Praise Worthy Prize

International Review of Mechanical Engineering (I.RE.M.E.), Vol. 18, N. 4
ISSN 1970 - 8734 *April 2024*

Determination of the Optimum Speed Mode of the Carding Machine

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Abstract – *In rotor spinning line, which is one of the new generation spinning systems, improving the operating parameters of the carding machine is of great importance in preparing the fibers effectively to be fed into the spinning system. In this case, issues such as separating the fibrous mass into individual fibers, making the fibers parallel to each other, separating hard and foreign substances from the fibers, and removing short fibers from the system influence the efficiency of carding. In this study, the effect of different speed modes of the taker-in, main drum and flats in the carding machine on the quality of fiber and card sliver was investigated. The obtained card sliver samples with a linear density of 5.9 ktex were tested by USTER TESTER-5, USTER AFIS PRO-2 and HVI laboratory equipment. According to the research results, in order to produce high-quality yarn, it is recommended to adjust the speed of the carding machine as follows: taker-in speed - 1260 mm/min, main drum speed - 520 mm/min and flat speed - 320 mm/min.* ***Copyright © 2024 Praise Worthy Prize S.r.l.-All rights reserved.***

Keywords*: Spinning Machine, Carding Machine, Card Sliver, Neps, Unevenness*

Nomenclature

CV	Coefficient of Variation [%]
U	Unevenness [%]
SC	Separated Seed Count [cnt/g]
SFC	Short Fiber Count [mm]
UQL	Average high length [mm]

I. Introduction

Today, industrial progress in machinery design has gained momentum with the development of excellently conceptualized, high-speed and efficient machines [1], [2].

By technologically updating and changing some components of the carding machines, it is possible to develop more technically advanced machine designs [3]-[5]. Special attention is paid to the manufacturing quality of high-efficiency carding equipment. In a carding machine, the main drum is utilized to clean and separate fibers from foreign sticky particles, while the taker-in drum separates foreign objects, straw, and other pollutants. When carding and managing fibers during manufacturing, the overall capabilities of the carding elements depend on the condition of the primary working segments (taker-in, main drum and flats) of the system and the optimal settings for the machine (Figure 1). In this context, the rotation frequency of the receiving drum and the main drum creates dynamic forces that separate the fibers fed to the machine [6]. Specifically, the carding process is realized in three main zones on the carding machine; taker-in zone, the area between main drum and flats, and release drum zone (Figure 1) [7]-[10].

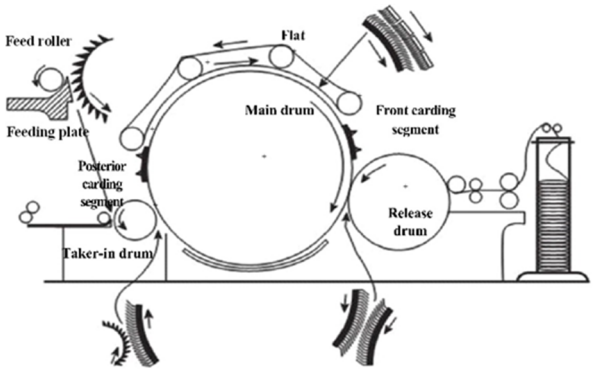


Fig. 1. Schematic diagram of carding machine [7]

Issues such as correct adjustment of the carding machine, harmonious rotation of the carding set's cogwheels, optimal processing of the fiber mass fed into the system, separation of fiber bundles into individual fibers that are parallel to each other, and purification of the fibers from certain impurities and defects are required in high efficiency carding machines [11]. According to Tozhimirzaev et al., the rotation speed of the main drum, which exceeds the rotation speed of the taker-in, leads to breakage or damage to the fibers, which negatively affects the physical and mechanical properties of the yarn [11].

