RAPID PROTOTYPING OF RING AND COMPACT YARN WITH IMDS LABSPINNER

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Abstract

The SKF laboratory ring spinning machine remains the most versatile machine of its kind; however, it was discontinued by the company over a decade ago. It used a now-obsolete DOS based notebook computer for parameter setup and conventional microprocessor control. Moreover, the programming source codes were lost. Therefore, as the old computers failed there was no way to make the system work again. Yet the high-quality mechanical parts of the machines could be easily repaired and maintained. A unique feature is the individually motor driven spindles, controlled by inverter, capable of exceeding 25,000 RPM. To reclaim this valuable laboratory tool, we undertook a reverse-engineering project that completely replaced the electronic control system and brought it into a state-of-the-art, MS Windows environment. All spinning parameters may be adjusted by computer entry, while the spinning process is running. This newly available spinner was further modified to utilize the Suessen compact spinning system, thereby enabling rapid evaluation of fiber spinning performance with both conventional and compact ring spinning. Examples are given of uses for this machine in cotton yarn product development, with emphasis on compact spinning and alternatives for making plied yarns.

Ring Spinning Machines for Spinning Process Research

The first generation of laboratory ring spinning machines was derived directly from full size production frames. A common motor drives the spindles (using a tangential belt) and the drafting cylinders. It also moves the ring and associated balloon control and thread guide rails. The spur gears with exchangeable wheels of the full size machinery are replaced by mechanical variable speed gears. Consequently, draft and twist are adjustable only while the machine is running – these parameters may not be set beforehand.

Laboratory spinning frames of this kind, generally known in Europe as “Spinntesters”, have been offered by various suppliers. Many units are still around, some showing up regularly for demonstration of spinning components at exhibitions. This kind of miniature size ring spinning machine is typically equipped with the drive and control technology used before the introduction of electronic drives and microprocessor control. While the problems in handling and use are evident - poor accuracy in the parameter setting and unacceptable noise in laboratory surroundings – a more critical problem is the lack of knowledge and skills required to maintain the machines. This is due to the fact that industrial drives and controls have been completely digital for more than a decade.

The former Textile Component Division of SKF was a prominent supplier of such “Spinntesters” and around 1990 this company developed the most advanced machine of this type in existence. It was offered on the market primarily to promote the use of individual motor driven spindles. This breakthrough in ring spinning technology proved too expensive to be commercially successful on full-scale machinery, but it is excellent technology for laboratory machines. It offers noiseless operation and extraordinary speed (30,000 RPM). The name IMDS LabSpinner derives from the individual motor driven spindles used on it.

The control of the original machine corresponds to the technology of the late 1980s, featuring a modular microprocessor system derived from numerical controlled (NC) machine tools. The parameters were prepared and stored separately on an early generation notebook computer, and then downloaded into the machine controller before starting each job. Operator control of the spinning operation is limited to start, slow mode for piecing up, and stop. These were selected using a few buttons on a small console.

It is the control system, especially the DOS-and-diskette based notebook, which makes the system obsolete now. Otherwise, the individual driven spindles and the AC servos for each function make the machine state-of-the-art. It enables optimum performance and accuracy with a minimum of maintenance. However, a completely new electronic control system is made necessary by failure of the microprocessor control module. Without the source codes, repair of the control module is impossible. Moreover, a state-of-the-art control system has the great advantage of making the IMDS LabSpinner much more flexible and user-friendly.

