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Research Article

Impact of Doubling and Auto leveling in Draw Frame on the Quality of Rotor-Spun Yarns

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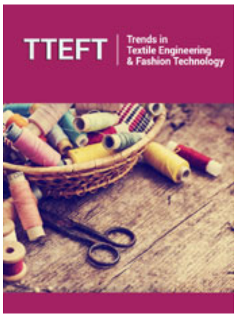

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Abstract

This study explores the impact of doubling and auto leveling in draw frame on the quality of rotor yarns. Virgin cotton of Ivory Coast (55%) and waste cotton (dropping-1: 25% and dropping-2: 20%) used as raw material. Rotor-spun yarns of 20 Ne were manufactured from the slivers produced from carding machine, breaker draw frame, and finisher draw frame without and with auto leveler. The quality parameters of slivers and rotor yarns such as Um%, CVm%, Imperfections (thick place, thin place, and neps), and count strength product (CSP) were tested and analyzed. The Um%, CVm% of different sliver gradually decreased due to the action of doubling and auto leveler. In yarns, Um%, CVm% showed a similar trend as slivers. Thick places, thin places and neps also exhibited the decreasing pattern with the increase of sliver doubling and the use of auto leveler. The quality of yarns improved with the increase of doubling and yarns produced from finisher draw frame sliver with auto leveler showed the best result. The reason can be attributed to the most evened out sliver with better fiber orientation due to the combined action of doubling and auto leveling.

Keywords: Doubling; Auto leveler; Neps; Imperfections

Introduction

The textile industry belongs to the oldest industrial branches and maintaining its sustained growth for improving the quality of human life. Despite being old, the spinning process is still developing and very essential for the production of most of the textile fabrics. The fact that spinning lies at the very early stage of the textile processing chain, its influence on the quality of the end products is vital. Especially some faults only are seen in the thread after the subsequent processing or even after the dyeing process. The main objective of the staple yarn spinning process is to achieve the highest possible yarn evenness with minimum imperfections, which impart uniformity in yarn strength. Consequently, these improvements positively influence the quality of subsequent processes, like weaving and knitting. Better fiber control due to controlled drafting ranks ring-spinning as the best yarn spinning system. Ring yarn has used as a benchmark against which the quality of yarn produced on other spinning systems is judged [1].

The higher demands of quality and economy are directly associated with the development of the spinning industry. For instance, because the processing speeds adversely influence the quality of the yarn, the spinning industry is always put under the extensive pressure of quality improvement at higher speeds. There are various types of spinning systems in the world [2-3]. Among different yarn production methods, rotor spinning accounts for more than 30% by volume of the staple yarn produced around the world [4]. In comparison to the ring-spinning process, rotor spinning involves a smaller number of the labor force, lower maintenance cost, a smaller number of spare parts, less floor space and lower energy cost because of less machinery involved in the yarn production process. Furthermore, working conditions are generally better in rotor spinning, which improves the workers' efficiency. Additionally, almost 2.5% less waste is generated for all yarn counts in rotor spinning as compared to ring spinning [5].

Global demand for rotor yarn is growing at a faster rate [6]. Currently, a vast amount of clothing needs in the developed countries met by rotor yarn goods. While textile production wastages are undesirable but inevitable in a spinning process, if these wastages are converted into useful products economically, there will be a significant contribution to the market, which is only possible because of rotor spinning/Open-end spinning. So, ensuring the required quality in a rotor yarn is a vital issue for the yarn manufacturer. There are various types of parameters that influence the quality of rotor yarn. After processing fiber in blow room and carding, the card slivers have high unevenness values that are unbearable and must be evened out at the drawing stage to produce the improved quality yarn. In the spinning process, the unevenness of the product increases from stage to stage after the draw frame because of the number of fibers in the section decrease [7]. The uniform arrangement of fibers becomes more difficult because of their smaller amounts. Drawing is a necessary process where the card slivers are doubled and drafted to level the unevenness present in each sliver [8].

