Present status of OE rotor spinning and influence of some raw material parameters on yarn quality

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The present level of OE rotor spinning technology and rotor yarn quality has been discussed in the light of ITMA 91, Hannover. An actual comparison of the quality of ring-spun and rotor-spun yarns has been made. Furthermore, machine user needs from the point of view of machine automation and flexibility are discussed. Regression models created on the basis of HVI cotton quality parameters have been found suitable for prediction of the quality of rotor- and ring-spun yarns.

Keywords: Automation, HVI line, ITMA 91, OE rotor spinning, Yarn properties.

1 Present Status of OE Rotor Spinning

During 34 years of its existence, OE rotor spinning has gained a remarkable proportion of short-staple yarns market. Last year, these yarns represented about 20% capacity of short-staple spinning in the world. Other non-conventional yarns represented only about 1% of production capacity. Production of rotor yarns, for example, in USSR was 65%, in ČSFR 50%, in Belgium 45%, in Germany 25%, in Italy, Spain and Greece 15-20%, in South America 8%, and in Asia about 5%. Therefore, there is still a big potential for the application of OE rotor-spinning technology.

At present, new ring spindles are used mainly for the modernization of existing ring spinning mills, while the new OE rotors are used for extending the production capacities. In relation to actual production we can say that the rotor-spinning machines produce 40% and the ring-spinning machines 60% of total yarns.

Thanks to their high productivity and good yarn quality, the range of yarn counts spun using different raw materials is very high. On a single machine it is possible to produce both soft and hairy low-twisted yarns with one hand and smooth high-twisted yarns on the other. The present world OE rotor capacities are divided as follows: 40% for fine knitting yarns, 20% for yarns used in men’s and women’s outerwear, 20% for denim, leisure wear and work clothes, and the remaining for production of yarns for furnishing fabrics, bed and table cloths, terrycloths and technical fabrics. In the coming future, more extensive application of OE rotors, both in warp and weft, can be expected. Due to the improved quality and favourable economics, a considerable increase in the range of finer yarn counts can be expected.

OE rotor-spinning technology can process all types of raw material used in short-staple spinning mills. Of the total OE rotors, 55% are used for 100% cotton, 30% for polyester/cotton blends, 10% for 100% PAN or PAN/cotton blends and 6% for viscose staple. Application range and flexibility of OE rotor-spinning technology are its most important aspects. Considering the range of processed materials and final products we can say that OE rotor spinning is the most universal technology. By simple change of the spinning elements such as rotor, navel or combing roller it is possible to process all kinds of short-staple fibres on the same machine in the count range of 13-200 tex. Naturally, compared with ring spinning, the major area of application of OE rotor spinning would be found rather in coarser yarns (Fig. 1).

Since the introduction of rotor spinning the rotor speeds as well as the take-up speeds have trebled. Such a high increase has been made possible by continuous and intensive basic research. The yarn quality has improved considerably and the yarn count range extended substantially.

An objective comparison of the quality of ring and rotor yarns of 20 and 27 tex spun from medium staple cottons was made. The spindle speed and the twist factor used for spinning the ring yarns were 10,000 rpm and 63-66 and that for rotor yarns 90,000 rpm and 75-80 respectively.
It may be seen from Fig. 2 that, in general, the only quality parameter in favour of ring yarn is the tenacity which is 17% lower in case of OE rotor yarn. The yarn breaking elongations of both the yarns are almost the same. The rotor yarns are very regular. CV % of tenacity is 24.7% lower and Uster CV 26% lower (thin places by 91% and thick places by 88%) for rotor yarns. Owing to lower CV % of yarn strength, the minimum tenacity (given by the difference of average value and 3 standard deviations) of ring and rotor yarns differ by 4.8% only.

Regarding the economic aspects in general, the advantages of OE rotor spinning over ring spinning would be clear in the following example. For 29.5 tex yarn, the average saving is 20% in space, 80% in manufacturing units, 60% in workers and 20% in total production costs. In addition to this retrospective view, it is necessary to consider as to what extent the present solutions fulfil the requirements of the spinning mill of the year 2000 (ref. 2). These requirements are as follows:

- automated process both within the machine and between the machines,
- total integration of the latest computer technique and electronics for quality and manufacturing, controls and management,
- continuous (7 days a week) operation with reduced number of workers, and
- general and considerable machine improvement which enables, due to their higher productivity, to divide higher investments into higher number of products.