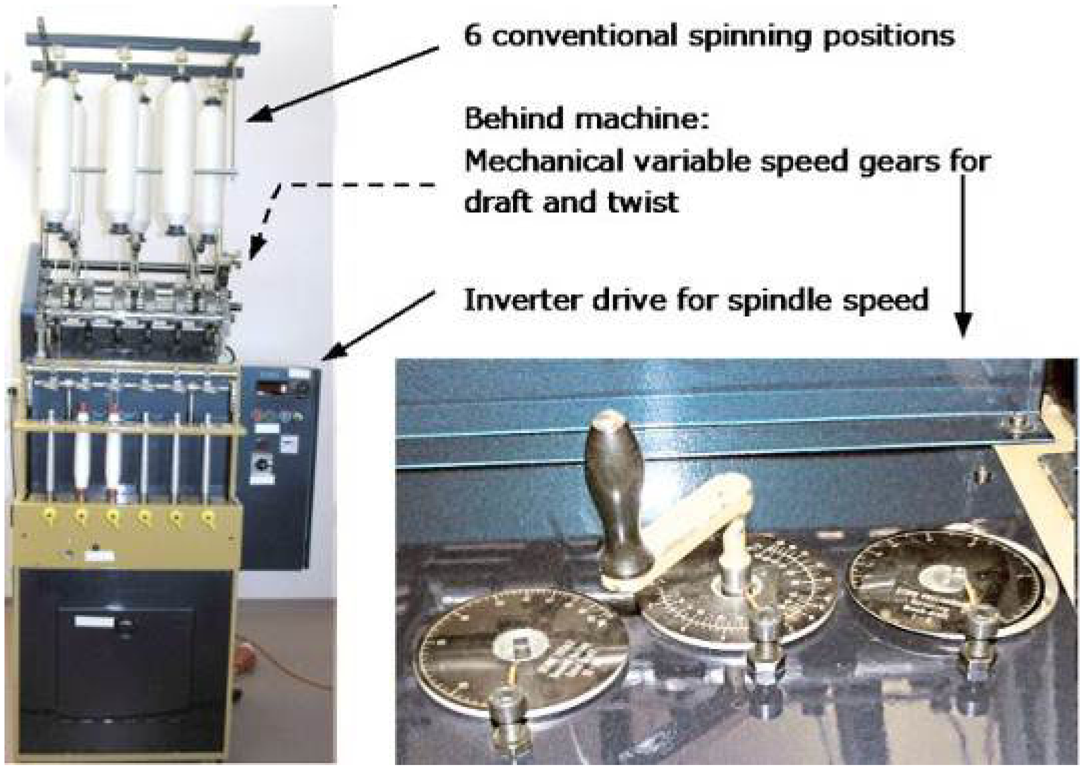


Fig. 1. Traditional “Spinntester” with mechanical drafting gear and belt drive for the spindles

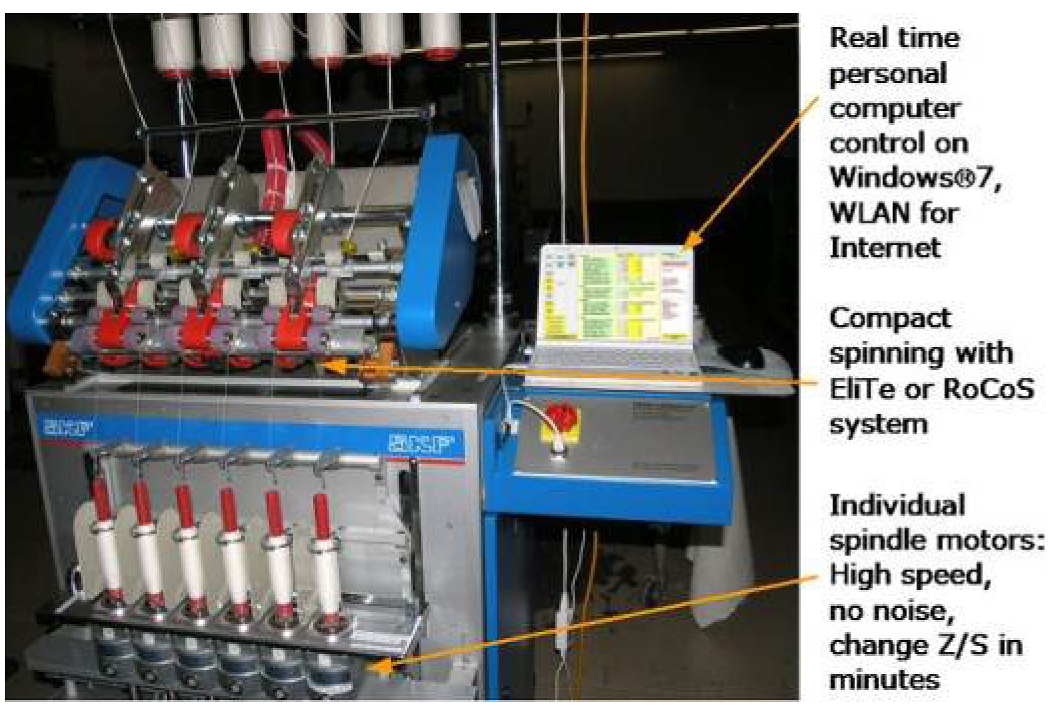


Fig. 2. IMDS LabSpinner with real time personal computer control and EliTe compact spinning equipment

A preliminary study of possibilities to replace the original control system revealed that neither a state of the art PLC controller nor a standard NC tool machine controller would cover the functions of this laboratory machine. It should be noted here that a proprietary controller is generally a good choice for an industrial production machine operating daily. After 10 years or around 20,000 up to 70,000 operating hours, a general overhaul is indicated and economically justified anyway. For a laboratory machine, the same 10 years represent at most a few thousand hours of operation. Therefore, the mechanical structure is hardly exposed to wear and tear, so an overhaul or replacement would be premature. Also, persons operating laboratory machines and instrumentation are more comfortable with the standard personal computer than with the simplified graphics and press-of-thumb operation of an industrial machine controller. The priorities for a laboratory machine include availability of a long-term supported standard in the operating system, ease of integration into a computer network, and the availability of service programs for printout, calculation and statistics.

Based on experience gained at the Swiss Federal Institute of Technology on other textile machinery controls, a real-time personal computer based system was developed to replace the original PLC controls and the original operator panel. The software is fully MS Windows® based, using VB.Net for programming language. Taking advantage of modern computing power and graphical displays, the operation is evident and self-explaining. Changing spinning parameters is now possible in real time, while the machine is running. Connected to a local wireless network, the machine control is fully accessible by any personal computer on the Internet. The personal computer is connected with the machine by USB. Transfer of control to another personal computer requires just the downloading of the control program and plugging in the USB cable. If the USB connection fails, the machine stops immediately, while the computer indicates this status and is further available working in a simulated mode.

