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Effect of Balloon Angle on the Hairiness and other Yarn Properties of Polyester Ring Spun Yarn

Abstract
In this research the effects of the yarn balloon angle on yarn hairiness and other yarn properties was investigated. The yarn balloon was changed by use of five different weights of C type travellers. The yarn counts chosen were 15 tex, 20 tex and 30 tex. Three spindle speeds were used: 9,000 r.p.m., 10,000 r.p.m. and 11,000 r.p.m. Yarn hairiness, yarn count, balloon angle, yarn surface helix angle, yarn twist, strength and elongation at break, as well as irregularity and imperfection tests were carried out for all the yarn samples. In this research it was noted that as the balloon angle increases, the yarn hairiness and yarn surface helix angle increase. Other yarn properties were also investigated and discussed.

Key words: *balloon angle, yarn hairiness, yarn properties, traveller weight, and yarn tension.*

Introduction

Yarn hairiness causes some problems during fabric production affects the final product. Hairiness on warp yarns can cause an entanglement amongst the warp yarns, and as a result yarn breakages and machine stoppages occur. Yarn hairiness can also cause pilling, changing the appearance and construction of the fabric. The research carried out shows that 46% of warp breakages occur due to yarn hairiness [1, 3, 12].

Yarn hairiness is caused by either protruding fibres or loops of fibres appearing outside the yarn body. The behaviour of these fibres within the yarn is dependent on a number of factors. These factors can be investigated under three headings: physical properties of the fibres, yarn parameters and machine parameters. Many researchers have investigated the effect of the physical properties of fibres and yarn parameters on hairiness. According to those researchers, hairiness decreases with an increase in fibre length and fibre fineness, the short fibre content [4-6, 11], the number of fibre in the yarn [15, 19], the flexural rigidity and torsional rigidity as well as in yarn twist. As far as the machine parameters are concerned, an increase in the spindle speed in the eccentricity of the spindle and increases the hairiness. An increase in the yarn tension decreases the hairiness, friction between separators increases the yarn hairiness, increasing the drafting ratio increases the hairiness, a weight increase in travellers decreases the hairiness, and the winding speed increases the yarn hairiness [7-9, 13, 14, 16-18, 20]. Apart from these findings, the compact spinning system used since the year 2000 has also been found to decrease the hairiness of yarn [2, 10]. But many areas of the world still use conventional spinning methods. One of the main problems of conventional spinning is still yarn hairiness. This work investigates the yarn hairiness and other yarn properties of polyester ring spun yarn on yarn ballooning, which is affected by the traveller weight.

Experimental

In this work yarns were produced using cotton type of 40 mm staple length, 2 dtex polyester fibre with irregularity values of CV% 4.3 703 tex (Ne0.83) polyester roving. From this roving, knitting yarns of 15 tex (Ne40), 20 tex (Ne30) and 30 tex (Ne20) with a twist level of α_{tex}38 (α_e3.5) were produced. A Suessen six-spindle laboratory-typespinning machine was used. Yarn production was undertaken at spindle speeds of 9,000 r.p.m., 10,000 r.p.m. and 11,000 r.p.m. with 51, 61, 73, 82 and 86 milligrams for 15 tex, 61, 73, 82, 86; 96 milligrams for 20 tex, and 73, 82, 86, 96 and 107 milligrams for C type travellers of 30 tex. All the yarns produced with these spindle speeds were coded as below. The cods of the particular yarns tested are listed in ***Table 1***.

During the yarn production, the spinning tension, yarn ballooning and yarn hairiness were measured. After the yarn production, the yarn hairiness, yarn surface helix angle (YSHA), yarn count, twist, strength, elongation, irregularity and imperfection were also measured. The whole yarn production and tests were carried out under standard atmospheric conditions (20 °C ± 2 °C and 65% ± 2% RH).

