Marek Idzik

Technical University of Lodz
Faculty of Material Technologies and Textile Design
Department Material and Commodity Sciences and Textile Metrology
ul. Żeromskiego 116, 90-924 Łódź, Poland
e-mail: marek.idzik@p.lodz.pl

Influence of the Elimination of Drawing Frames on Rotor Yarn Quality Parameters

Abstract
The technological process of yarn production is long and complicated, therefore costly. Modern spinning systems tend to shorten this process by assembling machines in technological lines or by eliminating some of them. This task is facilitated by modern draft regulators, whose application is to improve the quality of yarn produced . Especially important is the non-uniformity of the linear density of spun products, which should not increase when shortening the technological process, hence, the number of joints in the product should not be decreased within the process. This work presents an analysis of the possibilities of the manufacture of polyester yarns using the shortened cotton system when applying a carding draft regulator with a modified operation algorithm which takes into consideration the phenomenon of spinning sliver retardation after the short-section regulation.

Key words: *spinning systems, autoleveller, linear density, card sliver, rotor spinning machine.*

Introduction

Changes in the textile industry observed in the last several years have led to the transformation of big industrial mills into smaller units which are easier to manage. Small companies react to market demand more rapidly and are able to change their product assortment quickly.

Modern spinning systems tend to shorten this process by assembling machines in technological lines or by the elimination of some of the machines. In the preliminary fibre treatment phase, the final scutcher is eliminated, and the number of machines is reduced from several to a few of them. Right now, there are only 3 ÷ 4 machines which open and clean fibre preliminary, assembled in a technological line with a carding machine fed with a loose fibre mass from a container. There exist solutions in which the carding machine is directly connected to the drawing frame.

The number of drawing frames in modern spinning systems has decreased to two , or even one, most often with a draft regulator attached. Such regulators are also being installed on carding machines.

The two roving machines traditionally used in spinning mills (medium and fine roving frames) have been replaced by one only, which we will soon also be able to eliminate. In classical spinning mills solutions already exist in which the yarn is made directly of the drawing sliver – applying product refining in the drawing apparatus. In open-end spinning mills, roving machines do not appear in the technological process.

A diminished set of preliminary opening – cleaning machines introduced into the technological line with a draft regulator attached to the revolving 4 flat card, as well as an open-end or ring spinning machine for spinning from a sliver connected to a rewinding machine shall in the future constitute the only phases in the process of preparing a uniform yarn.

Another machine which could be eliminated from the yarn production process is the drawing machine. However, the condition is such that during the preparation of the card sliver, the yarn production process should not be disturbed and the quality parameters not worsened.

Issue description

It is worth considering whether shortening the technological process by means of eliminating drawing machines shall have a negative impact on the quality parameters of the card sliver, and if it has, what should be done to eliminate this negative effect. The most important parameters characteristic of card sliver are the linear density and its non-uniformity, the degree of fibre straightening out and the trash content.

The sliver's linear density is not limited to producing yarn directly from a card sliver. Carding machines constructed nowadays, similar to drawing machines, allow to receive a sliver of any linear density, within a range suitable for feeding open-end or roving machines. In many spinning mills, a uniform linear density of slivers for the production of yarns of any linear density has been introduced – from very fine to very coarse ones, making it impossible to feed the open-end spinning machine or roving machine with a sliver of an incorrect linear density.

The non-uniformity of sliver linear density is very important. Consecutive drawing frames in the technological process diminish this non-uniformity, particularly on long sections, as a result of folding the slivers when feeding. The revolving flat card shows a certain levelling tendency which may lead to a reduction in the fluctuation of the linear density of the product delivered, but it may be not sufficient. A tendency of the carding machine's efficiency to increase may cause that the increased velocity of individual working elements may considerably decrease the efficiency of the machine levelling capacity. This, in turn, in predefined conditions, may cause an increase in the non-uniformity of the sliver delivered, meaning that the raw material layer destined for feeding high-performance carding machines should be prepared very carefully, in particular, taking into consideration its non-uniformity.

