

STUDY OF THE WEAVABILITY OF ELASTANE BASED STRETCH YARNS ON AIR-JET LOOMS

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Abstract:

Elastane yarns are often used to produce stretch fabrics on knitting machines as well as rapier weaving machines. On air-jet weaving looms their use is still limited. That is why the objective of this paper is to investigate the weavability of elastane based stretch yarns on air-jet looms. Bobbins of elastane were woven on an air-jet loom and a distinction of the bobbins in three categories was made according to the most important production processes for elastane yarn: core twist, core spun and air covered. Yarn properties such as linear density, elongation at break and Air Index value were determined, weaving tests were performed and properties of the resulting fabric were determined.

Key words:

Elastane yarn, air-jet weaving, Air Index, fabric properties

1. Introduction

Elastane fiber is a manufactured fiber in which the fiber-forming substance is a synthetic elastomer consisting of at least 85% by weight of segmented long chains of polyurethane. The various production processes for elastane yield fibers with distinctively different attributes like cross-sectional geometry and stress-strain properties [1]. Today there are many elastane fiber producers all over the world and several brands and types of elastane on the market [2-13]. Elastane yarn is an artificial yarn with remarkable stretch properties, added in small quantities to fibers or yarns for comfortable and multifunctional clothing. 'Naked' elastane yarn is not used for weaving; it is always combined or covered with other yarns or fibers. The combined yarn will have the look and feel of the exterior yarn. Elastane yarn is mostly used in the braiding industry, but also in the nonwoven and weaving industry, often combined with cotton. Its applications in the apparel industry are mostly for body-confirming garments such as sportswear, foundation garments and intimate apparels which ensure a stable shape under loading during wearing [14]. Other outstanding features besides the shape retention properties are higher fabric elasticity [15] and elastic recovery [4], soft and smooth handle, abrasion resistance, resistance to pilling, resistance to most chemicals, resistance to normal apparel exposure to sunlight and lower moisture regain (< 1 %) [16].

There are four main methods to cover an elastane yarn: single core twisting, double core twisting, core spinning and air covering. Below is a description of these four methods. To produce a core twist yarn an inelastic yarn is twisted around the elastane yarn. This inelastic yarn can be both a filament yarn and a spun yarn. The core twist process is also called the conventional process as it is the first developed and most widely used process. It also forms the basis of the other processes. There are two distinct processes: single core twist and double core twist. In the single core twist process, the elastane yarn is pretensioned and is then passed through a first hollow spindle on which the inelastic yarn is located that

is twisted around the elastane yarn. In the double core twist process, the elastane yarn is then passed through another hollow spindle working according to the same principle. Finally the composite yarn is wound onto a bobbin. The hollow spindle is a speed limiting factor because of the mass of the bobbin. The speed is also dependent on the amount of twist given to the yarn. Speeds of 10-20 m/min can be obtained [13]. The composite yarn displays a relatively uniform structure in which the inelastic component is rather tight around the elastane yarn. The elastane yarn is almost completely covered by the inelastic yarn and is hence almost invisible. Single core twist is less applied than double core twist because the inelastic yarn often displays a tendency to untwist, uncovering the elastane yarn. Double core twist, in which the two yarns are twisted in opposite directions, can prevent the untwisting of the inelastic yarns. To produce a core spun yarn an inelastic fiber material is spun around the elastane yarn. Before the spinning the elastane yarn is stretched in order to prevent the fibers of the core spun yarn from pulling apart during use. The elastane yarn is again the core and no longer visible in the composite yarn. To produce an air covered yarn an inelastic filament yarn is blown together with the stretched elastane yarn through a jet of air. During the passage through the airjet the filament yarn is blown around the elastane yarn. The use of spun yarn as cover around the elastane yarn is only possible in combination with a filament yarn. The combined yarn now no longer displays a uniform structure, but instead varies strongly in volume. The twist of the inelastic filament yarn around the elastane yarn is visible under the form of "knots", which are only visible microscopically as rather flat structures. The elastane yarn is partially visible, because of which it will also be less protected and be more sensitive to wear. Since the yarn structure has an important influence in the resulting fabric, fabric produced with air covered yarns will also display less regularity than fabrics based upon core spun or core twist yarns.

