Impact of taker-in speed on the characteristics of ring-spun yarn

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ABSTRACT – REZUMAT

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In this study, experiments were carried out to determine to what extent the card sliver and final yarn quality were altered by a gradual increment in the speed of the taker-in roller on the carding machine. The speeds of the taker-in roller have been determined as 1200 rpm, 1400 rpm and 1600 rpm, respectively. The operating parameters of the carding machine and other equipment in the yarn production line were kept constant. Fibre breakage, neps removal efficiency, and defect index of samples have been measured by the AFIS PRO2 laboratory instrument. The characteristics of ring spun yarn (17.35 tex) were tested on a Uster Tester-5 (UT-5) laboratory device. Research results revealed that the enhancement of taker-in speed led to increased fibre breakage due to the greater impact force on the cotton fibre. This elevates the number of short fibres in the material and also negatively affects the final yarn properties including unevenness (U%), imperfection index (IPI), ultimate yarn strength (cN/tex), and hairiness index (H-value).

Keywords: *ring spinning, carding, taker-in speed, sliver, yarn properties*

Impactul vitezei cilindrului rupător asupra caracteristicilor firelor filate cu inele

În acest studiu, au fost efectuate experimente pentru a determina în ce măsură banda de cardă și calitatea finală a firului au fost modificate prin creșterea treptată a vitezei cilindrului rupător pe mașina de cardat. Vitezele cilindrului rupător au fost determinate ca fiind 1200 rpm, 1400 rpm și, respectiv, 1600 rpm. Parametrii de funcționare ai mașinii de cardat și ai altor echipamente din linia de producție a firelor au fost menținute constante. Ruperea fibrelor, eficiența de îndepărtare a nopeului și indicele de defect al probelor au fost măsurate cu instrumentul de laborator AFIS PRO2. Caracteristicile firului filat cu inele (17,35 tex) au fost testate pe dispozitivul de laborator Uster Tester-5 (UT-5). Rezultatele cercetării au arătat că creșterea vitezei cilindrului rupător a dus la un grad mai mare de rupere a fibrei din cauza forței mai mari de impact asupra fibrei de bumbac. Astfel, crește numărul de fibre scurte din material și, de asemenea, afectează negativ proprietățile finale ale firului, inclusiv neuniformitatea (U%), indicele de imperfecțiune (IPI), rezistența finală a firului (cN/tex) și indicele de pilozitate (valoarea H).

Cuvinte-cheie*: filare cu inele, cardare, viteza cilindrului rupător, bandă de fibre, proprietăți ale firului*

INTRODUCTION

One of the most important factors affecting the quality of final textile products is the efficiency of the utilized yarn production technology [1]. Today, machinery manufacturers and spinning mills face the challenge of producing high-quality yarns at high carding speeds and low waste levels [2–4]. Many studies in the literature state that the carding process is generally based on tasks such as separating the fibres from each other, cleaning them from foreign substances, separating defective fibres from the system, making the fibres partially parallel to each other, thinning the fibre layer up to 100 times, diminishing short term variation in sliver thickness and formation of carding sliver of the required quality and placing it in a basin [5–8].

During manufacturing, there is a close relation between increasing production rate and decreased quality level; as the production rate increases, the carding process gets more severe, and the risk of unfavourable impacts on quality propels [9–11]. Since 1770, the carding machine's operational principle and concept have remained unchanged. Statistical data revealed that, with the advancement of technology, carding productivity has increased from around 5 kg/h to about 100 kg/h since 1965 [12].

Numerous characteristics (tenacity, elongation, unevenness etc.) of the yarn manufactured in a spinning mill are determined by the fibre properties as well as the setting parameters of the machines in the spinning line where the carding process is one of the most crucial ones. To enhance production efficiency, it is necessary to maintain the carding quality and improve the carding process in the drum receiving area (taker-in zone) as well as between the main drum and the carding flats (figure 1). Furthermore, it is essential to ensure that the carded fibres pass completely from the main drum to the separation drum [13].