However, as the speed of the main drum increases, the amount of fibrous product fed into the carding machine and the output speed of the carded fibers also increases, which enhances the efficiency of the carding machine [12]. Therefore, optimal selection of the main drum rotation speed fosters the intensity of the carding process and improves the properties of the yarn. The impact of the

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wires of the taker-in set on the carded fibers rises with taker-in speed. In turn, the damage or breakage of fibers causes an upward trend in the quantity of short fibers in fibrous material. As a result, the overall length of the staple fiber will also decline. It is a fact that the qualities of yarn are directly impacted by fiber length deterioration and breakage [13]. The flat mechanism in the carding machine is in constant interaction with the fibers fed into the system. Enhancing the speed of the flat assembly also increases the number of flat movements acting on the fibers at a time during the processing of a fibrous material, resulting in the reduction of neps [14]. The following indicators are considered to assess the functionality and performance of the carding set:

- Clogging of the card sliver, ascertained by the quantity of defects and neps in per gram of the product;
- The card sliver's linear density and unevenness, which are measured by the coefficient of variation in unevenness (CV %);
- Orientation (straightening) of fibers in the card sliver;
- Quantity of waste released from the flat web and beneath the drums.

Additionally, when assessing the operation conditions of a carding machine, the fiber length in the carding sliver and the waste from the carding machines are determined.

The structure of the carded sliver (clogging, irregularity, and breakage etc.) affects the physical and mechanical properties of the yarn during production [15].

The clogging of the card sliver is one of the main parameters characterizing the efficiency of carding.

During high-performance carding, the adjustment of rotation speeds of the main working parts of the carding machine: the taker-in, main drum and flat system, have significant impacts on the quality of the produced sliver in terms of getting over the clogging problem [16]. The quality indicators of the card sliver are characterized by the correct operation of the carding machine and the stability of the wiring on the drums. The more advanced the machine, the set, and the more stable the wiring, the better the fibers are oriented in the card sliver. Periodic changes in the wiring ensure better direction of fibers in the card sliver and an increase in its tensile strength [17], [18]. Optimizing the process parameters of a carding machine depends on various factors so that plenty of experiments are necessary to achieve optimal performance. Speed of the main drum, flat, and taker-in segments of the carding machine are highly determinant variables to reach appropriate results [19], [20]. Setting the optimal process parameters on the carding machine will decrease the amount of waste fibers during yarn production, increase the machine's service life, and contribute to yield more competitive finished products. In literature, various studies have been recently conducted regarding the influence of the carding machine process parameters to the obtained carded sliver as well as to the ultimate yarn quality.

Teklehaimanot et al. investigated the combined impact of carding machinery settings (cylinder speed, flat speed, cylinder to flat setting, and taker-in speed) on open-end yarn characteristics including strength, elongation, unevenness, and overall yarn defects.

Empirical study revealed that extending the gap between the cylinder and flat settings, as well as increasing the taker-in speed, elevated the yarn unevenness, and substantially boosted the total yarn imperfection [21]. Bin Sayed et al. experimented with varied flat speeds (240, 260, 280, 300, and 320 mm/min) in the carding machine to determine the effect of altering speeds on the carded sliver and the properties of the produced Ne40 cotton yarn.

The quality of the yarn rises as the flat speed rate goes up, and in this case, the greatest feasible flat speed is recommended as 320 mm/min [22]. Motin et al. focused on the interaction between carded sliver characteristics and yarn quality, together with licker-in and flats speeds.

Higher licker-in speeds were found to improve carding effectiveness and reduce fiber entanglement within a specific range. On the contrary, exceptionally rapid speeds resulted in increased fiber breakage and neps. Faster flat speeds, on the other hand, aided fiber alignment, improving the evenness and strength of the carded sliver and yarn. Furthermore, it was determined that the optimal combination of licker-in and flat rates varied depending on the kind of fiber and processing variables [23]. The objective of this work is to determine the optimal speed mode of taker-in, main drum and flat segments of carding machine, which is one of the most crucial components in Open-End spinning line. To reach the optimal results, several altering speed modes have been set and the impact of these speeds on the unevenness, neps content, short fiber quantity, average high fiber length, and impurities in the card sliver has been compared. In addition, microscopic analyses of the obtained carded slivers have been realized to make visual assessments.

Therefore, Section I provides the general knowledge about the carding process and the specific functions of the taker-in zone, main drum, flats, and release drum as well as the previous related studies in the literature. Section II explains the properties of materials utilized and the technical parameters of the carding machine set ups as well as the methodology of the study. In Section III, findings of the current research have been explained and discussed. Section IV has been designed as the conclusion part to give final conclusive information about the experimental research and future perspective regarding the impact of carding process on the properties of obtained sliver and the quality of produced yarn.