Doubling is the combining of several slivers, and drafting is attenuation. Drawing, therefore, involves the processes of drafting and doubling, with reasonable fiber control being the essence throughout. Doubling refers to the action of combining two or more slivers during a process, such as drawing, doubling taking place at the input to the drawing stage. Slivers from different cards vary in evenness and other properties and should be blended to reduce the irregularity [9]. The drawing process, specially fitted with auto leveler, plays a predominant role in the control of count C.V% and enhances fiber orientation in the sliver. The draw frame primarily improves medium-term and especially long-term sliver evenness through doubling and drafting. The carding process generates fiber hooks, which cause errors in drafting, reduce the strength of the yarn, increase the end breakage rate, and lead to a general deterioration in performance. It is well known that the drafting process, in general, improves the fiber parallelization and straightens the hooks present in the card sliver [3,10]. The magnitude of the drawing process is huge in terms of quality perspective. A draw frame machine is feeding approximately 2 (two) simplex machines, and a simplex machine is supplying almost 3 (three) ring frames. Thus, the fault generated in the sliver delivered from a draw frame significantly affects the yarns produced in 3 (three) ring frames from that sliver. The draw frame contributes less than 5% of the production costs of the yarn. However, its impact on quality, especially evenness, is more significant. The drawing depends on some factors such as the number of doublings, feed sliver hank, and delivery sliver hank. The number of doublings may keep as 6 or 8 depending upon the process requirements [10].

With increasing global competition, the superior and constant sliver and yarn quality become the essential requirements of the customer. Auto leveler is an auxiliary device attached to the carding and draw frame machine to correct linear density variations in the delivered sliver by changing either the main draft or break draft according to the feed variations. The main objectives of an auto leveler are as follows: to measure sliver thickness variation on a real-time basis, to alter the machine draft so that a high consistent sliver thickness continuously produced. Generally, two types of auto levelers are available: open loop and closed loop. In open-loop auto levelers, sensing done at the feeding end, and the correction done by changing either a break draft or the main draft of the drafting system. In a closed-loop system, sensing is at the delivery side and correction is done by changing either a break draft or the main draft of the rafting system [7]. The open-loop system used in draw frame and very effective because the correction length in the open-loop system is many times lower than the closed-loop system. The open-loop system may generally use for the correction of short-term variations. In the case of an open-loop system, since the delivered material is not checked to know whether the correction has been done or not, sliver monitor is fixed to confirm that the delivered sliver has the required linear density. But in the case of a closed-loop system, it is confirmed that the delivered sliver is of required linear density [10].

Many researchers have already studied the effect of carding and rotor parameters on yarn quality from different outlooks [11-14]. The results of several investigations have revealed that machine parameters significantly affect the physical and mechanical properties of yarn [15-17]. Rotor yarns are less irregular compared to the ring-spun yarn because of multiple doubling [18]. Douglas [19] noted that high-speed modem machinery has resulted in overall quality improvement of rotor yarn. Haque [20] reported that the draw frame with auto leveler gave the best value of yarn count as compared to without an auto leveler draw frame. Siddique [21] concluded that delivery speed has a significant effect on the yarn count. Subramaniam & Moharned [22] found that both strength and evenness decrease as the break draft increased. Nawaz et al. [23] stated that CSP value mostly dependent upon the yarn lea strength. Ching & Sun [24] reported that in the initial drafting zone, the drafting process straightens the fiber crimps and hooks and improves the yarn quality. Klein [3] stated that short fibre has a greater influence on yarn strength and Arshad [25] found lea strength decreases with the addition of short fibres and moderate speed produced the lowest value of short fibers.

Although some research efforts have made on other process parameters from the above discussion, there is a lack of detailed research regarding the influence of doubling and auto-leveling in draw frame on the quality of rotor-spun yarn. This article has focused on the doubling and auto-leveling in draw frame for producing better quality sliver as well as yarn. Among many variables of the machine parameters, we worked on doubling in breaker draw frame and finisher draw frame without and with auto leveler, while all other parameters remain fixed. In this work, an attempt has been taken to investigate and analyze the impact of doubling and auto-leveling on the quality of produced rotor yarn.

Material

The raw materials used in this investigation were Ivory Coast cotton and cotton waste, which collected from blow room and carding wastages (dropping-2, dropping-1). These wastes passed into a filter to reduce impurity in cotton and strongly compressed into bales. The properties of the Ivory Coast and waste cotton fiber measured with the Uster HVI Spectrum instrument. The measured properties of fibers given in Table 1. Ivory Coast and waste cotton blended at the start of the blow room process with a ratio of 55% and 45%.

Table 1: Fibre properties summary.