Because of the characteristic dynamics of the carding process and related fluctuations of the value of the coefficient of fibre passing from the drum to the collector, the non-uniformity of card sliver liner density is considerably great and should be corrected by the drawing frames. However, by applying a draft regulator in the carding machine delivering zone, the sliver uniformity improves to a great extent and does not have to constitute a constraint shortening the technological process. What is more, the high uniformity of the regulated card sliver is equalised by the operation of the drawing frame drawing apparatus [2, 3].

The fact that, as a result of joining the slivers on the drawing frames, the non-uniformity of the density distribution on longer sections is improved should also be taken into consideration. Short-section non-uniformity can increase due to the operation of the drawing apparatus.

The activity of the drawing apparatuses causes an intensive straightening out of fibres. However, there remains a certain number of poorly straightened fibres, which is caused by adverse drawing conditions and by the structural fibre composition, characterised by great resilience. Hence, they put up considerable resistance to the straightening force; after this force ceases, they revert to their previous shape. The more straightened fibres there are in the sliver, the better the yarn quality. Therefore, if the drawing frames are to be excluded, this function must be taken up by other machines employed in the process.

The cleaning abilities of particular spinning machines are 60 ÷ 75% for opening-cleaning machines, 75 ÷ 85% for modern carding machines (90 ÷ 95% for the tandem type) and 45 ÷ 75% for rotor spinning machines.

The nep content in sliver is a very important sliver quality parameter. The efficiency of nep removal is one of the main factors characterising the effectiveness of carding frames. Neps concern mostly cotton and cotton/chemical fibre blends. Nevertheless the same situation is with the trash content. Trash mostly occurs in fibre blends containing cotton.

Neps and trash in the fibre stream are not a constraint when intending to eliminate the drawing frames from the technological process, because the drawing frames do not increase the degree of fibre cleanliness. The most modern carding machines are able to remove over 90% of neps and trash, and modern rotor spinning machines get rid of 75% of trash which still remains in the fibre stream after the carding process.

A card sliver is not suitable for the direct feeding of rotor spinning machines because of a too great non-uniformity of the linear density, small degree of fibre straightening, and poor degree of fibre arrangement along the product axis. In typical spinning processes, the quality of carding sliver has improved in this respect by drawing frames which additionally blend the fibre stream, improving its homogeneity in every type of section. In the shortened technological process, the drawing frame function must be passed on to other machines.

Omitting the drawing frames is related to the necessity of applying card drawing regulators (mainly short-section ones), which take over the task of decreasing the non-uniformity of the linear density, previously done by means of joining the slivers on the drawing frames.

The elimination of drawing frames from the technological process may be advantageous in many respects as it means the elimination of such unwanted phenomena as eccentricity, vibrations and the slide of the drawing rollers. The shortening of the technological process may contribute to decreasing production costs by means of no necessity of machine purchase, the elimination of operational transportation, smaller consumption of electrical power, smaller premises area, heat, handling, maintenance, spare parts, repairs, etc.

Technological studies

At the Department of Spinning Technology and Yarn Construction of the Faculty of Material Technologies and Textile Design, research on the possibility of directly feeding a rotor spinning machine with the card sliver, as well as omitting the drawing machines in the technological process had already been conducted. The yarn obtained had quality parameters close to those of the typical spinning process [1].

A basic element which then made it possible to shorten the technological process was a short-section drawing regulator installed in place of the drawing apparatus in the zone of delivery of the revolving flat carding machine.

Multiple analyses of the operation of short-section regulation systems [2, 3] showed that the linear density of the spinning sliver corrected by a short-section regulator is a function of time, and only measurements thereof in an on-line system allow an immediate and reliable inference about the efficiency of the regulation process. Test results led to the construction of a short-section draft regulator whose operation algorithm takes into consideration the phenomenon of spinning sliver retardation. Analysis of the phenomenon of sliver retardation and the classical operation algorithm of short-section draft regulation contributed to a proposal of changes in the regulator system. These changes make it possible to achieve the smallest fluctuation of the linear density of the spinning sliver – before it is introduced to a consecutive machine in the technological process [4].

