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# Compact Spinning for Improved Quality of Ring-Spun Yarns

**Abstract**
*A new impulse in the field of ring spinning technology is offered by compact-condensed spinning. The article presents the comparison of two chosen spinning systems for the production of compact ring yarns. We have analysed and compared the physical, mechanical and morphological properties of conventional and compact yarns, spun at the same technological and kinematical parameters from the same cotton, cotton/PES and cotton/viscose roving. The construction specificities of the Suessen and Zinser compact ring spinning frames, on which the comparative spinning was performed, are described within this work. The purpose of the study was to determine the influence of differences in compacting systems on yarn quality, and to compare the compact and conventional yarns produced.*

**Key words:** *ring spinning, compact spinning, compact yarns, physical/mechanical properties of yarns.*

## Introduction and Motivations

In spite of modernisation and rapid technological development in the field of ring spinning, the mechanism ring-traveller spindle has remained almost the same until now. Furthermore, ring spinning remains the dominant spinning technology even today. The producers of modern spinning frames have been developing the machines with improved construction of different working elements and optimal spinning geometry, with a ring diameter of 36 mm, a tube length of 180 mm and spindle speed of up to 25,000 min$^{-1}$. All serving and transport functions have already been automated. A high linking level of spinning and winding, and even of the winding and twisting technological processes, has been achieved using the elements of computer-assisted automation and control. Besides the conventional functions (spindle speed, delivery speed, productivity, twist, draft, machine efficiency), computer-based systems control and enable the optimisation of spinning conditions (formation of bobbins, position of ring rail, automated doffing and setting of empty tubes, cleaning and oiling of main machine parts). Construction improvements of different working elements of the ring-spinning frame and optimised spinning geometry of the continuous form of fibres (roving or sliver) enable increased productivity, better yarn quality, as well as flexibility and profitability of the process.

All these optimisations and improvements of the ring spinning frame, however, have not enabled the reduction of the spinning triangle, which can be defined as the most problematic and weakest spot in the yarn formation process using the ring-traveller system [1,2]. The spinning triangle that occurs while the yarn is formed is the cause of many fibres leaving the drafted roving, or being partly spun into the yarn with one end only. This causes greater waste of fibres, lower exploitation of fibre tenacity in yarn, poorer appearance and greater hairiness of the spun yarn. The newest research in the field of ring spinning has shown that modification of a three-cylinder drafting equipment with tow aprons in a region after front drafting rollers enables ring spinning to proceed with a minimised spinning triangle, or even without it at all. This modified process is called compact or condensed spinning [1,3,4].

The purpose of the study presented within this article was to produce, analyse and compare the yarns using two different systems for the production of compact and conventional ring yarns, offered by two well-known producers of ring spinning machines. In Predilnica Litija (Litija Spinning Mill), one of the Slovenian short-staple spinning mills, a need exists to modernise the existing ring spinning frames for medium-fine yarns produced from cotton fibres and blends consisting of cotton and chemical fibres, mainly PES and viscose. Today, the main goal of the company is to achieve improved yarn quality that will ensure better competitiveness and higher yarn prices. Therefore, a decision was made to compare the quality of conventional and compact yarns and (also taking into account the production costs), to explore whether the quality parameters of compact yarns had been improved significantly enough to justify the purchase of new machines, or the adaptation of drafting equipment of the existing ring spinning frames. For this reason, it was decided to use the same roving with a linear density of 588 tex produced by the Litija Spinning Mill, and to produce a certain amount of yarns using the Suessen and Zinser ring spinning frames equipped with compact and conventional drafting systems under comparable technical and kinematical conditions.

The tests were directed and supervised by the leading technical personnel of the Litija Spinning Mill, together with the specialists of Suessen and Zinser workshop spinning mills, where the production of yarn samples was carried out over approximately the same time period. 20 kilograms of each yarn type (one compact and one conventional from each ring spinning machine producer) was produced in order to ensure sufficient yarn quantity for testing purposes. Yarn testing was done by both machine producers in the laboratories of Suessen and Zinser, using valid standard methods and procedures that guaranteed the statistical significance of test results. The information on yarn quality was then sent to the Litija Spinning Mill, where the data was analysed and compared.