Fig. 1—Comparison of the distributions of OE rotor and ring yarn fineness [P—ring yarn, and R—rotor yarn]

Fig. 2—Comparison of the distributions of selected qualitative parameters of rotor (R) and ring (P) cotton yarns: (a) tenacity, (b) elongation, (c) CV % of tenacity, and (d) Uster CV %
At the same time we must take into account that the development is being made under permanent changes, e.g. extended operation time (about 8000 hours per year).

2 User and User’s Needs

There are no two spinners who would have the same needs and plans at the same time. Therefore, it is not possible to form some simple and universal model of “OE rotor-spinning machine user”. There are spinning mills with cheap labour on one hand and highly automated mills on the other. As we have mentioned, the trend towards automated spinning mills is irrevocable. Concerning the investments in the spinning mills, primary interest of the investors is to make profits. Other considerations such as reduction in operation costs, quality improvement, increase in productivity, reduction in yarn defects, and reduction in maintenance and spare parts costs are the secondary ones. The investors are only concerned with the benefits which could be derived by these improvements and which can effect savings and improve their position against competitors.

The problem of automation in the spinning mill must be overcome by machine and textile manufacturers. Supplier and customer are always partners in commercial relations. Therefore, at present, research, visual idea, development, testing procedure and practical application of new technologies in the spinning mill represent a process of mutual collaboration.

Earlier, the machine developments were usually made with minimum contact of the manufacturer and his feedback to the spinning mills. The present situation, however, is quite different. Market is the main driving force of almost all the innovations. New machines are now launched into the market as a result of intensive market research and close collaboration between machinery manufacturers and spinning mills. A successful machine is the result not only of thorough and innovative technical development but also of considerable financial means. It also represents precise evaluation and matching to the special needs and requirements of the market.

For the spinner who is interested in investments in the automation, the most important consideration is to have enough and right information. His motivation to the investment activities in the field of automation can be increased by the economy and potential profitability of automation. When he makes a mistake, capital investment can bring an adverse effect. Therefore, he needs information from machine suppliers and their partners concerning balanced relation between their intention to sell the machine and the knowledge of what is the profitable machine for the spinner.

The investor must be aware of the fact that the mill must be well prepared for automation. At the same time, he must know whether he wants to have a rationalized or a flexible mill.

Flexibility—first of all from the logistics point of view—is more expensive both from the point of view of investments and production costs. Therefore, a rationalized spinning mill can offer the yarns at cheaper prices than a universal mill. However, the specialized mill is more sensitive to the fluctuations of the textile market and fashion trends whereas the position of a universal mill is much better. The markets with high prices are not attainable for the specialized mill. Also, the concentration of specialized mills in a narrow and important yarn market has a negative influence.

The decision for specialization or flexibility in the case of automated mill is a final one which generally can not be changed later and, if necessary, only at very high costs.

3 Contributions of ITMA 91

During ITMA 91 only short-staple OE rotor-spinning machines were exhibited. At present, there are 5 competitors: 2 Elitexes, Savio (F), Rieter (R), Schlafhorst (A).

Compared with the survey of OE rotor-spinning machines published in International Textile Bulletin (1989), several parameters have been improved in machines exhibited in Hanover, e.g. extension of maximum number of spinning units on the machine up to 288 (A), pitch to 245 mm (R), machine length to 39.6 m (A), maximum rotor speed to 1,30,000 rpm, 2 package transport belts (F), and improved yarn quality control directly on the machine.

Except BD 200 DI machine (Elitex, Červený Kostelec), all other 5 machines can process fibres with maximum staple length up to 60 mm (BD 200 DI up to 40 mm). The narrowest range of yarns could be seen in the case of FRS machine (Savio)—120–16 tex. Fine yarns are extended in Elitex to 14.5 tex, in Autocoro to 12.5 tex and in Rieter RU 14 A and R1 to 10 tex. The coarsest yarns can be spun on BDA 10 N and RU 14 A, i.e. 170 tex. Except for BD 200 D1 and Rieter machines, the maximum diameter of silver cans is 510 mm. Only BD 200 D1 cannot use conical packages and yarn waxing.

