahov Et	Method and device for spinning of yarn with air vortex	Perforated drafting roller

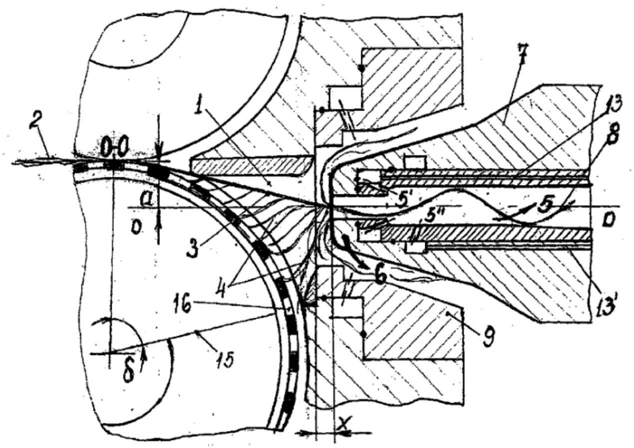


Figure 53 Patent drawing pneumatic compaction (WO02013138875A1)

This patent seems to be inspired by the compact spinning method. It describes a perforated bottom roller at the delivery roller pair in a drafting system of an air jet spinning machine. Through the effect of vacuum, the fibres get stretched by passing the roller pair with the perforated bottom roller. The patent claims to improve the integration of fibre end to decrease fibre fly and improve the yarn quality.

Year	Patent No.	Owner	Title	Content
2016	EP02966199A2	Murata Machinery LTD	Spinning machine and spinning method	Fiber guarding and delivery rollers with airsuction at high speed

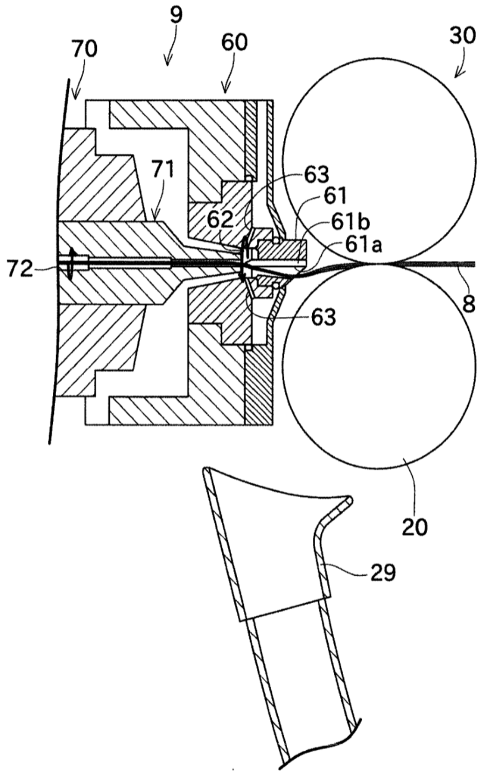


Figure 54 Patent drawing pneumatic cleaning (EP02966199A2)

This patent presents more a passive solution to prevent misaligned fibres influencing the yarn quality. It defines an air suction tube between the last bottom roller and the nozzle of an air jet spinning machine. This tube cleans the area of the spinning distance of flying fibres or disintegrated fibres. Especially in the moment of start and stop the spinning process, clogged fibres can be removed by the suction tube. The patent claims to improve the quality of the fibre flow.

2.4.2.3.4 Different cot/ roller geometries

Table 12 gives an overview of patents about improvements of the main drafting zone of an air jet spinning machine by specialized aprons or roller designs. Two of the inventions are described more in detail at the next page. They represent two different ways of handling misaligned fibres.

Table 12 Overview patents of cot/ roller geometries

Year	Patent No.	Owner	Title	Content
1988	US000004718225A	Murata Machinery LTD	Pneumatic spinning machine	Special arrangement of double-aprons to eliminate the rotational airflow at the rollers
2004	EP000001464740A2	Maschinenfabrik Rieter AG	Doppelriemchen-Streckwerk für Spinnereimaschinen	Special arrangement of double-aprons to eliminate the rotational airflow at the rollers
2005	EP01520919A2	Murata Kikai Kabushiki Kaisha	Draft device comprising rollers preventing the bundle of fibres from being spread during drafting	Step rollers for high speed drafting with 1.5 mm step to the sides
2006	EP01693491A2	Murata Kikai Kabushiki Kaisha	Draft roller in spinning machine	Texture of roller surface
2012	EP000002455518A2	Murata Machinery LTD	Draft roller, draft device, and spinning machine	Special roller cot geometry to eliminate rotational airflow at rollers

Two developments of the list below are explored more in detail. They are two different types of solution to the problem of fibre misalignment caused by the axial fibre flow. The first development by Murata influences the axial fibre flow “directly” to decrease the fibre loss and misalignment in following passive way (Ota, 2012). Murata solved the fibre misalignment problem with a narrow top roller cot at the delivery roller pair (figure 55). This top roller allows occurring axial air flow to escape sideways and fibres can bundle into the yarn. However, this solution is still limited because it can only narrow the fibre strand to a certain extent as the total width of the fibres which are at the nip point (Ota, 2012).

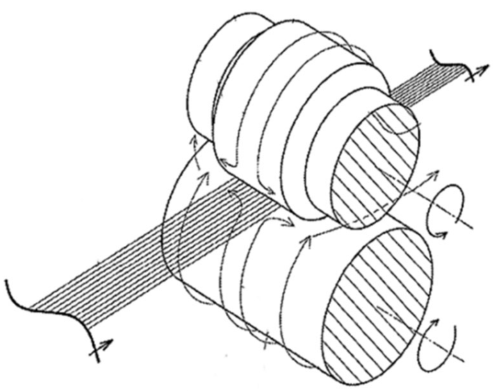


Figure 55 Patent drawing special cot geometry (EP000002455518A2)

The second innovation by Rieter influences the axial fibre flow not directly. Instead of trying to decrease the axial fibre flow actively, they try to increase the fibre guidance through the sensitive main drafting zone where the axial fibre flow appears – an “indirect” solution (Stahlecker, 2014). A special double-apron arrangement is used at the main drafting zone to minimize the distance from the nip of the apron to the nip of the delivery roller. [Stahlecker 2004]

In figure 56 the principle of the special double apron arrangement is shown.

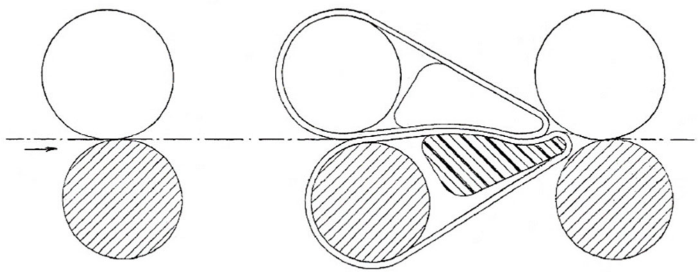


Figure 56 Patent drawing special apron arrangement (EP000001464740A2)

2.4.3 Concepts for the analysis of air- and fibre movement in the drafting zone

Over the last decades, research has been done to analyse the drafting process and its related fibre movement and the occurring air flows. The concepts of research differ from the aim, the result and the methods which were used.

Some of the research handle the fibre movement between two rotating roller pairs in general. Other innovations analyse an exact problem of one machine or one process step. However, they have all in common that the accuracy of the results improved over the years.

In 1954 D. S. Taylor published his research about his concept of using a radioactive treatment of fibres for the observation of the fibre flow through a drafting system. Besides of the huge health risk, the radioactive radiation is not stable because of its half-time decay, so that the accuracy of the data was limited.

Bauer (1987), Weber (1991, 1993, 1994, 1997) and Wulfhorst (1991, 1994, 1997) did research in analysing the fibre movement with a Laser-Doppler-Anemometer and luminous fibres. This method presents an accurate concept for the analysis of the fibre movement in a drafting zone. Still, it is necessary to imply luminous fibres into the fibre bundle. This could affect the fibre-fibre-friction, the fibre mass and the fibre bundle running behaviour in general.

Besides those examples of experimental methods for analysing the fibre movement, several theoretical attempts with numerical methods have been done. The history of these research appears in a periodic way. In the 1950’s and 1960’s Hannah, Foster, Grishin, Tayor, McVittie, Audivert and Belov published comprehensive studies about the theory of drafting. In 1951, G. A. Foster presented several mathematical theories of the fibre movement between two roller pairs during the drafting process developing hypothesises of the behaviour of floating fibres and their origin.

Since the production speed of spinning machines increased over the last decades and with the development of the air jet spinning technology, new research attempts about the high-speed drafting came up at the beginning of the 2000’s.

The history of air flow analysis in the drafting zone is related to the development of possible methods. Since the computing power steadily increases and possibilities of computer simulations improve, a simulated model is a considerable way to compare the experimental results with theoretical ones. Research regarding the air flow, especially the occurring axial airflow at the main drafting zone has been carried out by Bergada (2007) and Wischnowski (2015). Besides the given theories and modelling attempts, mathematical solutions from other disciplines than research in drafting systems can help. For example, modelling of hair movement for animated movies gives an interesting aspect and can help for a suitable solution of the modelling task (Iben 2013, Bertails-Descoubes 2011, Bergou 2008, 2010).

Nevertheless, this work concentrates on the visual analysis of the fibre motion at the main draft zone and the possibility to gain reproductible data to build a base for oncoming investigations regarding mechanical developments to improve the drafting system at high speed spinning machines.

3. Motivation, objectives, and structure of Thesis

3.1 Problem definition and motivation

High production speed with air jet spinning is limited by two main factors. First factor is the amount of twisting wrapping fibres, created by the distribution of the rotational and the axial air flow inside the nozzle. Those fibres are responsible for the tenacity of the yarn. If the distribution of rotational and axial air flow is not correctly set, the yarn gets not enough tenacity. Because of this sensible air flow geometry at the spinning nozzle, the spinning process demands high quality standards for the delivered sliver. Processing of 100 % carded cotton is limited because of the short fibres inside the sliver. Unfortunately, the preparation of the sliver to increase the demanded quality is not solved by more draw frame passages. Combed cotton is a possible solution, but it includes an additional machine and additional costs (Raes 1962, Chennot 2007, Germanova-Krasteva 2007, Planck 2008).

Second factor is the drafting system, where several fluid dynamic problems appear with increasing speed and limits the possible production speed. The drafting system must deliver the right number of fibres at the same time as the nozzle creates the yarn. Here, the main problem is that conventional drafting systems are not constructed for high speed. Especially in the main drafting zone high surface speeds of the roller pairs are necessary to deliver the fibres to the nozzle entry. If the delivery roller pair rotates in high speed, air flow appears at the inlet of the drafting rollers which causes misalignment of fibres [Bergada, 2007].

The challenge of high-speed air jet spinning remains in the performance of the drafting unit. Although there are some concepts of regular fibre transportation in high-speed drafting systems, the problem of losing peripheral fibres is not finally solved. This study takes efforts to present and analyse the influence of new innovative solutions compared to regular fibre guidance in high-speed drafting systems.

3.2 Main objectives

The main objective of the thesis is to develop and to analyse alternative solutions of fibre compaction in high-speed drafting of air jet spinning machines. The air jet spinning machines are prevailing in the market spin yarn from sliver with delivery speeds up to 500 m/min. In this work, a prototype with a production speed of 250 m/min is used.

The objectives of this work are listed as followed:

Part-1: Theoretical fibre motion

- Create a process control simulation to model the false twist signal output and its influence for the fibre motion in the drafting zone

- To find the theoretical frequency range for the signal input and compare it with the experimental signals
- Evaluate the theoretical signal input and output with the experimental signal input and output

Part-2: False twist device

- To analyse the signal of the false twist device regarding frequency and number of rotations per period
- To insert false twist into the second pre-draft of a high-speed drafting system of an air jet spinning unit
- To analyse the fibre motion in the high-speed drafting zone and regarding the inserted false twist signal and the delivery speed
- To analyse the impact of the false twist insertion regarding the resulting yarn quality
- To compare the experimental values of fibre motion with the theoretical values from the simulation
- To insert false twist in a regular drafting system of a roving frame to analyse the influence for the fibre motion, especially the spinning triangle
- To analyse the roving quality and its impact for the ring yarn quality and correlate them with regular drafted products

Part-3: Spiral Condenser

- To develop a new condenser geometry for drafting systems (patent applied) and use rapid prototyping to implement it directly in the drafting system
- To analyse the fibre motion in the high-speed drafting zone and the impact of the delivery speed
- To analyse the impact of the spiral condenser regarding the resulting yarn quality
- To analyse the influence of a spiral condenser for the fibre motion in a regular drafting zone of a roving machine, especially the spinning triangle
- To analyse the roving quality and its impact for the ring yarn quality and fabric quality and correlate them with regular drafted products

3.3 Structure thesis

The main part of the thesis consists of the experimental chapter, which starts with trial preparation and the used methods. For the trial preparation, the used machines, and prototypes of the developed spinning auxiliaries like the false twist device and the spiral condenser are presented. This is followed by the methods to test the influence of those spinning auxiliaries for the spinning behaviour and the yarn quality. A new method is developed to investigate the fibre flow behaviour with a high-speed camera and a motion analyser software. For further investigations and simulation, the software MATLAB and Scilab are used.

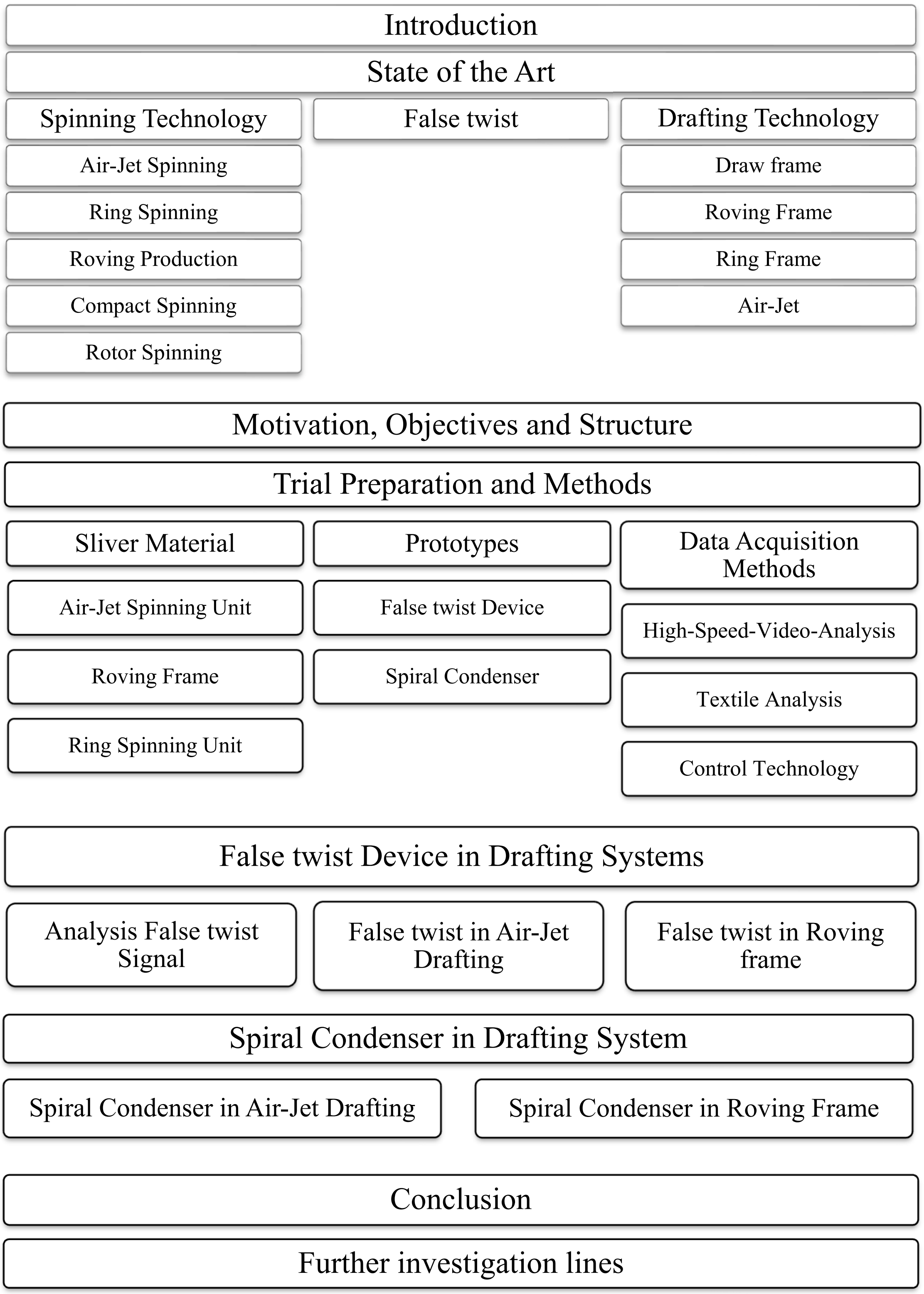


Figure 57 Structure of PhD-Thesis

4. Trial preparation and methods

4.1 Material

The used material for this work is a 100 % cotton draw frame sliver with two passages with a medium quality. The parameters as mean values are shown in table 13 and have been tested by an Uster 5 and AFIS.

Table 13 Overview of used sliver fibre material for the trials

Finesse [Nm]	Nm0.26
Staple length [mm]	24.69
Fibre count [dtex]	2.08
Short fibre content [%]	8.2
Trash content [%]	0.012
Micronaire	4.8

4.2 Spinning unit

For the trials, a prototype of one spindle air jet spinning unit is used.

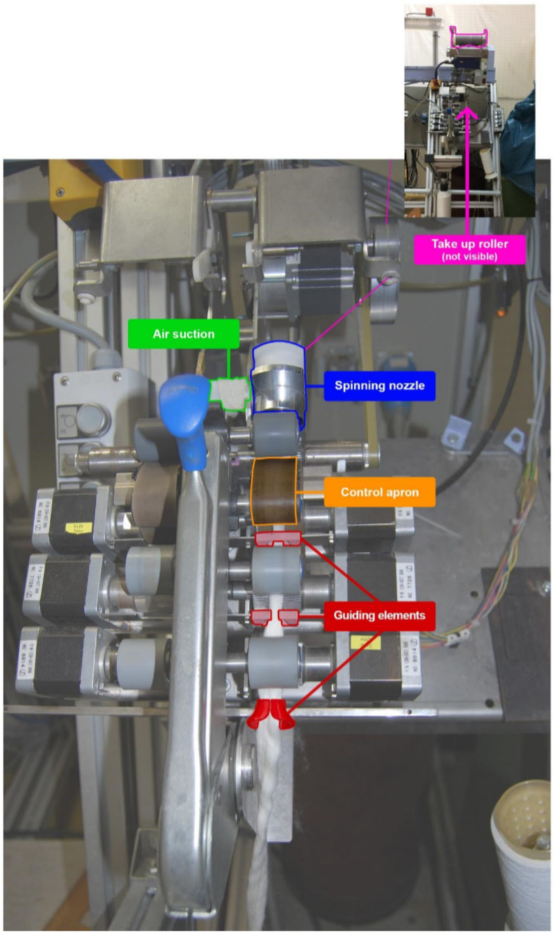


Figure 58 Picture of used spinning unit (Lerner, 2018, p. 25)

The spinning unit consists of a 4-over-4-roller drafting system with single motor drives for each bottom roller. The roller speed can be individual adjusted and the different drafting -folds can be set. Delivery speeds up to 275 m/min is reachable. The drafting unit is followed by the spinning nozzle, a yarn take-up roller, and a winding unit. The spinning nozzle consists of fibre entry with fibre guidance needles, a spinning chamber with eight tangential arranged injector boreholes and a spinning cone. Air pressure up to 6 bar can be adjusted; for the trials 4 bar is used.

4.3 Roving frame machine

For the trials of the roving production a ZinserSpeed 5M machine from the company Zinser is used. The machine is capable of “EasySpin” control, where four drive systems for the drafting system, the hub of the bobbins, the spindle rotation and the flyer rotation are independent coordinated by increase of the bobbin diameter and related centrifugal force.

Figure 59 Picture of used roving frame machine (Kötzsch, 2018, p. 31)

The main settings of the machine for the trials are set by pre-trials, using the sliver material of 100 % carded cotton.

Table 14 Overview roving frame settings

Twist [T/m]	52
αm	32
Pre-draft WV NV	1.17 28 40
Main draft D15 NW	9.31 52 27
Flyer speed [rpm]	950
Delivery speed [m/min]	18.28

4.4 Ring spinning unit

The processing of the produced rovings takes place at a laboratory testing ring spinning machine LSE 2000 from the company Cetex GmbH. The ring spinning unit provides space for 6 roving bobbins and a fully equipped drafting system and spinning unit for 6 cops.

Figure 60 Picture of used ring spinning machine (Kötzsch, 2018, p. 31)

The main settings of the ring spinning machine for the trials are set by pre-trials, using the sliver of 100% carded cotton.

Table 15 Overview of ring spinning settings

Twist [T/m]	778
αm	110
Pre-draft Main draft Total draft	1.3 16,58 21.55
Spindle speed [rpm]	10000
Delivery speed [m/min]	12.86

Furthermore, several types of distance clips and the traveler weights are used for the trials.

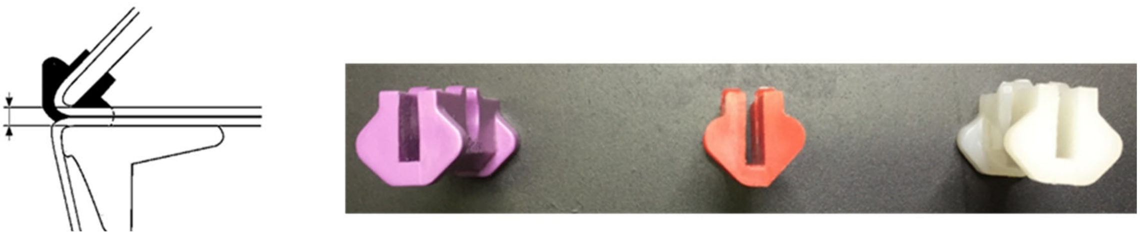


Figure 61 Examples of used distance clips

4.5 Developed prototypes to investigate

The two following subchapters present two prototypes to implement false twist into the drafting system. The first prototype uses a dynamic alternating false twist-insertion, driven by a motor. The second prototype is an invention which led to a patent during the trials. Here, the false twist is implemented by a static device. The aim of the two prototypes is to analyse their impact for improving the spinning process of an air jet spinning machine and a roving frame machine. All trials include results of a conventional drafting system of an air jet spinning machine and a roving frame machine without false twist insertion to show the comparison.

4.5.1 False Twist Device

The dynamic false twist insertion is processed by a false twist device. The prototype device contains a slot plate which is driven by a toothed belt connected to a brushless BLDC motor. The control instrument is a control card with two external inputs to set the torque and the velocity of the rotational slot plate. The rotational signal output can be individually set by the relation between the torque and the velocity input. In figure 62, a picture of the inner parts and the used slot geometry is shown. The slot has the shape of an elliptical hole which narrows slightly centrically both sides.

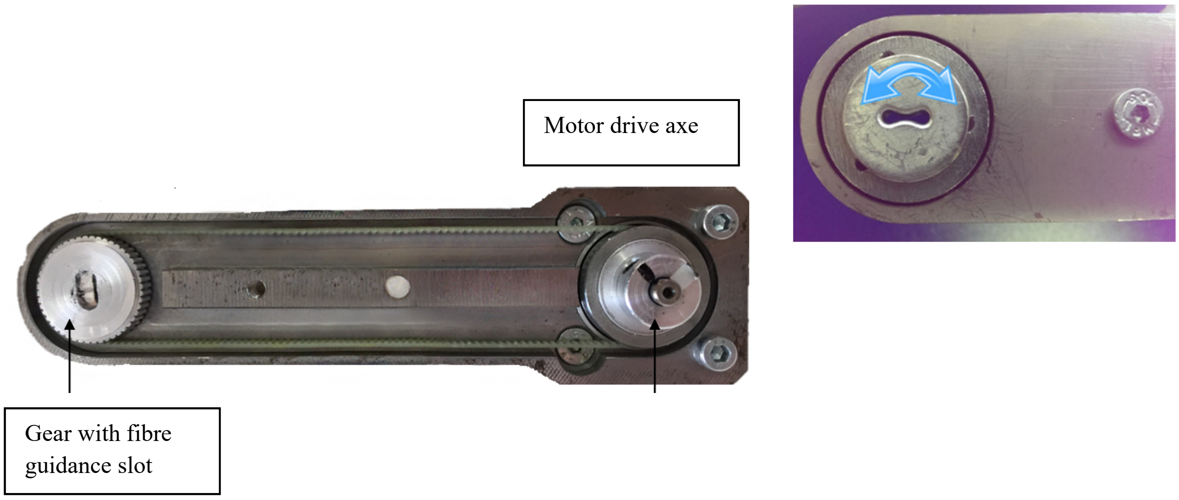


Figure 62 Pictures of dynamic false twist device

The false twist insertion with the dynamic false twist device takes place within the second pre-draft zone of a high-speed drafting system of the air jet spinning unit. The sliver is guided through the rotational slot plate of the device instead of a conventional condenser. For the trials at the roving frame machine, the false twist device is placed at the pre-draft zone of the drafting unit.

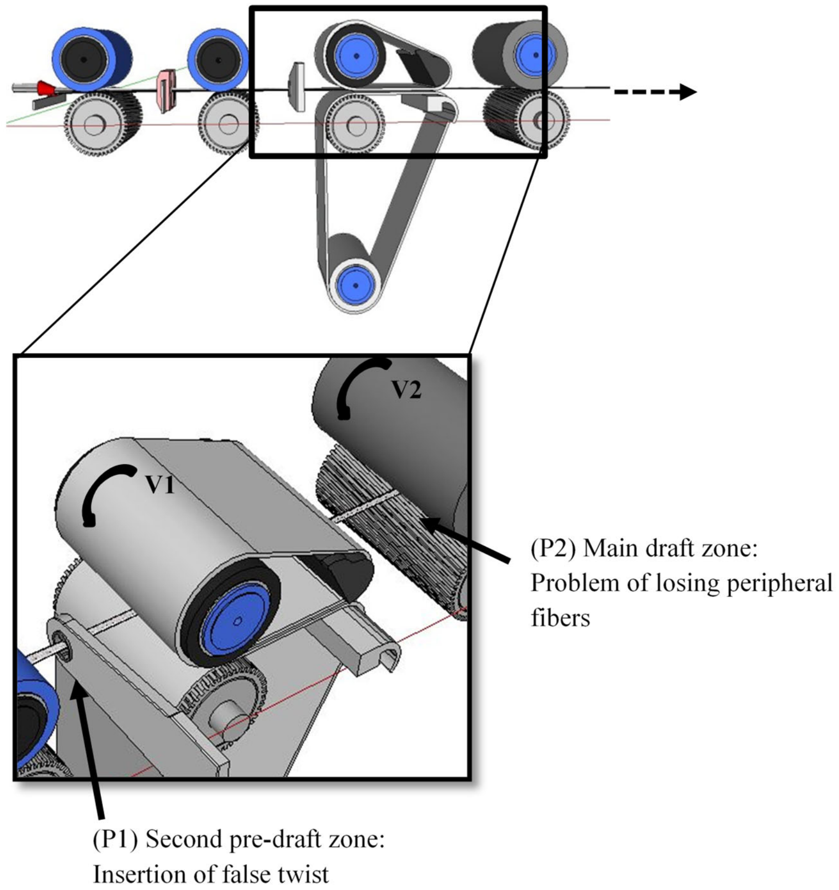


Figure 63 4 over 4 drafting unit with false twist device at the second pre-draft zone

The alternating rotation of the slot gives the passing drafted sliver temporally a false twist. In figure 64 is shown how the sliver gets compacted by the false twist. The challenge is to insert enough false twist to compact the sliver for the main drafting zone, but to keep the sliver loose enough for the high draft.

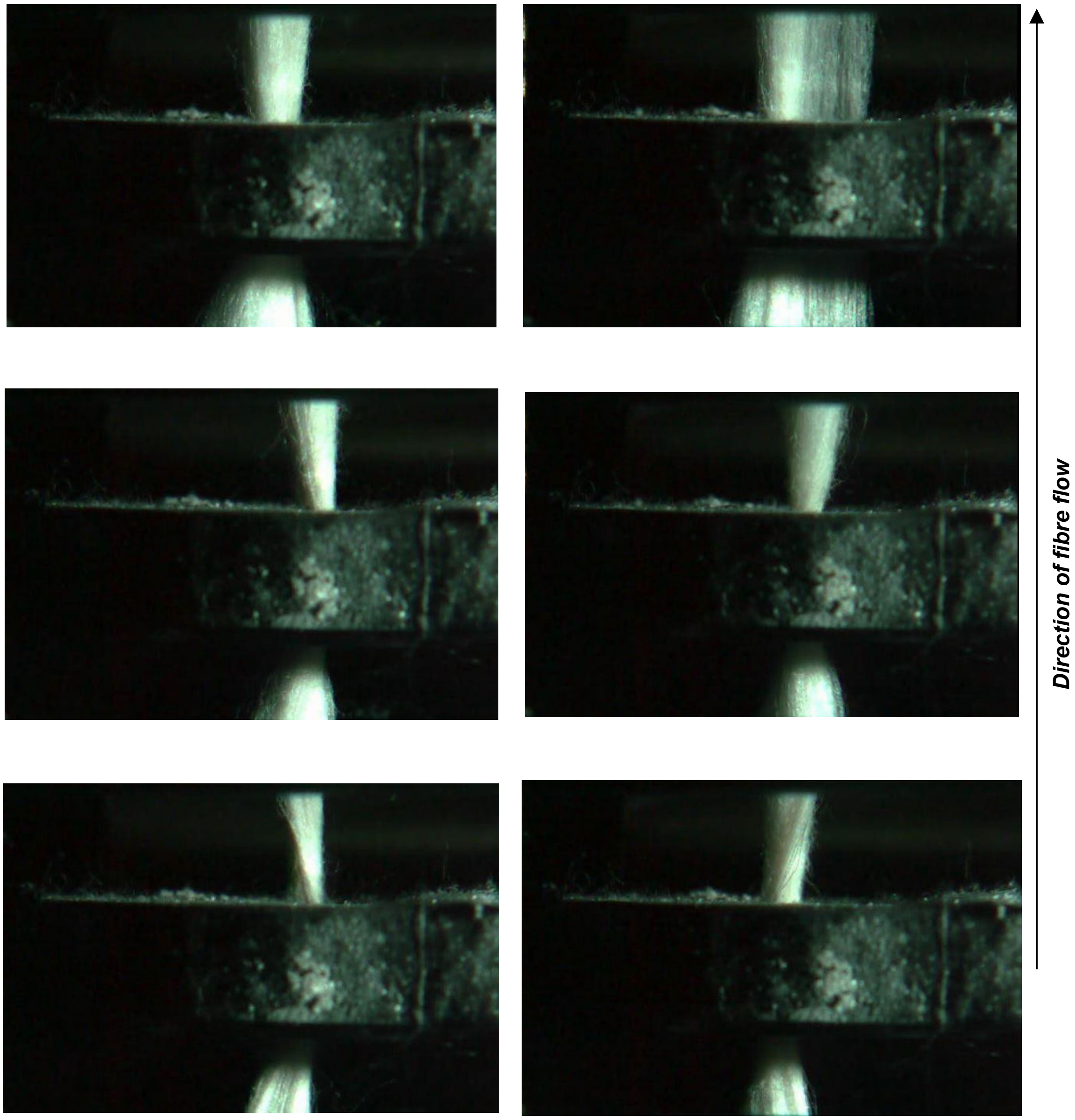


Figure 64 Alternating false twist insertion and its impact for the fibre bundle

The aim of analysing this prototype is to understand and to cluster the signals that can be set and to analyse the impact of the signals for the fibre flow at the drafting system and the resulting yarn quality. Several pre-trials have shown that an alternating rotation has the most positive impact for a compaction of the fibre bundle over the main drafting zone. This alternating rotation signal is analysed by its frequency and number of rotations per period.

4.5.2 Spiral Condenser

In addition to the dynamic false twist insertion into the sliver at the drafting unit, condensers produced by 3D-printing with Fused Deposition Modelling (FDM), consisting of polyamide, are tested.

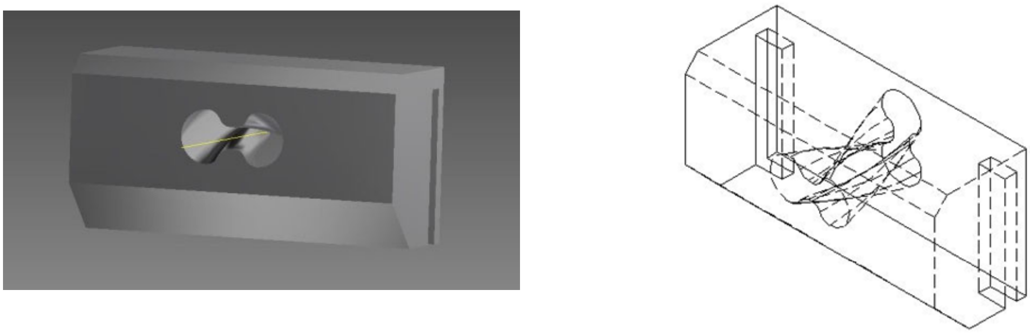


Figure 65 Technical drawings of spiral condenser

The idea behind the condensers is to insert false twist by a static device, the spiral condenser. In general, at a four-over-four roller drafting system a conventional condenser is placed at the first pre-draft zone (and at the second pre-draft zone). For higher control of the fibre flow at the main drafting zone a double apron is used. The conventional condensers guide the drafted fibre bundle through the drafting system and reduce the width of the guided fibre bundle due to their narrowed sides. The sliver width reduction is limited because of the friction behavior between the fibres and the condenser sides. Therefore, conventional condensers consist of a defined width depending on the fineness of the inserted sliver.

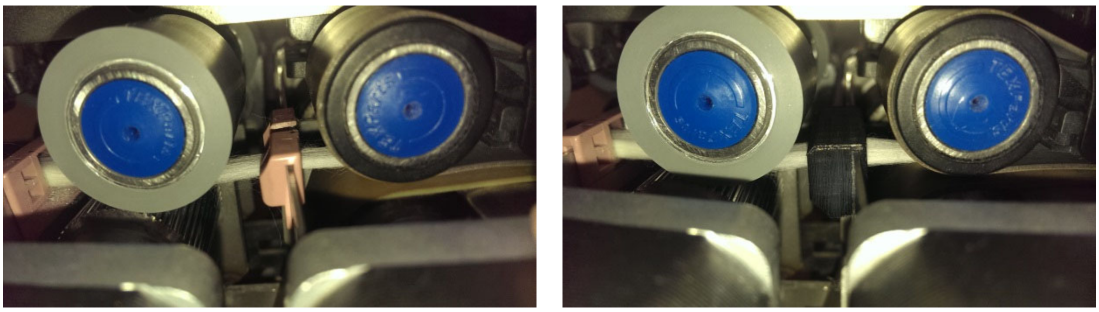


Figure 66 Comparison of condensers applied into the second pre-draft zone

The aim of the spiral condenser is not only to guide the fibre bundle through the drafting zone like a conventional condenser. The fibre bundle enters the spiral condenser in a horizontal, almost flat, position. Whilst passing the spiral canal of the condenser, the fibre bundle twists from the horizontal position to a vertical position with a 90° direction change (figure 66 right picture). The fibre bundle has temporally a false twist, with a higher compaction to all bundle sides.

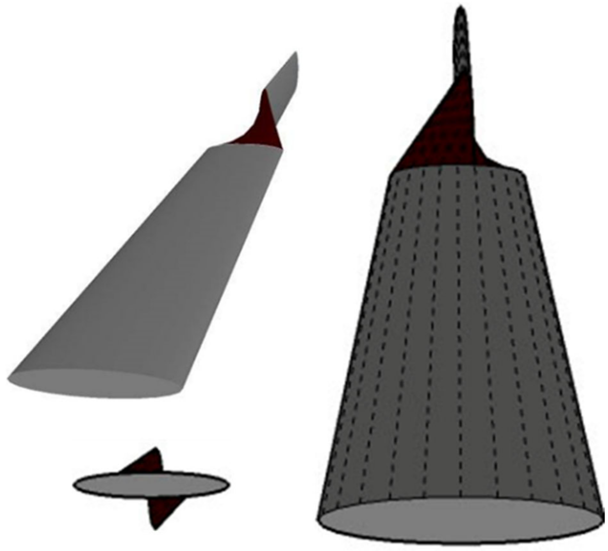


Figure 67 Schematic principle of spatial deformation of the fibre bundle

Besides of the direction change, a slight narrowing of the condenser exit can increase the compaction rate, too. The impact of the spiral condenser for the fibre flow at the main draft zone and for the resulting yarn quality is tested.

The concept of the spiral canal is transferred to condensers used in a drafting system for roving production. The geometry of the condenser itself and the width of the canal is adjusted for the roving machine (figure 68).

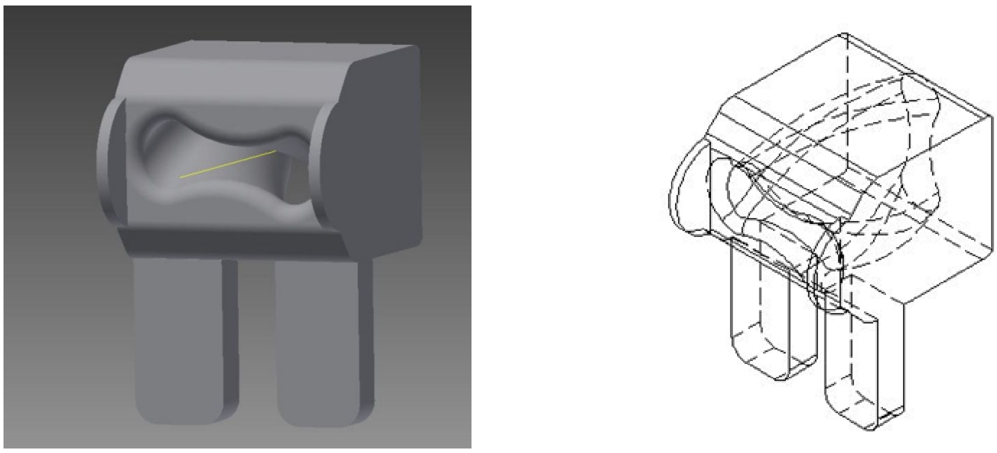


Figure 68 Technical drawings of spiral condensers for roving machines

The additional aspect of testing the influence of spiral condenser for roving production gives an interesting comparison to the high-performance drafting systems of air jet spinning. The produced roving is used to spin ring yarn. The comparison of ring yarn, produced with spiral condensed roving, to ring yarn, produced with conventional condensed roving, wides the field of the study.

4.6 Data acquisition methods

4.6.1 High-Speed Video Analysis

The analysis of the motion of the rotational plate of the false twist device and the motion of the fibres at the drafting zone require a detailed visual way of investigation. Furthermore, the visual investigation needs a source of data acquisition which represents the actual values of the motion.

For these requirements, a high-speed camera and digital microscope from the company KEYENCE is used. The model VW-9000 can record high-speed motion with up to 230 000 fps with a magnified observation with a CMOS sensor. A motion graph function allows to visually track and quantify the amount of motion (amount of change) of a specific target. It gives the possibility to correlate the recorded data from multiple videos and quantify the motion by velocity, acceleration, change of placement in different axes.

The motion analysis software works with a threshold comparison and automatically generates the motion values. There are different possibilities of visualisation of those values. For the investigation, the data acquisition is visualized with graphs where the horizontal axis represents the time in milliseconds and the vertical axe the change of motion. The data can be processed as .cvs file for further investigation.

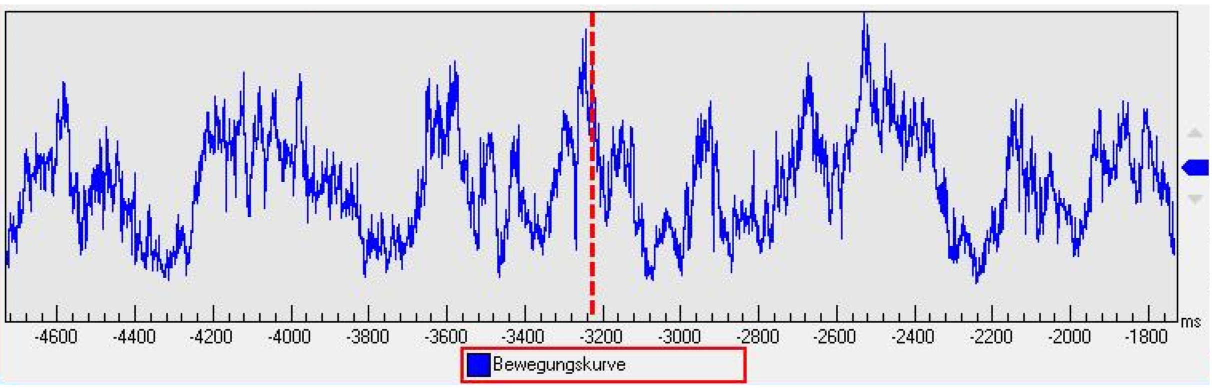


Figure 69 Example of original motion curve, generated by the analysing software

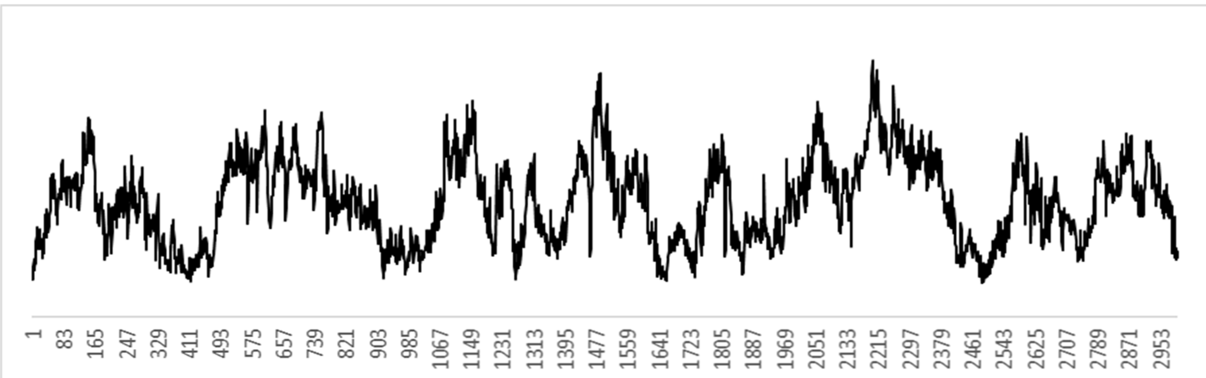


Figure 70 Example of motion curve after processing as .cvs file

The motion curve is used for the analysis of the alternating rotation of the slot plate of the dynamic false twist device. A framerate of 1000 fps and a light exposure time of 1/3000 s is set to gain data of the motion. The length of the recording in total is 3 seconds.

Moreover, the “image curve” is used for visualisation. The image curve is an analysing tool which tracks a selected point on a chosen line in the video. The result is shown as a series of single pictures recorded at that line. Furthermore, the resultant all-in-one picture can be examined with a standard motion analysis and visualized as a graph.

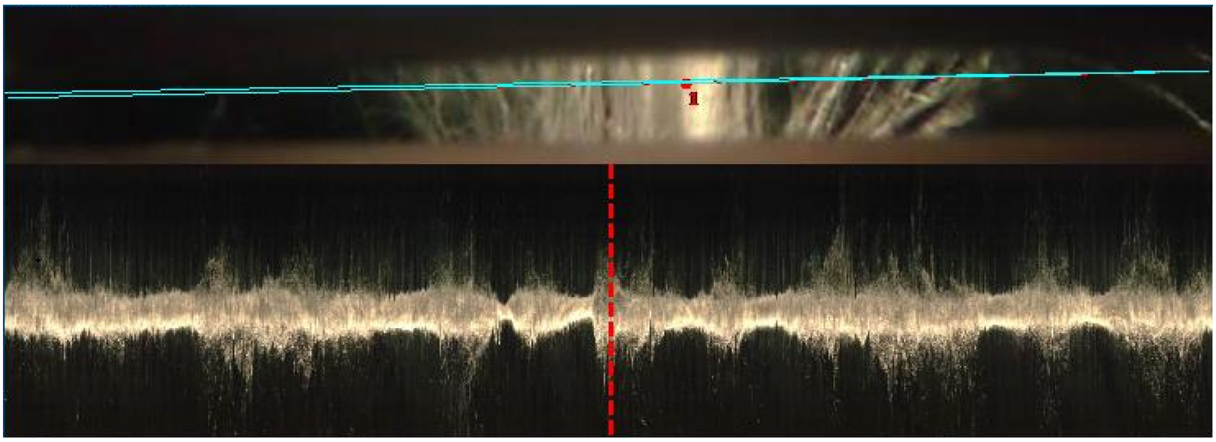


Figure 71 Example of original image curve processing and its result, generated by the analysing software

The image curve is used for the analysis of the fibre motion in the main draft zone. Here, a framerate of 1000 fps and a light exposure of 1/3000 s is used with a total recording time of 3 seconds. In figure 71 an example is shown how the image curve generates its data. The video of the main draft zone records the fibre motion. The analysis line is set between the apron roller and the upper delivery roller. Each frame along this line is set into single pictures and set together which results in the image curve.

The handling of the motion curve and the image curve is explained more in detail in the following sub-chapters.

4.6.1.1 False twist signal as frequency

Since the signal output of the false twist device is an alternating rotation, a parameter must be found to identify and cluster the signals. The signal can be described by the resulting signal output caused by the correlation between potentiometer velocity and potentiometer torque along a time-series. This leads to two measurable parameters. Firstly, the frequency of the alternating rotation is measured. Secondly, the number of rotations during one period of the frequency is used to describe the signal output.

The definition for “frequency” by ISO 19762 (p. 271) is: “number of cycles a periodic signal executes in unit time. Usually expressed in hertz (cycles per second) or appropriate weighted units such as kilohertz (kHz), megahertz (MHz) and gigahertz (GHz).”

Since the signal output of the dynamic false twist device is a periodic signal, the frequency is an adequate value to describe the signal. And the number of rotations during one period is to differentiate the output signals if they have the same frequency.

The aim of the high-speed-video-analysis is to gain the actual data of the alternating rotation of the false twist device and cluster it. By recording the alternating motion of the motor shaft of the false twist device, it is possible to mark dots (black and silver) without interfere the rest of the false twist device. For better understanding, the top of the motor axe is visualized as a clock which can go clockwise and counter clockwise (seen in figure 72).

For example, in figure 72 the black dot points between 1 and 2 o’clock and the silver dot points between 4 and 5 o’clock. When the false twist device starts, the motor axe rotates, and the marking dots change their positions. Thanks to the different colours (black and silver) the direction of the motion is easily to follow.

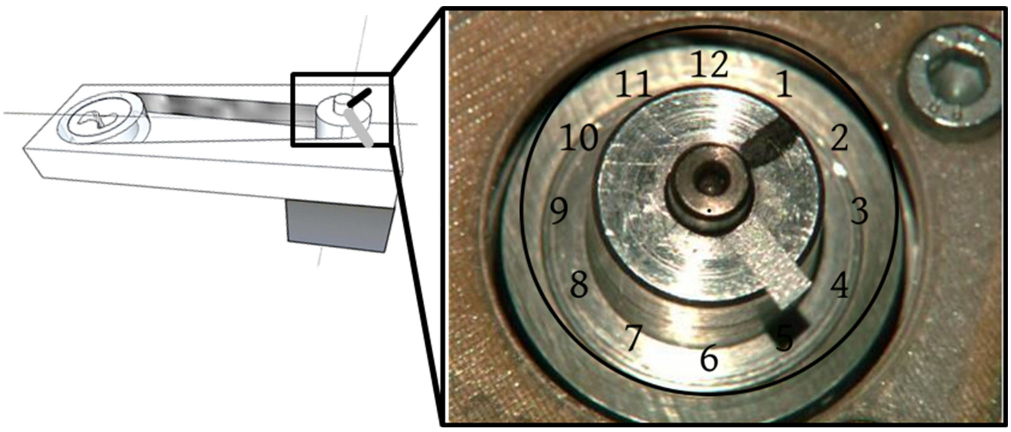


Figure 72 Picture of the motor axe of the false twist device to visualize the recording principle

In figure 73, two rows of images show exactly one period of the signal output. The images are all 0.013 seconds apart to see enough of the motion steps. The upper row’s first image shows the same image as in figure 72. The upper row’s second image shows the rotation after 0.013 sec counter clockwise, where the black marking dot wandered to 10 o’clock and the silver marking dot to 1 o’clock. Figures 73 and 74 show the motion of the dots counter clockwise for around 3 rounds. The last two images in the upper row show almost no motion of the dots (black dots stand around 6 o’clock) during the 0.013 seconds apart. That indicates the motor shaft changes the direction to clockwise and stays almost still for that short time. By looking at the next row at the first image after 0.013 seconds, the dots moving again – this time clockwise for 3 rounds.

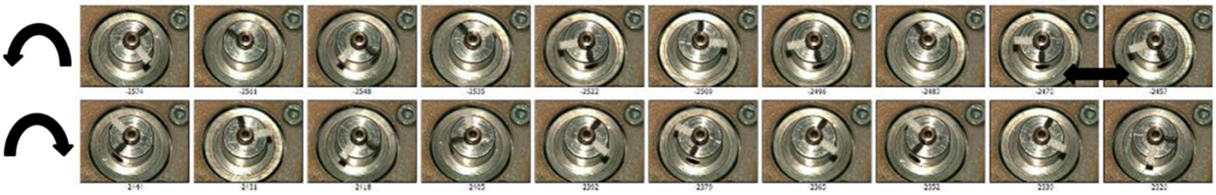


Figure 73 Example of visual time-series tracking of the alternating motion of the motor axe

It can be concluded that by visual examination of the single images recorded by a high-speed-camera, it is possible to see a periodic motion of the false twist device's motor shaft. Furthermore, it is possible to automatically generate a motion curve, where this periodic motion is even more noticeable.

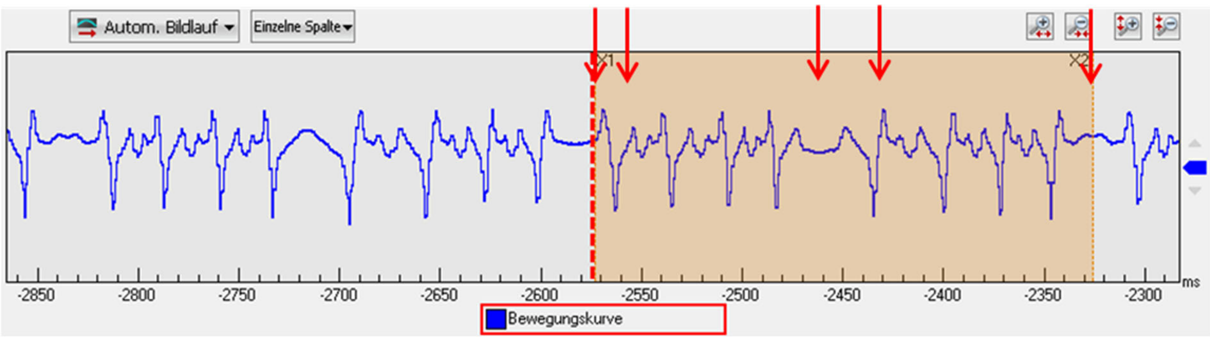


Figure 74 Example of original motion curve generation

In figure 74 the graph shows the motion curve where one period is followed by the next period. The orange background displays the previous explained period. It can be observed that the pattern of "three repeating peaks, looking to the left", followed by a "stop" and finished with "three repeating peaks, looking right" is repeating (marked with red arrows). This is where the periodic motion of three round counter clockwise, followed by a short stand still and the three rounds clockwise takes place. The three main peaks show noisy tops, which are the different reflections of the black dot and the silver dot. With that noise it is possible to see, in which direction the motor axe rotates and when the rotation direction changes. This graph can be saved as .csv file and processed by Excel or Matlab. The marked orange background shows the window to analyse the motion. The left side "X1" is the start of the periodic motion and the right side "X2" is the end.

Possible data acquisition is the length of one period (X2-X1) and the resulting frequency (1/(X2-X1)).

Table16 Overview possible data acquisition of the motion curve

	Object	Result
Start period	X1	-2.578 sec
End period	X2	-2.327 sec
1 period	X2-X1	0.251 sec
Frequency	1/(X2-X1)	3.983 Hz

In conclusion, the possible parameters to analyse are:

- The Frequency by the length of one period [Hz]
- The number of rotations during one period [n]

4.6.1.2 Fibre motion in the main draft zone

In addition to the high-speed camera, an external cold light source is used to increase the necessary illumination of the fibre flow at the main draft zone. Here, the frame must be zoomed in to get a detailed picture of the single fibres during the drafting. Without an external cold light source, the usual light source of the camera would produce light in a wrong angle which results in unwanted shadows and a blurred image of the fibres. For trial preparation, a cold light source KL 300 LED with two flexible goosenecks of the company Schott is used. The position of the high-speed camera and the goosenecks of the cold light source is shown in figure 75.

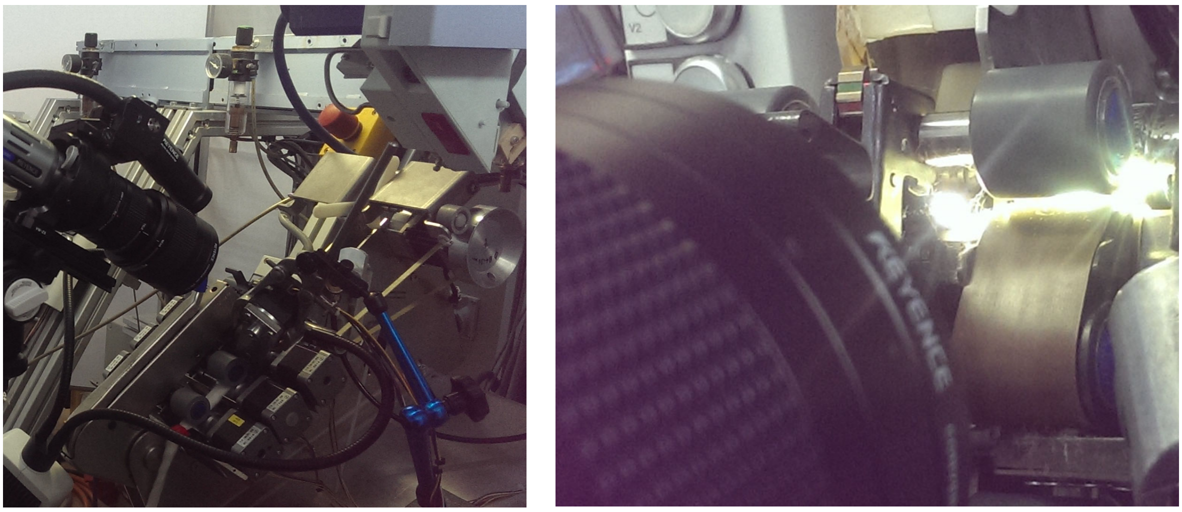


Figure 75 Picture of camera position to record the main draft zone

For recording the fibre motion the high-speed camera stands in front of the spinning unit. The camera is positioned in the right angle to ensure a maximal possible frame at the slim main draft area between the apron and the front roller.

By zooming in the recorded video, an exact frame of 310 x 65 pixels can be adjusted to guarantee a reproducible frame size.

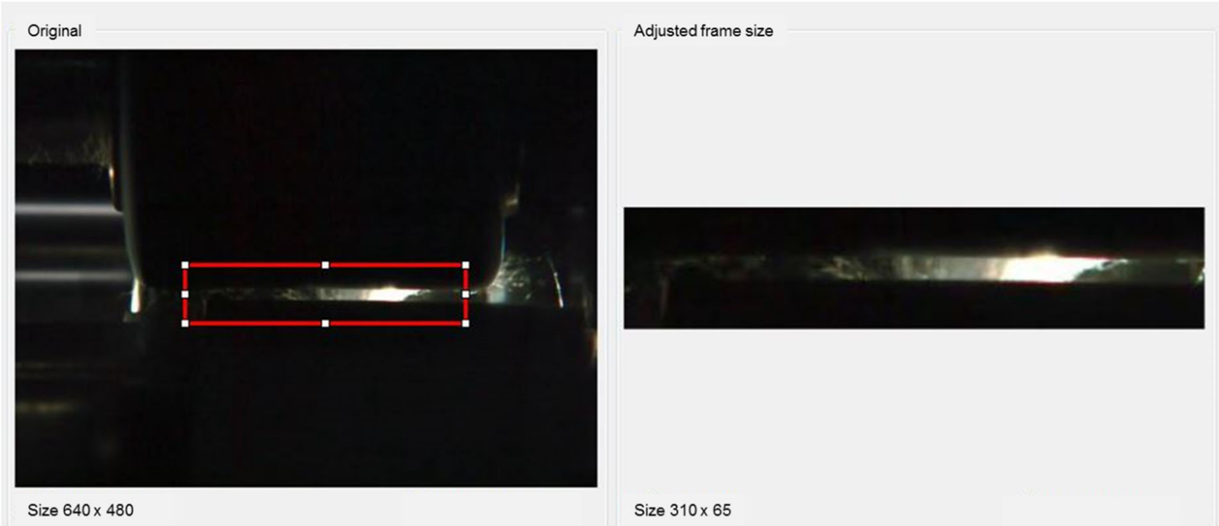


Figure 76 Example of original video frame adjusting tool

The first possibility of visualization the fibre motion is to use a sequence of images. It helps to get a quick visual of the fibre motion during a defined time. The figure 77 shows the impact of the false twist device after the alternating signal reaches the main draft zone and compacts the fibre bundle.

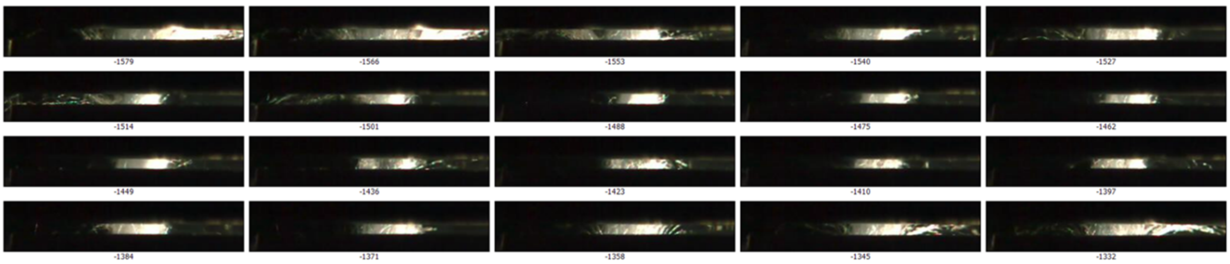


Figure 77 Example of visual time-series tracking of fibre motion in the main draft zone

Still, the image sequence shows only partly the fibre motion in a defined repeating time sequence. To gain actual values of the fibre motion over the whole recording time, another tool is necessary. The chosen method for the analysis is the image curve. The exact frame of 310 x 65 pixels of the main draft zone is analysed with the analysis line to gain the image curve. For better understanding a screenshot of the handling of the tool is shown in the next figure.

