**Influence of Flow Angle on Yarn Strength in Ring Spinning Machines**

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**Abstract:** The mechanical strength of yarn made by ring spinning machines is examined in relation to the flow angle. To minimize yarn defects and maximize fiber alignment, a redesigned drafting apparatus with a pressure roller system was created. In order to assess yarn strength under various flow angles, both theoretical analysis and experimental experiments were conducted. The findings show that a decrease in flow angle enhances fiber orientation in the drafting zone, which raises the yarn's tensile strength noticeably. The results offer useful information for improving yarn quality in industrial applications and streamlining ring spinning procedures.

**Keywords:** pressure roller, drafting tool, ring spinning, yarn strength, flow angle, textile equipment, and fiber orientation

INTRODUCTION

Ring spinning continues to be the industrial standard for producing high-strength yarn due to its ability to provide fine structural integrity and wide adaptability across fiber types (Khan, Begum, & Sheikh, 2020) [1]. However, the geometric configuration within the drafting zone—particularly fiber interaction in the spinning triangle and the path angle at which sliver exits the front rollers—directly affects yarn characteristics such as strength, uniformity, and hairiness.

Prior studies have highlighted how drafting geometry changes might lessen the drawbacks of traditional approaches. For example, significant decreases in hairiness and increases in yarn strength have resulted from advancements meant to reduce the spinning triangle, particularly through compact spinning technology (Khan et al., 2020) [1]. Numerical simulation has been employed in complementary research to show that yarn mechanical characteristics are dramatically changed by three-dimensional modulation of fiber tension and orientation (Liu et al., 2016) [2]. These results confirm that one important leverage point for quality optimization is the geometry of the drafting zone.

The angle of draw-off, or the angle at which yarn leaves the drafting rollers, also influences twist deployment and tension distribution. According to May et al. (2005), even small geometric changes can result in detectable tensile gains by identifying the ideal draw-off angles that produce stronger but low-friction spinning [3]. In a similar vein, Ahmed, H. A. H., et al. (2018) discovered that airflow behavior and channel geometry significantly affect fiber movement and final yarn qualities in ring spinning systems through a combination of computational and experimental investigations [4].

Despite these developments, nothing is known about the precise quantitative relationship between yarn tensile performance and the flow angle surrounding the front drafting rollers. Designing sophisticated drawing systems requires an understanding of how lower flow angles improve fiber path alignment and lessen mechanical imperfections.

The current work fills this knowledge gap by introducing a revised drafting arrangement that incorporates a double pressure roller to better manage the flow angle and align fiber pathways. To determine how different flow angles impact fiber alignment in the drafting zone and hence improve the yarn's tensile strength, we conduct controlled experiments in addition to theoretical modeling. It is anticipated that the findings will help develop more effective ring spinning techniques for the manufacturing of industrial textiles [5-10].

METHODS

Improved control over the flow of fibers is accomplished in a number of methods in current drawing device designs, such as by adding more straps, rollers, clutches, guides, trays, etc. One prevalent flaw in this design is that when one flaw is fixed, others are exacerbated; for instance, the assembly's design gets more intricate or maintenance becomes challenging.

Yarn breakage is one of the primary issues influencing the quality of yarn generated on ring spinning machines. High breakage lowers the equipment's productivity and degrades the quality of the yarn that is produced.

Selecting the design spinning line—that is, the lines of transit of the silver yarn from the drawing device to the bobbin—is crucial when creating ring spinning machines. In certain ring spinning machines, the front pressure roller moves forward by around 50 degrees in order to decrease the flow angle. The rise of the ring bars affects the flow angle γ for various ring spinning machine types. For basic ring spinning machines with a lift of 220 mm, ,  [3, 4].

It is well recognized that a yarn's physical characteristics—such as its fineness, diameter uniformity, surface character, specific gravity, etc.—are what mostly determine its quality. The uneven structure of the yarn, which dictates the heterogeneity of its qualities, is caused by the heterogeneity of the fibers' properties as well as flaws in the spinning technology.

In order to improve the yarn's structure, as well as its mechanical and physical properties, we have developed a number of devices and units that allow for the creation of favorable conditions for fiber migration during the process of imparting twist to the fibrous product. These devices include devices for sealing the welt, a runner rotating along the spinning ring through the thread guide, and devices that bring the twist threshold closer to the line of clamping of the welt by the exhaust pair of the drawing device.