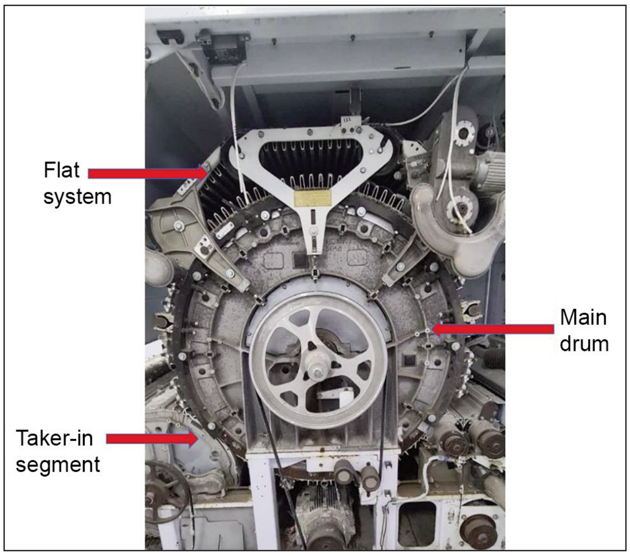

Fig. 1. Main parts of the carding machine

The taker-in zone is crucial during the separation of the bundles into individual fibres and removing the foreign substances and defects from fibrous material. The taker-in zone includes a feed plate, feed roller, taker-in and mote knives. Under a specific load, fibre matt is held between the grooved feed roller and the smooth-curved surface of the feed plate and fed to the taker in segments by the feed roller rotations [14]. In this machine segment, approximately, 70–80% of the fibres are split into individual fibres, and foreign substances and defects are eliminated almost in the same percentage [15]. The following variables have major consequences on the processing of the fibre tuft in the taker-in zone; feed roller speed, setting between the feed plate and the taker-in, feed fibre matt uniformity and its characteristics, taker-in speed, adjustment between taker-in and mote knife, and taker-in wire specifications [16].

The speed of the taker-in drum in the carding machine influences the amount of debris leaving the system; nevertheless, excessive speed may also cause fibre damage. The rotation frequency of the main drum is very effective in opening the fibres individually. The speed of the knives is responsible for the removal of short fibres but does not affect the homogeneity of the product [17].

Several studies were conducted to determine the best configuration parameter for a carding machine to generate a high-quality card sliver. For instance, Ghosh and Bhaduri discovered that the card web is primarily governed by cylinder and doffer speeds, as well as the linear density of the delivered sliver [18]. Zhang and Sun explored the effects of carding machine rear stationary flat gauge and taker-in speed selection [19]. Simpson et al. examined the influence of carding rate and cylinder speed on fibre hooks and spinning efficiency and discovered that enhancing the carding rate elevated minority hooks while declining majority hooks [20].

Despite extensive investigation efforts on various process parameters of carding machine, there is a shortage of specific research on the influence of taker-in speed on the quality of card sliver and the properties of ring spun yarn. In current research, as a novel approach, the impact of three different taker-in speeds (1200 rpm, 1400 rpm and 1600 rpm) on the fibre breakage, cleaning efficiency, carding and drawing sliver unevenness, and the ring spun yarn's strength, unevenness and hairiness have been examined.

MATERIALS AND METHODS

Fibre samples were selected from flowing materials by random sampling method at the Azala Cotton LPP Spinning Mill (Shymkent, Republic of Kazakhstan). Cotton samples were tested on laboratory equipment with AFIS and HVI systems [21]. The properties of the studied cotton fibre samples are depicted in table 1.

Table 1

DETAILED PHYSICAL AND MECHANICAL PROPERTIES OF FACTORY-SORTED COTTON FIBRE

Parameters	Values
2.5% Spun length (mm)	28.5–29
Uniformity ratio (%)	49
Strength (cN/dtex)	2.85–3
Elongation (%)	8
Micronaire, MI	4.4–4.8
Short fibre index (%)	6–10
Reflectance, Rd	74.8
Yellowishness, +b	9.4

In table 1, the micronaire value has been presented as MI by the calculation of equation 1 [22].

$$dtex = MI \times 0.394 \quad (1)$$

The following equations have also been used to analyse the measurement results of the current study. For instance, the uneven distribution of fibres along the length of the yarn is the cause of the unevenness (U%), which is the mass deviation of a unit length of material (equation 2) [23].