## Conventional Versus Compact Ring Spinning Technology

The twist that is transmitted to the yarn in the ring spinning process originates along the curve between the traveller and front drafting rollers. Transmission of twists is opposite to the yarn movement in this area. The traveller transmits twists to already drafted fibres as close as possible to the clamping point after the front rollers. However, the twists never reach the clamping point, because after leaving the front rollers the fibres tend to direct towards yarn axis. The different length of the path of the inner and outer fibres that form the yarn cause a so-called spinning triangle in ring spinning [5]. The length of the spinning triangle depends on spinning geometry and twisting intensity [6,7]. The form and dimensions of the spinning triangle significantly influence the structure, surface characteristics, physical and mechanical characteristics of spun yarn. Not all fibres that are placed at the external edges of the triangle can be spun into the yarn structure, and can leave the drafting equipment without having been spun into the yarn. Such fibres also increase yarn hairiness.

The gradual transmission of twists with the traveller along the yarn balloon causes a certain tension in the fibre bundle that forms the spinning triangle, a tension which is not distributed symmetrically in the yarn cross section. It is greatest in fibres that are positioned at the edges of the spinning triangle, and smallest in fibres lying in the middle of the triangle. This asymmetric distribution is the reason for fibre breakage according to their position in the spinning triangle during subsequent processing [4,6,8,9]. Furthermore, the fibres gradually take over the external axial yarn loading; therefore, they also break one after another. The consequence is lower yarn strength and poorer utilisation of the fibre tenacity (35 to 50%).

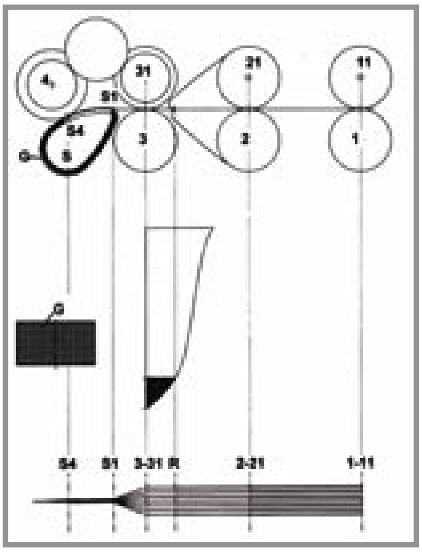


***Figure 1.*** *Drafting equipment of the Suessen Fiomax E1 spinning machine [10,13].*

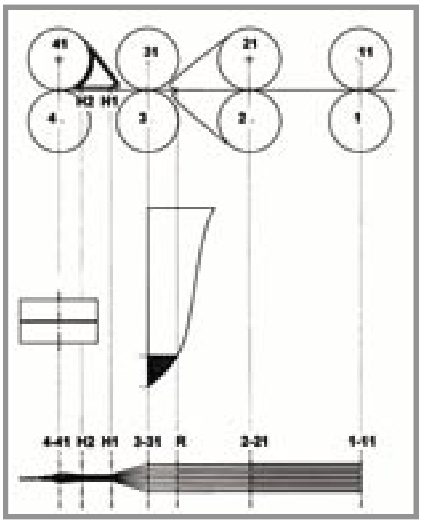


***Figure 2.*** *Drafting system of the Zinser AIR-COM-TEX 700 condenser ring spinning machine [6,13].*

Much has already been done to minimise the influence of the spinning triangle in the ring spinning process. Different mechanical devices such as condensers have been used in the past to retard the widening of the roving [10]. However, these measures were only partly successful. The length between the mechanical condenser in the main drafting area and clamping point between the front rollers was too long to ensure the condensing effect. As soon as the condensed fibre bundle left the mechanical condenser, the fibres were relaxed and again formed an undesirably wide fibre bundle.

Minimisation or even elimination of the spinning triangle, enables almost all fibres to be incorporated into the yarn structure with maximum possible length and pre-tension of the fibres, irrespective of their position in the spinning triangle. The uniform pre-tension of the majority of fibres enables more synchronic breakage of the majority of the fibres, which contributes to higher yarn strength and better utilisation of the fibre tenacity (from 65% up to even 80%).