Let's examine how the design elements of the produced devices for sliver release affect the yarn's structure and characteristics. The mathematical tool suggested in this article is used to predict the physical and mechanical properties of yarn by using dependencies such as specific linear hairiness (h), absolute breaking load (Ppr, cN), coefficient of variation for linear density (CV, %), absolute breaking elongation of yarn (Lpr, mm), and the computed value of the generalized indicator of physical and mechanical properties (AP, Ω, cN).

The specific linear hairiness of yarn h can be determined as follows:

 (1)

where Tyarn, Tfiber – average linear density of yarn and fiber, respectively, tex; Pfiber – relative breaking load of the fiber, cN/tex; КF – fiber spinning coefficient; ℓfiber – average fiber length, m; dsl – diameter of the exhaust cylinder, m; γ – angle of flow around the exhaust cylinder by the shoulder, degrees; b – sliver width, m; K – yarn twist, cr/m; CV – coefficient of variation in linear yarn density, %.

Coefficient of variation in linear density, %:

 (2)

Absolute breaking elongation of yarn, mm:

 (3)

The effect of yarn hairiness h on its absolute breaking load can be expressed as follows:

 (4)

where

where n is the number of fibers in the cross section of the yarn; nh – number of sliding (non-deformable) fibers.

EXPERIMENTAL PART

The technical procedure is characterized by certain linear hairiness and a coefficient of variation in linear density. Strength rises as they fall, and the final product becomes closer to perfection. However, compared to the effect on specific hairiness, the ability to affect the coefficient of variation in linear yarn density is restricted. The idea of compact spinning's physical significance arises from research into the potential for strength enhancement through the manipulation of equipment and technological parameters that impact the yarn's particular linear hairiness. The K44 ring spinning machine from Rieter (Switzerland) uses technology that aims to decrease the spigot's width (parameter -b), increasing the yarn's strength qualities.

Let's examine how the release device stripes' design elements affect the yarn's qualities, as seen in Fig. 1 (which lowers the flow arc around the exhaust cylinder lip).

|  |  |
| --- | --- |
|  |  |

**FIGURE 1.** Scheme for determining the angle of flow around the sliver front cylinder:   
*a) existing fume hood; b) a new hood.*

RESULTS AND DISCUSSION

The serial machines GSM2114B and P-76-5M6, which we chose for the study and which we modernized, were fitted with SKF-type exhaust devices. These were used to perform the computations. Modernization includes the development of a new two roller pressure roller design to decrease the flow angle of the exhaust cylinder web and increase the stability of the roller due to the cylinder's corrugation. Fig. 1 displays the design approach, while Table 1 displays the starting data.

**TABLE 1.** Value Х1, У1, R and r, mm.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Brand | GSM2114B | | | | P-76-5M6 | | | |
| Calculated pairs. | Ring strip position | | | | | | | |
| At the top | | At the top | | At the top | | At the top | |
| Exist | Exist | Exist | Exist | Exist | Exist | Exist | Exist |
| Х1 | 38 | 37 | 37,5 | 36 | 38 | 37 | 37,5 | 36 |
| У1 | 98,5 | 100 | 154 | 155 | 88,5 | 90 | 149 | 159 |
| R | 12,5 | 14 | 12,5 | 14 | 12,5 | 14 | 12,5 | 14 |
| r | 14 | 7 | 14 | 7 | 14 | 7 | 14 | 7 |

**TABLE 2.** Index of specific hairiness of cotton yarn

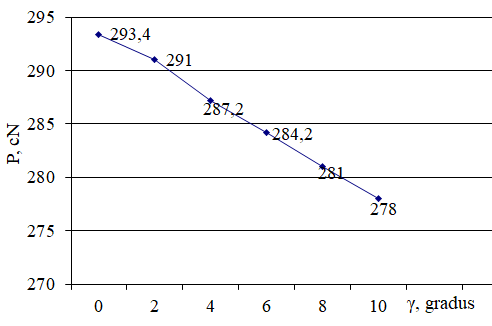
|  |  |  |
| --- | --- | --- |
| Exhaust flow angle cylinder with sliver γ, degree. | Specific linear hairiness of yarn h | |
| sliver width b = 0.002 m | sliver width b = 0.001 m |
| 10 | 5,8 | 5,78 |
| 8 | 4,65 | 4,62 |
| 6 | 3,5 | 3,48 |
| 4 | 2,34 | 2,32 |

Then at b = 0.002 m CV = 17.5 (according to GOST 4.8–2003 (ISO 10290:1993) CV - yarn evenness - is determined in accordance with ASTM D1425; the maximum value for carded yarn is CV = 17.5). Absolute breaking load of yarn, determined by formula (4), is presented in table. 3.