New Developments in Ring Spinning Technology

The concept of compact spinning goes back to the Ring DREF process invented by Dr. Ernst Fehrer in the 1980's, originally targeted at direct spinning from sliver. In this process, the sliver would be split in the drafting zone to get two strands for spinning two yarns on a pair of spindles. This invention was further developed into a full scale spinning process by Rieter. Their proprietary design proved to be a major step in improving yarn structure, resulting in significantly better tenacity and regularity. The new approach was called "compact spinning" because its purpose was to condense the fiber flow in the drafting zone, thereby eliminating the conventional "spinning triangle" coming off the front roller. In subsequent years alternative designs for compacting the yarns were developed; some of these brought the advantage of being able to accommodate medium and short lengths of staple fibers. Regardless of design, the common purpose is to make the spinning triangle as small as possible. This improves the tying-in of the fibers into a regular yarn structure and reduces the amount of protruding fibers and the loss of fibers into suction. As can be seen in Figure 3, the structure of the yarn is more compact than with conventional ring spinning. The fibers share the tension load on the yarn with better efficiency, which shows up in the higher tenacity of the compact spun yarn. The pictures in Figure 3 were taken with a deep focus microscope of yarns that were pulled off the cop straight after spinning on the IMDS LabSpinner, without any additional handling or preparation.

The original compact spinning concept presently offered by Rieter is in its 4th generation, as machines of the K45 series, under the name ComforSpin. The compacting of the fiber flow is accomplished by a revolving perforated sheet metal cylinder that is exposed underneath to suction applied by a slot slightly slanted against the direction of the fiber flow. The collection of fibers involves a gentle, but distinct twisting motion, taking place at the same time as the fibers are redistributed in the drafting process. This solution is covered by comprehensive patents and proprietary to the Rieter compact spinning machines.

A similar concept is offered by the company Suessen, part of the Rieter group, as an aftermarket solution under the name EliTe (Figure 4). The fiber flow is again controlled by suction through a slanted slot. The moving carrier of the fibers is a fine mesh screen apron that slides over a fixed suction tube. Extensive technical support is available for equipping existing ring spinning machines with this compact spinning system.

A different concept of fiber collection is offered by the Zinser brand of the Schlafhorst/Oerlikon group. Again, suction is used to collect the fibers, but in this case a conventional fiber guiding cot is perforated so as to attract fiber from both sides towards the center of the cot. Again, this solution is proprietary to the Zinser machines. A similar solution is offered by Toyota on their ring spinning machines.

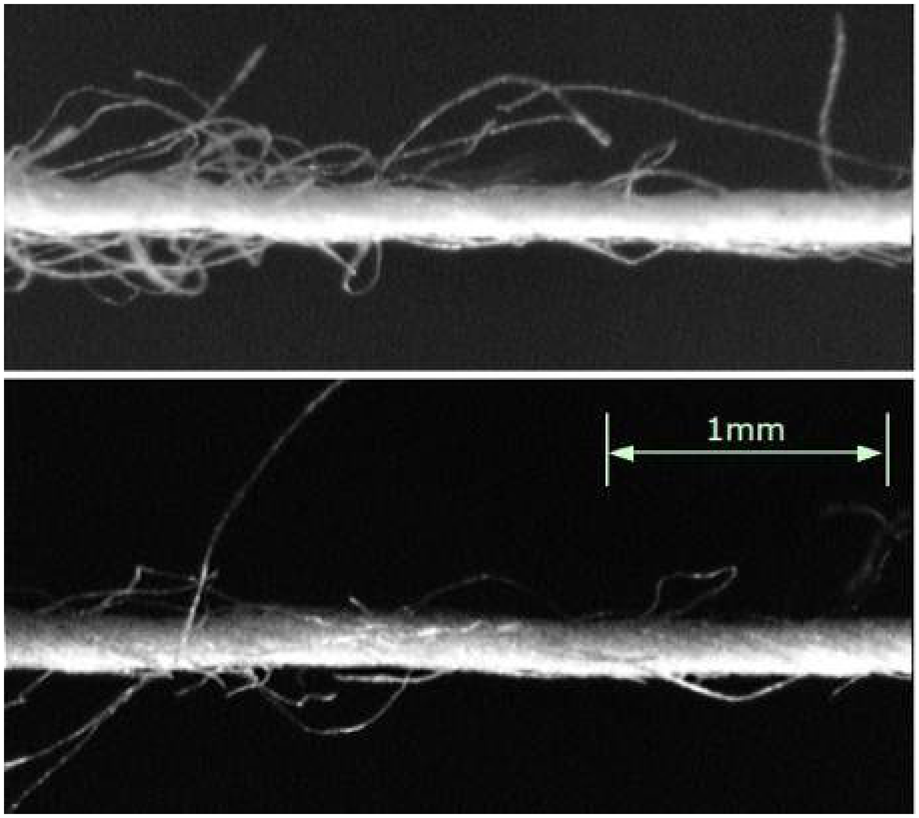


Fig. 3. Conventional ring spun yarn (top) and compact spun yarn (bottom),
Yarn data: Ne 30, twist factor αm = 120 (αin = 3.7), Upland Cotton, combed