All compact yarns, whether produced of short-staple fibres (cotton, cotton-type chemical fibres and their mixtures) or long-staple fibres (wool, wool-type chemical fibres and their mixtures) represent a whole new range of yarns as regards their quality and appearance. When compared with conventional ring-spun yarns, compact yarns have significantly higher tenacity and elongation, work to break, and abrasion resistance. In addition, their surface smoothness, elasticity and softness are much better thanks to the almost ideal structure of compact yarns. To achieve tenacity comparable with conventional ring-spun yarns, a lower number of turns per metre can be used, which enables higher productivity of the spinning machine, as well as better elasticity and softer hand of different flat textile products.

The better use of the fibres' tenacity in compact yarns enables the use of cheaper raw material. Yarn singeing is not required because of minimal secondary hairiness, caused by the fibres exceeding the length of 3 mm. One should also mention savings in the sizing process of up to 50% compared to the conventional yarns. In some cases, sizing is even not required [11]. Lower primary hairiness (hairs with a length of 1 to 2 mm) and significantly lower secondary hairiness (hairs with a length of 3 mm and more) result in less prominent pilling in yarns and in the finished textile products.

Lower yarn hairiness enables the production of flat textiles with better appearance and more explicit, sharp contours, for example in jacquard-woven and printed fabrics. When smooth surface, high gloss and durability of the end product is required, compact yarns should be used for production in spite of the slightly higher price. In spite of the difficult situation of the whole textile sector, there are still some spinning mills in Slovenia that continue production and successfully compete on the national and international markets. Most of them use conventional ring and rotor spinning [12]. The most successful yarn manufacturers are already testing different compact spinning machines and searching for the most appropriate way to modify the drafting equipments of their existing ring spinning machines.

## Comparison of the Two Compacting Principles

The drafting equipment of the Fiomax E1 compact spinning machine (Figure 1) consists of a pair of delivery rollers (1-11), a double aprons area (2-21), a pair of front rollers (3-31) and a condensing zone (S1-S4). The condensing unit consists of a profile tube (S), the lattice apron (G) and the delivery top roller (4).

Regarding the configuration of the drafting unit (1-11) to (3-31), it is a standard three-cylinder system with two aprons, and enables the processing of a wide spectrum of raw materials. The tube (S) has a built-in slot in order to create negative pressure in the area (S1-S4). Drafted roving comes into the condensing field (S1-S4), where the fibres are condensed up to the clamping point (4-S4) consisting of the top roller (4) and sucking tube (S).

The delivery top roller (31) is connected with the top roller (4) by the gear wheel. The top rollers (31) and (4) are driven by the delivery drafting cylinder (3). Using friction, the top roller (4) drives the endless lattice apron, which slides over the profile tube (S) that is not moving. To guarantee a slight axial tension of fibres in the condensing zone (S1-S4), the roller diameter (4) is slightly larger than that of the top roller (31). In this way, a small drafting of fibre bundle is ensured in the condensing zone, which enables optimal axial tension and fibre orientation.

***Table 1.*** *Technological and machine set parameters for production of yarn samples.*

| Technological / machine parameters | Unit | Spinning machine type | | | |
|---|---|---|---|---|---|
| | | Suessen | | Zinser | |
| | | Fiomax E1 | Fiomax 1000 | RM 700 | RM 350 |
| Ring yarn type | - | compact | conventional | compact | conventional |
| Drafting system type | - | HP - A 320 | HP - A 320 | PK 2025 | PK 2025 |
| Load in nip points | dN | 14 - 12 - 12 | 14 - 12 - 12 | 14-15-14-15 | 12-10-14 |
| Spindle speed | r.p.m. | 16,500 | 16,500 | 16,500 | 16,500 |
| Delivery speed | m/min | 21.2 | 21.2 | 21.2 | 21.2 |
| Twist | turns/m | 778 | 778 | 780 | 780 |
| Ring diameter | mm | 42/1 | 42/1 | 40 | 40 |
| Traveller type | - | EL1 hf 4/0 | EL1 hf 4/0 | EL1 hf 4/0 | EL1 hf 4/0 |
| Traveller speed | m/s | 36.3 | 36.3 | 34.5 | 34.5 |