$$\text{Unevenness (U\%)} = \text{(mean deviation)/mean} \times 100 \quad (2)$$

The imperfection index of yarns (IPI) has been determined according to equation 3 [23].

$$IPI = \text{Thick places (+50\%), thin places (–50\%), and neps (+200\%)} \quad (3)$$

The following samples were obtained using the random sampling method: at running speeds of 1200 rpm, 1400 rpm and 1600 rpm for the taker-in, the samples were taken from the feed hopper. All the other process parameters remained the same during the production. Selected samples were tested on the AFIS PRO2 laboratory instrument where fibre breakage, neps removal efficiency, and defect index of samples, fed into and exited from the device, have

Table 1

PROCESS PARAMETERS FOR 17.35 TEX COUNT RING YARN PRODUCTION			
Process type	**1**	**2**	**3**
Carding	RIETER C60		
Drawing hank (tex)	~ 70	~ 70	~ 70
Taker-in speed (rpm)	1200	1400	1600
Maim drum speed (rpm)	520	520	520
Flats speed (mm/min)	330	330	330
Doffing drum speed (m/min)	152	152	152
Wadding density (g/m)	500-600	500-600	500-600
Productivity (kg/h)	120	120	120
1st drawing transition	RIETER SB-40		
Drawing hank (tex)	~ 70	~ 70	~ 70
Break draft	1.2	1.2	1.2
Total draft	4.56	4.56	4.56
Outlet velocity (m/min)	300	300	300
Doubling	8×8	8×8	8×8
Rolls between settings	A-39, B-37	A-39, B-37	A-39, B-37
2nd drawing transition	RIETER RSB-D 40		
Drawing hank (tex)	~ 70	~ 70	~ 70
Break draft	1.2	1.2	1.2
Total draft	6	6	6
Outlet velocity (m/min)	600	600	600
Doubling	6×6	6×6	6×6
Rolls between settings	A-42, B-37	A-42, B-37	A-42, B-37
Roving	RIETER F-35		
Roving No. (tex)	~ 484	~ 484	~ 484
Flyer speed, rpm	1250	1250	1250
Twist (Turn/meter)	43	43	43
Condenser	Black	Black	Black
Total draft	7	7	7
Break draft	1.2	1.2	1.2
Condenser (mm)	12	12	12
Spinning	RIETER G-35		
Total draft	35.7	35.7	35.7
Break draft	1.1	1.1	1.1
Condenser	White	White	White
Rolls between settings	49	49	49
Spinning chamber speed (rpm)	17400	17400	17400
Twist/meter	771	771	771

been measured. The cleaning efficiency of the carding process was tested using an analyser (MESDAN). The studied material went through a spinning process with constant technical parameters indicated in table 2 and the produced yarn from a ring spinning machine (G-35, RIETER) was tested on a laboratory device Uster Tester-5 (UT-5) in terms of defects (IPI), unevenness (%), hairiness and strength of single yarn. For each test, a total of 30 samples (10 samples from each taker-in speed) were analysed and average results were calculated. Also, ring-spun yarns were examined under a light microscope (Mikromet) at 10× magnification.

RESULTS AND DISCUSSION

Figure 2 illustrates an increase in fibre breakage as the taker-in speed is raised from 1200 to 1600 rpm. The amount of short fibre at the taker-in speeds of 1200 rpm, 1400 rpm and 1600 rpm was determined as 5.6%, 6%, and 6.8% on average, respectively. It may be noted here that as the carding machine's taker-in speed increases, the cotton fibres are exposed to harsher impacts and fibre breakage occurs. This has elevated the number of short fibres in the material. Besides, the overall fibre length of the material has declined. The increase in the number of short fibres directly affects the final yarn properties negatively.