II. Materials and Methods

The experimental work was carried out at LLC FT-TEXTILE GROUP. During the experiment, medium-fiber cotton of 4th type, I-II grade of Maktaaral-4007 selection, grown in the south of Kazakhstan, was used. Cotton fibers were processed on TC-15 model carding machine. The three options with different speed modes of the carding machine are shown in Table I. The carded sliver was prepared to be processed into yarn on AUTOCORO-9 rotor spinning machine from SAURER® [24].

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TABLE I
SPEED PARAMETERS OF THE CARDING MACHINE FOR THREE OPTIONS

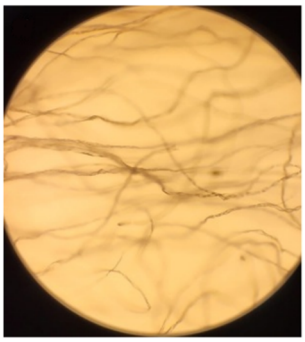
No.	Process	Option 1	Option 2	Option 3
1	Flat speed, mm/min	360	320	280
2	Main drum speed, mm/min	560	520	480
3	Taker-in speed, mm/min	1360	1260	1100

The resulting card sliver samples with a linear density of 5.9 ktex were tested on USTER TESTER-5, USTER AFIS PRO-2 and HVI laboratory equipment [25]. In addition, carded slivers were examined under a light microscope (Mikromet) at 10x magnification. The studied properties of the carded sliver for three options are shown in Tables II and III.

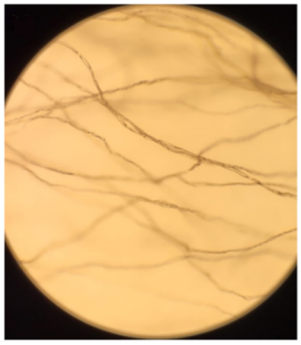
III. Results and Discussion

Based on the results of Table II, it can be determined that the card sliver from the 2nd option is more even compared to the other two options. The quality of the card sliver acquired via option 3 is lower in comparison to 1st and 2nd options. This is due to the slower speeds of carding, taker-in, main drum, and flats as compared to the other two options. This prevents intensive carding of the fibers, beginning at the taker-in area, where fibers are not sufficiently separated. When carding the coarse and more clogged cotton fibers, it is recommended to increase the taker-in speed and, thus, the carding intensity.

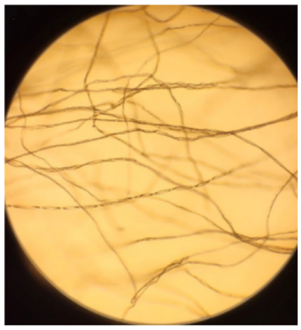
From Table III, it can be determined that the fibers on the card sliver of the 2nd option are of better quality than the 1st and 3rd options. This is explained as follows: the carding speed in the 1st option is high, which could lead to the fiber breakage and increase the short fiber content (SFC), and the carding speed of the 3rd option is less than the previous 1st and 2nd options and could reduce the intensity of carding and removal of trash. Figures 2 exhibit the microscopic pictures of carded slivers obtained from three options explained in Table I. According to the visual observations, the fibers in the carded sliver, which were produced by applying the parameters of 2nd option, were found to be more parallel to each other comparing with 1st and 3rd options. To analyze the results of the studies in more detail, the experimental data have been compared by bar charts. From Figure 3, it can be seen that the unevenness of the card sliver in the 3rd option, where the speeds of the taker-in, main drum and flats are respectively 1100 mm/min, 480 mm/min, 280 mm/min, is worse compared to the other two options. This can be explained by the fact that at a lower taker-in speed, the amount of fiber separation is less, and also, the fibers become less parallel to each other due to the main drum and flats moving at a lower speed.