Fibre Property	Cotton	Dropping-1	Dropping-2
Fineness (Mic)	4.2 -4.8	-	-
Strength (gm/tex)	28	25	24
Length (mm)	27-29	19-20	20-22

Methods

Four different slivers used to produce yarns of Ne 20 on a rotor-spinning machine. At first, raw cotton of Ivory Coast and waste cotton fibers supplied in blow room with a blend ratio of 55% and 45%. From the carding machine, cotton slivers of 0.10Ne produced with 140m/min delivery speed. Then the carded slivers fed to the rotor machine and produced 20Ne rotor yarn. Six (6) slivers were taken from the carding machine and fed into a breaker draw frame to produce 0.11Ne breaker drawn sliver. Then the breaker drawn slivers fed to the rotor machine and produced 20Ne rotor yarn. After that, eight (8) breaker drawn slivers passed through finisher draw frame and produce two types of finisher drawn sliver; one is without using auto leveler, and another is using auto leveler. Then the drawn slivers were fed to the rotor spinning machine and produced 20 Ne rotor spun yarns. Yarn samples conditioned at (20±3) °C temperature and (65±2) % RH according to the standard. Finally, all-cotton slivers and rotor yarn samples were taken for testing with Uster tester- 4, according to ASTM D 142596. After then, Yarn tensile strength tested with the help of Uster Tensojet-4, according to the standard ASTM D-76.

Irregularity of sliver

It observed from Figure 1 that in card sliver, breaker draw frame sliver, finisher draw frame silver without auto leveler and with auto leveler the corresponding Um% and CVm% are 3.30, 3.08, 3.03, 2.69, and 4.12, 3.88, 3.83, 3.39 respectively, which shows a decreasing trend. The Um% and CVm% of card sliver decrease by 18% when the breaker draws frame and auto leveler used in the finisher draw frame. Because in breaker draw frame, sliver doubling occurs and drafted fibre straight by removing tailing hook, which reduces irregularity of the card sliver Figure 2. Finisher draw frame without auto leveler also does the same, but when we use auto leveler, the degree of parallelization of fiber becomes higher and thus decreases sliver irregularity [8]. The significant improvement in sliver evenness achieved by controlling the short, medium- and long-term variations at the draw frame Table 2.

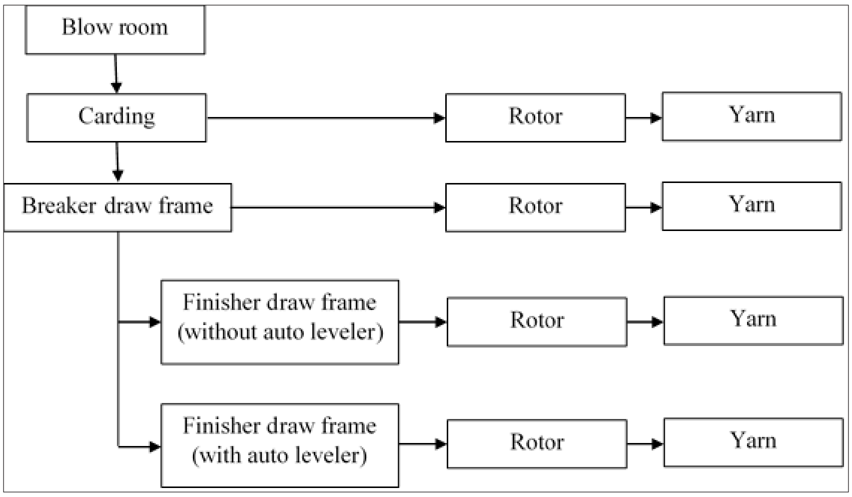

Figure 1: Flow chart of different rotor yarn manufacturing.

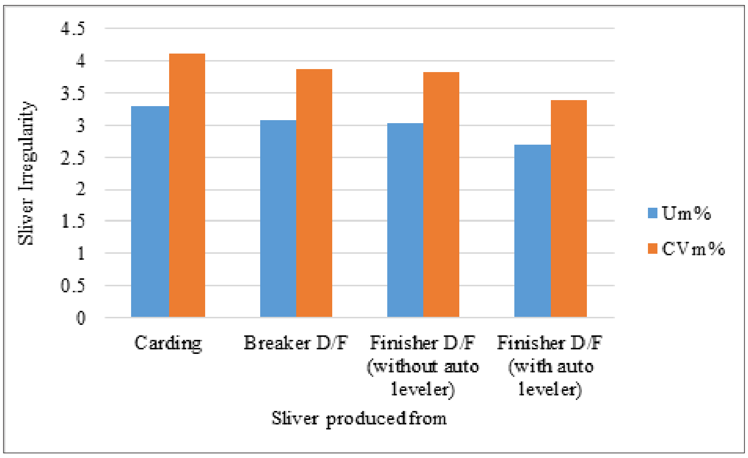

Figure 2: Sliver Irregularity values.

Table 2: Sliver test results.