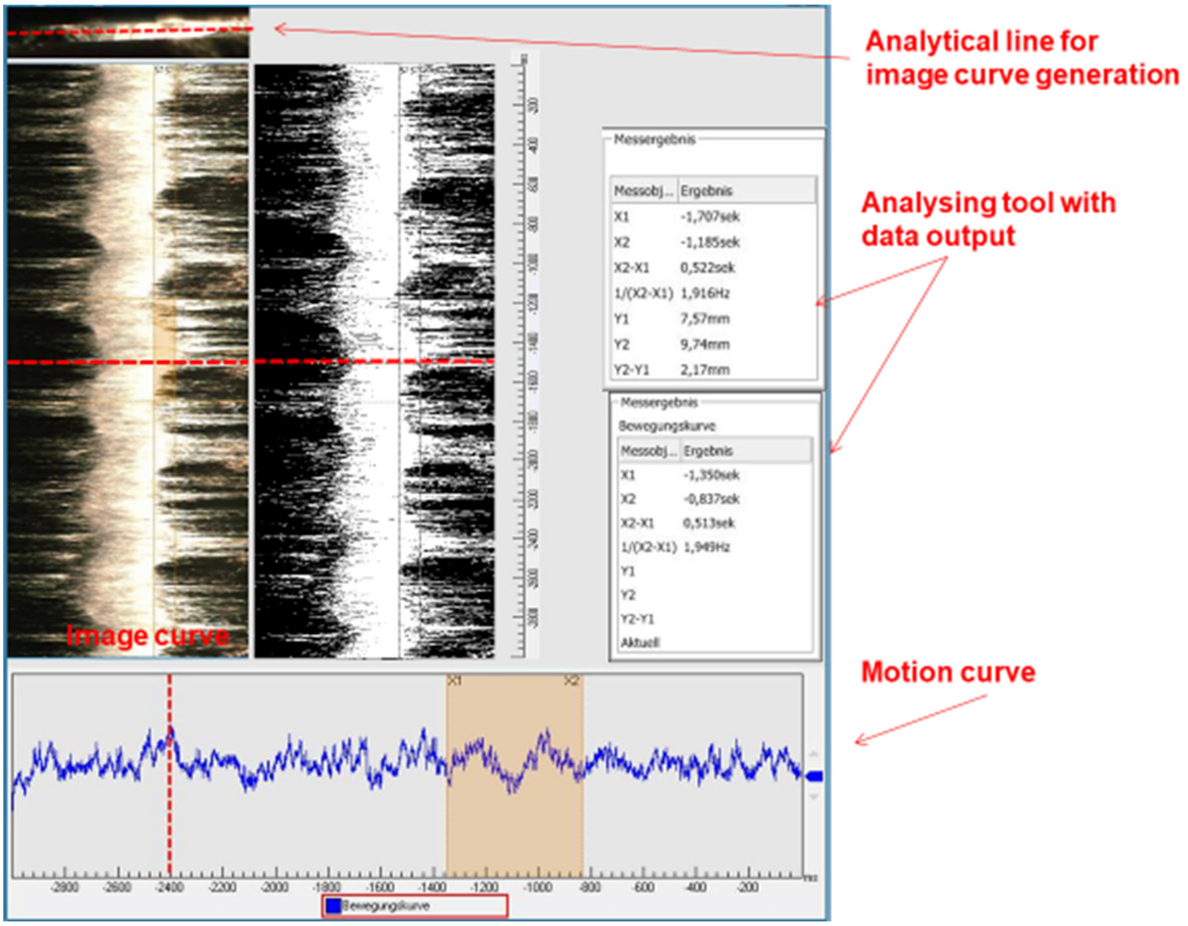


Figure 78 Example of original analysing software tools

Firstly, there is the adjusted frame of the recorded video (310 x 65 pixels) placed at the left corner at the top of the screenshot. The red dotted line is the analytical line for the image curve generation. Thus, the fibre motion of each recorded time frame along this line is put together to one image – the image curve. Secondly, this resulting image curve is placed at the left side of the screenshot. It shows the fibre motion in the main draft zone along the line for 3 seconds. Consequently, it can be already regarded as visual possibility to evaluate the fibre motion, but measurable values are still absent. Therefore, the image curve is saved as .png file for further investigation. Here, Matlab is the software of choice to perform an image analysis.

A fixed colour threshold is used to separate the pixels representing the fibres to the pixels representing the background and filter the image curve. The resulting black and white picture gives the possibility to count the number of white and black pixels to gain actual values of fibre motion during the recorded timeframe. Regarding the relative number of white pixels in the image curve, a "compaction rate" is identified to measure the impact of the false twist device and the spiral condenser for the fibre motion in the main draft zone. Therefore, the lower the number of white pixels, the higher the compaction rate and the fibre bundle control in the main draft zone increased. The used filter program for the image processing can be found in the appendix.

Furthermore, the generated motion curve of the recorded fibre motion can be used as measurabl data.

4.6.2 Yarn quality Analysis

The yarn quality analysis is the common method to evaluate the produced yarn. The tested qualities are:

- Unevenness [CVm%]
- Thickplaces [+ 50 %/km]
- Thinplaces [- 50 %/km]
- Neps [+ 200 %/km]

The testing device to analyse the irregularities of the yarn, the MT5 Evenness Tester in combination with a hairiness tester by MESDAN-Lab is used. For the quality of the produced roving, the data of unevenness [CVm%] is analysed.

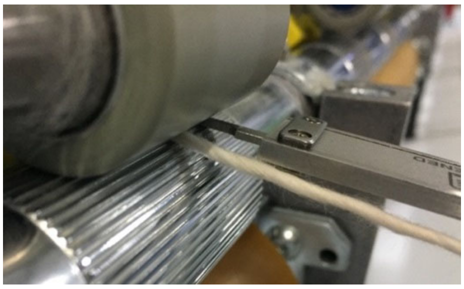
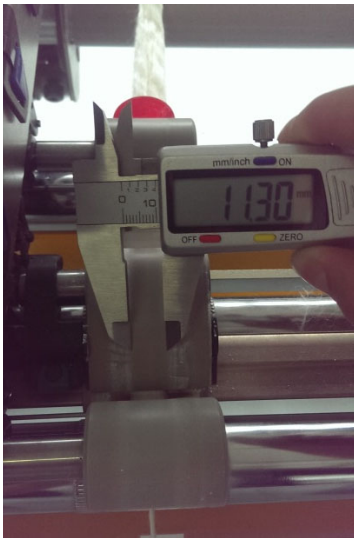
4.6.3 Measurement of the spinning triangle

The analysis of the spinning triangle is used for the trials at the roving frame machine. A calliper is the tool of choice to measure the spinning triangle parameters.

Three parameters can be measured:

- Spinning triangle length
- Spinning triangle width
- Apron tread

Table 17 Examples of measuring the spinning triangle

Spinning triangle length	Spinning triangle width	Apron tread
		

4.6.4 Analysis of the fabric quality

The analysis of the fabric quality includes knitted fabrics, produced with rotor yarn, two different ring yarns and two different air jet yarns. The used ring and air jet yarns differ from conventional drafted yarn to spiral condensed yarn. The following parameters are presented.

- Fabric haptics (PHV)
- Pilling resistance (Martindale)

The evaluation of fabric haptics is not standardized. However, there are several regulations or advice for the evaluation of fabric haptics. The method of choice is the subjective evaluation based on *PHV*. PHV stays for *"primary hand values"* and describes the evaluation of different fabrics regarding their haptics *to each other.* That means, there is no scale for "good" or "bad", but the fabrics are graded in relation to each other [Reumann, 2000, p. 615]. The evaluation team of 30 persons consists of textile specialists and textile students from 3 different continents.

The pilling resistance is tested with DIN EN ISO 12945-2 with Martindale. The evaluation takes place after 125, 500, 1000 and 2000 tours and the grading system is as followed [DIN ISO].

Table 18 Grading system for pilling resistance (DIN EN ISO 12945-2)

Grade	Evaluation
5	No change of surface
4	Slight change of single parts of surface (small pills)
3	Different pills of different size at single spots at surface
2	Strong pills of several sizes at many spots of surface
1	Surface shows mainly pills of several sizes at the whole surface

4.7 Theoretical background: Control technology

In the previous subchapters the idea of an alternating rotation signal is explained. A control procedure shows the effect of the alternating system in comparison to a constant rotation and their output.

Theoretical control technology is used to design and regulate systems with or without feedback and to analyse the influence of single parameters in every phase of a process cycle. It can be used as a prediction tool to anticipate problems and provide solutions BEFORE a process or a product gets implemented in practice (George Ellis, "Control System Design Guide", 2012).

Therefore, a control system gives two possibilities for the analysis of the false twist signal in theory to decrease the number of trials. First, the false twist signal as one-directional rotation input and the resulting signal output. Second, the implementation of an alternating rotation input and the resulting signal output. Moreover, the alternating rotation input can be analysed by several parameters and helps to investigate which parameter is significant for the experimental trials.

For better understanding of the use of an alternating false twist signal, the control system explains the difference of a static rotation to a dynamic alternating control system and their theoretical impact for the fibre motion in the main draft zone. Moreover, the control system helps to predict the impact of the alternating rotation for the fibre motion in the main draft zone and its impact for the intended compaction of the fibres.

The control system of the implementation of a one-directional rotation input is shown in figure 79. That means, the false twist device rotates continuously in one direction.

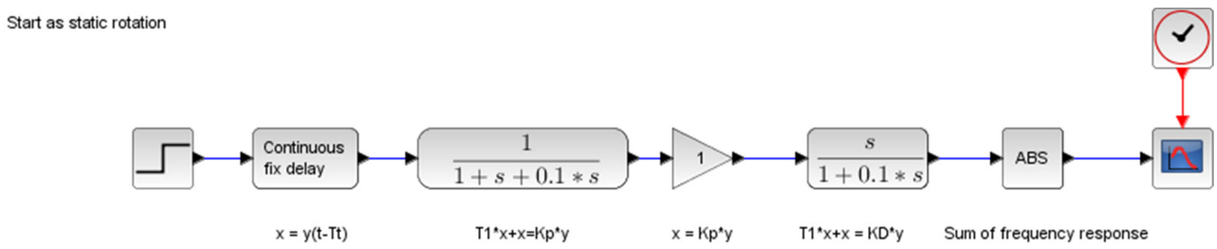
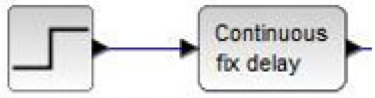
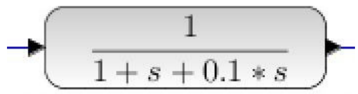
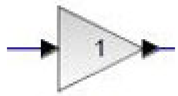
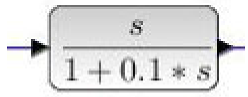


Figure 79 Control system for one-directional rotation insertion

The input of the continuously rotation in one direction is shown as a step function element. Since the false twist device is implemented in the second pre-draft zone, it takes time for the rotational signal to reach the main draft zone. In theory, a “delay time” is needed, here used as continuous fix delay element Tt. The parameters are followed by two transfer function elements and a gain element. Those three blocks represent the drafting system with several influencing parameters. Here the first transfer function stays as a PT1-element, followed by a gain element as P-element and the second transfer function as DT1 element. *K* is a coefficient.

Each used control element represents its differential equation with a frequency response. Table 19 gives an overview of the used control elements to simulate the drafting system.

Table 19 Overview and explanation of used control elements

Name	Differential equation	Frequency response	Used control element
Step function with Tt-Delay element	$x = x_e(t - T_t)$	$F = e^{-j\omega t} * x_e(s)$	
Transfer function PT1	$T\,\dot{x}_a + x_a = K\,x_e$	$F = \frac{K}{1 + T_{j\omega}}$	
Gain function P-element	$x_a = K * x_a$	$F = K$	
Transfer function DT1	$T\,\dot{x}_a + x_a = K_D\,\dot{x}_e$	$F = \frac{K_D\, j\omega}{1 + T_{j\omega}}$	

The scope at the end of the control system shows the resulting sum of the responses as a graph. In figure 80 the graph of the one-directional rotation signal is shown.

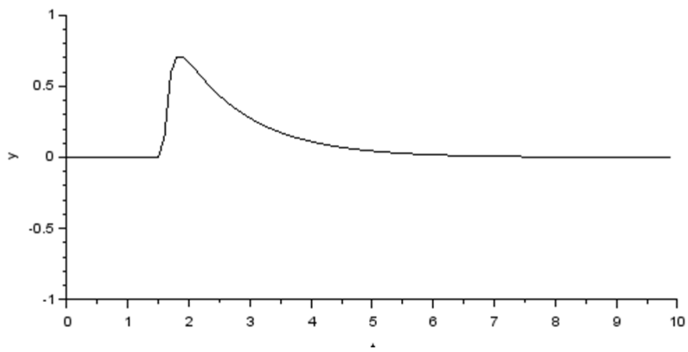


Figure 80 Graph of resulting output with one-directional rotation insertion

The graph presents the output signal after passing the control system. The signal output displays a peak after the delay time. After reaching a certain limit, the rotation disappears until zero. In practice, it is explainable by the drafting process which is a continuous process where the fibres continuously move to reach the nozzle for the yarn formation. Consequently, the inserted one-directional rotation signal disappears because of the moving fibres which is not recommendable.

On the other hand, by implementing an alternating rotational signal, the fibre bundle is forced to change the twist rotation that results in a continuous twist change. This example is shown in the following model.

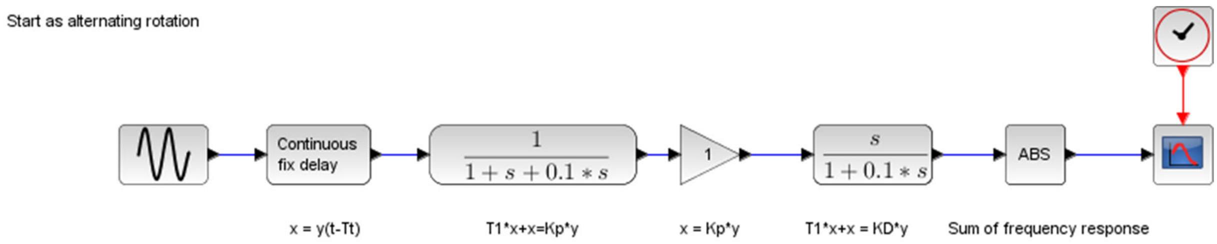


Figure 81 Control system for alternating twist insertion

The inserted rotation signal is a sinusoidal signal to simulate the continuous twist direction change of the false twist signal. After the delay time, the clockwise and counter clockwise rotation of the false twist device results in alternating twists of the fibre bundle, visualized as peaks (seen in figure 82). The example shows the frequency of 3 Hz and $K = 1$ in a time range of 10 seconds. The frequency value can be set at the source element of the sinusoidal signal as angular acceleration [rad/s]. For that, the analysed frequencies need to be converted from Hertz to rad/s.

$$1\ Hz = 2\pi\ rad/s$$

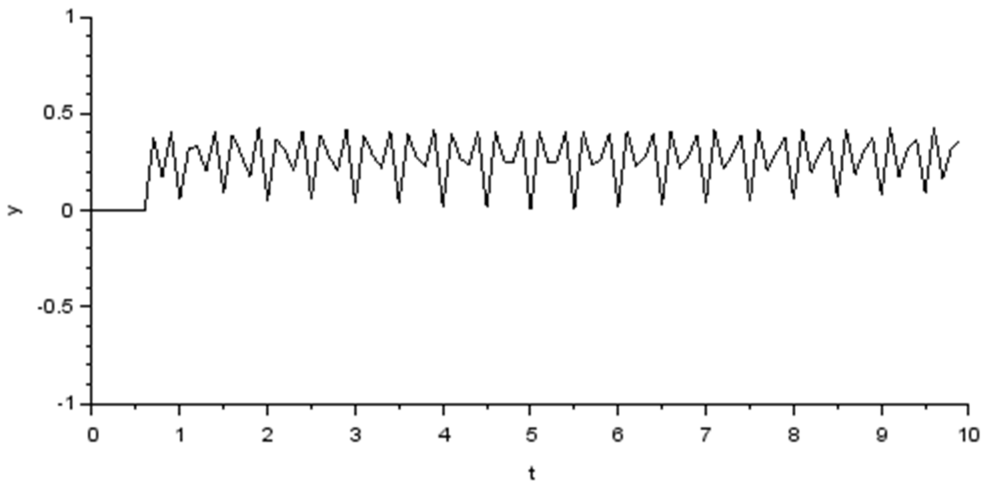


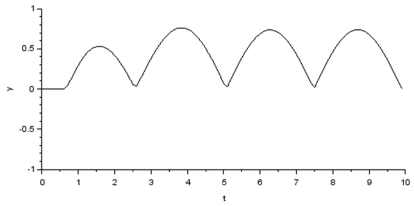
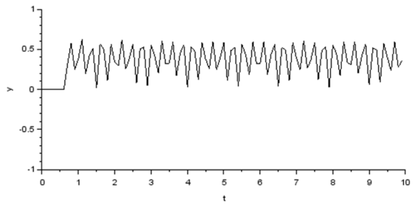
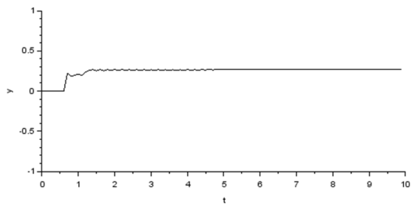
Figure 82 Graph of resulting output with alternating twist insertion

The question appears, which parameter of the control system influences the resulting output and what parameter of the input signal influences the output signal in general. Simulating several parameter changes results in 2 main points – change of coefficient K and change of frequency.

Initially, the frequency shows a certain range, where the rotation direction change takes place in a defined time. The frequency must be sufficiently high in order to produce enough rotations and rotation direction changes in a certain time range to be continued through the drafting system. This results in frequencies between 0.4 Hz and 4 Hz. Below 0.4 Hz. The simulated signal output as fibre motion has still a sinusoidal appearance with a low amplitude. In practice, a sinusoidal fibre motion curve results in a recurring compaction and non-compaction of the fibre bundle in the main draft zone. This effects the yarn appearance negatively as periodic failure. Frequencies higher than 4 Hz show irregularities in the performance of the signal output It is expected to reach an unstable process of false twist insertion in general.

The table 20 displays this result in detail by showing examples below, higher, and exactly in the frequency range.

Table 20 Three categories of graph outputs to evaluate input signal

0.2 Hz		Output signal shows a sinusoidal curve shape, equal to a recurring fibre motion structure. High risk of periodic yarn failure. The frequency is not recommended for trials.
1.8 Hz		Output signal shows a curve with sharp peaks, equal to a compacted fibre motion. The frequency is recommended for trials.
5 Hz		Output signal shows unstable behaviour. No motion as output, probably an overload. The frequency is not recommended for trials.

The coefficient *K* influences mainly the amplitude of the signal output curve and consequently impact of the no. of rotation per period for the compaction of the fibre motion. That relates the coefficient *K* to the frequency itself.

Considering the results from the theoretical process control simulation, the false twist signal works as alternating rotation with frequencies between 0.4 Hz and 4 Hz. The number of rotations stays within the used frequency and must be analysed in practice.

Since the control system is an idealized process simulation, it is not expected to reach the same experimental signal output, but it is helpful as prediction tool and to decrease the number of experimental trials. In chapter 5.2.4 the theoretical results from the control system are validated by the actual motion curve from the high-speed video analysis of the main draft zone.

5. Impact of the false twist device in drafting systems

5.1 The false twist signal

The analysis of the false twist signal is necessary to generate exact initial data in order to analyse its impact for the resulting fibre flow behaviour at the drafting system. Therefore, measurable quantities must be found to evaluate the false twist signal. The false twist device works as a unique prototype with 2 potentiometers which are adjustable. The signal of the false twist device is the result of those two potentiometers.

As in chapter 4.6.1.1 explained, it is possible to create measurable quantities by analysing the resulting alternating rotation signal of the false twist device. That leads to two main parameters, which are measurable and evaluable. Firstly, the period length of one left and one right rotational movement which leads to the frequency. Secondly, the actual number of rotations during one period is a measurable parameter for the evaluation.

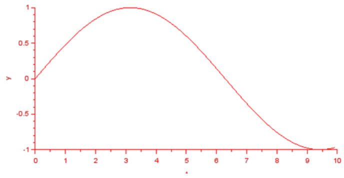
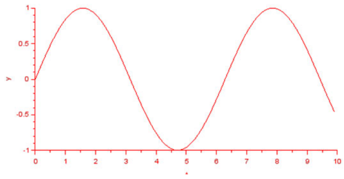
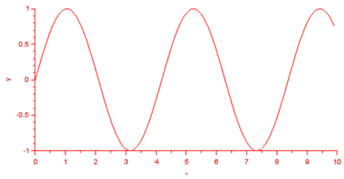
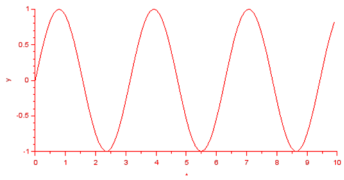
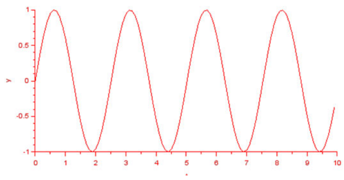
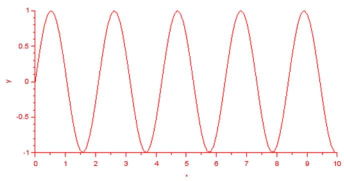
The main aim of the false twist device signal is to generate a uniform alternating rotation of the slot plate to influence the fibre flow compaction in a defining way, but without breaking it. Consequently, the number of rotations need to be high enough to significantly compact the fibre flow, but low enough that the drafting process can proceed. In the same way, the velocity of the rotation periods (the length of one period) need to be high enough to implement the rotations into the fibre flow, but low enough to not disturb the drafting process.

Pre-trials have shown that one and the same frequency can have a different number of rotations, regarding the relation between the settings of the two potentiometers of the false twist device. Consequently, the parameter of number of rotations is analysed separately.

That results in two catalogues of parameter settings. The first table presents six tested frequencies of the dynamic false twist device, independent from the number of rotations during one period. Here, the curves show a simplification of the theoretical sinusoidal wave of the tested frequencies. The curves demonstrate the relation between frequency value and period length. The longer the period, the lower is the frequency.

The following sub-chapter 5.1.1 presents the investigation of the actual signal output of the false twist device and analyses the resulting frequency by their period length. The theoretical curves from the table give the possibility of a visual comparison with the motion curves of false twist signal. Moreover, the regularity of the motion curves is analysed with regard to their possible impact for the fibre motion in the drafting zone. Aim of the investigation is to find the optimum false twist signal for a uniform compaction of the fibre bundle through the drafting process.

Table 21 Overview tested frequencies and their theoretical signal curve

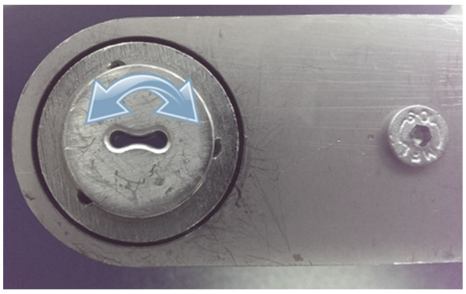
Frequency	Theoretical Signal
0.5	
1.0	
1.5	
2	
2.5	
3	

Pre-trials have shown that the number of rotations to the left and to the right should be between 3 and 10 each in both directions to keep a uniform false twist insertion.

The table 22 shows the tested settings of number of rotations, independent of the frequency. The minimum value is 3 rotations per direction to see an actual impact of the rotation after the drafting process. Main reason is that the main draft is about 25-fold, which has an enormous effect on fibre displacement inside the fibre bundle. This effect challenges a uniform guidance of the fibres to keep the effect of false twist insertion through the main draft zone. Nevertheless, the number of rotations is limited. If the number of rotations is too high, the fibre bundle cannot be drafted anymore because the fibre- fibre friction is too strong to let the fibres slide along each other.

The sub-chapter 5.1.2 presents the investigation of the influence of the number of rotations for the signal output of the false twist device. Specifically, the regularity of the signal and the resulting rotation pauses between changes of direction are analysed.

Table 22 Overview number of rotations of the false twist device



Left rotation	Right rotation
3	3
3.5	3.5
4	4
4.5	4.5
5	5
5.5	5.5
6	6
6.5	6.5
7	7
7.5	7.5
8	8
8.5	8.5
9	9
9.5	9.5
10	10

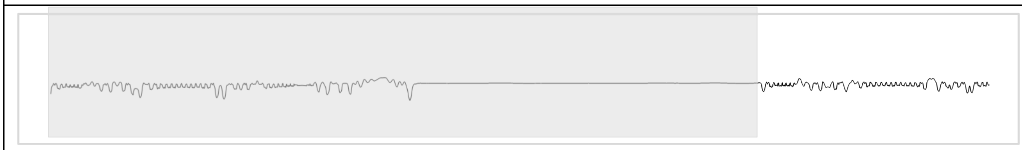
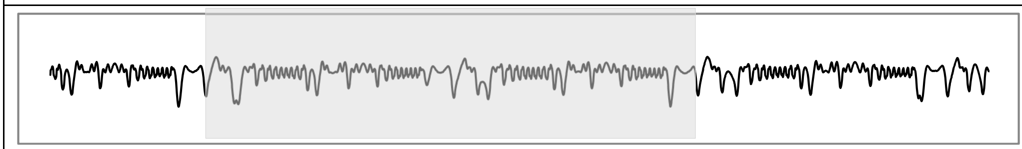
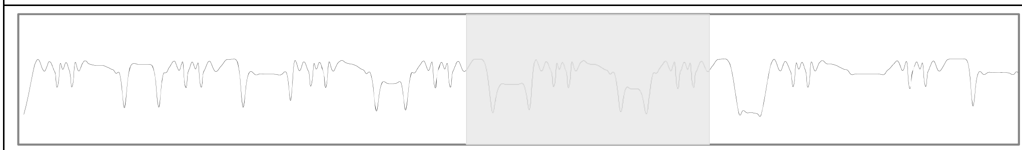
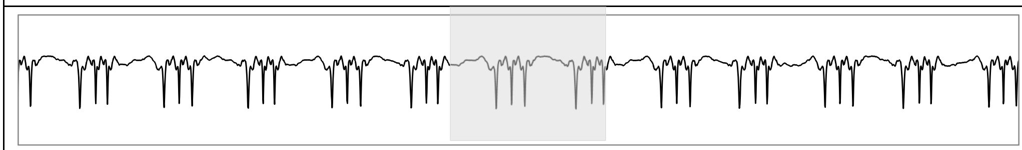
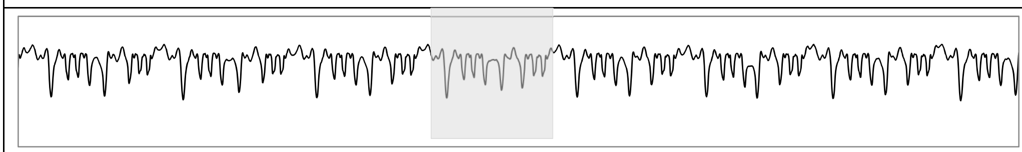
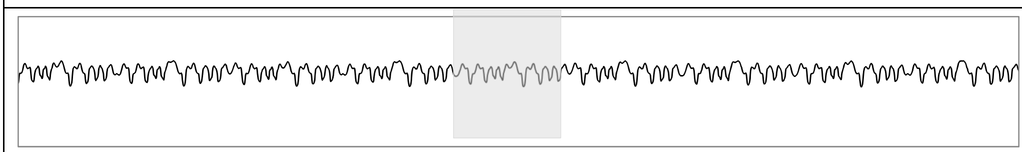
5.1.1 Investigation of the frequency of the twist range

The definition for “frequency” by ISO 19762 (p. 271) is: “number of cycles a periodic signal executes in unit time.”

Consequently, for the investigation of the frequency it is necessary to analyse the rotation of the false- twist device in a defined time. Recurring pattern of the rotations indicate a possible periodic signal and can be analysed further.

In chapter 4.6.1.1 the data acquisition method for the frequency of the false twist device is explained. The high-speed video software gives the possibility to generate motion curves of the false twist-device. The motion curves display the actual motion of the false twist device and present an adequate analysing tool. The table 23 shows examples of motion curves with increasing frequency values, observable with the period length (visualized with the grey boxes). The examination time of the analysed motion is 3 seconds, set by the time which is necessary for an adequate examination of the motion.

Table 23 Overview resulting motion curves regarding their input frequency

Motion curve	Frequency Hz
	0.5
	1.0
	1.5
	2.0
	2.5
	3.00

0 1 2 3 sec

The motion curves show significant differences. They differ by length (frequency) and curve shape (number and deflection of peaks). As higher the frequency value the smaller appear the peaks. The grey boxes in each motion curve show the length of one single period including left and right rotations. However, the measurement of the frequency is only related to the periodic pattern. The number of rotations helps to identify the single period of the signal, but the frequency itself is not causally related to the number of rotations inside one period. Depending on the velocity of one rotation there can be rotations in one period by the same frequency.

Therefore, the analysed frequency is the frequency within the actual twist range. Nevertheless, with increasing frequency value, the period length and the number of peaks is changing. Furthermore, some settings show more uniform curves than other. The presented motion curves in table 22 present data from the motion analysis, smoothed by the factor of 10. Nevertheless, some curves show the challenge of finding recurring patterns to identify the frequency.

The identification of the frequencies with the help of motion graphs or motion images is possible in consideration of three parameters.

1.) The length of the tested signal: The periodic pattern is only visible if the graph has enough space to show the periodic pattern -> horizontal axe setting at least 3 seconds
2.) The magnification of the graph: the periodic pattern is only visible if the peaks are distinguishable as actual motion peak or noise peaks -> setting of vertical axe
3.) The comparison between the signal output curve with the theoretical frequency curves

Considering those three parameters, the identification of the frequency for each motion curve is possible. The first parameter, the length of the signal, is the same for each curve to start with a fixed parameter to have a comparison parameter. The second parameter, the magnification of the graph by setting the vertical axe helps to magnify single peaks.

For example, the last curve of 3 Hz shows no clear recurring pattern at first sight. The motion data analysis results in a regular wave-shaped curve. Each peak in the curve can be the start of a period. This can be observed in Figure 83, that presents the example of magnifying the graph of the motion curve of 3 Hz for better analysis.

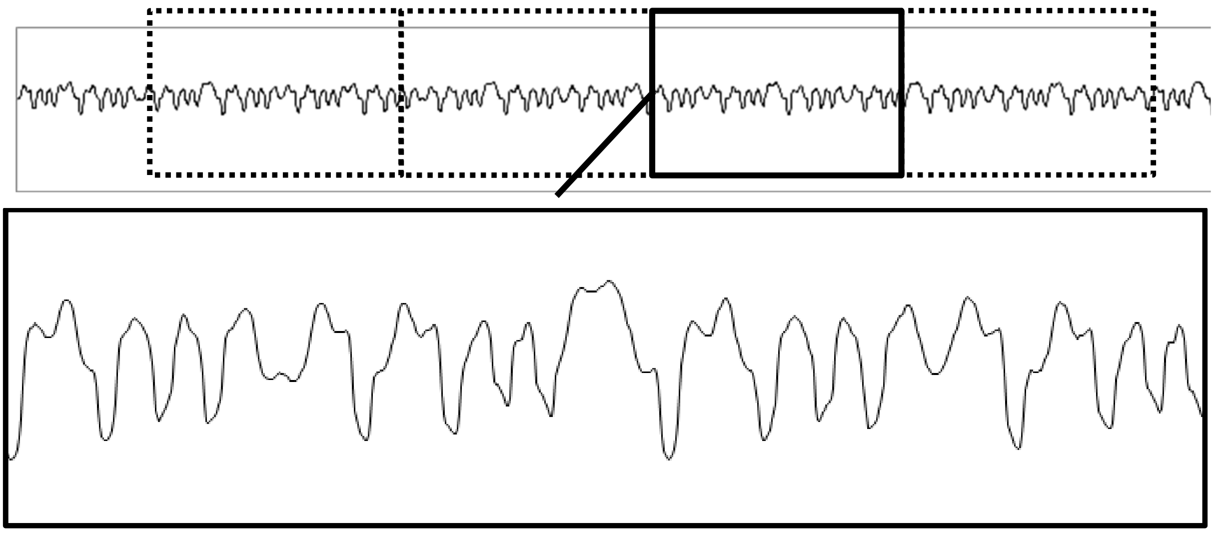


Figure 83 Example of magnifying motion curve for accurate analysis

The magnification of the graph in figure 84 reveals differences of the appearance of the peaks. They can be clustered as followed. The green marked peaks show two uniform rotations clockwise of the false twist device. On the other hand, the blue marked peaks show two uniform rotations counter clockwise. The orange marked V-shaped peak presents the slow change of rotation. Here, the left peak of the V-shaped peak is still a clockwise rotation until it changes to a counter clockwise peak at the right peak of the V-shaped peak. The crosshatched peaks are rotations corresponding to the overall identified signal. After clustering the peaks, the recurring pattern is observable and the length of one period can be identified.

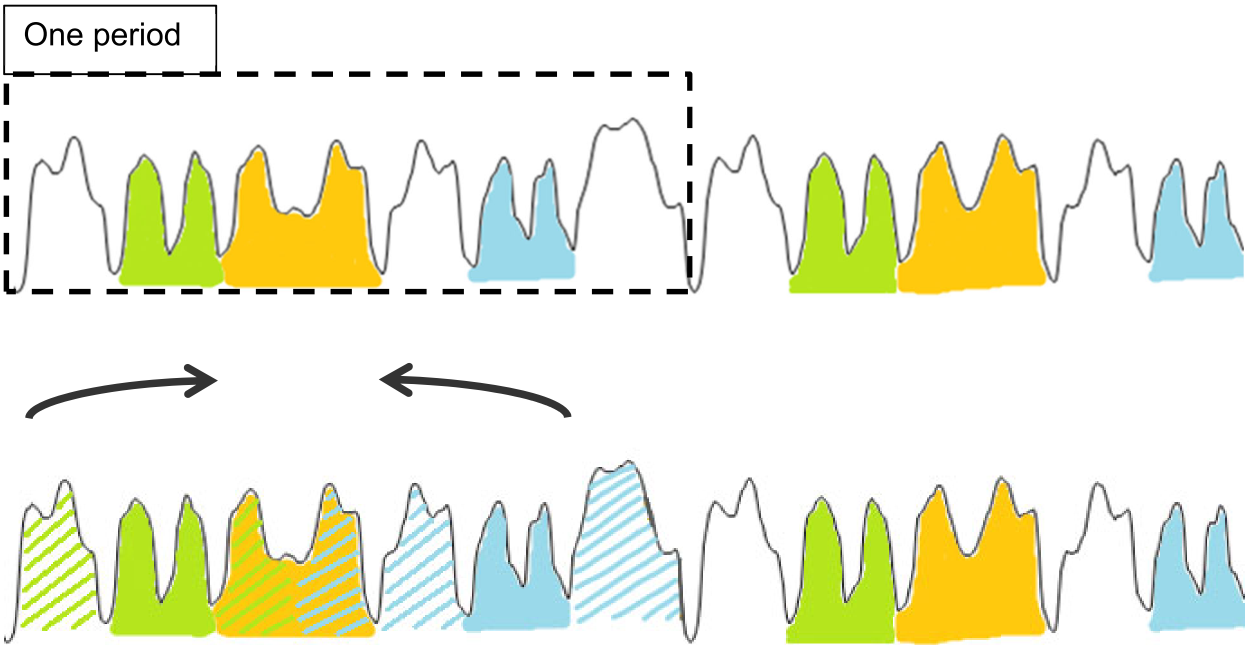


Figure 84 Example of the procedure of motion curve analysis

The third identification parameter can be helpful to identify the frequency. The comparison of the output signal curve with a theoretical frequency curve is presented in the table 24. The theoretical curves are simply generated by using the process control tool Scilab with the following model.

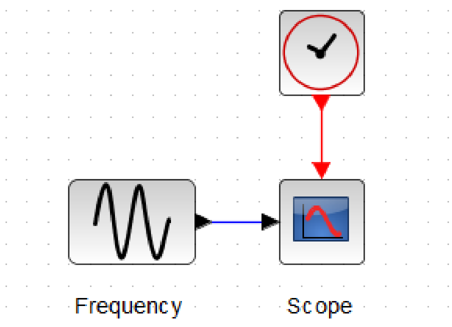
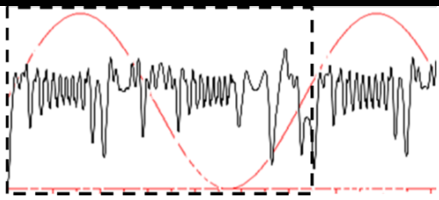
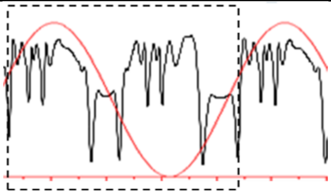
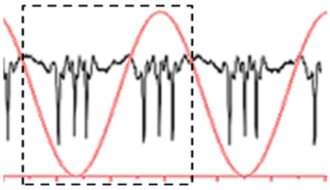
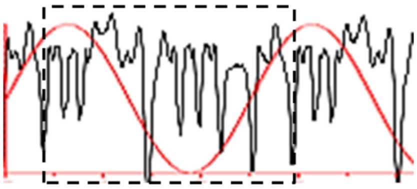
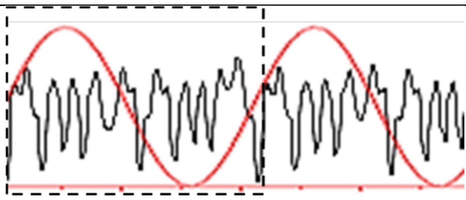


Figure 85 Process control for simplification of frequencies

Table 24 Comparison between theoretical frequency curves and measured motion curves

Frequency	Comparison between theoretical frequency curve and measured motion curve
1	
1.5	
2	
2.5	
3	

By examining the motion curves of the false twist signal in comparison with the theoretical sinusoidal frequency curves, it occurs that there are significant differences by their appearance. Since the motion curves show all movements recorded in the high-speed videos, including reflections of light, possible vibrations or reflections of metal, peaks of noise appear besides the actual rotation motion. In the same way, the clockwise rotations are in one half of a sinusoidal period and the contra clockwise rotations are in the other half of the sinusoidal curve – independent form the number of the rotations. That effect shows the necessity to use all three parameters to identify the frequency of the false twist signal.

Considering the identification parameters, it is possible to cluster the motion curves by their regularity regarding recurring pattern, smoothness of the curves and length of stops (no valuable peaks) between the rotations (actual valuable peaks) into three categories.

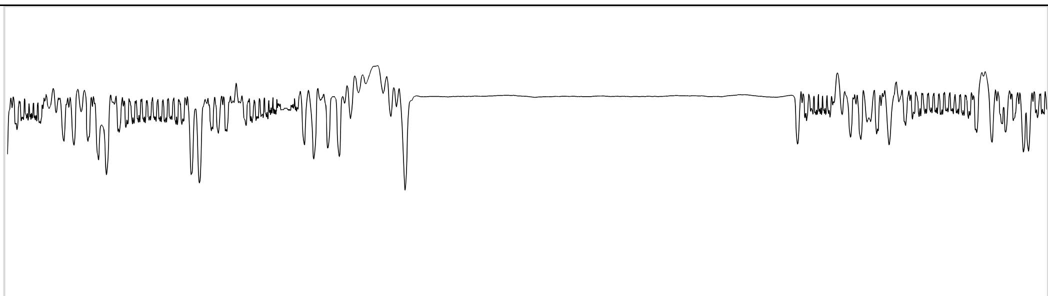
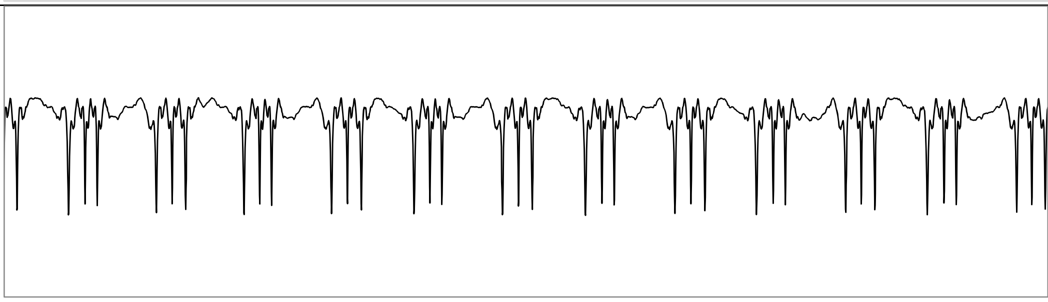
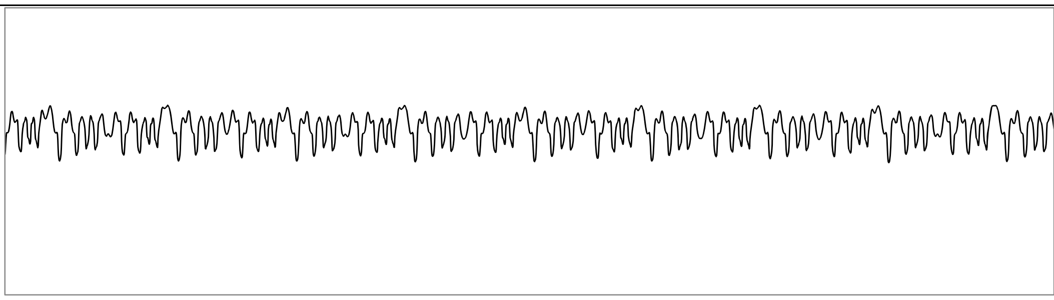
The table 25 gives examples of the three categories of motion curves where a

1.) most irregular curve with long stop (0.5 Hz)
2.) most regular curve with short stop (2 Hz)
3.) most regular curve without stop (3 Hz)

appears.

The first curve shows a discontinuously recurring pattern of the rotation with a long total stop of motion. The second curve represents settings where a short total stop of the rotation follows each rotation period with the same length as the rotation period. The third curve represents settings where during the change of rotation direction the rotation does not stop like a break, but it swings back and forward up to one or two full mid-rotations. Considering the regularity of the output signal, a uniform false twist insertion is expected with a frequency value > 2 Hz.

Table 25 Overview of three motion curve categories

1.		0.5 Hz
2.		2.0 Hz
3.		3 Hz

5.1.2 Investigation of the number of rotations during one period

In chapter 5.1 the parameters for the analysis of the false twist signal are presented as the length of one period of a recurring pattern, the frequency, and the number of rotations during one period.

The definition for "frequency" by ISO 19762 (p. 271) is: "*number of cycles* a periodic signal executes in unit time."

The last chapter 5.1.1 demonstrated the investigation of the frequency of the false twist signal. Here, in chapter 5.1.2, the number of rotation/ cycles during one period stays in focus and its relation to the parameter frequency is analysed. The range of tested rotations per period is from 3 to 16 in steps of 0.55.

The identification of the number of rotations per period is possible by analysing the peaks of the motion curve and (if visually identified) by counting them. A clear example is the motion curve in Figure 86, where 3 left rotations – stop – 3 right rotations per period are visual at first sight. It represents the false twist frequency of 2 Hz.

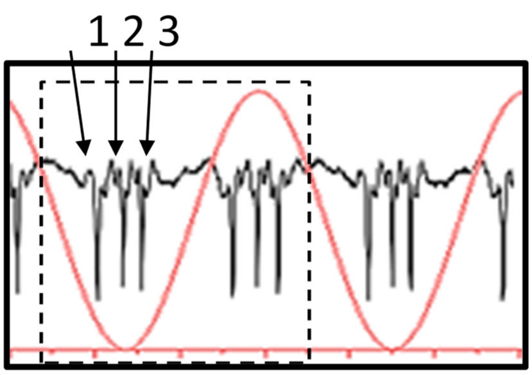


Figure 86 Example to identify the number of rotations in a motion curve

Nevertheless, 2 Hz can have more rotations during one period if the recurring pattern of the left and right rotations can be identified in this period length of 2 Hz. The same effect is observable the other way around. The same number of rotations during one period is recorded at different frequencies.

This effect can be explained by the setting of the false twist device. Since the signal output is set by two potentiometers and their values influence each other, several rotation motions and frequencies can be generated with the false twist device.

The figure 87 shows a selection of measured frequencies and different recorded number of rotations of the false twist device. The measured frequency range is from 0.5 Hz to almost 3.5 Hz and the recorded number of rotations per period results in the range of 3 to 16.

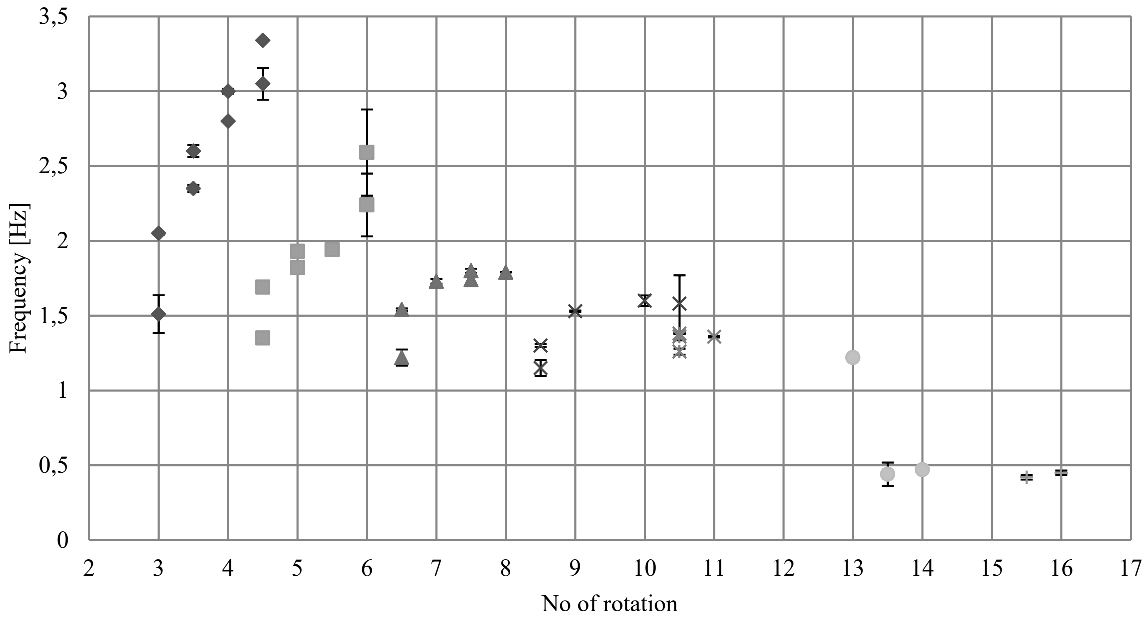


Figure 87 Diagram of relation between no. of rotations and the frequency

By using the set categories from the previous chapter, the selection of measured frequencies in relation with the number of rotations during one period can be clustered. The three categories are based on the criteria of the false twist signal regularity.

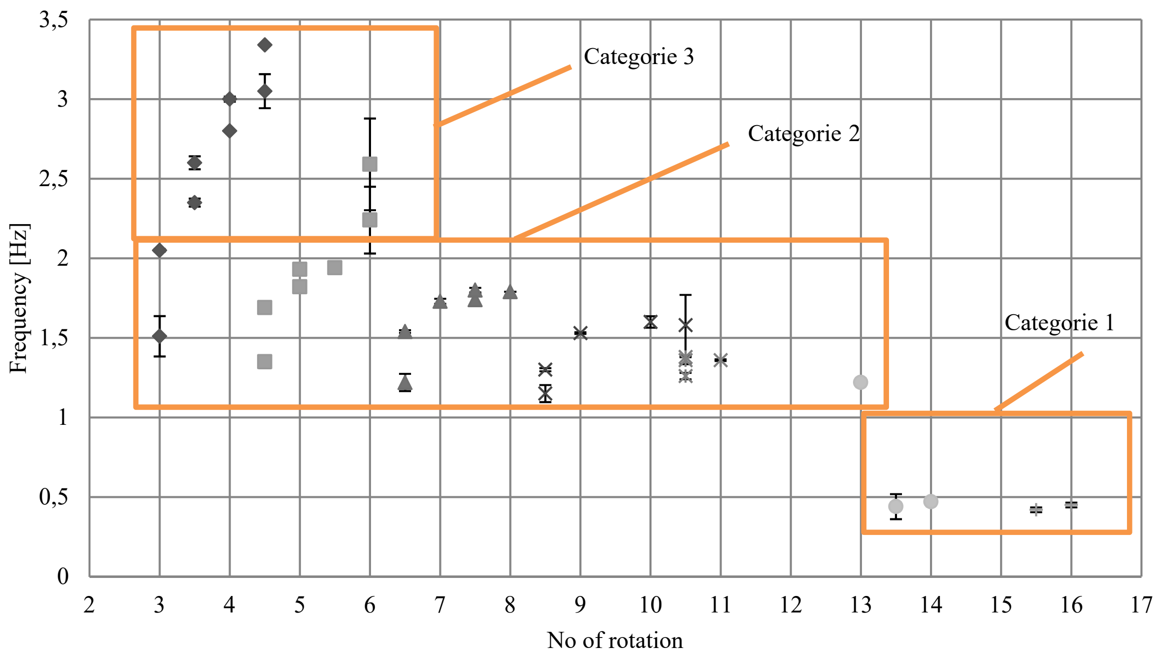


Figure 88 Diagram of relation between no. of rotations and frequency categorized

Another way to demonstrate the correlation between the frequency and the number of rotations during one period gives the figure 89. A selection of single frequencies and number of rotations during one period is observable. It shows that with increasing frequency, the number of rotations during one period decreases. In other words, if the velocity of rotations increases and results in more rotations during one period, the frequency decreases. This selection helps to minimize the amount of tested false twist signals for further investigations.

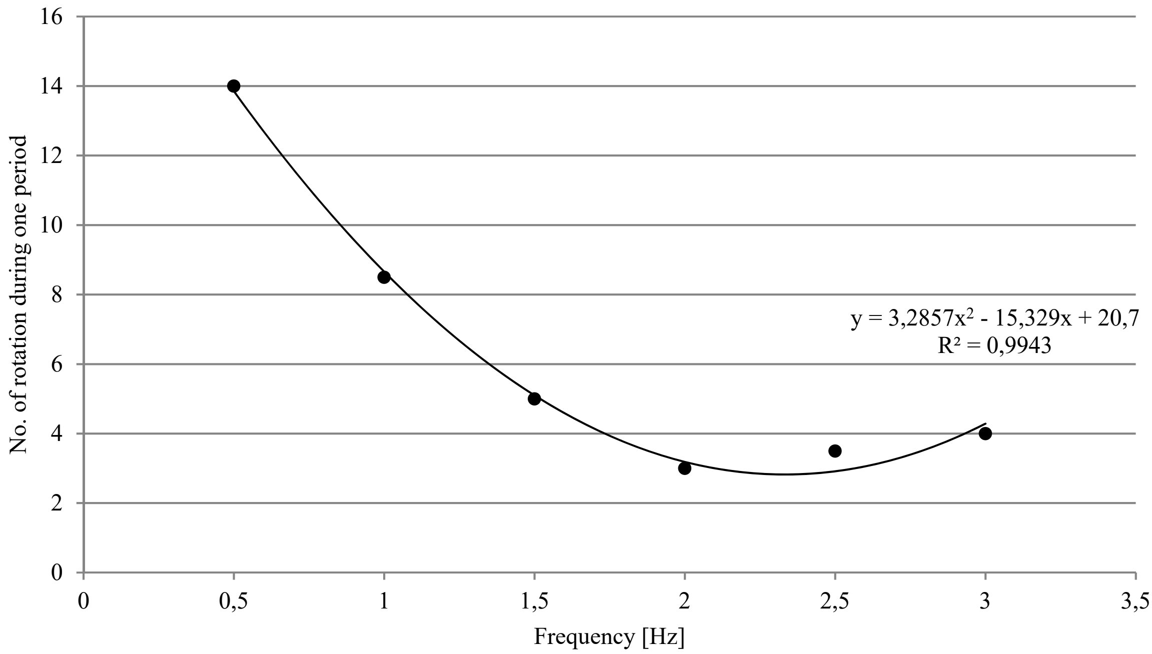


Figure 89 Diagram of correlation between frequency and no. of rotations

5.1.3 Summary and evaluation of the false twist signal

The false twist signal can be measured by its motion with the analysis of the resulting frequency and the number of rotations per period. The aim of the investigation of the false twist signal itself is to understand the variety of the alternating motion of the false twist device with the aspect of finding the optimum setting for the resulting fibre motion in the main draft zone.

The acquired motion curves from the high speed analysis method show the alternating rotation as recurring patterns which can be identified further by frequency and number of rotations per period. The length of a recuring pattern equals one period for the identification of the frequency and the deflection of peaks within one period are identified as single rotations. As a result, the analysis of the false twist signal contains the investigation of the interaction of two main parameters:

- The frequency value [Hz]
- The number of rotations within one period [n]

The individual motion curves of set frequencies between 0.5 and 3 Hz are presented. Hereby, the significance of the used analysis parameters like length of the recorded signal and the level of magnification of the motion curve is described to assure the correct identification of the frequency with the motion curve. Additionally, standard sinusoidal signal curves of each set frequency serve as comparison for better orientation.

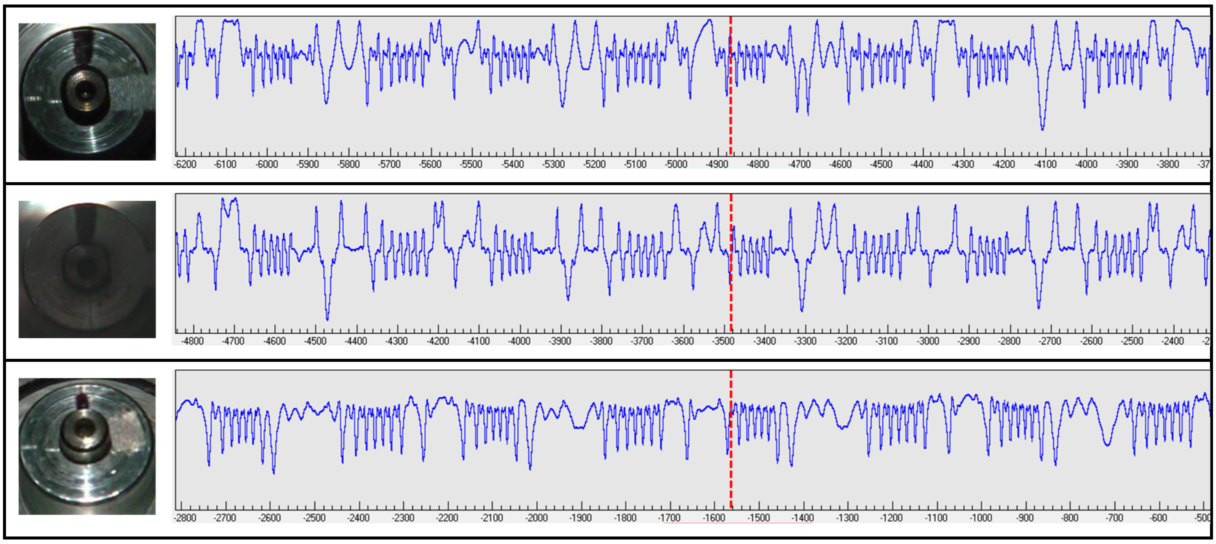
Those three analysis parameters are used to cluster the motion curves of the false twist signals of the false twist device into three categories:

1.) most irregular curve with long stop (0.5 Hz)
2.) most regular curve with short stop (2 Hz)
3.) most regular curve without stop (3 Hz)

Furthermore, the influence of the number of rotations within one period for several frequency values has been analysed and assigned to the named three categories. It can be seen that if the velocity of rotations increases and results in more rotations during one period, the frequency decreases. This effect must be considered for the selection of finding the optimum false twist settings for the fibre motion in the main draft zone.

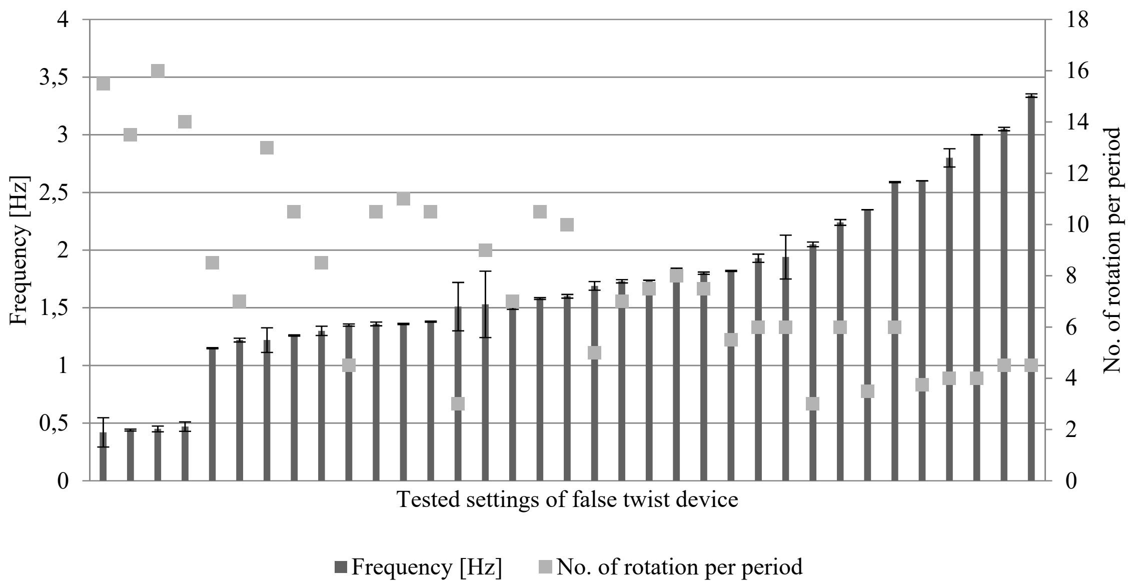
Nevertheless, since the evaluation of the frequency of the motion curves is a visual method, the question of reproducibility occurs. Several tests with different camera angles and illuminations have shown that all resulting motion curves have similar recurring patterns

Table 26 Examples of different camera angles and illuminations and their results



Only the deflections of peaks are slightly different like in the examples in table 26. Here, a false twist signal is filmed from different camera angles and illuminations. The recurring pattern in the original motion curves from the software keeps the same. The red dotted line presents the point of the recording which is shown. Each motion curve starts here at the same periodic pattern with 5 peaks which are equal to 5 rotations.

The following diagram shows the measured frequencies with their deviation rate of multiple videos and their motion curves. Considering the identification categories, examples will be analysed further at the drafting system by spinning yarn.



As a result, the deviation of measured frequencies appears considerable low. They deviate between 0 and 0.29 Hz, where only 5 settings show a deviation > 0.1 Hz. The deviation of the number of rotations per period is zero, since different camera angles or illuminations do not influence the recorded motion of the rotations. In summary, the method of analysing the motion curves for data acquisition is an adequate tool to measure the frequency and the number of rotations per period.

Moreover, the visualization with the diagram shows another aspect of the relation between frequency and number of rotations per period. As higher the frequency, the lower the number of rotations per period appears as trend. The following chapters will deal about the question how the inserted false twist signal will influence the fibre motion at the main draft zone and the resulting yarn quality. Consequently, the trend of the relation between the frequency and the number of rotations per period will be analysed more in detail.

5.2 The fibre motion in the drafting system of air jet spinning

In chapter 5.1 the motion of the false twist device has been analysed. The false twist signal can be clustered in three categories regarding their regularity of frequency and number of rotations. The following sub-chapters deal with the impact of the false twist device frequencies for the fibre motion in the drafting system of an air jet spinning machine. The high-speed camera is the method of choice to have a direct comparability to the values of the false twist signal and to work with the same software to limit the possibility of inaccuracy. The method for the data acquisition is explained in chapter 4.6.1.2

The aim of this chapter is to analyse the behaviour of the fibres in the main draft zone in comparison to a conventional drafting system.

In figure 90 a scheme of the drafting system is shown. The theory behind the false twist insertion is, to compact the fibre bundle through the main draft zone and decrease the amount of losing peripheral fibres to improve the resulting yarn quality. The influence of the false twist frequency and the role of the number of rotations during one period are analysed to find the optimum setting for a uniform fibre flow in the main drafting zone.