(a)



(b)



(c)

Figs. 2. Microscopic pictures of carded slivers obtained from three options; (a) 1st option, (b)2nd option and (c) 3rd option

TABLE II
PROPERTIES OF THE CARD SLIVER IN THREE OPTIONS ACCORDING TO USTER INDICATIONS

Option	U %	CV %	CV 1m %	CV 3m %	mMin 1m %	mMax 1m %	mMin 3m %	mMax 3m %
1	1.58	2.04	0.56	0.39	-1.22	1.35	-0.63	0.72
2	1.55	1.98	0.54	0.7	-1.19	1.41	-0.65	0.66
3	1.64	2.08	0.57	0.37	-1.22	1.33	-0.70	0.65

TABLE III
PROPERTIES OF THE FIBER ON THE CARD SLIVER DETERMINED ON THE AFIS DEVICE

Processes	Total Nep s Count [cnt/g]	SC Nep Cnt [cnt/g] Separated Seed Count	SFC(w) %<12,7 Short Fiber Count [mm]	Maturity [mat1]	Fine [mteks] Linear density	UQL (w) [mm] Average High Length	Trash Count [Cnt/g]
Option 1	124	9	10.8	0.89	166	29.4	5
Option 2	94	15	8.4	0.91	167	29.7	1
Option 3	95	9	8.3	0.90	167	30.2	3

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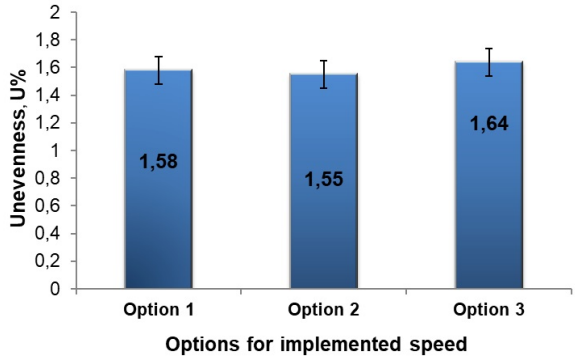


Fig. 3. The dependence of the card sliver unevenness U% on the speed modes of the carding machine

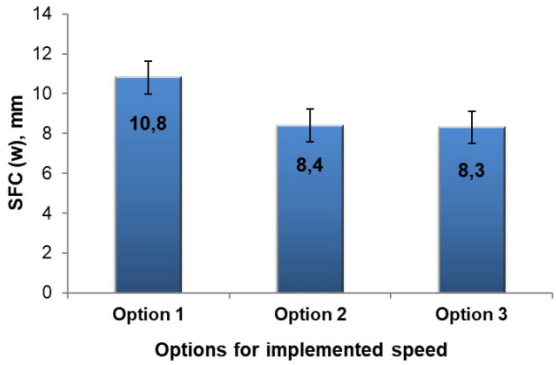


Fig. 5. The dependence of the short fiber content SFC(w) % < 12.7 mm in the card sliver on the speed modes of the carding machine.

Therefore, the speed of the taker-in, main drum, and flats must be raised to the optimal level in order for the fibers in the card sliver to become more parallel and the degree of evenness to enhance. Figure 4 shows the content of neps on the card sliver for various speeds of the taker-in, main drum and flats.

According to the graph, it is clear that in the 1st option, the number of neps is higher in comparison with other two options, where the speeds of the working segments of the carding machine are lower. Although the carding machine is considered as the final step in the process of removing impurities and defects from the fibers in the spinning system, 30% of impurities and defects still remain in the card sliver. In addition, it should be noted that the carding machine itself is also considered as a source of additional defects, particularly neps, which reduces the quality of the card sliver and the finished product. Elevated taker-in speed is known to boost the level of fiber separation; nevertheless, at high speeds during the carding process, the flats' speed causes the carding sliver's neps content to rise.

The amount of neps diminishes when these functioning segments of the carding machine move at a slower pace.

Therefore, optimization of carding machine speed modes still attracts the attention of researchers today. Figure 5 illustrates that the reason for the increased number of short fibers in the sliver produced through the carding machine by utilizing the parameters of 1st option is that the machine operating speeds in 2nd and 3rd options are comparatively lower than in the 1st option.

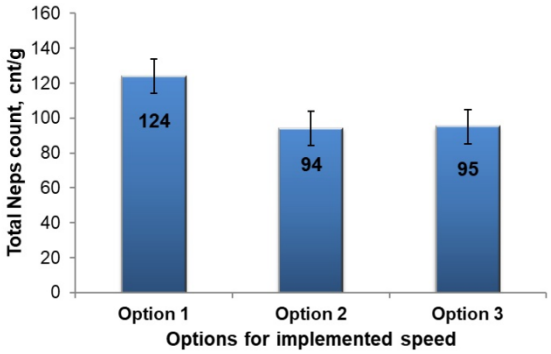


Fig. 4. The dependence of the content of neps on the card sliver on the speed modes of the carding machine

This makes sense because the fibers are subjected to severe impacts of the wires placed on the taker-in and main drum during opening and cleaning, which causes fiber breaks and a decrease in the average fiber length.