Quality Parameter	Sliver Produced from			
	Carding	Breaker draw frame	Finisher draw frame	
			Without auto leveler	With auto leveler
Um (%)	3.3	3.08	3.03	2.69
CVm (%)	4.12	3.88	3.83	3.39

Irregularity of rotor yarn

The irregularity (Um% and CVm%) of yarn count of 20Ne highlighted in Figure 3. In this Figure 3, there is a clear trend of decrease in the unevenness of yarn with the using breaker draw frame and finisher draw frame without and with auto leveler. The better equalizing effect occurred when the auto leveler did the leveling action in the finisher draw frame. When breaker draw frame and finisher draw frame with auto leveler use, it increases the fiber parallelization, straight fibre by removing the hook from fibre and level the sliver thickness, control of short fibre thus helps to decrease the irregularity of yarn Table 3.

Table 3: Yarn test results.

Quality Parameter	Yarn Produced from			
	Carding sliver	Breaker draw frame sliver	Finisher draw frame sliver	
			Without auto leveler	With auto leveler
Um (%)	11.24	11.14	10.87	10.68
CVm (%)	14.1	14.04	13.76	13.51
Thin (-50%)/km	16	5	3.5	3
Thick (+50%)/km	57	51	49.5	33.5
Neps (+280%)/km	30.5	24.5	21.9	15.5
Imperfection index	103.5	80.5	74.9	52
CSP	1702	1774	1789	1797

Imperfections of rotor yarn

Figure 4-7 depicts the imperfections of rotor yarn. Here, we consider thick place, thin place, and neps. In all these cases, it is clearly shown that rotor yarn imperfections (thick places +50%, thin placse –50%, and neps +280%) decrease when we use a breaker draw frame and finisher draw frame without and with auto leveler. Altogether, we also investigated the IPI values and found the same results. The IPI value decreased tremendously to 50%, by increasing doubling and leveling of sliver by auto leveler. The reason for this result is simple. We know that the number of short fibres proportionally related to the quality parameters of yarn. As we increase the drawing process, it controls short fibre, straight fibre by removing fibre hook, which increases fibre length, and adjusts the short, medium- and long-term variations of the sliver thickness [10]. As a result, the degree of fiber parallelization increases and the yarn imperfections (thick place, thin place, and neps) decrease.

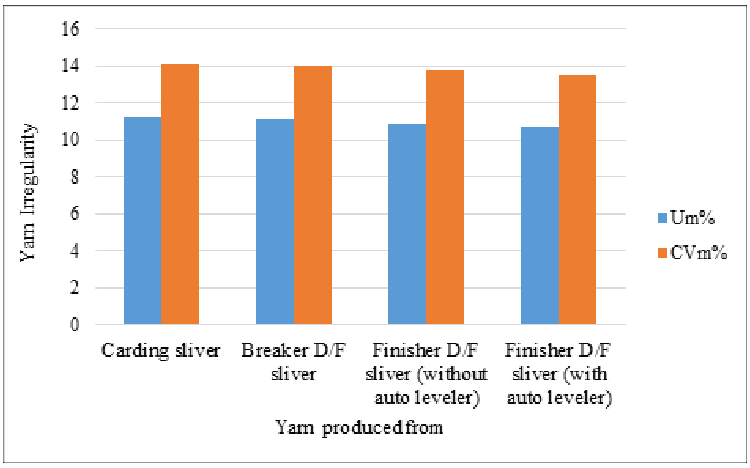

Figure 3: Yarn Irregularity values.

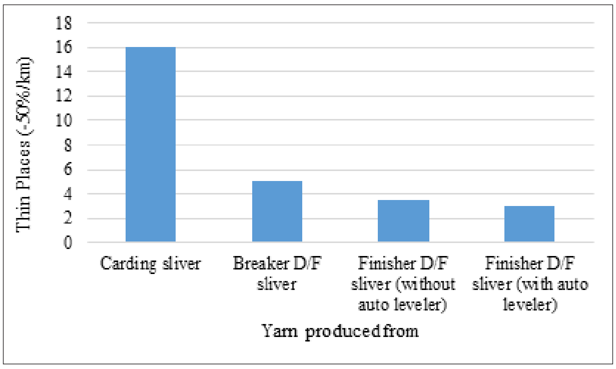

Figure 4: Yarn thin places (-50%/km) values.