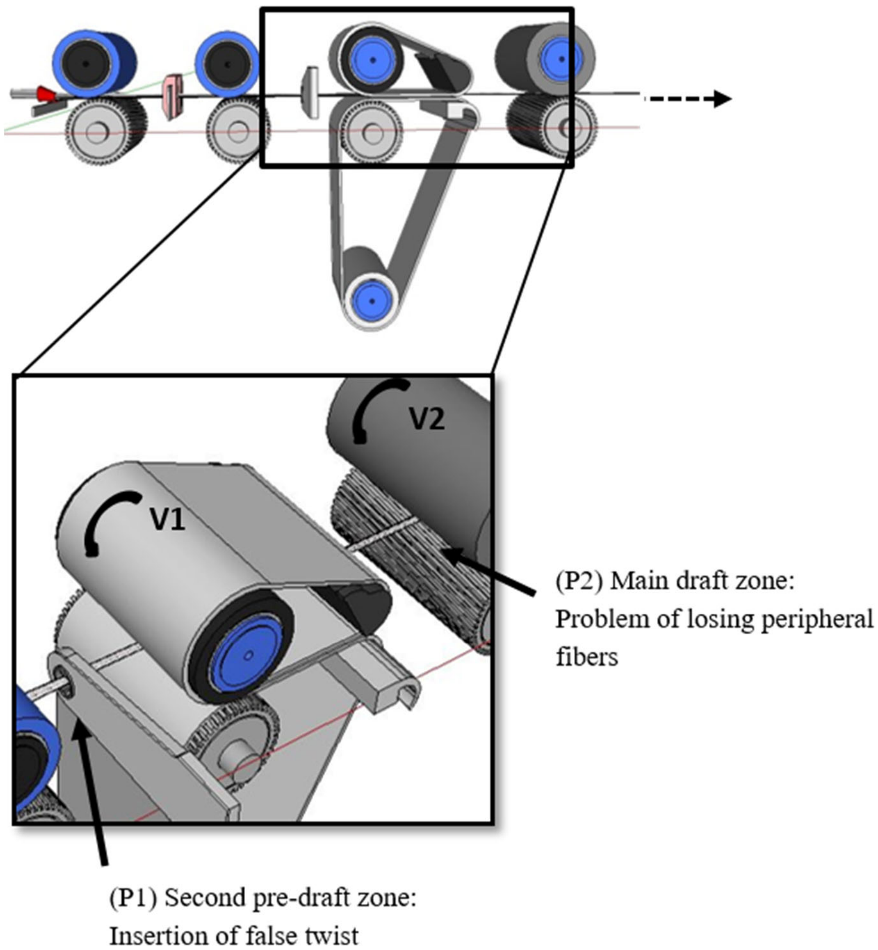
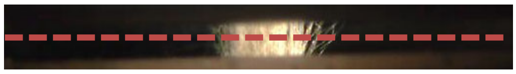
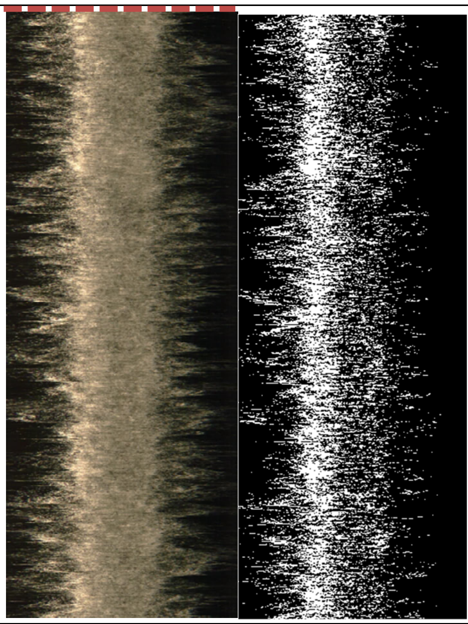
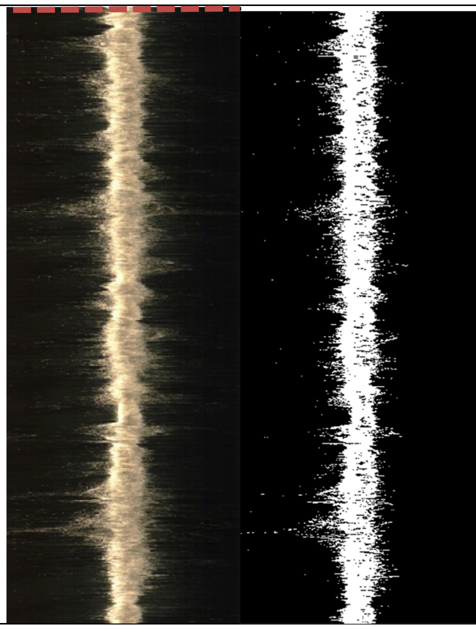


Figure 90 Scheme of drafting system and magnification of challenging zone

One example in table 27 shows the significant impact of the false twist device for the main draft zone. The fibre motion of a conventional drafting system and of a false twist inserted drafting system is compared to each other by an image curve for 3 seconds. The red dotted line is the analysis line for the generated image curve. Next to the two original image curves, black and white pictures are generated by threshold to improve the division of fibre pixels and background pixels.

Table 27 Visualization of impact of false twist device for the fibre motion in the main draft zone

	Conventional	False twist
Frame of main draft zone		
Image curve of 3 seconds		

The decrease of peripheral fibres with the false twist insertion is tremendous. The example shows the fibre flow of a production speed of 200 m/min and the setting for the false twist signal with a frequency of 3.35 Hz and 4.5 rotations in both directions per period. The production speed of 200 m/min includes here a 25-fold draft at the main draft zone with a theoretical fibre acceleration of 130 m/s^2.

The black and white pictures are processed with Matlab software as explained in chapter 4.6.1.2 to gain data about the percentage of white pixels. This provides a data acquisition method to measure the compaction rate of the fibre flow at the main draft zone for a predefined time of 3 seconds.

Using the data of each false twist setting, the influence of the false twist frequencies for the compaction of the fibre flow at the main draft zone can be evaluated and be set in relation to each other.

5.2.1 Influence of the false twist signal for the fibre motion

The evaluation of the fibre flow compaction at the main draft zone with the percentage of the compaction rate identifies the influence of the false twist frequency. Consequently, the results show the relative percentage values of the compaction in comparison to the compaction rate of a conventional drafted process. In figure 91 the diagram shows the relation between tested false twist frequencies and their resulting fibre flow compaction. The pixel values as compaction rate are generated by the analysis method, explained in chapter 4.6.1.2.

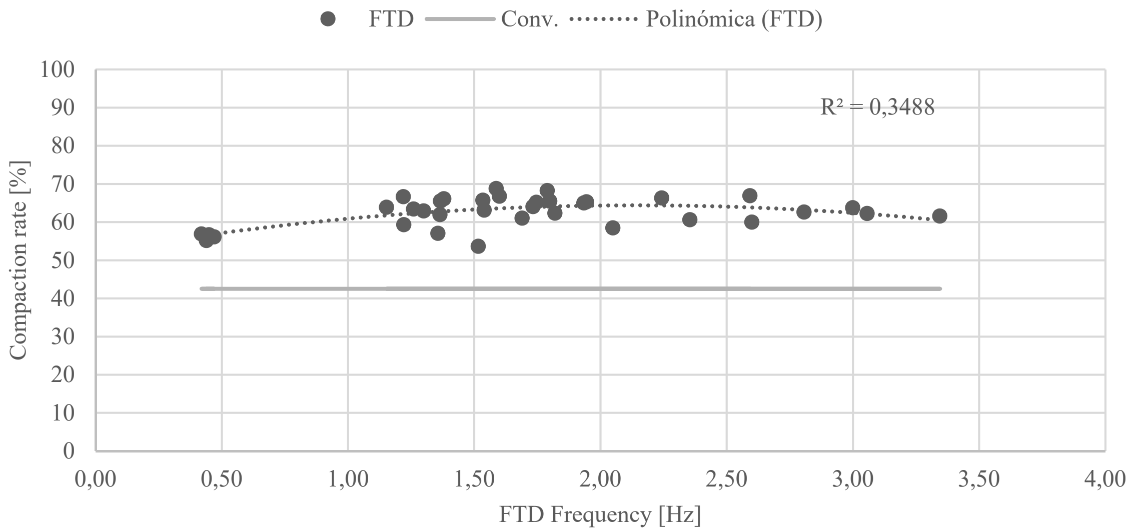


Figure 91 Diagram of relation between false twist frequency and resulting fibre flow compaction

The grey line represents the compaction rate in the main draft zone of a conventional drafting system. It shows a value of 43 %. There is a significant increase of the compaction rate at the main draft zone with the use of the false twist device. Even the lowest value of white pixels, processed by the false twist device at 1.5 Hz shows a value 54 %, which is an absolute decrease of 11 % compared to the compaction rate of the conventional drafting system. However, it also shows that with increasing frequency value, the increase stagnates at the value range between 65 and 70 %. That means there is no unlimited possibility of compaction. It only indicates that the use of the false twist device helps to compact the fibre flow and reduces the development of peripheral fibres at the main zone.

The challenge is to analyse the resulting compaction rate in relation to the false twist frequency and number of rotations during one period to find the optimal impact for the fibre compaction. Consequently, the highest compaction rates are investigated further. Therefore, a limit of acceptable compaction rate is stated at 65 %, shown in the Figure 92 as black line, based on the tangent of the polynomial line. Each false twist signal which results in compaction rate values higher than 65 % are investigated in detail. The number of rotations during one period and the regularity of the compaction effect itself (may) lead to the optimal false twist setting.

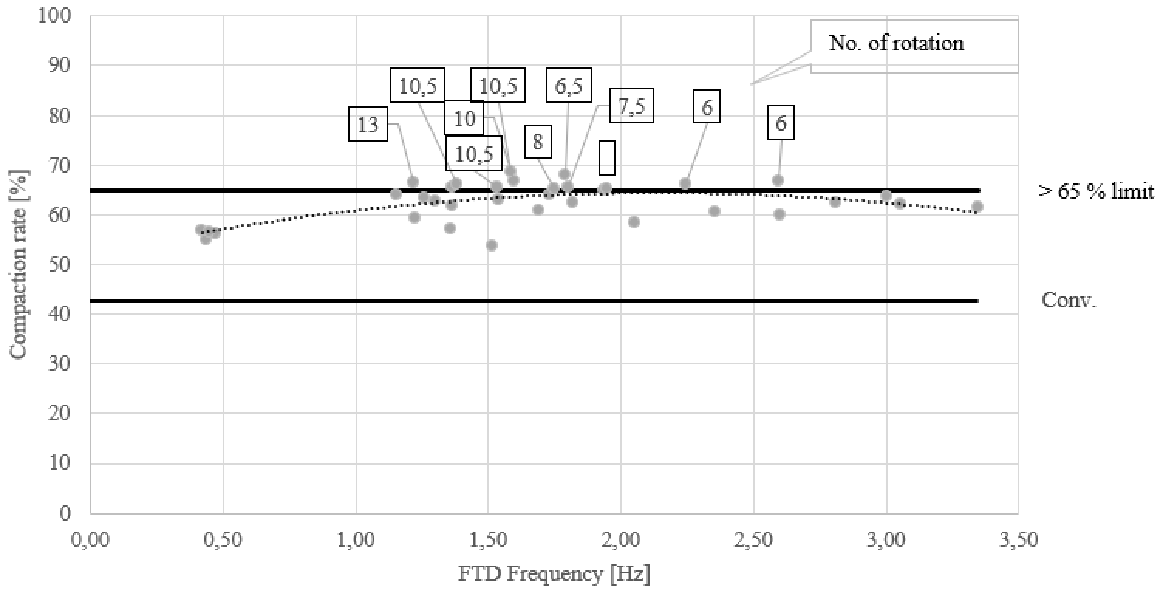


Figure 92 Diagram of compaction rate regarding the input false twist frequency

In figure 92, a diagram shows which false twist settings result in a compaction rate value > 65 % in combination with their number of rotations during one period. It is observable that mainly values between 6 and 10.5 rotations per period result in a higher compaction rate.

The figure 93 gives another perspective. Here, a selection of single frequencies and the resulting compaction rate are shown. It demonstrates that with increasing frequency value the compaction rate increases until it stagnates. The number of rotations per period seems to play a subordinated role for the compaction rate since there is no relatable tendency.

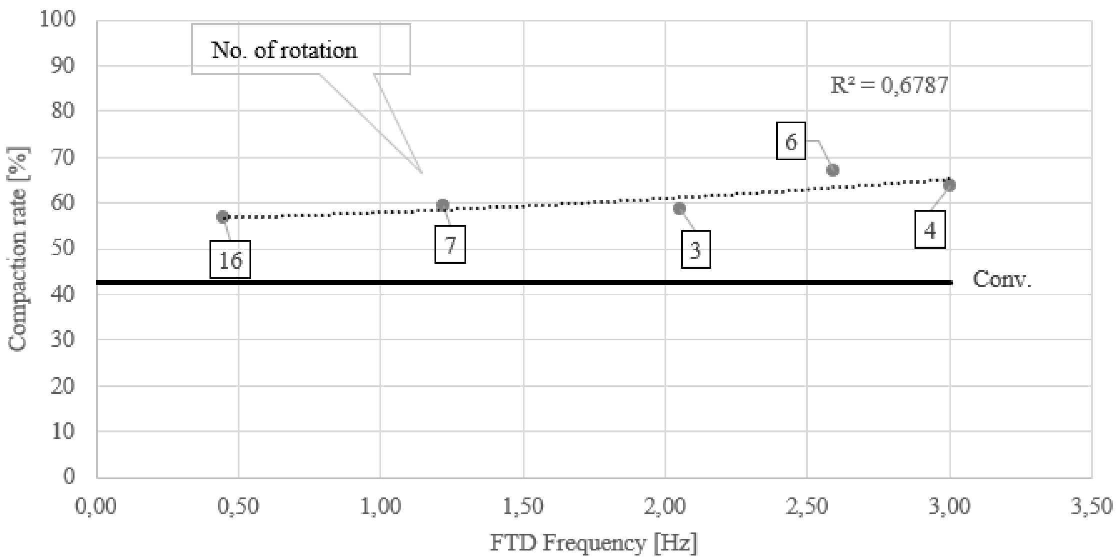
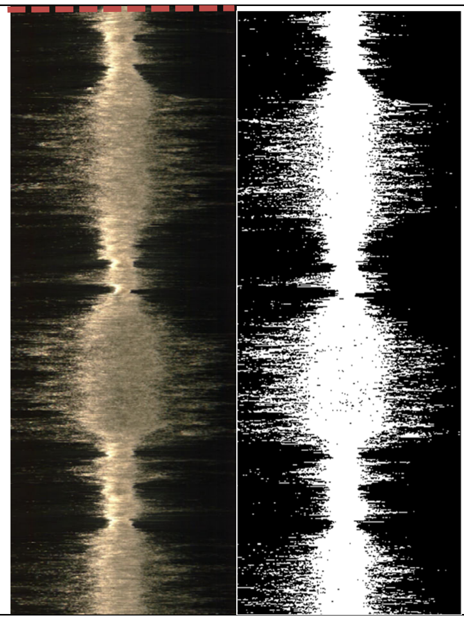


Figure 93 Diagram of compaction rate regarding of input false twist frequency

An interesting result is shown by the false twist setting with 0.45 Hz and 16 rotations per period. The lowest frequency value, caused by the total rotation stops, retrieves in the resulting fibre flow at the main draft zone and even in the compaction rate value. Although the compaction rate is considerable high, it does not indicate automatically more regular fibre flow at the main draft zone.

The table 28 shows the image curves of the fibre flow in the main draft zone of the 0.45 Hz setting where the rotation totally stops for the same time period as the rotation itself.

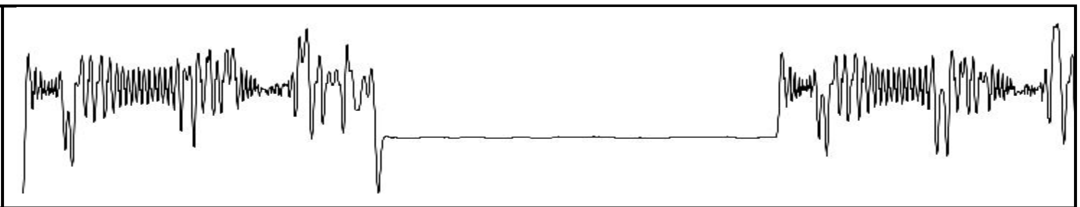
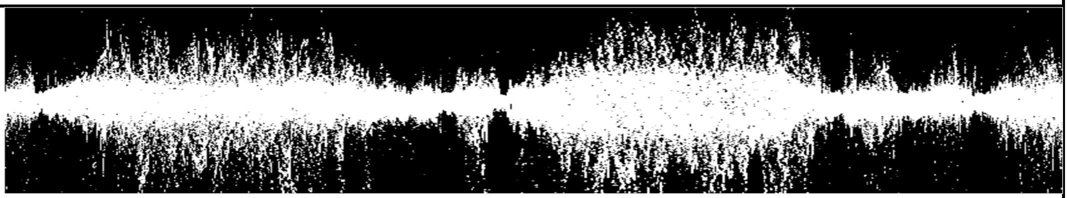
Table 28 Example of resulting image curve of fibre motion of 0.45 Hz in 6 seconds

	0.45 Hz with 16 rotations per period
Frame of main draft zone	
Image curve of 6 seconds	

The image curves show the development of the fibre flow in the main draft zone for 6 seconds to increase the observing time to secure that the pattern of total stops, followed by strong rotation, is clearly a recurring pattern. As a result, low frequencies in combination with high number of rotations per period may mislead the fibres in a periodic way and result in higher yarn unevenness. That non-uniform development of the fibre flow indicates the focus of the false twist signal stays in higher frequency values > 0.5 Hz and a smaller number of rotations per period < 16 to reach a uniform compaction of the fibre flow.

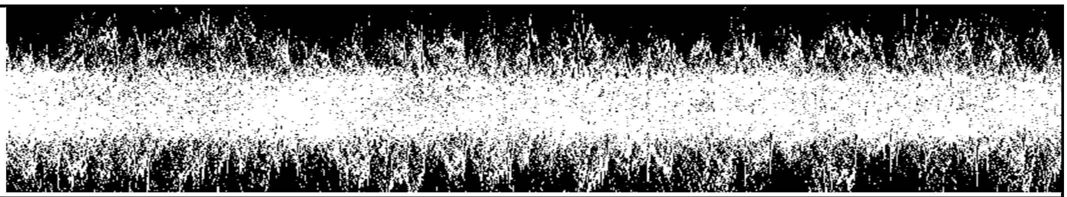
To underline this indication, the table 29 shows the motion curve of the input false twist signal of the presented 0.45 Hz with 16 rotations per period and the image curve of resulting fibre motion in the main draft zone. It is clearly shown that the long stop between the active rotations causes periodical misalignment of fibres in the same way as the input false twist signal. Naturally, the length and start of the resulting misalignment shifts slightly since the drafting is a continuous process, where the input signal has a delay time to reach the main draft zone.

Table 29 Resulting motion curve and image curve of 0.4 Hz

Motion curve input signal 0.4 Hz	
Resulting Image curve 0.4 Hz	

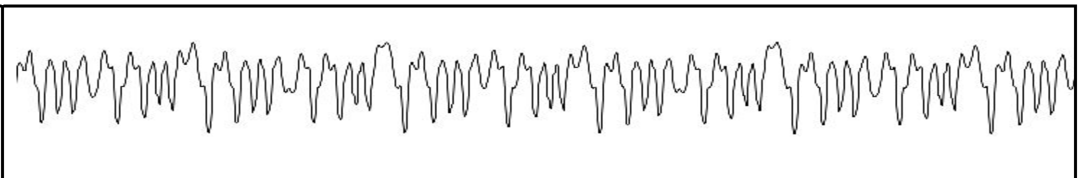
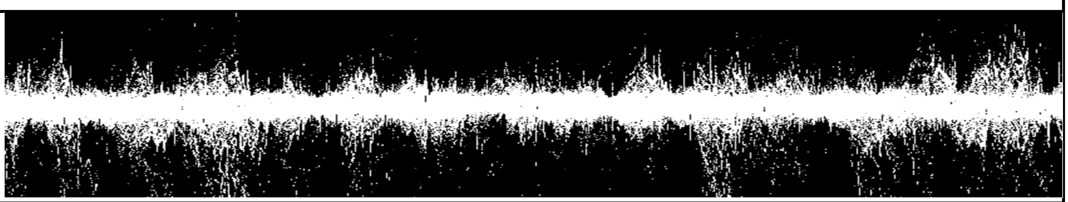
Additionally, three false twist input signals as motion curve with their resulting fibre motion in the main draft zone are presented in the following tables. In comparison to the image curve of the fibre motion in the main draft zone of a conventional drafting zone, all false twist settings reduce the fibre motion significantly (seen in the next figure).

Table 30 Resulting image curve of a conventional drafted fibre bundle

Resulting image curve Conventio nal	

To follow the categories set in chapter 5.1.1, the next example shows the input false twist signal of category 3 with the most regular curve without stops between the rotation direction changes. It represents the false twist signal input of 3 Hz with 4 rotations per period.

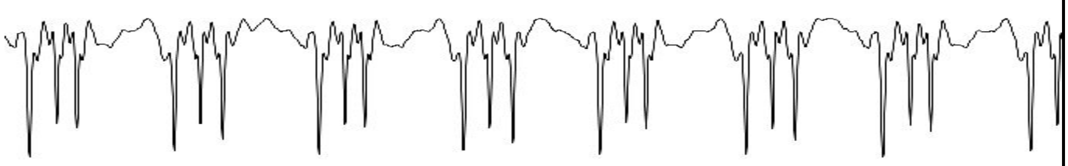
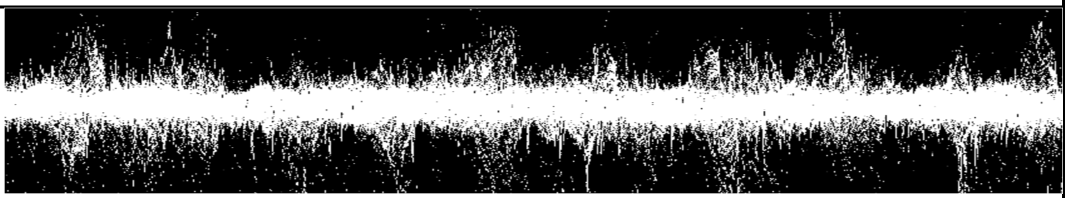
Table 31 Resulting motion curve and image curve of 3 Hz

Motion curve input signal 3 Hz	
Resulting image curve 3 Hz	

Compared the input signal of 0.45 Hz with 16 rotations per period, the stop during one period disappeared and a regular false twist rotation is visible. This effect continues in the output of fibre motion in the main draft zone. The compaction of the fibre bundle shows a more regular behaviour.

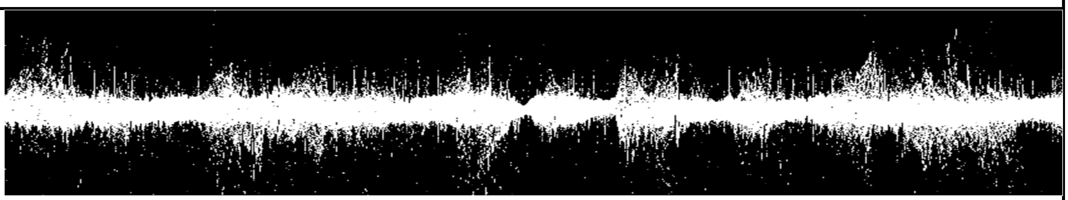
The next example shows the false twist signal input of 2 Hz with 3 rotations per period and its resulting fibre motion in the main draft zone. This false twist signal is an example of the set category 2, where the signal is most regular with a short stop.

Table 32 Resulting motion curve and image curve of 2 Hz

Motion curve input signal 2 Hz	
Resulting image curve 2 Hz	

Compared to the previous presented examples, the fibre motion is slightly higher, and the compaction of the fibre bundle is minimal reduced. Therefore, the question arises, which parameter effects the fibre motion in the main draft zone, the frequency, or the number of rotations per period, significantly.

Table 33 Resulting motion curve and image curve of 1.8 Hz

Motion curve input signal 1.8 Hz	
Resulting image curve 1.8 Hz	

Another example of category 3 is presented. The motion curve of 1.8 Hz with 9 rotations per period shows a regular motion without stop. The rotation direction change takes place with a swinging back and forward, that the signal does not stop totally. The resulting fibre motion in the main draft zone shows a high compaction of the fibre bundle with this kind of dynamic stop.

In conclusion, the presentation of the examples indicates that the length of stops between the rotation direction changes is significant to influence of the fibre motion in the main draft zone. Since the main draft moves the fibres by 25-folds and the fibres accelerate, the effect of compaction during the part-time twist insertion must overcome the stops of the inserted false twist signal. Moreover, it appears to have a positive effect if there is a combination of high number of rotations per period with a dynamic stop, like presented with the example of 1.8 Hz and 9 rotations per period.

5.2.2 Influence of production speed

In addition to the investigation of different false twist signals and their impact for the fibre compaction at the main draft zone, this sub-chapter analyses the influence of the production speed.

In air jet spinning high production speed can be reached. The last roller pair, the front rollers, needs to perform in the same speed as the required production speed. The challenge is that with higher rotation speed of the front rollers, the effect of misaligned fibres at the main draft zone increases. This effect is observable in the figure 94 where the diagram shows the compaction rate by using the high-speed video analysis. The bars show the results of a conventional drafting system at three different production speeds (150 m/min, 200 m/min and 250 m/min). The higher the production speed, the higher the misalignment of fibres which results in lower compaction rates.

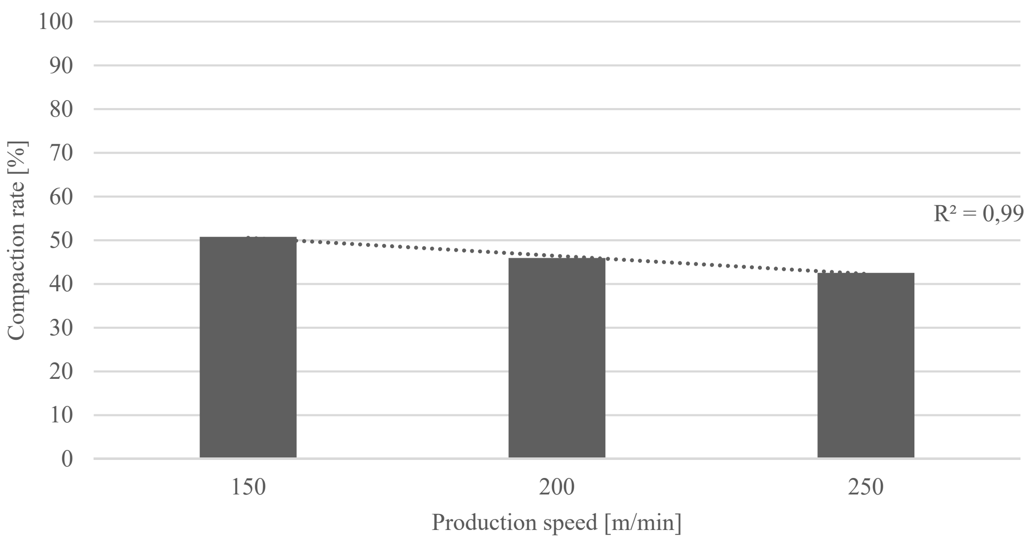


Figure 94 Diagram of the influence of the production speed for the fibre motion in a conventional drafting system

Under these circumstances, the effect of increasing misalignment of fibres with increasing production speed is analysed further with the implementation of the false twist device.

The figure 95 shows all tested false twist signals with increasing frequency value (horizontal axe) and their effect for the compaction rate at the main draft zone at the production speeds 150 m/min, 200 m/min and 250 m/min.

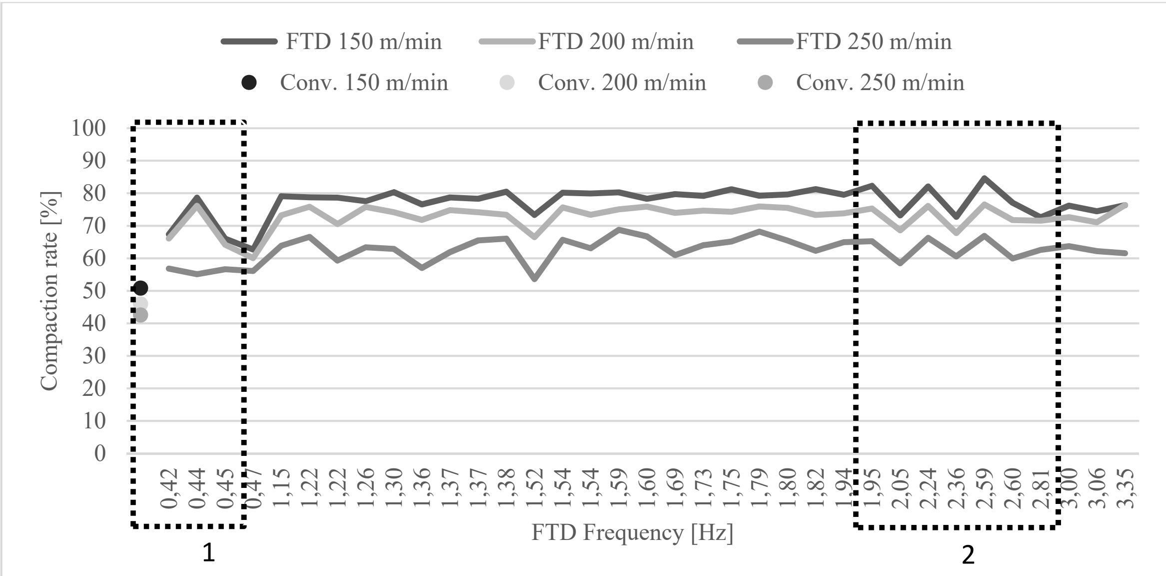


Figure 95 Diagram of the influence of the false twist frequency for the compaction rate related to the production speed

The diagram provides evidence for increasing misaligned fibres with increasing production speed. Furthermore, the implementation of the false twist device decreases the misalignment of fibres in the main draft zone with all tested frequencies. Moreover, the effect of the false twist signal results differently regarding the used frequency and tested production speed.

Firstly, the development of the compaction rate at 150 m/min and 200 m/min shows minimal effects of the false twist device with frequencies between 1.2 Hz and 1.9 Hz. The compaction rate stagnates around 75 % to 80 %. The results of the compaction rate of 250 m/min on the other hand, shows nearly an up and down development between 1.2 Hz and 1.9 Hz. It seems, with increasing production speed, the sensitivity of the inserted false twist signal for the fibre motion increases.

Secondly, at frequencies around 0.45 Hz, the results of 150 m/min and 200 m/min, the misalignment of fibres increases rapidly (seen at the dotted box 1). This effect is not observable at the production speed of 250 m/min. The compaction rate stagnates around 65 %, followed by a decrease with increasing frequency values. Regarding the presented fibre motion of the false twist signal of 0.45 Hz at chapter 5.2.1, the effect of periodic pattern of compaction and non-compaction might be an explanation for the different values and confirms the sensitivity of the fibre motion.

Thirdly, the dotted box 2 shows similarities in the development of compaction rate values for all three production speeds. Here, the sensitivity of the inserted false twist signal for the fibre motion increases.

In conclusion, these observations of the influence of the false twist device at different production speeds, show that the use of the false twist device reduces the misalignment of fibres at the main draft zone at all three tested production speeds. Nevertheless, at higher production speeds ≥ 250 m/min, the sensitivity for the fibre motion related to the false twist signal increases. That results in the conclusion, that each production speed, especially > 250 m/min, has its own optimum false twist frequency range to reach a positive effect for the compaction rate at the main draft zone and consequently for the yarn quality. However, for the validation of the sensitivity at higher production speed, the following sub-chapter will handle the amount of deviation of the compaction rate for the tested false twist frequencies at the production speed of 250 m/min.

5.2.3 Valuation of the compaction rate regarding the false twist signal at 250 m/min

Using the high-speed-video analysis and the developed compaction rate to evaluate the impact of the false twist device for the fibre motion in the main draft zone, the question of deviation arises. Especially, production speeds ≥ 250 m/min show high sensitivity in the fibre motion related to the inserted false twist signal. The figure 96 shows the diagram of the compaction rate related to their false twist frequency at the production speed of 250 m/min and their deviation value as error bars. The number of samples is 5 to achieve a representable deviation value.

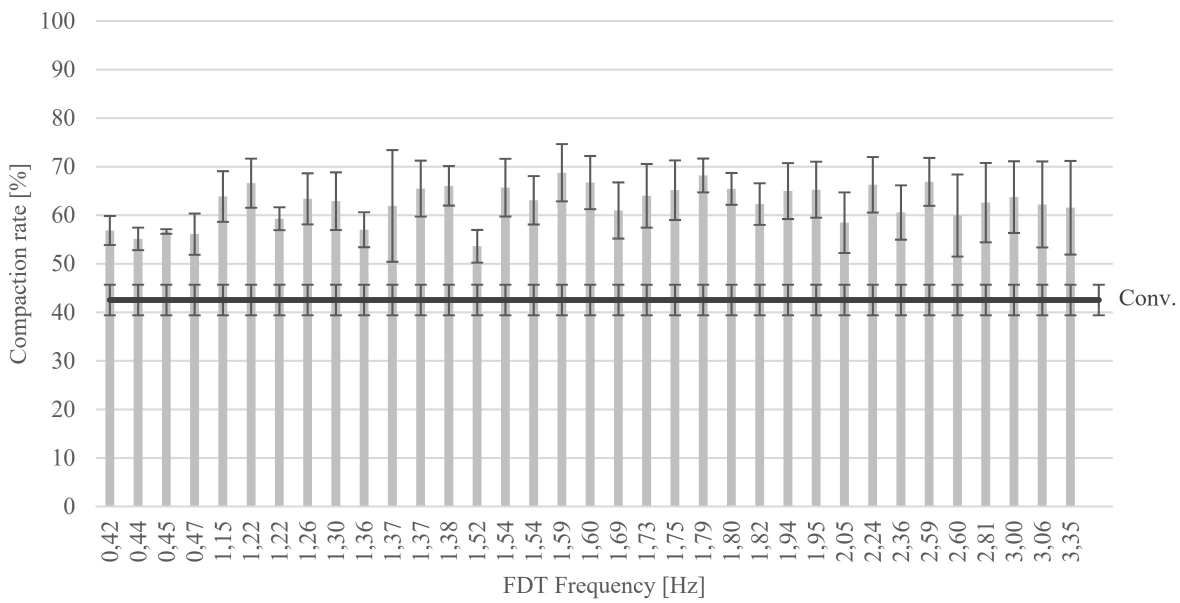


Figure 96 Diagram of the compaction rate regarding the false twist frequency at 250 m/min

Clearly, the highest maximum deviation of a false twist generated compaction rate is still 4 % lower than the lowest minimum deviation of a conventional generated compaction rate.

Nevertheless, the error bars represent relative standard deviations values between 0.4 and 11.5, which gives the possibility to evaluate the regularity of the resulting compaction rate related to their false twist frequency. The figure 97 shows the relative standard deviation values for each frequency separately from the mean compaction rate value for better visualisation.

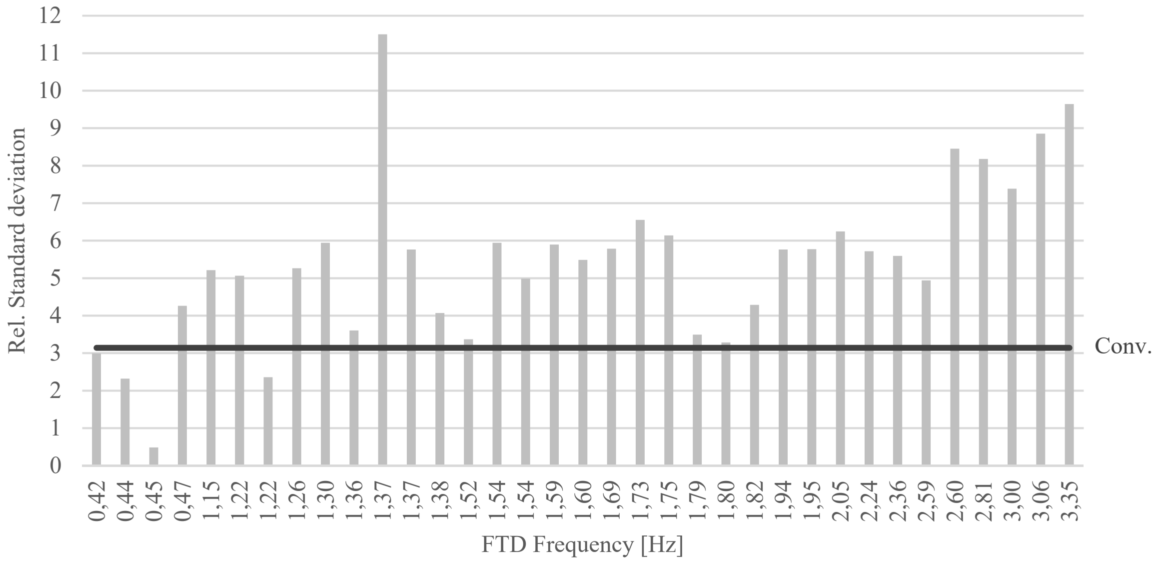


Figure 97 Diagram of the relative standard deviation values of the compaction rate regarding the false twist frequency

In this case, the diagram clearly shows the distribution of relative standard deviation values of the compaction rate. Predominantly, the deviation values of the compaction rate generated with the false twist device are higher than the one of a conventional drafting system.

However, the deviation values of the lowest false twist frequency values appear around 0.45 Hz. Since those settings are already analysed as a periodic development of compaction and non-compaction, it only shows that the periodic appearance is regular. The other deviation values which are lower than the others are false twist frequencies of 1.22 Hz, 1.52 Hz and 1.80 Hz. Regarding the mean value of compaction, the false twist frequency of 1.8 Hz is the only setting which shows a considerable high mean compaction rate value AND a considerable low deviation.

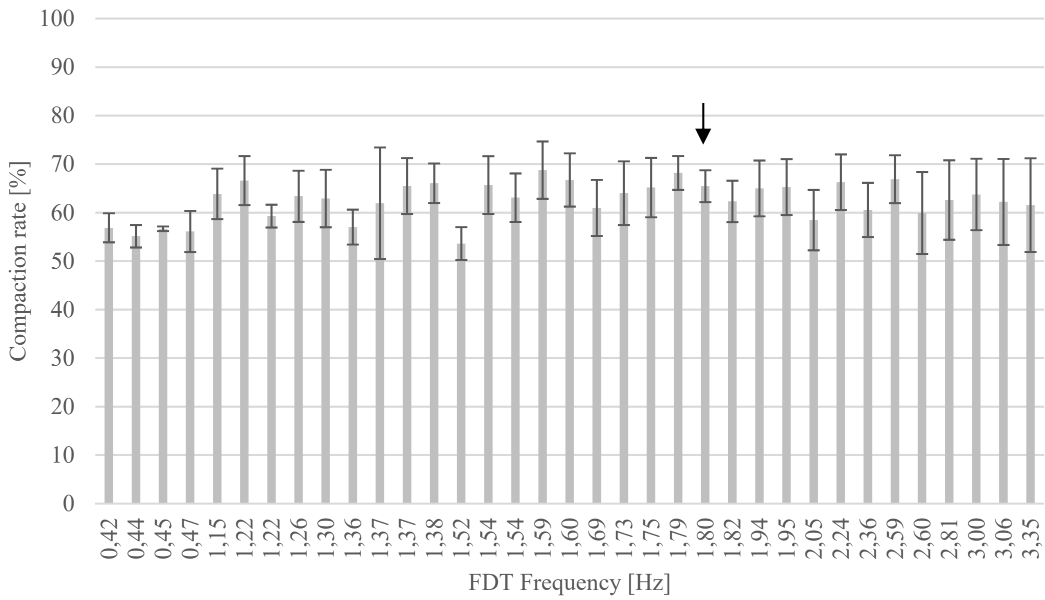


Figure 98 Diagram of compaction rate regarding the false twist frequency at 250 m/min

5.2.4 Verification of the control system output with the actual signal output

In chapter 4.7 a control system is presented to simulate the false twist signal input in order to analyse the significance of several parameters for the false twist signal output. Hereby, the theoretical frequency value shows a crucial influence for the process stability. The suggested frequency range results between 0.4 Hz and 4 Hz for a stable process and enough impact for the fibre flow in the main draft zone.

The analysis of the false twist signal for the fibre motion in the main zone in the previous chapters confirms the suggested frequency range from the control system. A stable process is possible by using frequencies between 0.4 and 3.35 Hz. Although, the frequency of 0.4 Hz shows a limitation for the regularity of the false twist insertion and higher frequencies than 3.35 Hz are limited by the false twist device itself.

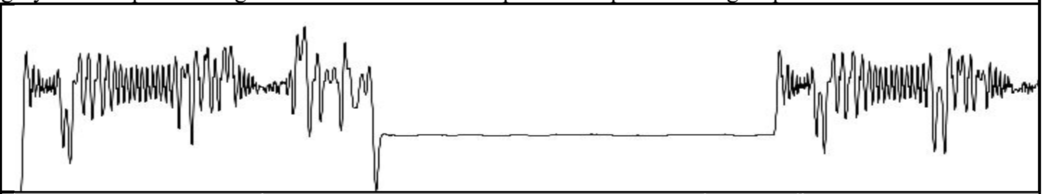
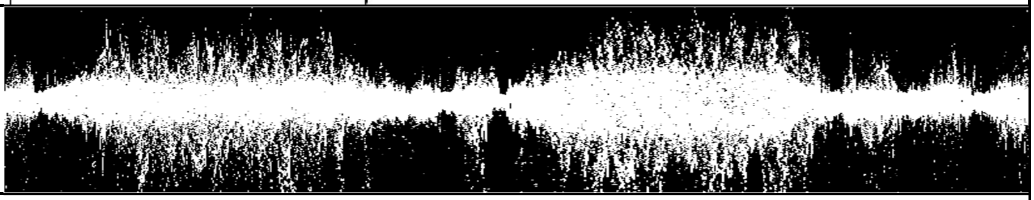
Since the control system is an idealized model for the false twist insertion and its impact for the fibre motion as output, it does not show the natural irregularities of fibre motion in the main draft zone. It does show however fibre motion as bundle and the effect of compaction which relates it to the resulting output as theoretical curve. The tables 34 to 37 provide an overview of the signal input and the resulting image curve output from chapter 5.2.1, complemented with the theoretical fibre motion curves from the control system and the actual fibre motion curves form the trials as output within the tested time range of 3 (or 6 for 0.4 Hz) seconds.

For better visualization, the set categories from chapter 5.1.1 are used to cluster the results and the following examples are presented.

- For the first category as most irregular curve with long stops, the results of the frequency of 0.4 Hz are presented.
- For the second category as most regular curve with short stops, the results of the frequency of 2 Hz are presented.
- For the third category as most regular curve without stops, the results of the frequency of 3 Hz are presented.

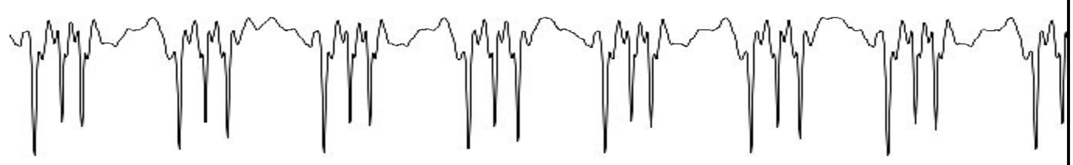
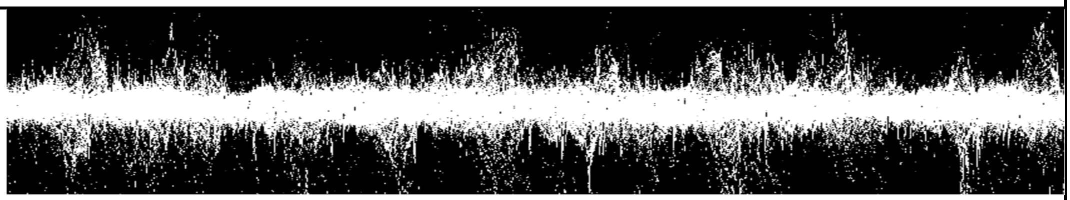
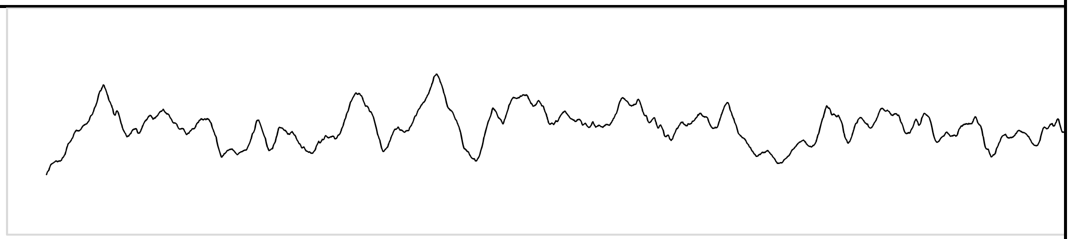
Moreover, the results of the frequency of 1.8 Hz are shown since this frequency is identified with the highest compaction rate.

Table 34 Verification of signal input and output from theory to trial of category 1

Category 1: Example for irregular false twist insertion input and output with long stops with 0.4 Hz	
Motion curve input signal	
Resulting Image curve	
Theoretical curve fibre motion	
Experimental motion curve fibre motion	

The false twist signal of 0.4 Hz is identified as limit for the false twist insertion. As presented in chapter 5.2.1, a sinusoidal curve shape as signal output holds a risk of recurring fibre motion structures. The comparison of the simulated fibre motion curve from the control system and the actual fibre motion curve confirms this theory. Although, the curves result in similar peak shapes, the offsets of the peaks are different. Especially the offsets, provoked by the long stops between the peaks, are not visualized by the simulated curve. The recurring fibre motion structure is observable which is an indicator for periodic yarn failures and confirms the frequency of 0.4 Hz as limit. Moreover, it confirms that the frequency of 0.4 Hz is not practical for a uniform fibre compaction.

Table 35 Verification of signal input and output of theory and trial from category 2

Category 2: Example for most regular false twist insertion input and output with short stops with 2 Hz	
Motion curve input signal	
Resulting image curve	
Theoretical curve fibre motion output	
Experimental curve fibre motion output	

The false twist signal of 2 Hz is identified as most regular frequency with short stops. The theoretical fibre motion curve has regular changes of peaks with sharp direction changes. The peaks show a uniform repetition, provoked by the regular short stops of the false twist signal input. The comparison of the simulated fibre motion curve from the control system to the actual fibre motion curve from the trial result in similar geometries. For better visualisation, both fibre motion curves – the theoretical and the experimental curve – are presented in one graph. Here, the similar overall geometry of both curves is visible.

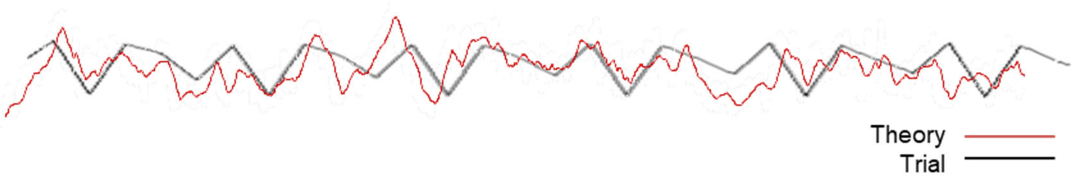
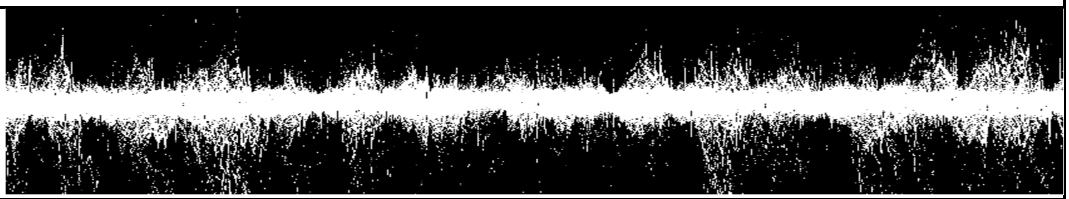
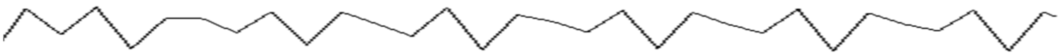
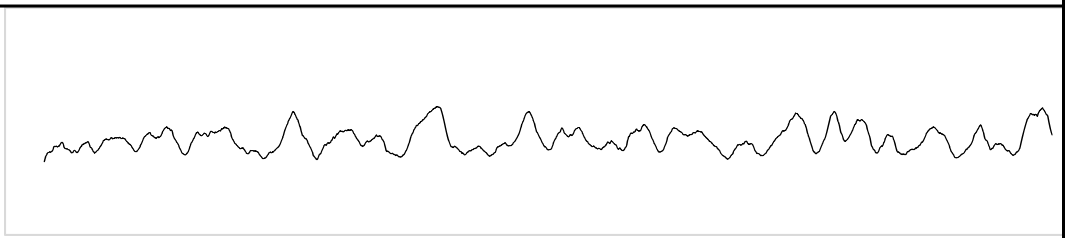


Figure 99 Comparison between theoretical and experimental motion curve for 2 Hz

Table 36 Verification of signal input and output of theory and trial from category 3

Category 3: Example of most regular false twist insertion input and output without stops with 3 Hz	
Motion curve input signal 3 Hz	
Resulting image curve 3 Hz	
Theoretical curve fibre motion output	
Experimental motion curve fibre motion output	

The false twist signal of 3 Hz is identified as an example of the most regular frequency without stops. Although, the theoretical curve of the signal output as fibre motion in the main draft zone has similar appearance like the frequency of 2 Hz, they significantly differ by their overall level of peaks. The peaks of 3 Hz are slightly lower than the ones of 2 Hz. That can be explained by the interaction of higher number of rotations per period and the absence of rotation stops of the signal input. Consequently, the signal input with 3 Hz has a higher effectiveness for the compaction of the fibres in the main draft zone than the one with 2 Hz. The comparison of the simulated fibre motion curve from the control system to the actual fibre motion curve from the trial results in similar geometries. Both curves show lower level of peaks, which indicates higher compaction of the fibre bundle in the main draft zone. For better visualisation, both curves are presented in one graph.

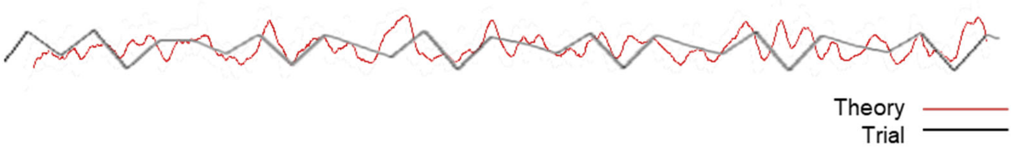
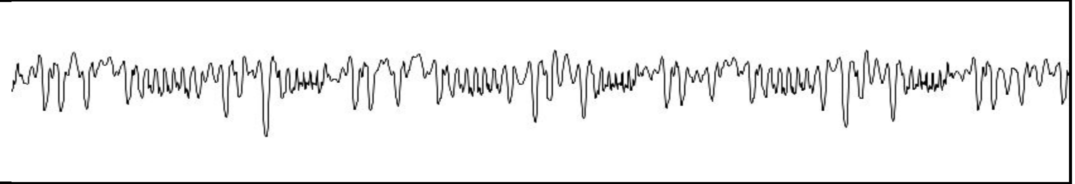
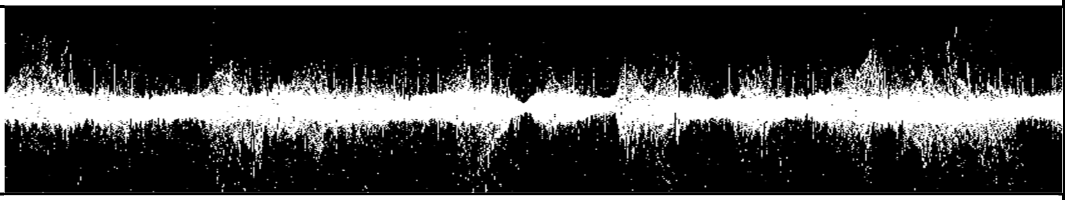
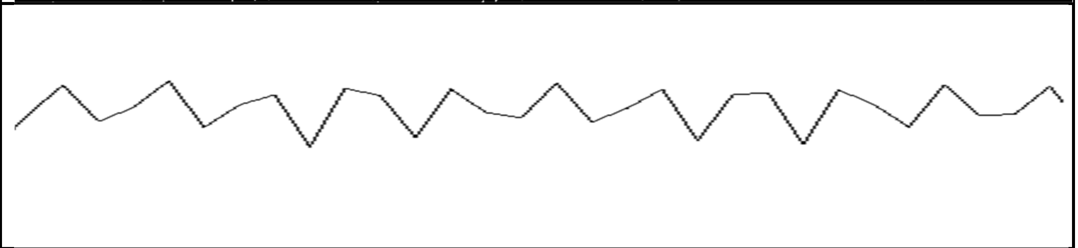
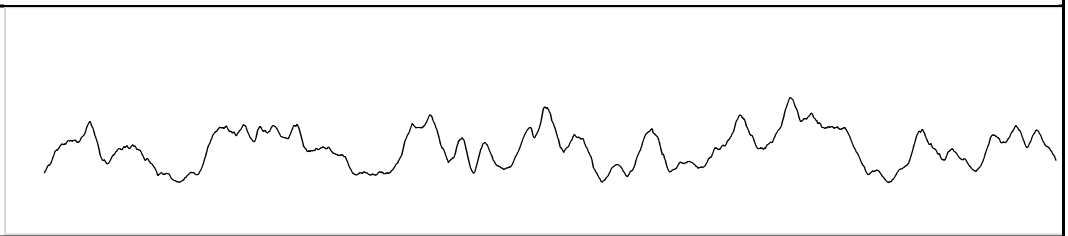


Figure 100 Comparison between theoretical and experimental motion curve for 3 Hz

To conclude the analysis of the comparison of the theoretical fibre motion with the actual fibre motion, the false twist signal of 1.8 Hz with 9 rotations per period as recommended false twist setting is presented, too.

Table 37 Verification of signal input and output of theory and trial from recommended 1.8 Hz with 9 rots/period

Motion curve input signal	
Resulting image curve	
Theoretical curve fibre motion output	
Experimental curve fibre motion output	

The false twist setting of 1.8 Hz with 9 rotations per period has the highest compaction with a uniform fibre motion through the main draft zone. The simulated curve from the process control system shows lower regularity in the signal output than the previous presented frequencies of 2 or 3 Hz. Nevertheless, the level of the peaks is considerable low which confirms the high compaction rate in the main draft zone. The comparison to the actual fibre motion curve results in similar curve shapes and peak level. For better visualisation, the theoretical and the experimental curve is presented in one graph.

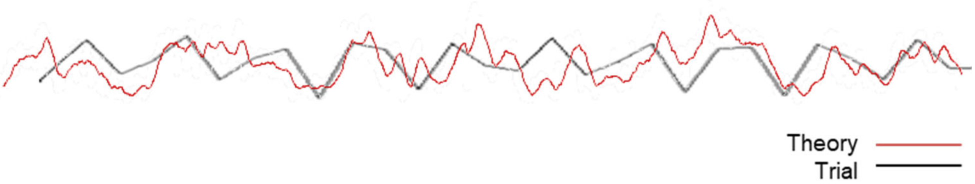


Figure 101 Comparison between theoretical and experimental motion curve for 1.8 Hz

5.2.5 Analysis of the yarn quality

The previous chapters dealt with the fibre motion in the main draft zone using the false twist device. As a result of the analysis, the compaction rate clearly shows a reduction of misaligned fibres which indicates lower yarn unevenness by using the false twist device. For the investigation of the yarn quality all false twist settings have been tested to produce yarn.

This chapter presents the influence of the false twist device for the yarn quality produced at 250 m/min and deals with the question of relatability to the compaction rate to the yarn unevenness. The analysis of the compaction rate is used to reduce the amount of main spinning trials by clustering their effectiveness of compaction for the fibre motion at the main draft zone.

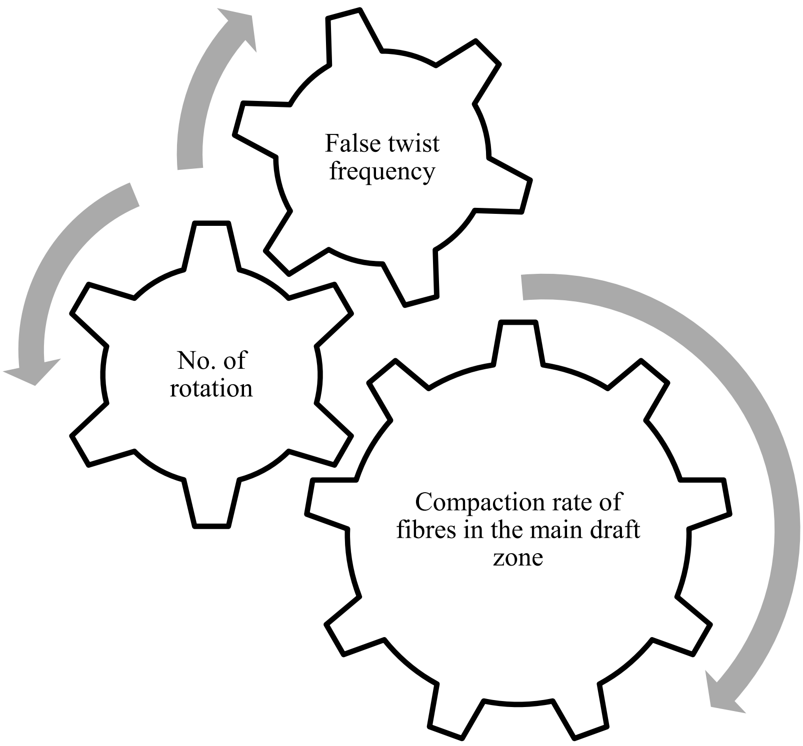


Figure 102 Visualisation of relation between false twist frequency, no. of rotations and compaction rate

Considering the data from the previous chapters, the regularity of the inserted false twist frequency, the number of rotations of the false twist device, the regularity of the compaction rate and the value itself, the false twist settings shown in table 38 are utilized in this chapter.

Table 38 List of presented false twist settings, compaction rate and resulting yarn unevenness [CVm%]

False twist frequency [Hz]	No. of rotation [n]	Compaction rate [%]	Mean Yarn Unevenness [CVm%]
0 (conv.)	0 (conv.)	42.5	24.2
3.0	4	63.7	23.9
1.8	9	65.4	23.0
0.4	16	56.8	26.6

The figure 103 shows the relation between the developed compaction rate and the yarn unevenness. It is possible to analyse a reliable correlation.