The majority of machines are equipped with the devices for automation, data collection and machine control, i.e. from the spinning-in, piecing, tube transport, package doffing and transport to the end of machine up to packing and palletizing. In all the cases, electronic control system integrates data col-
lection with a superior central control system. For the quality control in weight non-uniformity, capacitance system Polyguard UPG4 has been used and for the control of optical non-uniformity, Corolab (A) system has been used. Machine BD 200 D1 has got only joint spinning-in system, full package transport belt, a gravitation magazine for full packages, and electronic control with the display for operational data; Polyguard system can be installed in addition.

Besides the above-mentioned features, some machines can use 2 automatic piecers per machine. In case of FRS machines it is possible to use independent drives of both machine sides, i.e. it is possible to produce 2 different yarns on one machine.

More extensive innovation was evident in the field of sliver supply. Three manufacturers, viz. Elitex, Cerveny Kostelec, Schlafhorst and Rieter, exhibited unique solutions for automatic exchange of sliver cans.

The next part of the paper concentrates on some specialties of individual exhibitors.

BD 200 D1 (Elitex, Cerveny Kostelec) was the only non-automated high-speed OE machine with a pitch of 200 mm, sliver cans of up to 400 mm diameter and maximum yarn package weight of 4 kg. This machine is suitable for modernization of the spinning mills originally equipped with BD 200 machines, and from the point of view of price it is suitable especially for low-wage countries. In this sense, this machine has attracted considerable attention. Spinning unit of this machine which is based upon CE II spinning unit, i.e. well-proven spinning unit of previous generation machine, can guarantee good yarn quality.

Automatic spinning mill A OE-S was the most attractive part of the exhibition of Elitex, Ústí nad Orlici (ref. 6). It consists of the following products made by the manufacturers in CSFR, USA, Sweden and Germany: opening machine Quadrafeed, sliver machine, automatic AGV carriage for the transport of rectangular sliver cans, rotor-spinning machine BDA 10 N, full package doffing device Railly and the control system Autospin (Fig. 3). The regulated carded sliver made from the supplied fibres is coiled into the rectangular can which is then automatically taken by the carriage, while sliver tip being ensured in the can. After replacing the empty can by a new one, the sliver piecing automat introduces sliver into the spinning unit and then starts the spinning. The whole automatic system—filling station, carriage and spinning machine—is electronically controlled. At the same time, continuous control and data collection is ensured. This line is supposed to be applicable in both small flexible mills and large spinning mills.

As in case of BD 200 D1, there were different spinning elements available for different rotor speeds, materials and yarn counts including the elements for softer lower twist yarns, self-cleaning rotors and eccentric separators.

Compared with other OE rotor-spinning machines, FRS machine of Savio consumes 25% less power, requires 15% less maintenance cost and 20% less floor space and gives 10% better yarn quality and subsequent processing. Piecing automat gives strength to the piecing equal to 95% of yarn strength. Two automat with intelligent operation control give 3-24% higher machine efficiency, depending on the number of spinning units and package diameter, for 29.5 tex. The dependence of FRS machine (240 spinning units) efficiency with one automat (lower plane) or two automat (upper plane) on the yarn count and package diameter can be seen.
in Fig. 4. Independent operation of both the sides of the machine also makes it possible to extend produced assortment, to increase machine output in case of lower and middle size production lots and independent maintenance of one side of the machine while the other being in operation.

