

Future prospects of rotor spinning

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Received 21 January 1992

Labour productivity has been continuously increasing since the days of spinning jenny to the modern day rotor frames. To visualize the spinning industry in the year 2000, the past and the present technological changes have been analyzed so as to assess their overall impact in terms of labour complement, material handling, required operative skill and automation. The automation in textile industry has already begun with the introduction of micro-electronics, computer systems, special textile manipulators, automatic guided vehicles and integration of automated machines into the production line by computer control. Computer Integrated Textile Enterprise (CITE) system has been considered for the mill of the future.

Keywords: Computer Integrated Textile Enterprise, Labour productivity, Rotor spinning

1 Historical Remarks

In the last few decades the scientific and technical progress influenced the textile industry all over the world. The technological changes brought into spinning mills the new automatic machines resulting in considerable reduction in labour costs, enhancement of product quality and process flexibility. All these factors must be taken into consideration to review the development of spinning in the past years and to make some prognostic remarks for the future. The history of the last 200 years, as found by Krause¹, shows that the manhours required to produce one kilogram of cotton yarn since the beginning of the mechanization till date has a constant rate of reduction. The data indicate that during a 75-year period the decrease is by a factor of 10. It is possible to interpret these data from the point of view of labour productivity to have a fresh look on this matter^{2,3}. The production of 30 tex yarn per worker in a spinning mill increased from 0.075 kg/h in 1767 (Spinning Jenny) to 0.7 kg/h on the first ring frame in 1860. The modern ring frame produced 8.1 kg/h in 1960 and the automatic open-end spinning machine about 40 kg/h per worker in 1989. The extrapolation for the year 2000 shows 100 kg/h. The future spinning mill, therefore, ought to calculate the machinery requirements with this production figure (Fig. 1).

The new features of the modern spinning mill were practically developed in the last few decades. To look at the progress in spinning in the year 2000 it will be very useful to analyze the past and present technological changes, to compare which trends were

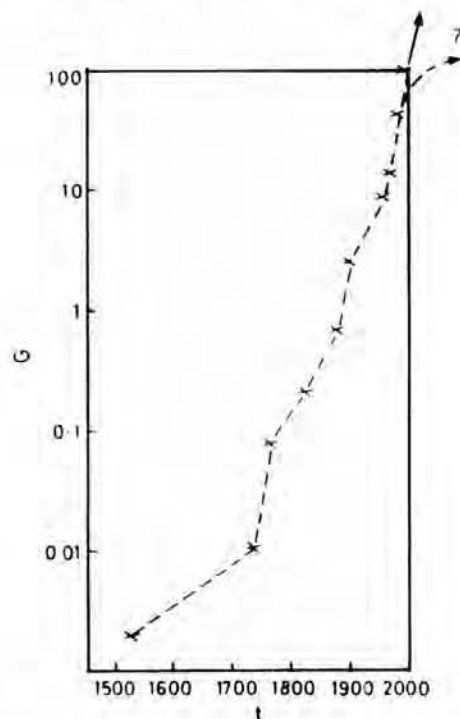


Fig. 1—The labour productivity in spinning during the period of years 1500-2000 [t—time; and G—yarn production per operator in kg/h]

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wrong and which innovations were successful. In sixties, the textile manufacturers emphasized on high production machine, e.g. carding and jet looms. Around the year 1970 the great interest concentrated on the reduction of labour (number of workers). Flock feeding and storing of material in bigger can was introduced in carding machine. The open-end rotor spinning also spared a lot of workers and increased productivity.

The decade of the eighties showed the lesser dependence of qualified operators. Exchangeable modules were used for the maintenance of machines and monitoring systems were adopted on the productive machines. During 1990-2000 there is the premise to apply a computer technique and the broader use of microprocessors together with industrial robots.

The realization cycles of the R&D results are becoming more and more shorter. In the beginning (1950) it took 35 years and now the introduction of automatic machines and links is expected to be in about 10 years only. There is a great interest to increase quality, reliability and economical aspects of the production.

With time the approach of 'automation' is being changed⁴. With the development of technology we have seen first the 'mechanization' of machines which after some years changed to 'hard automation'. This system has still mass application in the present textile mills. The negative connotation of hard automation is that these machines can do the job but to do any other job they must be completely turn apart. Examples are many types of spinning machines.