Measurements during spinning

During the yarn production stages, the yarn hairiness and spinning tension were measured between the top roller and yarn guide. For the measurement of yarn hairiness, a *Shirley Yarn Hairiness Monitor* was used. Which can measure fibres of 3 mm length with 70° angles to the yarn

Table 1. *Yarn codes.*

code	Yarn linear density, tex	Spindle speed, r.p.m.
15tex09	15	9,000
15tex10	15	10,000
15tex11	15	11,000
20tex09	20	9,000
20tex10	20	10,000
20tex11	20	11,000
30tex09	30	9,000
30tex10	30	10,000
30tex11	30	11,000

within a 5 mm distances of the apparatus. For reproducibility, 10 tests were carried out. Yarn tension was measured at the bottom of the ring rail. For this measurement *Schmidt Zf2* yarn tension equipment of a 10-100 cN range was used. A *Sony* digital camera was used for investigation of the yarn ballooning. Pictures were taken exactly opposite the yarn guide to be able to accurately measure the yarn ballooning . From the pictures the balloon angle was measured by taking the spindle as the centre ***(Figure 1)***. All the measurements were taken in relation to the traveller weight and spindle speed, which are given in ***Table 2***.

Measurements after spinning (in cops)

The yarn counts were calculated by taking 50 samples of 100 meter in length. Yarn surface helix angle (YSHA) measurements were carried out under a microscope of the *Projectina* projection type with x50 magnification ***(Figure 2)***. Angle measurements were taken 50 times for each sample. For yarn twist measurements the opening and closing technique was used. 500 mm samples were taken and 50 measurements were carried out for each sample. For the yarn hairiness measurement, the *Shirley Yarn Hairiness Monitor* was used. The measurement was carried out at a speed of 50 m/min with 50 repeats, and the results were evaluated in terms of hairiness per meter. The irregularity and imperfection of the yarns were determined with a *Uster Tester I-B*. Imperfection measurement of thin places (-50%), thick places (+%50) and neps +200% sensitivity was performedusing one km of yarn. Strength and elongation at break measurements of the yarn were carried out with an *Instron 4411* tensile tester. Strength values of the yarns were in cN, and the elongation was in %. The test speed of the equipment was 500 mm/min, with test lengths of 500 mm, and 50 tests were carried out for each sample.

The measurement results for the yarn surface helix angle, yarn count, twist, hairiness, irregularity, imperfections, strength, elongation against the spindle speed and traveller weight are listed as an example for a linear density of 15 tex in numbers in ***Table 3*** and for all cases tested in ***Figures 3-14*** see pages 43 and 44.

Results and discussion

Results during spinning

The results for the balloon angle, spinning tension and hairiness values measured during spinning are given in ***Figures 3, 4 and 5*** respectively.

In ***Figure 3*** it can be clearly seen that during spinning, as the traveller weight increases, the balloon angle decreases. Here, the traveller weight increases the friction between the ring and traveller, which in turn decreases the yarn balloon and causes an increase in yarn tension. The centrifugal force occurs as a result of the spindle speed, which makes the balloon larger by overrunning the tension between the top roller and traveller in the area between the yarn guide and traveller. As the traveller gets heavier, the swinging effect, which is caused by the centrifugal force, diminishes to make the balloon narrower. As a result of all these, the narrower yarn balloon leads to a narrower balloon angle. This narrower balloon angle, as can be easily understood from the correlation coefficient, is affected by the weight of the traveller. What is more the traveller weight can be addressed as the only effective factor concerning the traveller weight. When the spindle speed increases are closely examined, it can be seen that the yarn balloon and, thus, the balloon angle increase. Here, the increase in centrifugal force, in return for the increase in spindle speed, leads to an increase in yarn balloon and balloon angle.