As far as weaving is concerned, stretch yarn is already widely used on rapier machines, especially for making stretch jeans

garments. Weaving stretch yarns on airjet machines, which can weave faster, is still rather limited. For this reason, the aim of this paper is to provide a better insight into the weavability of stretch yarns on airjet machines.

2. Material and methods

2.1. Materials

The weft yarn bobbins to be used as weft yarns were produced by different spinners in Belgium which included: the Department of textiles (Ghent University), UCO Sportswear (Ghent), Utexbel (Ronse) and Gillemans (Ronse). The bobbins were classified into three categories according to their production process: core twist, core spun and air covered.

2.2. Methods

2.2.1. Standard methods

The weft yarn bobbins were subjected to different tests for determining the material, the linear density, elastane composition percentage and tensile properties. Determining the type of yarn ('core spun', 'core twist' or 'air covered') was done using images of the three different types, paying attention to the laying of the core yarn. Determining the material composition was done by using the microscope, if that didn't suffice, using melting tests, and if that still didn't suffice chemical tests were performed. Determining the elastane percentage was done gravimetrically. Determining the tensile strength and properties was done using the Statimat M in a conditioned room according to the norm ISO 2062 (1993) [17].

2.2.2. Air Index Tester

The Picanol Air Index Tester device was developed by Picanol N.V. of Belgium and it determines the speed of a weft yarn accelerated by a main nozzle at a specific air pressure. The Air Index value (AI) determined is an indication of the airfriendliness of yarns and hence their weavability on airjet looms. The tester determines the following values for yarn speed: minimum, maximum and average AI-value in m/s, min., max., and average standard deviation in m/s and min., max. and average coefficient of variation of yarn speed (CVAI) value in %. The CVAI value is the coefficient of variation between the different winding insertion durations. Values more than 5% indicate a yarn of poor weavability with many insertion stops, values between 3% and 5% indicate yarns reasonably weavable with the possibility of stops or defects and values below 3% indicate yarns weavable without significant problems [18].

2.2.3 Weaving tests

The goal of the weaving tests was to determine the number and nature of the weft-related stoppages per 100000 picks as well as determining the speed at fixed AIC/Q values. The AIC/Q on a Picanol loom is the value for the blowing intensity of the main nozzles, 100% being the maximum [19]. For each selected yarn 2500 picks were woven with a pick density of 12, 14 and 16 picks per cm respectively. The machine speed was set at 750 rpm for cotton (when possible) and 650 rpm for wool, at this rpm the AIC/Q value was recorded. After weaving 7500 picks the loom speed was increased or decreased accordingly to obtain an AIC/Q value of 80%.

2.2.4. Yarn stability tests

During the weaving tests there were often problems with the

stability of the yarn structure for the 'core spun' yarns. When the yarn remains in a continuous airflow in the main nozzle, needed for retaining the yarn inside the nozzle during a warp stop or when inactive, the 'spun' part of the yarn can get loose which causes weft and warp breaks as well as quality defects in the fabric. The goal of these tests was hence accordingly to check the stability of the 'spun' (or 'cover') part of the yarn around the 'core' in an airflow. Sampling for testing for this effect on the yarn linear density was limited to bobbins of 20, 42 and 61 tex because the results of the yarn stability tests were always the same. A few 'core twist' and 'air covered' yarns were also tested, but these gave very few problems and hence aren't covered in detail here. The test setup illustrated in Figure 1 consists of a clamp, a tension sensor connected to a computer and a main nozzle, all aligned. When the yarn exits the main nozzle, it is measured at 28 cm and a small weight is attached to it. Because at high pressures all 'core spun' yarns were immediately broken, the tests were performed at pressures of 1 bar, 1,4 bar and 2 bar and for 5 seconds.

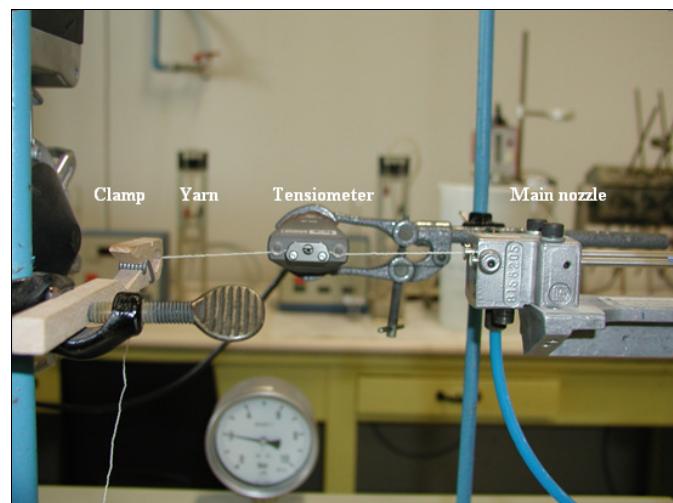


Figure 1. Test setup.