**TABLE 3.** Absolute breaking load of yarn

|  |  |
| --- | --- |
| Angle of flow around the exhaust cylinder by the shoulder γ, degree. | Absolute breaking load of yarn Ррр, sN. |
| 10 | 278,0 |
| 8 | 281,0 |
| 6 | 284,2 |
| 4 | 287,2 |
| 2 | 291,0 |
| 0 | 293,4 |

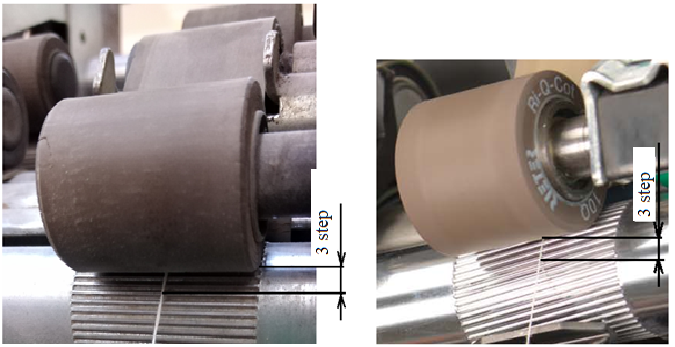
Thus, with a decrease in the angle of flow around the shoulder of the front cylinder of the exhaust device, an increase in the absolute breaking point is observed yarn loads.

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**FIGURE 2.** Dependence of the absolute breaking load of yarn on the angle of flow around the sliver of the exhaust cylinder of the exhaust device.

Figure 2 illustrates the relationship between the angle of flow around the exhaust cylinder's slice and the yarn's absolute breaking load. The flow angle was checked through experiments.

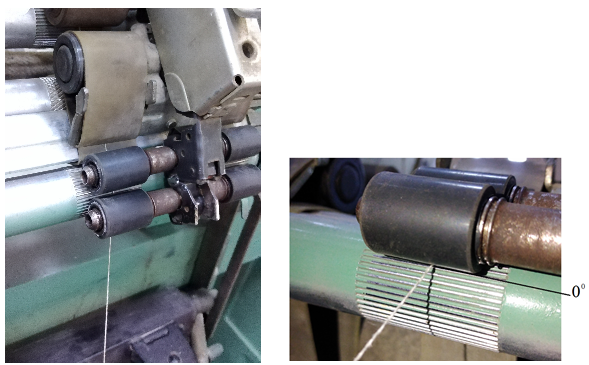
A lens-equipped plastic enclosure is fastened to the exhaust device's cylinder rack. The sliver created by the front cylinder will be magnified four times by the lens. A Zenit camera is then used to take pictures through the lens. Photographs are shown in Figs. 3 and 4. A picture of a sliver emerging from a traditional exhaust device is shown in Figure 3, and a sliver emerging from an exhaust pair with a double pressure roller is shown in Figure 4. It is evident from the pictures above that the cylinder is touched by the sliver exiting a typical exhaust pair at a length that is roughly equivalent to 1.3 to 1.5 from the riffle pitch. We calculate a flow angle equal to, given that the riffle pitch is 1.57 mm. As observed in the picture, the lip exiting the exhaust pair with a double pressure roller does not make contact with the front cylinder's surface. The flow angle was determined from the calculations above. The ring bar's lowest position was used for the experiments.



a) Photo of the flow angle on b) Photo of the flow angle on the

the R-76-5M6 vehicle. G 32 machine from Rieter.

**FIGURE 3.** The sliver coming out of a conventional exhaust device.



**FIGURE 4.** The sliver coming out of the exhaust pair with double pressure roller**.**

It has been demonstrated that a yarn's strength and breakage decrease with decreasing flow angle. As a result, different design strategies are employed to lower the flow angle. For instance, installing the exhaust cylinder's pressure roller with its displacement relative to the cylinder axis rearward by 2 to 3 mm is a common practice for this reason. The roller on the SKF exhaust device is positioned 2 mm in front. Even in this instance, though, the flow angle values are high. It is structurally challenging to move the roller forward any more. As a result, the double pressure roller allows the flow angle to be greatly decreased.

Tests were conducted to determine how flow angle affected yarn breakage. The studies were conducted in "PAPFEN" OOO's spinning shop. Two spinning machines that produced yarn with linear densities of 25 and 28 tex, respectively, were used to measure breakage. One exhaust device staff member on each machine has two pressure rollers on the exhaust cylinder. Over a period of 15 days, eight hours each, two methods of measuring breakage were used: "PAPFEN" OOO. The measurement results are displayed in table Figure 4.