A system working without suction, using completely mechanical guidance of the fibers, is offered by Rotorcraft and by Oerlikon Textile Components under the name RoCoS (Figure 5). It takes advantage of a second top roller on the front cylinder and uses a condenser to align the fibers between the first and the second top roller. This condenser slides on the front cylinder under the gentle pressing force of permanent magnets. To control the location where the fiber flow enters the condenser, the incoming roving is pre-aligned by a clip-on roving guide in the breaker draft zone. This is an extremely simple, clip-on aftermarket or OEM solution, offered e.g. by Lakshmi on their spinning machines.

Other recent developments pertain to modifications of the fiber flow in the drafting zone. Guiding pins in the main draft zone and guiding devices in the breaker draft zone are claimed to improve regularity and imperfection count. A new system to make a pseudo-plied yarn spinning off two rovings fed in parallel offers an alternative to the conventional twisting process. All of these designs create opportunities to find new alternative products in a mature market for ring spun cotton and cotton blends. The impact of compact spinning goes beyond the incremental improvements of ring spinning in the past, and calls for a new phase of systematic research and product development in the conversion of cotton type fiber into yarn.

The key element of such product development is a rapid prototyping method with a concept for efficient scaling to full production. This was conceived along with testing the two dominant aftermarket systems, EliTe and RoCoS, on the IMDS LabSpinner. Since such a rapid prototyping method was used in the project reported here, it is introduced first.