2.2.5. Tensile tests on fabric samples

The goals of this test were to determine the tensile properties of the fabrics, the influence of the pick density on the tensile properties and whether the tensile properties were uniform across the fabric. For every fabric 18 samples were prepared: 6 per pick density. These six samples were cut in such a way that 2 were from the right hand side of the fabric, 2 from the middle and 2 from the left hand side. In accordance to the norm description [17] the samples need to be cut at least 10 cm from the side of the fabric and are not allowed to contain weft defects. To determine whether there is a significant difference in the properties related to the sample position in the fabric, according to the norm at least 5 samples per location (left, middle, right) are required. However, due to testing-based constraints, only 2 samples per location were used. In total 23 fabrics were tested, resulting in 414 samples in total. The device used was an INSTRON 4301 tensile tester.

3. Results and discussions

3.1. Overview and most important properties of the tested bobbins

From the three yarn types tested in §2.2.1, it was determined the yarn material compositions were cotton (CO), wool (WO) and polyamide 6.6 (PA). For ease of reporting of the results

and discussions, the yarn bobbins were coded with a code always consisting of three parts: the first part indicates the material, the second part the number given to the bobbin and the last part indicates the type of stretch yarn: 'CT' stands for 'core twist', 'CS' for 'core spun' and 'AC' for 'air covered' yarn. The most important properties of the tested bobbins are given in Table 1.

Table 1. Overview of tested bobbins with linear density and elastane percentage.

Bobbin code	Linear density (tex)	Elastane percentage	Bobbin code	Linear density (tex)	Elastane percentage
CO1CT	63	1,2	CO8CS	34	3,3
CO2CT	63	1,5	CO9CS	20	7,5
CO3CT	63	1,3	CO10CS	34	2,8
CO4CT	63	1,5	CO11CS	34	3,1
CO5CT	40	7,4	CO12CS	33	5,4
CO6CT	40	4,8	CO13CS	33	5,6
CO7CT	40	8,0	CO14CS	34	3,3
CO8CT	40	6,4	CO15CS	34,5	3,5
CO9CT	74	4,3	CO16CS	63	2,1
PA1AC	18	7,3	CO17CS	63	2,2
PA2AC	26	6,0	CO18CS	63	2,2
PA3AC	17	6,0	CO19CS	63	2,3
PA4AC	25	4,5	CO20CS	42	9,7
WO1CT	35	0,4	CO21CS	42	9,6
WO2CT	35	0,6	CO22CS	42	10,7
WO3CT	24	1,1	CO23CS	42	9,9
CO1CS	33	5,6	CO24CS	33,5	3,2
CO2CS	33,5	3,4	CO25CS	42	9,7
CO3CS	35	2,1	CO26CS	55,5	6,5
CO4CS	33	5,5	CO27CS	71,5	9,5
CO5CS	33	5,5	CO28CS	33,5	3,9
CO6CS	61	6,4	CO29CS	71,5	4,6
CO7CS	43	8,1			

3.2. Tensile test results

3.2.1. Shape of tensile curve

The typical tensile curves of the three different types of yarns tested are illustrated in Figures 2-4. For the 'core spun' yarn, the tensile force F doesn't start at zero due to the pretension of 0,5 cN/tex. CO29CS has a linear density of 71,5 tex and hence a pretension of 35,75 cN. The tensile curve is completely different from that of a classical yarn. The extension as function of the force initially increases slowly because after applying the pretension, the yarn is in a state in which the sheath lies almost stretched. This causes pulling on the sheath from the start of the test, which is naturally less elastic than the core. The 'core spun' fibers break one by one and once most fibers are broken, the extension as function of the force will increase faster because the core starts to determine the elasticity of the yarn. Once the entire sheath has been pulled apart, the test ends. For the 'core twist' yarn, the behavior is rather identical. For the 'air covered' yarn, we notice a change in the curve between 14 and 24% at the x-axis. This is probably due to the moment at which the loops forming the sheath have entered a stretched state. The extension as function of the force now increases at a slower rate than at the start, during which only

the elastane filament core is pulled, as the sheath is less elastic than the core.