The profile tube (S) has a small slot in the area (S1-S4) and is closely embraced by a lattice apron. The porosity of the apron and the negative pressure in the slot area result in a condensed fibre bundle that is transported up to the zone (4-S4). The oriented fibres remain completely condensed and closed up to the delivery clamping and twist insertion line (4-S4) because of the slot length. Therefore, no spinning triangle is formed, which enables literally all the fibres to be wound into the yarn and optimal yarn structure. The slot in the profile tube (S) can be positioned in the direction of fibre movement or at an incline to the direction of fibre flow, for instance when processing shorter fibres, such as carded cotton. This ensures the firm incorporation of outer fibres into the yarn because of a transverse force on the fibre band during the fibre transport and the rotation of fibres around their axis. The lattice apron is made of the cotton fabric in plain weave, and has more than 3000 holes per square centimetre. The drafting unit of the Fiomax E1 spinning machine enables the fibres to stay condensed up to the clamping and twist insertion line, which results in a minimised spinning triangle. The result is spun yarn with maximum strength and minimal hairiness. Besides the condensing effect, a light tensioning of the fibre bundle during condensing is also crucial for this process.

The drafting equipment of the Zinser RM 700 spinning machine (Figure 2) consists of the standard three-cylinder drafting unit with two aprons (1-11-2-21-3-31) and condensing unit (4-41).

The top roller (41) is covered by the endless apron with a set of holes in the middle. The apron runs over the profile tube (H), which has a suction slot in the zone (H1-H2). The drafting unit construction in zones (1-11), (2-21) and (3-31) is a modern three-cylinder drafting system that enables the processing of a wide range of fibre lengths. The final drafting occurs between the zones (2-21) and (3-31). The fibre bundle is condensed under suction on a perforated surface in the zone (H1-H2). In a short zone between (H2) and (4-41), the fibre bundle is not under suction and therefore loses some of its hitherto gained condensed form. Therefore, in the zone (4-41) the spinning triangle is not reduced to the minimum, which negatively influences the quality of spun yarn. This undesired effect is more obvious when processing shorter fibres. The suction slot is directed in the fibre bundle axis in the area (H1-H2). It is not possible to set it under a certain incline regarding the fibre bundle axis. The drafting system construction enables light axial tension acting on fibres in a condensing zone between (3-31) and (4-41), which has a positive effect on increased adhesion between fibres that are incorporated into the yarn. The technological data of the Suessen and Zinser compact and conventional ring spinning machines used for production of yarn samples is given in Table 1.

## Direction of Yarn Samples' Production and Raw Material Characteristics

The production of yarn samples was directed and supervised by the leading technical personnel of the Litija Spinning Mill together with the specialists from Suessen and Zinser. Since we wanted to compare the compact and conventional yarns produced on at least two different spinning machines types, the production of yarn samples was carried out at the Suessen and Zinser workshop spinning mills at approximately the same time period. 20 kilograms (20 bobbins with roving) of each yarn type (one compact and one conventional from each ring spinning machine producer) was produced in order to ensure sufficient yarn quantity for testing purposes.

The following fibrous material was used for the production of yarn samples:
- 100% combed cotton (CO), fibre length $1^{3/32}$ ” – $1^{1/8}$ ”, Micronaire=4.5,
- polyester fibres (PES), fibre length 38 mm, fineness 1.5 dtex,
- viscose fibres (CV), fibre length 38 mm, fineness 1.3 dtex.

The following fibre blends were processed:
- 100% combed CO (noil extraction: 15.5%),
- 50% combed CO /50% PES and
- 87% combed CO/13% CV.

A standard spinning preparation and modern machinery were used to produce the roving with a linear density of 588 tex from each fibre blend at the Litija Spinning Mill using the same fibre lots for each blend. After that, conventional and compact yarns with a linear density of 20 tex were produced under comparable technological and kinematical conditions on the Suessen and Zinser ring spinning frames.

## Quality Properties of Produced Yarns

After production, the quality of yarns was tested in the laboratories of the Suessen and Zinser machine producers, where the yarn samples were spun using valid standard methods and procedures that guaranteed the statistical significance of test results. Ten bobbins of each compact and conventional yarn were tested. The information on yarn quality was then sent to the Litija Spinning Mill, where the data was analysed and compared. The following physical, mechanical and morphological properties of the compact and conventional yarns produced were tested