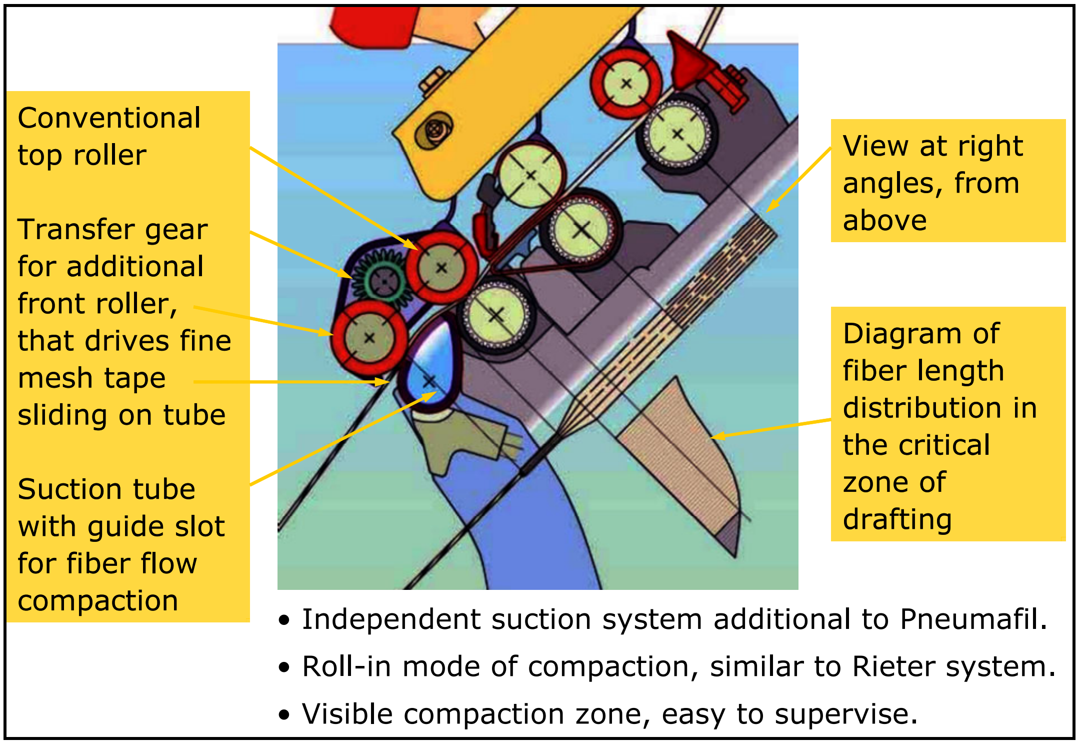


Fig. 4. Schematic drawing of the EliTe compact spinning system

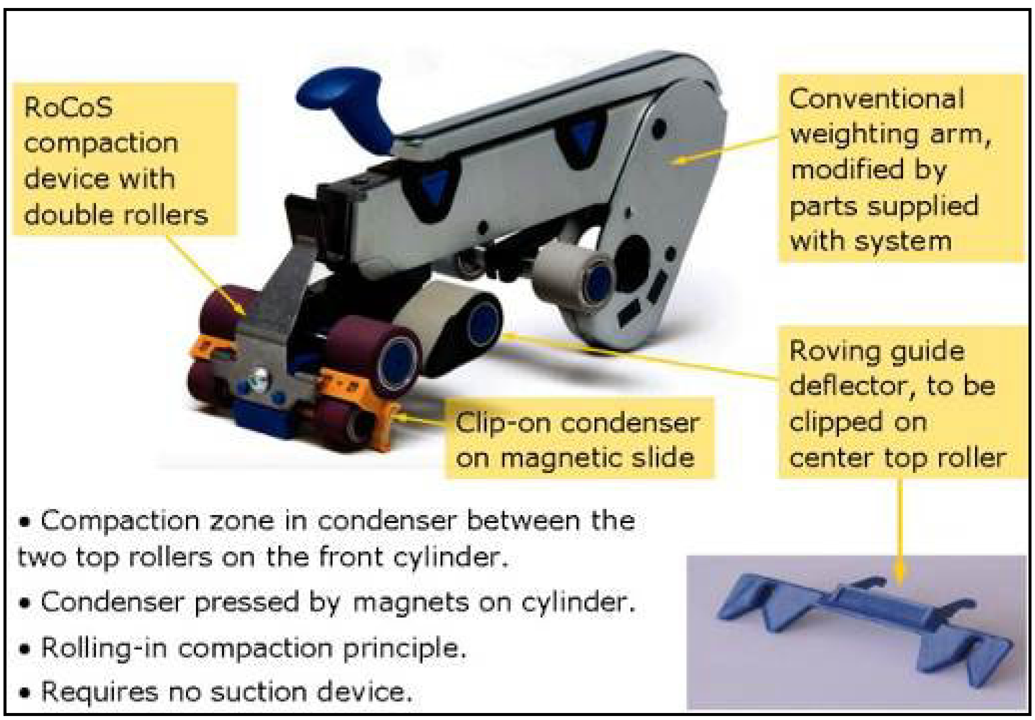


Fig. 5. The RoCoS clip-on compact spinning system

Efficient Product Development in Fiber-to-Yarn Processing

The traditional workflow of yarn development, represented in Figure 6, uses a single section on a full or reduced size ring spinning machine. A limited set of cops is made in each test run and handed over to the yarn lab for test. The results are discussed in the group of persons involved, and the spinning parameters are set for next production run. This group generally consists ~~in general~~ of the supervisor of the spinning section, the technician who sets up the machine, the operator of the machine involved, and the person doing the tests in the lab. In usual mill conditions, this procedure is scheduled in one production-and-test cycle per working day. This favors working within the boundaries imposed by the existing settings of machinery, and by the practical experience of the operators on the shop floor. Scaling up from test to full production is straightforward. But, this procedure is far from being supportive in development of new products. The time-consuming and costly process discourages the introduction and development of new ideas for products.

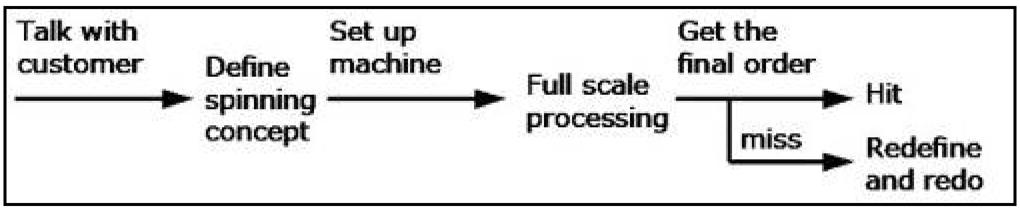


Fig. 6. Traditional procedure for yarn development, using a spinning frame in the spinning hall.

A much more efficient development process is illustrated in Figure 7. The IMDS LabSpinner with individual driven spindles is compatible with other yarn testing instruments regarding space, noise, and fiber fly produced. By placing it in the lab room, the whole production-and-test cycle may take place there, which makes it much simpler to supervise. There is no requirement of an operator and a technician to attend and set up the machine. All the setup takes place on a standard personal computer, which is like those used on other laboratory instruments. Consequently, a single person in the lab is able to make four production-and-test cycles per day. The critical path in time between test runs is no longer imposed by the communication between mill hall and lab, but by the decisions and reviews in the development process.

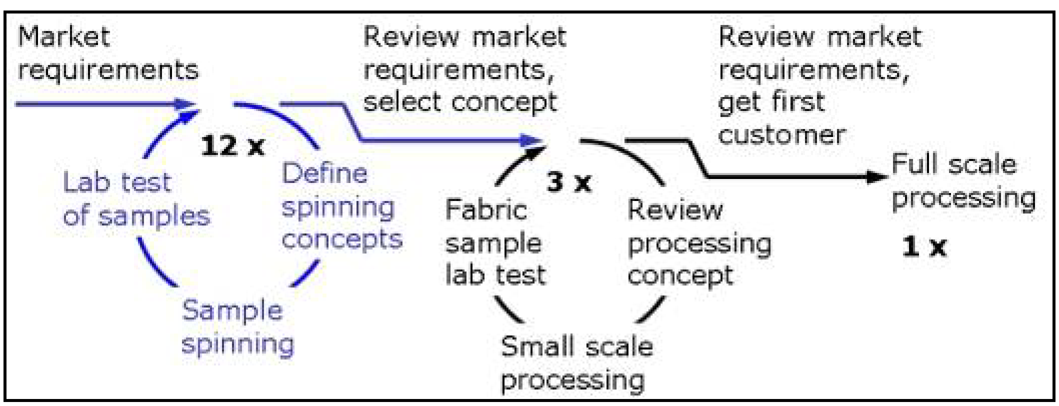


Fig. 7. State-of-the art procedure for yarn development, starting on a LabSpinner