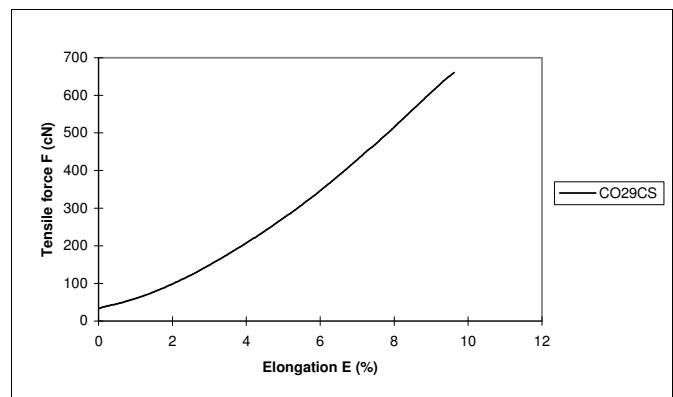


Figure 2. Tensile curve of a 'core spun' yarn.

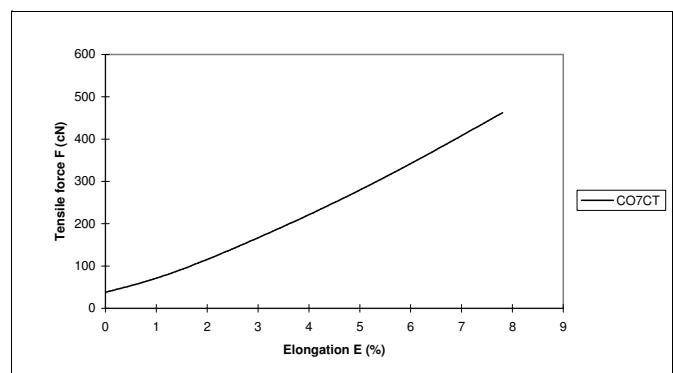


Figure 3. Tensile curve of a 'core twist' yarn.

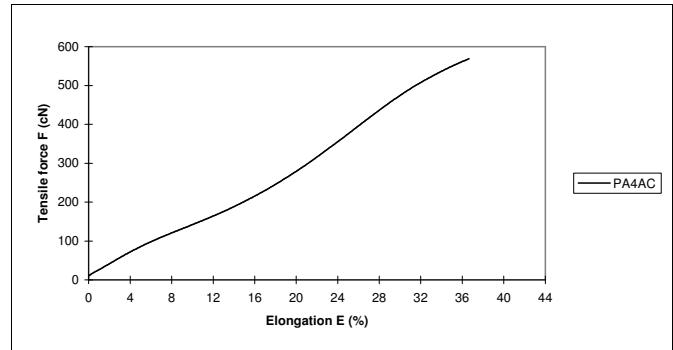


Figure 4. Tensile curve of an 'air covered' yarn.

3.2.2. Correlation between the elastane percentage and the elongation at break

Logically one could assume that a higher elastane percentage results in a higher extension at break, but during the tensile tests it was established that it is often the sheath and not the core that breaks. This is why in Figure 5 the elastane percentage doesn't seem to matter for 'core twist' and 'core spun' yarns. For 'air covered' yarns we notice surprisingly an inverse correlation and a higher extension at break than for the other types. We also notice the bigger elongation of 'air covered' compared to the other yarns. This can be explained by the nature of 'air covered' yarns. In Figure 6 we notice the yarns are resp. in large and small loops. During the tensile tests the yarn is always pretensioned, which causes the sheath of 'core twist' and 'core spun' yarns to be already reasonably stretched. For 'air covered' yarns on the contrary the sheath is still in loops, which causes the tensile test to last longer. Larger loops

hence mean less elastane percentage but yet a higher extension at break. The extension at break is hence dependent on the size of the loops around the core.