*Table 2. Determined quality parameters of compact and conventional yarns 20 tex made of 100% cotton fibres, produced on Suessen and Zinser ring spinning machines.*

| Yarn quality parameters | | Unit | Suessen | | Zinser | |
|---|---|---|---|---|---|---|
| | | | compact | conventional | compact | conventional |
| Real fineness | | tex | 19.90 | 18.90 | 20.28 | 19.96 |
| CV of fineness | | % | 2.02 | 1.99 | 1.42 | 0.97 |
| Twist | | turns/m | 771 | 780 | 771 | 748 |
| CV of twist | | % | 2.57 | 3.30 | 2.57 | 3.32 |
| Breaking force | | cN | 347 | 268 | 357 | 300 |
| CV of breaking force | | % | 11.10 | 9.92 | 6.56 | 7.02 |
| Tenacity | | cN/tex | 17.50 | 14.20 | 17.61 | 15.05 |
| Elongation at break | | % | 5.61 | 5.20 | 5.90 | 5.51 |
| CV of elongation at break | | % | 10.51 | 7.52 | 5.55 | 5.85 |
| Work to break | | cN.cm | 511 | 387 | 547 | 449 |
| Irregularity | | Uster CV% | 11.80 | 12.30 | 11.52 | 11.81 |
| Thin places per $10^3$ m (-50%) | | - | 0 | 1 | 0 | 0 |
| Thick places per $10^3$ m (+50%) | | - | 34 | 30 | 25 | 32 |
| Neps per $10^3$ m (+200%) | | - | 121 | 107 | 87 | 101 |
| Uster hairiness (H) | | - | 3.80 | 5.80 | 4.64 | 5.54 |
| Number of hairs per $10^2$ m with length up to: | 1 mm | - | 5775 | 13925 | 8448 | 9260 |
| | 2 mm | - | 460 | 2474 | 1114 | 1530 |
| | 3 mm | - | 66 | 1016 | 149 | 289 |
| | 4 mm | - | 19 | 726 | 62 | 159 |
| | 6 mm | - | 6 | 350 | 17 | 57 |
| | 8 mm | - | 2 | 130 | 4 | 18 |
| | 10 mm | - | 0 | 21 | 0 | 0 |
| | 12 mm | - | 0 | 2 | 0 | 0 |

and compared: real fineness, twist, breaking force, elongation at break and work to break, Uster properties, hairiness and length distribution of hairs on 100 m of a yarn. An Uster Tester 3 was used for testing the hairiness of the produced yarns. The results are given in Tables 2-4.

## Discussion

Based on the researched and compared mechanical, physical, morphological and Uster values of the conventional and compact ring yarns spun on the Zinser and Suessen spinning machines, the following conclusions can be drawn:

**Properties of compared yarns made of 100% cotton fibres**

The breaking force of the compact yarn with a nominal linear density of 20 tex and spun on a Zinser ring spinning machine is 18.88% higher than the conventional ring spun yarn, produced on the same machine but without the condenser unit. The breaking force of the compact yarn spun on the Suessen ring spinning machine is up to 29.48% higher when compared with the conventional ring spun yarn, produced on the same machine but without the condenser unit. A higher difference in breaking force between the compact and conventional yarns produced on the Suessen ring spinning machine can be explained with the construction of the drafting system that enables maximum fibre condensation all the way up to the clamping line, which is not the case in Zinser's drafting system. A greater breaking force was measured in the yarn produced on the Zinser spinning machine.

Elongation at break of compact yarns is 7 to 8% higher compared to conventional yarns. The tenacity of a compact yarn produced on the Zinser spinning machine surpasses the conventional yarn by 17%, while this value is higher by up to 23.24% in the yarns spun on the Suessen spinning machine. A slightly higher value is noted in the yarn produced on the Zinser spinning machine.

The work to break of a compact yarn spun on a Zinser spinning machine is 21.82% higher than in conventional yarn. In the compact yarn produced on the Suessen spinning machine, the work to break is 32% higher than that of the conventional yarn. the higher absolute value of work to break was determined in the compact yarns produced on the Zinser spinning machine. The physical and mechanical properties of the compact and conventional yarns are represented in Figure 3.

No significant changes regarding Uster properties (Uster CV%, number of thin, thick places and neps) in the conventional and compact yarns were determined. This can be explained by the use of the same three-cylinder drafting equipment, which is proven to be the major influence on these yarn properties.