When ***Figure 4*** is examined, we can see that as the traveller weight increases, the yarn spinning tension increases. As was mentioned before, the increase in traveller weight increases the friction between the ring and traveller. This increase in friction between the ring and traveller leads to the conclusion that the yarn in

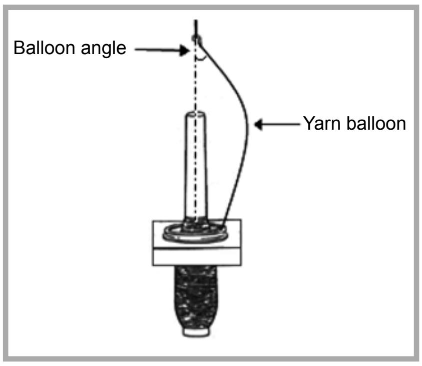

Figure 1. *Yarn balloon and balloon angle.*

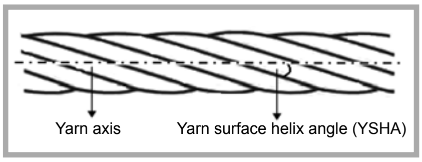

Figure 2. *Measurements of the yarn surface helix angle.*

Table 2. *Values of yarn hairiness, balloon angle and spinning tension during spinning.*

Parameter	Linear density, tex	Spindle speed: 9,000 rpm					Spindle speed: 10,000 rpm					Spindle speed: 11,000 rpm				
Traveller weight, mg	15 tex (Ne40)	51	61	73	82	86	51	61	73	82	86	51	61	73	82	86
Balloon angle, °		22	21	19	17	16	22	21	20	18	17	23	22	20	19	18
Spinning tension, cN		22.1	23.0	24.7	27.0	28.3	26.0	29.1	30.7	33.0	33.7	30.2	32.3	34.9	36.2	41.3
Hairiness, H/m		28.9	20.3	17.7	16.1	14.2	26.3	16.9	14.5	15.2	13.0	18.6	15.8	15.4	12.2	9.9
Traveller weight, mg	20 tex (Ne30)	61	73	82	86	96	61	73	82	86	96	61	73	82	86	96
Balloon angle, °		22	20	19	17	16	24	22	20	18	17	25	24	20	19	17
Spinning tension, cN		25.0	27.3	29.0	32.2	33.7	27.5	28.3	29.2	32.8	36.3	29.8	34.0	36.5	39.0	39.3
Hairiness, H/m		57.1	48.6	42.2	27.6	19.8	47.3	34.2	23.9	20.0	17.8	23.0	22.5	13.6	13.8	16.0
Traveller weight, mg	30 tex (Ne20)	73	82	86	96	107	73	82	86	96	107	73	82	86	96	107
Balloon angle, °		28	26	26	25	22	28	27	26	25	23	29	28	26	25	24
Spinning tension, cN		33.1	34.0	35.6	37.0	41.0	38.0	39.2	41.9	44.0	46.3	42.0	45.2	48.2	49.7	51.2
Hairiness, H/m		60.7	53.8	47.0	38.5	32.5	49.0	30.9	26.4	24.3	22.7	39.6	22.2	16.3	15.8	15.5

Table 3. Physical properties of polyester ring spun yarns for linear density of 15 tex.