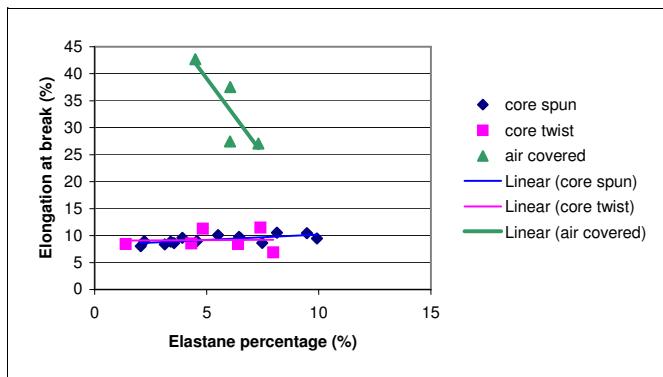


Figure 5. Relationship between elastane percentage and elongation at break.

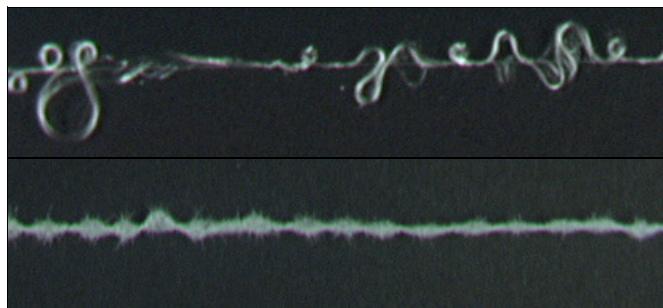


Figure 6. 'Air covered' yarn in large (PA3AC) and small (PA1AC) loops.

3.3. Air Index Tester results

The CVAI-values measured were always below 3%, which give to expectations of good yarn weavability. Only the AI-value of CO6CS could not be determined because it continuously lost its sheath in the main nozzle. In Figure 7 the relationship between Air Index value versus the yarn count is illustrated. No linear correlation could be demonstrated, although a lower yarn count usually results in a higher Air Index value. We can further observe that the values for 'core spun' and 'air covered' yarns are of the same magnitude and 'core twist' yarns display lower values. This observation is however no certainty as three types of yarns with different yarn counts and different materials were compared.

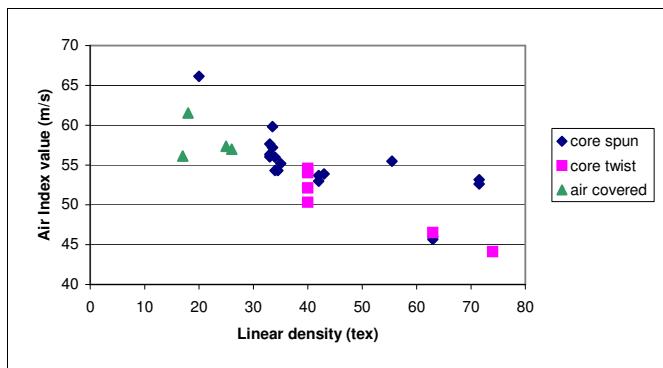


Figure 7. Relationship between Air Index value and yarn count.

3.4. Weaving test results

During the weaving tests it turned out to be impossible to raise the AIC/Q to 80% for all the weft yarn qualities by raising the

loom speed, because loom speed had an upper limit at 920 rpm. For this reason, differentiation was made between yarns weavable at an AIC/Q of 80% and yarns weavable at an AIC/Q of 67%. Switching to a different pick density, described in the test setup, also necessitated change of weaving settings due to the change in contraction of the fabric. The scissors at the arrival side of the loom needed to be readjusted and for fabrics with a larger contraction (lower pick density) it was best to use temples with multiple pinned rolls. For 'air covered' yarns, several problems were observed when weaving. A first problem was that originally, the yarn did not arrive on time regardless of the air pressure. This was due to the large stretch properties of the yarn. The yarn is wound on the prewinder under tension and relaxes when inserted, which causes the yarn to be too short to reach the arrival side of the loom. Increasing the diameter of the windings on the prewinder solved this problem. A second problem illustrated in Figure 8, was that the yarn often clogged the stretch nozzle at the arrival side of the loom, causing stops. This is a phenomenon not observed with any other yarn. A third problem was that the fabric contained reoccurring errors on the arrival side of the loom, again due to the large stretch properties of the yarn. The last part of the yarn jumps back after the insertion, leading to double picks and causing thick places at the arrival side of the fabric. For 'core spun' yarns, few problems were observed. CO7CT and CO9CT the AIC/Q value was 100% from the start, which means the yarn arrives too late. WO3CT was not weavable at a loom speed of 750 rpm and was woven at 650 rpm instead. For 'core spun' yarns, no problems were observed when weaving.