The new algorithm of regulator activity is as follows:

$$D'(t) = \left[1 + r(t)\right] \cdot D(t)$$

where:

D'(t) – temporal draft in the regulator with the correction of the controlling signal;

D(t) – temporal draft in a classical regulator;

r(t) – retardation of sliver thickness.

The realisation of the new algorithm was carried out digitally based on the correction system, consisting of a computer and appropriate software.

The introduction of the correction of the control signal during short-section draft regulation caused a considerable improvement in the linear density of spinning slivers of stabilised internal structure.

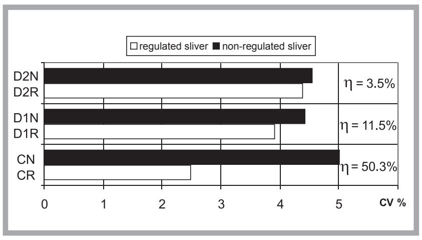

***Figure 1.** Linear density coefficient of the variation of slivers on short sections.*

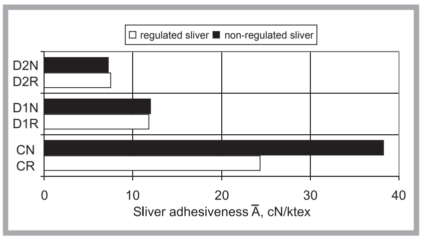

***Figure 2.** Mean sliver adhesiveness Ā cN/ktex.*

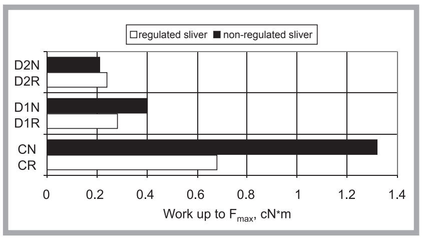

***Figure 3.** Work up to F_{max}, cN·m for various slivers.*

The draft regulator prepared in this way was the core element of testing the possibility of shortening the technological process.

The objective of the test was the assessment of the possibility of directly feeding a cotton rotor spinning machine with a card sliver, using a card draft regulator with a modified operation algorithm.

The tests used a revolving flat carding machine made by Falubaz, a drawing frame made by Befama and a R1 rotor spinning machine of Rieter. A short-section draft regulator was installed on the carding machine only, whereas the drawing frames were not equipped with draft regulators.

Six polyester spinning slivers were produced, which were of the same linear density – 4.5 ktex: a card sliver (regulated CR and non-regulated CN), a sliver after the first drawing frame (regulated D1R and non-regulated D1N), a sliver after the second drawing frame (regulated D2R and non-regulated D2N).

On the open-end spinning machine, three yarns of linear densities of 20, 40 and 60 tex were made from each of the slivers (18 variants in total).

Table 1. *Results of measurements of parameters characterising sliver adhesiveness.*

Sliver variant	Adhesive force F_{max}	Elongation not break	Work up to F_{max}
	cN	%	N·m
CN	162,74	9,31	0,0132
CR	103,48	9,00	0,0068
D1N	54,41	9,78	0,0040
D1R	48,35	9,99	0,0028
D2N	28,29	8,34	0,0021
D2R	29,75	8,15	0,0024