Parameter	Spindle speed: 9,000 rpm					Spindle speed: 10,000 rpm 15 tex (Ne40)					Spindle speed: 11,000 rpm				
Traveller w., mg	51	61	73	82	86	51	61	73	82	86	51	61	73	82	86
YSHA, degree	23.3	21.5	19.3	19.0	18.1	24.3	23.3	22.5	21.0	19.5	26.0	24.7	22.7	21.3	20.8
Yarn count, tex	15.2	15.4	14.9	15.4	15.7	15.7	15.5	15.6	15.8	15.7	15.6	15.7	15.8	15.6	15.8
SD	0.3	0.3	0.4	0.5	0.2	0.5	0.4	0.4	0.3	0.4	0.4	0.3	0.5	0.3	0.4
CV, %	2.0	1.9	2.7	3.2	1.3	3.2	2.6	2.6	1.9	2.5	2.6	1.9	3.2	1.9	2.5
Twist, T/m	908	847	845	854	838	900	857	842	850	842	916	859	850	847	839
SD	29.4	26.3	29.6	21.5	25.4	31.7	31.7	21.9	30.9	17.0	22.9	20.7	23.9	27.3	27.7
CV, %	3.2	3.1	3.5	2.5	3.0	3.5	3.7	2.6	3.6	2.0	2.5	2.4	2.8	3.2	3.3
Hairiness, H/m	5.9	5.1	4.9	4.2	3.9	7.5	5.3	4.8	4.5	3.5	9.7	6.3	5.2	4.8	4.1
SD	0.6	0.8	0.3	0.6	0.6	1.1	0.5	0.5	0.3	0.3	1.5	1.0	0.6	0.6	0.5
CV, %	10.1	15.7	6.1	14.3	15.4	14.7	9.4	10.4	6.7	8.6	15.5	15.8	11.5	12.5	12.2
Strength, cN	523.6	515.4	502.5	499.6	496.2	533.3	528.0	513.0	509.3	505.1	546.3	525.5	534.3	518.8	511.1
SD	32.5	37.0	56.1	44.6	51.7	29.9	28.9	33.4	30.0	27.4	30.7	29.9	34.7	44.6	31.2
CV, %	6.2	7.2	11.2	8.9	10.4	5.6	5.4	6.5	5.9	5.4	5.6	5.7	6.5	8.6	6.1
Elongation, %	10.7	10.4	10.6	10.4	10.2	10.4	10.7	10.6	10.2	10.4	10.6	10.6	10.2	9.9	10.1
SD	0.6	0.8	1.0	0.6	0.8	0.7	0.7	0.7	0.6	0.5	0.6	0.7	0.7	0.8	0.6
CV, %	5.6	7.7	9.4	5.8	7.8	6.7	6.5	6.6	5.9	4.8	5.7	6.6	6.9	8.1	5.9
Irregularity, U%	9.9	9.7	10.0	9.8	10.5	9.8	9.9	9.8	10.0	10.6	10.2	10.2	10.1	10.9	10.6
Thin places	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thick places	12	10	5	10	13	6	8	6	11	13	4	10	16	13	11
Neps	15	18	12	22	25	10	12	20	21	18	10	30	23	22	32

the top roller is pulled down with greater force. At the same time, the increase in the spindle speed has an effect on the increase in the yarn spinning tension. These significant effects on the spinning tension can be easily seen in ***Figure 4***.

Figure 5 shows that during spinning, yarn hairiness between the top roller and yarn guide decreases rapidly as the traveller weight increases. The increase in the spindle speed also decreases the hairiness of the yarn. It is well known that the spinning triangle after the top roller affects yarn hairiness. The wider the spinning triangle is, the higher the hairiness on the yarn is, and the narrower the spinning triangle, the lower the hairiness is. The increase in traveller weight increases the yarn tension, which in turn narrows the spinning triangle, and as a result, reduces the hairiness. Fibres in this area are gathered in the yarn body with a narrower helix angle, and this results in lower hairiness on the yarn. At the same time, an increase in yarn tension due to the spindle speed between the top roller and yarn guide reduces the yarn hairiness.

Results measured in cops

When after yarn spinning the results are considered, almost the only factor affecting the yarn balloon angle is the traveller weight. Because of this, the yarn balloon angle was accepted as the main parameter. ***Figures 6-14*** show the yarn balloon angle against the change in yarn hairiness, yarn surface helix angle, yarn count, twist, strength, elongation, as well as irregularities and imperfections.

Figure 6 shows that as the yarn balloon angle increases, yarn hairiness increases as well. The rise of the yarn balloon also increases the balloon angle. The yarn guide between the top roller and traveller helps the yarn move to the spindle centre. The top of the spinning balloon that appears at the point where the yarn passes through the yarn guide can be wide or narrow depending on the size of the balloon. At this point the fibre on the yarn surface touches the guide and gets affected by the balloon angle caused by the yarn settling in its own structure . Yarn diameter is considered to be cylindrical, when fibre is wound on the yarn body at a narrow angle , the wound fibre length on the body of the yarn increases, while for fibres wound at a wider angle, the fibre length decreases on the body of the yarn. This is a stable occurrence as long as the twist does not change, which produces lower hairiness when the balloon angle is narrower, and higher hairiness when it is wider .