The Uster hairiness (H) of compact yarns is significantly lower when compared with the hairiness of conventional yarns (Figure 4). Conventional ring spun yarn produced on the Suessen spinning machine has an Uster hairiness H=5.80, and the yarn spun on Zinser spinning machine has an Uster hairiness H=5.54. A lower value of Uster hairiness, H=3.80, was determined in compact yarn produced on the Suessen spinning machine, while that spun on the Zinser spinning machine has an Uster hairiness H=4.64. The reason for this is the construction of the drafting equipment, as explained above.

The morphology of the yarn, defined as the number of hairs of different length per 100 metres, shows the significantly lower primary hairiness (1 to 3 mm) and secondary hairiness (4 to 12 mm) of compact yarns. Better results and significant improvements were achieved with the Suessen spinning machine, which can also be explained by the special construction and elements of the drafting unit.

**Properties of compared yarns made of 50% CO/50%PES fibre blend**

When comparing the physical and mechanical properties of conventional and compact yarns produced of 50% CO/50% PES fibre blend, we found no significant differences. This can be explained by the greater bending rigidity of polyester fibre component, which reduces the fibre condensing effect and its contribution to better physical and mechanical properties of compact yarns.

The analysed Uster properties of conventional and compact yarns are very similar, which confirms the fact that the condensing effect significantly influence neither the yarn irregularity nor the number of yarn faults.

The Uster hairiness (H) of compact yarns is significantly lower when compared with the hairiness of conventional yarns. A slightly better hairiness value was determined in yarn spun on the Zinser spinning machine (H=3.26) when compared with the yarn produced on the Suessen spinning machine (H=3.20).

The primary and secondary hairiness of a compact yarn made from this mixture and spun on the Zinser spinning machine are better than in yarn produced on the Suessen ring spinning machine. Both compact yarns have significantly improved primary and secondary hairiness when compared with conventional ring yarns.

### Properties of compared yarns made of 87% CO/13% CV fibre blend

The breaking force of the compact yarn with a nominal linear density of 20 tex and spun on a Zinser ring spinning machine is 18.32% higher than the conventional ring spun yarn produced on the same machine but without the condenser unit. The breaking force of the compact yarn spun on the Suessen ring spinning machine is up to 32.30% higher than the conventional ring spun yarn produced on the same machine but without the condenser unit.

Elongation at break of compact yarns is 4 to 11% higher compared to conventional yarns. The tenacity of a compact yarn produced on the Zinser spinning machine surpasses the conventional yarn by 15.90%, while this value is higher at up to 28.87% in yarns spun on the Suessen spinning machine. A higher absolute value of tenacity is determined in yarn produced on the Suessen spinning machine.

The work to break of a compact yarn spun on the Zinser spinning machine is 20.87% higher than in conventional yarn. In compact yarn produced on the Suessen spinning machine, the work to break is up to 41.88% higher compared to the conventional yarn. A slightly higher absolute value of Work to break was determined in compact yarns produced on the Suessen spinning machine.

The analysed Uster properties of conventional and compact yarns have very similar values. Conventional ring spun yarn produced on a Suessen spinning machine has an Uster hairiness of H=5.20, and the yarn spun on the Zinser spinning machine has an Uster hairiness of H=4.72. A lower value of Uster hairiness, H=3.40, was determined in compact yarn produced on the Suessen spinning machine, while the yarn spun on the Zinser spinning machine has an Uster hairiness of H=3.60, which can be explained by the inability of Zinser's drafting system to keep thoroughly condensed fibres up to the clamping line. The Uster hairiness (H) of compact yarns is significantly lower when compared with the hairiness of conventional yarns, irrespective of the machine system.

Both the primary and secondary hairiness of a compact yarn made of this fibre blend and produced on the Zinser ring spinning machine are lower when compared with the yarn spun on the Suessen spinning machine. Both primary and secondary hairiness of compact yarns

