No. 4 December 1996

melliand INTERNATIONAL

Frankfurt · Milan · New York · Hongkong

Automation in textile mills: a comprehensive approach

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Current state of automation

Yarns of the most widely differing nature are produced in textile mills. The production stages necessary for this are carried out with the aid of textile machines. Between these individual textile machines - from cards to spinning machines - sliver cans serve as a rule as transport containers, in which the sensitive sliver material is temporarily stored, and presented to the next production stage.

With the constant optimization of production capacity and quality in the production stages, a high degree of automation has been attained [1] on the textile machine. Independently of this, automation solutions for material flow [4] between the production stages are encountered. Textile machinery and transport automation manufacturers are already offering solutions for automated sliver can transport. This transport automation has led to heterogeneous control diversity in the spinning operation.

- High degree of textile machinery automation

In comparison with conventional spinning processes, such as ring spinning and spinning from the can, the unconventional processes of rotor, friction or wrap spinning are much more highly automated due to their reduced number of production stages, easier comprehensibility, less complex processes, fewer interfaces, more reliable solutions and flexible production and capacity adaptation [5].

- Independent transport systems

Current emphasis on material flow automation is on the transport of roving bobbins and sliver cans. The multiplicity of can transport systems encountered today can be divided into the following groups:

- above-ground endless conveyors,
- driverless transport vehicles
- portal equipment, and
- suspension conveyor systems.

- Heterogeneous control diversity

The functions of textile machines and technical conveyor systems in material flow are controlled as a rule via their individual, independent control systems. Various control systems are used. Integration in overriding process control systems is currently to be regarded rather as a realizable planning quantity for the future.

The state of automation is characterized by tailor-made island solutions, the economics of which can be calculated from the relationship between machine dimension and structure [5, 6].

There is no integral consideration of all the production stages in the spinning process from the value analysis and value engineering standpoints [7].

The objective therefore is to demonstrate this by means of the solution components which go beyond current automation levels. The selection and customer-specific combination of these modular solution components depends on the answers to important deciding questions. Their influence and effects on spinning line configuration and automation [1-3] are illustrated.

Overall consideration with answers to deciding questions

For overall assessment, the following features should be considered:

- building planning and machine installation,
- spinning production and performance and capacity data of the textile machines to be linked by automation,
- textile machine and automation system functional reliability,
- strategies for sliver can changing on the textile machine,
- production flexibility (including batch changing and production buffers),
- economic considerations,
- establishing sliver can specifications and automation systems,
- control and data transfer systems.

These features find their application in new projects as well as in integration in an existing plant. So that yarns can be produced economically in terms of quality and quantity, it is essential to match all spinning process functions to each other in reference to the overall result.

- System-determining factors

System-determining factors can be subdivided into process and production related factors.

Process-related factors include the material range, entire plant throughput, the spinning process, the machine type and number and special requirements.

For the plant, the production-related factors include the material to be produced, the throughput range, machine combination and floor space. For the production line, machine combination and material buffer sizes, and for the machine, production quantity, yarn count, can format and filling quantity, changing intervals, the material buffer for the machine, and efficiency and handling times should be considered.

- Spinning lines

The necessary production stages between cards and spinning machines for the production of carded and combed yarns are understood as spinning lines. There are therefore six different spinning lines for the conventional ring spinning process, since sic to ten textile machines can be used in different sequences.

With the unconventional rotor spinning process, six spinning lines with four to six textile machines in different sequences can also be used.

Systematic consideration reveals that automation combinations can be defined independently of the spinning process.

- Automation combinations

For the ring and rotor spinning process, there are eight automation combinations for the sliver transport field, independently of the number of machines. The following automation combinations (AC) derive from the production stages

- AC 1: card - drawframe,
- AC 2: card - labcenter,
- AC 3: drawframe - drawframe,
- AC 4: drawframe - speedframe.
- AC 5: drawframe - superlab,
- AC 6: comber - drawframe,
- AC 7: drawframe - rotor spinning machine, and
- AC 8: card - rotor spinning machine.

- Automated-transport systems

The features of the floor-level equipment, suspension conveyor systems and driverless vehicles in practical existence are taken as known. In overall assessment however, evaluation should not be undertaken exclusively in accordance with transport system features and their possible use in automation combinations, but the following deciding questions should be included.

- Answers to deciding questions

Automation with system-determining factors and defined automation combinations for ring and rotor spinning is leading to new solution formulations. The answers to the following eight deciding questions determine solution shaping in this respect:

- Which combination possibilities?