When the hairiness is examined in conjunction with the spindle speed, the spindle speed increases the hairiness. The increase in centrifugal force as a result of an increase in spindle speed causes the yarn balloon to increase, and thus an increase in the balloon angle. This affects the fibre entanglement within the yarn body, which causes hairiness.

Furthermore, as far as the yarn counts are concerned, the hairiness in 20 tex and 30 tex yarns follows a much more vertical path compared to 15 tex yarn. The thickness of the yarn is considered to be effective here. As the yarn gets thicker, the fibres on the yarn increase, and more fibres are active on the yarn surface, which makes it clearer. This can be clearly illustrated by the case of 30 tex yarn.

When ***Figure 7*** is examined, the increase in the yarn balloon, leading to an increase in the balloon angle, increases the yarn surface helix angle (YSHA) in conjunction with the yarn diameter of the fibres of the yarn. This relation is clear, as can be understood from the correlation coefficients. In the yarn guide, the angle friction effect that occurs as a rest of balloon angle which affects the spindle speed of the yarn in the process of twisting. During the friction, the fibres in the yarn are moulded around the structure of the yarn upon the effect of the balloon angle. As the balloon angle increases, the fibres are wound around with a wider YSHA. and as the balloon is diminished, they settle on the yarn structure with a narrower helix angle.

When the effects of the spindle speed on YSHA are examined, it is clear that as the spindle speed increases, the YSHA increases again. Instability is observed only in 15 tex09 yarns. When the effects of the spindle speed are examined, yarn count should be taken into consideration. As the yarn gets thicker, change in the YSHA happens more slowly. It should be taken into consideration that the increase in the number of fibres on the yarn surface is important.

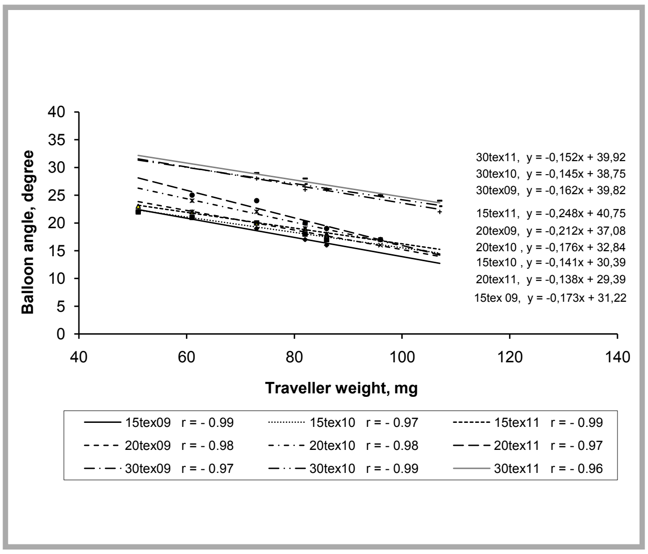

Figure 3. *Yarn balloon angle at different traveller weights and spindle speeds.*