Figure 8. 'Air covered' yarn clogging the stretch nozzle.

3.5. Yarn stability test results

Generally for 'core twist' yarns the sheath around the elastane filament rarely came off. Only in exceptional cases did the elastane filament lose its cohesion due to the airflow, leading to a tension increase. A complete untwisting of the yarn was not observed. For 'air covered' yarns the sheath around the elastane filament never came off either. Sometimes a shift in the location of the nodes occurred. The nodes are the places where the filament yarn is blown fixed upon the core elastane filament yarn. This however didn't result in any changes in the tension profile of the yarn. The tension profile of both these types of yarns is hence generally of the shape illustrated in Figure 9. In this figure, we observe first a peak at 300 ms due to the start of the blowing, followed by a constant tension profile as the yarn structure is not significantly affected by the

airflow. Generally for 'core spun' yarns, the sheath frequently came off. The bobbins investigated were CO9CS of 20 tex; CO20CS of 42 tex and CO6CS of 61 tex. At 1 bar, the yarns rarely lost their sheath, at 1,4 sporadically and at 2 bar in most cases. When the sheath came off, it came off instantly, gradually or in two phases, but eventually the elastane filament lied naked after 5 seconds. The tension profile of 'core spun' yarns in an airflow is illustrated in Figure 10. In this figure we observe first a peak at 400 ms due to the start of the blowing, followed by the start of the loss of the 'spun' part. Next the tension remains constant until about 2700 ms, after which the tension lowers because the yarn has completely lost its 'spun' part and the elastane filament lies naked. From then on the tension drops and remains constant because the surface area is smaller and the airflow has less grip on the yarn. Figure 11 is a photo of unchanged, partially and totally changed structure of a 'core spun' yarn under airflow. The naked elastane filament core spun is encircled. The 42 tex yarn was the strongest and the 20 tex and 61 tex were both about as weak, so we conclude there is no connection between yarn count and yarn strength in an airflow. The strength is probably related to the process in which the elastane yarn is covered with spun material.

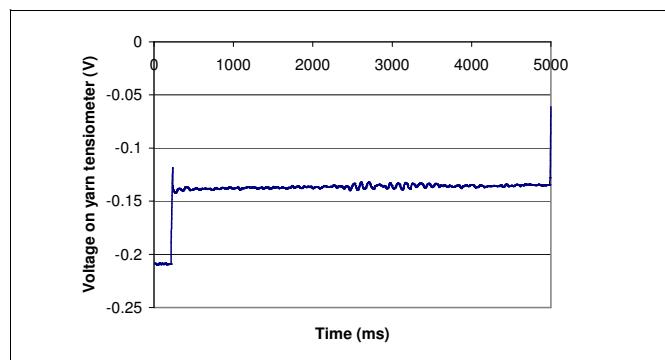


Figure 9. Typical tension profile of 'core twist' and 'air covered' yarns in an airflow.

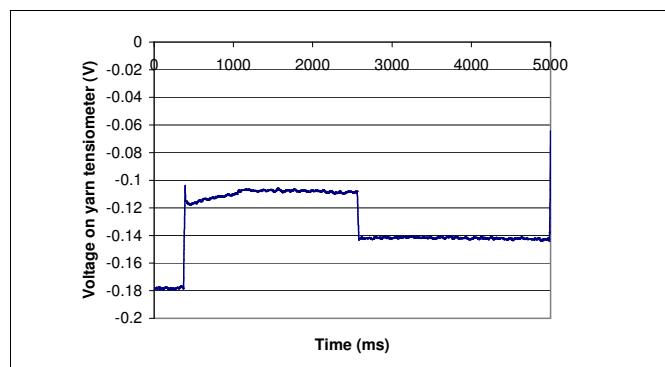


Figure 10. Typical tension profile of 'core spun' yarns in an airflow.

3.6. Fabric tensile test results

The results of the tensile tests were subjected to a statistical investigation, trying to answer the following questions:

- Is there a significant difference in modulus depending on the location in the fabric?
- Is there a significant difference in modulus and maximum force at break at the different pick densities?
- Is there a significant difference in modulus depending on the location in the fabric?