One essential decision derives from the material flow conditions. Here, we need to differentiate between flexible, fixed and indirect combination, and select one of them: In the case of flexible combination, several machines, freely eligible and variable by the user in the mill, are combined with each other.

By fixed combination, we understand direct machine combination, in which two machines are invariably linked. With indirect combination, several machines are linked invariably with each other.

In the combination decision, a decision is made about the degree, effect and potential of automation on the process-related and production-related factors, fixed combination being developed for integrated automation in the mechatronic sense [8]. At the forefront of the above-mentioned technical engineering integration are production line shortening, transport minimisation and easily comprehensible control and data systems. In this respect, indirect and flexible combination is developed primarily in the transport automation direction. The combination possibilities and the system transport features, considered against the production-related factors, lead in stages to the optimum transport system choice.

- How many material buffers?

Independently of the combination possibilities, the necessary provision of material buffers should not be used exclusively for interim storage but also for balancing:

- for stochastically occurring differences between a sliver delivering machine (source) and a sliver fed machine (destination), and
- with stochastically occurring transport performance requirements which cannot be met by the transport system within the times specified by the production process.

These functions can be performed by an entry buffer, which can be incorporated within relatively small dimensions and with a small stock, if necessary in front of the textile machine. Computer-aided, dynamic material flow simulations make optimal dimensioning possible.

- Which functional reliability and comprehensibility?

The production capacity of textile machines and automation modules is essentially determined by functional reliability. High efficiency levels, above 90 % as a rule, are therefore prerequisites, due to the multiplicative linking of individual machine and module reliability levels.

The prerequisites are largely met in the case of spinning lines. Drawframes are the weak point however. Analysis reveals crucial trouble spots in the entry zone. Achievable solutions should be developed.

The following recommendations for achieving intelligibility in an automated plant also make their contribution:

- sliver ends in the can over the can rim,
- drawframes with single-row creels and roller entry,
- block package changing in the creels,
- sliver separation on the final passage drawframes,
- components for the automation combinations as modular units,
- the overall system and all individual components must allow manual intervention, and also be manually operable.

- Which sliver lengths and residual quantity disposal?

The target for reaching minimum residual sliver quantities is determined by a high degree of sliver length accuracy. Sliver lengths (on cards and drawframes) with a minimum accuracy of ± 0.25 % relative to DIN/ISO 93 standard filling, independently of sliver count, are a small enough residual quantity. Cards and drawframes with roller entry achieve this degree of accuracy. Automatic residual sliver quantity disposal is an overall consideration factor. Solution formulations for block changing in the drawframe creel and in the rotor spinning machine entry buffer can station have already been put forward in practice. Integral, closed recycling systems are to be recommended however, any residual sliver occurring being disposed of centrally. We find analogies in speedframe bobbin disposal.

- Which sliver piecing?

Automating sliver piecing is an essential decision. The high degree of automation of the rotor spinning machine has also developed solutions for sliver feed changing. There are sliver pieces which are linked either with spinning start-up automation or with automatic can changing. With all solutions, defined positioning of the sliver end in the sliver can is essential. The preparations for this involve units on the final drawframe passage and/or in the rotor spinning machine entry buffer. For automatic sliver piecing in the drawframe and comber creels, automatic individual changing should be the target solution in the medium-term. With the development stages, starting from automatic block changing with manual sliver piecing to automatic block changing with automatic sliver piecing, automatic individual changing should be the target.

In overall consideration of the ring spinning line, the use of automatic sliver piecing should be tested critically with regard to expenditure and the degree of reliability achievable in the comber, drawframe and speedframe creels, particularly as sliver piecing is especially difficult in speedframe creels.

- Which control and data systems?

In the case of control and data systems, the structures and linkage levels selected are decisive. In contrast to the systems encountered today, an open, interactively useful network should be targeted from the overall standpoint. With this data and control network, control and data clarity will then be useful, depending on the application requirement at different levels. Process and production related factors should be used in order to achieve this clarity at the various levels.

The machine level (level 1) includes the relevant controls for the textile machine and automation module function cycle. Data such as production capacity and quality parameters are recorded. Purposeful, interactive application is essential for operation. The production line (level 2) records selected current relevant machine and automation module data. Defined, interactive application is significant for the decision level responsible here. The combination of several production lines into a plant (level 3) gives current, targeted, selected data clarity with the possibility of interactive application for plant management.

This structure makes possible variable control and data message networking.

- Which sliver can versions?

The largest possible sliver cans, requiring fewer changes, are used for achieving better sliver quality, good flow characteristics and improved efficiency.

Sliver can dimensions are determined by adaptation to the machine dimensions.