***Table 3.*** *Determined quality parameters of compact and conventional yarns 20 tex made of 50% PES/50% CO fibre blend, produced on Suessen and Zinser ring spinning machines.*

| Yarn quality parameters | | Unit | Suessen | | Zinser | |
|---|---|---|---|---|---|---|
| | | | compact | conventional | compact | conventional |
| Real fineness | | tex | 20.10 | 20.80 | 20.32 | 20.25 |
| CV of fineness | | % | 1.52 | 1.83 | 1.52 | 1.83 |
| Twist | | turns/m | 782 | 779 | 782 | 741 |
| CV of twist | | % | 3.57 | 4.00 | 3.57 | 4.00 |
| Breaking force | | cN | 370 | 365 | 376 | 379 |
| CV of breaking force | | % | 8.80 | 9.30 | 7.90 | 8.45 |
| Tenacity | | cN/tex | 18.40 | 17.60 | 18.51 | 18.72 |
| Elongation at break | | % | 8.10 | 8.20 | 8.10 | 8.16 |
| CV of elongation at break | | % | 8.50 | 8.50 | 8.17 | 7.72 |
| Work to break | | cN.cm | 826 | 838 | 827 | 823 |
| Irregularity | | Uster CV% | 12.80 | 12.90 | 12.98 | 12.22 |
| Thin places per $10^3$ m (-50%) | | - | 1 | 0 | 1 | 0 |
| Thick places per $10^3$ m (+50%) | | - | 39 | 45 | 65 | 39 |
| Neps per $10^3$ m (+200%) | | - | 95 | 95 | 111 | 85 |
| Uster hairiness (H) | | - | 3.20 | 4.10 | 3.26 | 3.76 |
| Number of hairs per $10^2$ m with length up to: | 1 mm | - | 5786 | 9693 | 5096 | 5952 |
| | 2 mm | - | 492 | 1513 | 559 | 855 |
| | 3 mm | - | 87 | 580 | 73 | 152 |
| | 4 mm | - | 33 | 380 | 25 | 84 |
| | 6 mm | - | 14 | 192 | 6 | 29 |
| | 8 mm | - | 4 | 72 | 0 | 0 |
| | 10 mm | - | 1 | 10 | 0 | 0 |
| | 12 mm | - | 0 | 1 | 0 | 0 |

***Table 4.*** *Determined quality parameters of compact and conventional yarns 20 tex made of 87% CO/13% CV fibre blend, produced on Suessen and Zinser ring spinning machines.*

| Yarn quality parameters | | Unit | Suessen | | Zinser | |
|---|---|---|---|---|---|---|
| | | | compact | conventional | compact | conventional |
| Real fineness | | tex | 20.50 | 20.01 | 20.90 | 20.47 |
| CV of fineness | | % | 1.30 | 1.90 | 1.29 | 1.90 |
| Twist | | turns/m | 785 | 743 | 785 | 743 |
| CV of twist | | % | 4.15 | 3.30 | 4.15 | 3.30 |
| Breaking force | | cN | 340 | 257 | 340 | 287 |
| CV of breaking force | | % | 7.40 | 11.00 | 8.20 | 7.94 |
| Tenacity | | cN/tex | 16.60 | 12.90 | 16.26 | 14.03 |
| Elongation at break | | % | 5.80 | 5.20 | 5.77 | 5.94 |
| CV of elongation at break | | % | 6.70 | 7.50 | 6.65 | 7.38 |
| Work to break | | cN.cm | 542 | 382 | 536 | 443 |
| Irregularity | | Uster CV% | 12.10 | 12.40 | 12.19 | 12.42 |
| Thin places per $10^3$ m (-50%) | | - | 0 | 0 | 0 | 0 |
| Thick places per $10^3$ m (+50%) | | - | 29 | 20 | 23 | 22 |
| Neps per $10^3$ m (+200%) | | - | 75 | 53 | 61 | 58 |
| Uster hairiness (H) | | - | 3.40 | 5.20 | 3.60 | 4.72 |
| Number of hairs per $10^2$ m with length up to: | 1 mm | - | 7900 | 14239 | 6290 | 8473 |
| | 2 mm | - | 772 | 2635 | 712 | 1418 |
| | 3 mm | - | 120 | 1003 | 82 | 257 |
| | 4 mm | - | 32 | 638 | 22 | 134 |
| | 6 mm | - | 10 | 303 | 5 | 43 |
| | 8 mm | - | 5 | 116 | 1 | 15 |
| | 10 mm | - | 1 | 18 | 0 | 0 |
| | 12 mm | - | 0 | 1 | 0 | 0 |