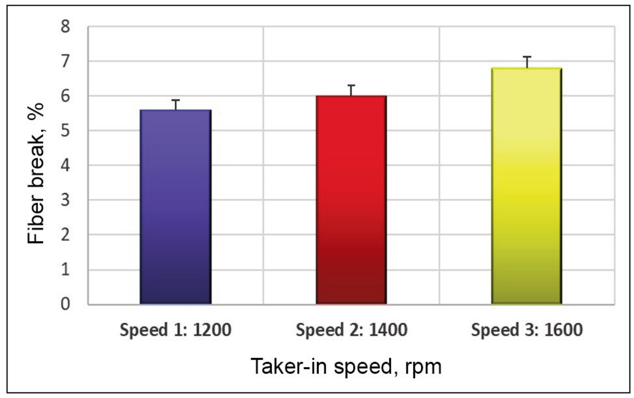

Fig. 2. Effect of taker-in speed modes on fibre breakage

The correlation between taker-in speed and cleaning efficiency is demonstrated in figure 3. Average cleaning efficiency values have been measured as 85.5%, 88.5%, and 94.5% for taker-in speeds of 1200 rpm, 1400 rpm, and 1600 rpm, subsequently.
Experimental observations have proved that the cleaning efficiency improves as the main drum speed accelerates. Moreover, enhancing the taker-in speed

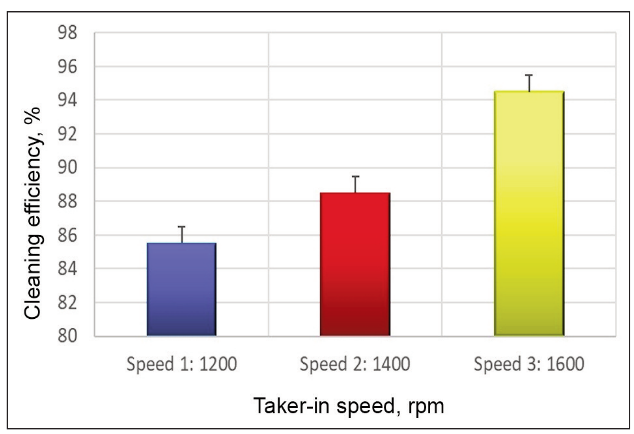

Fig. 3. Effect of taker-in speeds on cleaning efficiency when carding

increases the number of strokes during carding and improves the card's cleaning efficiency. On the other hand, neps removal efficiency increases up to a certain degree as the drum speed goes up, however, further increase in speed reduces the effectiveness of neps removal.

Figure 4 presents the effect of taker-in speed on the unevenness (U%) of the card sliver. According to the graph, unevenness firstly lessens as the taker-in speed increases from 1200 rpm to 1400 rpm, and then it exhibits an enhancing trend at 1600 rpm. Unevenness has been measured as an average of 3.75%, 3.35%, and 4.15% for the taker-in speeds of 1200 rpm, 1400 rpm, and 1600 rpm, respectively. Propelling the taker-in speed induces fibre breaks to occur and, as a result, the percentage of short fibre yield increases. At the optimum speed of entry, short fibres are removed from the flat slivers, thus improving the unevenness in the carding sliver.

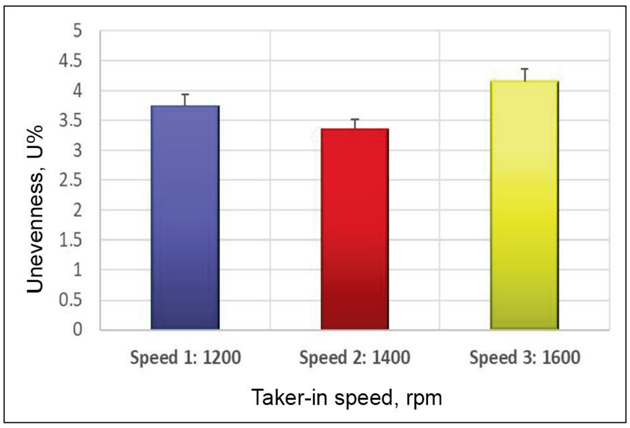

Fig. 4. Effect of taker-in on carding sliver unevenness (U%)

Figure 5 depicts the relation between the taker-in speed and the first draw frame (RIETER SB-40) transition's unevenness. It has been found that the unevenness of the first draw frame pass declines with the increment of taker-in speed. The highest value of the draw frame sliver unevenness (U%-3.39) was measured when the taker-in speed was set to 1200 rpm. Also, unevenness of draw frame sliver values was averagely determined at the taker-in speeds of 1400 rpm and 1600 rpm as an average of U%-3.29 and 3.23%, respectively. For further minimizing the carding sliver unevenness level, the drawing frame process plays a crucial role. The main task of the draw frame is to reduce the unevenness by drawing and doubling the sliver [24]. The draw frame's unevenness is lowered due to the doubling of 8 carding slivers.