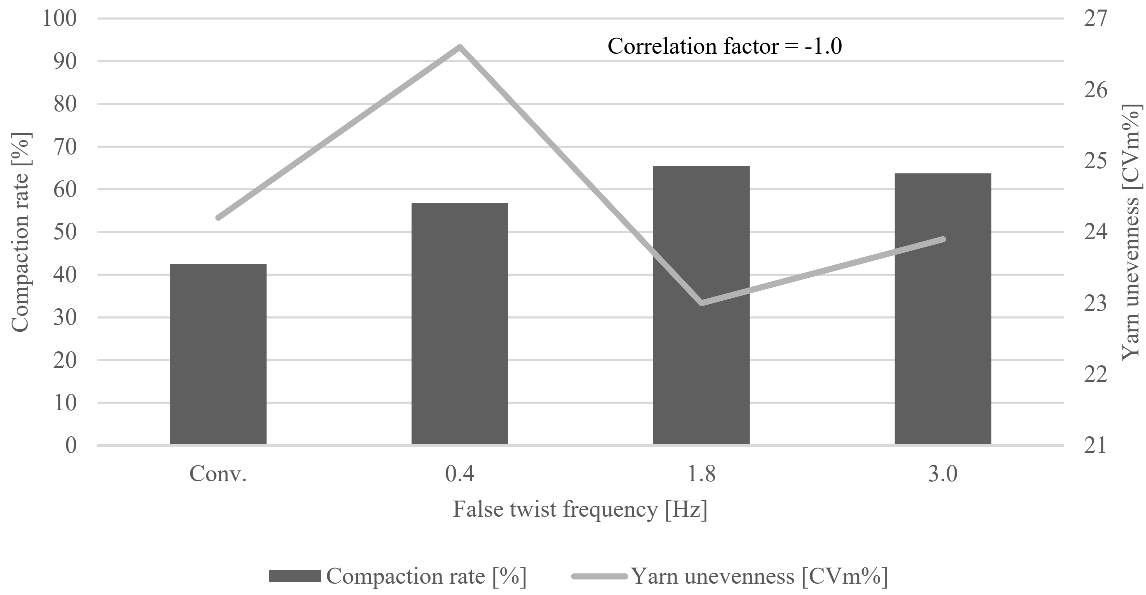


Figure 103 Diagram of relation between false twist frequency, compaction rate and yarn unevenness

The diagram relates the inserted false twist frequency to the measured compaction rate in the main draft zone and the resulting yarn quality as yarn unevenness in CVm%. Clearly, the use of the false twist device improves the yarn evenness compared to a conventional drafting system without false twist insertion. Furthermore, the predicted high yarn unevenness with the frequency 0.4 Hz is confirmed in the same way as the predicted lowest yarn evenness with the frequency of 1.8 Hz. Therefore, the developed analysis tool of the compaction rate is an adequate tool to predict the resulting yarn unevenness.

The diagram displays the correlation between the compaction rate and the yarn unevenness CVm%. Furthermore, the results show that the frequency value itself has a subordinated role for the resulting yarn evenness. The implementation of a false twist in general is the main factor for improvements of the yarn quality.

However, the frequency value plays a role for the spinning stability. Since the number of rotation and the timing of rotation direction change of the false twist device influences the fibre flow actively in the drafting zone, it influences the spinning stability. The misalignment of edge fibres in the main draft zone is one of the main challenges for the performance of an air jet spinning machine. By using the right false twist frequency, this challenge can be taken up and be overcome. The spinning stability is significant for the productivity of the spinning machine and consequently for the efficiency.

In conclusion, the implementation of the false twist device into the drafting system of an air jet spinning machine improves the performance of the spinning process. The compaction rate represents a possible prediction tool for the impact of the false twist device.

5.3 Analysis of the fibre movement in the drafting zone of roving production

5.3.1 Influence of the false twist device at the drafting system of a roving machine

The positive effect of the false twist device in a drafting system of an air jet spinning machine has been presented. This chapter deals with the opportunity of the false twist device implemented in a drafting system of roving frame machine as comparison. For the trials at the roving frame machine, the frequency of the false twist device has been adjusted to the settings shown in table 39.

The adjustments of the false twist settings are necessary because of the different width of the drafted fibre bundle. The main draft of the roving frame machine is significantly lower than the draft of a drafting system of an air jet spinning machine. Consequently, the number of fibres in the fibre bundle is higher and the inserted false twist can only perform with lower number of rotations to keep the fibres sliding through the false twist device.

Table 39 Overview of presented false twist settings, resulting apron tread and roving unevenness [CVm%]

False twist frequency [Hz]	No. of rotation [n]	Apron tread [mm]	Mean Roving Unevenness [CVm%]
0 (conv.)	0 (conv.)	18.16	4.44
3.4	4.75	10.43	4.07
1.9	8	14.66	4.10
1.5	3	13.86	4.14

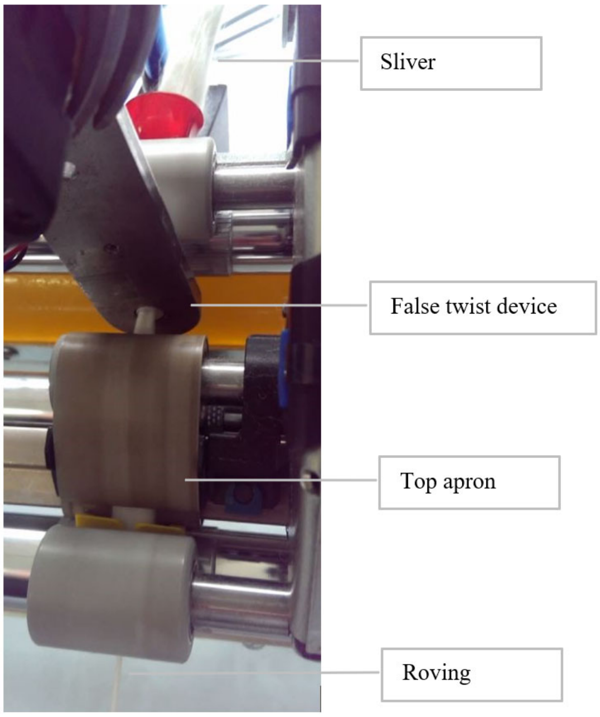


Figure 104 Picture of false twist device integrated into the drafting system of a roving frame machine.

5.3.2 Analysis of the spinning triangle

Since the measurement of the spinning triangle is an adequate tool to analyse the impact of the compaction with the inserted false twist, it is the method of choice for the investigation. The measurement process is explained in chapter 4.6.3. An analysis with the high-speed-camera is not necessary since the drafting speed is much lower than in air jet spinning. With reference to the improvements of the fibre motion in the main draft zone of an air jet spinning machine, the measurement of the spinning triangle parameters confirms the positive effect of false twist insertion.

Each false twist setting improves the spinning triangle by reducing the width, the length, and the apron tread, compared to a conventional drafting system without false twist insertion.

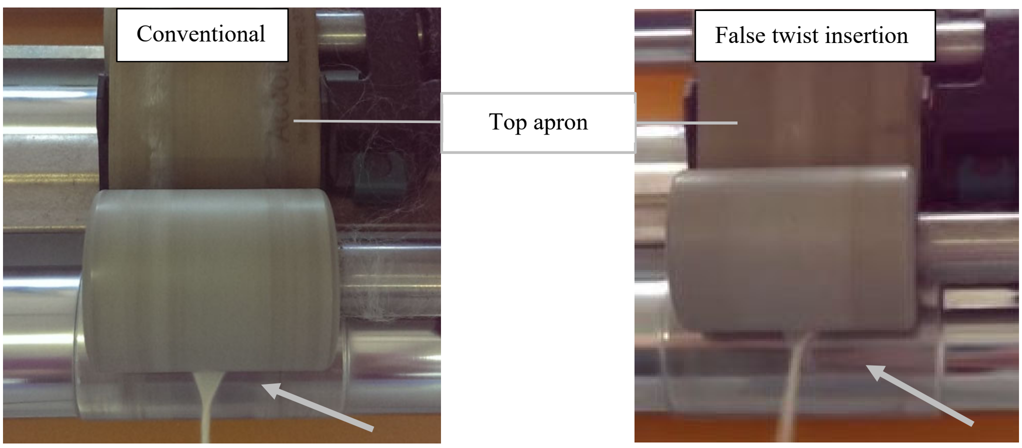
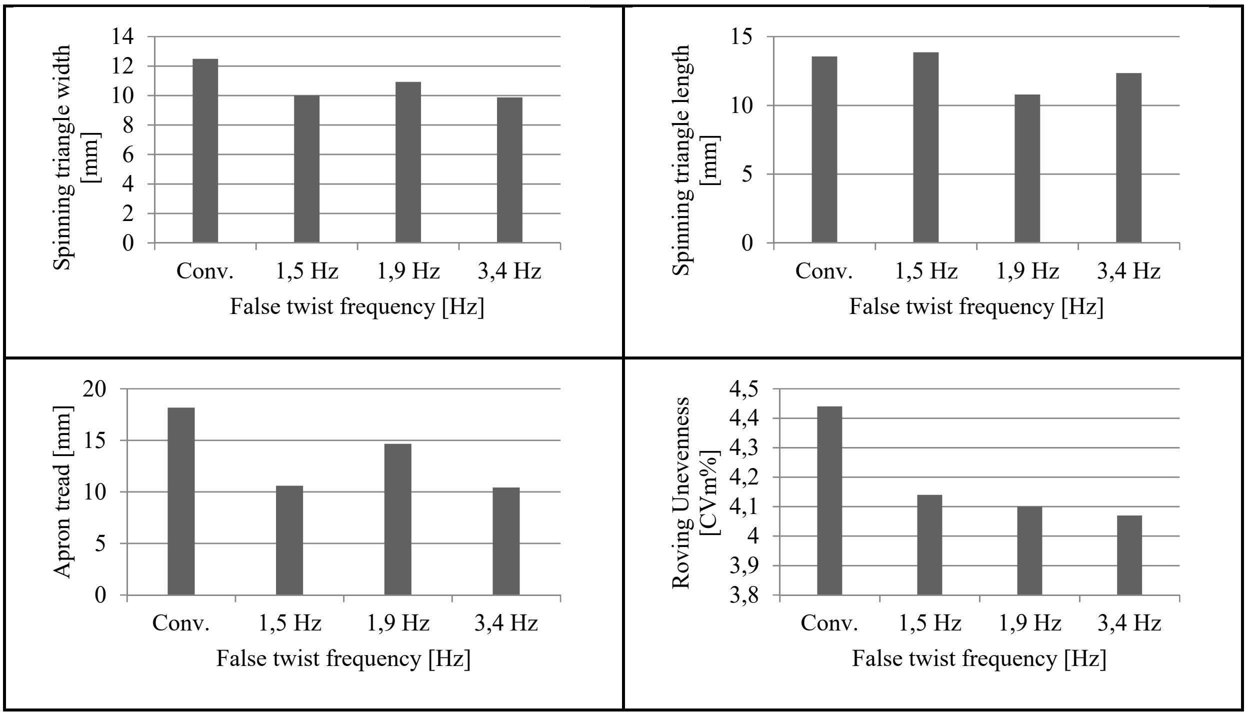


Figure 105 Pictures of roving spinning triangle of conventional (left) and false twist inserted (right) drafting

Firstly, the spinning triangle width (grey arrows) is reduced by 13 % - 21 % regarding the used false twist setting. Furthermore, the spinning triangle length is reduced by 2 % - 21 %. Finally, the measurement of the apron tread shows a reduction of 19 % - 42 %. Overall, the use of the false twist device in the drafting system of the roving frame machine results in significant improvements of the spinning triangle parameters. Therefore, the reduced spinning triangle has a positive effect for the produced roving in unevenness CVm% (seen in the next diagrams).

Table 40 Diagrams of influence of the false twist settings for the spinning triangle, apron tread and roving unevenness



In addition to the reduction of the roving unevenness, the effect for the spinning triangle parameters implies that the use of false twist insertion improves the spinning stability of the roving process regarding fibre fly. This leads to less roving breaks during the production. All trials show an exact reduction in roving breaks of 50 % using the false twist device.

Although the results of the roving unevenness show an improvement by using the optimal false twist setting, the effect needs to be continued in the following production step, the ring spinning.

5.3.3 Analysis of roving quality and its impact for the ring yarn quality

The use of the false twist device in the pre-draft of the roving frame machine shows significant improvements for the roving process and for the roving quality. This chapter deals with the question if the improvement continues in the next process step, the ring spinning.

Firstly, the relation between the resulting roving apron tread with the ring yarn unevenness is presented. The figure 106 clearly shows a relation between the used false twist frequency in the roving production to the resulting yarn quality. The positive effect of the false twist for the apron tread continues proportional in the quality of the ring yarn.

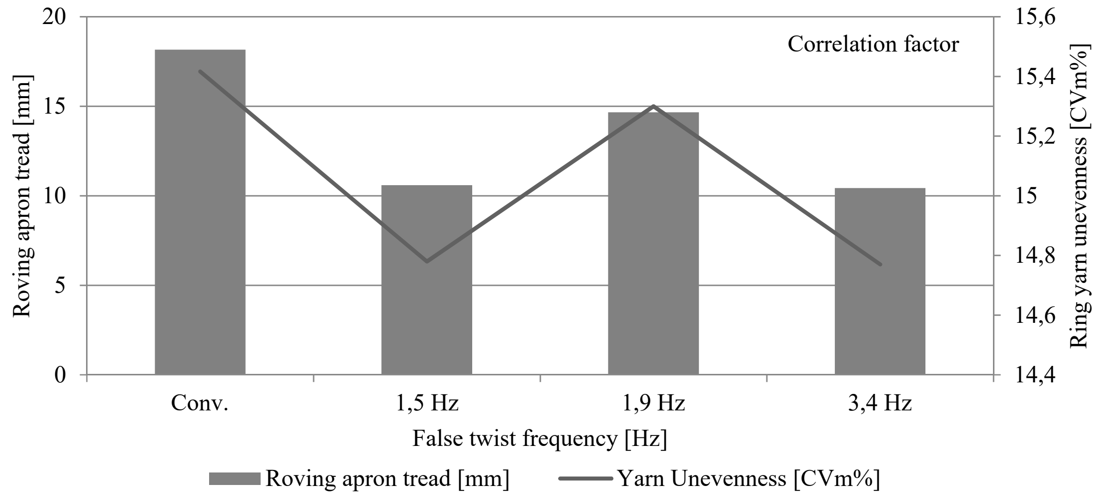


Figure 106 Diagram of the relation of roving apron tread and ring yarn unevenness regarding the frequency

Secondly, the direct relation between the resulting roving unevenness [CVm%] with the ring yarn unevenness [CVm%] is presented in the diagram of figure 107.

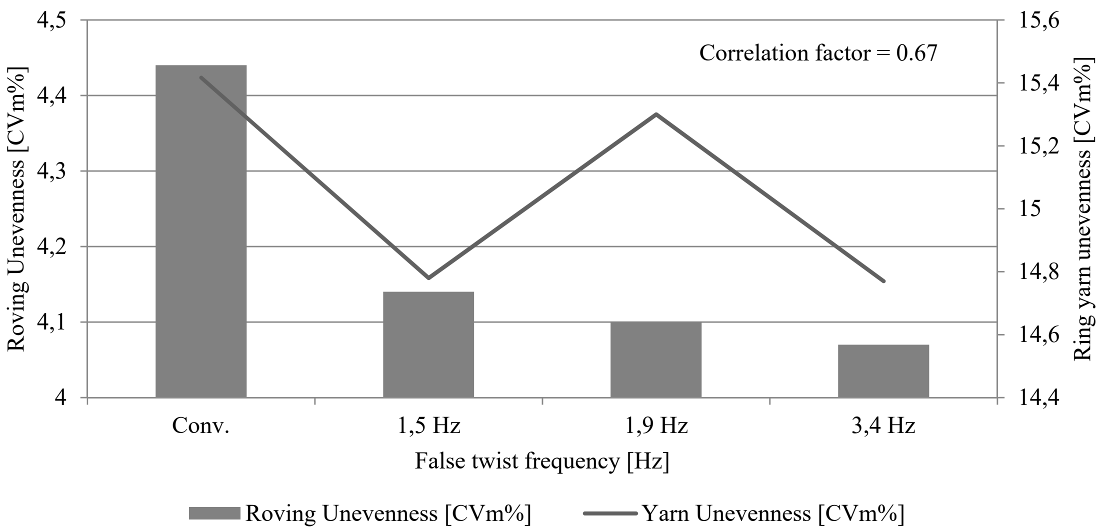


Figure 107 Diagram of the relation between roving and ring yarn unevenness regarding the frequency

Observing the results in the diagram of figure 107, a proportional relation between the roving unevenness with the resulting ring yarn unevenness considering the used false twist frequencies, cannot be detected. A decrease of the roving unevenness value with a specific false twist frequency does not result in a proportional decrease in the ring yarn unevenness. This effect is observable at the false twist frequency of 1.9 Hz, where the low roving CVm% does not continue proportional to the ring CVm% value. For further investigation, the figure 108 shows besides the CVm%-values, the mass variations in detail like number of thin places, thick places and neps (IPI's) of the produced ring yarns.

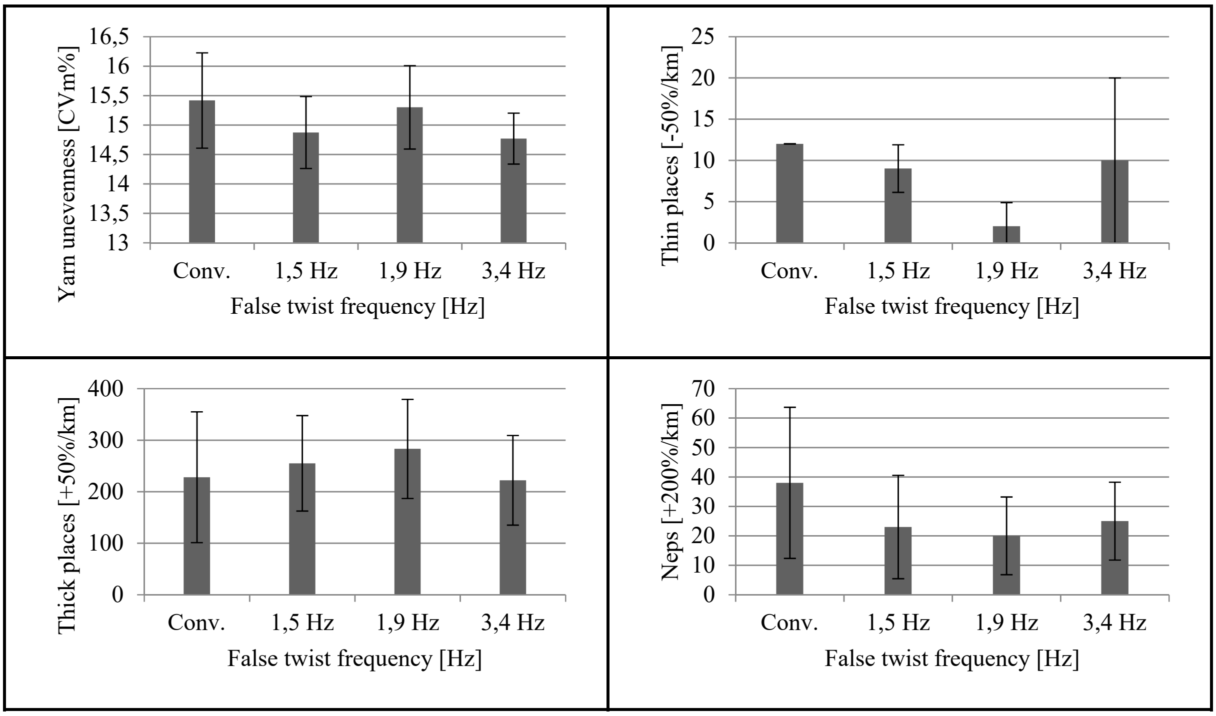


Figure 108 Diagrams of the ring yarn unevenness and IPI's regarding the frequency

The analysis of the IPI values can explain the non-proportional development of the CVm% values from the roving to the ring yarn. On one hand, the values of 1.9 Hz for thin places and neps show the lowest values of all settings. On the other hand, the setting with 1.9 Hz shows the highest value of thick places. In total, the unevenness CVm% results in a higher value for 1.9 Hz. It can be concluded that the use of the false twist device with the setting of 1.9 Hz with the highest number of rotation (8) positively integrates the fibres in the roving that keeps the thin place value for the ring yarn low. Nevertheless, this positively integration results also in negatively higher thick places. The reason can be the considerable high number of rotations of 8 through the false twist insertion into the roving with the frequency of 1.9 Hz.

Besides of this observation, all false twist settings show relatively high thick place values, compared to the conventional produced ring yarn. The integration of temporary twist might cause slight interferences during the drafting, especially higher friction forces between the single fibres. In general, thick places in ring yarn are influenced by the drafting settings, for example by the pressure of the top rollers. It is possible, that in addition to the number of rotations through the false twist insertion, the settings of the drafting system of the ring spinning machine including the pressure of top rollers need to be adjusted for the processing of the roving, processed with the false twist device.

It can be nevertheless concluded that the use of the false twist device for the roving production shows advantages for the roving quality which continues into the next process step, the ring spinning process, and the ring yarn quality. With regards to the right false twist setting, it needs to be mentioned that the drafting settings of the roving frame machine and the ring spinning machine must be adjusted and the number of rotations through the false twist insertion should be considerable low.

6. Impact of a spiral condenser in drafting systems

The use of condensers in drafting systems is state of the art. They are inserted before or between two drafting rollers with the main purpose to compact the processed material and to control floating fibres. They can either have a shape of a funnel or a tube to guide the fibres through the drafting system. Funnel shaped condensers are mainly used at the entrance of the drafting system to bring the fibre bundle in a centred position entering the drafting system. Tube shaped condenser can be found at the pre-draft zone to control the floating fibres and keep the fibre bundle compacted. At roving frame machines "flying" condensers at the main draft zone ensure a smaller spinning triangle.

All those condensers have in common that their role is narrowed to "guide" the fibre bundle. There is no attempt to "actively" interact with the fibre bundle. Since it is a usual auxiliary in drafting systems, there was no necessity to change the use of a condenser. The semi-finished products to process them are simple and cheap. Implementing a new shape of a product, like a spiral shaped condenser, takes time and needs results to show the positive effects. Therefore, rapid prototyping is used for the development and testing of the spiral condenser. In combination with 3D-printing it gives a relatively cheap, outstanding time-saving and flexible method to analyse the effect of a spiral-shaped condenser.

The compaction effect of a fibre bundle using a common funnel-shaped condenser is limited by the number of fibres in the fibre bundle. Especially, if the number of fibres is high, like in a sliver, the funnel end must be wide enough that the fibres can pass through the condenser. Because of the fibre-fibre-friction it can result in a compression of the fibre bundle which causes sliver breakages during the drafting. Consequently, the funnel must be tide enough to compact the fibre bundle, but wide enough that the fibres can move and slide against each other during the drafting. That limits the compaction effect of funnel-shaped condensers.

The aim of a spiral-shaped canal is to overcome this limitation. The spiral causes a spatial deformation of the fibre bundle. The fibre bundle gets drafted because of rotating roller pairs where pressure from the top rollers to the bottom rollers creates the necessary force to keep the fibres in line of the system. The pressure of the rollers changes the cross-sectional shape of the sliver from an almost round cross-section into a flat cross-section. Loosing peripheral fibres in the main draft zone happens mainly due to fibres at the edges of the flat cross-section where fewer fibres can be found consequently less possibilities of fibre-fibre friction to keep them together. By the spatial deformation of 90° degrees the former edge fibres of the fibre bundle are in the middle of the fibre bundle. That reduces the spinning triangle at the main draft zone and compact the fibre bundle through the challenging main draft zone (see principle in figure 109).

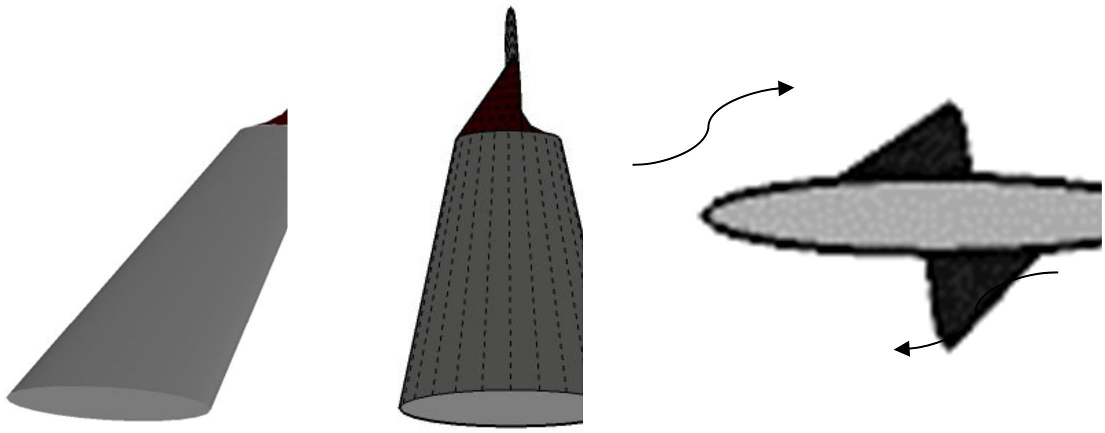


Figure 109 Principle of spatial deformation of the fibre bundle through the spiral condenser

The spatial deformation of 90° can be defined as a false twist insertion. Since it is a part-twist insertion which is "*locally present [...], the twist is only at one defined place of a process and it is disintegrated afterwards at the next process step*" [Schwabe, 2009]. This kind of false twist can be named as a *passive* false twist insertion.

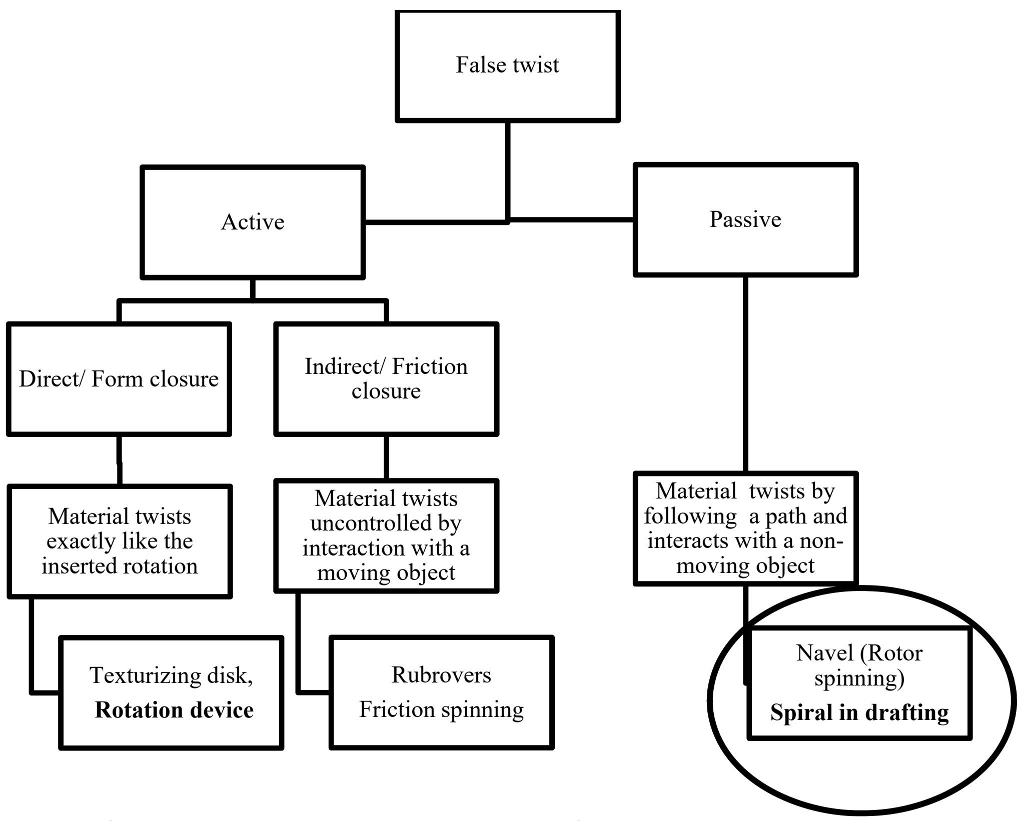


Figure 110 Spiral condenser categorized as passive false twist insertion

6.1 The fibre motion in the drafting system of air jet spinning

6.1.1 Spiral condenser for air jet spinning

The outer shape of the developed spiral condenser is similar to a generally used condenser in air jet spinning. On the sides are gaps to implement the condenser between two roller pairs. The side of entry is slightly flattened at the top and bottom to position the condenser as near as possible to one of the roller pairs. The inner shape shows the spiral canal.

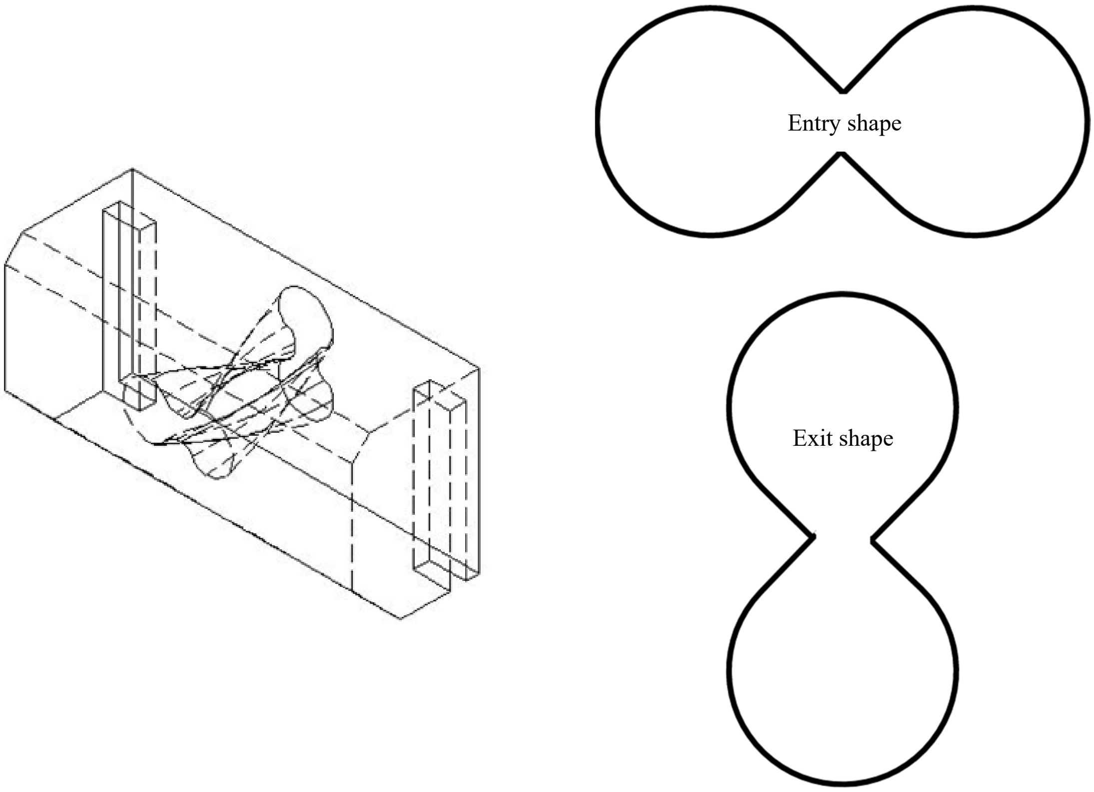


Figure 111 Technical drawings of spiral condenser for air jet spinning

The entry of the canal has a horizontal elliptical shape with a narrowing in the middle. The horizontal elliptical shape helps the flat fibre bundle enter the condenser. The narrowing in the middle has the effect of almost splitting the fibre bundle into two strands, like the entry of the slot plate of the dynamic false twist device. The splitting of the fibre bundle into two strands helps to increase the effect of overlapping and compact the fibre bundle during the spatial deformation of 90°. The spiral canal guides the fibre bundle to the vertical elliptical shaped exit of the condenser to uphold the spatial deformation after leaving the condenser.

The effect is presented with the use of a model in the figure 112, where two coloured fibre strands represent a fibre bundle in the main draft zone of a running air jet prototype machine. The use of two different colours underlines the effect visually. For the analysis of the spatial deformation, the top apron is removed, and the total draft is decreased to 1.

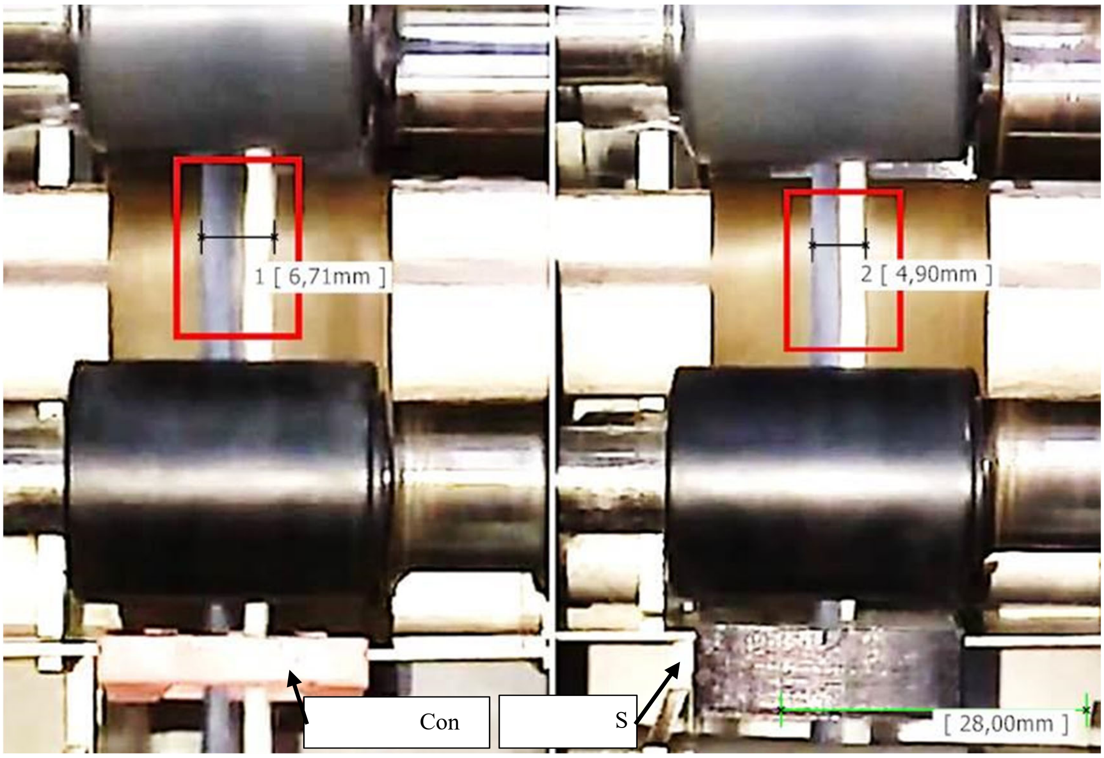


Figure 112 Pictures of fibre flow model comparison between conventional and spiral draft

The picture to the left shows the model of fibre flow with a conventional condenser. The two strands are guided through the main draft in the same width as they have entered it. There is only the effect of guidance. The picture to the right demonstrates the effect of using a spiral condenser. The two strands entering the spiral condenser in a parallel way like with a conventional condenser. At the same time of guidance, the two fibre strands change their position to each other. Just after leaving the spiral condenser, the two strands are almost on top of each other. The spiral canal deformed the position of the two strands by almost 90°. This 90° direction change cannot be fixed at this point because of the pressure of the top rollers to the bottom rollers. However, it reduces the width of the fibre strands through the main draft zone from 6.71 mm to 4.90 mm which indicates a compaction of fibre material at this point.

The following chapters analyses this effect of using a spiral condenser in an air jet spinning prototype machine. This includes the position of the spiral condenser in the drafting system, the effect of compaction for the fibres of 100 % cotton at different production speeds and their influence for the yarn quality.

6.1.2 Influence of a spiral condenser for the fibre motion at the main draft zone of air jet spinning

The spiral condenser is positioned at the second pre-draft zone of the drafting system of an air jet prototype machine. The impact of using the spiral condenser instead of a conventional condenser is tested by analysing the fibre motion in the main draft zone and the resulting yarn quality at different production speeds.

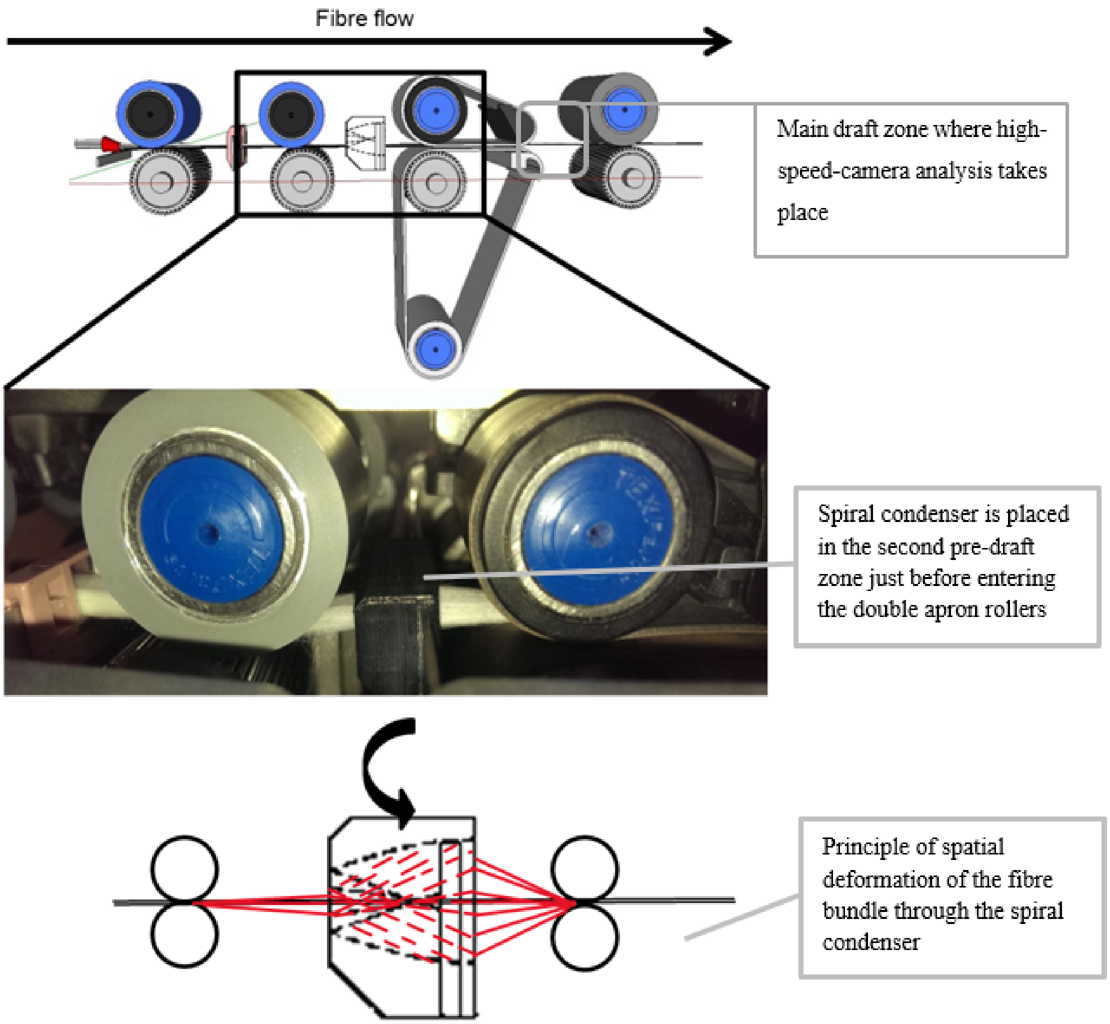


Figure 113 Principle of fibre flow compaction with the spiral condenser

The second pre-draft zone is the position of choice for the spiral condenser because of the direct influence for the following main draft zone after the aprons. Here, the spatial deformation of the fibre bundle can be transported further into the challenging main draft zone. If the the position of the spiral condenser is at the entry or at the first pre draft zone of the drafting system, the effect of spatial deformation would disappear before it reaches the main draft zone.

The analysis of the fibre motion itself takes place at the main draft zone with the help of a high-speed camera and the pixel analysis method. The influence of different delivery speeds and its impact for the yarn quality is presented.

The spiral condenser is a static device to insert false twist into the delivered sliver. It changes the orientation of the sliver by 90° which is synonymous with one quarter-turn of false twist. Figure 114 shows examples of the fibre motion at the main draft zone at a production speed of 200 m/min after the black and white pixel threshold process. The image to the left shows the fibre motion in the main draft zone by using a conventional condenser whereas the image to the right shows the fibre motion using a spiral condenser in which the spatial deformation took place. The analysis time is 3 seconds.

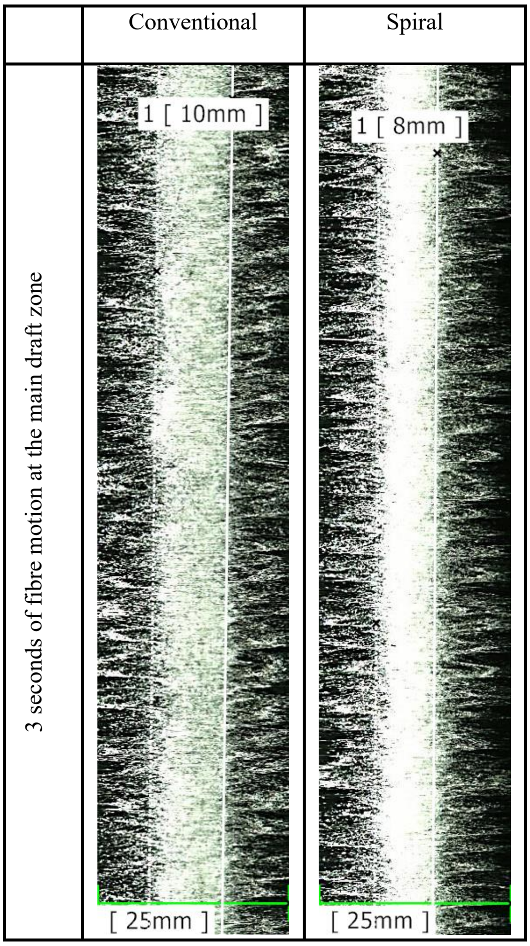


Figure 114 Comparison between a conventional and a spiral drafted fibre motion

The general appearance of misaligned single fibres at the edges of the fibre flow is similar. However, the core of the drafted sliver is more compacted after passing the spiral condenser. The core where the major portion of the drafted sliver gets delivered is decreased by 2 mm from 10 mm to 8 mm using the spiral condenser. Furthermore, the range of misaligned fibres to the left and to the right of the core is decreased. That indicates a reduction of fibre motion at the main draft zone by using a spiral condenser at the second pre-draft zone. The figure 115 shows a magnification of the two pixel-analysis pictures with the focus on the reduction of misaligned fibres on the right side of the fibre flow core. It is obvious that by using the spiral condenser the number of white pixels which are synonymous for misaligned fibres are decreased.

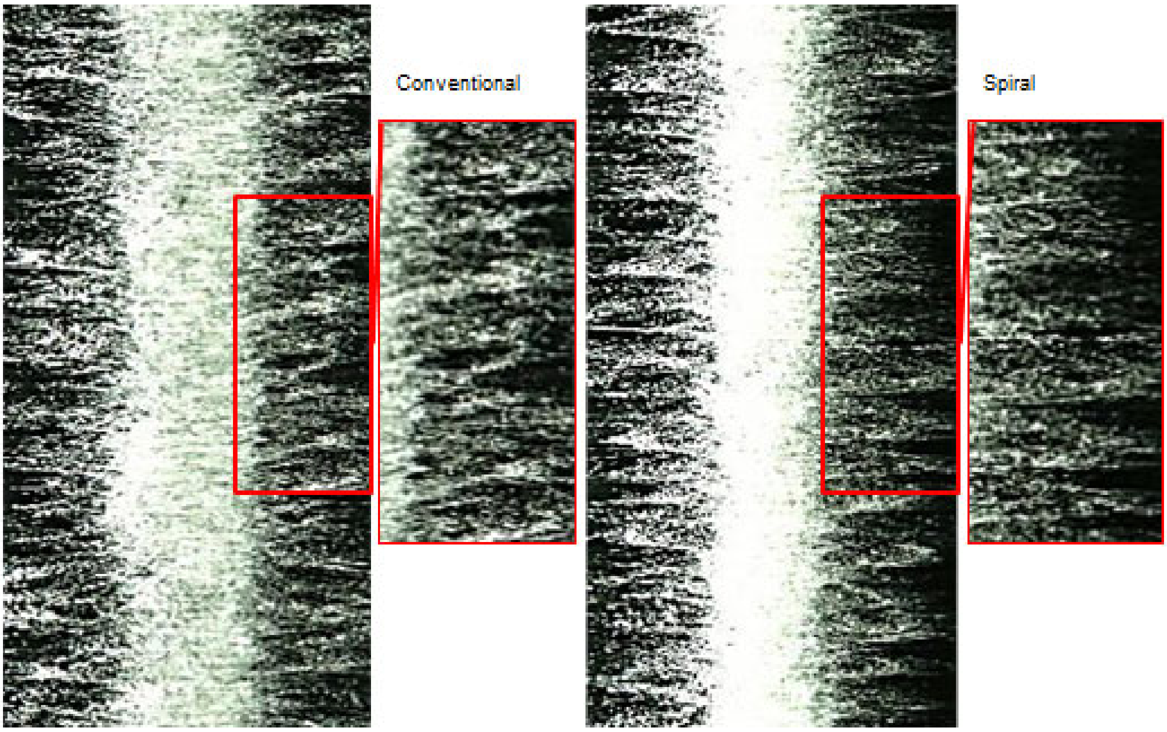


Figure 115 Detailed view of a conventional (left) and spiral (right) drafted fibre motion

In theory, the spiral canal of the condenser changes the cross-section of the flattened sliver by 90° to reintegrate the edge fibres into the fibre flow and increase the fibre-fibre friction to compact the sliver through the high-speed drafting process. The image of the fibre motion shows clearly higher fibre integration of the sliver core which confirms the theory of higher compaction with the spiral condenser.

Using the pixel analysis method with the help of the high-speed video software, the influence of the spiral condenser is analysed furthermore. It shows a slight increase of the compaction rate of 4 % with the spiral condenser, compared to the compaction rate with a conventional condensed fibre bundle (figure 116). Since the sliver core has a higher compaction with the spiral condenser, the translation of the fibres into white pixels might result in a lower compaction rate without showing the actual reduction of the misaligned fibres at this point. Nevertheless, the analysis shows overall an increase of the compaction rate, including the deviation data.

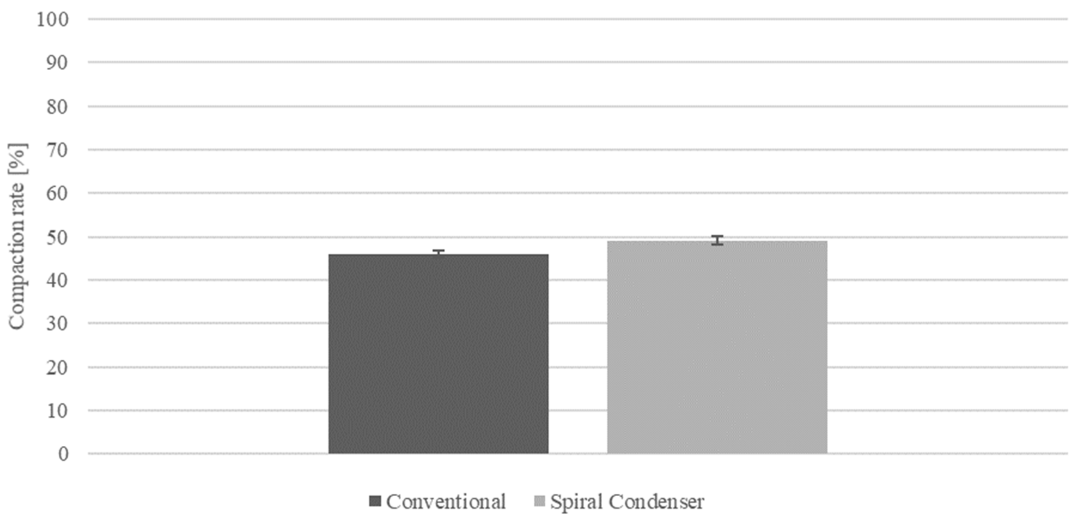


Figure 116 Diagram of compaction rate using a conventional or a spiral condenser

6.1.3 Influence of production speed

Since increasing the production speed results in a simultaneously increase of the surface speed of the rollers pairs of the drafting system, the problem of misaligned edge fibres increases, too. This effect is observable by analysing the fibre motion at the main draft zone of a conventional drafting system as well as the fibre motion at the main draft zone of an integrated false twist drafting system. Therefore, the compaction rate is used to compare differences of the fibre motion at different production speeds.

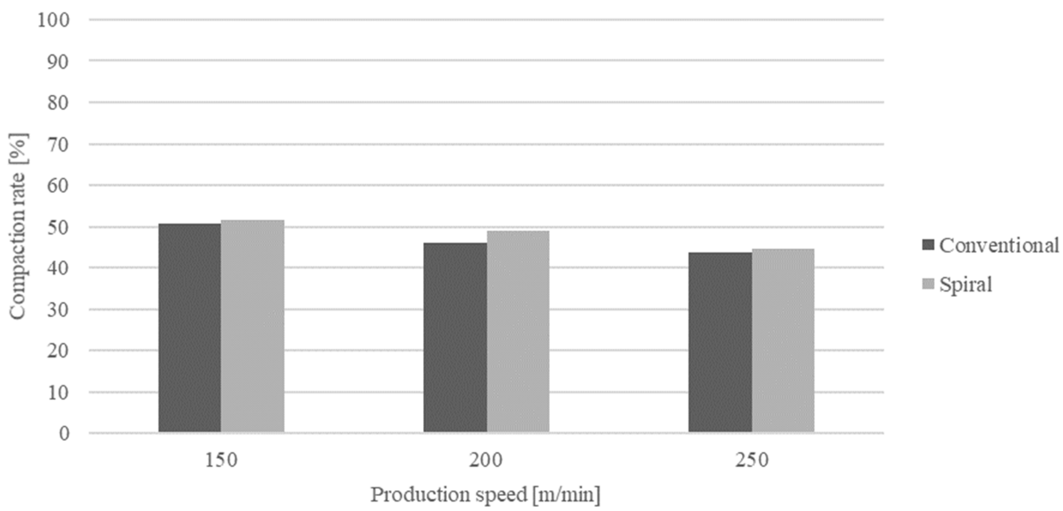


Figure 117 Diagram of the compaction rate regarding a conventional or a spiral condenser at different production speeds

The diagram in figure 117 shows the results of the analysed compaction rate at the main draft zone by increasing production speed. The increase of fibre motion, plotted as decrease of the compaction rate, is observable with a conventional condenser as well as with a spiral condenser. The significant difference is the general compaction rate. It shows that at all tested production speeds, the use of the spiral condenser increases the compaction rate by reducing the fibre motion at the main draft zone (also seen in table 41 with examples of fibre motion images). This reduction indicates a higher compaction of fibres through the drafting system which is the key for higher spinning stability and yarn quality.

Table 41 Examples of conventional and spiral drafted fibre motion images at different delivery speeds

		150 m/min	200 m/min	250 m/min
3 seconds of fibre motion at the main draft zone	Conventional			
	Spiral			

6.1.4 Analysis of the yarn quality

The pixel analysis of the fibre motion in the main draft zone in chapter 6.1.2 indicates higher yarn quality by using the spiral condenser in the drafting system. The figures 118 and 119 show the comparison between yarns spun with a conventional condenser and a spiral condenser.

In the first diagram, the development of the yarn unevenness in CV%-value is observable. The diagram contents data of the compaction rate as bars and data of the yarn unevenness as lines at increasing production speeds. The lines show that the development of the yarn unevenness is equivalent to the results of the fibre motion with the compaction rate.

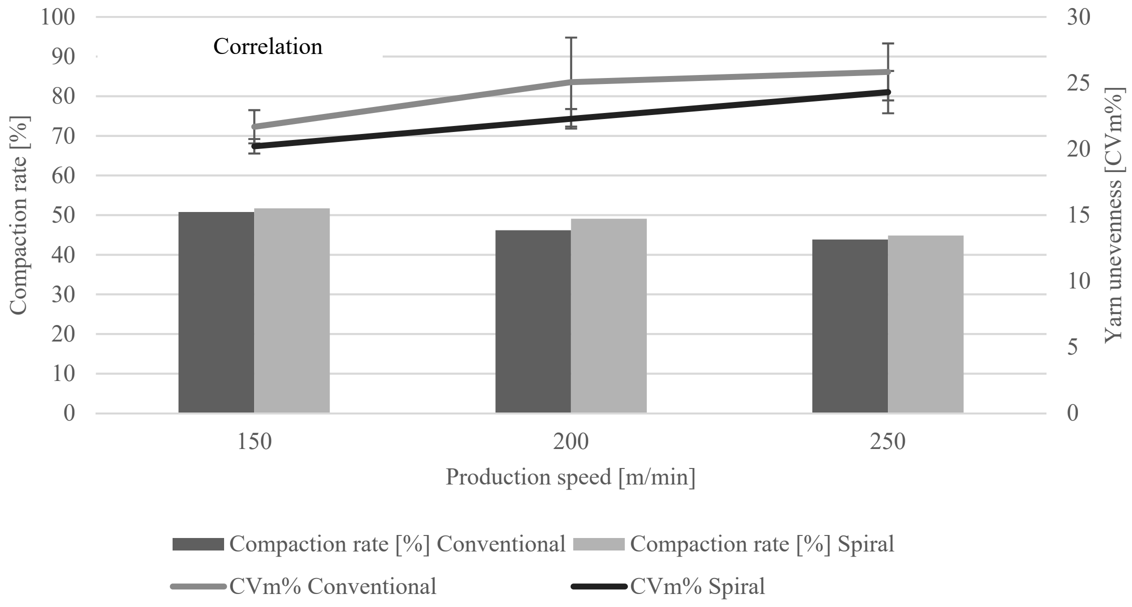


Figure 118 Diagram of the yarn unevenness regarding to the delivery speed using the spiral condenser

Firstly, the CV%-value of the yarns spun with the spiral condenser is lower than the yarns spun with the conventional condenser. This positive effect can be seen at all three tested production speeds 150, 200 and 250 m/min. The CV%-values decrease between 1 to 3 % by using the spiral condenser. The reduction of the CV%-values is an important indicator for higher the yarn quality. The deviation of the CV%-values, presented as error bars, reveal that the data is not statically secured, but all trials have shown the positive effect of using the spiral condenser.

Secondly, the diagram shows that the compaction rate is an adequate analysis method for this study which helps to predict the resulting yarn evenness without spinning thousands of meter yarn. There is a direct relation observable between the fibre motion of the main draft zone and its impact on the yarn unevenness.

The second diagram of the yarn quality presents the IPI-values like thin places [-50%], thick places [+50%] and neps [+200%] at increasing production speed. The positive impact of the spiral condenser is similar for the IPI's like for the CV%-value. At almost every tested production speed, the results of the yarn spun with the spiral condenser have lower IPI-values than the ones spun with a conventional condenser. Specifically, the number of thin places decreases by using the spiral condenser. It is only the number of neps at the production speed of 150 m/min being slightly higher. Still, the deviation values show a similar wide range of values like the CV% results.

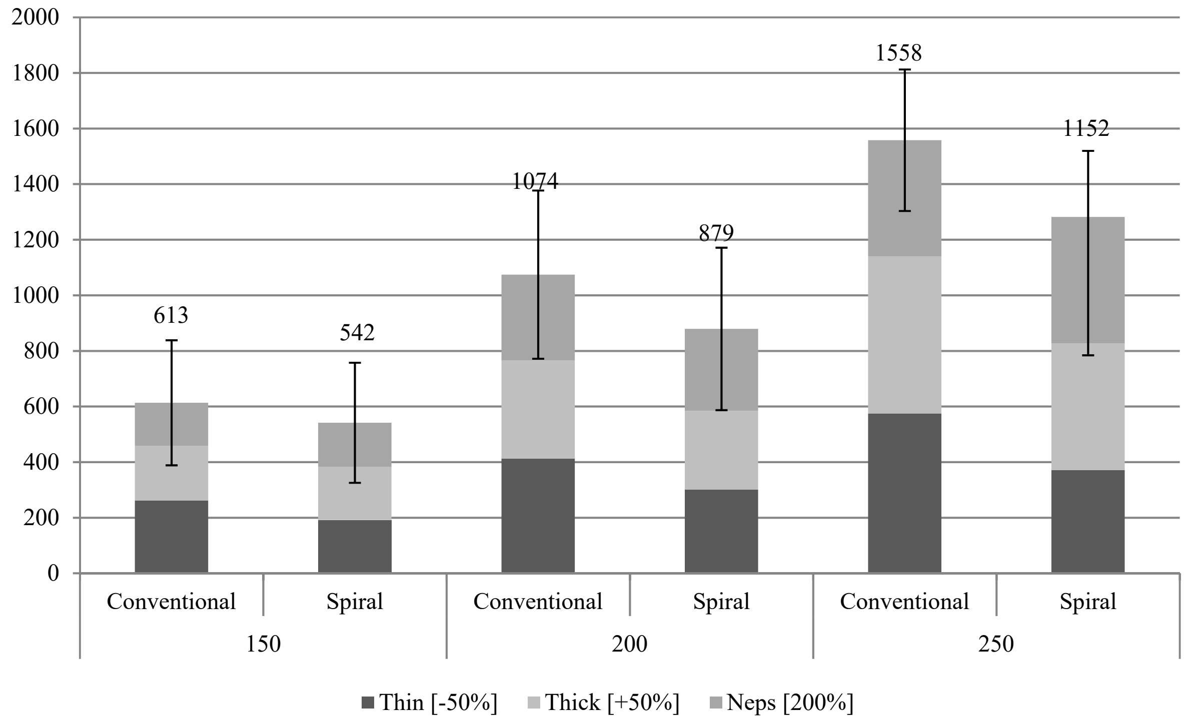


Figure 119 Diagram of sum IPI's of conventional and spiral drafted yarn at different delivery speeds

6.1.5 Summary and evaluation of the use of a spiral condenser in air jet spinning

The spiral condenser provokes a spatial deformation of the fibre bundle at the middle draft zone during the drafting process. This spatial deformation equals to a quarter rotation to insert false twist. This quarter rotation results by a 90° direction change of the inner channel of the condenser, that forces the edge fibres of the fibre bundle into the core of the fibre bundle.

This effect is presented in a simplified model of a drafting system where two different coloured single fibre strands pass the spiral condenser. The visualization of two parallel laying fibre strands at the entry of the condenser and the effect after passing the spiral condenser in a compacted way shows the spatial deformation on first sight. The reduction of the overall fibre strand width is reduced from 6.71 mm to 4.90 mm.

The confirmation of the compaction effect takes place at a spinning unit of an air jet spinning machine. The spiral condenser is placed at the middle draft zone, just before the double apron roller pair. The drafted fibre bundle enters the spiral condenser in a conventional way and leaves the spiral condenser with a slight spatial deformation where the edge fibres are integrated into the core of the sliver bundle during the drafting and spinning process. The compaction of the fibre bundle is transmitted further through the controlled double apron roller area until the delivery roller pair, where the fibres leave the drafting system by entering the spinning nozzle. The resulting fibre motion in the main draft zone was analysed by the developed high speed video analysis method. The comparison of the image curves of a conventional drafted fibre bundle and a spiral drafted fibre bundle confirms the effect of higher compaction with the spiral condenser. Further analysis using the compaction rate shows an increase of the compaction rate of 4 % with the use of the spiral condenser. This promising result was investigated further with experimental spinning trials with different production speeds. As a result, the positive impact of the increase of the compaction rate with the spiral condenser could be correlate to the resulting yarn quality in yarn unevenness.

It can be concluded that the analysis of the incorporation of the spiral condenser into the drafting system of an air jet spinning machine shows promising results regarding fibre motion control, improvements in the yarn quality and practicability.

Firstly, the use of the spiral causes a geometrical change of the fibre feed which results in higher fibre-fibre friction. This leads to a decrease of misaligned fibres in the main draft zone. The analysis of the compaction rate via high-speed camera analysis shows the positive impact of the spiral condenser for the fibre motion the main draft zone.

Secondly, higher compaction of the fibre bundle through the drafting system leads to better yarn evenness. The yarn quality parameter CVm% and IPI's show all improvements using the spiral condenser in comparison with a conventional condenser. However, it needs to be taken into consideration that the deviation values of the yarn parameters of a conventional condenser and of the spiral condenser do still overlap. An improvement of the smoothness of the inner surface of the condenser might be a solution to reach higher impact.