The last type of automation is the 'intelligent automation' that we discuss presently. Its most advanced form is the robot. The American definition shows exactly what intelligent automation is supposed to be about: "A reprogrammable, multifunctional manipulator designed to move material, parts, tools and other specialized devices, through variable programmed motions to accomplish a variety of tasks". In connection with it we speak sometimes about the textile robots where we expect to have not only the possibility to move textile material of all forms but also to control the action of the manipulator by the 'Tactile Sensor Systems' or even the 'Vision Systems'⁵.

All these considerations aim at the new technological processes with small number of operations on automated machines. This tends towards high rate of productivity, especially because of the changes in the technological structure of production. The reduction in the number of

operations and the progress of automation tends to better quality and the high performance allows uninterrupted operation of 3 to 4 shifts in 24 hours. What is important is that the streamlining of the yarn production simplifies the technological control^{6,7}. It is possible to say that the modern spinning mill was developed, as mentioned before, in the last few decades. The technological changes bring the reduction in the number of technological operations in the spinning process³. The example of this trend is the spinning of short staple fibres (Table 1).

The reduction in technological steps in spinning has increased the production of single machines. The modern textile mill can be characterized by linkage of processes, progressive automation, complex control systems and last but not least improved technologies.

2 Spinning

The modern mill of today has, however, some problems. The management of the spinning mill ought to strike a balance between the yarn quality and the production costs⁸ and the produced yarn quality is connected with the requirements of customers. To reduce production costs, the latest machines and technologies must be applied. To reduce personnel costs, more automation is necessary both within and between machines and integrated electronic supervisory systems must be introduced. The production costs are also limited by mill production and the surrounding conditions. Considering these facts the competition of the mills in yarn sales is to be taken into account⁷.

The management of the mill must follow nowadays the following trends in spinning:

- the raw material is taking a large share of yarn costs
- the fibre quality of cotton is decreasing although the demands on the yarn quality are increasing
- the costs of new machinery, energy and salary are rising
- the availability of qualified personnel is decreasing
- the demands of care to the environment are growing.

Besides the product costs the quality is the main issue for competitive position of the mill in the market. Therefore, it is important to secure the TQM—Total Quality Management. Regarding this, the approach of Zellweger Uster is interesting⁷⁻¹⁰.

To necessitate an intensive quality control and reach the acceptable limits of yarn characteristics, the best and most economic possibilities are:

- on-line quality and productivity control at the processes prior to spinning
- on-line quality and productivity control at spinning
- off-line quality control in the mill laboratory.

These would also represent the fundamental requirements for instituting some form of computer-

Table 1—Reduction in technological steps in spinning

1950	1960	1970		1980		1990	
		S	OE	S	OE	S	OE
O	O + B	L	L	L	L	L	L
B	Cb	D1	D1	D1	D1	D	D
Cb	K	D2	D2	D2	D2	R + S + W	OE
K	D1	R	OEb	R	OE		
D1	D2	S	W	S + W			
D2	Ro	W					
D3	Ri						
Ro	S						
Ri	W						
Rf							
S							
W							
n = 12	9	6	5	5	4	3	3

n—No. of technological operations (passages)

OE—Open-end rotor spinning on conical bobbins

OEb—Open-end rotor spinning on cylindrical bobbins

R—Roving

Ro—Roving, first speed frame

Ri—Roving, intermediate frame

Rf—Roving, fine speed frame

W—Winding

O—Opening

S—Ring spinning

D—Drawing (1-3 passage)

B—Blending

Cb—Cleaning and beating

K—Carding

L—O + B + Cb + K = Link

integrated manufacture. On-line supervision is the only means of ensuring a 100% control of each stage of processing. Its main purpose is to single out the 'outside tolerance' production positions. This is not possible only by off-line testing, i.e. by means of spot checks. Outside tolerance can be referred to various sliver and yarn characteristics^{7,8}, e.g. too high random variation, periodic short- or long-term variation, thick and thin places, deviations from nominal count, etc. All these characteristics can be measured off-line, with mill laboratory equipment, but the wrong production positions cannot be detected in this way, or if so, only by chance!