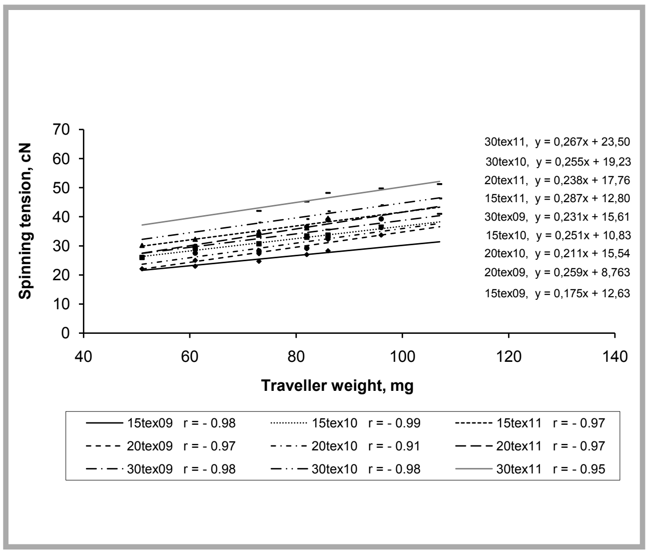

Figure 4. *Spinning tension at different traveller weights and spindle speeds.*

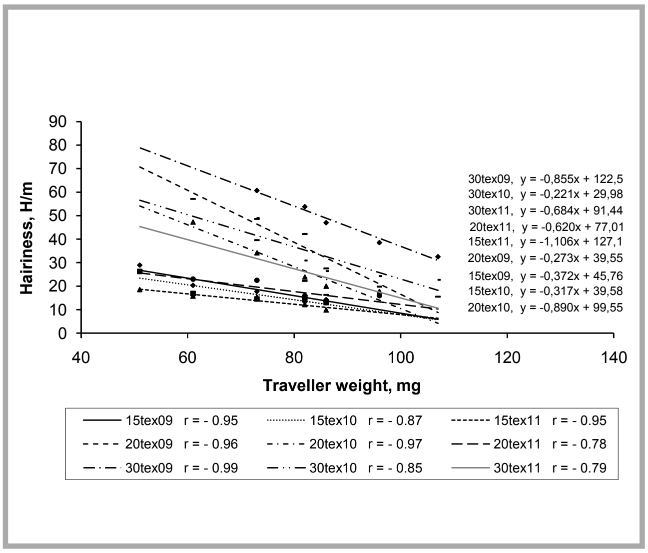

Figure 5. *Yarn hairiness at different traveller weights and spindle speeds.*

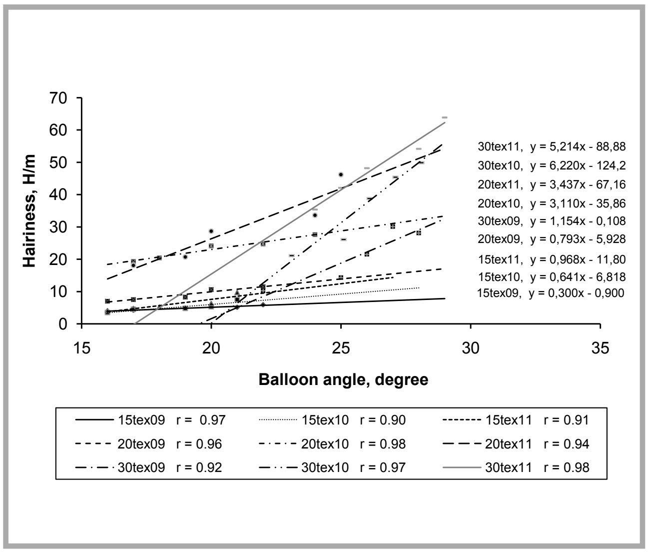

Figure 6. *Yarn hairiness at different balloon angles and spindle speeds.*

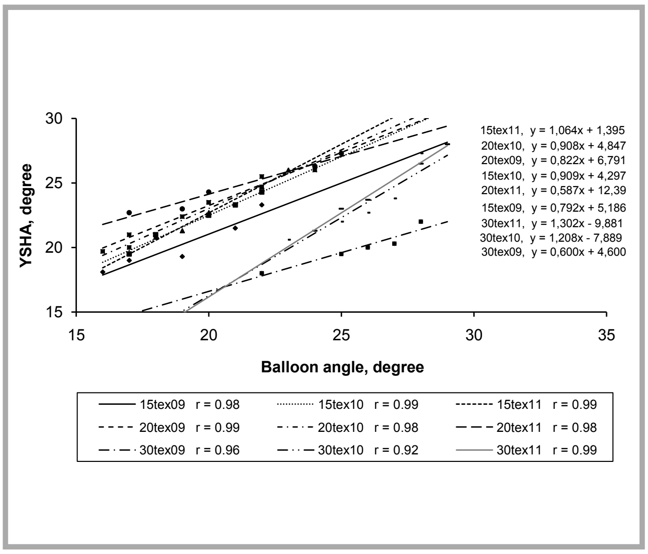

Figure 7. *Yarn surface helix angle (YSHA) at different balloon angles and spindle speeds.*