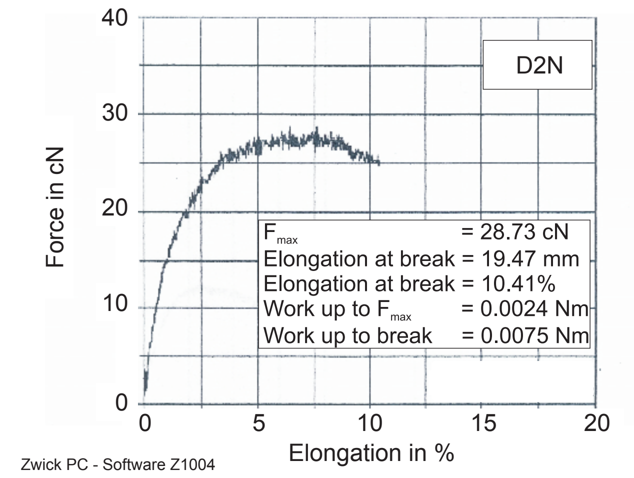

Figure 4. *Graphs of the adhesive force F_{max}, cN in relation to the breaking elongation, % (variant D2N).*

In order to define technological conditions of the shortened spinning process, the following equipment was used during the tests:

- to measure the spinning slivers' adhesiveness as well as yarn strength and elongation – a Zwick tension tester;
- to measure the real linear density of the yarn – an Uster Autosorter;
- to measure the coefficient of variation of the linear density of the spinning slivers and yarns as well as yarn faults – an Uster Tester 3.

There was no analysis of trash in the card web because, as an earlier test had shown, the appearance of trash in the fibre stream does not constitute a constraint when trying to omit the drawing frames in the technological process.

Analysis of results

On the Uster Tester 3 apparatus, value measurement of the coefficient of variation of the linear density of spinning slivers on short sections was carried out, the results of which are presented in ***Figure 1***. The graph also marks values of the equalising ability coefficient (h) of the modified draft regulator.

The calculation results received prove that regulation of a good level takes place only for card slivers, whereas for the drawing frame sliver, the regulation is not enough. The card regulated sliver (CR) was tested 4 hours after the regulation process, that is, in the state of an already stable internal structure.

Adhesive force measurements made on the Zwick tension tester served as an assessment of the degree of fibre straightening out in the sliver. Tests were performed according to Standard PN – 88/P – 04771. Adhesiveness is defined as the mean adhesive force in relation to the mean linear density of the spinning sliver sections tested, whereas the adhesive force is the highest value of the drawing force of the spinning sliver, following only from the friction and adhesion resistance between the fibres mutually relocating inside the drawn section, without breaks. The measurement results obatined are presented in ***Table 1***.

The calculation was made based on the following dependence:

– i adhesiveness (A_i) – of this section of the sliver: $A_i = \frac{F_i}{Tt_i}$ cN/ktex

where:

F_i – i adhesive force – of this section of the sliver, cN,

Tt_i – real linear density of the sliver, ktex.

Measurement results and calculations are presented in ***Table 1*** and on ***Figures 2, 3 & 4***.

The adhesiveness of card slivers is greater than that of those from a drawing frame . As the adhesiveness indirectly characterises the fibre arrangement in the sliver, it could be inferred that in a card sliver there are more fibres bent and not parallel to the axis of the fibre stream than in the sliver from a drawing frame. The regulation process orders, to a certain degree, fibres in a card sliver, but the differences become less visible after consecutive drawing frames.

Greater work should be done on card slivers in order to make them finer dur-

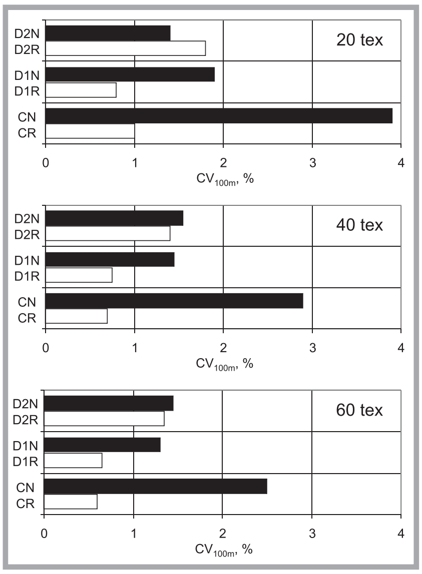

Figure 5. *Graphs of the non-uniformity of the linear density of yarns on long sections (CV100 m).*