**TABLE 4.** Effect of flow angle on yarn breakage

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Linear density of yarn, tex. | Yarn breakage (1000 spin/hour). | | | Difference in breakage in %. |
| allowed according to standard | existing VP | new VP |
| 25 | 0,12 | 0,101 | 0,06 | 40 |
| 28 | 0,12 | 0,066 | 0,046 | 30 |

It is well known that the contact pad in the exhaust pair will also be uneven when the pressure roller's axis bends; that is, the clamping force of the sliver during pulling will change as the pressure roller lengthens. This situation may have an impact on the yarn's unevenness and breakage. Experiments were conducted in this section of the investigation to examine how the sliver's position affects breakage. This is accomplished by dividing the pressure roller column's length along the coating into three portions (Fig. 5). Additionally, a unique template was created to fix the yarn break placement. In the spinning shop "PAPFEN" OOO, 15 removals were conducted during which breakage measurements were made. Comparing the null hypothesis for the homogeneity of dispersions in each measured region of the roller allowed for the processing of the collected data. The Cochran test was used to test the null hypothesis of homogeneity of variances. The following formula is used to determine the dispersion in each section:

 (5)

Cochran's criterion is calculated using the formula:

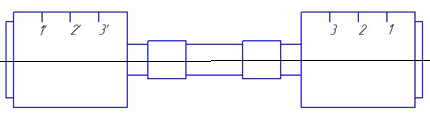


Here: *n*- number of repetitions of each series of experiments. We have accepted *n=15*;  - number of breaks during measurements;

 - arithmetic average number of breaks;  - maximum dispersion.

Cochran's tabular value for our case was equal to:

 Means 



**FIGURE 5.** Scheme of dividing the pressure roller pedestal to the site.

This demonstrates that there is no justification for rejecting the null hypothesis, which states that the distributions of breakage in the various roller sections vary considerably from one another. Consequently, it can be said that the yarn's quality is impacted by uneven touch.

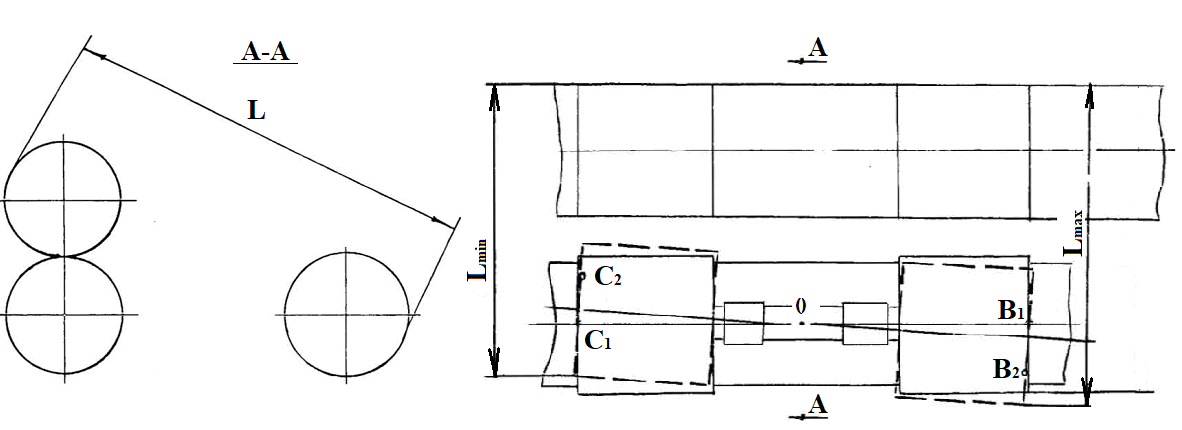
Above, we have established that the pressure roller may lose stability under operating loads; in this case, one of its possible positions may be the intersection of the axes of the pressure roller and the reef cylinder. The design of the load lever and the load and saddle allow the roller to rotate relative to the axis of the load spring 0 (Fig. 6-a.) up to 3°-3.5°, and the amount of misalignment depends on the force of pressing the roller to the cylinder.