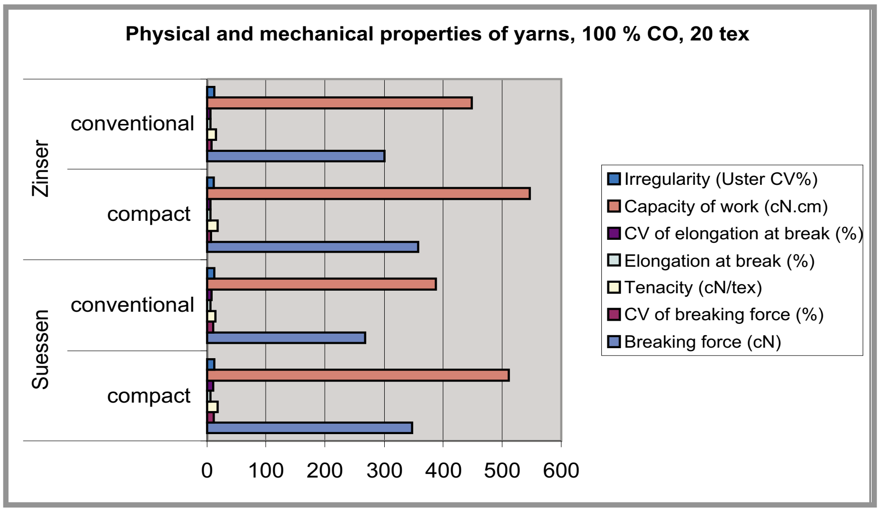


***Figure 3.*** *Physical and mechanical properties of compact and conventional yarns.*

are significantly lower than in conventional yarns, irrespective of the machine system. The improvement is more obvious when comparing conventional and compact yarns spun on the Suessen ring spinning machine, with or without a condenser unit.

## Conclusions

The aim of the study presented herein was to analyse and compare the yarns using two different systems for the production of compact and conventional ring yarns from the producers Suessen and Zinser. The same roving produced by the Litija Spinning Mill with a linear density of 588 tex was used to produce 20 kg of yarns from cotton, cotton/PES and cotton/viscose fibre blends under comparable technical and kinematical conditions. The tests were directed and supervised by the leading technical personnel of the Litija Spinning Mill together with the specialists of the Suessen and Zinser spinning mills, where the production of yarn samples was carried out over approximately the same time period. Yarn testing was carried out by both machine producers in laboratories using valid standard methods and procedures that guaranteed the statistical significance of the test results. An analysis of results obtained within the comparative research into the quality properties of conventional and compact ring yarns produced at the Suessen and Zinser companies led to the following conclusions:

- Compact yarns can be regarded as completely new ring spun yarn types as regards their morphological, physical and mechanical properties. With regard to fibre straightening, light axial tension and condensing of the fibrous bundle that form compact yarn, the new yarn structure can be defined as near-optimal.
- The compact yarns have the following advantages when compared to the conventional ring yarns: significantly reduced primary and secondary hairiness, smooth surface, high gloss, improved mechanical and physical properties (with the exception of compact yarn produced from 50% CO/50% PES fibre blend), similar Uster properties, better resistance to rubbing, softer touch, and lower pilling effect in woven and knitted fabrics.
- It is obvious that in the future compact yarns will be used as referential samples and benchmarks, based on which the quality of different types of spun yarn will be estimated.
- Because of the numerous advantages of compact spinning, it can be assumed that the new spinning technique represents a promising impulse for ring spinning and spun yarn production.
- If the spinning mills' customers - producers of woven and knitted fabrics - require high quality spun yarns and are ready to pay approximately a 10% higher price for them (because of the higher cost of the compact ring spinning machine and the slightly higher energy costs), then the compact spinning has a promising future because of the higher production and improved quality of compact yarns.

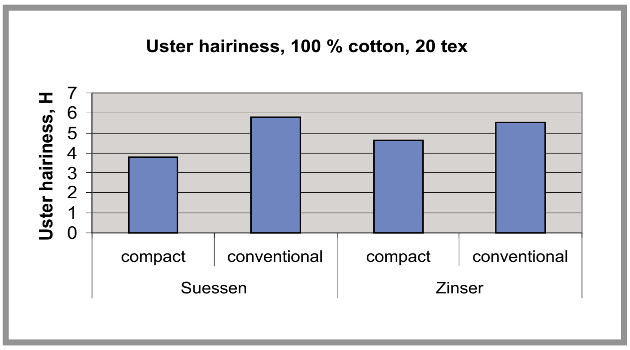


***Figure 4.*** *Uster hairiness of compact and conventional yarns.*

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