For the assessment of yarn quality the Zellweger Uster company recommended the use of Uster Labdata System. The "Quality Certificate" refers to:

- the header data, i.e. count, fibre fineness, style, date of test, laboratory assistant carrying out the test, etc.,
- *Count*, count variation and the 95% confidence lists of the mean value,
- *Evenness*, mean the statistical values as well as those for *Thin places*, *Thick places* and *Neps* (Imperfection Indicator),
- *Seldom yarn faults (Classimat)* in terms of the frequency of yarn faults according to length and cross-sectional size, and

- *Tensile* properties of breaking force and elongation, tenacity, work done, etc.

With this yarn quality certificate, which could be made available to the yarn processor (knitter or weaver) on request, all the most important yarn parameters are available on this yarn certificate whether:

- the yarn parameters are according to those required and requested,
- the yarn parameters satisfy the requirements of manufacture (type of processing, appearance of cloth) for the particular fabric being produced,
- etc.

3 Open-end Rotor Spinning

The questions dealing with the increasing productivity of machines, reduction in the technological processing steps and the stress on quality are the basis for the development of future modern mills. Automation of spinning operation is the reality of present and of future too. For a High-Tech automation of a spinning mill the key-point will be a completely automated spinning machine. The open-end rotor spinning technology has all the properties to meet this requirement. Let us, therefore, make an analysis of that technological operation.

The modern rotor spinning machines are the results of long dated research and development in textile technology, machine aggregation, automation and computerization¹¹.

The mill managements and technologists are mainly interested in production capabilities of spinning machines, namely:

- processing capabilities of available fibres, range of spinnable counts of yarns;
- production parameters (highest yarn take-up speed, maximum speed of spinning rotors);
- important yarn properties (quality, tenacity, elongation, imperfection, seldom faults, etc.);
- yarn package (shape and size, kind of winding, lengths of wound yarn, yarn reserve, fixing of yarn tails);
- machine design (arrangement of spinning unit, gauge, drives, winding device, automatic devices travel, transportation of packages and tubes, etc.); and
- functions of automatic devices and their coupling with machine environment and in case of need a possibility of manual yarn spinning-in.

The automation of a rotor-spinning machine as regards its design is, however, necessary from another point of view. It is possible to describe the automation as 'use of automatic equipment to save mental and manual labour'. The designer of automated machines is, therefore, interested in such activities of spinning operations which will at first facilitate the work of operator on the machine and, in perspective, will shift him into a function of supervision control.

Such activities of operations are the following ones:

- (1) Start of spinning (either by stop-start motion for simultaneous spinning-in of all spinning units, or by successive spinning-in of individual spinning units by an automatic piecing device).
- (2) Indication of the presence of sliver in spinning unit.
- (3) Automatic cleaning of spinning rotor and yarn spinning-in (piecing).
- (4) Checking of piecing slub quality during automatic piecing.
- (5) Spun yarn waxing.
- (6) Conveying of tubes to automatic doffer.
- (7) Doffing of full packages (by travelling doffer of another automatic device).
- (8) Conveying of full packages on the rotor-spinning machine.
- (9) Loading and transport of full packages from the machine.
- (10) Automatic cleaning and checking of spinning units.

It is also necessary to consider the kind of machine control (electric/electronic), data acquisition,

integral or independent computer system, inspection of yarn quality, e.g. by Uster Polyguard, etc.¹².

The operations specified above are automatic on most of the new OE machines and it may be said that they work reliably.

The features of the presently manufactured machines can be compared with the information presented by Artzt¹³ and in Table 2 (refs 14 & 15). Table 2 illustrates the specified technical parameters of modern Czech rotor spinning machines produced by ELITEX in Ústí n.O. (BDA 10) and ELITEX Červený Kostelec (BD 200D1).

The features of the fully automated rotor spinning machine have been described earlier in this text.

The reason why the above types of Czech automated machines have been mentioned in Table 2 is that these machines have the longest reputation and comprise the greatest technological knowledge since their development in 1968-1969. These

Table 2—Specifications of two modern Czech rotor-spinning machines

Specification	Type of machine	
	BDA 10 N	BD 200 D1
Max. number of spinning units (SU)	224	192
Standard number of SU	192	192
Gauge, mm	216	200
Max. speed of SU (in thousand), rpm	90 ^a	31-90
Range of combing rollers speed (in thousand), rpm	5-8	5-9
Machine standard length, mm	28980	23685
width, mm	2000	1040
height, mm	2930	1955
Max. dimensions of sliver cans, mm	508 × 914	406 × 914
Max. staple length, mm	60	19-40
Range of sliver counts, tex	2500-6250	2200-5000
Draft range	13-284	40-243
Range of yarn counts, tex	166-14.5	50-14
Twist range, tpm	214-3629	238-3780
Max. yarn delivery speed, m/min	168	170
Max. package size (cylindrical), mm	300 × 150	300 × 150
weight, kg	4.15	4.15
Type BDA 10 NK:		
Max. package size (conical), mm	250 × 150	
weight, kg	2.5	
angle of taper	4°20'	
Total installed capacity, kW	60.5	51

^aBDA 10: for special order and after technological tests, max. speed—105,000 rpm.