While the IMDS LabSpinner was originally conceived to promote the SKF drafting system and spindle products, it is easily adapted to the configuration of any of the popular ring spinning machines. For example, the IMDS LabSpinner at the Fiber and Biopolymer Research Institute uses the same components and thread line geometry as the Suessen EliTe spinning machine operating in that lab. Tests that carefully control the variability of fiber properties have shown negligible differences in yarn parameters between the IMDS LabSpinner and the full-size spinning frame.

Fiber Evaluation Procedure for Spinning Stability

This case study compares the performance of compact spinning versus conventional ring spinning. In actual practice, the choice of ring spinning methods is often predetermined. But the same procedure used here could also be used for a quick comparison of the spinning performance of different fiber blends.

It is essential to vary only one parameter at a time in evaluations such as this and to avoid ambitious settings on all other process parameters, in order to ensure useful cause-and-effect information. In this case, we use a moderate speed on the spindles, corresponding to a traveler speed of about 35 m/s. Spinning starts at high twist factor, e.g. αm = 150 (αin = 4.6). The twist factor is reduced approximately every 100m of yarn, in steps of αm = 10 or αin = 0.1 while continuously spinning. One or more of the cops are replaced at each step for testing tenacity. When approaching the lower limit of the twist factor, check for ends down; cease the test when piecing up is no longer possible. If the test on tenacity is done concurrently with spinning, the whole test run can be done in less than one hour.

In this project, the same method was used for comparing different spinning systems. The improvement in structure due to compact spinning is evident, especially in the knitting yarn twist zone. The diagram shows that the same tenacity – always in the range sufficient for knitting – may be obtained at up to 20% lower twist. In this application, the gain alone in energy cost is expected to justify the investment in a new compact spinning machine or in the conversion of an existing machine with an aftermarket device.