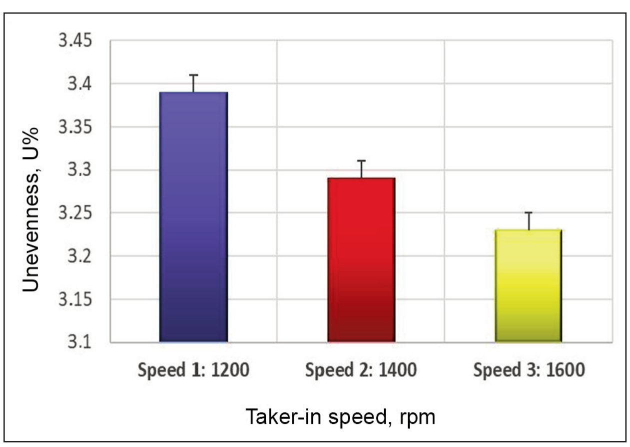

Fig. 5. Effect of taker-in speed on the first transition of the drawing sliver unevenness

At the second transition of the drawing (RIETER RSB-D 40) sliver, the unevenness lessens as the taker-in speed gets higher (figure 6). As represented in the graph, unevenness values have been determined as the average of 2.5%, 2.52%, and 2.21% at the taker-in speeds of 1200 rpm, 1400 rpm, and 1600 rpm, respectively. The primary aim of the second transition of the drawing sliver is to reduce the unevenness by doubling and auto-adjusting [25]. The results proved that a noticeable reduction occurred in unevenness on the second transition of the drawing sliver.

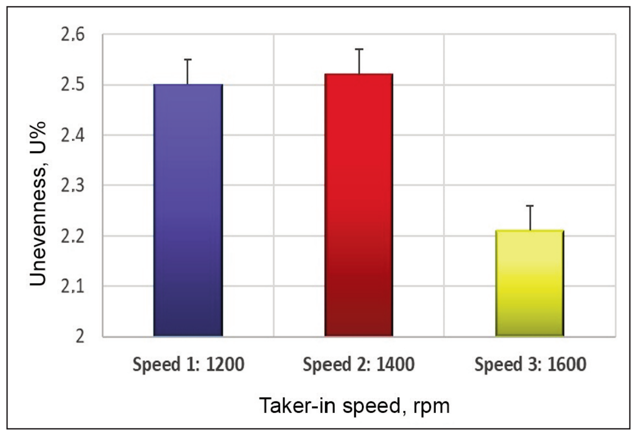

Fig. 6. Effect of taker-in speed on the second transition of the drawing sliver

Figure 7 illustrates the effect of the taker-in speed on the unevenness of the yarn produced by ring spinning. Ten ring bobbins were tested for each taker-in speed to determine yarn unevenness, and the average was determined. Yarn unevenness values were averagely found to be 11.7% for 1200 rpm, 11.4% for 1400 rpm and 10.9% for 1600 rpm, respectively (figure 7). As can be seen from the graph, the most positive result was obtained when the taker-in speed was 1600 rpm. This result could be explained by the fact that at the high speed of the taker-in drum in the carding machine, the amount of fibre per unit area is sufficient and an optimum amount of fibre can be transferred for subsequent processes. As it is known, yarn irregularity reflects negatively on the performance and strength of the yarn, which causes the quality of the yarn to decrease [26].

Figure 8 exhibits the impact of taker-in speed on IPI values. The imperfection index of yarns, or IPI for short, describes the thick places, thin places, and neps in a 1000 m length of yarn [23]. According to the