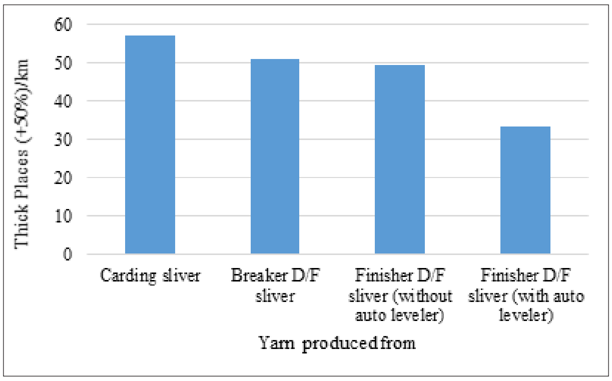

Figure 5: Yarn thick places (+50%/km) values.

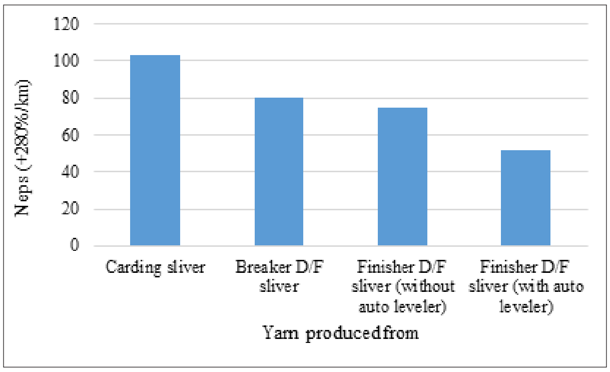

Figure 6: Yarn neps (+280%/km) values.

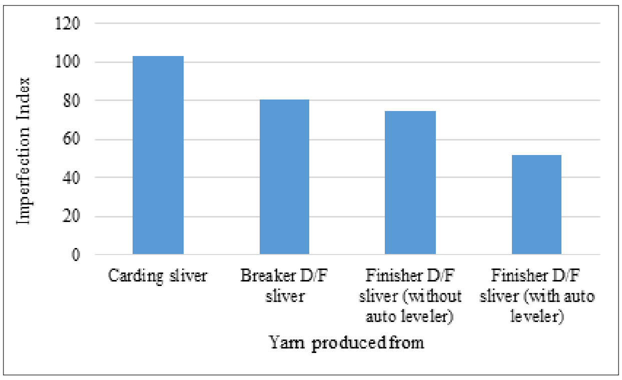

Figure 7: Imperfection Index values.

Strength of rotor yarn

Figure 8 provides a significant effect on the yarn strength with the use breaker draw frame and finisher draw frame without and with auto leveler. From this graph, we observe that with the use of breaker draw frame and finisher draw frame without and with auto leveler, yarn strength (CSP) increases. This result suggests that there is an association between doubling and the leveling of sliver with yarn strength. Hence, the increase of fibre length and fibre orientation, higher twist insertion, and more fiber migration occur, which results in increasing of yarn strength.

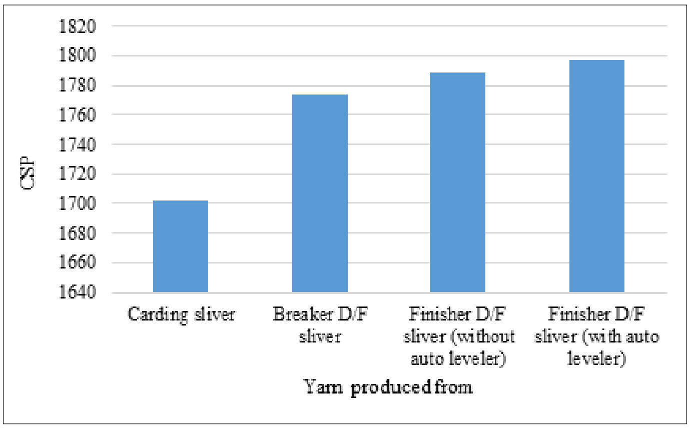

Figure 8: Yarn CSP values.

Conclusion

In this work, 20 Ne rotor yarns manufactured from different types of slivers such as sliver from carding, breaker draw frame, and finisher draw frame without and with auto leveler. The Um%, CVm% of different sliver gradually decreased due to the action of doubling and auto leveler. In yarns, Um%, CVm% showed a similar trend as slivers. Especially thick, thin places and neps, also exhibited the decreasing pattern with the increase in sliver doubling and the use of auto leveler. The structural parameters of yarns such as Um%, CVm%, thick places, thin places, and neps found to have directly reflected the yarns' strength. Yarn strength increases with the use of breaker draw frame and finisher draw frame without and with auto leveler. The quality of yarn improves when doubling is done and further improves done when we use finisher draw frame without and with auto leveler. The doubling and auto leveler influenced all the quality parameters investigated in this research, like neps, irregularity, strength, and so on. The current work has opened the scope for further study in this context.

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