For all yarns no significant difference was found due to the

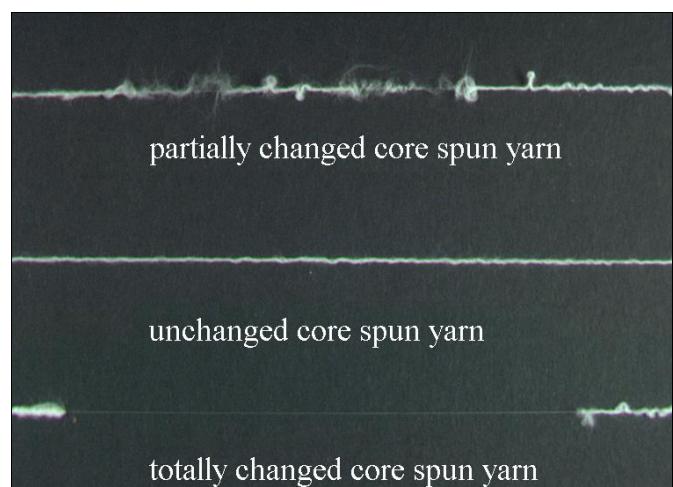


Figure 11. Photo of unchanged, partially and totally changed structure of a yarn in an airflow.

location. For three yarns however, one of each type (CO7CT, PA2AC and CO28CS), five samples per location were taken at the respective pick densities of 16, 14 and 12 picks/cm. For CO7CT (at 16 picks per cm) and PA2AC (at 14 picks per cm) a significant difference between the higher modulus in the middle and the lower modulus left and right was observed. Between the modulus left and right only, no difference was observed. For the extension at break the same was observed, a lower extension in the middle and a higher left and right. For the maximum force at break no significant difference was observed. For CO 28 CS (at 12 picks per cm) no significant differences were observed. When only two values were compared for CO7CT and PA2AC, no significant difference was observed. So we can suspect that if five samples per location had been taken, a systematic slight difference between the moduli and the extension at break in the middle and left and right would have been observed. It is important in the confection industry that there is no large difference in elasticity e.g. when producing a pair of pants. Apart from a single yarn, a systematic difference for the modulus at different pick densities was observed and illustrated in Figure 12 for the modulus in the middle of the fabric. The modulus increases with increasing pick density, as could be expected. A fabric woven less tight should extend more easily and hence also theoretically break at a lower force, which was also observed in reality. The relationship between pick density and maximum force at break looks very similar and is hence not illustrated.

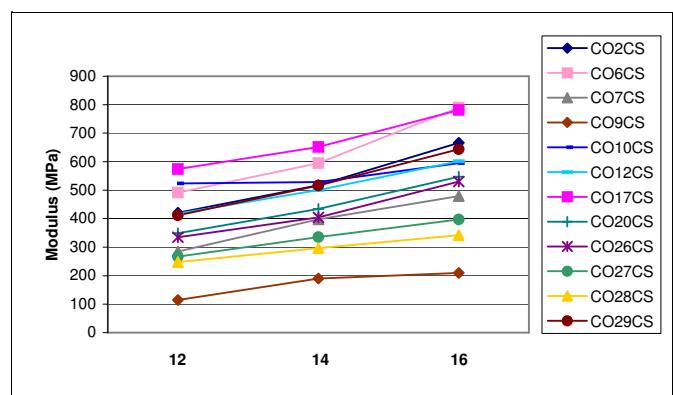


Figure 12. Relationship between fabric modulus and pick density.

3.7. Influence of the yarn properties on the fabric modulus

The modulus-values of the 'air covered' yarn are significantly

smaller than those of other types of yarn and this was also found to result in a smaller modulus of the fabric. For 'core spun' and 'core twist' yarns the values are going in a different direction. In Figure 13 the relationship between the yarn count and fabric modulus is illustrated. There is no real trend, but one can see a larger yarn count with 'core spun' yarn often correlates with a larger fabric modulus and vice versa. The value of the modulus also has a lot to do with the elastane percentage in the yarn. Generally and for 'air covered' yarns in specific it was observed that a larger elastane percentage results in a yarn with a lower modulus. This is illustrated in Figure 14.