BD 200 D1 has manually package doffing. Full package is placed onto package conveyor after opening the winding arm.

machines were also installed in large quantities in several countries all over the world¹⁶.

There still exist several problems which are to be mastered before aggregating the OE machine into a continuous production line coupled with the preceding and following procedures, so as to obtain a real High-Tech intelligent automatic spinning mill.

Naturally, besides these technical and technological problems to be taken into consideration the questions regarding the economy and perspective of the respective mill must be solved.

Let us mention for instance the relation of *labour costs* and *full cost* of an automatic High-Tech machine connected with the system CITE. Sometime ago the trend to a spinning mill of future was considered as *a long and stony path which textile producers and machinery manufacturers will have to take*¹⁷. This path with all its problems still exists. A complete replacement of operators by robots or robotized machine which can only be supervised by highly qualified electronics/mechanical-electronics engineers will depend more on the mill possibilities to invest a large amount for the pretentious equipment and on the possibilities of all the systems CITE, than on the research and development of such machinery.

The unsolved and partly solved problems in the way to the future spinning mill are:

- Aggregation between drawing (or possibly carding) and spinning machines. There is a problem whether to arrange for a continuous flow of stock for feeding each spinning unit of the machine or to give preference to the predominant opinion to accept discontinuous method of feeding. The use of AGV with robot for transporting cans and their locating at a machine with sliver piecing is a solution which is now being investigated by several companies.
- Introduction of sliver end into spinning unit in case of interruption of yarn spinning. With this problem the question of sliver feeding control is connected.
- Visual checking of complete machine function and removal of defects on a spinning unit or machine which cannot be mastered by travelling automatic device for robot cleaning and yarn piecing.
- Controlling of tubes and yarn packages transportation on the machine (in particular for conical packages).
- Classifying of yarn packages as to their size and yarn tail forming.
- Exchange of faulty spinning units or those with *rogue rotors* producing downgrade yarns.
- Technological supervision.

In the considerations about future ways of automation in rotor-spinning technology, the long experience of experts in the Cotton Industry Research Institute (VUB) which they had with the technology of BD 200 machines and with the

designing of all the types of OE machines since 1968-1969 has been taken into account¹⁶.

To conclude the remarks concerning the development of OE spinning it is possible to say that the High-Tech automatic rotor machine must respect the following trends:

- *Production of quality yarn*—This may be achieved by the ingenious design of the spinning unit, demanding technological research and complex on-line supervision of the machine. The manufacturers of the machine must consider to be competitive with ring spinning.
- *High rotor speed*—The revolutions of rotors on modern machines are increasing especially for production of fine yarns. This trend has the technological limit because of the decreasing quality of yarns and the effectiveness of spinning process.
- *The flexible inter-linkage systems between machines*—The OE machine has all the presumptions to follow this demand, but the intelligent robot for this attendance operation must be outfit with tactile and vision systems. Some machine makers are working on the development of automated sliver piecing, spinning from rectangular cans from the card sliver, etc.
- *Users comfort*—The automation of several operations and on-line control will result in reduction of manual piece of job on the machine.

The economical studies must determine the rational relation between labour costs and investments in expensive machines, instruments, robots and supervision systems.

4 Future Mill

The entry of computers into the managements of companies and into the technology of production evoked discussions, experimental solutions, hopes and even losses. The Computer Integrating Manufacturing (CIM) system is frequently discussed especially in engineering, electronics, aircraft and automobile industries. Naturally, the interpretation of CIM introduces certain simplifying conceptions. The defenders of the modern management state that 'M' should be derived from the word 'management' and sometimes they recommend to give preference to CIB (B=business), denoting integrated management of enterprise. In our consideration regarding a textile mill of future the abbreviation CITE (Computer Integrated Textile Enterprise) has been used because of the fact that the textile production, including its preparation and control, is much more different to single part engineering production for which the system CIM has been developed. In USA, the abbreviation CITE has been used for general determination of computerization of textile enterprise¹⁹.