Thirdly, the incorporation of the spiral condenser is easy to handle. Standard mounting for condensers is already known in the drafting system and no extra tools, energy or process control systems are needed. Th effect of the spiral geometry might be even adjustable regarding the delivered sliver material by using a combination of ceramic, plastic or metal parts and arrange them like a part-in-part-change system for higher flexibility.

In conclusion, the implementation of the spiral condenser in a drafting system of an air jet spinning machine is a simple tool with a positive impact on the yarn quality. The position for a conventional condenser is already embedded in the drafting system and can be used for the spiral condenser without changing the holding rod that the condenser can be used just like any other known spare part.

6.2 The fibre motion in the drafting system of roving frame

6.2.1 Spiral condenser for roving production

The shape of the spiral condenser for the drafting system of the roving frame machine adapts the idea of the spiral canal for air jet spinning and combines it with the regular outer shape of a roving frame condenser. The spiral shaped canal causes the drafted sliver to change its cross-section from horizontal laying ribbon into vertical laying ribbon.

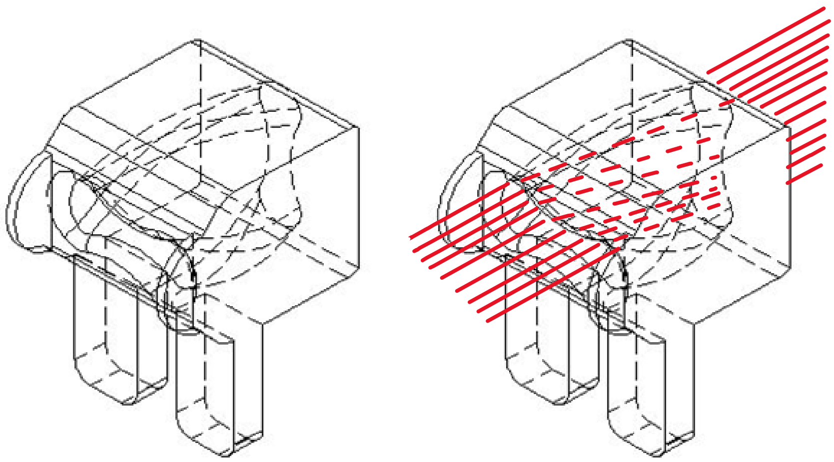


Figure 120 Technical drawing of spiral condenser for roving drafting

The outer shape of the spiral condenser is similar to the conventional condenser and is positioned at the same spot in the drafting system. The funnel shaped condensers are positioned at the pre-draft zone just before the double apron system and the main draft zone. The narrowing funnel helps to reach as close as possible the nip point of the two aprons for better control of the fibres.

For a better presentation of this effect, the figures 121 and 122 show the drafted sliver at the drafting system of the roving machine after running. The pressure arm is opened to demonstrate the fibre flow of the sliver and spatial deformation of 90° by using the spiral condenser in comparison to the conventional condenser.

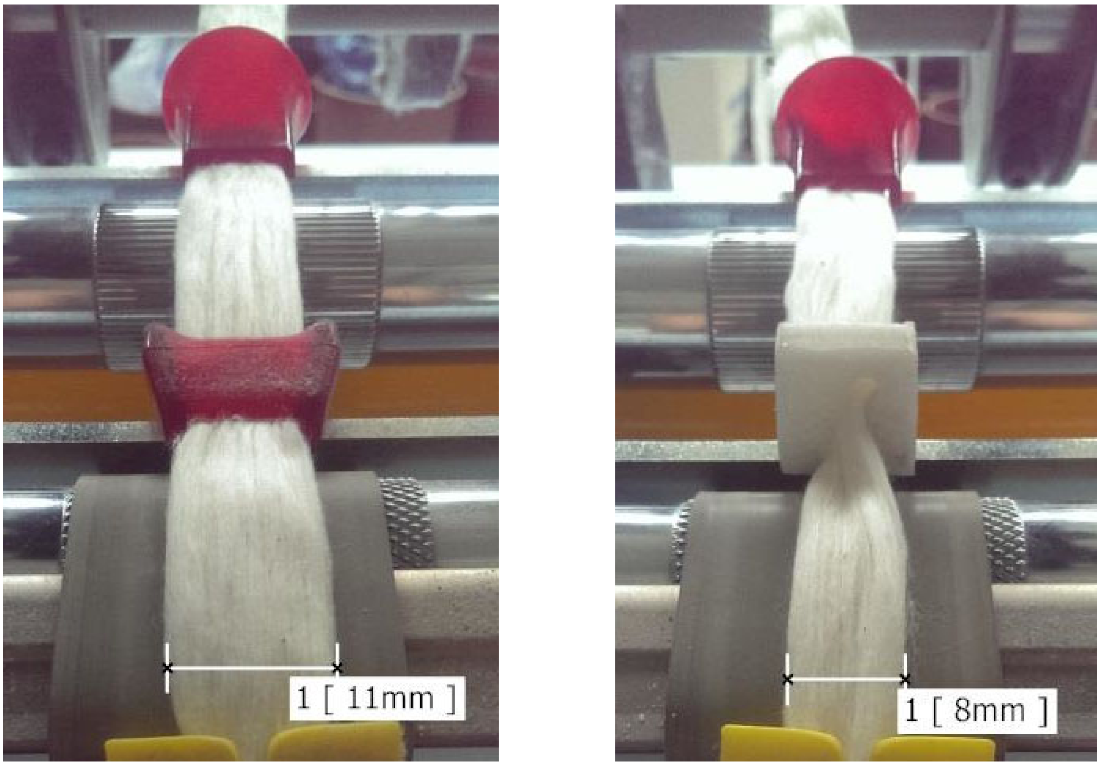


Figure 121 Pictures of spatial sliver deformation through conventional (left) and spiral (right) condensers

The impact of the spiral condenser in the drafting system of a roving machine is tested by analysing the spinning triangle in width and length and the resulting tread of the fibre bundle between the aprons. As a quality factor, the unevenness in CV% of the rovings is tested. Moreover, the resulting yarn quality of the produced rovings is analysed in yarn unevenness CV% and IPI values to demonstrate the consistent effect of the spiral condenser in the following production step of ring spinning.

Figure 122 Pictures of conventional (left) and spiral (right) condenser integration

The pixel analysis with high-speed videos is not used at this point, because of the absence of a clear shot for the camera at the main draft zone. In roving frame machines, a flying condenser is positioned exactly at the main draft zone where the pixel analysis usually takes place. For that reason, the measurement of the spinning triangle in combination with the resulting tread at the apron surface is used to gain measureable data for the impact of the spiral condenser.

6.2.2 The spinning triangle

The measurement of the spinning triangle is used for the analysis of the impact of the spiral condenser for the fibre motion at the drafting system. The figure 123 shows visually a direct comparison of the spinning triangles on a running drafting system. On the left roving, the spiral condenser is placed at the drafting system. On the right-hand side, a conventional condenser is used. The geometries of the spinning triangles differ from each other in width and length.

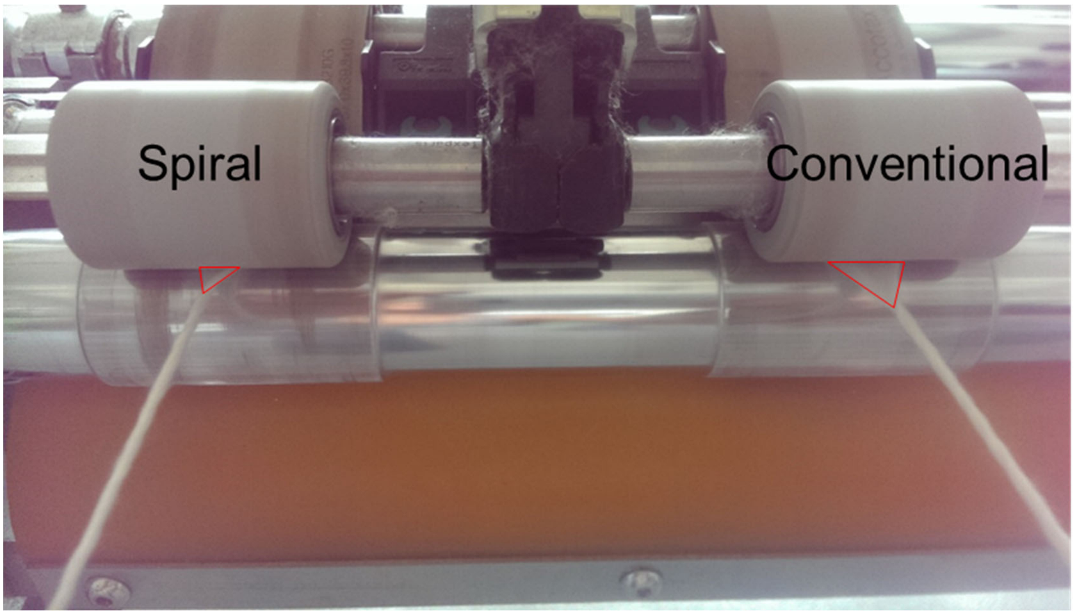


Figure 123 Picture of spinning triangles of conventional and spiral drafted

The figure 124 displays measurements of the spinning triangle geometries. The comparison between the spinning triangle produced by the spiral condenser and the conventional condenser clearly shows the impact of the spatial deformation on the drafted sliver with the spiral condenser.

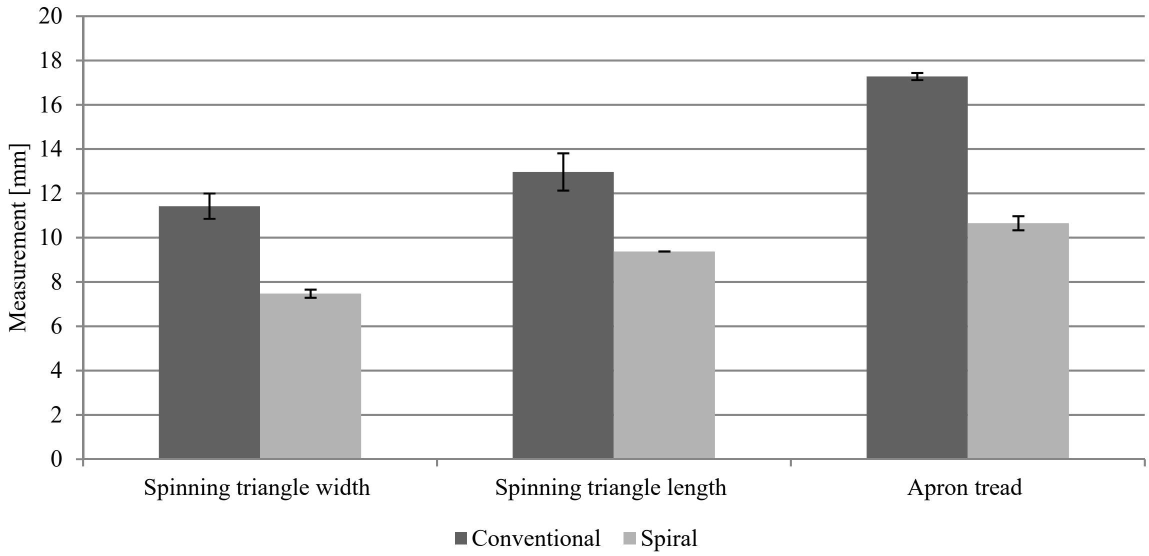


Figure 124 Diagram of spinning triangle qualities of conventional and spiral drafted roving

The measured data of the spinning triangle geometries clearly demonstrates the reduction of the fibre motion in the drafting system by using the spiral condenser in spinning triangle width, length and resulting tread width between the aprons. The measurements show a decrease of 34 % in spinning triangle width, 28 % in spinning triangle length and 38 % in the tread width. This measured data indicates the enormous impact of the spiral condenser for the fibre motion of a roving drafting system. The next chapter presents the roving quality in unevenness CV% in order to analyse the significance of this effect.

Nevertheless, the roving is just the pre-step of the actual ring spinning process. In order to analyse the consistency of the effect of the spiral condenser in a roving frame, the produced rovings must be tested at a ring spinning machine. The following diagram displays measurements of the tread width between the aprons of the roving frame and of the ring spinning machine. The previous difference of the tread width at the roving frame decreases at the next production step of ring spinning, but the effect is still observable.

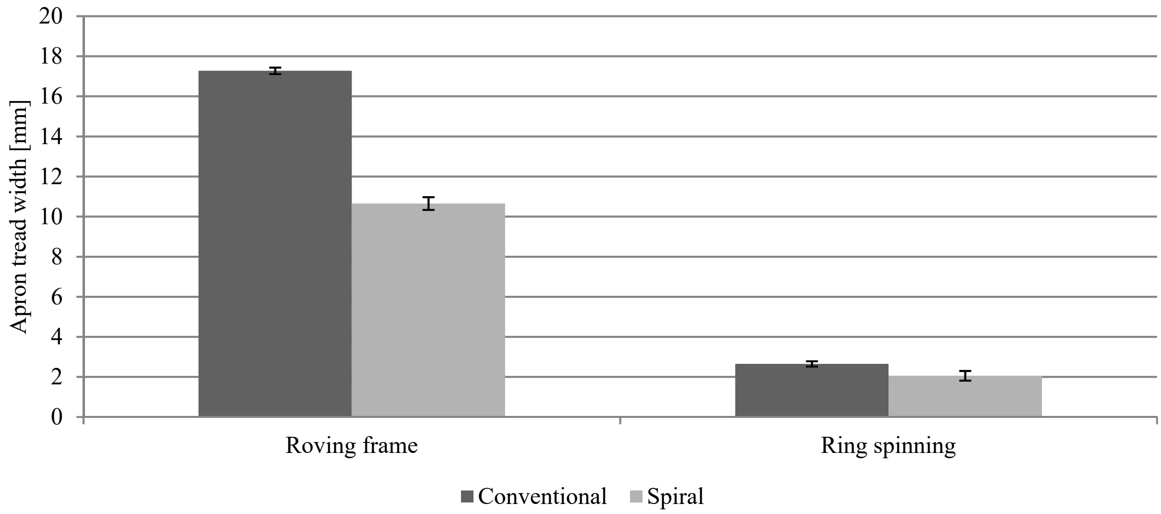


Figure 125 Diagram of impact of spiral based roving for ring spinning regarding the apron tread

This decrease of the effect at the drafting system of the ring spinning machine can have several reasons.

Firstly, the impact of the spiral condenser for the roving is not high enough to get transported further until the yarn production step.

Secondly, the position of inserting the spatial deformation with the spiral condenser is too early to uphold the effect at the following production step of ring spinning. The insertion might have a higher impact at the ring spinning machine itself.

Thirdly, and this is a combination of the two other reasons, the drafting of the roving at the ring spinning machine lets the effect decrease. Focusing on the influence of the spiral condenser for the roving itself, it shows still potential for a higher production rate by reducing the necessary twist. The possible reduction of the twist can result in higher spinning stability and less fibre fly during the roving process.

Since the draft in a ring spinning machine can be up to 80-fold, the position of fibres in the roving change rapidly during the drafting process. Any improvement like reintegration of edge fibres into the roving might vanish since the fibre bundle gets drafted again and the misalignment of edge fibres reoccurs. Nevertheless, there is a slight reduction of the tread width detectable at the aprons using the roving produced with the spiral condenser. The following chapter investigates if this slight improvement is significant enough to affect the yarn quality.

6.2.3 Analysis of the roving evenness and its impact for the yarn quality

Using the measurements of the tread width in a direct comparison with the resulting roving unevenness, the positive effect of the spiral condenser is observable. The 38 % reduction of the tread width at the aprons results in a reduction of the roving unevenness of 0.94 CV%. This improvement of the roving unevenness is a relative reduction of 19 % by using the spiral condenser at the drafting system of a roving frame. The method of fibre motion analysis using the tread width indicates a relation to the resulting roving quality improvement of 50 %. Several settings at the roving frame have been tested. All trials verify the positive effect of the spiral condenser on the resulting roving unevenness [CVm%], shown in the figure 126.

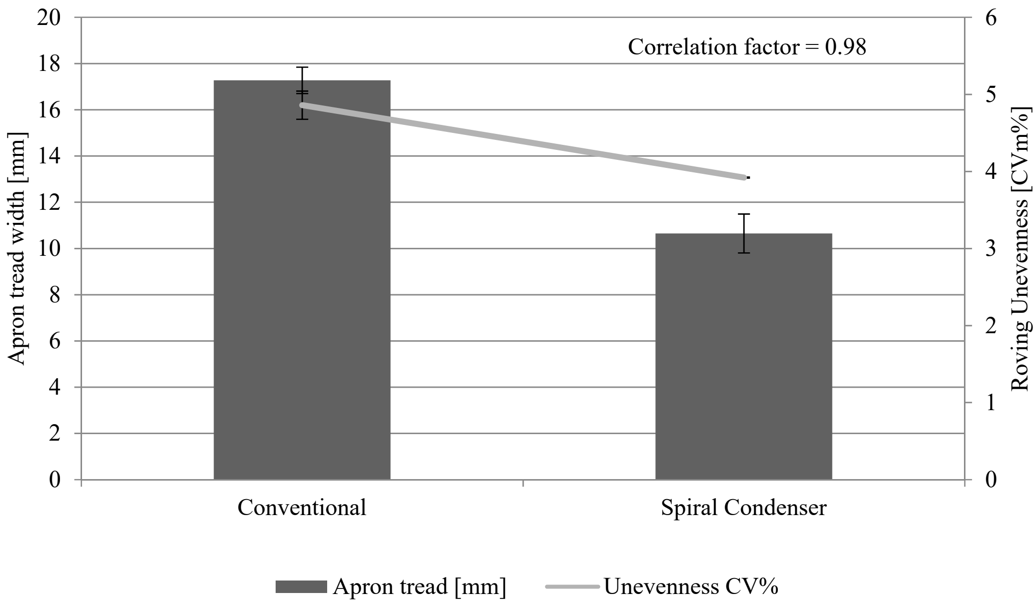


Figure 126 Diagram of the impact of the spiral based roving for the ring yarn quality

The previous chapter demonstrated that this positive effect for the roving is not necessarily reoccurring at the next production step of ring spinning. Therefore, the next diagrams present the spinning stability and the resulting yarn quality of using rovings produced by the spiral condenser in comparison with conventional ones. In this case, the ring spinning machine is set with different drafting parameters like relation of pre-draft to main draft and different spinning parts like distance clips and traveler weights. The aim of those adjustments is to uphold the positive effect of the spiral based roving at the ring spinning machine and consequently in the yarn.

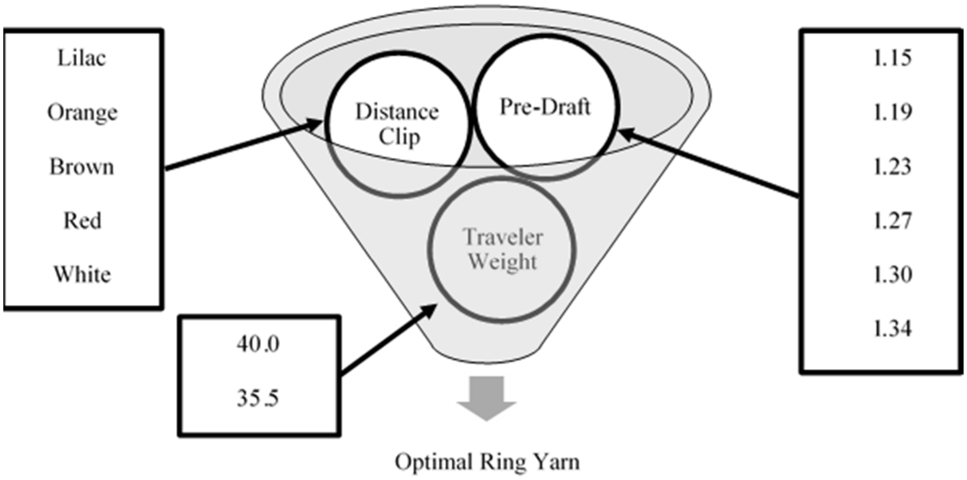


Figure 127 Visualisation of ring spinning settings

The scheme in figure 127 represents the different tested ring spinning parameters. As a result, the combination of a pre-draft of 1.3-fold, the orange distance clip which displays 3.2 mm and a traveler of 35.3 is the setting of choice.

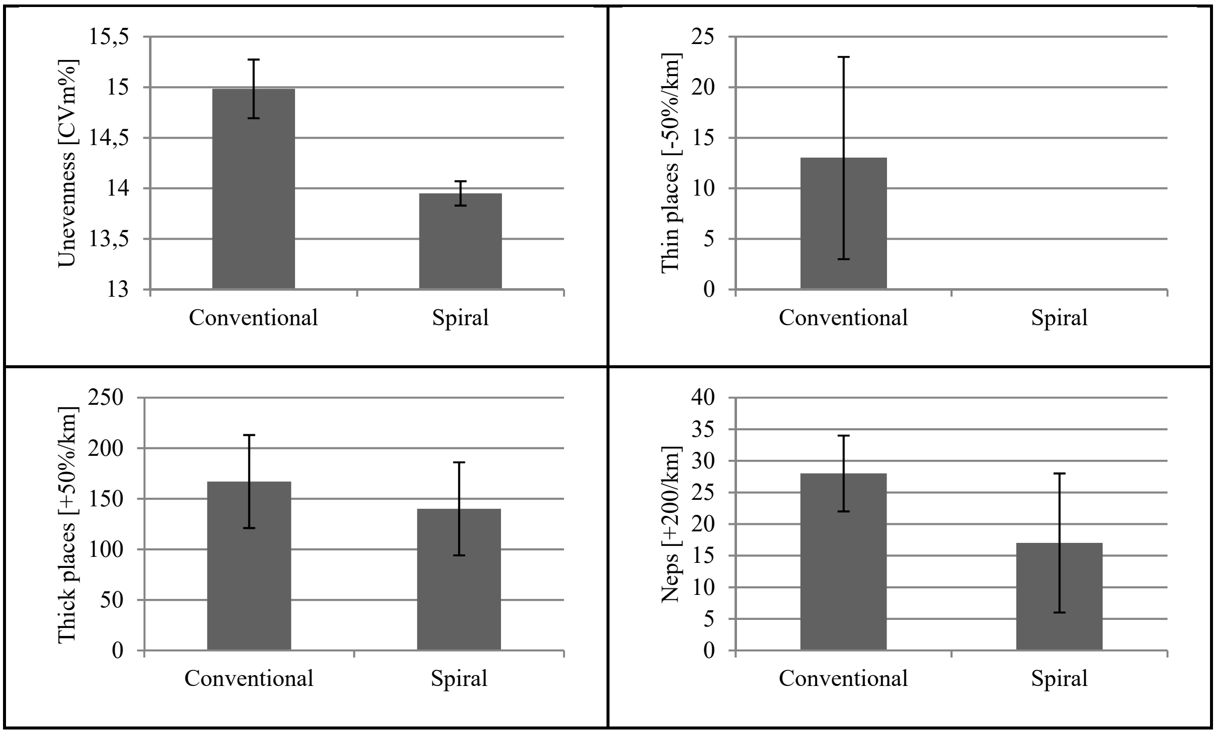


Figure 128 Diagrams of the ring yarn qualities spun with conventional and spiral based rovings

Each yarn quality parameter demonstrates the positive effect of using a spiral condenser in the pre-step of roving production. That means the effect of the spiral condenser in the roving process continues at the next production step of ring spinning. The improvements of the ring yarn quality confirm the effectiveness of the spiral condenser for the roving.

6.2.4 Summary and evaluation of the use of a spiral condenser in roving frame

It was already summarized in chapter 6.1.5 that the spiral condenser provokes a spatial deformation of the fibre bundle at the middle draft zone during the drafting process. This spatial deformation equals to a quarter rotation to insert false twist and it can be transferred to a drafting system of a roving frame machine. For this purpose, an adaption of the developed spiral condenser for air jet spinning was made for the drafting system of a roving frame machine. Therefore, the quarter rotation results again by a 90° direction change of the adapted inner channel of the condenser, that forces the edge fibres of the fibre bundle into the core of the fibre bundle.

This effect is visualized and examined with several measurement methods at the roving frame. The measurement of the spinning triangle in combination with the resulting tread width at the top apron surface is used to gain measureable data for the impact of the spiral condenser. The results of measurements in comparison to a conventional drafting system of a roving frame machine are tremendous. The measurements show a decrease of 34 % in spinning triangle width, 28 % in spinning triangle length and 38 % in the tread width. This measured data indicates the enormous impact of the spiral condenser for the fibre motion of a roving drafting system. Considering this effect for the roving unevenness CVm% value, the improvement shows a relative reduction of 19 % by using the spiral condenser at the drafting system of a roving frame.

The analysis of the incorporation of the spiral condenser into the drafting system of roving frame machine reveals a highly positive impact for the roving spinning triangle by reducing it. This indicates higher integration of edge fibres through the main draft zone of the roving machine. By the reduction of the spinning triangle another positive effect is visible. The roving process with a spiral condenser shows a reduction of fibre fly. In conclusion, the use of the spiral condenser can lead to higher productivity. It is possible to reduce the twist insertion which allows higher production speeds [Lord, 2003, p.173].

The positive effect on the roving, continues in the quality of the ring yarn. It shows improvements in the yarn unevenness and the IPI values. Nevertheless, the settings of the drafting system and of the spinning parts of the ring spinning machine must be adjusted for an optimal result. This individual setting can be explained by the different fibre to fibre friction of the spiral drafted roving compared to a conventional drafted roving. Here, a combination of higher pre-draft, higher traveler weight and smaller distance clip than usual shows the highest impact for the continuation of the positive effect from the roving.

In summary, the implementation of the spiral condenser in a roving frame machine is a simple tool with a highly positive impact on the roving and on the resulting ring yarn quality. The position for a conventional condenser is already embedded in the drafting system and can be used for the spiral condenser without changing the holding rod.

6.2.5 Analysis of knitted fabrics

The previous chapters analysed the impact of a spiral shaped condenser in a drafting system of an air spinning machine and on a roving frame machine. This chapter presents the fabric quality, explained like in chapter 4.6.4 regarding haptic and pilling behaviour. For the fabric analysis, yarn from conventional drafted air spun yarn and conventional drafted roving spun ring yarn are compared to spiral condensed drafted air spun and spiral condensed roving spun ring yarn. The exemplary applications for the knitted fabrics are produced by a small diameter circular knitting machine for single face fabrics with rotating cam, manufactured by Krenzler GmbH & Co. KG.

The fabrics analysis confirms the positive impact of a spiral condenser during the drafting process for both spinning technologies.

Firstly, the results of the pilling behaviour, tested with Martindale, are presented. Table 42 provides an overview of the rating after several tours. There are two significant findings. The fabric of spiral drafted ring yarn clearly shows an improvement in pilling resistance since the value after 125 tours is 1 to 2 grades higher than the pilling resistance of the fabric with conventional drafted ring spun yarn. Furthermore, this positive effect continues at 500, 1000 and 2000 tours. The pilling resistance of fabrics with air jet spun yarn shows higher grades in general. In this case, the improvement of the spiral drafted air jet spun yarn is observable by 1 grade.

Table 42 Results of Martindale test for fabrics made of ring and air jet yarn

	after 125 tours	after 500 tours	after 1000 tours	after 2000 tours
Conventional drafted ring yarn	2 to 3	2 to 3	2 to 3	2
Spiral drafted ring yarn	4	3 to 4	3 to 4	4
Conventional drafted airjet yarn	4	3	3	4
Spiral drafted airjet yarn	4	4 to 5	4 to 5	5

Secondly, the results of the PHV survey are presented. Exemplary, only the fabrics made of ring yarn, conventional drafted and spiral drafted, is evaluated. The reason for using this example is that fabrics made of different spinning technologies have in general different haptics because of their specific yarn structure. Avoiding influencing the survey members, only the fabrics from the exact same spinning technology were compared and evaluated. This results in two separate surveys, from which the results are presented in figure 129 and 130.

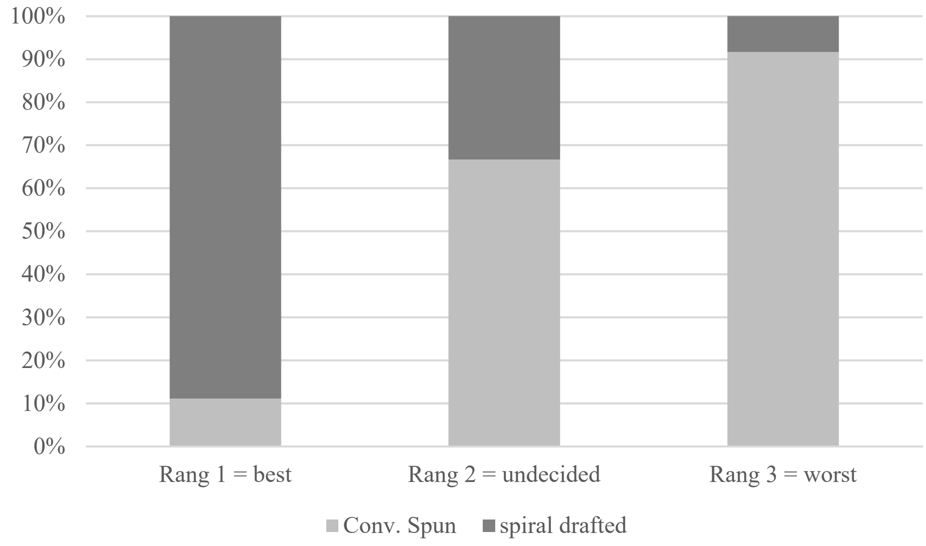


Figure 129 Evaluation of fabric haptic (PHV method) made of conventional spun ring yarns and spiral drafted spun ring yarns

The diagram in figure 129 shows the relative distribution of the PHV survey with regards to the fabric haptic. The results of the survey provide significant evidence for the fact that the fabric made of spiral drafted ring spun yarn is evaluated better than the conventional drafted ring spun yarn.

The results of the evaluation of the fabric haptic from conventional drafted air jet spun yarn and spiral drafted air spun yarn are not that significant to the same extent. In general, the survey members evaluated the fabric haptic, regardless of the spiral drafted or conventional drafted yarn, as good.

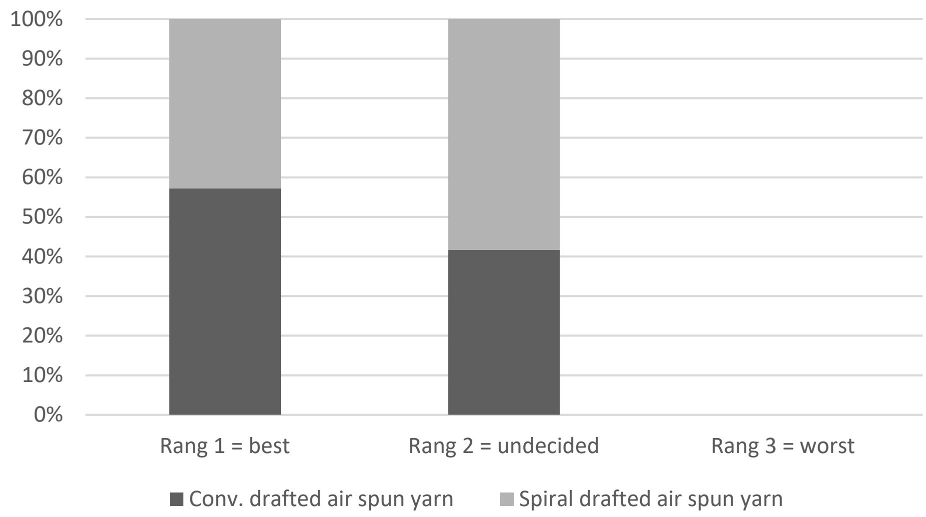


Figure 130 Evaluation of fabric haptic (PHV method) made of conventional spun air jet yarns and spiral drafted air jet yarns

7. Conclusion

Air jet spinning works with the highest delivery speeds of all established short staple spinning technologies. This challenges the drafting process where the delivered sliver material must reach its final number of fibres in cross-section for the yarn, just before entering the spinning nozzle. In general, the air jet yarn evenness is related to the quality of the pre-processing steps like carding and draw frame settings and the drafting process of the air jet spinning machine itself. Particularly, the quality of the high speed drafting process in air jet spinning influences the yarn quality, due to the fact that the position of fibres entering the spinning nozzle for the yarn formation is directly decided by the regularity of the previous drafting step.

The challenge of the high speed drafting stays in the control of the fibre motion during the drafting process. The high drafts are the result of high surface velocities of the drafting roller pairs, especially of the deliver roller pair, where the delivery speed is equal to the final spinning production speed. The high surface velocities of the delivery drafting roller pair cause air turbulences at the main draft zone which provoke a misalignment of fibres.

The PhD-Thesis has presented two different mechanic tools to improve the control of the fibre motion through the challenging main draft zone. The tools are based on the false twist principle, which is already well known in other spinning processes to improve spinning stability or to influence the yarn surface.

Several analysis methods were developed and used to gain knowledge of the impact of the two different false twist integration tools for the fibre motion in the drafting system of an air jet spinning machine. For this purpose, a high speed video analysis was used and adapted for the case of observing the false twist integration procedure itself and for the impact it creates for the fibre motion at the main draft zone of the drafting system. A theoretical model for the simulation of the impact of the false twist for the fibre motion was established by the use of a process control system.

The first tool for false twist integration is a dynamic rotational device, which provokes alternating false twist at the drafted fibre bundle before entering the double apron rollers. The false twist signal can be set at different alternating rotations by frequency in Hertz and number of rotations per period using. The interaction and influence of the combination of the two parameters were visualized by a high speed video analysis method – the motion curve.

As a result, the motion curves could be categorized by their appearance of regularity. Therefore, three main categories of the dynamic false twist motion curves were defined as:

1.) most irregular curve with long stop
2.) most regular curve with short stop

3.) most regular curve without stop

Several false twist signals were analysed and clustered by these three categories to choose the most adaptable signals for the aim of controlling the fibre bundle in the most regular way during the drafting process. The effect of the false twist signal input for the resulting control of the fibre bundle motion was examined and visualized by a high speed video analysis of the main draft zone.

For this purpose, the dynamic false twist device was integrated into the middle draft zone of an air jet spinning unit in order to analyse the direct impact of the false twist signal during the spinning process and evaluate it by the fibre motion in the main draft zone and the yarn quality. The high speed video analysis uses the possibility of combining single pictures of one defined point in the video frame to create an "image curve". The image curve shows exactly the defined point over an analytical line where the fibres move through the main draft zone. Hereby, it was possible to visualize any misalignment of edge fibres during drafting and periodical mass variations over a defined time frame. The further processing of the image curve was realized by Matlab where the original-coloured image curve was transferred into a black and white image. The fibres were identified over a set threshold as white pixels and the background without fibres was identified as black pixels. Moreover, the relation between the number of black and white pixels gave the possibility to declare a rate for the level of fibre compaction in the main draft zone – the compaction rate. It was able to evaluate the false twist input signals from the set categories with the resulting compaction rates from the fibre motion in the main draft zone.

As a result, the false twist signal with 1.8 Hz and 9 rotations per period shows the highest compaction rate equal to the lowest misalignment of fibres during drafting which comes along with the category 3 from the false twist motion curves. The analysis of the resulting yarn quality as yarn unevenness confirms the aspect of high compaction rate and lowest yarn unevenness.

The process control system, created with Scilab, has been developed to simulate several false twist input signals and to predict their influence on the fibre motion output. This control system starts with a sinusoidal function as frequency signal input to simulate the alternating twists of the dynamic rotational device. A continuous fix delay function simulates the reaction time when the alternating rotation interferes with the fibre bundle in the drafting process. The drafting system itself is represented by a transfer function PT1, a gain function P and again a transfer function DT1. The visualization as a plotted graph works as the output of the control system where the shape of the output curve simulates the resulting fibre bundle motion over time. In this case, the prediction of the fibre motion output provided the possibility to cluster the influencing factors of the false twist signal for the fibre motion.

It can be summarized that the inserted frequency value at the start of the control system has the major impact for the resulting motion output. Moreover, with the developed control system, the most favourable frequency range for the experimental trials could be defined between 0.4 and 4 Hz. As a result, it was able to evaluate the simulated fibre motion by the results of the experimental trials, where the results of the image curve were produced. Hereby, the image curve was processed with the motion curve. All set categories of the false twist signal could be identified and evaluated by the comparison of the simulated motion output and the motion curve of the processed image curve of the fibre motion in the main draft zone.

The second tool for false twist integration is a spiral shaped condenser which guides the drafted fibre bundle before entering the double apron rollers and provokes a spatial deformation of the fibre bundle during the drafting process. The spatial deformation of the fibre bundle during drafting is set by a 90° geometry change by passing the condenser. In other words, the horizontal laying, almost flat, sliver bundle rotates by a quarter by passing the condenser. The quarter rotation effects the fibre bundle after leaving the condenser that the horizontal fibre bundle deforms to a more vertical shape. This represents a passive false twist integration. The edge fibres which were at the sides of the fibre bundle are shifted to the core of the sliver bundle just before entering the controlled area of the double apron rollers.

As a result, the amount of misaligned fibres at the edges of the fibre flow at the main draft zone was successfully reduced. The analysis of the impact of the spiral condenser for the fibre motion in the main draft zone was realized with the high speed video analysis and the developed compaction rate. Moreover, the produced yarns of the experimental trials confirm a reduction of the yarn unevenness by using the spiral condenser. The innovation of the spiral condenser was successfully applied as a patent.

It can be concluded that false twist insertion at the middle draft, before the double apron rollers, has a positive impact for the drafted fibre bundle and decreases the possibility of fibres getting misaligned by the air turbulences at the delivery roller pair. This decrease of fibre misalignment at the main draft zone was called compaction rate. For the investigation and evaluation of the impact of the false twist insertion tools, a measurement method based on a combination of high-speed videos, Matlab and software analysis was developed and has been successfully evaluated. The experimental trials concluded different production speeds to assure the processability in air jet spinning machines.

Both false twist insertion tools have shown their significant impact for a high-speed drafting system of an air jet spinning unit. In order to widen the application possibilities and having a comparison to another drafting system, the drafting system of an industrial roving frame machine has been selected to test both false twist insertion tools in more detail. Hereby, the measurement of the width of the drafted fibre bundle at the double apron roller and the spinning triangle of the roving was used to evaluate the impact of the false twist insertion for the compaction effect. The reduction of the spinning triangle width had a direct positive effect for the process stability of the roving frame by reducing the number of roving breaks and a decrease of the roving unevenness. Furthermore, the subsequent step of ring spinning confirms that the false twist integration into a roving can be transmitted to the quality results of the ring yarn. An evaluation of knitted fabrics from the spiral based yarns of the air jet and the ring spinning process successfully complemented the analysis of the impact of false twist integration.

False twist implementation into a drafting system can be considered as a relevant tool to improve the high-speed drafting process of air jet spinning as well as the drafting process of a roving frame.

8. Further investigation lines

Overviewing the latest patent applications, the future will hold several new competitors for Murata and Rieter. Since the launch of Autoairo by Saurer with building up new concepts of drafting in air jet spinning machines, the market of air jet spinning machines will reach a new level of innovations and shifts in market values.

During the research, the possibility occurred to test the developed prototypes at a drafting system of an industrial air jet spinning machine at 450 m/min and 100 % viscose as sliver material. The implementation and the impact of the dynamic false twist device as well as the spiral condenser was reproducible.

A possible development regarding the false twist integration is a combination of the spiral shaped condenser and a periodic motion of the condenser at the drafting system. Especially in individual driven drafting systems, the concept of implementing an additional motorized motion of the condenser would be a possibility. In this case, less effort would be needed regarding additional motors or control elements.

Developments regarding the spiral condenser itself, the possibilities are concentrated by optimizing the geometry of the spiral canal > 90° and the depth of the guidance canal. Moreover, the impact of the spiral condenser for different sliver counts and materials should be investigated. Particularly the divergent friction forces of synthetic materials in sliver blends, could give another possibility of optimizing the shape of the spiral condenser geometry and its position at the drafting system.

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ISO 19762 Frequency

ISO 12945-2 Pilling resistance

DIN ISO 16875: 2006-04 Ring spinning (2006): Textilmaschinen – Ringspinnmaschinen für das Baumwollspinnverfahren – Begriffe, Baugrundsätze

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10. Appendix

10.1 Matlab filter program for the image processing

```
>> I = imread('ImageCurve.png');                          % Upload original image curve as .png file
>> figure
>> imshow(I)
>> level = graythresh(I)                                  % Set threshold level

level =

    0.4824

>> background = imopen(I,strel('disk',15));               % Estimate background illumination
>> surf(double(background(1:8:end,1:8:end))),zlim([0 255]);
>> I2 = I-background;                                     % Substract background from original to have clean data
(>> figure
>> imshow(I2)
)
>> bw = im2bw(I2,level);                                  % Categorize pixels according to threshold to black and white
(>> figure
>>imshow(bw)
)
>> numwhitepixel = nnz(bw==1)                             % Results in no. of black and white pixels

numwhitepixel =

       43481

>> numblackpixel = nnz(bw==0)

numblackpixel =

      562963
```

10.2 Patents derived from the thesis

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(54) **DRAFTING SYSTEM UNIT AND DRAFTING SYSTEM FOR A SPINNING MACHINE**

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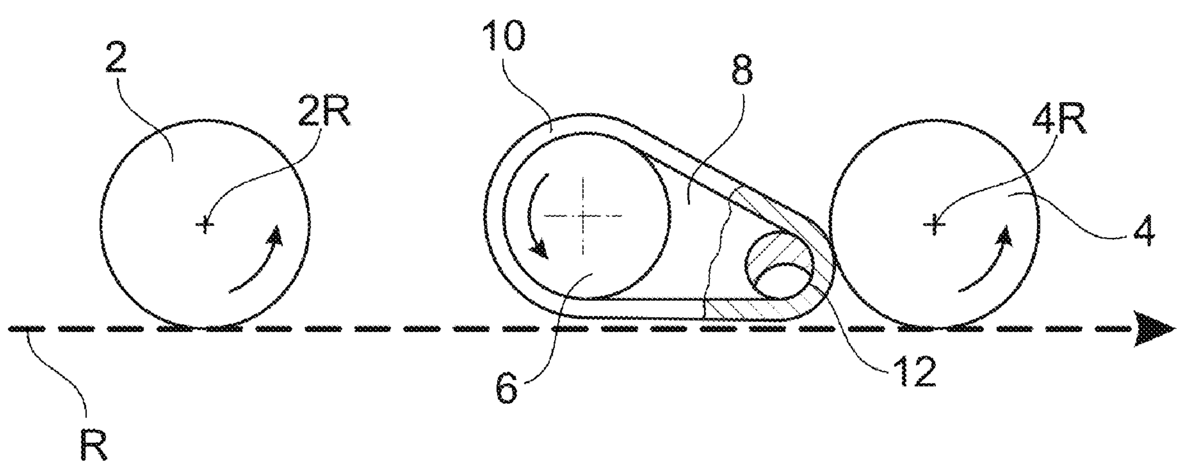
CPC ***D01H 5/565*** (2013.01)

(57) **ABSTRACT**

A drafting system unit for a drafting system of a spinning machine. In a fiber band transport direction (R), the drafting system unit has a first top roller and a second top roller spaced apart therefrom, which are provided for drafting a fiber band, transported from the first to the second top roller, in cooperation with accordingly assigned bottom rollers, the respective axes of rotation of the first and second top roller extending transversely to the fiber band transport direction. The drafting system unit is characterized in that an apron cage to which negative pressure can be applied is arranged between the first top roller and the second top roller for guiding an air-permeable apron in circulation jointly around the apron cage and an apron top roller, the apron top roller being formed by the first top roller or by a third top roller that is assigned to the apron cage and arranged on the same side as the first and second top roller in relation to the fiber band being transported. The apron cage has at least one through-opening, to which negative pressure can be applied, for applying suction air to the fiber band running between the first and second top roller, through the air-permeable apron.



Stand der Technik

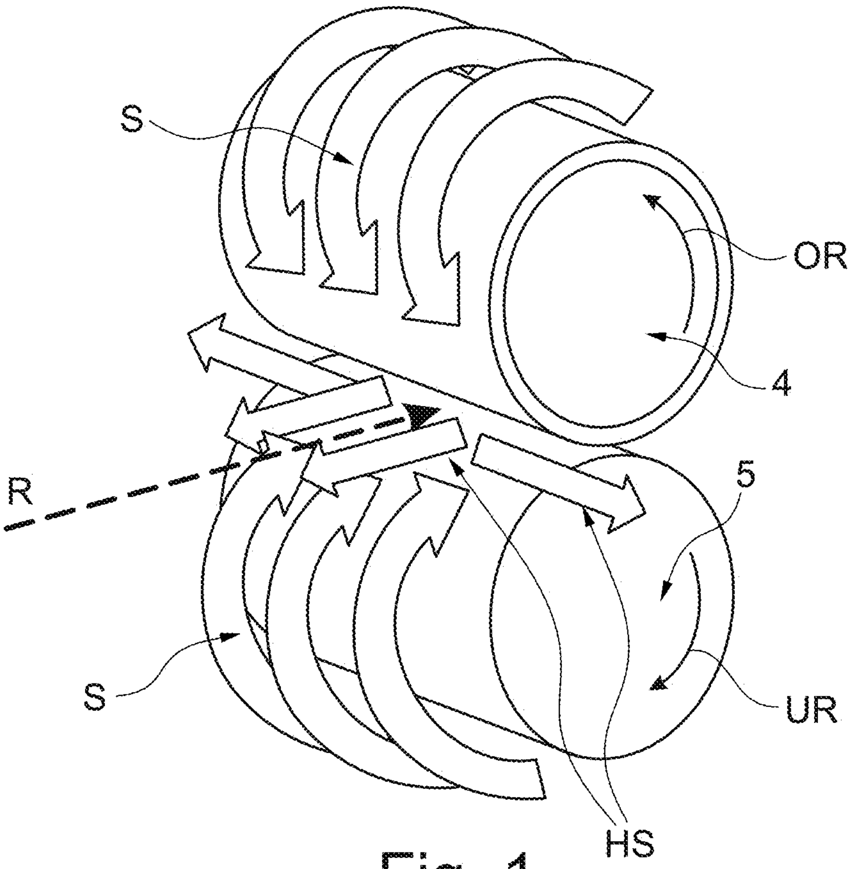


Fig. 1

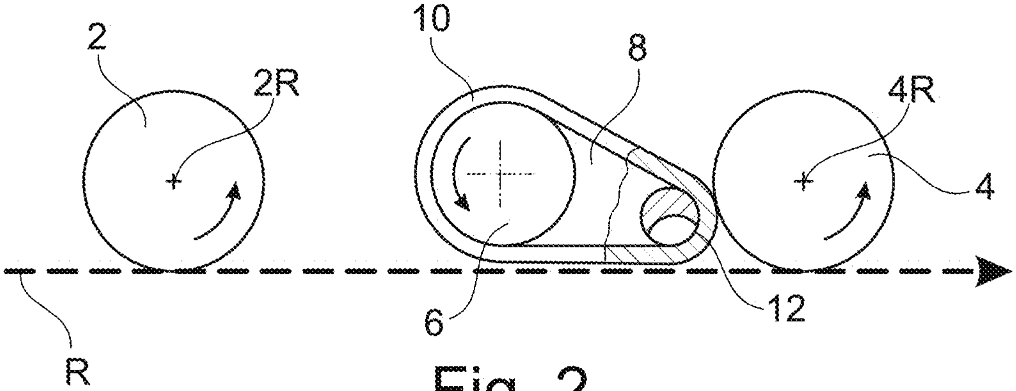


Fig. 2

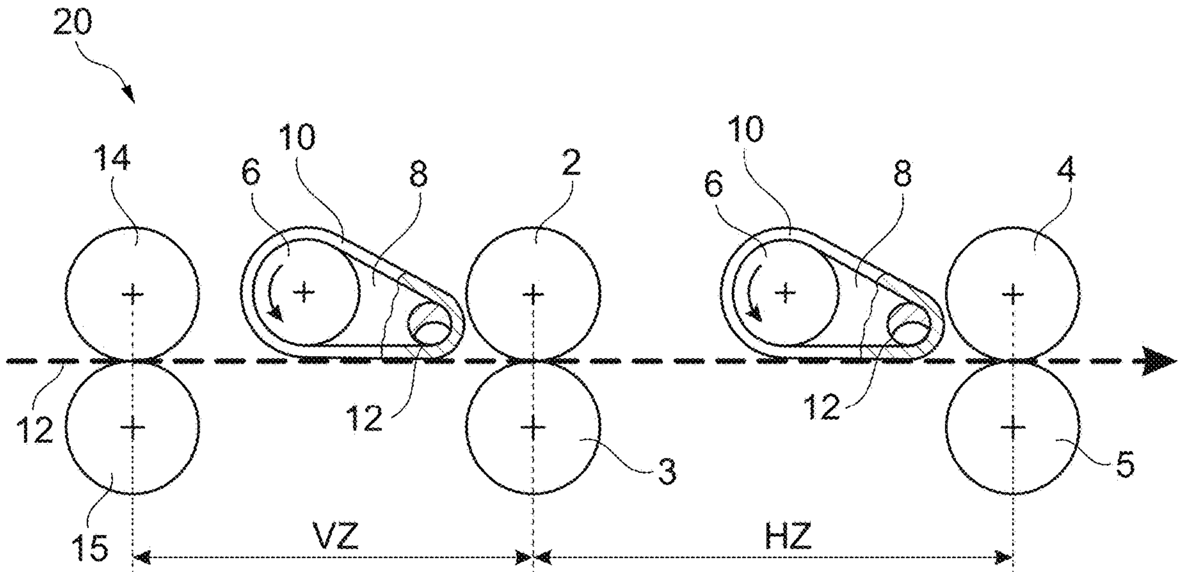


Fig. 3

DRAFTING SYSTEM UNIT AND DRAFTING SYSTEM FOR A SPINNING MACHINE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from German National Patent Application No. 10 2018 006 100.1, filed Aug. 3, 2018, entitled "Streckwerkeinheit and Streckwerk für eine Spinnmaschine", the entire contents of which are incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The invention relates to a drafting system unit for a drafting system of a spinning machine, in particular for an air spinning machine, the drafting system unit having, in a fiber band transport direction, a first top roller and a second top roller spaced apart therefrom, which are provided for drafting a fiber band, transported from the first to the second top roller, in cooperation with accordingly assigned bottom rollers, the respective axes of rotation of the first and second top roller extending transversely to the fiber band transport direction. The present invention also relates to a drafting system of this kind.

BACKGROUND OF THE INVENTION

[0003] Conventionally, in a spinning process, for example by means of a ring spinning machine or an air spinning machine having fixed production rates, a drafting system makes it possible to generate a fiber band that is drawn to a final fineness. Air spinning is a spinning process that has recently become established in addition to the known spinning processes, such as ring spinning, compression spinning and rotor spinning, and in which a yarn can be spun by the controlled use of an air flow in an air spinning unit. In spinning machines in general, the drafting system is arranged upstream of the spinning unit in the fiber transport direction, for example arranged upstream of the air spinning unit in the case of an air spinning machine. A drafting system of this kind is disclosed, for example in European Patent Publication EP 2 865 792 A1. In the case of an air spinning machine, at the drafting system end formed by an output roller pair, the drawn fiber band passes through a nozzle block of the downstream air spinning unit and arrives at an inlet opening of a hollow spinning spindle assigned to the air spinning unit. Upon entry into the spinning spindle, the free ends of the fiber band are looped around by a directed air flow circulating around a conical spindle head and in the process wind around the core fibers helically while the thread is being drawn into the spindle. Together with the "entwisting fibers" helically wound around the core fibers, the core fibers form the air-spun yarn.

[0004] Uniformity of the fiber band used to produce the yarn is essential for the quality of the yarn obtained in this manner. It is particularly important in this regard that the fibers of the fiber band are reliably arranged in parallel. The plurality of roller pairs typically arranged one behind the other in a drafting system, each consisting of a bottom roller and a top roller, are used to draft and transport the fiber band in the direction of the inlet opening of the hollow spinning spindle, the peripheral speed of the roller pairs increasing in the transport direction off the fiber band in order to obtain defined drawing. As shown schematically in FIG. **1** by way of example, in the nip region of the output roller pair, which is configured to transport the fiber band in the fiber band transport direction R by means of a top roller **4** rotatable in a direction of rotation OR and a bottom roller **5** rotatably in the opposite direction of rotation UR, the high rotational speeds of the output roller pair of the drafting system in particular generate air flows such as drag flows S and flows HS directed sideways out of the nip region. Flows S, HS of this kind may result in individual drafted fibers being deflected out of the fiber band or even being partly detached from the fiber band, thus having a negative impact on the fiber band quality and thus the yarn uniformity and the yarn quality in general. In the process, the effect of the air flows on the quality increases as the rotational speed of the output roller pair **4**, **5** increases and thus as the air flows S, HS become more pronounced.

SUMMARY OF THE INVENTION

[0005] In particular, the present invention is intended to provide a drafting system unit for a drafting system of a spinning machine, for example an air spinning machine, by means of which it is possible to minimize deflection of fibers out of the fiber band due to an air flow caused by rotation of a roller pair.

[0006] To this end, the present invention proposes a drafting system unit having, in a fiber band transport direction, a first top roller and a second top roller spaced apart therefrom, which are provided for drafting a fiber band, transported from the first to the second top roller, in cooperation with accordingly assigned bottom rollers, the respective axes of rotation of the first and second top roller extending transversely to the fiber band transport direction.

[0007] The present invention is characterized in that an apron cage to which negative pressure can be applied is arranged between the first top roller and the second top roller for guiding an air-permeable apron in circulation jointly around the apron cage and an apron top roller. In the process, the apron top roller can be formed by the first top roller or by a third top roller that is assigned to the apron cage and arranged on the same side as the first and second top roller in relation to the fiber band being transported. The apron cage has at least one through-opening, to which negative pressure can be applied, for applying suction air to the fiber band running between the first and second top roller, through the air-permeable apron.

[0008] Advantageous developments of the invention are stated herein.

[0009] By means of the proposed invention, it can be ensured in a simple manner that the fibers that otherwise come out of the fiber band in the nip region due to drag flows and/or outward flows remain in the fiber band and can be entrained together with the fiber band in the fiber band transport direction. This can ensure a particularly high-quality fiber band, improved yarn uniformity and thus the possibility to produce a better-quality yarn.

[0010] According to a preferred embodiment, in the fiber band transport direction, the through-opening is at a smaller distance from the second top roller than from the apron top roller. The arrangement close to the second top roller favors the effect of fiber cohesion in the fiber band within the nip region of the downstream roller pair.

[0011] In a further preferred configuration, the through-opening can be arranged close to or within an nip region between the top roller and the fiber band in order to directly counteract the drag flows and outward flows by means of a counterforce exerted by the application of suction air. This preferred embodiment is also advantageous for the fiber cohesion in the fiber band within the nip region.

[0012] Preferably, the through-opening is formed at an opposite end of the apron cage to the second top roller. This enables an arrangement extremely close to the second top roller.

[0013] In a further preferred embodiment, the through-opening is formed as a slot extending transversely to the fiber band transport direction. The fiber band region to which suction air can be applied can be enlarged in a direction running transversely to the fiber band transport direction, in which case even better fiber cohesion in the fiber band within the nip region can be achieved.

[0014] According to a further preferred embodiment, the apron cage can have more than one through-opening. For instance, the respective dimensions of the through-openings and their arrangement facing the fiber band can be selected and provided as required in order to ensure further improvement to the fiber cohesion in the fiber band within the nip region.

[0015] Preferably, the through-opening is arranged so as to face the fiber band between the opposite side edges thereof. As a result, a suction flow directed towards the center of the fiber band can act on the fiber band through the air-permeable apron, in which case the fiber cohesion, in particular of the edge fibers, in the fiber band within the nip region can be further improved.

[0016] The through-opening can be coupled to the apron cage either directly or indirectly. Direct coupling is provided when the through-opening is formed for example in the apron cage. Indirect coupling occurs when the through-opening is formed by a means that can be attached to the apron cage and to which negative pressure can be applied either by means of the apron cage or directly.

[0017] According to a further preferred embodiment, the second top roller forms an output top roller for the drafting system comprising the drafting system unit. The apron cage to which negative pressure can be applied is consequently arranged in a main drawing field of the drafting system. As a result, the fiber cohesion in the fiber band can be reliably ensured directly upstream of the exit of the fiber band from the drafting system and upstream of the transition, for example, into a spinning unit arranged downstream in the fiber transport direction.

[0018] Alternatively or additionally, it is conceivable that the apron cage, to which negative pressure can be applied, is arranged in a pre-drawing field upstream of the main drawing field in the fiber band transport direction in order to ensure, as early as at this point, the fiber cohesion in the fiber band within the nip region of a roller pair arranged upstream of the output roller pair in the fiber band transport direction. The preferred alternative arrangement already favors improvement to the quality of the fiber band compared with a previously known drafting system. The additional arrangement is also advantageous in that fiber cohesion in the fiber band within the nip region of each roller pair associated with the drafting system is ensured over approximately the entire length of the drafting system in the fiber band transport direction.

[0019] According to a further aspect of the present invention, a drafting system for a spinning machine, in particular an air spinning machine, is provided, having a first roller pair comprising a first top roller and a first bottom roller, and a second roller pair formed by a second top roller and a second bottom roller. The first and second roller pair are spaced apart from one another in the fiber band transport direction and are provided for drafting a fiber band transported from the first to the second roller pair. The respective axes of rotation of the first and second roller pair, i.e. the axes of rotation of the assigned bottom and top rollers, extend transversely to the fiber band transport direction.

[0020] The drafting system is characterized in that an apron cage to which negative pressure can be applied is arranged between the first roller pair and the second roller pair for guiding an air-permeable apron in circulation jointly around the apron cage and an apron top roller, the apron top roller being formed by the first top roller of the first roller pair arranged upstream, i.e. earlier, in the fiber band transport direction, or by a third top roller that is assigned to the apron cage and arranged on the same side as the first and second top roller in relation to the fiber band being transported, between said top rollers. The apron cage has at least one through-opening, to which negative pressure can be applied, for applying suction air to the fiber band running between the first roller pair and the second roller pair, through the air-permeable apron.

[0021] According to a preferred embodiment, the apron top roller, the first and second top roller, and the apron cage form a drafting system unit according to any of the embodiments described above.

[0022] By means of a drafting system of this kind, the same advantages as described above can be achieved.

[0023] According to a further aspect of the present invention, it is proposed to use a fiber band compression device, which is provided in a draft ng system for compressing a drafted fiber band passing through an output top roller of a drafting system, the fiber band compression device having an apron cage, to which negative pressure can be applied, for guiding an air-permeable apron in circulation jointly around an apron top roller and the apron cage, which has at least one through-opening to which negative pressure can be applied.

[0024] The use is characterized in that the fiber band compression device is arranged between a first roller pair and a second roller pair of the drafting system such that the apron cage guides the air-permeable apron jointly around the apron top roller and the apron cage, the apron top roller being formed by the first top roller of the first roller pair arranged upstream in the fiber transport direction, or by a third top roller that is assigned to the apron cage and arranged on the same side as the top rollers of the first and second roller pair in relation to the fiber band being transported. The through-opening is arranged so as to apply suction air to a fiber band running between the two spaced-apart roller pairs, through the air-permeable apron.

[0025] According to a preferred embodiment, the apron top roller, the first and second top roller, and the apron cage form a drafting system unit according to any of the embodiments described above.

[0026] By means of such a use of a fiber band compression device, the same advantages as described above can be achieved.

[0027] The preferred embodiments described above are particularly advantageous for an air spinning machine. However, the preferred embodiments described above can also be used in other spinning machine types, such as ring spinning machines, roving frames, compact spinning machines, Siro spinning machines and the like.

[0028] It should be understood that the detailed description and specific examples, while indicating the preferred embodiments of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] The invention will be explained in greater detail below on the basis of embodiment examples shown in the drawings.