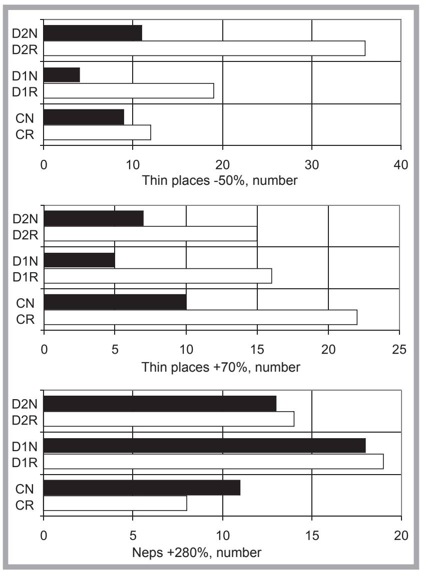

Figure. 6. *Examples of thin and thick places and neps at a length of 1 km of yarn of 40 tex linear density.*

ing the drawing process than those from drawing frames, which may cause difficulties when garneting card slivers in the garneting cylinder of an open-end spinning machine.

It results that a card sliver of a stabilised internal structure, made uniform by the regulator of a variable operation algorithm, is less adhesive than a sliver made uniform with a standard regulator [1, 4].

Out of each of the 6 sliver variants, three rotor yarns were made of linear densities of 20, 40 and 60 tex. All the yarns were subject to complete metrological analysis using equipment such as the Uster Autosorter, Uster Tester 3, and Zwick tension tester.

The Uster Tester 3 tested yarns at a passage velocity of 400 m/min within 7.5 min. These parameters make it possible to test a 3000-meter yarn section, which allows to conclude about the impact of card regulator work on yarn quality. Tests of the yarn non-uniformity of the linear density and of the hairiness were carried out.

Selected characteristic dependencies are presented in ***Figures 5*** and ***6***.

The best polyester yarn as far as linear density non-uniformity is concerned was obtained after the direct feeding of the open-end spinning machine with the regulated card sliver, which is particularly visible in the case of yarns of greater linear densities. However, the result received for the finest yarn allows to classify it at a level below 25% – according to Uster Statistics [7]. As far as the number of faults is considered, a slightly increased number of thin and thick places was observed for yarns of smaller linear density; however, these are values which do not deviate from the average world level.

Yarn strength analysis was carried out in accordance with Standard PN-84/P-04654. Measurements were made of the breaking force, breaking elongation, work up to break and work up to reaching the maximal force. On the basis of the measurement results, calculations of the tenacity of individual yarns were made.

Example graphs are presented in ***Figures 7, 8*** & ***9***.

The tests showed that when using a short-section draft regulator with a modified operation algorithm on a cotton carding machine, the differences between the tenacity of polyester yarn made directly from a card sliver and that of polyester yarn made from drawing frame slivers are statistically insignificant, which proves, indirectly, that the coefficient of straightening fibres out in the open-end yarn would not have decreased significantly if the drawing frames had been omitted in the technological process. The straightening out of fibres then takes place in the draft regulator on the carding machine and in the feeding zone of the open-end spinning machine.

Summary

The tests carried out showed that:
- When applying a draft regulator on a carding machine, it is possible to omit at least one drawing frame in the technological process. Using two drawing frames in the process levels the positive operation of the regulator and causes a blurring of the differences between the quality parameters of regulated and non-regulated yarns.
- A short-section card draft regulator with a modified operation algorithm considerably improves polyester yarn uniformity on long sections, where it is possible to achieve a CV_{100m} Uster coefficient of a level lower than 1%.
- The shortened technological process does not cause a considerable worsening of yarn quality parameters; only the number of thick places (+70%) is higher, but it does not exceed the level of 25%, according to Uster Statistics.