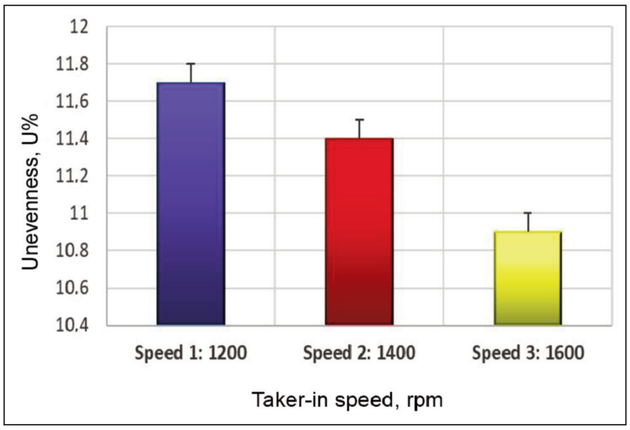

Fig. 7. Effect of taker-in speed on yarn unevenness (U%)

graph, IPI values of the ring spun yarn have been averagely calculated as 190 for 1200 rpm, 250 for 1400 rpm, and 360 for 1600 rpm. It can be concluded that the defect IPI index increases as the taker-in speed goes up. Short fibres directly affect the IPI because more fibres are damaged with increasing taker-in speed.

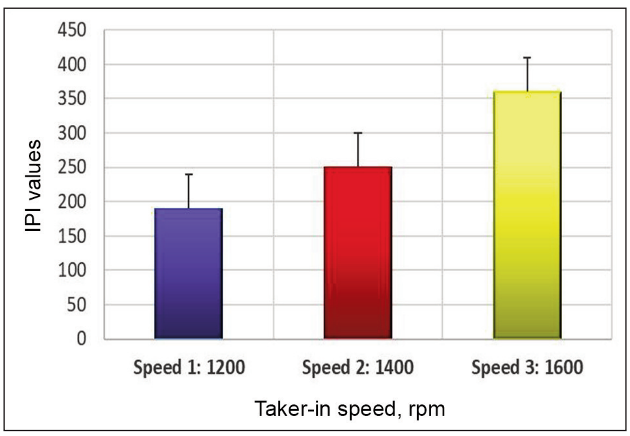

Fig. 8. Effect of taker-in speed on yarn defects (IPI)

Figure 9 represents the influence of taker-in speed on the ultimate yarn strength. It is calculated by utilizing the data gathered from tests of single-yarn strength. The breaking force and associated elongation of

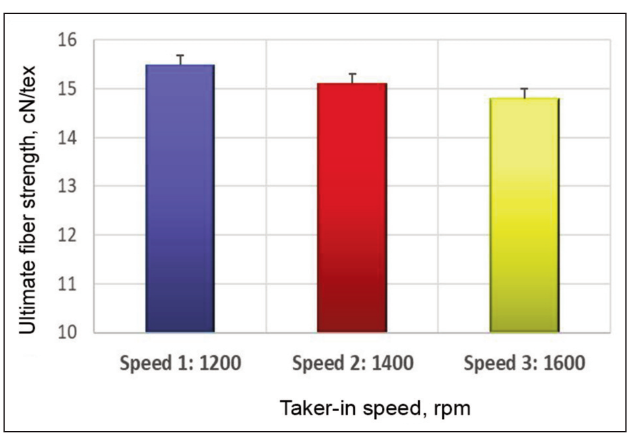

Fig. 9. Effect of taker-in speed on ultimate yarn strength (cN/tex)

100% carded cotton were ascertained by these strength tests. There is a strong correlation between ultimate yarn strength (cN/tex) and breaking elongation ratio (%) [27]. According to the graph, ultimate yarn strength values have been averagely determined as 15.49 cN/tex for 1200 rpm, 15.1 cN/tex for 1400 rpm, and 14.8 cN/tex for 1600 rpm, respectively. Results revealed that the ultimate yarn strength of ring-spun yarn decreases as the taker-in speed increases. Because of fibre breakage at greater speeds, the number of short fibres in the sliver surges. An enhanced number of short fibres reduces the yarn's relative strength.

The effect of taker-in speed on yarn hairiness is demonstrated in figure 10. The total length of protruding fibre/cm length of yarn is the definition of the hairiness index (H-value). Throughout seven length zones, the number of protruding fibres is counted within a 1–10 mm range. The individual count of protruding fibres in each length zone is normalized to 100 m yarn length [28]. According to the graph, the hairiness properties of the obtained yarns were averagely determined as 5.4 at 1200 rpm, 5.9 at 1400 rpm, and 6.2 at 1600 rpm, respectively. From the graph, it can be determined that as the speed of the receiving drum of the carding machine increases, the hairiness of the ring yarn also increases. This is most probably due to fibre damage at elevated speeds and the formation of short fibres in the system. The rising quantity of short fibres in a yarn causes the growth of protruding fibres, which contributes to the increased hairiness of the yarn.