From Figure 6, it is possible to consider the dependence of the average high fiber length (UQL) in the card sliver on the speed modes of the carding machine in 3rd option where the mean peak length (UQL) of the fibers has been measured as 30.2 mm. For the 1st and 2nd options, UQL of the fibers has been found as 29.4 mm and 29.7 mm, respectively. This can be explained by the fact that in the 3rd option, where the speeds of the working segments are lower compared to the 1st and 2nd options, because of that fiber breakage occurs less. Consequently, in order to reduce fiber breaks during the carding process, it is necessary to optimize the speeds of the working parts of the machine.

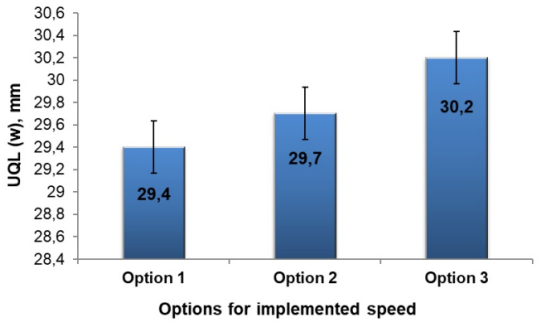


Fig. 6. The dependence of the content of neps on the card sliver on the speed modes of the carding machine

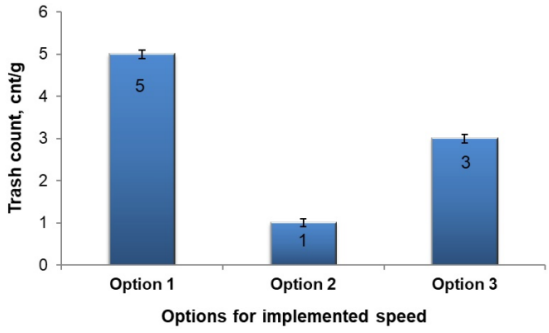


Fig. 7. The dependence of impurities in the card sliver on the speed modes of the carding machine

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As can be seen from the bar chart in Figure 7, the pre-combination speed increases due to the activity of the taker-in drum. As a consequence, the fibers are separated at a high rate, and due to the impact of the metal wires, foreign substances (micron size) in the fibrous web are grinded, and this induced the amount of foreign substances in the sliver to be accumulated. Despite the rapid speed of the flats, these heavy contaminants generated in the sliver are not eliminated. For efficient cleaning, the speed mode of the combing machine (next step in the spinning line), which is the second alternative, should be optimized.

IV. Conclusion

The quality of the yarn is an important factor in producing a long-lasting and appealing fabric. Yarn tensile and elongation characteristics, evenness, and regularity are some of the most critical yarn properties that can be managed during spinning. Optimal carding machine settings are crucial for achieving better quality slivers and yarn. Current research on the production of high-quality card sliver revealed that the optimum speed conditions must be set for the carding machine. It was recommended to adjust the speeds of the taker-in, main drum and flats according to the 2nd option in our experiments. Therefore, the suggested taker-in speed was 1260 mm/min, the speed of the main drum has been determined as 520 mm/min, and the speed of the flats has been adjusted as 320 mm/min. At these speeds, the unevenness, neps content and short fiber content of the sliver diminished, on the other hand, the amount of removal of the foreign substances in the card sliver increased. Therefore, the opportunity to directly use the card sliver to produce high-quality Open-End (OE) yarn has been established. The textile and clothing market, which is constantly growing and developing, is becoming more competitive day by day. One of the important steps for the development of high-quality textile materials is yarn production. By optimally adjusting the speeds of units such as taker-in, main drum and flats in the carding machine, which is a very important stage in the yarn production line, it is possible to produce superior quality yarn by executing flawless, reproducible, and cost-effective production. We believe our findings will contribute to future research in this area.

Acknowledgements

The authors would like to thank the LLC FT-TEXTILE Group, which operates in Uzbekistan, for being supportive with the experimental part of this study as well as the university-academia collaboration.

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