[0030] FIG. **1** shows a schematic view of air flows occurring in a rotating roller pair according to the prior art;

[0031] FIG. **2** shows a schematic view of a drafting system unit according to a first embodiment example; and

[0032] FIG. **3** shows a schematic view of a drafting system comprising a drafting system unit shown in FIG. **1**.

[0033] In the following description of embodiment examples, the same or similar reference signs are used for the elements shown in the various figures and those having a similar action, in which case the descriptions of these elements are not repeated.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0034] The following description of the embodiments of the present invention is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses. The following description is provided herein solely by way of example for purposes of providing an enabling disclosure of the invention, but does not limit the scope or substance of the invention.

[0035] FIG. **2** is a schematic side view of a drafting system unit **1** according to one embodiment example. In a fiber band transport direction R, the drafting system unit **1** has a first top roller **2** and a second top roller **4** spaced apart therefrom. The first **2** and second **4** top roller are provided for drafting a fiber band transported from the first to the second top roller in the fiber band transport direction R, in cooperation with accordingly assigned bottom rollers **3**, **5** (FIG. **3**). The respective axes of rotation **2**R, **4**R of the two top rollers **2**, **4** extend transversely to the fiber band transport direction R. Configuring and arranging such "drafting system top rollers" is routine and would be familiar to one of ordinary skill in the art.

[0036] Between the first top roller **2** and the second top roller **4**, an apron cage **8**, to which negative pressure can be applied, is arranged for guiding an air-permeable apron **10** in circulation jointly around the apron cage **8** and an apron top roller **6**, which is formed by a third top roller **6** that is assigned to the apron cage **8** and arranged in the apron cage **8** according to this embodiment example. In relation to the fiber band being transported in the fiber band transport direction, the apron top roller **6** is arranged on the same side as the first **2** and second **4** top roller. Alternatively, according to one embodiment example, the apron top roller can be formed by the first top roller **2**, in which case the air-permeable apron **10** thus runs around the first top roller **2**.

[0037] The apron cage **8** has at least one through-opening **12**, to which negative pressure can be applied, for applying suction air to the fiber band running between the first **2** and second **4** top roller, through the air-permeable apron **10**. The through-opening **12** is arranged on the apron cage **8** facing the fiber band, and is connected to a negative pressure source (not shown) either indirectly by means of the apron cage **8** or directly. For this purpose, the through-opening **12** can be coupled to negative pressure conduit formed together with the apron cage **8**, or to an external negative pressure conduit leading to the through-opening **12**. The through-opening **12** can have a shape selected as required for applying the suction air to the fiber band by means of the air-permeable apron **10**.

[0038] FIG. **3** is a schematic view of a drafting system **20** comprising a drafting system unit **1** shown in FIG. **1**, in each case in a fiber drawing region or fiber drafting region VZ, HZ.

[0039] The drafting system **20** has a first roller pair **2**, **3**, which is formed by the first top roller **2** and a first bottom roller **3** interacting therewith. The first top roller **2** and the first bottom roller **3** are arranged such that a clamping line is formed in between them for clamping the fiber band being guided between the first top roller **2** and the first bottom roller **3**. During drafting system **20** operation, the first roller pair **2**, **3** rotates at a defined first rotational speed in such a manner as to transport the fiber band in the fiber band transport direction R.

[0040] In addition, a second roller pair **4**, **5** is provided, which is formed by the second top roller **4** and a second bottom roller **5** interacting therewith, in a manner equivalent to the first roller pair **2**, **3**. During drafting system **20** operation, the second roller pair **4**, **5** rotates at a higher speed than the first roller pair **2**, **3**. In this embodiment example, the second roller pair **4**, **5** forms the output roller pair of the drafting system **20**. Due to the different rotational speeds between the first **2**, **3** and second **4**, **5** roller pairs, the fiber band being transported in a clamped manner from the first roller pair **2**, **3** to the second roller pair **4**, **5** is drawn. In this embodiment example, the region formed between the clamping lines of the first **2**, **3** and second **4**, **5** roller pairs forms a "main drawing field" HZ. The first **2**, **3** and second **4**, **5** roller pairs can be driven in the normal manner, for example by means of a single drive of the associated top or bottom roller or by means of a common drive driving a plurality of bottom rollers or one joint bottom roller of drafting systems arranged in the machine longitudinal direction.

[0041] The drafting system **20** further has a third roller pair **14**, **15**, which is formed, in an equivalent manner to the first **2**, **3** and second **4**, **5** roller pairs, by a fourth top roller **14** and a fourth bottom roller **15** interacting therewith. In this embodiment example, the third roller pair **14**, **15** forms the input roller pair for the drafting system **20**, the fiber band being introduced into the drafting system **20** by means of said input roller pair. During drafting system **20** operation, the third roller pair **14**, **15** rotates at a lower speed than the first, roller pair **2**, **3**. As a result, an additional drafting region, a "pre-drawing field", is formed between the first roller pair **2**, **3** and the input roller pair **14**, **15**, the fiber band undergoing initial drafting to a lesser extent in said pre-drawing field than in the main drawing field.

[0042] According to this embodiment example, an apron cage **8** having an apron top roller **6** and an air-permeable apron **10** circulating jointly around the apron cage **8** and the apron top roller **6** is arranged in each case in both the pre-drawing field VZ and the main drawing field HZ. The apron cage **8** is connected to a negative pressure source (not shown) and has a negative pressure conduit leading to a through-opening **12**. In each apron cage **8**, the through-opening **12** is provided facing the fiber band being transported, close to the first **2**, **3** or second **4**, **5** roller pair arranged downstream in the fiber band direction R, so as to apply suction air to the fiber band through the air-permeable apron **10**. Advantageously, the through-opening **12** can be formed at the opposite edge of the apron cage **8** to the downstream first **2**, **3** or second **4**, **5** roller pair so as to ensure the suction air is applied to the fiber band through the air-permeable apron **10** either as close as possible to or in the nip region of the corresponding downstream first **2**, **3** or second **4**, **5** roller pair.

[0043] The described embodiment examples shown in the figures are only selected by way of example. Different embodiment examples can be combined with one another completely or with regard to individual features. Also, an embodiment example can be supplemented by features of a further embodiment example.

[0044] If an embodiment example has an "and/or" link between a first feature and a second feature, this should be understood to mean that the embodiment example according to one embodiment comprises both the first feature and the second feature and, according to a further embodiment, comprises either only the first feature or only the second feature.

LIST OF REFERENCE SIGNS

[0045] **1** Drafting system unit
[0046] **2** First top roller
[0047] **2**R Axis of rotation of the first top roller
[0048] **3** First bottom roller
[0049] **4** Second top roller
[0050] **4**R Axis of rotation of the second top roller
[0051] **5** Second bottom roller
[0052] **6** Third top roller
[0053] **7** Third bottom roller
[0054] **8** Apron cage
[0055] **10** Air-permeable apron
[0056] **12** Through-opening
[0057] **20** Drafting system
[0058] HS Outward flow
[0059] OR Top roller direction of rotation
[0060] R Fiber band transport direction
[0061] S Drag flow
[0062] UR Bottom roller direction of rotation
[0063] VS Pre-drawing field
[0064] HZ Main drawing field

[0065] It will therefore be readily understood by those persons skilled in the art that the present invention is susceptible of broad utility and application. Many embodiments and adaptations of the present invention other than those herein described, as well as many variations, modifications and equivalent arrangements, will be apparent from or reasonably suggested by the present invention and the foregoing description thereof, without departing from the substance or scope of the present invention. Accordingly, while the present invention has been described herein in detail in relation to its preferred embodiment, it is to be understood that this disclosure is only illustrative and exemplary of the present invention and is made merely for purposes of providing a full and enabling disclosure of the invention. The foregoing disclosure is not intended or to be construed to limit the present invention or otherwise to exclude any such other embodiments, adaptations, variations, modifications and equivalent arrangements.

What is claimed is:

1. A drafting system unit for a drafting system of a spinning machine, the drafting system unit having, in a fiber band transport direction (R), a first top roller and a second top roller spaced apart therefrom, which are provided for drafting a fiber band, transported from the first to the second top roller, in cooperation with accordingly assigned bottom rollers, the respective axes of rotation of the first and second top roller extending transversely to the fiber band transport direction (R),

characterized in that

an apron cage to which negative pressure can be applied is arranged between the first top roller and the second top roller for guiding an air-permeable apron in circulation jointly around the apron cage and an apron top roller, the apron top roller being formed by the first top roller or by a third top roller that is assigned to the apron cage and arranged on the same side as the first and second top roller in relation to the fiber band being transported, and the apron cage having at least one through-opening, to which negative pressure can be applied, for applying suction air to the fiber band running between the first and second top roller, through the air-permeable apron.

2. The drafting system unit according to claim **1**, characterized in that, in the fiber band transport direction (R), the through-opening is at a smaller distance from the second top roller than from the apron top roller.

3. The drafting system unit according to claim **1**, characterized in that the through-opening is formed at an opposite end of the apron cage to the second top roller.

4. The drafting system unit according to claim **1**, characterized in that the through-opening is formed as a slot extending transversely to the fiber band transport direction (R).

5. The drafting system unit according claim **1**, characterized in that the through-opening is arranged so as to face the fiber band between the side edges thereof.

6. The drafting system unit according to claim **1**, characterized in that the second top roller forms an output top roller for the drafting system comprising the drafting system unit.

7. A drafting system for a spinning machine, having a first roller pair, which comprises a first top roller and a first bottom roller, and a second roller pair, which is formed by a second top roller and a second bottom roller, the first and second roller pair being spaced apart from one another in a fiber band transport direction (R) and being provided for drafting a fiber band transported from the first to the second roller pair, the respective axes of rotation of the first and second roller pair extending transversely to the fiber band transport direction (R),

characterized in that

an apron cage to which negative pressure can be applied is arranged between the first roller pair and the second roller pair for guiding an air-permeable apron in circulation jointly around the apron cage and an apron top roller, the apron top roller being formed by the first top roller of the first roller pair arranged upstream in the fiber band transport direction, or by a third top roller that is assigned to the apron cage and arranged on the same side as the first and second top roller in relation to the fiber band being transported, and the apron cage having at least one through-opening, to which negative pressure can be applied, for applying suction air to the fiber band running between the first roller pair and the second roller pair, through the air-permeable apron.

8. The drafting system for a spinning machine according to claim **7**, characterized in that the apron top roller, the first and second top roller, and the apron cage form a drafting system unit having, in a fiber band transport direction (R), a first top roller and a second top roller spaced apart therefrom, which are provided for drafting a fiber band, transported from the first to the second top roller, in cooperation with accordingly assigned bottom rollers, the respective axes of rotation of the first and second top roller extending transversely to the fiber band transport direction (R),

wherein an apron cage to which negative pressure can be applied is arranged between the first top roller and the second top roller for guiding an air-permeable apron in circulation jointly around the apron cage and an apron top roller, the apron top roller being formed by the first top roller or by a third top roller that is assigned to the apron cage and arranged on the same side as the first and second top roller in relation to the fiber band being transported, and the apron cage having at least one through-opening, to which negative pressure can be applied, for applying suction air to the fiber band running between the first and second top roller, through the air-permeable apron.

9. A method of using a fiber band compression device for compressing, within a drafting system, a drafted fiber band passing through an output top roller of a drafting system, the fiber band compression device having an apron cage, to which negative pressure can be applied, for guiding an air-permeable apron in circulation around an apron top roller and the apron cage, which has at least one through-opening to which negative pressure can be applied,

characterized in that

the fiber band compression device is arranged between a first roller pair and a second roller pair of the drafting system such that the apron cage guides the air-permeable apron jointly around the apron top roller and the apron cage, the apron top roller being formed by the first top roller of the first roller pair arranged upstream in the fiber transport direction, or by a third top roller that is assigned to the apron cage and arranged on the same side as the top rollers of the first and second roller pair in relation to the fiber band being transported, and the through-opening is arranged to apply suction air to the fiber band running between the spaced-apart roller pairs, through the air-permeable apron.

10. The method of using a fiber band compression device according to claim **9**, characterized in that the apron top roller, the first and second top roller, and the apron cage form a drafting system unit of a spinning machine, the drafting system unit having, in a fiber band transport direction (R), a first top roller and a second top roller spaced apart therefrom, which are provided for drafting a fiber band, transported from the first to the second top roller, in cooperation with accordingly assigned bottom rollers, the respective axes of rotation of the first and second top roller extending transversely to the fiber band transport direction (R),

characterized in that

an apron cage to which negative pressure can be applied is arranged between the first top roller and the second top roller for guiding an air-permeable apron in circulation jointly around the apron cage and an apron top roller, the apron top roller being formed by the first top roller or by a third top roller that is assigned to the apron cage and arranged on the same side as the first and second top roller in relation to the fiber band being transported, and the apron cage having at least one through-opening, to which negative pressure can be applied, for applying suction air to the fiber band running between the first and second top roller, through the air-permeable apron.

* * * * *

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(54) **COMPACTOR DEVICE**

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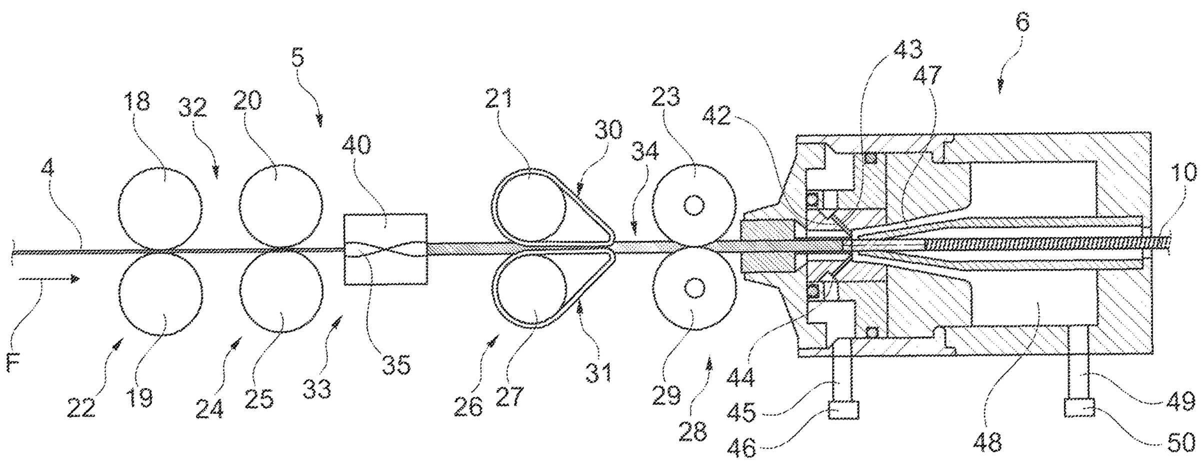
(52) **U.S. Cl.**
CPC ***D01H 5/72*** (2013.01)

(57) **ABSTRACT**

A compactor device for compacting a sliver that is drawn by a drafting system of a textile machine is provided. In accordance with the invention, it is envisaged that the compactor device is designed as a channel compactor and has a guide channel, designed in the shape of a screw in the running direction of the sliver, wherein the entry opening of the guide channel is widest horizontally and the exit opening of the guide channel is arranged rotated at least 30° with respect to the entry opening.



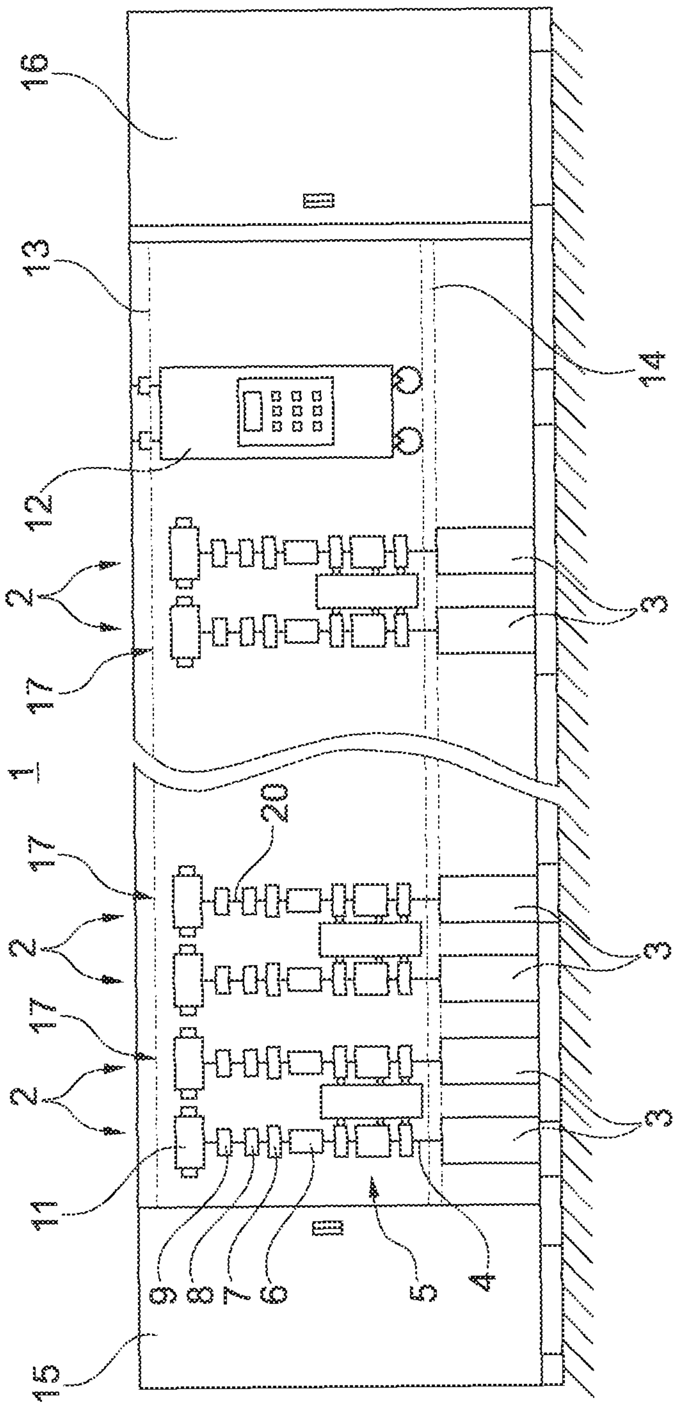


FIG. 1

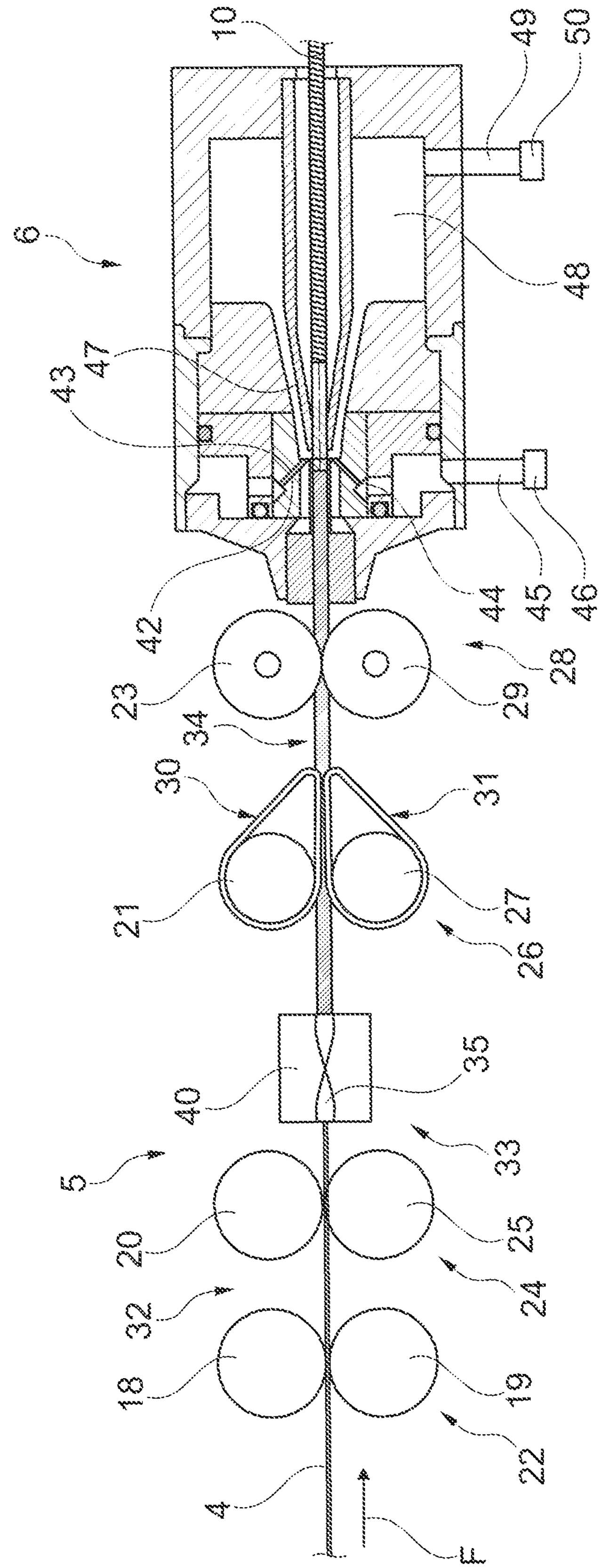

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FIG. 2

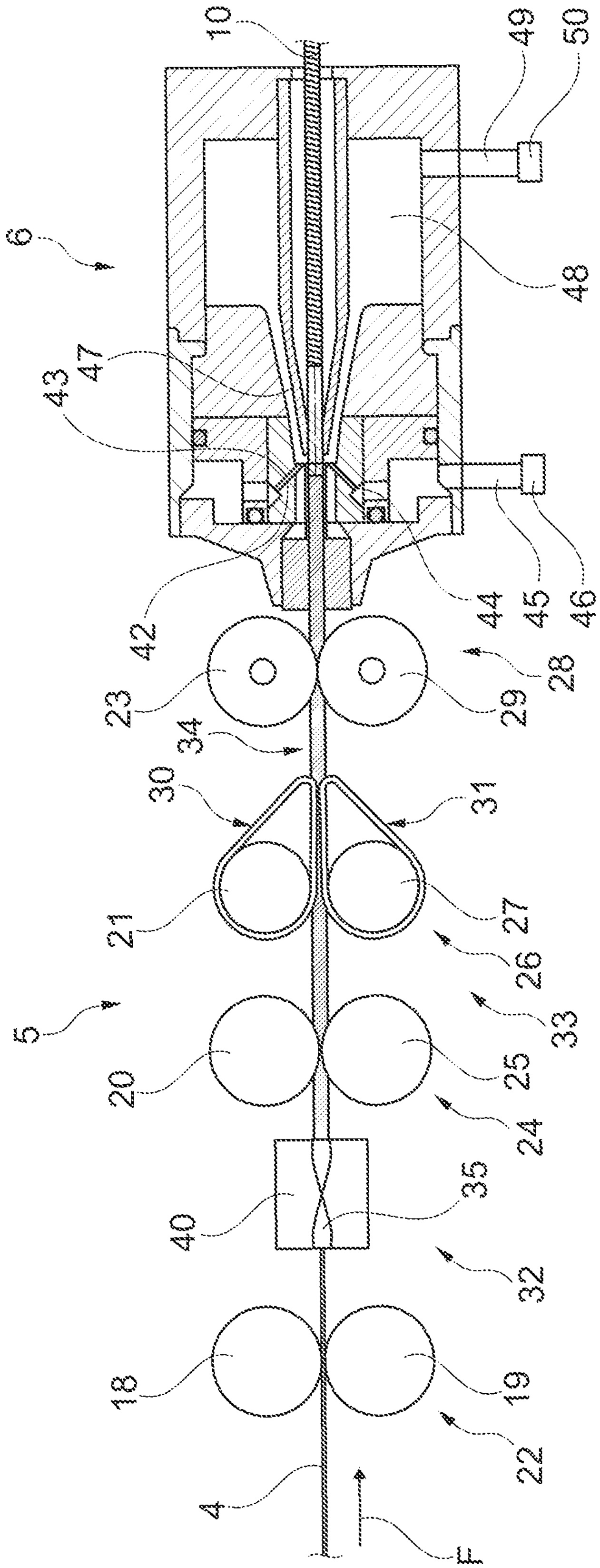
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FIG. 3

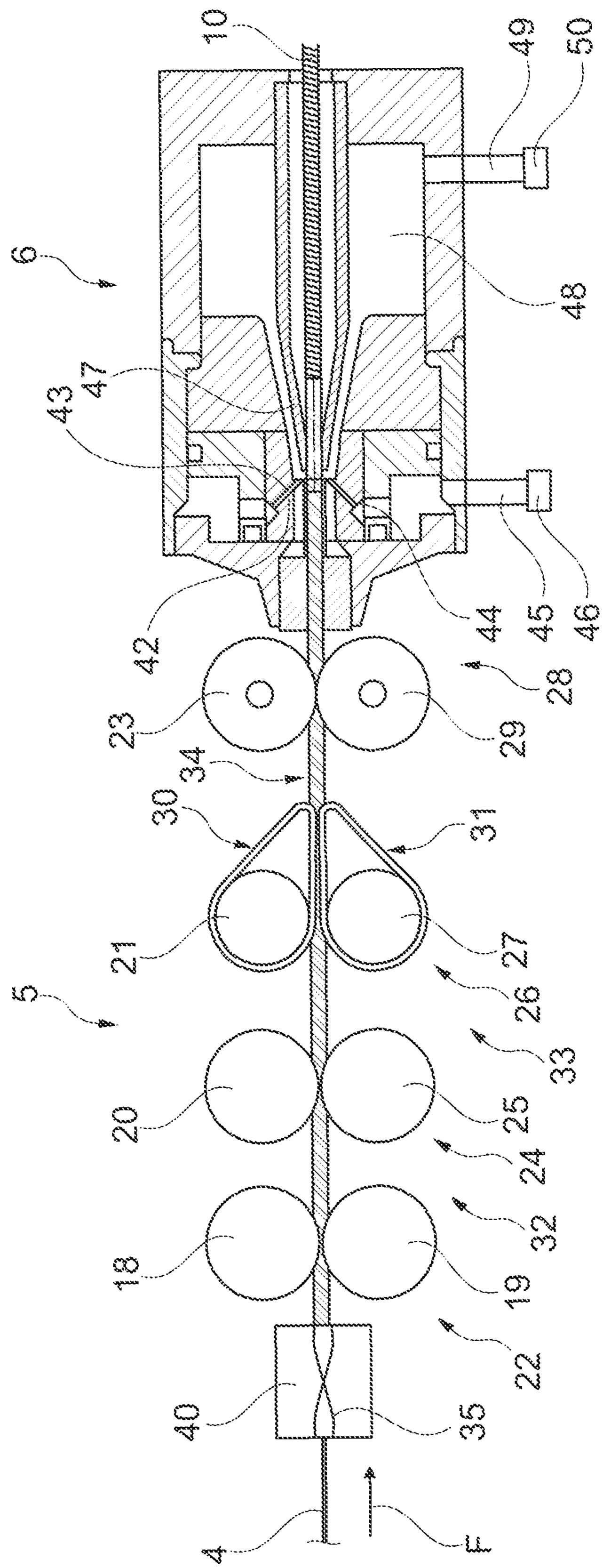
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FIG. 4

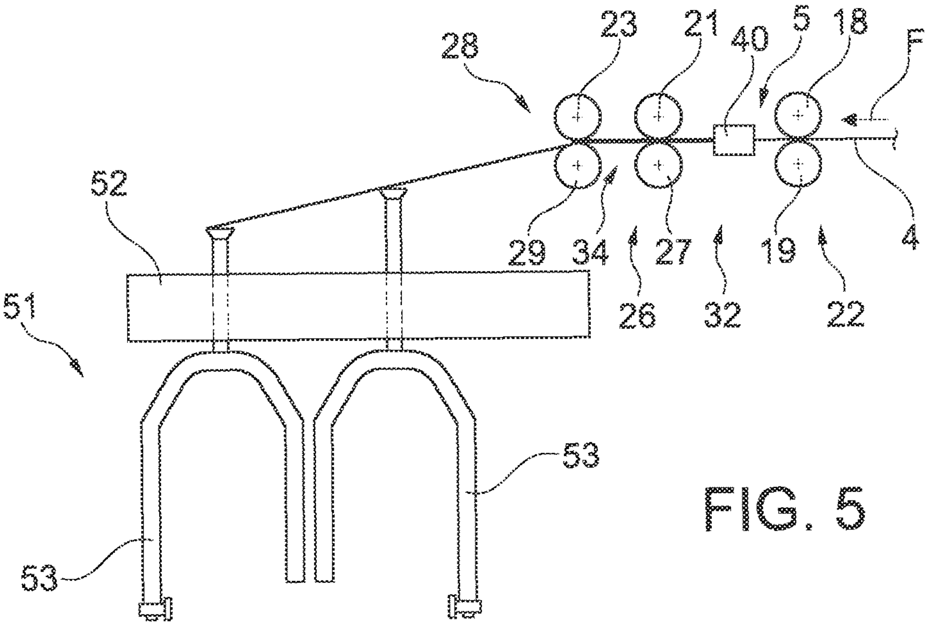

FIG. 5

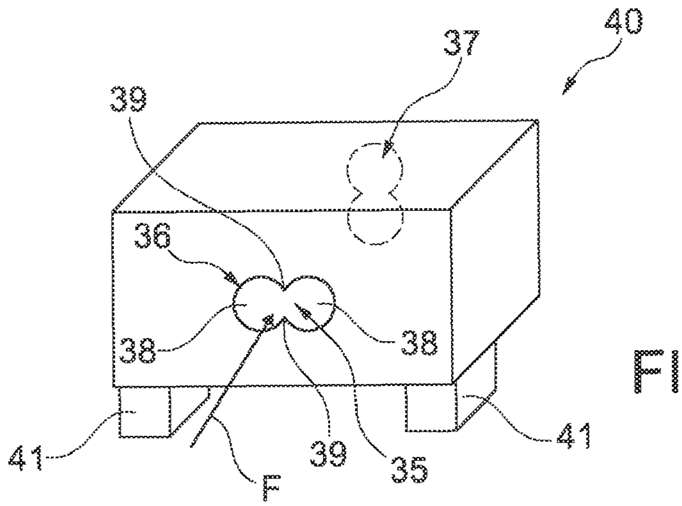

FIG. 6

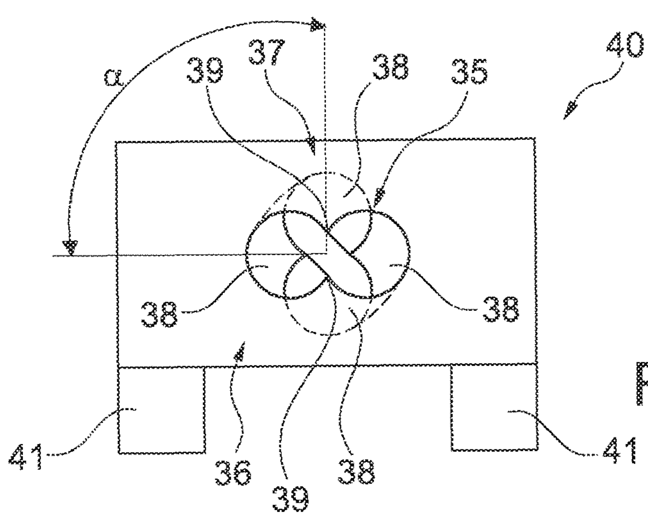

FIG. 7

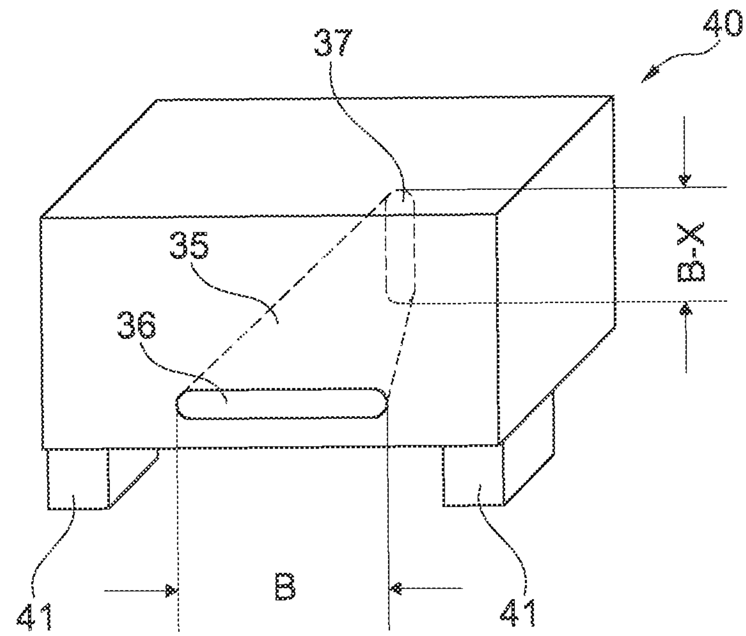

FIG. 8

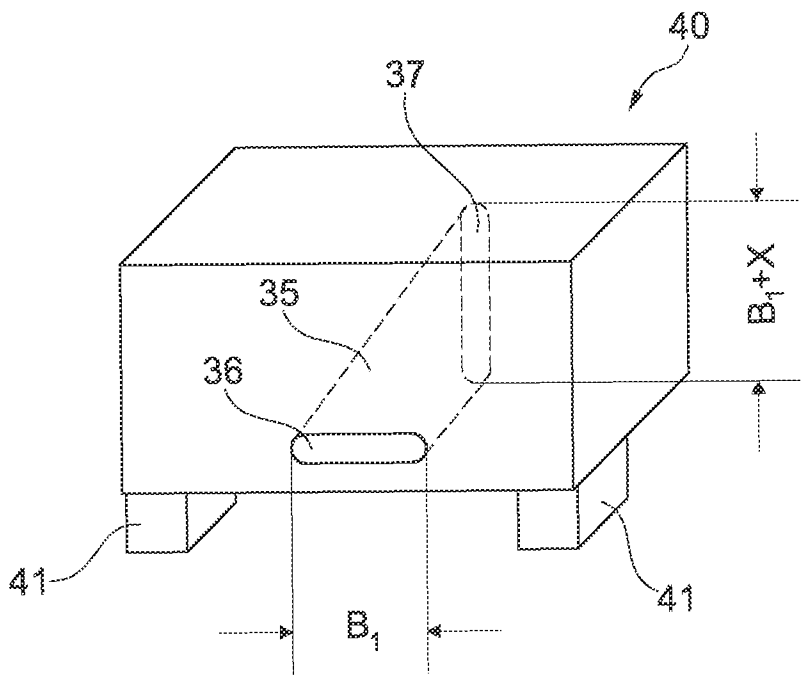

FIG. 9

COMPACTOR DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from PCT International Patent Application No. PCT/EP2018/075750, filed Sep. 24, 2018, which claims priority from German National Patent Application No. 10 2017 122 318.5, filed Sep. 26, 2017, entitled "Verdichtereinrichtung", the entire contents of which are incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The invention generally relates to a compactor device, more particularly to a compactor device for compacting a sliver that is drawn by a drafting system of a textile machine.

BACKGROUND OF THE INVENTION

[0003] Both drafting systems and associated compaction devices have long been well-known in the context of textile machines.

[0004] The known drafting systems are arranged in front of each of the spinning units of the textile machine, and they draw a material supplied to them, usually a sliver or roving frame fibre, to a desired fineness. These kinds of drafting systems have several pairs of rollers lying one in front of the other in the running direction of the sliver that rotate at different circumferential speeds and transport the sliver to the associated spinning unit.

[0005] Because the circumferential speed of the roller pairs increases in the running direction of the sliver, the sliver is constantly accelerated within the drafting system, thus undergoing a so-called draft warp. With known drafting systems, the total draft of the sliver differs greatly depending on the textile machine in question.

[0006] For the drafting systems of air spinning machines, the total draft of the sliver can be up to 180 times, while the drafting systems of pre-spinning machines, for example roving frames, usually work with significantly lower total drafting.

[0007] Among other things, the compactness and hairiness of the drafted sliver has a decisive influence on the quality of the yarn material supplied by the drafting system. This means that, when it is running into the drafting system, the sliver has a width that is first reduced to a significantly narrower width during the course of the drafting process. On the outgoing side of the drafting system, in the area of the so-called spinning triangle, there should be a width that is once again significantly lower than the intermediate width of the material running in.

[0008] During the drafting process, however, there is the problem that edge fibres are often either not bound in and increased peeling away of fibres occurs, or the edge fibres are bound in a disorganized way, leading to increased hairiness and an increased width of the spinning triangle, and therefore to a reduction in quality of the drafted sliver.

[0009] In order to achieve a secure guidance and as good a compacting of the sliver as possible during the drafting of the material in question, the known drafting systems often also have so-called compaction units.

[0010] In German Patent Publication DE 10 2011 015 748 A1, for example, a drafting system for a pre-spinning machine is described that has a pre-drafting field, a main drafting field and a downstream compaction zone.

[0011] A compaction unit is positioned in the compaction zone, which is described as a condenser component ("Kondenserbauteil") in German Patent Publication DE 10 2011 015 748 A1. The condenser component has a guide slit that opens upward for the sliver, where the guide slit is significantly higher than it is wide. The condenser component serves to homogenise the thickness of the sliver and reduce the hairiness of the sliver, which means that the quality of the material is improved.

[0012] In German Patent Publication DE 10 2013 017 636 A1, in addition, drafting systems for the air spinning units of air spinning machines are known that are fitted with comparable compaction units.

[0013] One of the depicted embodiments shows and describes a drafting system that is designed as a so-called four-roller drafting system, and that has a pre-drafting field, a mid-drafting field and a main drafting field.

[0014] With this known four-roller drafting system, a pre-compactor is positioned in front of the input roller pair of the drafting system, and a second compactor is positioned in the pre-drafting field. Moreover, the main drafting field of the drafting system is equipped with a third compactor.

[0015] For this known drafting system too, the compaction units are designed to reduce the hairiness of the stretched sliver and increase the number of entwined fibres.

[0016] A four-roller drafting system for the air spinning units of air spinning machines is also described in German Patent Publication DE 10 2015 110 980 A1.

[0017] This known drafting system is also fitted with a special device for improving the quality of the drafted sliver. This means that, with this four-roller drafting system, a false spinning component is positioned in the pre-drafting field of the drafting system, which twists the sliver with alternating twist directions, before it is pulled to the desired yarn fineness in the main draft field and guided to an air spinning unit.

[0018] The alternating twisting direction of the sliver is intended to minimize edge fibres being diverted, which occurs in particular due to the air stream in the area of the output rollers of the drafting system, which rotate at a relatively higher speed.

[0019] Although the drafting systems described above have different options for improving the quality of a concealed sliver, they can have the problem that, when pulling the sliver, edge fibres occur or the sliver has insufficient compactness, so that on the output side of the drafting system a relatively wide spinning triangle occurs, which cannot be completely alleviated.

SUMMARY OF THE INVENTION

[0020] Given the above-mentioned state of the art, the invention has the task of developing a compactor device or unit for one of the drafting systems positioned in front of the spinning device of a textile machine that is designed so that during the drafting process it is ensured that the width of the sliver to be drafted is reliably minimized both in the main drafting area and in the area of the spinning triangle occurring on the output side of the drafting system.

[0021] In accordance with the invention, this task is completed by a compactor device that is designed as a channel compactor and has a guide channel designed in the shape of a screw in the running direction of the sliver, where in the entry opening of the guide channel is widest horizontally and the exit opening of the guide channel is arranged rotated with respect to the entry opening.

[0022] Advantageous embodiments of the invention are set forth in detail herein.

[0023] The design of a channel compactor in accordance with the invention has the particular advantage that the guided sliver, which initially runs in a flat horizontal direction into the entry opening of the guide channel of the channel compactor, is turned somewhat within the channel compactor, temporarily creating a false twist. This means that, when it is running out of the guide channel of the channel compactor, the sliver is rotated so that in the following draft roller pair, the edge fibres are immediately compacted, thereby leading to an initial compacting of the sliver.

[0024] This means that, through the compacting of the twisted sliver, the edge fibres are bound in to a high degree, which not only reduces the peeling away of fibres, but also minimizes the width of the spinning triangle, with the result that there is an overall increase in the quality of the material produced.

[0025] In the advantageous embodiment, it is envisaged that the rotation angle between the entry opening and the exit opening of the guide channel of the channel compactor is between 30° and 160°, and preferably 90°.

[0026] Due to this rotated positioning of the entry and exit opening of the guide channel, the sliver not only temporarily receives a so-called false spin, which leads to a positive stabilisation of the materials, but also preparation is done for further compacting by the downstream drafting rollers.

[0027] It has proven especially advantageous if the sliver is twisted by 90°, i.e. if the sliver that is originally running on a horizontal direction in the guide channel of the channel compactor is twisted in a vertical direction and runs into the downstream drafting system roller pair in this direction.

[0028] In the most advantageous embodiment it is moreover envisaged that the guide channel has a light cross-section area, which is depicted through two narrowing ellipses extending towards the centre from both sides.

[0029] Numerous trials have shown that in such a design, the guide channel cross-section can always ensure an even and secure guidance of the sliver in the depicted screw-shaped guide channel.

[0030] The channel compactor is preferably manufactured from an abrasion-resistant plastic in a 3D printing process. Polyamides have proven to be advantageous as plastics, these can be designed in almost any three-dimensional shape using fused deposition modelling. This means that the manufacturing of the channel compactor in a 3D printing process in accordance with the invention represents an advantageous, relatively simple manufacturing method.

[0031] The channel compactor in accordance with the invention can be manufactured in another 3D printing process.

[0032] Regarding the installation position of the channel compactor in accordance with the invention, various locations are possible.

[0033] For drafting systems of textile machines that work with relatively high draft values, such as the drafting systems of air spinning machines, positioning of the channel compactor in accordance with the invention can be advantageous both in the area of the pre-draft field of the drafting system and in the area of the mid-draft field of the drafting system of the air spinning unit.

[0034] Such a positioning keeps the distance between the channel compactor and the exit roller pair of the drafting system relatively small, which has a very positive effect on the development of the width of the spinning triangle that occurs at the exit side of the exit roller pair of the drafting system.

[0035] In the context of drafting systems for air spinning units, however, it has emerged that positioning the channel compactor in front of the entry roller pair of the drafting system or a simultaneous positioning of several channel compactors at various positions of a drafting system can be very advantageous.

[0036] Particularly for the simultaneous positioning of several channel compactors, multiple compacting of the twisted sliver, that is also processed by the roller pair of the drafting system, occurs so that the width of the sliver set in the area of the drafting system and in the area of the spinning triangle is minimized.

[0037] Various positions of the channel compactor can be advantageous in accordance with the invention, including for textile machines for which their drafting systems work with relatively low draft values, for example for roving frames.

[0038] In tests it emerged that, for example, both a positioning of the channel compactor in front of the entry roller pair of the drafting system as well as a positioning of the channel compactor in the area of the pre-draft field of the drafting system are very advantageous.

[0039] It was shown, for example, that with such a positioning of the channel compactor with the drafting systems, roving flyers can be created that are significantly more compact and less hairy than previously known roving fibres.

[0040] This means that, with the drafting systems of roving frames in which a channel compactor is arranged front of the entry roller pair of the drafting system in the area of the pre-draft field of the drafting system, roving fibres can be created that have significant advantages during their further processing by ring spinning machines.

[0041] These improved roving fibres meant, for example, that spinning triangles were set up at the drafting systems of the ring spinning machines during the spinning process that were significantly lesser in width than the previously standard spinning triangles, which is a good sign for the excellent quality of the drafted sliver.

[0042] Also regarding the exact design of the guide channel of the channel compactor, various types of embodiment are possible.

[0043] In an initial embodiment type, the guide channel of the channel compactor can, for example, be designed so that it has its maximum width in the area of its horizontally positioned entry opening. This maximum width then reduces through the guide channel and has its final minimum width in the area of the exit opening, which is arranged rotated in a vertical direction compared to the entry opening.

[0044] In another advantageous embodiment, the guide channel of the channel compactor has a width in the area of its horizontally positioned entry opening that "grows" throughout the length of the guide channel, having its maximum width in the area of the exit opening, which is arranged rotated in a vertical direction compared to the entry opening.

[0045] Which of the above described embodiments is more advantageous can depend on a number of factors, for example the material of the sliver or roving fibres, the desired fineness of the drafted material, the degree of sliver drafting, etc.

DETAILED DESCRIPTION OF THE DRAWINGS

[0046] The invention is explained in greater detail below on the basis of embodiment examples shown in the drawings.

[0047] The figures show:

[0048] FIG. **1** is a schematic front view of an air spinning machine with a number of spinning positions, each of which has an air spinning unit with an upstream drafting system,

[0049] FIG. **2** is a side view of a drafting system shown as a four-roller drafting system positioned in front of an air spinning unit, with a channel compactor in accordance with the invention in the area of the mid-drafting field,

[0050] FIG. **3** is a side view of a four-roller drafting system as in FIG. **2**, with a channel compactor in accordance with the invention in the area of the pre-drafting field of the drafting system,

[0051] FIG. **4** is a side view of a four-roller drafting system as in FIG. **2**, with a channel compactor in accordance with the invention in front of the entry roller pair of the drafting system,

[0052] FIG. **5** is a side view of a workstation of a roving frame, with a three-roller drafting system, that has a channel compactor in accordance with the invention in the area of the pre-drafting field of the drafting system,

[0053] FIG. **6** is a perspective view of a first embodiment in accordance with the invention,

[0054] FIG. **7** is a front view of the channel compactor as in FIG. **6**,

[0055] FIG. **8** is a view of another embodiment of the channel compactor in accordance with the invention, and

[0056] FIG. **9** is a view of another embodiment of the channel compactor in accordance with the invention.

DETAILED DESCRIPTION OF THE DRAWINGS

[0057] FIG. **1** shows a schematic front view of an air spinning machine **1**. As shown, these types of air spinning machines **1** have a number of workstations **2** positioned in a row next to one another between their so-called end stations **15**, **16** at their end sides, which are often also designated as spinning positions.

[0058] Material is processed on these spinning positions **2**, for example sliver **4** stored in a spinning can **3**. This means that sliver **4** is spun into a yarn at this spinning position **2**.

[0059] For this purpose, spinning position **2** has various devices. The spinning positions **2** each have, for example, a drafting system **5**, an air spinning unit **6**, a thread drafting device **7**, a yarn clearer **8** and a winding device **11**.

[0060] The drafting system **5**, which can, for example, be designed as a four-roller drafting system or as a three-roller drafting system, also has a channel compactor in accordance with the invention, which is not represented in FIG. **1** for reasons of improved clarity. This channel compactor **40** is explained below in detail using FIGS. **2** to **9**.

[0061] As indicated in FIG. **1**, the yarn prepared in the air spinning unit **6** from sliver **4** is wound by an associated thread changing device **9** in cross-wound layers onto a take-up package **17**, creating a cross-wound package.

[0062] The cross-wound package **17** is held, in the usual way, in a package cradle (not shown) and is rotated during the spinning process by a package drive (also not shown).

[0063] As further represented in FIG. **1**, the workstations **2** of the air spinning machine **1** are supplied by an independently working operating unit **12**, that can be moved on rails **13**, **14** along the workstations depicted as spinning positions **2**.

[0064] The FIGS. **2**, **3** and **4** each show a positioning option of a channel compactor **40** in accordance with the invention positioned in the area of a drafting system **5**.

[0065] In the embodiment examples, the drafting system **5**, that drafts a sliver **4**, is depicted as a four-roller drafting system and is arranged in front of an air spinning unit **6** of an air spinning machine **1**.

[0066] In accordance with FIG. **2**, the channel compactor **40** in accordance with the invention is positioned in the area of the so-called mid-draft field **33**.

[0067] As can be seen, a sliver **4** that is drawn from a (not shown) spinning can **3** by an intake roller pair **22**, which consists of an upper roller **18** and a lower roller **19**, is drawn into drafting system **5**, and is finally transported to air spinning unit **6** and drafted by means of the additional pairs **24**, **26**, **28**.

[0068] The roller pairs **24**, **26**, **28** are each consisting of an upper roller **20** and a lower roller **25**, and upper roller **21** and a lower roller **27** or an upper roller **23** and a lower roller **29**. The upper roller **21** and the lower roller **27** each work together with one of the aprons **30** or **31**, which are positioned in the area of the so-called main drafting field **34**. The upper roller **23** and the lower roller **29** represent the exit roller pair **28** of the drafting system **5**. This means that, in the present four-roller drafting system **5**, the first two roller pairs **22**, **24** represent a pre-drafting field **32** for the sliver **4**, looked at in running direction F of the sliver **4**. The following drafting system section between the roller pair **24** and the roller pair **26** form a so-called mid-drafting field **33**, in which the channel compactor **40**, designed in accordance with the invention, is also positioned, while the roller pairs **26**, **28**, as indicated above, form the main drafting field **34** of the drafting system **5**.

[0069] As can be seen, the sliver **4** is transported to air spinning unit **6** by the roller pairs **22**, **24**, **26** and **28**.

[0070] Because the circumferential speeds of the roller pairs **22**, **24**, **26**, **28** increase in the running direction F of the sliver, the sliver **4** is drafted during transport.

[0071] The drafting of the sliver **4** can be up to 180 times its original length.

[0072] As is moreover shown in FIG. **2**, the air spinning aggregate **6** has a nozzle device **42** on its input side, the nozzles **43**, **44** of which are connected with a pressurised air source **46** via a pneumatic line **45**. A hollow spinning cone **47** is connected to the nozzle device **42**, which is surrounded by an air chamber **48**, which is connected with a low pressure source **50** via an additional pneumatic line **49**.

[0073] During the spinning operation, the air emerging from the nozzles **43**, **44** creates a rotation flow, which hits the drafted sliver **4**. This means that, through the cooperation of the nozzle device **42** and spinning cone **47**, a yarn **10** is formed in the air spinning unit **6** that is drawn from the air spinning device **6** through the hollow spinning cone **47**.

[0074] Further details on the spinning process using this type of air spinning unit **6** can be found in German Patent Publication DE 199 26 492 A1, for example.

[0075] The channel compactor **40**, designed in accordance with the invention and in accordance with the embodiment example of FIG. **2**, positioned in the area of the mid-drafting field **33**, ensures that during the drafting process the sliver **4**, which runs into the drafting system **5** in a flat horizontal direction, is turned in the channel compactor **40** in e.g. a vertical direction by means of its screw-shaped guide channel **35**. The sliver **4** thereby temporarily receives a false twist, which leads to the compacting of the sliver **4** on all sides.

[0076] This compacting of the sliver **4** on all sides is not only maintained during the passage of the sliver **4** through the drafting system **5**, but rather is enhanced even further in drafting system **5**.

[0077] The embodiment example depicted in FIG. **3** differs from the embodiment example depicted in FIG. **2** only in the positioning of the channel compactor **40** in the area of the drafting system **5** in accordance with the invention.

[0078] As can be seen, in the embodiment example in FIG. **3** the channel compactor **40** in accordance with the invention is positioned in the area of the pre-drafting field **32** of the drafting system **5**.

[0079] Even with such a positioning of the channel compactor **40**, the sliver **4** temporarily receives a false twist and is thereby compacted on all sides.

[0080] The embodiment example depicted in FIG. **4** also essentially differs from the embodiment examples depicted in FIGS. **2** and **3** in the positioning of the channel compactor **40** in the area of the drafting system **5** in accordance with the invention.

[0081] As can be seen, in this embodiment example the channel compactor **40** in accordance with the invention is positioned in front of the entry roller pair **22** of the drafting system **5**. Such a positioning of the channel compactor **40** means that the sliver **4** is already turned in, for example, a vertical direction from a flat horizontal position before it enters drafting system **5**.

[0082] Even with a positioning of the channel compactor **40** in front of the entry roller pair **22** of the drafting system **5**, the sliver **4** temporarily receives a false twist and is thereby compacted on all sides.

[0083] The further integration of the edge fibres into the sliver **4** that is associated with the compacting of the vertically positioned sliver **4** not only leads to an improvement in the quality of the sliver **4** running into the air spinning unit, but also leads to a significant reduction in the peeling away of fibres that occurs during the spinning process.

[0084] FIG. **5** shows a strongly schematic side view of a workstation of a pre-spinning machine, in the represented embodiment example, the workstation of a so-called roving frame **51**.

[0085] As is generally known, slivers **4** that are not rotated are drafted using roving frames such as roving frame **51**, and thereby processed into roving threads that already have some yarn rotation.

[0086] These roving threads with some yarn rotation are then spun into fine yarns in textile machines further downstream in the production process, for example ring spinning machines.

[0087] As depicted, the workstations of such roving frames **51** usually have two rotatable roving frame flyers **52** in one flyer bench **51**, which are usually supplied by an upstream three-roller drafting system **5**.

[0088] In the present embodiment example, there is also a channel compactor **40** in accordance with the invention positioned in the area of the pre-drafting field **32** of the drafting system **5**.

[0089] As can be seen, a sliver **4** that is drawn from a (not shown) spinning can **3** by an intake roller pair **22**, which consists of an upper roller **18** and a lower roller **19**, is drawn into drafting system **5**, and is finally transported to drafting system **5** and drafted by means of the additional roller pairs **26**, **28** of drafting system **5**.

[0090] As is standard, the roller pairs **26**, **28** are each composed of a top roller **21** or **23** and a bottom roller **27** or **29** whereby, looked at in the running direction F of the sliver **4**, the first two roller pairs **22**, **26** form a pre-drafting field **32**, in which a channel compactor **40** is positioned and is designed in accordance with the invention.

[0091] The roller pairs **26**, **28** form the connected main drafting field **34** of the drafting system **5**, whereby the roller pair **28** also represents the exit roller pair **28** of the drafting system **5**.

[0092] The sliver **4** is transported through the roller pairs **22**, **26** and **28** to the roving frame flyer **51**, which is located on a rotatable flyer bench **52**, and is thereby drafted, because the circumferential speeds of the roller pairs **22**, **26**, **28** increase in the running direction F of the sliver **4**.

[0093] The rotating roving frame flyer **51** also ensures that the drafted sliver is twisted slightly, i.e. it becomes a so-called shaped roving frame fibre.

[0094] As with the drafting systems for air spinning units, the channel compactor **40**, positioned in the area of the pre-draft field **32** in accordance with the invention, also ensures that the sliver **4**, which is initially running into the drafting system **5** in a flat horizontal direction, is twisted in, for example, a vertical direction when it runs through the channel compactor **40**.

[0095] It does this by means of its screw-shaped guide channel **35**. The sliver **4** thereby temporarily receives a false twist, which leads to the compacting of the sliver **4** on all sides.

[0096] This compacting of the sliver **4** on all sides is not only maintained as the sliver **4** is running through the drafting system **5**, but rather in the area of the roller pairs **26**, **28** a compacting of the vertically positioned sliver **4** occurs with the result that there is further increased integration of the edge fibres into the sliver **4**.

[0097] The roving frame thread is significantly more compact and less hairy than previously known roving frame threads, which means that the roving frame thread can be better processed during the subsequent work process on a ring spinning machine. This means that, during the processing of such compact and less hairy roving frame threads, spinning triangles occur on the spinning positions of the ring spinning machines that are minimised as regards their width, which represents a significant improvement in the quality of the roving frame threads.

[0098] FIG. **6** shows, on a larger scale and in a perspective view, an initial embodiment of a channel compactor **40** in accordance with the invention, which preferably is manufactured in a 3D printing process from an abrasion-resistant plastic.

[0099] As can be seen, the channel compactor **40** has a guide channel **35** with an entry opening **36** and an exit opening **37**, whereby the entry opening **36**, is positioned horizontally in the casing of the channel compactor **40**.

[0100] This means that the entry opening **36** of the channel compactor **40** has its greatest width horizontally, when the channel compactor **40** is attached to the relevant drafting system construction, for example by means of locking devices **41**.

[0101] In this mounted state a sliver **4**, the running direction of which is labelled with F in FIG. **5**, can run into the guide channel **35** of the channel compactor **40** in a flat, horizontal direction through the entry opening **36**.

[0102] Because the exit opening **37** is positioned at an angle α with respect to the entry opening **36**, in the embodiment example of FIGS. **6**, **7**, **8** and **9** at 90°, the sliver **4** is also twisted when running through the channel compactor **40** and has a vertical direction after running out of channel compactor **40**.

[0103] According to the embodiment examples in FIGS. **6** and **7**, the guide channel **35** has a light cross-section area, which is formed by two narrowing ellipses **38** extending towards the centre from both sides. This means that there are flange-like protrusions **39** between the ellipses **38**.

[0104] Such a design ensures an even, secure guiding of the sliver **4** through the channel compactor **40** during its passage.

[0105] FIG. **7** shows a front view of the channel compactor **40** in accordance with the invention pursuant to FIG. **6**.

[0106] As can clearly be seen here, the exit opening **37** is positioned at an angle of a with respect to the entry opening **36**. The angle α has a measurement in the embodiment example of, for example, 90°. However, other angles between, for example, 30° and 160° are also possible.

[0107] FIGS. **8** and **9** show further possible embodiments of a channel compactor **40** according to the invention.

[0108] FIG. **8** shows a channel compactor **40**, the guide channel **35** of which has a maximum width of B in the area of its horizontally positioned entry opening **36**. As, can be seen, this maximum width B then reduces throughout the guide channel **35** and has its final minimum width of B-X in the area of the exit opening **37**, which is arranged rotated in a vertical direction compared to the entry opening **36**.

[0109] FIG. **9** shows a channel compactor **40**, which is comparable in principle. In this embodiment, the guide channel **35** of the channel compactor **40** has a minimum width of B_1 in the area of its horizontally positioned entry opening **36**.

[0110] This minimum width B_1 then reduces through the guide channel **35** and has its final maximum width B_1+X in the area of the exit opening **37**, which is arranged rotated in a vertical direction compared to the entry opening **36**.

LIST OF REFERENCE NUMBERS

[0111] **1** Air spinning machine
[0112] **2** Spinning position
[0113] **3** Spinning can
[0114] **4** Sliver
[0115] **5** Drafting system
[0116] **6** Air spinning unit
[0117] **7** Yarn take-up device
[0118] **8** Yarn clearer
[0119] **9** Yarn changing device
[0120] **10** Yarn
[0121] **11** Winding device
[0122] **12** Operating unit
[0123] **13** Rail
[0124] **14** Rail
[0125] **15** End frame
[0126] **16** End frame
[0127] **17** Cross-wound package
[0128] **18** Top roller
[0129] **19** Bottom roller
[0130] **20** Top roller
[0131] **21** Top roller
[0132] **22** Entry roller pair
[0133] **23** Top roller
[0134] **24** Roller pair
[0135] **25** Bottom roller
[0136] **26** Roller pair
[0137] **27** Bottom roller
[0138] **28** Roller pair
[0139] **29** Bottom roller
[0140] **30** Apron
[0141] **31** Apron
[0142] **32** Pre-draft field
[0143] **33** Mid-draft field
[0144] **34** Main draft field
[0145] **35** Guide channel
[0146] **36** Entry opening
[0147] **37** Exit opening
[0148] **38** Ellipse
[0149] **39** Protrusion
[0150] **40** Channel compactor
[0151] **41** Arresting device
[0152] **42** Nozzle device
[0153] **43** Nozzle
[0154] **44** Nozzle
[0155] **45** Pneumatic line
[0156] **46** Pressurised air source
[0157] **47** Spinning cone
[0158] **48** Air chamber
[0159] **49** Pneumatic line
[0160] **50** Negative pressure source
[0161] **51** Roving frame
[0162] **52** Flyer bench
[0163] **53** Flyer
[0164] F running direction

What is claimed is:

1. A compactor device for compacting a sliver that is drawn through a drafting system of a textile machine,

characterised in that,

the compactor device is designed as a channel compactor and has a guide channel designed in a shape of a screw in a running direction of the sliver, wherein an entry opening of the guide channel is widest horizontally and an exit opening of the guide channel is arranged rotated at a rotation angle of at least 30° with respect to the entry opening.