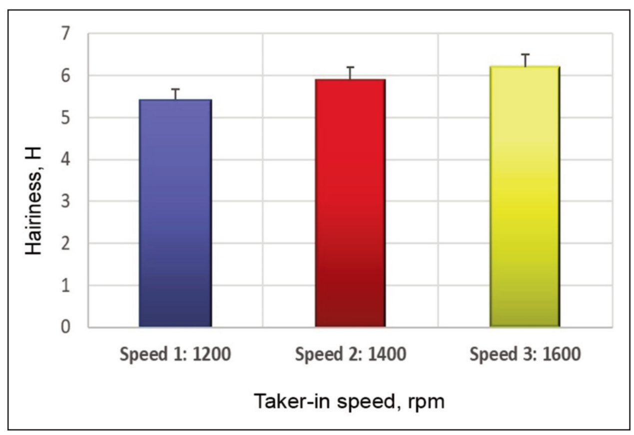

Fig. 10. Effect of taker-in speed on hairiness

Microscopic analyses were also conducted to further investigate the surface characteristics of the ring-spun yarns (17.35 tex) that were produced by utilizing three taker-in speeds of 1200 rpm, 1400 rpm, and 1600 rpm (figure 11). Pictures exhibit that as the taker-in speed increments, unevenness and hairiness properties of the yarns also increase.

CONCLUSION

In the current study, to obtain 17.35 tex count cotton yarn in the ring yarn production line, the speeds of the taker-in segment of the carding machine were set

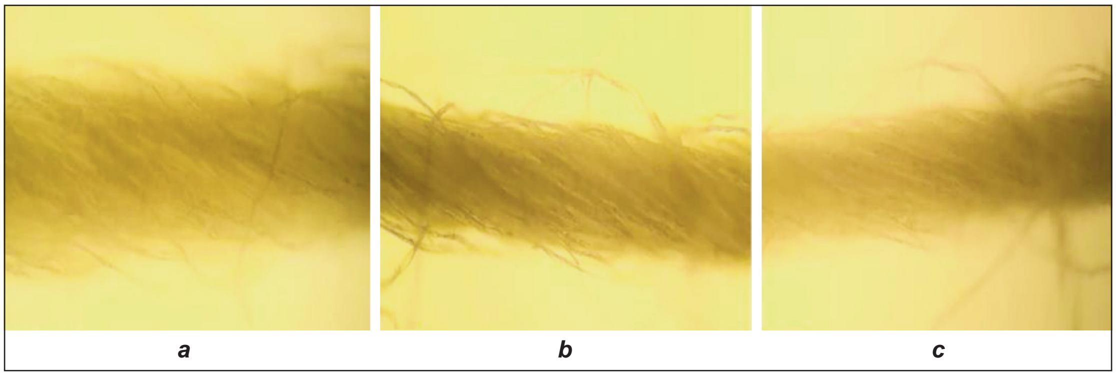

Fig. 11. Microscopic pictures (10x) of ring spun yarn (17.35 tex) produced in different taker-in speeds: *a* – 1200 rpm; *b* – 1400 rpm; *c* – 1600 rpm

as 1200 rpm, 1400 rpm and 1600 rpm and the effect of these speeds on the sliver and yarn characteristics was observed. In addition, the changes in intermediate processes along the yarn manufacturing were analysed. With the increase in taker-in speed, the cleaning efficiency in the carding machine increased. Moreover, with the increment of taker-in speed, the unevenness of the card sliver fluctuated. It has been discovered that the unevenness of the initial draw frame passes declines with the enhancement of taker-in speed. As the taker-in speed increases at the second transition of the drawing, the unevenness decreases. On the other hand, specific properties of ring-spun yarn including unevenness, IPI, ultimate yarn strength (cN/tex) and hairiness exhibited a downward tendency, when the taker-in speed went up. Current research proved that the speed of the taker in the segment of a carding machine is highly influential on the properties of the sliver and yarn qualities so it should be taken into consideration during the experiments regarding the increase of productivity.

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