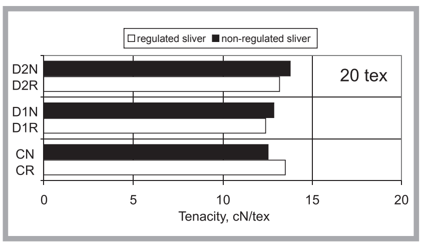

Figure 7. *Graphs of tenacity for selected linear densities of the yarn (20 tex).*

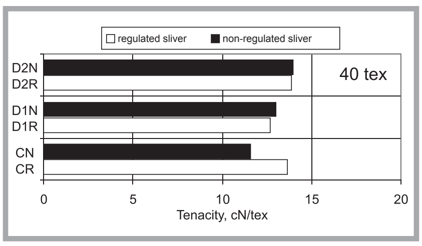

Figure 8. *Graphs of tenacity for selected linear densities of the yarn (40 tex).*

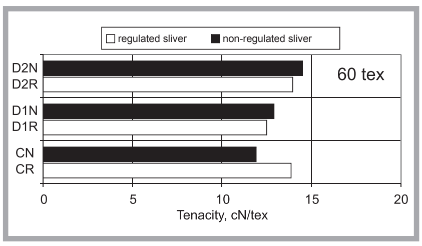

Figure 9. *Graphs of tenacity for selected linear densities of the yarn (60 tex).*

- The shortening of the polyester yarn production technological process by means of removing the drawing frames is possible (mainly for thicker yarns) on the condition that a modified short-section regulation is applied on the carding machine.

References

1. Repczuk M. – „Technological Conditions of Direct Feeding of Open-End Spinning Machines with Card Sliver". Master Thesis – in the Department of Spinning Technology and Yarn Construction, under the supervision of Marek Idzik, Dr. Sc.
2. Idzik M. – „Analysis of Work of a Card Autoleveller with a New Algorithm of Operation". Fibres & Textiles 2006 No. 2.
3. Idzik M. – „Short Term Levelling Analysis of Regularized Sliver". Fibre & Textiles 1995 No. 4.
4. Idzik M. – „Assumptions for Construction of Draft Regulator with a New Operation Algorithm". Przegląd Włókienniczy 2007 No. 5.
5. McAllister I. – „Parkdate Moves up to a New Quality Level". Textile Word 1993 No. 5.
6. Remmerige J., Cruycke B. – „Qualitätsüberwachung an der Strecke". Melliand Textilberichte 1993 No. 6.
7. Uster Statistics 2007. Fiber & Yarn Quality. Sliver Quality.
8. Zhu R., Ethridge M. D. – „A Method for Estimating the Spinning-potential Yarn Number for Cotton Spun on the Rotor-spinning System". Journal of the Textile Institute 1998 No. 2.
9. Idzik M., Patent No. 180506.
10. Frydrych I., Matusiak M. – „Factors Influencing Nep and Trash Transfer from the Sliver to the Rotor Yarn". Fibres & Textiles 2002 No. 4.
11. Furter R., Frey M. – „Analyse des Spinnprozesses durch Messung von Zahl und Grősse der Nissen". Melliand Textilberichte 1991 No. 7.
12. Taher Halimi M., Ben Hassen M., Azzouz B., Sakli F. – „Effect of Cotton Waste and Spinning Parameters on Rotor Yarn Quality". Journal of the Textile Institute 2007 No. 5.
13. Nikolic M., Cerkvenik J., Stjepanovic Z. – „Influence of a Spinning Process on Spun Yarn Quality and Economy of Yarn Production". International Journal of Clothing Science and Technology 1994 No. 4.
14. Baumann M., Heitmann U., Planck H. – „Reduzierung der Faserbeanspruchung und Kardierkräfte beim Hochleistungskardieren". Melliand Textilberichte 2008 No. 1-2.

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