The main condition for an integrated system is the introduction of uniform information basis. In such

case, all the departments of an enterprise have an easy access to all mutually tuned internal data. It is of course necessary to bear in mind that in such a case the computer network is very widespread. Hence, emphasis should be laid on a good and complexed preparation, effective organization and maximum automation of the respective production. Managing and training of staff is not any subordinate affair but a very important factor influencing substantially the final effects⁶.

The decision regarding controlling and conducting an enterprise by means of computers must be derived from the strategic aims and belongs to the executive management. The management must also take active part in its preparation and understand that the introduction of CITE will influence the organization of enterprise, its structure, methods of work, etc. It will, however, enable to respond quickly to the changed market requirements, preparation of calculations and presentation of preliminary offers.

The basic steps in textile production (from fibre to fabric) are the following ones:

- fabric designing,
- production planning,
- manufacturing (spinning, weaving, dyeing, printing and finishing),
- inspection,
- fabric handling and distribution.

It is possible to integrate these production steps into one subject "CITE". The integration is to imagine as a complex consisting of several computer-aided systems, e.g. CAD, CAE, CAPP, CALB, KBES, etc. Such an integration shows the possibilities of computer technique during various operations in a textile mill. In the literature we find heterogeneous introductions of the abbreviations which are derived from the experience acquired with part-systems especially CAD/CAM or with the system CAQ which is a system for inspection of quality. With the most progressive enterprises the present state is characterized in the meantime by an effort of connecting planning and management with designing and manufacturing. Naturally, such integrations have their own benefits. An effort is being made to connect these isolated 'islands of automation' with transient programs and data transformations. At present, it is a big problem to find a common 'language' between the different systems.

Before integrating textile enterprises by computer-aided systems, the textile technology and management operations should be taken into consideration. It is necessary at first to simplify all the

operations and only after that to begin with the project of automation. Furthermore, it is also necessary to minimize the quantity of information to be transmitted to the another level of computer supported control or between workstations. For instance, if the stock is in the right form and in the right place than minimum information for manipulation is necessary. If technology of an automated machine is mastered then the necessity of information is minimal¹⁸. In case the working team is capable of taking care of the whole production task, i.e. preparation of material, manipulation, machine attendance, programming, maintenance and inspection of quality, the necessity for the operation is also minimized. Consequentially, in the system CITE there is not only one centralized databank but also several sectional databanks which are, however, supervised and controlled centrally. The data from these banks are naturally accessible to any one who is in need of them¹⁰.

When concluding the remarks concerning the introduction of computers the following most important part from the "Japan lessons of management" should be mentioned:

"The system of production is to be effectively organized and only after that automated, i.e. first of all the system must be made as efficient as possible".

In modern textile mills the integration of production is proceeded by computer systems. For this, the system of Zellweger Uster, Switzerland or BARCO, USA has been found suitable. The description of these systems may be found in technical literature from ITMA and manufacturers' leaflets^{7,12}.

The technology of yarn spinning and fabric processing in the 21st century is an object of considerations in the world. With the present technology a fully automated textile plant without people is not yet conceivable. Therefore, an automated mill with minimum number of attending personnel is taken into consideration. It seems to be realistic that such kind of automated plant may start production in a near future^{19,20}.

The plant of future must be very flexible regarding the assortment of products so as to respond quickly to the needs of market. It is assumed that it will be composed of four parts—modules (Fig. 2). The first part of the plant is a stable module projected as a complete preparation line for spinning. It will contain warehouse for raw materials, blow room and carding and drawing machines linked into a production line. The second module, enabling a high adaptability to the required assortment, is based on OE rotor spinning machines equipped with automated