Rieter introduced its spinning unit Ri-Q-Box with the possibility to spin fine yarns of up to 10 tex. This spinning unit has new sliver feeding system for drafts up to 400, improved trash removal system (20-25% increased efficiency brings 40-60% reduction in end-breakage rate caused by impurities), feeding tables for different staple lengths, ceramic doffing tube with 4 grooves (which gives suitable hairiness—about 3 times higher) for softer hand. Ri-Q-Box can be used for production of high-quality denim yarns using so called “Denim-rotors” with the diameter of 40 mm. Combed rotor-spun RICOFIL yarns made by above-mentioned spinning unit complete the spectrum of yarns in the range between carded yarns and combed ring-spun yarns. Syncro Plus System, besides higher reliability, ensures 90% strength of the piecings compared with 73%, and 120% thickness compared with 145% of the conventional system (Fig. 5). Spincontrol as a control center of RU 14A controls the operation of the spinning units and automats, gives command to the magazine of tubes and to Doffomat for package take off, controls operational data and parameters, indicates operational data and failures. Spincontrol Center SCC-II is the data collection and information system of RU 14A machine (up to 32 machines) with graphic indication and visual signalization of manufacturing changes, maintenance intervals and failures, giving a comprehensive information about the machine, spinning units, shift protocol, idle time analysis, etc. with possible integration to computer networks.

Automatic transportation and palletizing system SERVOcone takes directionally-oriented packages from the machine and places them in groups of four packages by means of hang-up electric carriage onto the system of storage belts. The packages are then taken from these belts and with the help of a triaxial portal they are deposited on pallets. This system makes it possible to reduce the number of operators. Automatic can exchange system CANOMATIC of Scaglia also uses rectangular cans like Elitex system.

Autocoro concept represents automatic manufacture of rotor yarns from sliver can supply until take off and palletizing of full packages. It consists of a can exchange system, OE rotor spinning and winding automat Autocoro, electronic yarn control system with extended evaluation of qualitative data.

**Fig. 4**—Comparison of effective outputs of FRS machine with one or two automats in relation to yarn count and package diameter

**Fig. 5**—Comparison of the quality of automatic piecings from conventional piecer and SYNCRO PLUS (Rieter) in relation to yarn thickness and yarn strength [Y—yarn, C—conventional piecing, and S—piecing (Syncro Plus)]. Points and ellipses represent mean values and dispersion of values respectively.

“Control PLUS”, information systems for Autocoro—Central informator “COROSULT”, packing system for cones AUTOROBBY or ROBOCONE (Matics, Italy) for package take off and palletizing.
The transporting carriage has three places for cans; during transport two places become full and one remains empty. This carriage goes on one rail along the machine with a speed of 22 m/min. The magazine has 14 places. The device is able to change 20 cans/h. With production capacity of 700 kg/h, this system replaces one operator per shift.

Spinning unit SPINNB0X has rotor speed of up to 1,30,000 rpm and rotor diameters of 30-56 mm. For production of fine yarns, special swinging element—COROSET—is available. By modifications of the transport tube and withdrawal tube it is possible to improve yarn quality, especially the strength.

Expert system COROSULT was introduced by Schlafhorst in 1989 for the selection of right components for OE rotor spinning on Autocoro. In the form of consultation on computer display, a user can obtain recommendations for spinning elements and speeds together with a protocol with input data recommendations. A COROSULT system for piece-exhibited at ITMA 91 has the available information about all machine activities. It processes the data including adjustment parameters of the automat, makes their diagnostics and gives recommendations to better setting. Together with CORODATA it compares the output of automats of one or more machines.

Elitex (Usti nad Orlici) showed a program for calculation of basic operational parameters of BDA 10N machine and a program for prediction of yarn parameters from the machine. Such a program was also applied on BD 200 D1 machine of Elitex (Cerveny Kostelec). Above-mentioned software was made by Cotton Industry Research Institute (VUB) on the basis of works described partially in the following section.

4 Prediction of Rotor Yarn Properties

The relationship between the properties of raw material and yarn made from it is still unsolved and is very important for yarn manufacturers. In recent years, this topic has been joined with the application of HVI lines. The parameters of HVI lines constitute extremely favourable conditions for the development and industrial application of the knowledge of this field. The Cotton Industry Research Institute (VUB), in cooperation with Czech spinning mills, is carrying out research works oriented to optimum blending of cotton raw materials. For this, a 900 System Spindlab, together with FMT-3 Maturity Tester of Shirley Developments Ltd, has been installed in VUB.