Sliver can standardisation is necessary for limiting diversity and for optimum use of the modular components in the automation combinations.

If the automation combinations in the ring and rotor spinning processes are considered, we can standardize on three sliver can versions, at least two versions being used in a spinning line.

Recommendable here are sliver can dimensions (diameter x height) diameter 1000 x 1200 mm (diam. 40" x 48") for the automation combinations AC 1 to AC3 and AC5 and AC6. In the ring spinning process for the AC4 diam. 600 x 1200 mm (diameter 24" x 48") and for the rotor spinning process for AC7 diam. 400 x 900 mm (diameter 16" x 36").

In the case of sliver can transport automation with driverless vehicles, flat can versions (rectangular, oval) have been developed, particularly in the rotor spinning process.

Since then, the features of rectangular as compared with round sliver cans have been the subject of discussion, as the effects on textile technological and engineering technological aspects reveal their impact. The above-mentioned standardisation features also apply to flat cans.

The standardisation features should be selected according to the combination possibilities, the automation combinations and the modular solution components: thus, with fixed, direct combinations with endless conveyors, cans without rollers are to be recommended, with flexible combinations with non-continuous conveyors (driverless vehicles) cans with roles should be used. The sliver can dimensions standardized here take account of the standardisation features over and above the other deciding questions mentioned. One example of this is the AC7 automation combination (drawframe - rotor spinning machine). The standardized sliver can dimensions there make all combination contingencies possible, and consequently the selection of several solution modules. In contrast, other non-standardized dimensions (e.g. diam. 17.5" x 40" or flat can) would substantially

Tab. 1 Integral automation model

Start: overall evaluation	
system-determining factors - process-related - production-related	spinning processes and lines - conventional - unconventional
automation combinations	
automated transport systems?	deciding questions? answers 1) to 8)
automation	
process-independent	process-dependent
degree of automation	
transport automation - partially automated - fully automated	integrated automation - partially automated - fully automated
result: *modular automation components*	

Tab. 2 Solution survey of modular automation components

Automation combinations (AC)		machine combination direct	indirect	flexible
AC 1:	card-drawframe	-	BP, BH	BF, BH
AC 2:	card-LabCenter	-	BP, BH	BF, BH
AC 3:	drawframe-drawframe	A, B, AB	BF, BH	BF, BH
AC 4:	drawframe-speedframe	B, AB	B, BH	B, BH
AC 5:	drawframe-superlab	A, B, BA	BF	BF
AC 6:	comber-drawframe	-	B, BH	B, BH
AC 7:	drawframe-rotor spinning machine	A, AB	F, H, ABP	F, H, ABF
AC 8:	card-rotor spinning machine	-	BP	F

A: automation units (integrated, independent, track-guided, driverless vehicles with processing and transport functions)
B: floor-level systems (above or below ground transport systems with rollers, chains or belt components)
F: driverless vhicles (machine-independent, inductive or track-guided)
H: suspension systems (above-ground, flexible rail systems)
P: portal systems (above-ground, track-guided suspension systems)

limit combination possibilities and selection.

- Which economic aspects

Last but not least, in overall consideration we should pose the question of economics. The answer is made more complex by consideration of the material flow-specific, textile technological and engineering technological aspects: the economics are independent of the degree of automation. Thus, a lower degree of automation can also be economic. On the other hand, integrated automation with a high degree of automation and shortened transport routes, including process functions, can be economic. Generally speaking, any type of automation will stabilize and ensure quality levels. In practice, "return on investment" often determines automation timing, extent and degree. The modular components make staged automation possible, so that efficiency is gradually increased.

Solutions with automation modules

From the overall consideration standpoint, defined automation combinations can be used independently of spinning processes and spinning lines and all system-determining factors as the first step towards a solution.

In the second solution stage, the question of automation and degree of automation is answered with the inclusion of an automated transport system and the answers to the deciding questions. The result can be subdivided into process-independent transport automation or integrated automation. Integrated automation is process-dependent, contains machine processing functions, and therefore makes for a higher degree of automation. Modular automation units are the result of this model (Tab. 1). These can be used both for the entire spinning line and for each individual automation combination.

- Modular automation units

With consideration of all the results of the integral automation model, a solution survey (Tab. 2) is reproduced for the eight ring and rotor spinning process automation combinations relative to machine combination. In it, individual components are identified by a recognition letter, and component combinations by two or more letters (e.g. AB or ABP). Enquiries about this solution survey and which of the components listed in it is the optimum solution in the individual case can be made via the authors' evaluation system.

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