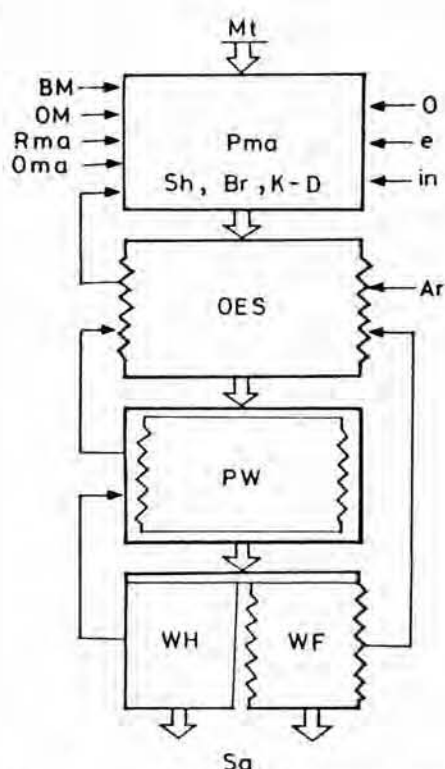


Fig. 2 The future textile mill [Mt—market requirements; Pma—complete material preparation; Sh—storehouse; Br—blow room; K-D—carding and drawing machines; BM—basic material; OM—other means; Rma—raw material; Oma—other material; o—operators; e—energy; in—R&D information; OES—OE rotor spinning; AR—assortment requirements; PW—preparation for weaving; WH—hard programmed weaving room; WF—flexible programmed weaving room; and Sa—sale (distribution)]

transportation. The third module is connected with the preparation of spun yarn for weaving. In this case, sufficient flexibility is required for handling of wide assortment of yarns. Both the production equipment and technology are relatively stable. The last module of the plant of future is internally divided in two parts, out of which the first one has a fixed stable program whereas the second part is a flexible production line enabling quick response to the needs of market. The textile material after each stage of processing is accumulated in intermediate storage hoppers and transportation is secured by means of special textile manipulators and automatically-guided vehicles (AGV).

In the project let us assume a production of 150 tonnes of fabrics for printing to be continually manufactured (seven working days per week). There is anticipated spinning of yarns of an average count 17 tex from 50% cotton and 50% polyester fibres. For this purpose, 16 carding machines, frames with 5500 spinning rotors and 300 weaving machines are to be

taken into account. In such a mill, the efficiency is expected to be 36 kg per operator per hour. The number of direct operators will be decreased whereas the number of indirect workers and managing staff will be increased. The method of management will shift from supervision to controlling the actual technology¹⁹.

In this project the expected development, which is supposed to be as follows, is very interesting:

- In the first stage, the *process control On-Line* is to be solved. Such a control necessitates diagnostic sensors and decision elements capable of communicating with the host computer on one side and with a machine on the other side. The control and quality inspection will especially be concentrated on the process of carding and preparation of weaving.
- In the next stage, it will be necessary to ensure continual flow of material. All the lots will be marked by codes so as to identify their location and quantity, whenever necessary, and to determine the optimum logistic of transportation.
- The next stage to follow the flow of material is *selective automation*. Its implementation will be carried out by taking into account the effectiveness of costs and management. It means that only such kind of automation will be effected which will be found at a given period advantageous from the point of economy.
- The next most interesting stage of the conception and development of the mill of future is the mentioned *modular production*. The project comprises two levels. The first technological level includes relatively simple but fully automated machines which do not require any complicated control. The second technological level implies much more care for the quality as well as computer-assisted management of production. By means of exchangeable programs a quick change of technology and products will be made possible.
- In the last stage, it will be necessary to effect 'High-Tech Automation'. According to the level of technology it will be possible to link together all the machines by automated production lines so that in this stage a *flexible plant* is created¹⁹.

The described project may serve as an example of the complexity connected with the building of automated textile production. The sequential solution and implementation for the mentioned stages has its own reasoning. It should, however, be emphasized once more that it will be necessary to adhere to the sequentiality of individual stages which are to follow one after the other, whereby each stage must be completely finished. Skipping over some of the stages will result in losses. It is not possible to introduce the 'selective automation' without preceding continual flow of material and the process control on-line. Only in such case the success and final **satisfactory** economical effect of the future plant will be safeguarded.

A start for automating the textile industry has already begun by means of microelectronics, computer systems, special textile manipulators, automatic-guided vehicles, integration of automated machines into production lines and by computer control.

The examples have been demonstrated at ITMA 91 in Hannover²⁰. It is to be expected that the application of mechanotronics will mean a real revolution in the textile technology. The textile industry faces fundamental modernization of its production base. If such reconstruction is to pass into qualitatively higher level of automated plants operating in the CITE mode, it will necessitate investments not only in machinery and buildings, and research and development, but also in training and education of employees and their social protection.

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