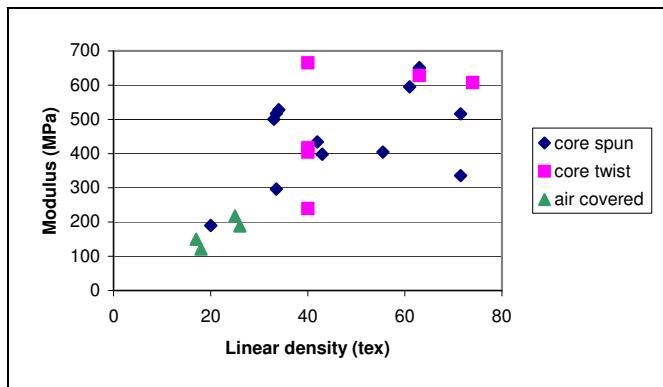


Figure 13. Relationship between fabric modulus and yarn count.

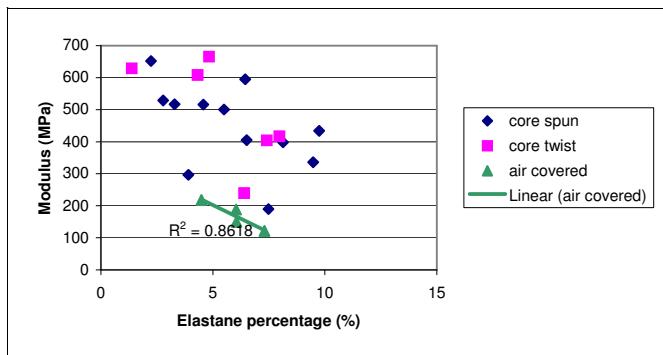


Figure 14. Relationship between fabric modulus and elastane percentage.

3.8. Comparison of several test results with weaving test results

A first relationship investigated was whether there was a correlation between yarn count and the attainable loom speed. We could theoretically expect that lighter yarns should fly faster in the air stream and hence should be weavable at greater speeds. This was also experimentally observed. It was observed however that the four 'core twist' yarns of 40 tex were not weavable at the same speed, so yarn count is by far not the only factor. CO5CT, CO6CT, CO7CT and CO8CT are weavable at an rpm of respectively 802, 800, 650 and 750 rpm at the same AIC/Q. There are only two comparable yarns, the others differ greatly. This is probably due to the amount of twist with which the cotton yarns are wound around the core. Under the microscope for these four yarns of equal yarn count a completely different appearance was observed due to the twist. Because not for all yarns the amount of twist was known, a possible relationship could not have been investigated. Further it was also observed that 'core spun' yarns are often weavable at greater speeds. A second relationship investigated was whether there was a relationship between the Air Index value and attainable machine speed. This was not ob-

served although the Air Index test should be a good determination for the weavability of yarns. For elastane yarns this is apparently not the case as the behavior of the yarn in the reed channel seems to play an important role as well. Besides these conclusions are on a limited number of bobbins. A third relationship investigated was whether there was a correlation between the tensile strength and the machine speed at a certain rpm. No connection whatsoever was observed.

4. Conclusion

From literature review, we determined three main types of stretch yarns based on elastane: core spun; core twist (single en double) and air covered. From the tensile tests we learned these three types have their own characteristic curve. The 'air covered' yarns shows the greatest extension and hence also greatest force at break. For 'air covered' yarns we further found an inverse linear correlation between elastane percentage and elongation due to the sheath lying in loops around the filament core. From the Air Index tests, the CVAI values below 3% predicted good weavability, which was not always found to be accurate for the attainable speed. The 'core twist' yarns didn't result in specific insertion problems. The 'core spun' yarns had problems due to being blown apart under influence of the airflow, causing weft stops. The 'air covered' yarns resulted in recurring fabric defects at the arrival side of the loom. The maximum attainable loom speeds were for core spun yarn: 900 rpm, core twist yarn: 800 rpm and air covered yarn: 750 rpm. Lighter yarns were weavable faster. During these weaving tests the phenomenon of change of yarn structure was observed, so this was investigated on a specific test setup. 'Core spun' yarns were found to lose their spun either immediately, gradually or in two phases while 'core twist' and 'air covered' yarns experienced little influence of the airflow. The fabrics were further subjected to tensile tests. When testing five samples per location a significant difference was often observed between the modulus and extension at break in the middle and that left and right while testing two samples showed no significant difference; so presumably there is a trend, which could not be conclusively proven with only two samples. Further a significant difference was demonstrated for the modulus, extension and force at break at different pick densities. Fabrics with smaller pick density have a smaller modulus and break at greater extension and smaller force. Finally for the weaving tests only a small connection was established between yarn count and loom speed.

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