2. The compactor device according to claim **1**, characterised in that the rotation angle between the entry opening and the exit opening of the guide channel is between 30° and 160°.

3. The compactor device according to claim **2**, characterised in that the rotation angle between the entry opening and the exit opening of the guide channel is 90°.

4. The compactor device according to claim **1**, characterised in that the guide channel has a light cross-section area, which is depicted through two narrowing ellipses extending towards the centre from both sides.

5. The compactor device according to claim **1**, characterised in that the compactor device designed as a channel compactor is manufactured from an abrasion-resistant plastic in a 3D printing process.

6. The compactor device according to claim **1**, characterised in that the channel compactor is positioned in an area of a pre-drafting field of the drafting system of an air spinning unit.

7. The compactor device according to claim **1**, characterised in that the channel compactor is arranged in an area of a mid-drafting field of the drafting system of an air spinning unit.

8. The compactor device according to claim **1**, characterised in that the channel compactor is positioned in front of an entry roller pair of the drafting system of an air spinning device.

9. The compactor device according to claim **1**, characterised in that the channel compactor is arranged in front of an entry roller pair of the drafting system of a roving frame.

10. The compactor device according to claim **1**, characterised in that the channel compactor is arranged in an area of the pre-drafting field of the drafting system of a roving frame.

11. The compactor device according to claim **1**, characterised in that several channel compactors are arranged in various positions in the drafting system of the textile machine.

12. The compactor device according to claim **1**, characterised in that the guide channel of the channel compactor has a maximum width in an area of its horizontally positioned entry opening that diminishes in size throughout the length of the guide channel having a minimum width in an area of the exit opening, which is arranged rotated in a vertical direction compared to the entry opening.

13. The compactor device according to claim **1**, characterised in that the guide channel of the channel compactor has a width in the area of a horizontally positioned entry opening that changes throughout the length of the guide channel, having a maximum width in the area of the exit opening, which is arranged rotated in a vertical direction compared to the entry opening.

* * * * *

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(54) SPINNING POSITION, AIR SPINNING MACHINE AND METHOD FOR PRODUCING A YARN

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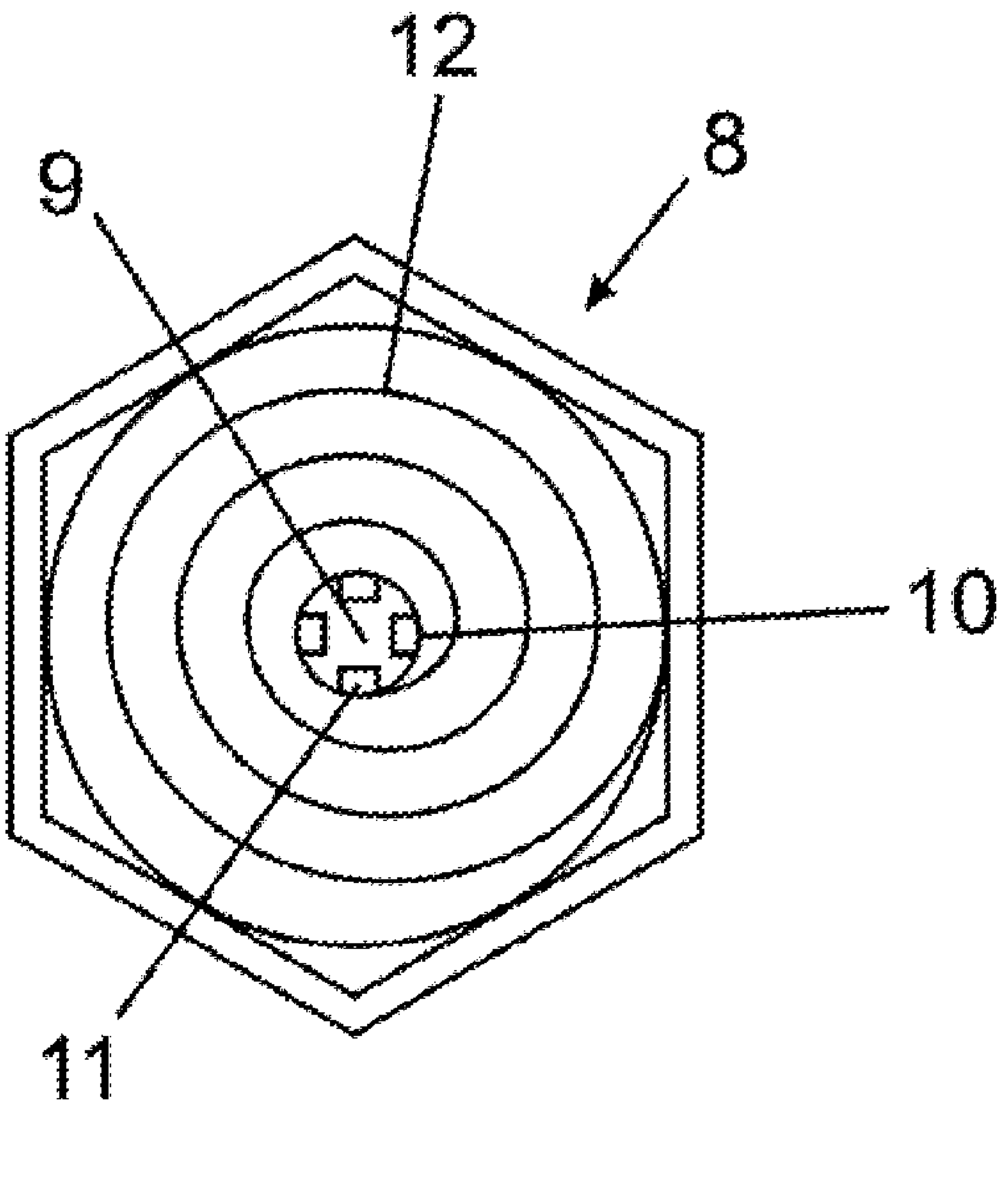
(52) U.S. Cl.
CPC ***D01H 4/34*** (2013.01); ***D01H 13/00*** (2013.01); ***D01H 4/02*** (2013.01)

(57) ABSTRACT

A spinning position for producing a yarn from a fed fiber band, having an air spinning nozzle with an inlet opening for the fed fiber band and an outlet area with an outlet opening for the spun yarn is provided. In order to provide a spinning position, an air spinning machine and a method which allow for the yarn surface finish to be modified advantageously without the yarn properties deteriorating at the same time, while also avoiding expensive and complex modifications to the spinning position, there is provision for a navel to be arranged in the outlet area behind the outlet opening for modifying the surface finish of the spun yarn.



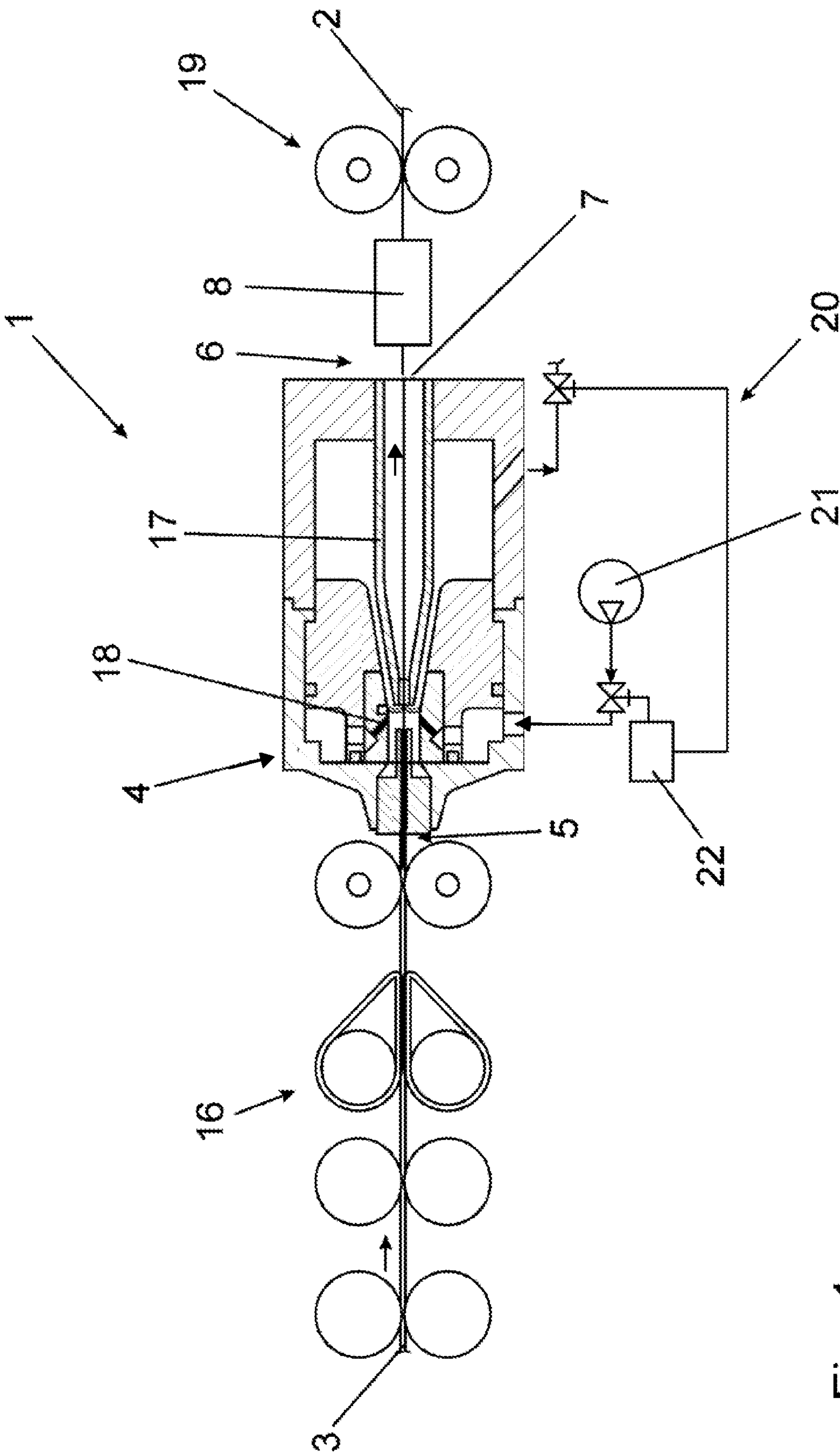


Fig. 1

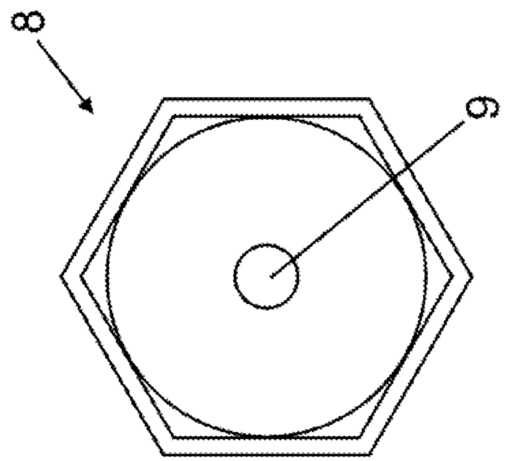


Fig. 2b

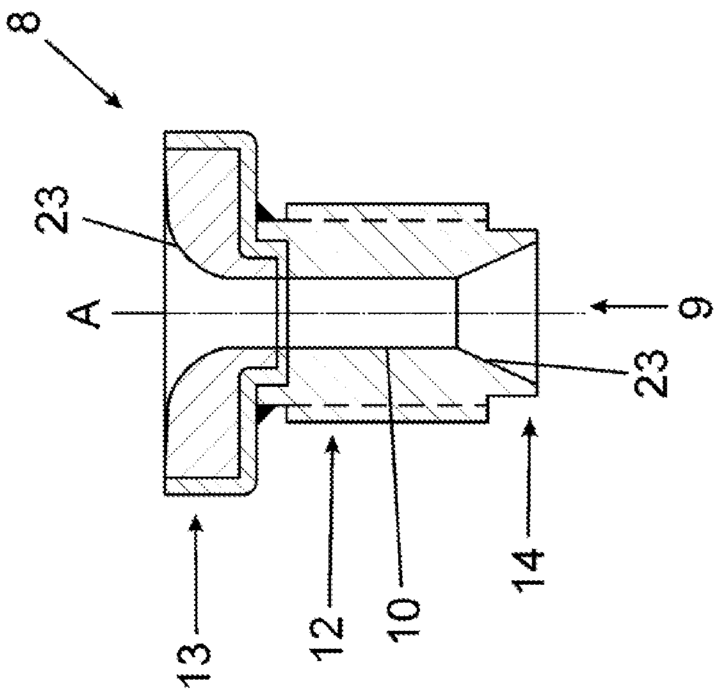


Fig. 2a

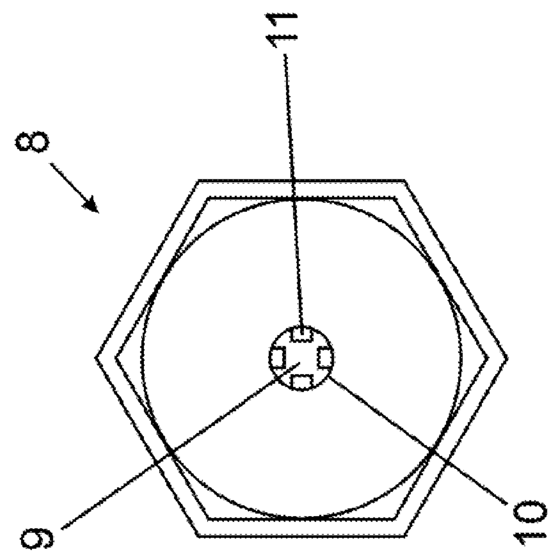


Fig. 3b

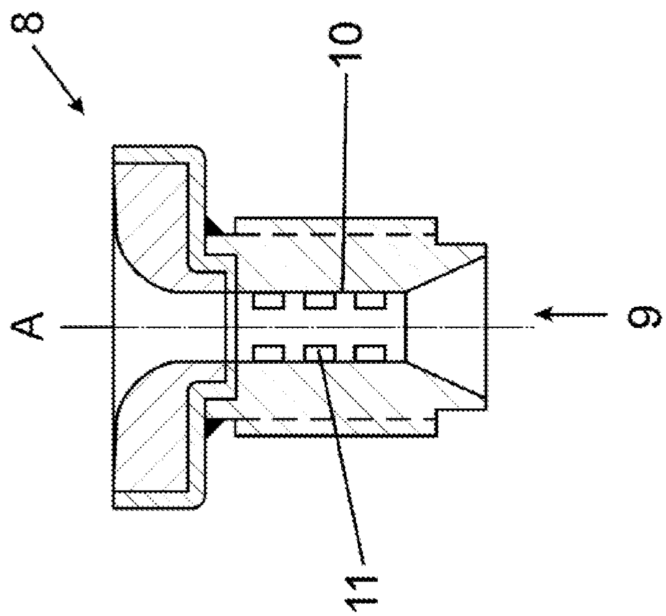


Fig. 3a

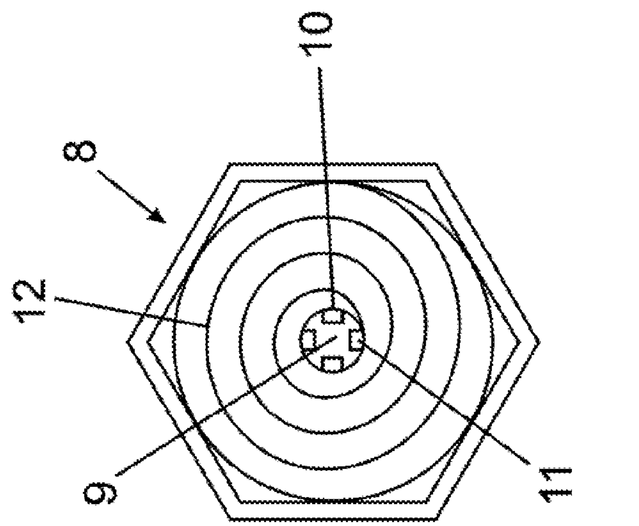


Fig. 4b

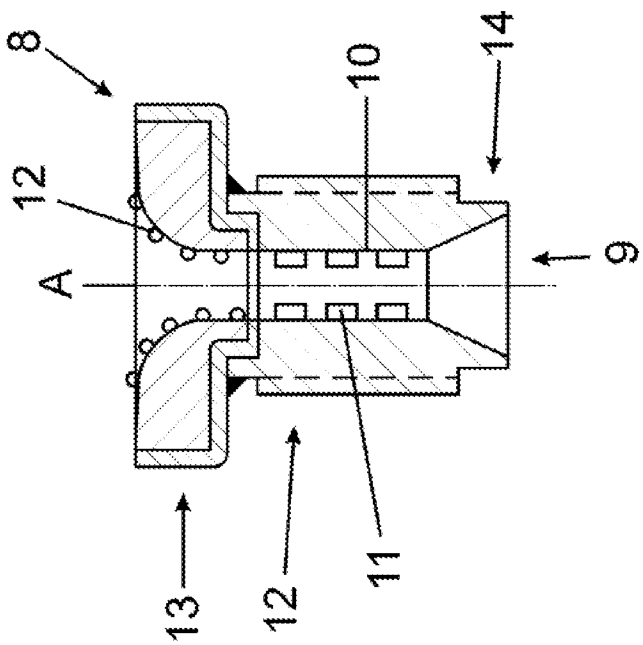


Fig. 4a

SPINNING POSITION, AIR SPINNING MACHINE AND METHOD FOR PRODUCING A YARN

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority from German National Patent Application No. DE 102019111035.1, filed Apr. 29, 2019, entitled "Spinnstelle, Luftspinnmaschine and Verfahren zum Herstellen eines Garns", the entire contents of which are incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention concerns a spinning position and an air spinning machine for producing a yarn from a fed fiber band, comprising an air spinning nozzle with an inlet opening for the fed fiber band and an outlet area with an outlet opening for the spun yarn. Furthermore, the present invention concerns a method for producing a yarn with a modified surface finish. Finally, the present invention concerns the use of a navel in the outlet area of the air spinning nozzle of a spinning position for modifying the surface finish of an air-spun yarn.

BACKGROUND OF THE INVENTION

[0003] Spinning positions and air spinning machines are known from the state of the art in a wide variety of configurations and, in addition to rotor spinning machines, are machines that are frequently used for producing a yarn from a fiber material, in particular from a fiber band fed to the spinning position.

[0004] In air spinning, a sliver or fiber band is typically drafted according to the yarn count to be achieved by means of a drafting system comprising several roller pairs and fed to the air spinning nozzle. Inside the air spinning nozzle, a part of the fed fibers is wound around the parallel fiber core by means of a rotational flow. This results in the air-yarn-specific yarn structure of a parallel yarn core with winding fibers attached at a certain angle, which ensure the strength of the yarn. As there are no mechanical points of contact when the rotation of the fibers is input, air-spun yarn usually has a particularly low hairiness.

[0005] This low hairiness can have a negative effect after further processing into a textile web or a knitted fabric, for example by resulting in a rough feel. The proportion of protruding fibers can generally be influenced by changing the compressed air supplied for setting the spinning pressure and/or by changing the spinning speed. However, when the spinning pressure and/or spinning speed is/are changed, other properties of the air-spun yarn are also negatively influenced, meaning that better hairiness can indeed be achieved, but the yarn properties, such as yarn stability, will deteriorate generally at the same time.

SUMMARY OF THE INVENTION

[0006] The problem addressed by the present invention is therefore one of providing a spinning position, an air spinning machine and a method which allow for the yarn surface finish to be modified advantageously without the yarn properties deteriorating at the same time, while also avoiding expensive and complex modifications to the spinning position.

[0007] According to the present invention, the problem is solved by means of a spinning position according to claim **1**, an air spinning machine according to claim **9**, a method according to claim **10** and through the use of a navel according to claim **11**. Advantageous further developments of the present invention are stated in the dependent claims.

[0008] The spinning position according to the present invention for producing a yarn from a fed fiber band has an air spinning nozzle with an inlet opening for the fed fiber band and an outlet area for the spun yarn which emerges from an outlet opening in the outlet area. Also according to the present invention, a navel is arranged in the outlet area downstream of the outlet opening in the direction of the yarn take-off for modifying the surface finish of the spun yarn.

[0009] An air spinning machine according to the present invention has at least one, preferably several and particularly preferably several identical spinning positions each for producing a yarn from a fed fiber band, in which case the spinning position, of which there is at least one, and preferably all spinning positions are formed according to the present invention.

[0010] In the method according to the present invention for producing a yarn with a modified surface finish, air spinning of a yarn from a fiber band by means of an air spinning nozzle is carried out first, followed by guiding of the air-spun yarn through a navel for modifying the yarn surface, which is preferably carried out in the course of taking the yarn off the air spinning nozzle.

[0011] Finally, the present invention comprises the use of a navel in the outlet area of an air spinning nozzle downstream of an outlet opening in the direction of a yarn take-off for modifying the surface finish of an air-spun yarn in a spinning position or in an air spinning machine, both in particular according to the present invention.

[0012] The inventors have recognized that it is not possible to directly influence the air spinning method, for example by changing the spinning parameters such as the spinning nozzle geometry, the spinning pressure or the spinning speed, without the associated disadvantages in terms of yarn quality. Starting from this position, it is part of the present invention that a surface modification of the air-spun yarn is carried out immediately following the air spinning process, in which case the quality of the air-spun yarn, which is conditional on the spinning method, is not negatively influenced. The present invention thus makes it possible to modify the surface of a spun yarn without intervening in the spinning process, so that firstly the spinning process can be performed with the optimum parameters for this purpose, in particular without taking aspects of the yarn surface finish into account, and subsequently the yarn surface finish can be changed to a desired condition by means of the navel. This enables a significant expansion of the fields of application and the possible uses of air-spun yarn, in particular as knitting yarn with a softer and/or more fibrous or hairy surface, which is advantageous for this purpose.

[0013] The spinning position is any unit of a machine, in particular of an air spinning machine, or an independent device intended to produce a yarn from a fiber material and in particular from a fiber band. Accordingly, an air spinning machine is a device with at least one and preferably several spinning positions, in particular spinning positions that are identical to one another, which are provided in each case for producing a yarn from a fiber material by means of air spinning.

[0014] The air spinning nozzle basically comprises a component intended for forming the yarn, such as a yarn forming element. In particular, the air spinning nozzle can be an assembly of several components of any air spinning device formed for this purpose. The air spinning nozzle is preferably arranged within a spinning position in this case. In addition, the spinning position can have any other components with any functions. For feeding the fiber material to be air-spun, the air spinning nozzle has an inlet opening through which the fiber material, in particular in the form of a fiber band, can preferably be fed continuously.

[0015] Furthermore, the air spinning nozzle has an outlet opening for the finished spun yarn, which is preferably arranged opposite the inlet opening. The outlet opening is arranged in an outlet area of the air spinning nozzle or of a unit having the air spinning nozzle, in which case any other components, in particular for removing the yarn from the air spinning nozzle, can be arranged between the actual air spinning nozzle and the outlet opening, i.e. the area from which the finished air-spun yarn emerges. In a particularly preferable embodiment the outlet opening is a thread channel output at the end of a thread channel assigned to the air spinning nozzle, and in a particularly preferable embodiment the outlet opening is the end of a piecing tube which is arranged downstream of a spinning cone of a yarn forming element of the air spinning nozzle in the yarn take-off direction. Thus the outlet area extends from the outlet opening in the direction in which the finished spun yarn is taken from the air spinning nozzle.

[0016] According to the present invention, the navel is arranged in the outlet area downstream of the outlet opening in the yarn take-off direction. The navel can be arranged both directly behind the outlet opening, and in that case in particular directly at a thread channel output or a piecing tube, as well as at a distance from that between the outlet opening and a winding device for winding the air-spun yarn. However, it is preferable for the navel to be the component closest to the outlet opening in the direction of the yarn take-off, i.e. preferably at least no functional component or component acting on the finished spun yarn is arranged between the outlet opening and the navel, preferably with the exception of one or more yarn guiding elements in this area. Furthermore, it is preferable for the navel to be arranged in a locationally fixed and/or rotationally fixed manner at the outlet opening or in the outlet area.

[0017] The navel can basically be formed from any material and from any number of components. Preferably, at least the area of the navel that comes into contact with the yarn, and particularly preferably the entire navel, is formed from ceramic and/or in one piece. Furthermore, the navel preferably has, at least in sections and preferably completely, a conical or conically tapered and/or cylindrical shape.

[0018] The size and/or geometry of the navel is also preferably adapted to the spun yarn that is to be modified. The inner diameter of the navel or a nozzle opening is preferably between 0.5 mm and 2.5 mm, particularly preferably between 1 mm and 1.5 mm and even more particularly preferably between 1.1 mm and 1.3 mm. Furthermore, the length of the navel or the nozzle opening for taking up the yarn is preferably at least the diameter of the nozzle opening, particularly preferably at least twice the diameter and even more particularly preferably between twice the diameter and ten times the diameter of the nozzle opening. The cross-section of the nozzle opening of the navel can basically be of any shape, although an essentially round cross-section is preferable.

[0019] According to the present invention, the navel causes an advantageous surface modification of the air-spun yarn, in which case the surface modification is preferably carried out essentially by friction on the navel surface. The modification of the surface finish preferably includes creating a puffed and/or hairy yarn surface. For this purpose, it is particularly preferable for fiber ends to be created which protrude from the surface of the yarn. The modification of the yarn surface takes place in particular immediately after the air spinning process, i.e. the navel preferably influences the air-spun yarn and in particular its surface finish directly when or after leaving the air spinning nozzle. For this purpose, the spun yarn preferably runs through the navel when it is taken from the air spinning nozzle, and there the desired influence is applied to the yarn surface.

[0020] Furthermore, the yarn preferably runs behind the navel over at least one and preferably several take-up rollers and/or through at least one thread monitor and/or through at least one thread clearer and/or over at least one thread guide. The yarn is then preferably wound onto a package.

[0021] In a preferable configuration of the spinning position according to the present invention, the navel has a nozzle opening for all-around take-up of the air-spun yarn, in which case particularly advantageous contact can be achieved between the yarn surface and the surface of the navel, and thus particularly effective interaction. An all-around take-up is defined as contact between the nozzle surface of the navel and the yarn surface, in which at least one section of the yarn in the navel is in contact with the nozzle surface on essentially all sides or over the entire circumference.

[0022] As per an advantageous further development of the spinning position according to the present invention, the navel, preferably in the area of the nozzle opening and/or in an area coming into contact with a surface of the air-spun yarn, has a structured nozzle surface for mechanical interaction with the surface of the yarn to be modified, thus enabling particularly intensive and effective mechanical interaction. Different degrees and/or forms of structuring are basically possible in this case, in particular depending on the desired surface modification or the surface modification to be obtained as well as depending on the fiber material used in air spinning and/or the thickness of the air-spun yarn. In particular, the navel preferably has several differently structured areas in order to achieve an optimum surface modification. The area of the navel that comes into contact with the yarn surface is particularly preferably a wall area on the inside of the nozzle opening, which is also referred to as the nozzle surface.

[0023] As per a particularly advantageous further development of the spinning position according to the present invention, structure elements protruding from the nozzle surface for intensified mechanical interaction with the yarn surface to be modified are arranged in the navel in the area of the nozzle opening, in particular on the structured nozzle surface, by means of which the navel can be adapted in a particularly straightforward manner to the specifically required modification of the yarn surface. The structure elements in this case protrude from the remainder of the nozzle surface and/or opposite a cylindrical base surface of the nozzle opening. The structure elements on the nozzle surface can basically be arranged in a non-ordered or ordered manner, in particular within a grid. The inner diameter of the navel or the diameter of the nozzle opening is preferably selected in such a way that the yarn surface to be modified comes into contact at least with the surfaces of the structure elements. It is particularly preferable for at least contact on all sides of the yarn surface to be modified to be achieved with the surfaces of the structure elements. This contact can be exclusively with the structure elements protruding from the nozzle surface or simultaneously with the remainder of the nozzle surface.

[0024] The structure elements can basically be formed as elevations of any shape. Preferably, the structure elements protruding from the nozzle surface are formed as a spiral, rings, crosses, notches, grooves, squares, circles, dots and/or other elevations, in which case the desired properties of the yarn surface can be adjusted in a straightforward manner. All structure elements, however at least those of an area or zone, preferably have a shape, height, size, length and/or width that is/are identical to one another. It is even more particularly preferable for all structure elements, at least those of an area or zone, to be formed identically to one another. However, several different structure elements can also be arranged in one area or zone at the same time. In the case that several different structure elements are arranged, these can be arranged both randomly next to one another as well as according to a defined pattern, for example two different structure elements alternating in at least one spatial direction, in particular along the circumference and/or parallel to the central longitudinal axis of the nozzle opening.

[0025] The respective shape of the structure elements protruding from the nozzle surface, for example a cross shape, can relate to the shape of the individual structure element protruding from the surface, i.e. along both directions on the surface of the nozzle opening or on a wall of the navel delimiting the nozzle opening. Alternatively, the respective shape can also basically relate to the shape of the entire nozzle opening, which is formed in particular in this case by several structure elements arranged along the circumference of the nozzle opening, in which case the resulting shape that is particularly preferable is then in a direction along a cross-sectional plane through the nozzle opening, in particular normal to the central longitudinal axis of the nozzle opening.

[0026] In the case of an advantageous configuration of the spinning position according to the present invention, protruding structure elements differing from one another are arranged in several zones on the nozzle surface, each of the zones preferably extending over the entire circumference of the nozzle surface and/or the zones being arranged one behind the other in the nozzle opening, in particular along the central longitudinal axis of the nozzle opening, thus enabling an even more precise and effective modification of the yarn surface. A configuration in which the nozzle opening is divided along the central longitudinal axis into at least two zones is even more particularly preferable, the first zone comprising a first shape of the protruding structure elements and/or a constant cross-section of the nozzle opening and the second zone having a different shape of the protruding structure elements and/or a conically widening cross-section of the nozzle opening.

[0027] In another advantageous configuration of the spinning position according to the present invention, the navel is fixed so as to be rotatable, in particular about the central longitudinal axis of the nozzle opening, as a result of which the yarn taken from the air spinning nozzle can be drawn or moved through a rotating navel, leading to even stronger interaction with the air-spun yarn, which can be regulated during operation of the spinning position, and thus an even more effective modification of the yarn surface can be achieved in a particularly advantageous manner.

[0028] Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating the preferred embodiments of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] Several embodiment examples of a spinning position according to the present invention, each with different navels, are explained in more detail below with reference to the drawings. In the drawings:

[0030] FIG. **1** shows a schematic view of a spinning position of an air spinning machine with a navel arranged behind an air spinning nozzle,

[0031] FIG. **2***a* shows a lateral sectional view of a first embodiment of a navel,

[0032] FIG. **2***b* shows a view of the rear of the navel depicted in FIG. **2***a*,

[0033] FIG. **3***a* shows a lateral sectional view of a second embodiment of a navel,

[0034] FIG. **3***b* shows a view of the rear of the navel depicted in FIG. **3***a*,

[0035] FIG. **4***a* shows a lateral sectional view of a third embodiment of a navel, and

[0036] FIG. **4***b* shows a view of the rear of the navel depicted in FIG. **4***a*.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0037] The following description of the embodiments of the present invention is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses. The following description is provided herein solely by way of example for purposes of providing an enabling disclosure of the invention, but does not limit the scope or substance of the invention.

[0038] At a spinning position **1** of an air spinning machine depicted in FIG. **1**, a fiber band **3** is fed to an air spinning nozzle **4** and spun into a yarn **2** here. For this purpose, the fiber band **3** is first stretched by means of a drafting system **16** and then fed to the air spinning nozzle **4** through an inlet opening **5**. In the area of the air spinning nozzle **4**, there is a blowing air nozzle **18** which swirls the fibers lying outside in the fiber band **3** around fibers in the center of the fiber band **3** and thus forms a yarn **2** by means of the yarn forming element **17**. For this purpose, the spinning position **1** has a compressed air system **20** with a compressed air source **21** and a control unit **22**.

[0039] The yarn **2** produced in this way is then guided from the air spinning nozzle **4** through a thread channel of the yarn forming element **17** to an outlet opening **7** in an outlet area **6** in order to be wound up subsequently. A navel **8** is also arranged in the outlet area **6** downstream of the outlet opening **7** in the yarn take-off direction, through which navel **8** the finished air-spun yarn **2** is drawn by means of a thread take-off device **19** of the spinning position **1**. The thread take-off device **19** can be, in particular, a roller pair or take-off roller downstream of the navel **8** in the yarn take-off direction or, in addition alternatively, the thread take-off device **19** can be the winding device for winding a take-up package such as a cross-wound package.

[0040] The navel **8** is provided to modify the surface finish of the finished yarn **2** spun in the air spinning nozzle **4**, thus generating a softer yarn surface and increased hairiness of the yarn **2**, which makes it more suitable as a knitting yarn and allows the production of fabrics with a more pleasant feel.

[0041] For this purpose, a first embodiment of a navel **8** depicted in FIG. **2***a, b* has a nozzle opening **9** through which the finished air-spun yarn **2** is taken, the diameter of the nozzle opening **9** being adapted to the diameter of the yarn **2** drawn through it in such a way that the surface of the yarn **2** can be modified by mechanical interaction and, in particular, by the friction occurring when the yarn **2** is drawn through. The nozzle opening **9** is arranged centrally in the navel **8** in this case.

[0042] For this purpose, the navel **8** has a structured, in particular a roughened nozzle surface **10** in at least one zone on the wall of the nozzle opening **9** which comes into contact with the yarn **2**. The zone with a structured nozzle surface **10** has a constant diameter over the entire length, which is adapted to the diameter of the yarn **2** to be modified. Furthermore, the wall in the nozzle opening **9** is rotationally symmetrical to the central longitudinal axis A of the navel **8**, so that the navel **8** can be used both in a stationary arrangement and without rotation, as well as rotating about the central longitudinal axis A.

[0043] In front of this zone with a structured nozzle surface **10**, there is an input zone **14** in the yarn take-off direction with a conically narrowing round cross-section (see FIG. **2***a*), which allows the air-spun yarn **2** to run into the navel **8** in a particularly straightforward manner, and advantageously prevents the yarn **2** from tearing. This input zone **14** has a smooth, non-structured nozzle surface **23**, in which interaction with the air-spun yarn **2**, especially the friction, is particularly low.

[0044] A further zone **13** is arranged in the yarn take-off direction behind the zone with a structured nozzle surface **10**, the cross-section of which zone **13** widens in a non-linear manner, in particular exponentially, and is also round. The nozzle surface **23** is also smooth and unstructured in this embodiment of the navel **8**.

[0045] A second embodiment of a navel **8** depicted in FIG. **3***a, b* basically differs from the first embodiment in that identical structure elements **11** protruding from the nozzle surface **10** and forming the structure of the nozzle surface **10** are arranged in the nozzle opening **9** in the area of the first zone **13**. In this case, the structure elements **11** are arranged in a grid and have the shape of cuboids protruding from the nozzle surface **10**, i.e. a rectangular shape. These structure elements **11** protruding from the nozzle surface **10** enable an intensification of the interaction between the surface of the air-spun yarn **2** to be modified and the wall of the nozzle opening **9**.

[0046] A third embodiment of a navel **8** depicted in FIG. **4***a, b* basically differs from the embodiment depicted in FIG. **3***a, b* in that in the second zone **14** of the nozzle opening **9**, which is arranged downstream of the first zone **13** with a structured nozzle surface **10** in the yarn take-off direction, a structured surface of the nozzle opening **9** is also provided, which is a second structure element **12** in the form of a spiral protruding from the nozzle surface.

[0047] By means of the spinning position **1**, and in particular by means of an air spinning machine with several identical spinning positions **1**, an air-spun yarn **2** can be produced in a particularly straightforward manner and without negative influence on the spinning process and the spinning result, which air-spun yarn **2** has significantly better surface properties than a conventionally air-spun yarn and can therefore be used in a much more versatile manner.

[0048] To produce an air-spun yarn **2** with a modified surface finish, a fiber band **3** is first stretched in a drafting system **16** and then fed to an inlet opening **5** of an air spinning nozzle **4**, where the fiber band **3** is spun into a yarn **2**. The spinning position **1** is controlled by means of a control unit **22** to form an optimum yarn **2**. The finished spun yarn **2** leaves the air spinning nozzle **4** through a spinning cone **17** and is then drawn through a navel **8** by means of a thread take-off device **19** with several take-up rollers in order to modify the yarn surface or the surface finish of the yarn **2**, thereby in particular creating increased hairiness of the yarn surface.

[0049] Downstream of the navel **8** and, if applicable, also the thread take-off device **19**, the yarn **2** runs through at least one thread monitor and through a thread clearer. The yarn **2** is then wound onto a package.

LIST OF REFERENCE SIGNS

[0050] **1** Spinning position
[0051] **2** Yarn
[0052] **3** Fiber band
[0053] **4** Air spinning nozzle
[0054] **5** Inlet opening
[0055] **6** Outlet area
[0056] **7** Outlet opening
[0057] **8** Navel
[0058] **9** Nozzle opening
[0059] **10** Structured nozzle surface
[0060] **11** Structure element
[0061] **12** Second structure element
[0062] **13** First zone
[0063] **14** Second zone
[0064] **16** Drafting system
[0065] **17** Yarn forming element
[0066] **18** Blowing air nozzle
[0067] **19** Thread take-off device
[0068] **20** Compressed air system
[0069] **21** Compressed air source
[0070] **22** Control unit
[0071] **23** Smooth nozzle surface
[0072] A Central longitudinal axis

[0073] It will therefore be readily understood by those persons skilled in the art that the present invention is susceptible of broad utility and application. Many embodiments and adaptations of the present invention other than those herein described, as well as many variations, modifications and equivalent arrangements, will be apparent from or reasonably suggested by the present invention and the foregoing description thereof, without departing from the substance or scope of the present invention. Accordingly, while the present invention has been described herein in detail in relation to its preferred embodiment, it is to be understood that this disclosure is only illustrative and exemplary of the present invention and is made merely for purposes of providing a full and enabling disclosure of the invention. The foregoing disclosure is not intended or to be construed to limit the present invention or otherwise to exclude any such other embodiments, adaptations, variations, modifications and equivalent arrangements.

What is claimed is:

1. A spinning position for producing a yarn from a fed fiber band, with an air spinning nozzle with an inlet opening for the fed fiber band and an outlet area with an outlet opening for the air-spun yarn,

characterized in that

a navel is arranged in the outlet area downstream of the outlet opening in the yarn take-off direction for modifying the surface finish of the spun yarn.

2. The spinning position according to claim **1**, characterized in that the navel has a nozzle opening for all-around take-up of the air-spun yarn.

3. The spinning position according to claim **1**, characterized in that the navel has a structured nozzle surface in the area of the nozzle opening for mechanical interaction with the surface of the yarn to be modified.

4. The spinning position according to claim **1**, characterized in that structure elements protruding from the nozzle surface are arranged in the area of the nozzle opening for intensified mechanical interaction with the yarn surface to be modified.

5. The spinning position according to claim **1**, characterized in that the structure elements protruding from the nozzle surface are formed as a spiral, rings, crosses, notches, grooves, squares, circles, dots, other elevations, or a combination.

6. The spinning position according to claim **1**, characterized in that several zones of protruding structure elements differing from one another are arranged on the nozzle surface, each of the zones extending over the entire circumference of the nozzle surface and/or the zones being arranged one behind the other in the nozzle opening.

7. The spinning position according to claim **1**, characterized in that the nozzle opening is divided along the central longitudinal axis into at least two zones, the first zone comprising a first shape of the protruding structure elements and/or a constant cross-section of the nozzle opening and the second zone having a different shape of the protruding structure elements and/or a conically widening cross-section of the nozzle opening.

8. The spinning position according to claim **1**, characterized in that the navel is fixed so as to be rotatable about the central longitudinal axis of the nozzle opening.

9. An air spinning machine with at least one spinning position according to claim **1** for producing a yarn from a fed fiber band.

10. A method for producing a yarn with a modified surface finish, comprising:

air spinning of a yarn from a fiber band by an air spinning nozzle, and

guiding of the air-spun yarn through a navel for modifying the yarn surface as the air-spun yarn is taken from the air spinning nozzle.

11. A method of using a navel in the outlet area behind an outlet opening of an air spinning nozzle of a spinning position according to claim **1** for modifying the surface finish of an air-spun yarn.

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(54) APRON DRAFTING SYSTEMS

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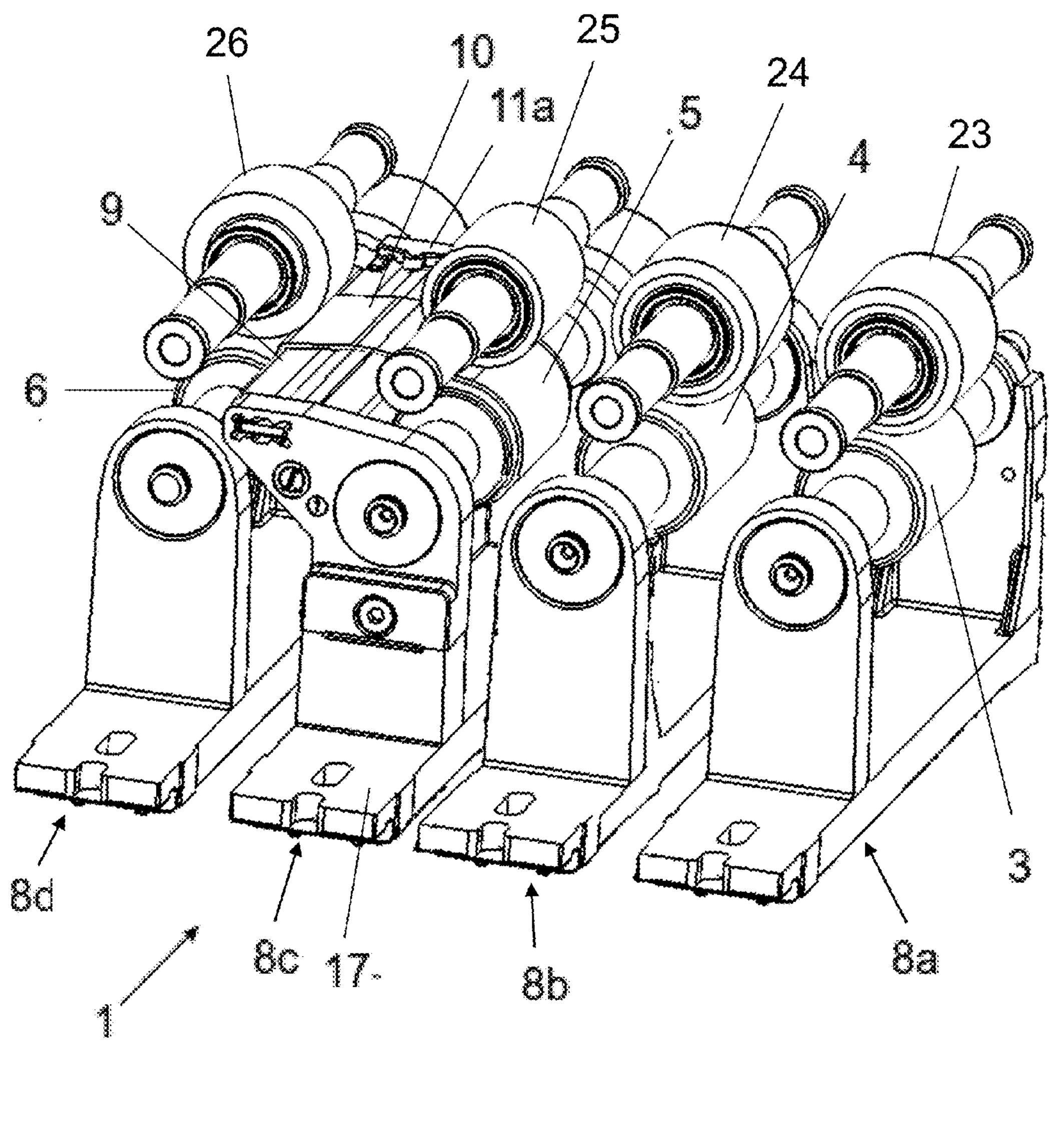
(57) **ABSTRACT**

An apron drafting system for a spinning machine, in particular an air spinning machine, with a bottom apron guided over a drivable bottom roller, the bottom apron being supported in the area of a drawing zone, in particular a main drawing zone, by a sliding section of an apron bridge. In order to provide an apron drafting system in which reliable guidance of the bottom apron is ensured while maintaining a high drive power, there is provision for the apron bridge for guiding the bottom apron to have a line section with guiding means for lateral guidance of the bottom apron circulating around the apron bridge.



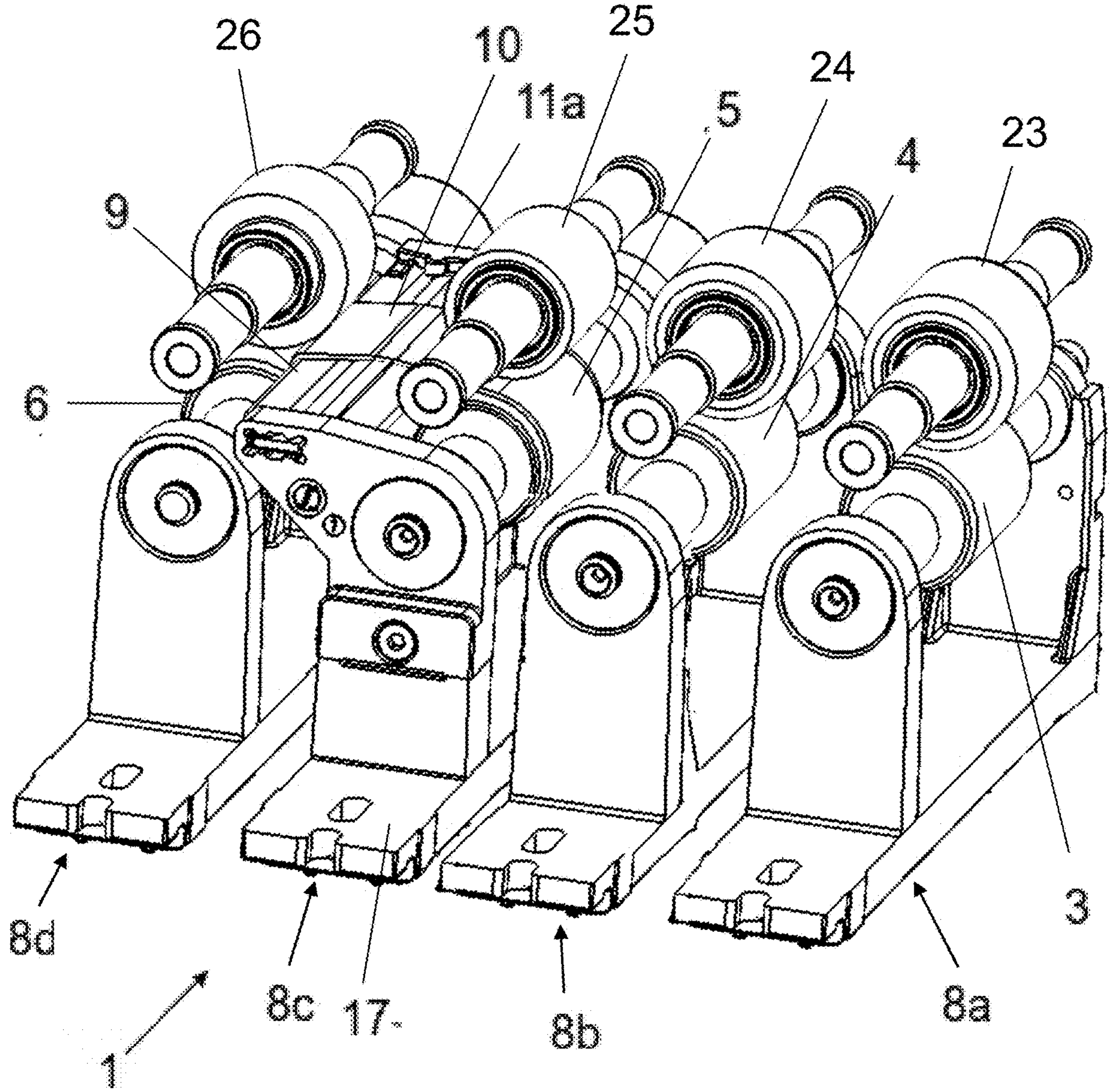


FIG. 1

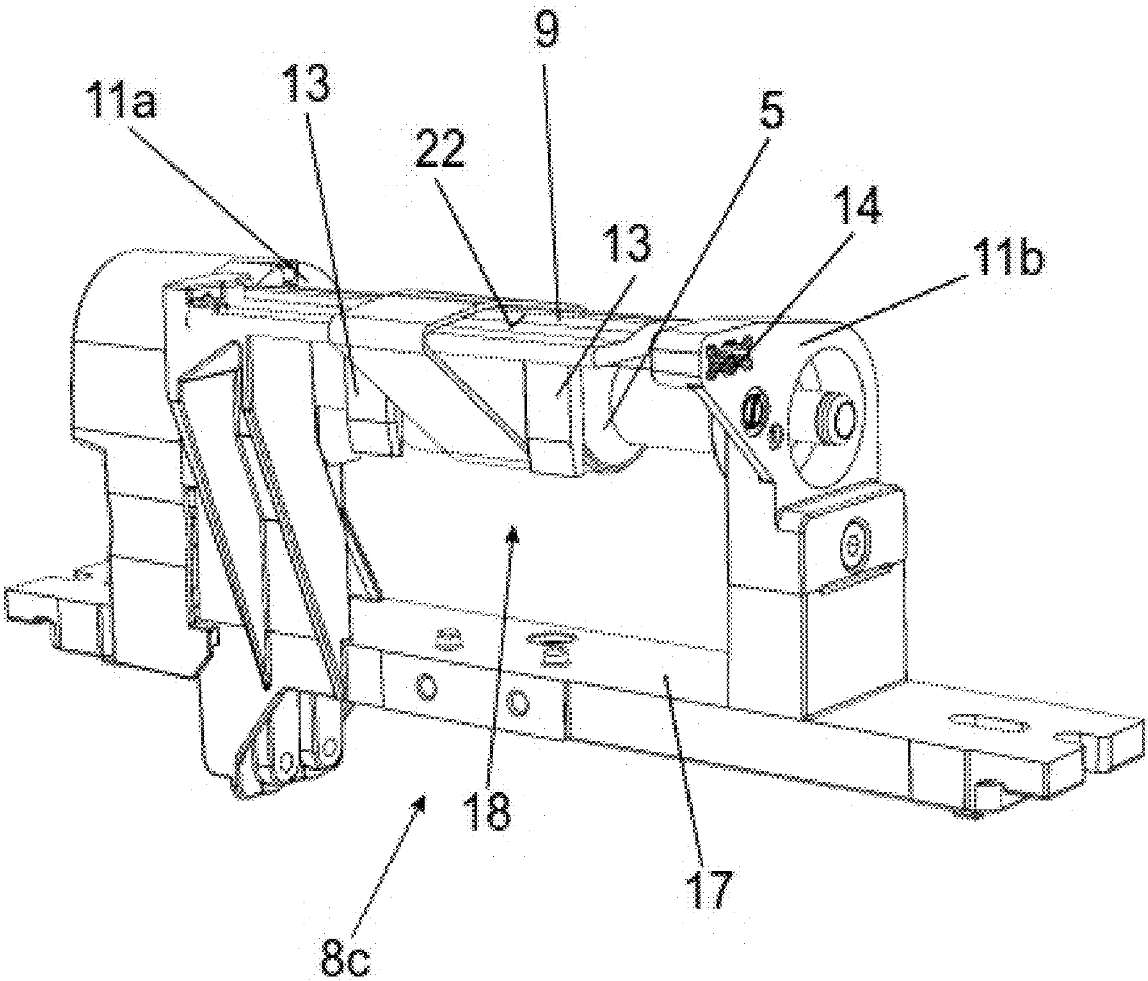


FIG. 2

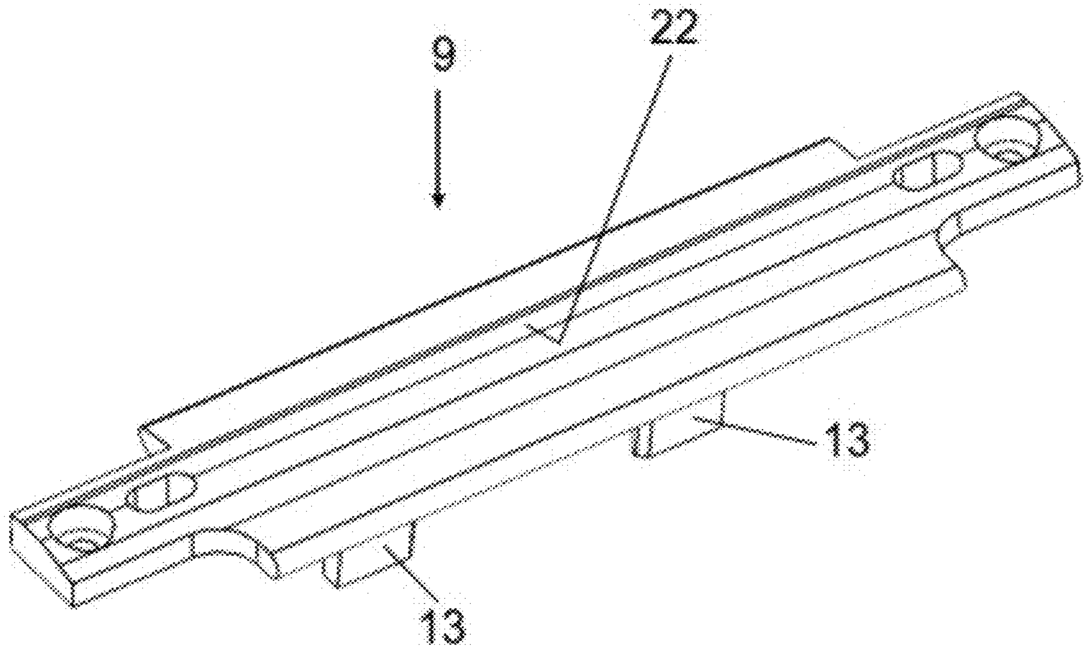


FIG. 3

APRON DRAFTING SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority from German National Patent Application No. DE 102019110881.0, filed Apr. 26, 2019, entitled "Riemchenstreckwerk", the entire contents of which are incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to an apron drafting system for a spinning machine, in particular an air spinning machine, with a bottom apron guided over a drivable bottom roller, the bottom apron being supported in the area of a drawing zone, in particular a main drawing zone, by a sliding section of an apron bridge.

BACKGROUND OF THE INVENTION

[0003] Drafting systems of various embodiments for spinning machines are known from the prior art. They are used to draft or draw a fiber band, in which case the cross-section of the fibers is reduced. During the drawing, the fibers must be slid next to each other as uniformly as possible so that a uniform fiber band is achieved, which is a prerequisite for producing a uniform yarn. In order to draft the fiber band, the drafting systems generally have a plurality of roller pairs arranged one after the other, which roller pairs, arranged lying on each other, clamp the fiber band running between them. A roller pair usually consists of a driven bottom roller and a top pressure roller lying on the bottom roller. Drawing of the fiber band is achieved in that the circumferential speed increases from roller pair to roller pair in the transporting direction of the fiber band defined by the direction of rotation of the roller pairs.

[0004] Since the fibers of the fiber bundle lose their cohesion, especially in the main drawing zone where the fiber band is drawn with high drawing values, drafting systems implemented as apron drafting systems of the type mentioned above have already been disclosed, in which the fiber band is passed through aprons between the clamping lines of the two drawing roller pairs. What are referred to as double apron drafting systems are particularly widespread in this context, in which one apron each is guided around a first top and bottom roller in the area of the main drawing zone and is deflected by a deflecting device from the fiber guidance direction towards the second roller pair into the return direction, so that the fiber band is guided between the top and bottom apron.

[0005] Usually, the aprons, which are configured as an endless band, are guided at least around the drivable bottom roller, a deflecting device and a tensioning apparatus which keeps the bottom apron at the pretension required for operation. The bottom apron can be driven via the drivable bottom roller, in which case the transmission of the drive torque from the roller to the apron is usually ensured by a frictional connection with a top apron or a top roller.

[0006] An essential factor in the yarn quality is the fiber guidance of the fiber band or the drawing quality, in which case a uniformly spun yarn is achieved by uniform drawing of the fiber band. Due to the main drawing in an apron drafting system in the area of the apron guide, perfect guidance in this area is of decisive importance. It has already been disclosed in European Patent Publication EP 2 034 060 that guidance is ensured by an apron tensioning apparatus with a tensioning arm and a weighting device. However, this apron tensioning apparatus has the disadvantage that it leads to a loss of drive power.

SUMMARY OF THE INVENTION

[0007] Based on this, the problem addressed by the present invention is that of providing an apron drafting system in which reliable guidance of the bottom apron is ensured while maintaining a high drive power.

[0008] The problem is solved by the present invention by an apron drafting system having the features as set forth herein.

[0009] Advantageous further developments of the present invention are also stated herein.

[0010] It is characteristic of the apron drafting system according to the present invention that the apron bridge for guiding the bottom apron has a line section with guiding means for lateral guidance of the bottom apron circulating around the apron bridge.

[0011] The bottom apron, which is guided around the drivable bottom roller, is supported by the apron bridge which prevents the bottom apron from diverting downwards, especially in the area of the main drawing zone. In the area of contact with a top roller or a top apron, the bottom apron is guided over a sliding section of the apron bridge on which the bottom apron is thus supported in the area of the drawing zone. According to the present invention, the apron bridge also has a line section which is provided with guiding means for the purpose of lateral guidance of the bottom apron circulating around the apron bridge. The guiding means ensure that the bottom apron is held so as to run centrally in an area deviating from the sliding section, so that the bottom apron is reliably prevented from running off to the side, which would lead to losses of quality in the yarn to be produced.

[0012] The configuration of the line section on the apron bridge allows additional components to be dispensed with, so that the apron drafting system can be manufactured particularly easily and cost-effectively. In addition, the guiding means guiding the bottom apron laterally ensure minimal friction, so that any loss of drive power is excluded or minimized.

[0013] The embodiment of the guiding means on the apron bridge also makes it possible to dispense with separate guiding devices which would increase the complexity of the apron drafting system. The apron drafting system according to the present invention is thus characterized by its simplicity and compactness, which makes it possible to ensure that the bottom apron circulates reliably even without a device for tensioning the bottom apron, in which case production tolerances of the bottom apron also do not negatively influence the functioning.

[0014] The embodiment of the guiding means for guiding the bottom apron is basically freely selectable. According to a particularly advantageous embodiment of the present invention, however, there is provision for the apron bridge to have two guide bars arranged at a distance from one another and laterally enclosing the bottom apron in the area of the line section.

[0015] The use of guide bars is characterized by the fact that they can be configured in a particularly simple way on the apron bridge. These are arranged in any area of the apron bridge in such a way that they laterally enclose a bottom apron circulating around the apron bridge and thus prevent the bottom apron from diverting to the side. The guide bars can, for example, be configured as one-piece pins configured with the apron bridge, the distance between them essentially corresponding to the width of the circulating bottom apron. The line section configured by means of the guide bars can be configured at any point on the apron bridge, in which case the particularly preferable arrangement is on an underside of the apron bridge opposite the sliding section in the return area of the bottom apron.

[0016] The embodiment of the guide bars is basically freely selectable. For example, these can be made of a special ceramic or plastic material which has a low coefficient of friction for the circulating bottom apron. According to a particularly advantageous embodiment of the present invention, however, there is provision for the guide bars to have a sliding coating in the area of contact with the bottom apron. This embodiment of the present invention makes it possible to implement the apron bridge with the guide bars independently of any sliding properties and then to adapt the guide bars optimally to the bottom apron by applying a suitable coating to the guide bars.