The measurement scheme is shown in Fig. 6-b. The surface of the corrugated pedestal of the 2nd line of cylinders was chosen as the measurement base. A caliper was used as a measuring tool. The measuring surfaces of the caliper are applied to the reef cylinder of the 2nd line and the pressure roller of the exhaust pair at both ends. The distance B1B2 and C1C2 is taken as the skew value, which  is  obtained by subtracting the value from. The experiments were carried out under production conditions in the spinning shop of “PAPFEN” OOO, on two machines of the GSM2114B and P-76-5M6 brands. The measurement results are summarized in table. 5. The first column of the table shows the skew values, the frequency - in the 2nd column. Based on these data, frequency polygons were constructed (Fig. 7 and 8 ).

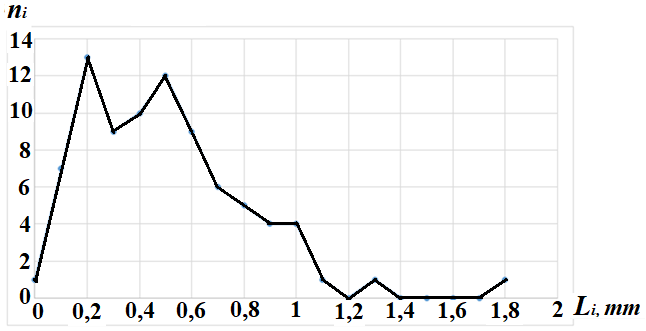
**TABLE 5.** Press roller skew value, mm.

|  |  |  |  |
| --- | --- | --- | --- |
| Item No | Yarn thickness. | 25 tex. | 28 tex. |
| skew amount, mm. | frequency, | frequency, |
| 1 | 0 | 1 | 2 |
| 2 | 0,1 | 7 | 9 |
| 3 | 0,2 | 13 | 14 |
| 4 | 0,3 | 9 | 14 |
| 5 | 0,4 | 10 | 11 |
| 6 | 0,5 | 12 | 8 |
| 7 | 0,6 | 9 | 14 |
| 8 | 0,7 | 6 | 6 |
| 9 | 0,8 | 5 | 1 |
| 10 | 0,9 | 4 | 4 |
| 11 | 1,0 | 4 | 4 |
| 12 | 1,1 | 1 | 5 |
| 13 | 1,2 | - | 3 |
| 14 | 1,3 | 1 | 2 |
| 15 | 1,4 | - | 1 |
| 16 | 1,5 | - | 2 |
| 17 | 1,6 | - | - |
| 18 | 1,7 | - | - |
| 19 | 1,8 | 1 | - |

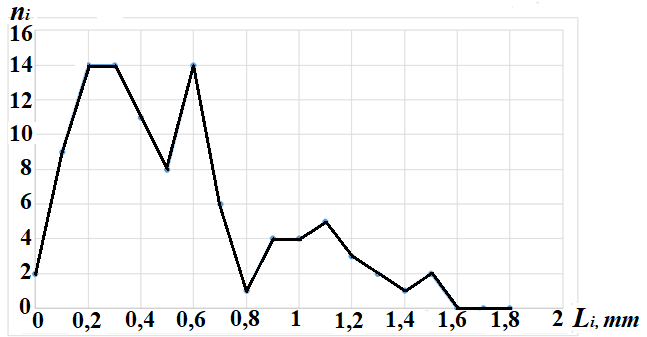
Analysis of the frequency polygon (Fig. 7 and 8) shows that the most common misalignment is in the range from 0.2 to 0.6 mm, which corresponds to a rotation of the roller axis from 0.230 to 0.70. However, from Fig. 4.4 it is also clear that the maximum misalignment can reach 1.8 mm or this corresponds to a rotation of the roller axis by 20. A comparison of the frequency range when producing 25 tex. and 28 tex. yarn shows that the frequencies of misalignment in the drawing devices of the GSM2114B and P-76-5M6 spinning machines are approximately the same.



**FIGURE 6.** Scheme for measuring roller misalignment relative to reef cylinder of the second line.



**FIGURE 7.** Polygon of frequencies of roller misalignment during the production of 25 tex yarn.



**FIGURE 8.** Polygon of frequencies of roller misalignment during the production of 28 tex yarn.

CONCLUSION

The results of this study demonstrate that the implementation of a new two-roller pressure roller design in ring spinning machines significantly reduces the flow angle around the front cylinder, resulting in improved fiber alignment. Experimental findings indicate that narrowing the flow arc from 10° to 2° leads to a 13–15% increase in yarn tensile strength. Additionally, the modernization of the drafting system contributes to decreased yarn breakage and better yarn uniformity. These results provide valuable insights for upgrading spinning equipment and optimizing production processes to enhance yarn quality in the textile industry.

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