In a comprehensive survey of the publications dealing with the prediction of yarn properties from the quality of raw materials, Hunter \(^1\) opined that HVI systems will be used for this purpose to a great extent in the future. It follows from the experience that it is not possible to find any universal prediction equation and consequently, it is necessary to use equations adequate to concrete spinning mill. However, there is not a negation of active raw material experiments, because passive experiments bring a risk of latent variables, not included in the regression equation. \(^2\) and \(^3\), and cannot substitute active experiments. This can also be seen from numerous publications reporting the results of raw material experiments. \(^4\) We would like to give some important information related to this problem.

At first, let us mention that the relationships among the individual parameters of yarn quality also influence their application in the prediction of regression equations. From the parameters of cotton quality, bundle strength (STR) has got medium to strong linear relationship with 2.5% span length, SL2.5 = L_n, and medium relationship with 50% span length, SL50 = L_n × UR (UR = Uniformity Ratio), and short fibre content. The percentage of mature fibres indicated medium correlation with SL2.5 and UR. We found while optimizing the regression equations by step-wise selection method that in some cases SL2.5 was eliminated even with its high correlation with yarn quality parameters. In some cases, it is more advantageous to use SL50 instead of SL2.5 (refs. 7&8).

In the set of experiments for three cotton yarns (20, 27 and 59 tex) production on rotor and ring systems, SL2.5 indicates middle linear relationship with the quality strength factor JCP (analogous to CSP), yarn tenacity and hairiness.

In prediction of equations for yarn quality parameters derived by step-wise selection method, SL2.5 is influential in case of hairiness, Uster CV and thin places, length uniformity ratio (UR) in case of hairiness, and SL50 in case of thick places. SL2.5 is not influential in case of JCP and yarn tenacity, obviously for its high correlation with STR. When we substitute STR in prediction equation for JCP of 20 tex rotor yarn by factor SL2.5, the value of index of determination \(R^2\) = 90.4% goes down, but up to 87%, and the standard error of estimate increases from 54.0 to 62.9. However, we must not forget that correlations between STR and SL2.5 and other factors are the properties of cottons used for active experiment.

In the prediction of information on models, some authors recommend to use complex characteristics, i.e. predictors, in the form of products, proportions and/or sums of individual factors, e.g. STR × SL2.5, STR × SL50 and STR × E1 × SL2.5/FIN (where E1 is the fibre elongation and FIN, the fibre fineness).
Table I - Determination index (%) of prediction of JCP of 27 tex yarn

<table>
<thead>
<tr>
<th>Predictor</th>
<th>STR</th>
<th>STR × SL2.5</th>
<th>STR × SL50</th>
</tr>
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<tbody>
<tr>
<td>Ring-spun</td>
<td>60.4</td>
<td>71.2</td>
<td>74.9</td>
</tr>
<tr>
<td>Rotor-spun</td>
<td>54.1</td>
<td>58.2</td>
<td>63.7</td>
</tr>
</tbody>
</table>

Fig. 6 - Linear regression relationships between JCP and different predictors for 27 tex ring yarn [(a) \( R^2 = 60.4\% \), and (b) \( R^2 = 74.9\% \)].

In case of yarn quality factor JCP of rotor- and ring-spun yarns of 27 tex, we can see the influence of the predictor on the value of determination of the regression model.

As is evident from Table 1, the index of determination \( (R^2) \) for ring-spun yarn is higher than that for rotor-spun yarn and length parameters are more evident. In both cases, the \( R^2 \) value using SL50 is higher than with SL2.5 (Fig. 6—ring yarn).

In the prediction of regression equations for yarn quality parameters, all the three basic length characteristics, i.e. SL2.5, SL50 and UR, can be classified as influential values. Concerning the strength parameters of the yarn in many cases, STR can be substituted by SL2.5 and except of this it is necessary to find whether SL50 should be used.

5 Future Prospects

Considering the economy, the continuously improving yarn quality and the potential range of yarn counts, we can be sure that OE rotor spinning will be further extended. Owing to the shortened process and high level of automation from the point of view of manufacturing technology, OE rotor spinning represents the best controllable process which is being continuously developed. If the manufacturer is able to find a system which meets the requirements of modern rotor-spinning mill, will find a good business. The end user must be able to distinguish between possible and necessary.

The modern methods for the prediction of yarn properties and optimization of cotton blends using HVI lines make the management to function rotor-spinning mill more objectively and to contribute to its accuracy and speed.

References