[0017] The guide bars can basically be connected directly to an underside of the apron bridge. According to a particularly advantageous embodiment of the present invention, however, there is provision for the guide bars to be arranged on a stabilizing bar which runs along an area of the apron bridge opposite the sliding section. The use of a stabilizing bar increases the strength of the apron bridge in a complementary way and thus particularly reliably ensures that the circulating bottom apron is sufficiently supported. Furthermore, the use of the stabilizing bar offers the possibility of a particularly reliable arrangement of the guide bars, thus ensuring reliable operation.

[0018] According to a further embodiment of the present invention, there is provision for adjustment of: a drafting system carriage with the bottom roller, the bottom apron and the apron bridge and/or the apron bridge in relation to the drafting system carriage, transversely to the circumferential direction of the bottom apron.

[0019] Since the bottom apron has to be pressed against a top apron or top roller, if there is one, for drafting a fiber band, in particular in the area of the main drawing zone, wear occurs on the surfaces in contact with the fiber bands as a result of friction. As wear progresses, the quality of the spun yarn is increasingly negatively influenced, which leads to considerable disadvantages, in particular in the case of high-drawing drafting systems, meaning that the aprons have to be replaced often.

[0020] The possibility of adjusting the apron bridge transversely to the circumferential direction of the bottom apron, as described in the further development of the present invention above, enables a traversing movement of the bottom apron transversely to the running direction of the fiber band. A traversing movement leads to uniform wear on the surface of the bottom apron and thus, compared to non-adjustable bottom aprons, ensures a consistently high quality of the produced yarn over a relatively long period of use of the bottom apron.

[0021] In the case of an adjustment movement of the apron bridge in relation to the drafting system carriage bearing it, the apron bridge is adjustably mounted in a corresponding manner on the drafting system carriage on which, among other things, the bottom roller and the bottom apron are arranged. An adjustment movement of the apron bridge transversely to the running direction of the fiber band can also be achieved by mounting the entire drafting system carriage on the apron drafting system in such a way that it can be adjusted transversely to the running direction of the fiber band.

[0022] The traversing movement of the apron bridge can also cause the rubbing effect on the fiber bundle, which has a positive influence on the tear resistance of the roving and the yarn because the individual fibers in the roving adopt a denser and less ordered position, so that the contact surfaces grow larger and the tensile strength of the roving also increases accordingly.

[0023] For an adjustment movement of the line section of the apron bridge for lateral adjustment of the bottom apron via the guiding means, on the one hand the apron bridge can be adjusted in relation to the drafting system carriage and/or the drafting system carriage of the drafting system can be adjusted in its entirety transversely to the running direction of the fiber band. According to an advantageous further development of the present invention, there is provision for the apron bridge and/or the drafting system carriage to be connected to an adjusting drive for adjustment of the apron bridge in relation to the drafting system carriage and/or of the drafting system carriage transversely to the circumferential direction of the bottom apron.

[0024] The adjusting drive can thus be used for a convenient adjustment of the apron bridge in relation to the drafting system carriage or of the drafting system carriage in relation to the apron drafting system, so that the bottom apron is moved laterally back and forth by shifting the line section. The use of an adjusting drive allows the traversing speed, which is decisive for the quality of the method, to be optimally adapted to the fiber band to be drafted. In this way, an excessively high traversing speed, which leads to a reduction in the strength of the roving, can be reliably avoided, while in addition to the traversing speed, the traversing breadth, which is also decisive for the quality of the method, can also be reliably defined via the adjusting drive.

[0025] The adjusting drive thus permits optimal adaptation of the traversing breadth and traversing speed, so that no losses of quality occur in the roving, while at the same time wear on the bottom apron is significantly reduced compared to a traversing movement that does not take place.

[0026] According to a particularly advantageous embodiment of the present invention, there is provision for the adjusting drive to be connected to a control device for defining the adjustment movement of the drafting system carriage and/or the apron bridge, in particular for defining the adjustment length and the adjustment frequency.

[0027] Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating the preferred embodiments of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] The present invention will become more fully understood from the detailed description and the accompanying drawings wherein:

[0029] FIG. **1** shows a perspective view of a roller pair arrangement of an apron drafting system according to an embodiment example;

[0030] FIG. **2** shows a perspective view of a drafting system carriage of the apron drafting system of FIG. **1** according to an embodiment example;

[0031] FIG. **3** shows a perspective view of an apron bridge of the drafting system carriage of FIG. **2**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0032] The following description of the embodiments of the present invention is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses. The following description is provided herein solely by way of example for purposes of providing an enabling disclosure of the invention, but does not limit the scope or substance of the invention.

[0033] FIG. **1** depicts a perspective representation of a roller pair arrangement **1** of an apron drafting system which can be assigned to a spinning position (not depicted here) of a textile machine, which apron drafting system can be fixed to the textile machine. The roller pair arrangement **1** has four first to fourth top rollers **23**, **24**, **25**, **26** arranged one behind the other in the running direction of a fiber band not depicted here running through the roller pair arrangement **1**, which are opposite corresponding, drivable first to fourth bottom rollers **3**, **4**, **5**, **6**. The first to fourth bottom rollers **3**, **4**, **5**, **6** include the infeed roller **3**, which is the first to come into contact with the fiber band, can be driven by a roller drive and represents the first bottom roller of the roller pair arrangement **1**. The infeed roller **3** can be arranged together with the roller drive on a first drafting system carriage **8***a*.

[0034] A first drawing roller **4** is installed downstream of the infeed roller **3** in the fiber band running direction and is arranged on a second drafting system carriage **8***b*. A second drawing roller **5** follows the drawing roller **4** in the fiber band running direction and is arranged on a third drafting system carriage **8***c*. The first **4** and second drawing roller **5** can each be coupled with their own roller drive, which can also be arranged on the corresponding second **8***b* or third drafting system carriage **8***c*.

[0035] The second drawing roller **5** does not come into direct contact with a fiber band to be drawn, but has a bottom apron **10** circulating around the drawing roller **5** and coming into contact with the fiber band. The bottom apron **10** is implemented as an endless band and, in addition to the second drawing roller **5**, also circulates around an apron bridge **9** arranged on supports **11***a*, **11** *b* of the third drafting system carriage **8***c*, in which case the supports **11***a*, **11***b* are arranged on a basic body **17**. In the area of the third drafting system carriage **8***c*, the bottom apron **10** rests against a sliding section **22** of the apron bridge **9** facing the bottom apron **10**. The bottom apron **10** is supported via the sliding section **22**, so that the bottom apron **10** cannot divert in the direction of the third drafting system carriage **8***c* (see FIGS. **2** and **3**).

[0036] On the side opposite the sliding section **22**, the apron bridge **9** has two guide bars **13** which project at a distance from one another from an underside and form a line section **18**, which rest against the side of the bottom apron **10** and serve as guiding means for the bottom apron **10**. The guide bars **13** are in contact with a bar **12** arranged on the underside in the longitudinal axis direction of the apron bridge **9**, which stabilizes the apron bridge **9**.

[0037] The apron bridge **9** itself is moveably mounted on the support **11***a* and in a receptacle **14** of the support **11***b*, so that the apron bridge **9** can be adjusted transversely to the fiber running direction or to the running direction of the bottom apron **10** via an adjusting drive (not depicted here) for the apron bridge **9**. A traversing movement of the bottom apron **10** can thus be performed via the guide bars **13** resting against the bottom apron **10**, in which case a control device (not depicted here) connected to the actuating drive defines the traversing speed as well as the traversing breadth.

[0038] The fiber band drafted in the roller pair arrangement **1** passes over an outfeed roller **6**, which is arranged on a fourth drafting system carriage **8***d*, into a spinning unit (not depicted here), which follows the drafting system **1**. The first to fourth drafting system carriages **8***a*, **8***b*, **8***c*, **8***d* can be arranged on a frame (not depicted) of the apron drafting system by means of suitable attachment points.

[0039] In an embodiment example not depicted here, an adjustment of the third drafting system carriage **8***c* transversely to the circulating direction of the bottom apron **10** or the fiber running direction is provided in addition to or as an alternative to the adjustment of the apron bridge **9** in relation to the third drafting system carriage **8***c*. The adjustment of the third drafting system carriage **8***c* can be carried out by means of an adjusting drive according to a preferable embodiment example, in which case the adjustment of the third drafting system carriage **8***c* can ideally be guided via at least one slot and a guide element projecting into it. In this way, a slot that can be provided in the drafting system carriage for fine adjustment of its position can be used in a simple manner for the traversing movement of the drafting system carriage. Drafting system carriages configured in this manner can therefore be used for an apron drafting system either with or without a traversing movement of the bottom apron. In order to improve the guiding stability, more than one slot can be provided in a particularly preferable embodiment.

[0040] In a further embodiment example not depicted here, the bottom apron is arranged in the same or a similar way in what is referred to as a pre-drawing field in addition to or as an alternative to the arrangement depicted in a main drawing field, this pre-drawing field being located upstream of the main drawing field in the transporting direction of the fiber band and being configured between two roller pairs lying in the transporting direction of the fiber band, which have rotational speeds that differ from one another. In this case too, traversing of the bottom apron can be carried out in a further preferable manner in the same or a similar way.

LIST OF REFERENCE SIGNS

[0041] **1** Roller pair arrangement

[0042] **3** Infeed roller

[0043] **4** First drawing roller

[0044] **5** Second drawing roller

[0045] **6** Outfeed roller

[0046] **8***a* First drafting system carriage (for the infeed roller)

[0047] **8***b* Second drafting system carriage (for the first drawing roller)

[0048] **8***c* Third drafting system carriage (for the second drawing roller)

[0049] **8***d* Fourth drafting system carriage (for the outfeed roller)
[0050] **9** Apron bridge
[0051] **10** Bottom apron
[0052] **11***a* Support
[0053] **11***b* Support
[0054] **12** Bar
[0055] **13** Guide bar (guiding means)
[0056] **14** Receptacle
[0057] **17** Basic body
[0058] **18** Line section
[0059] **22** Sliding section
[0060] **23** First top roller
[0061] **24** Second top roller
[0062] **25** Third top roller
[0063] **26** Fourth top roller

[0064] It will therefore be readily understood by those persons skilled in the art that the present invention is susceptible of broad utility and application. Many embodiments and adaptations of the present invention other than those herein described, as well as many variations, modifications and equivalent arrangements, will be apparent from or reasonably suggested by the present invention and the foregoing description thereof, without departing from the substance or scope of the present invention. Accordingly, while the present invention has been described herein in detail in relation to its preferred embodiment, it is to be understood that this disclosure is only illustrative and exemplary of the present invention and is made merely for purposes of providing a full and enabling disclosure of the invention. The foregoing disclosure is not intended or to be construed to limit the present invention or otherwise to exclude any such other embodiments, adaptations, variations, modifications and equivalent arrangements.

What is claimed is:

1. An apron drafting system for a spinning machine with a bottom apron guided over a drivable bottom roller, the bottom apron being supported in the area of a drawing zone by a sliding section of an apron bridge,

characterized in that

the apron bridge for guiding the bottom apron has a line section with a guide for lateral guidance of the bottom apron circulating around the apron bridge.

2. The apron drafting system according to claim **1**, wherein the spinning machine is an air spinning machine.

3. The apron drafting system according to claim **1**, wherein the drawing zone is a main drawing zone.

4. The apron drafting system according to claim **1**, characterized in that the apron bridge has two guide bars arranged at a distance from one another and laterally enclosing the bottom apron in the area of the line section.

5. The apron drafting system according to claim **1**, characterized in that the guide bars have a sliding coating in the area of contact with the bottom apron.

6. The apron drafting system according to claim **1**, characterized in that the guide bars are arranged on a stabilizing bar which is arranged in an area of the apron bridge opposite the sliding section.

7. The apron drafting system according to claim **1**, characterized in that adjustment of a drafting system carriage with the bottom roller, the bottom apron and the apron bridge and/or the apron bridge in relation to the drafting system carriage, is transverse to the circumferential direction of the bottom apron.

8. The apron drafting system according to claim **7**, characterized in that the apron bridge and/or the drafting system carriage is connected to an adjusting drive for adjustment of the apron bridge in relation to the drafting system carriage and/or of the drafting system carriage transversely to the circumferential direction of the bottom apron.

9. The apron drafting system according to claim **1**, characterized in that the adjusting drive is connected to a control device for defining the adjustment movement of the drafting system carriage and/or the apron bridge.

10. The apron drafting system according to claim **9**, wherein the adjusting drive is connected to a control device for defining the adjustment length and the adjustment frequency.

* * * * *

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(54) **COMPACTOR DEVICE**

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(21) Appl. No.: **17/749,655**

(22) Filed: **May 20, 2022**

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(63) Continuation of application No. 16/650,786, filed on Mar. 25, 2020, now Pat. No. 11,390,967, filed as application No. PCT/EP2018/075750 on Sep. 24, 2018.

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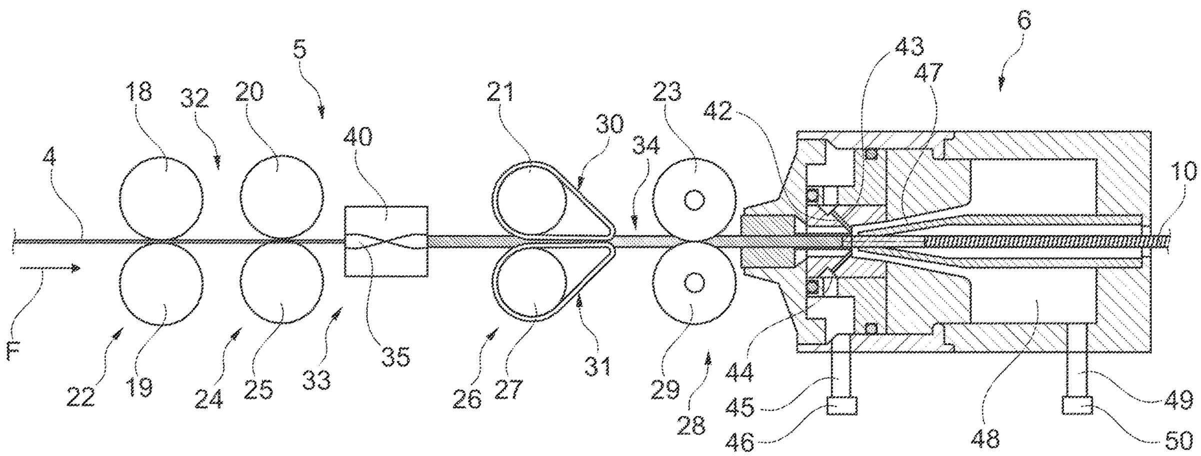
(52) **U.S. Cl.**
CPC ***D01H 5/72*** (2013.01)

(57) **ABSTRACT**

A compactor device for compacting a sliver that is drawn by a drafting system of a textile machine is provided. In accordance with the invention, it is envisaged that the compactor device is designed as a channel compactor and has a guide channel, designed in the shape of a screw in the running direction of the sliver, wherein the entry opening of the guide channel is widest horizontally and the exit opening of the guide channel is arranged rotated at least 30° with respect to the entry opening.



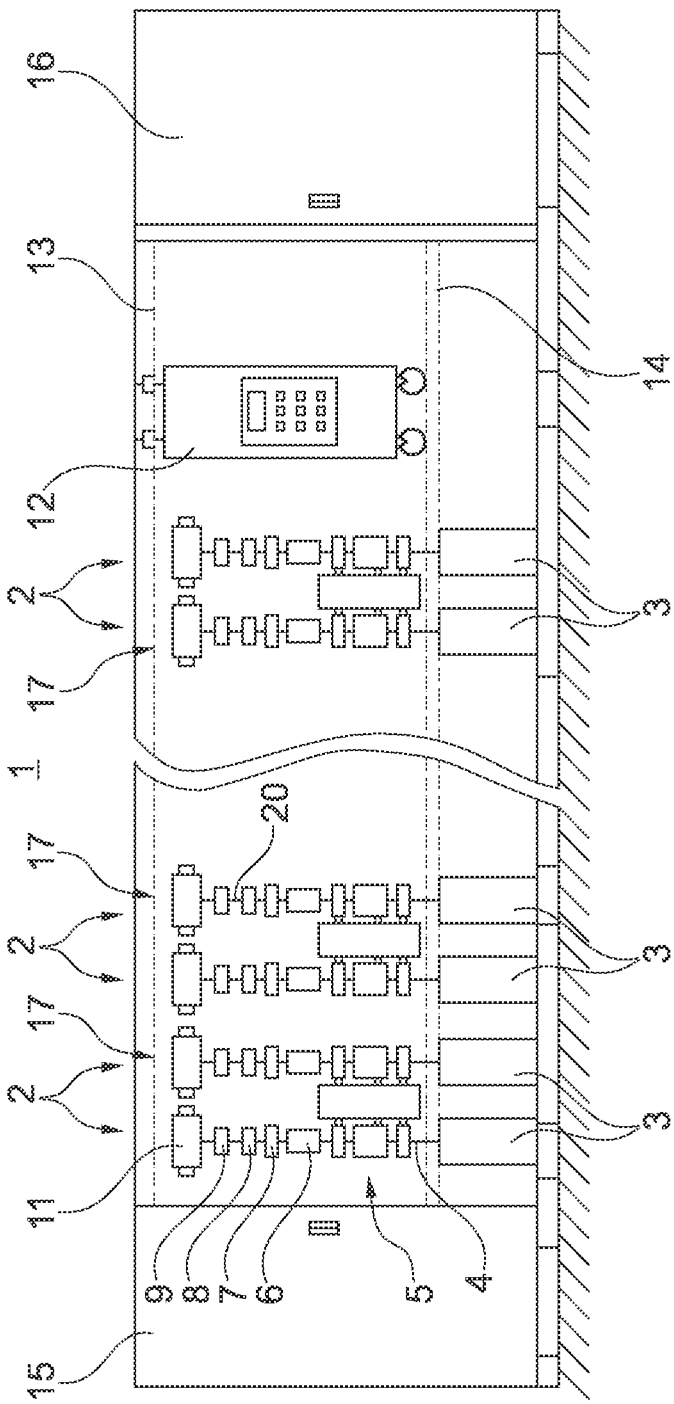


FIG. 1

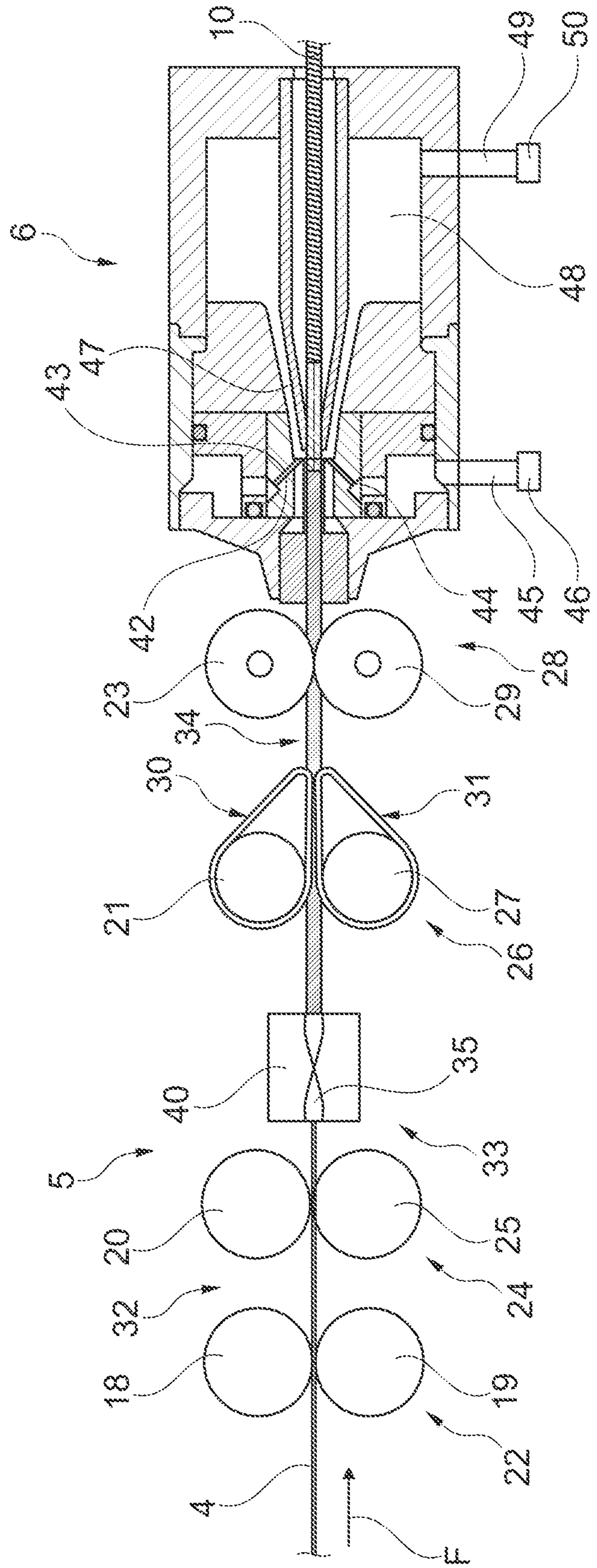

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FIG. 2

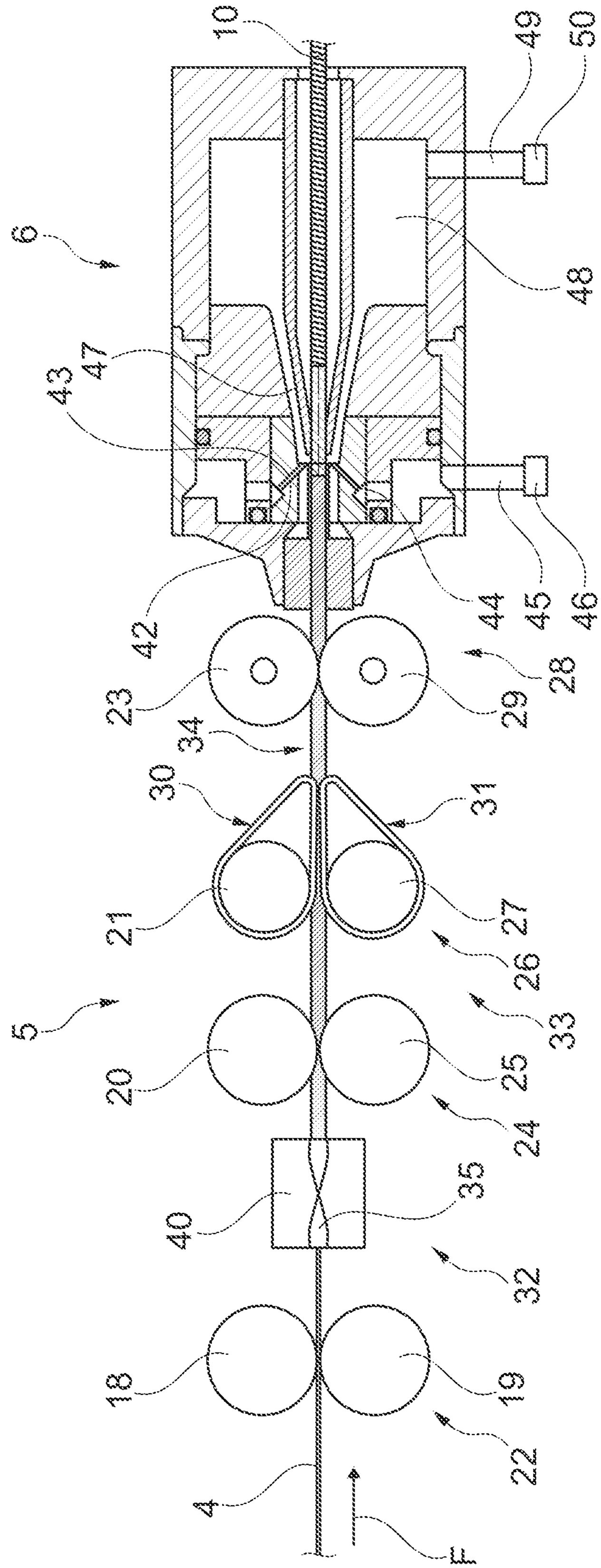
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FIG. 3

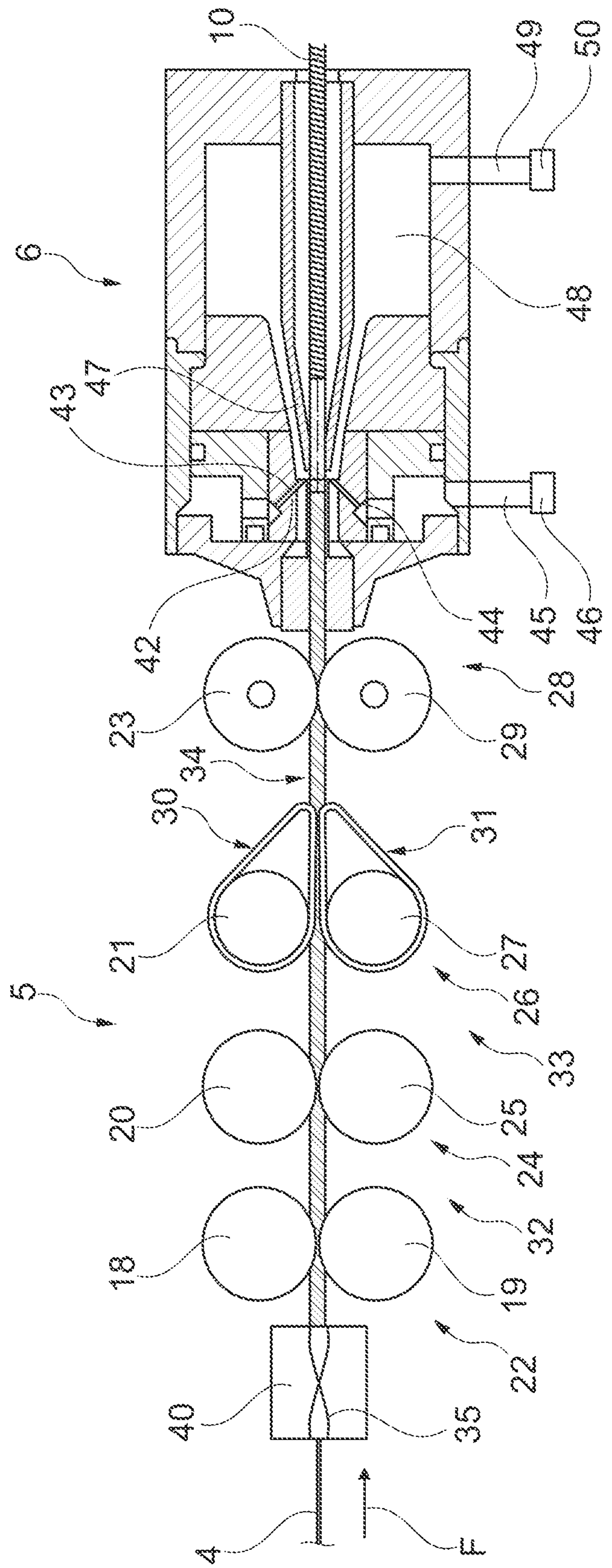
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FIG. 4

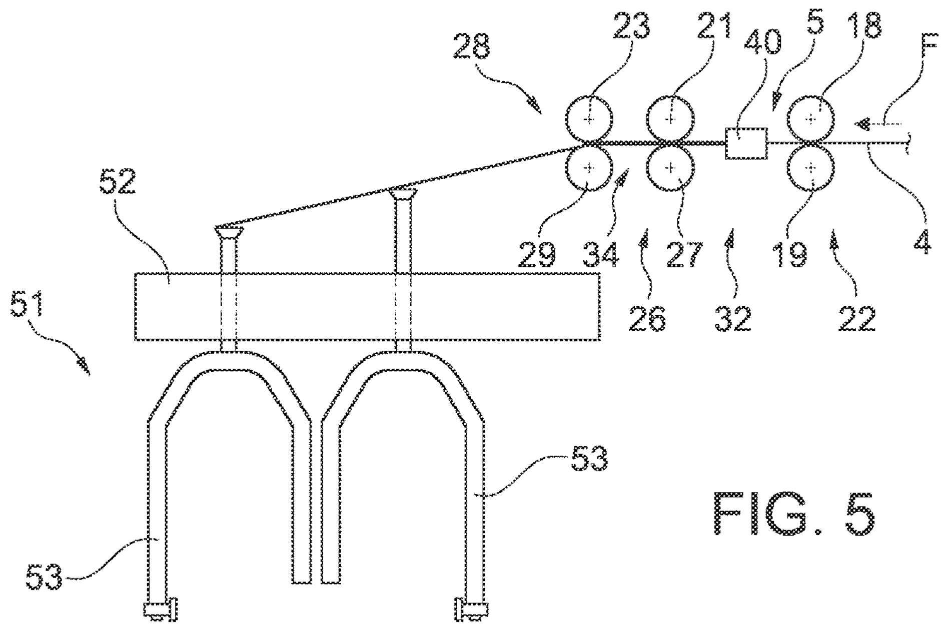

FIG. 5

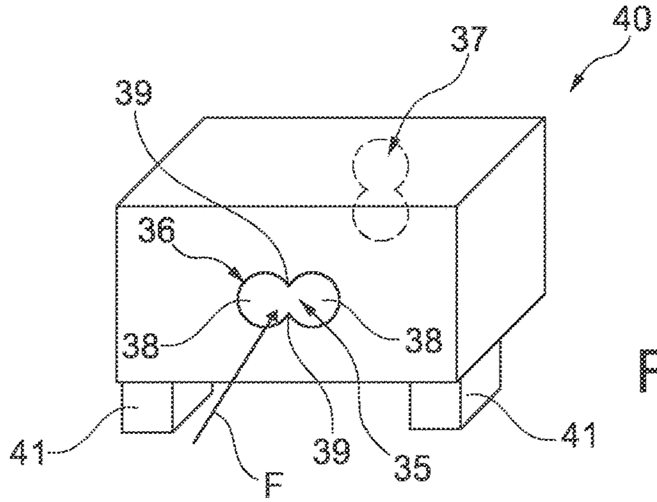

FIG. 6

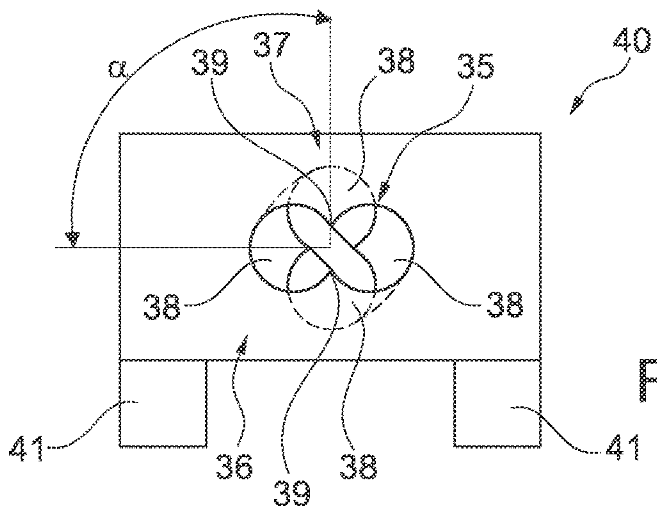

FIG. 7

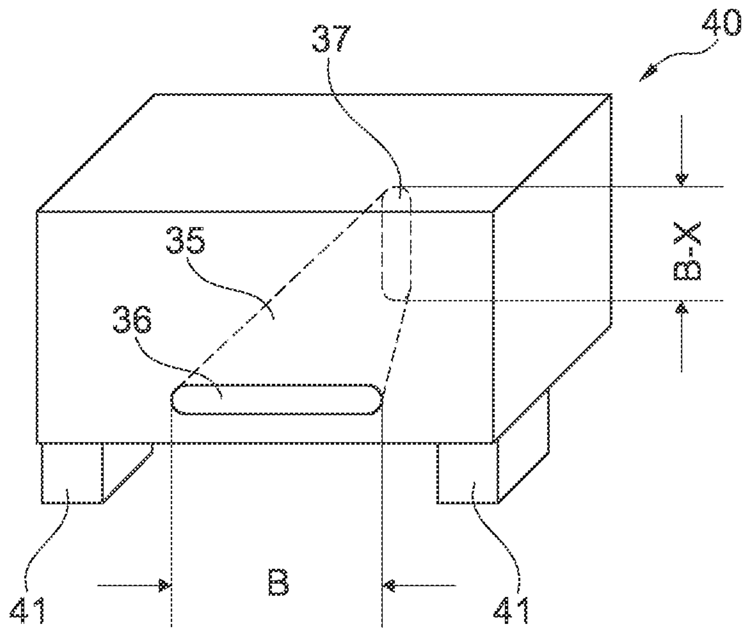

FIG. 8

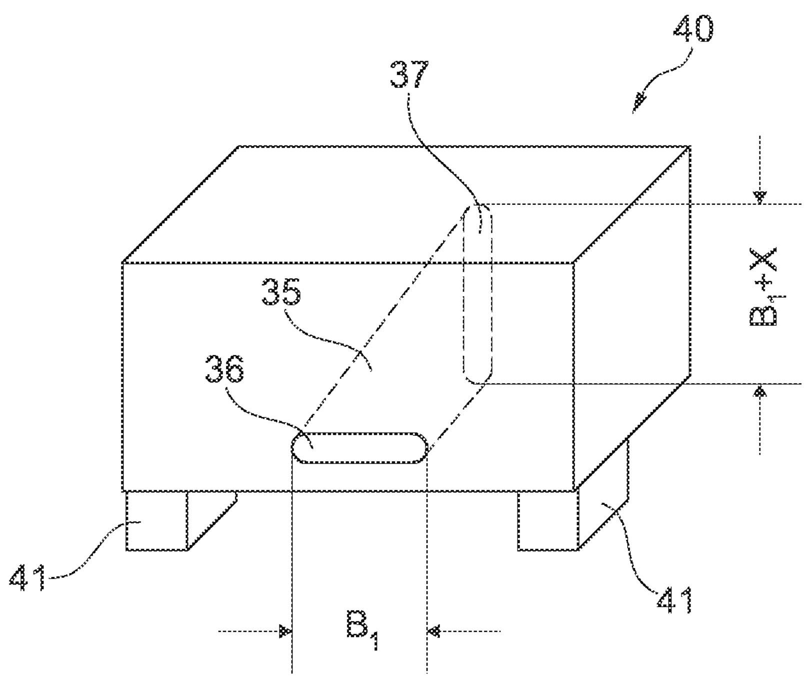

FIG. 9

COMPACTOR DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. patent application Ser. No. 16/650,786, filed Mar. 25, 2020, which is a 35 U.S.C. 371 national stage filing of International Application No. PCT/EP2018/075750, filed Sep. 24, 2018, which claims priority from German National Patent Application No. 10 2017 122 318.5, filed Sep. 26, 2017, entitled "Verdichtereinrichtung", the entire contents of which are incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The invention generally relates to a compactor device, more particularly to a compactor device for compacting a sliver that is drawn by a drafting system of a textile machine.

BACKGROUND OF THE INVENTION

[0003] Both drafting systems and associated compaction devices have long been well-known in the context of textile machines.

[0004] The known drafting systems are arranged in front of each of the spinning units of the textile machine, and they draw a material supplied to them, usually a sliver or roving frame fibre, to a desired fineness. These kinds of drafting systems have several pairs of rollers lying one in front of the other in the running direction of the sliver that rotate at different circumferential speeds and transport the sliver to the associated spinning unit.

[0005] Because the circumferential speed of the roller pairs increases in the running direction of the sliver, the sliver is constantly accelerated within the drafting system, thus undergoing a so-called draft warp. With known drafting systems, the total draft of the sliver differs greatly depending on the textile machine in question.

[0006] For the drafting systems of air spinning machines, the total draft of the sliver can be up to 180 times, while the drafting systems of pre-spinning machines, for example roving frames, usually work with significantly lower total drafting.

[0007] Among other things, the compactness and hairiness of the drafted sliver has a decisive influence on the quality of the yarn material supplied by the drafting system. This means that, when it is running into the drafting system, the sliver has a width that is first reduced to a significantly narrower width during the course of the drafting process. On the outgoing side of the drafting system, in the area of the so-called spinning triangle, there should be a width that is once again significantly lower than the intermediate width of the material running in.

[0008] During the drafting process, however, there is the problem that edge fibres are often either not bound in and increased peeling away of fibres occurs, or the edge fibres are bound in in a disorganized way, leading to increased hairiness and an increased width of the spinning triangle, and therefore to a reduction in quality of the drafted sliver.

[0009] In order to achieve a secure guidance and as good a compacting of the sliver as possible during the drafting of the material in question, the known drafting systems often also have so-called compaction units.

[0010] In German Patent Publication DE 10 2011 015 748 A1, for example, a drafting system for a pre-spinning machine is described that has a pre-drafting field, a main drafting field and a downstream compaction zone.

[0011] A compaction unit is positioned in the compaction zone, which is described as a condenser component ("Kondenserbauteil") in German Patent Publication DE 10 2011 015 748 A1. The condenser component has a guide slit that opens upward for the sliver, where the guide slit is significantly higher than it is wide. The condenser component serves to homogenise the thickness of the sliver and reduce the hairiness of the sliver, which means that the quality of the material is improved.

[0012] In German Patent Publication DE 10 2013 017 636 A1, in addition, drafting systems for the air spinning units of air spinning machines are known that are fitted with comparable compaction units.

[0013] One of the depicted embodiments shows and describes a drafting system that is designed as a so-called four-roller drafting system, and that has a pre-drafting field, a mid-drafting field and a main drafting field.

[0014] With this known four-roller drafting system, a pre-compactor is positioned in front of the input roller pair of the drafting system, and a second compactor is positioned in the pre-drafting field. Moreover, the main drafting field of the drafting system is equipped with a third compactor.

[0015] For this known drafting system too, the compaction units are designed to reduce the hairiness of the stretched sliver and increase the number of entwined fibres.

[0016] A four-roller drafting system for the air spinning units of air spinning machines is also described in German Patent Publication DE 10 2015 110 980 A1.

[0017] This known drafting system is also fitted with a special device for improving the quality of the drafted sliver. This means that, with this four-roller drafting system, a false spinning component is positioned in the pre-drafting field of the drafting system, which twists the sliver with alternating twist directions, before it is pulled to the desired yarn fineness in the main draft field and guided to an air spinning unit.

[0018] The alternating twisting direction of the sliver is intended to minimize edge fibres being diverted, which occurs in particular due to the air stream in the area of the output rollers of the drafting system, which rotate at a relatively higher speed.

[0019] Although the drafting systems described above have different options for improving the quality of a concealed sliver, they can have the problem that, when pulling the sliver, edge fibres occur or the sliver has insufficient compactness, so that on the output side of the drafting system a relatively wide spinning triangle occurs, which cannot be completely alleviated.

SUMMARY OF THE INVENTION

[0020] Given the above-mentioned state of the art, the invention has the task of developing a compactor device or unit for one of the drafting systems positioned in front of the spinning device of a textile machine that is designed so that during the drafting process it is ensured that the width of the sliver to be drafted is reliably minimized both in the main drafting area and in the area of the spinning triangle occurring on the output side of the drafting system.

[0021] In accordance with the invention, this task is completed by a compactor device that is designed as a channel compactor and has a guide channel designed in the shape of a screw in the running direction of the sliver, where in the entry opening of the guide channel is widest horizontally and the exit opening of the guide channel is arranged rotated with respect to the entry opening.

[0022] Advantageous embodiments of the invention are set forth in detail herein.

[0023] The design of a channel compactor in accordance with the invention has the particular advantage that the guided sliver, which initially runs in a flat horizontal direction into the entry opening of the guide channel of the channel compactor, is turned somewhat within the channel compactor, temporarily creating a false twist. This means that, when it is running out of the guide channel of the channel compactor, the sliver is rotated so that in the following draft roller pair, the edge fibres are immediately compacted, thereby leading to an initial compacting of the sliver.

[0024] This means that, through the compacting of the twisted sliver, the edge fibres are bound in to a high degree, which not only reduces the peeling away of fibres, but also minimizes the width of the spinning triangle, with the result that there is an overall increase in the quality of the material produced.

[0025] In the advantageous embodiment, it is envisaged that the rotation angle between the entry opening and the exit opening of the guide channel of the channel compactor is between 30° and 160°, and preferably 90°.

[0026] Due to this rotated positioning of the entry and exit opening of the guide channel, the sliver not only temporarily receives a so-called false spin, which leads to a positive stabilisation of the materials, but also preparation is done for further compacting by the downstream drafting rollers.

[0027] It has proven especially advantageous if the sliver is twisted by 90°, i.e. if the sliver that is originally running on a horizontal direction in the guide channel of the channel compactor is twisted in a vertical direction and runs into the downstream drafting system roller pair in this direction.

[0028] In the most advantageous embodiment it is moreover envisaged that the guide channel has a light cross-section area, which is depicted through two narrowing ellipses extending towards the centre from both sides.

[0029] Numerous trials have shown that in such a design, the guide channel cross-section can always ensure an even and secure guidance of the sliver in the depicted screw-shaped guide channel.

[0030] The channel compactor is preferably manufactured from an abrasion-resistant plastic in a 3D printing process. Polyamides have proven to be advantageous as plastics, these can be designed in almost any three-dimensional shape using fused deposition modelling. This means that the manufacturing of the channel compactor in a 3D printing process in accordance with the invention represents an advantageous, relatively simple manufacturing method.

[0031] The channel compactor in accordance with the invention can be manufactured in another 3D printing process.

[0032] Regarding the installation position of the channel compactor in accordance with the invention, various locations are possible.

[0033] For drafting systems of textile machines that work with relatively high draft values, such as the drafting systems of air spinning machines, positioning of the channel compactor in accordance with the invention can be advantageous both in the area of the pre-draft field of the drafting system and in the area of the mid-draft field of the drafting system of the air spinning unit.

[0034] Such a positioning keeps the distance between the channel compactor and the exit roller pair of the drafting system relatively small, which has a very positive effect on the development of the width of the spinning triangle that occurs at the exit side of the exit roller pair of the drafting system.

[0035] In the context of drafting systems for air spinning units, however, it has emerged that positioning the channel compactor in front of the entry roller pair of the drafting system or a simultaneous positioning of several channel compactors at various positions of a drafting system can be very advantageous.

[0036] Particularly for the simultaneous positioning of several channel compactors, multiple compacting of the twisted sliver, that is also processed by the roller pair of the drafting system, occurs so that the width of the sliver set in the area of the drafting system and in the area of the spinning triangle is minimized.

[0037] Various positions of the channel compactor can be advantageous in accordance with the invention, including for textile machines for which their drafting systems work with relatively low draft values, for example for roving frames.

[0038] In tests it emerged that, for example, both a positioning of the channel compactor in front of the entry roller pair of the drafting system as well as a positioning of the channel compactor in the area of the pre-draft field of the drafting system are very advantageous.

[0039] It was shown, for example, that with such a positioning of the channel compactor with the drafting systems, roving flyers can be created that are significantly more compact and less hairy than previously known roving fibres.

[0040] This means that, with the drafting systems of roving frames in which a channel compactor is arranged front of the entry roller pair of the drafting system in the area of the pre-draft field of the drafting system, roving fibres can be created that have significant advantages during their further processing by ring spinning machines.

[0041] These improved roving fibres meant, for example, that spinning triangles were set up at the drafting systems of the ring spinning machines during the spinning process that were significantly lesser in width than the previously standard spinning triangles, which is a good sign for the excellent quality of the drafted sliver.

[0042] Also regarding the exact design of the guide channel of the channel compactor, various types of embodiment are possible.

[0043] In an initial embodiment type, the guide channel of the channel compactor can, for example, be designed so that it has its maximum width in the area of its horizontally positioned entry opening. This maximum width then reduces through the guide channel and has its final minimum width in the area of the exit opening, which is arranged rotated in a vertical direction compared to the entry opening.

[0044] In another advantageous embodiment, the guide channel of the channel compactor has a width in the area of its horizontally positioned entry opening that "grows" throughout the length of the guide channel, having its maximum width in the area of the exit opening, which is arranged rotated in a vertical direction compared to the entry opening.

[0045] Which of the above described embodiments is more advantageous can depend on a number of factors, for example the material of the sliver or roving fibres, the desired fineness of the drafted material, the degree of sliver drafting, etc.

DETAILED DESCRIPTION OF THE DRAWINGS

[0046] The invention is explained in greater detail below on the basis of embodiment examples shown in the drawings.

[0047] The figures show:

[0048] FIG. **1** is a schematic front view of an air spinning machine with a number of spinning positions, each of which has an air spinning unit with an upstream drafting system,

[0049] FIG. **2** is a side view of a drafting system shown as a four-roller drafting system positioned in front of an air spinning unit, with a channel compactor in accordance with the invention in the area of the mid-drafting field,

[0050] FIG. **3** is a side view of a four-roller drafting system as in FIG. **2**, with a channel compactor in accordance with the invention in the area of the pre-drafting field of the drafting system,

[0051] FIG. **4** is a side view of a four-roller drafting system as in FIG. **2**, with a channel compactor in accordance with the invention in front of the entry roller pair of the drafting system,

[0052] FIG. **5** is a side view of a workstation of a roving frame, with a three-roller drafting system, that has a channel compactor in accordance with the invention in the area of the pre-drafting field of the drafting system,

[0053] FIG. **6** is a perspective view of a first embodiment in accordance with the invention,

[0054] FIG. **7** is a front view of the channel compactor as in FIG. **6**,

[0055] FIG. **8** is a view of another embodiment of the channel compactor in accordance with the invention, and

[0056] FIG. **9** is a view of another embodiment of the channel compactor in accordance with the invention.

DETAILED DESCRIPTION OF THE DRAWINGS

[0057] FIG. **1** shows a schematic front view of an air spinning machine **1**. As shown, these types of air spinning machines **1** have a number of workstations **2** positioned in a row next to one another between their so-called end stations **15**, **16** at their end sides, which are often also designated as spinning positions.

[0058] Material is processed on these spinning positions **2**, for example sliver **4** stored in a spinning can **3**. This means that sliver **4** is spun into a yarn at this spinning position **2**.

[0059] For this purpose, spinning position **2** has various devices. The spinning positions **2** each have, for example, a drafting system **5**, an air spinning unit **6**, a thread drafting device **7**, a yarn clearer **8** and a winding device **11**.

[0060] The drafting system **5**, which can, for example, be designed as a four-roller drafting system or as a three-roller drafting system, also has a channel compactor in accordance with the invention, which is not represented in FIG. **1** for reasons of improved clarity. This channel compactor **40** is explained below in detail using FIGS. **2** to **9**.

[0061] As indicated in FIG. **1**, the yarn prepared in the air spinning unit **6** from sliver **4** is wound by an associated thread changing device **9** in cross-wound layers onto a take-up package **17**, creating a cross-wound package.

[0062] The cross-wound package **17** is held, in the usual way, in a package cradle (not shown) and is rotated during the spinning process by a package drive (also not shown).

[0063] As further represented in FIG. **1**, the workstations **2** of the air spinning machine **1** are supplied by an independently working operating unit **12**, that can be moved on rails **13**, **14** along the workstations depicted as spinning positions **2**.

[0064] The FIGS. **2**, **3** and **4** each show a positioning option of a channel compactor **40** in accordance with the invention positioned in the area of a drafting system **5**.

[0065] In the embodiment examples, the drafting system **5**, that drafts a sliver **4**, is depicted as a four-roller drafting system and is arranged in front of an air spinning unit **6** of an air spinning machine **1**.

[0066] In accordance with FIG. **2**, the channel compactor **40** in accordance with the invention is positioned in the area of the so-called mid-draft field **33**.

[0067] As can be seen, a sliver **4** that is drawn from a (not shown) spinning can **3** by an intake roller pair **22**, which consists of an upper roller **18** and a lower roller **19**, is drawn into drafting system **5**, and is finally transported to air spinning unit **6** and drafted by means of the additional pairs **24**, **26**, **28**.

[0068] The roller pairs **24**, **26**, **28** are each consisting of an upper roller **20** and a lower roller **25**, and upper roller **21** and a lower roller **27** or an upper roller **23** and a lower roller **29**. The upper roller **21** and the lower roller **27** each work together with one of the aprons **30** or **31**, which are positioned in the area of the so-called main drafting field **34**. The upper roller **23** and the lower roller **29** represent the exit roller pair **28** of the drafting system **5**. This means that, in the present four-roller drafting system **5**, the first two roller pairs **22**, **24** represent a pre-drafting field **32** for the sliver **4**, looked at in running direction F of the sliver **4**. The following drafting system section between the roller pair **24** and the roller pair **26** form a so-called mid-drafting field **33**, in which the channel compactor **40**, designed in accordance with the invention, is also positioned, while the roller pairs **26**, **28**, as indicated above, form the main drafting field **34** of the drafting system **5**.

[0069] As can be seen, the sliver **4** is transported to air spinning unit **6** by the roller pairs **22**, **24**, **26** and **28**.

[0070] Because the circumferential speeds of the roller pairs **22**, **24**, **26**, **28** increase in the running direction F of the sliver, the sliver **4** is drafted during transport.

[0071] The drafting of the sliver **4** can be up to 180 times its original length.

[0072] As is moreover shown in FIG. **2**, the air spinning aggregate **6** has a nozzle device **42** on its input side, the nozzles **43**, **44** of which are connected with a pressurised air source **46** via a pneumatic line **45**. A hollow spinning cone **47** is connected to the nozzle device **42**, which is surrounded by an air chamber **48**, which is connected with a low pressure source **50** via an additional pneumatic line **49**.

[0073] During the spinning operation, the air emerging from the nozzles **43**, **44** creates a rotation flow, which hits the drafted sliver **4**. This means that, through the cooperation of the nozzle device **42** and spinning cone **47**, a yarn **10** is formed in the air spinning unit **6** that is drawn from the air spinning device **6** through the hollow spinning cone **47**.

[0074] Further details on the spinning process using this type of air spinning unit **6** can be found in German Patent Publication DE 199 26 492 A1, for example.

[0075] The channel compactor **40**, designed in accordance with the invention and in accordance with the embodiment example of FIG. **2**, positioned in the area of the mid-drafting field **33**, ensures that during the drafting process the sliver **4**, which runs into the drafting system **5** in a flat horizontal direction, is turned in the channel compactor **40** in e.g. a vertical direction by means of its screw-shaped guide channel **35**. The sliver **4** thereby temporarily receives a false twist, which leads to the compacting of the sliver **4** on all sides.

[0076] This compacting of the sliver **4** on all sides is not only maintained during the passage of the sliver **4** through the drafting system **5**, but rather is enhanced even further in drafting system **5**.

[0077] The embodiment example depicted in FIG. **3** differs from the embodiment example depicted in FIG. **2** only in the positioning of the channel compactor **40** in the area of the drafting system **5** in accordance with the invention.

[0078] As can be seen, in the embodiment example in FIG. **3** the channel compactor **40** in accordance with the invention is positioned in the area of the pre-drafting field **32** of the drafting system **5**.

[0079] Even with such a positioning of the channel compactor **40**, the sliver **4** temporarily receives a false twist and is thereby compacted on all sides.

[0080] The embodiment example depicted in FIG. **4** also essentially differs from the embodiment examples depicted in FIGS. **2** and **3** in the positioning of the channel compactor **40** in the area of the drafting system **5** in accordance with the invention.

[0081] As can be seen, in this embodiment example the channel compactor **40** in accordance with the invention is positioned in front of the entry roller pair **22** of the drafting system **5**. Such a positioning of the channel compactor **40** means that the sliver **4** is already turned in, for example, a vertical direction from a flat horizontal position before it enters drafting system **5**.

[0082] Even with a positioning of the channel compactor **40** in front of the entry roller pair **22** of the drafting system **5**, the sliver **4** temporarily receives a false twist and is thereby compacted on all sides.

[0083] The further integration of the edge fibres into the sliver **4** that is associated with the compacting of the vertically positioned sliver **4** not only leads to an improvement in the quality of the sliver **4** running into the air spinning unit, but also leads to a significant reduction in the peeling away of fibres that occurs during the spinning process.

[0084] FIG. **5** shows a strongly schematic side view of a workstation of a pre-spinning machine, in the represented embodiment example, the workstation of a so-called roving frame **51**.

[0085] As is generally known, slivers **4** that are not rotated are drafted using roving frames such as roving frame **51**, and thereby processed into roving threads that already have some yarn rotation.

[0086] These roving threads with some yarn rotation are then spun into fine yarns in textile machines further downstream in the production process, for example ring spinning machines.

[0087] As depicted, the workstations of such roving frames **51** usually have two rotatable roving frame flyers **53** in one flyer bench **52**, which are usually supplied by an upstream three-roller drafting system **5**.

[0088] In the present embodiment example, there is also a channel compactor **40** in accordance with the invention positioned in the area of the pre-drafting field **32** of the drafting system **5**.

[0089] As can be seen, a sliver **4** that is drawn from a (not shown) spinning can **3** by an intake roller pair **22**, which consists of an upper roller **18** and a lower roller **19**, is drawn into drafting system **5**, and is finally transported to drafting system **5** and drafted by means of the additional roller pairs **26**, **28** of drafting system **5**.

[0090] As is standard, the roller pairs **26**, **28** are each composed of a top roller **21** or **23** and a bottom roller **27** or **29** whereby, looked at in the running direction F of the sliver **4**, the first two roller pairs **22**, **26** form a pre-drafting field **32**, in which a channel compactor **40** is positioned and is designed in accordance with the invention.

[0091] The roller pairs **26**, **28** form the connected main drafting field **34** of the drafting system **5**, whereby the roller pair **28** also represents the exit roller pair **28** of the drafting system **5**.

[0092] The sliver **4** is transported through the roller pairs **22**, **26** and **28** to the roving frame flyer **53**, which is located on a rotatable flyer bench **52**, and is thereby drafted, because the circumferential speeds of the roller pairs **22**, **26**, **28** increase in the running direction F of the sliver **4**.

[0093] The rotating roving frame flyer **51** also ensures that the drafted sliver is twisted slightly, i.e. it becomes a so-called shaped roving frame fibre.

[0094] As with the drafting systems for air spinning units, the channel compactor **40**, positioned in the area of the pre-draft field **32** in accordance with the invention, also ensures that the sliver **4**, which is initially running into the drafting system **5** in a flat horizontal direction, is twisted in, for example, a vertical direction when it runs through the channel compactor **40**.

[0095] It does this by means of its screw-shaped guide channel **35**. The sliver **4** thereby temporarily receives a false twist, which leads to the compacting of the sliver **4** on all sides.

[0096] This compacting of the sliver **4** on all sides is not only maintained as the sliver **4** is running through the drafting system **5**, but rather in the area of the roller pairs **26**, **28** a compacting of the vertically positioned sliver **4** occurs with the result that there is further increased integration of the edge fibres into the sliver **4**.

[0097] The roving frame thread is significantly more compact and less hairy than previously known roving frame threads, which means that the roving frame thread can be better processed during the subsequent work process on a ring spinning machine. This means that, during the processing of such compact and less hairy roving frame threads, spinning triangles occur on the spinning positions of the ring spinning machines that are minimised as regards their width, which represents a significant improvement in the quality of the roving frame threads.

[0098] FIG. **6** shows, on a larger scale and in a perspective view, an initial embodiment of a channel compactor **40** in accordance with the invention, which preferably is manufactured in a 3D printing process from an abrasion-resistant plastic.

[0099] As can be seen, the channel compactor **40** has a guide channel **35** with an entry opening **36** and an exit opening **37**, whereby the entry opening **36**, is positioned horizontally in the casing of the channel compactor **40**.

[0100] This means that the entry opening **36** of the channel compactor **40** has its greatest width horizontally, when the channel compactor **40** is attached to the relevant drafting system construction, for example by means of locking devices **41**.

[0101] In this mounted state a sliver **4**, the running direction of which is labelled with F in FIG. **5**, can run into the guide channel **35** of the channel compactor **40** in a flat, horizontal direction through the entry opening **36**.

[0102] Because the exit opening **37** is positioned at an angle α with respect to the entry opening **36**, in the embodiment example of FIGS. **6**, **7**, **8** and **9** at 90°, the sliver **4** is also twisted when running through the channel compactor **40** and has a vertical direction after running out of channel compactor **40**.

[0103] According to the embodiment examples in FIGS. **6** and **7**, the guide channel **35** has a light cross-section area, which is formed by two narrowing ellipses **38** extending towards the centre from both sides. This means that there are flange-like protrusions **39** between the ellipses **38**.

[0104] Such a design ensures an even, secure guiding of the sliver **4** through the channel compactor **40** during its passage.

[0105] FIG. **7** shows a front view of the channel compactor **40** in accordance with the invention pursuant to FIG. **6**.

[0106] As can clearly be seen here, the exit opening **37** is positioned at an angle of α with respect to the entry opening **36**. The angle α has a measurement in the embodiment example of, for example, 90°. However, other angles between, for example, 30° and 160° are also possible.

[0107] FIGS. **8** and **9** show further possible embodiments of a channel compactor **40** according to the invention.

[0108] FIG. **8** shows a channel compactor **40**, the guide channel **35** of which has a maximum width of B in the area of its horizontally positioned entry opening **36**. As, can be seen, this maximum width B then reduces throughout the guide channel **35** and has its final minimum width of B-X in the area of the exit opening **37**, which is arranged rotated in a vertical direction compared to the entry opening **36**.

[0109] FIG. **9** shows a channel compactor **40**, which is comparable in principle. In this embodiment, the guide channel **35** of the channel compactor **40** has a minimum width of B_1 in the area of its horizontally positioned entry opening **36**. This minimum width B_1 then reduces through the guide channel **35** and has its final maximum width B_1+X in the area of the exit opening **37**, which is arranged rotated in a vertical direction compared to the entry opening **36**.

LIST OF REFERENCE NUMBERS

[0110] **1** Air spinning machine
[0111] **2** Spinning position
[0112] **3** Spinning can
[0113] **4** Sliver
[0114] **5** Drafting system
[0115] **6** Air spinning unit
[0116] **7** Yarn take-up device
[0117] **8** Yarn clearer
[0118] **9** Yarn changing device
[0119] **10** Yarn
[0120] **11** Winding device
[0121] **12** Operating unit
[0122] **13** Rail
[0123] **14** Rail
[0124] **15** End frame
[0125] **16** End frame
[0126] **17** Cross-wound package
[0127] **18** Top roller
[0128] **19** Bottom roller
[0129] **20** Top roller
[0130] **21** Top roller
[0131] **22** Entry roller pair
[0132] **23** Top roller
[0133] **24** Roller pair
[0134] **25** Bottom roller
[0135] **26** Roller pair
[0136] **27** Bottom roller
[0137] **28** Roller pair
[0138] **29** Bottom roller
[0139] **30** Apron
[0140] **31** Apron
[0141] **32** Pre-draft field
[0142] **33** Mid-draft field
[0143] **34** Main draft field
[0144] **35** Guide channel
[0145] **36** Entry opening
[0146] **37** Exit opening
[0147] **38** Ellipse
[0148] **39** Protrusion
[0149] **40** Channel compactor
[0150] **41** Locking device
[0151] **42** Nozzle device
[0152] **43** Nozzle
[0153] **44** Nozzle
[0154] **45** Pneumatic line
[0155] **46** Pressurised air source
[0156] **47** Spinning cone
[0157] **48** Air chamber
[0158] **49** Pneumatic line
[0159] **50** Negative pressure source
[0160] **51** Roving frame
[0161] **52** Flyer bench
[0162] **53** Flyer
[0163] F running direction

What is claimed is:

1. A drafting system of air-spinning machine or roving flyer, which drafting system has a pre-draft field and a compactor device for compacting a sliver that is drawn through the drafting system, wherein the compactor device is designed as a channel compactor and has a guide channel designed in a shape of a screw in a running direction of the sliver, wherein an entry opening of the guide channel is widest horizontally and an exit opening of the guide channel is arranged at a rotation angle being between 30° and 160° with respect to the entry opening,

characterized in that

the compactor device is arranged in front of a roller pair of the drafting system to deliver the sliver in such a rotated manner that the edge fibres of the sliver are immediately compacted by the roller pair.

* * * * *