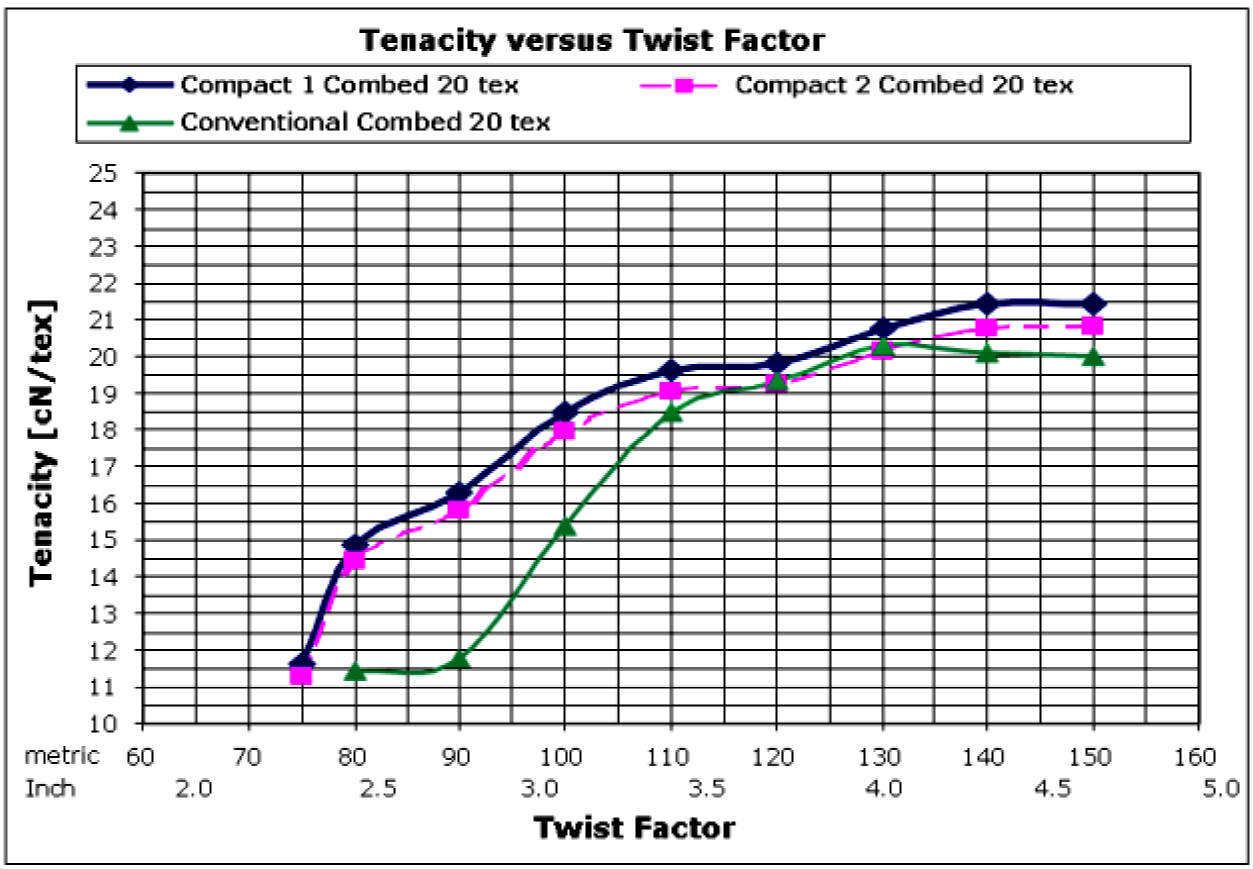


Fig. 8. Comparison of conventional and compact spun yarns: Tenacity versus twist factor. Upland cotton, combed.

The difference between the two compact spinning systems evaluated (Suessen EliTe and RoCoS) is in the order of the measuring error. To avoid an incorrect interpretation, the two traces are identified by number only. The limit for practical spinning stability is αm = 100 (αin = 3.1) for conventional spinning, αm = 80 (αin = 2.4) for compact spinning, values consistent with other publications.

Tuning of Spinning Parameters

Taking into account that 6 cops made on the IMDS LabSpinner do not completely reveal the behavior of the same material on a full size machine, comparative testing is indicated when evaluating a yarn quality problem. The same applies on the task of finding optimum parameters for machine setup. The repeatability of the LabSpinner spinning positions is excellent due to the rigid mechanical structure, the reduced length of the machine (consequently, a low load on the bearings and drives), and the electronic control. It is therefore possible to compare tests running sequentially on all 6 spindles, or in parallel, e.g. 3 different kinds of roving on 2 spindles each. The fineness of roving and yarn are pre-established, the initial twist factor and the length of yarn to produce are selected, and the progression for cops buildup estimated. To avoid accidental errors, it is recommended to use at least 2 spindles in identical setup. Test each cop for fineness, regularity, imperfections, and tenacity. From this first setting on, parameters are modified one-at-a-time to improve productivity; e.g., lower twist or higher speed. The limit on lowering the twist factor is determined by the minimum acceptable tenacity. The limit on increasing the spindle speed may be determined by either excessive ends-down or the endurance of the travelers. Results obtained enable a very efficient scaling up process on the industrial spinning machines.

An example of such a comparative test for comparison of spinning technologies is given in Figure 9. These results indicate that the EliTe system appears to perform better; however, it had an initial advantage in this test by getting installed complete with new weighting arms. The data for the RoCoS system could certainly be improved by better adjustment of the weighting arm and fiber flow.

Fiber: Upland cotton, combed. Yarn: Ne 30, α = 120 (3.7)				
Spinning process	Text	Conven-tional	EliTe	RoCoS
Tenacity at break	cN/tex	19.4	21.1	20.2
Elongation at break	%	6.3	6.5	5.4
Regularity, mass	CV%	12.1	10.7	11.5
Thin places -50%	on 1km	1	0	0
Thick places +50%	on 1km	22	15	20
Neps 140%	on 1km	170	189	248
Hairiness UT3	#	4.0	3.3	3.5

Fig. 9. Comparison of conventional and compact spun yarns: Yarn quality data.

It is generally recognized that HVI data greatly facilitate the blending of cotton to achieve a constant behavior in the spinning process over time. Extensive research has been devoted to the use of HVI data for pre-establishing spinning parameters, but without significant success in practice. Too many processes and impacts are applied on the fiber blend from the bale, where the HVI data are taken, up to the drafting zone of the spinning machine, where the critical yarn parameters are finally established. Tracing such data back from yarn to bale requires a fully equipped spinning preparation line devoted to treat single bale lots. This is feasible only in a research lab. Figure 10 gives an example of the impact of the entire fiber processing sequence for two bales. The fiber measurements were replicated multiple times to ensure accuracy.

Fiber: Upland cotton, combed. Yarn Ne30, compact spun				
HVI data:	Bale		3656	3211
	MIC		3.8	4.2
	LEN		1.19	1.15
	UNIF		82.8	82.6
	STR		31.9	30.8
	ELON		7.2	5.4
	Rd		82.2	77.3
	+b		9.1	8.5
	CGRD		11-1	31-1
	LEAF		1	3
Tenacity at break		cN/tex	19.6	21.1
Elongation at break		%	7.0	6.5
Regularity, mass		CV%	13.0	10.7
Thin places -50%		on 1km	2	0
Thick places +50%		on 1km	24	15
Neps 140%		on 1km	350	189
Hairiness UT3		#	3.7	3.3

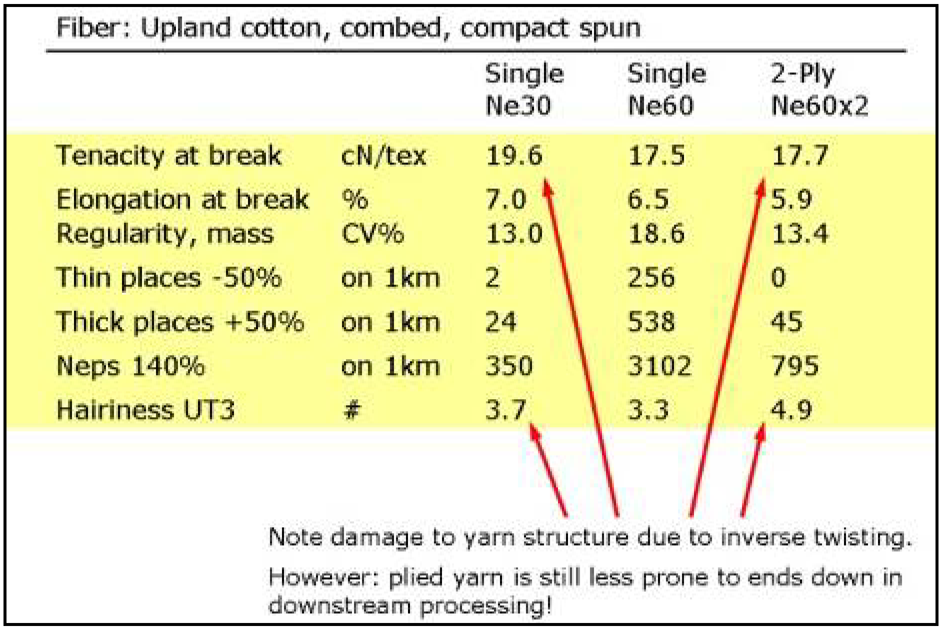
Fig. 10. HVI data on spinning performance for two distinct bales.

Choice of Processing Path: Single versus Plied Yarn

The IMDS LabSpinner makes it not only possible to vary and compare settings of spinning parameters, but also to make quickly different counts of yarn and even directions of twist. Things that may be done with a single set of roving bobbins include the following:

- Two strands of roving may be fed into each spinning position. This reduces considerably the part of irregularity and imperfections introduced by draw frames and flyers, which in turn allows a certain backtracking of quality problems.
- Two strands of roving may be fed into each spinning position and spun by the EliTwist method, which makes a pseudo-twist of the Siro-spun type. This affords comparison of an EliTe tube against an EliTwist tube.
- One or two strands of roving may be fed into each spinning position, along with a filament yarn component that bypasses the drafting zone. The result is a core yarn.
- Twist direction may be changed from cop to cop, in order to make, ply, and twist Z-twisted and S-twisted yarns on a simple twist direction input. Warning: This requires using a length of plied yarn for starting up the spindle when the direction of twist changes, because yarns with different twists will fall apart when reattached. (The same thing happens on any splicing or knotting of yarns with different directions of twist.)
- Two yarns may be fed so as to bypass the drafting zone, enabling a true plied yarn to be made. Also, the twist direction and the twist factor of the plied yarns are easily changed to get a multitude of various yarn structures.

Figure 11 gives an example of rapid prototyping of single versus plied yarns made from the same roving. In this case, the superior tenacity and regularity of the compact-spun yarn shows only in the single yarn. In the plied yarn, the twisting process going in the inverse direction (spinning = Z, twisting = S) tends to dissolve the original twist of the yarn. The test was made using two-for-one plying, which is the most efficient process and generally used for cotton yarn. While plying is by its principle hiding most of the imperfections of the original yarn, it is only able in the number of thin places to beat the values of the single yarn. The big advantage of plied yarn is the unlimited resistance against local false twist that may occur in downstream processing.



Fiber: Upland cotton, combed, compact spun		Single Ne30	Single Ne60	2-Ply Ne60x2
Tenacity at break	cN/tex	19.6	17.5	17.7
Elongation at break	%	7.0	6.5	5.9
Regularity, mass	CV%	13.0	18.6	13.4
Thin places -50%	on 1km	2	256	0
Thick places +50%	on 1km	24	538	45
Neps 140%	on 1km	350	3102	795
Hairiness UT3	#	3.7	3.3	4.9

Fig. 11. Improvement by finer count spinning and plying/twisting.

Is compact spinning still attractive for preparing plied yarn? Its superior performance at reduced twist factor shows how to take advantage also here. Tentative trials indicate that lower twist yarn is more likely to maintain its structure in the de-twisting effect of two-for-one twisting. The same effect is observed if a lower twist factor is applied in the twisting process. Of course, if the twist applied in plying goes the same direction as the yarn, e.g. Z-Z twist, there is no such loss in tenacity. However, the increased snarling tendency of the plied yarn effectively discourages use of the Z-Z twist in commercial practice.

Conclusion

Compact spinning and other innovations have recently added a whole pallet of new opportunities to the ring spinning process. To take advantage of these, a rapid prototyping method is presented here. It enables the workflow of sample spinning and testing to be reorganized for better efficiency and quick response. Matching the customer's requirements, while optimizing the spinning process, affords systematic development with a plurality of samples. Doing this on full size machines is a waste of investment and production capacity. To implement a state-of-the-art workflow for systematic trials and test, the IMDS LabSpinner can be a valuable tool.

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