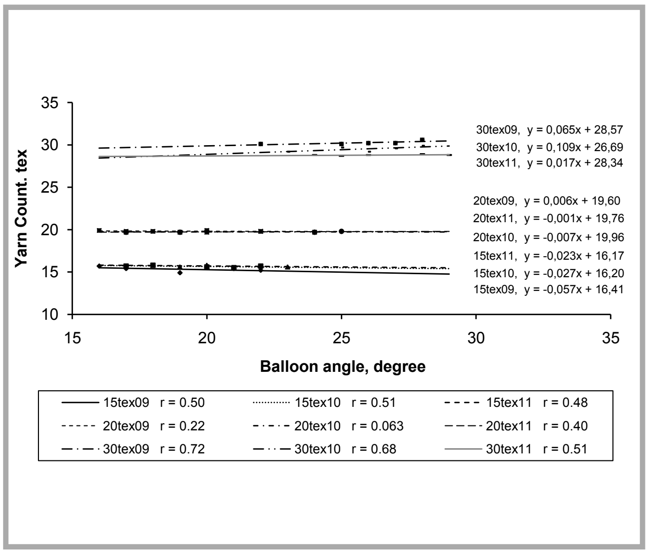

Figure 8. *Yarn counts at different balloon angles and spindle speeds.*

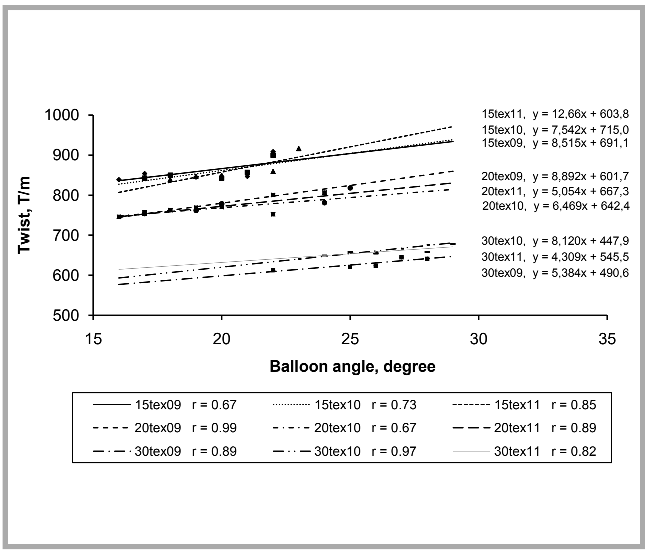

Figure 9. *Yarn twists at different balloon angles and spindle speeds.*

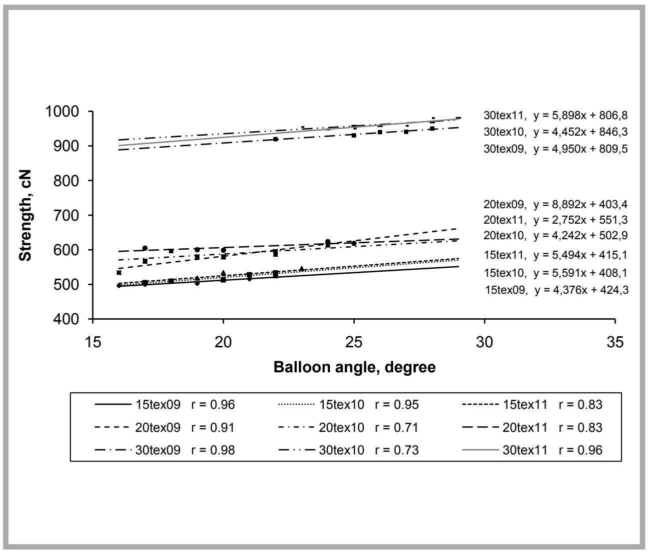

Figure 10. *Yarn strengths at different balloon angles and spindle speeds.*

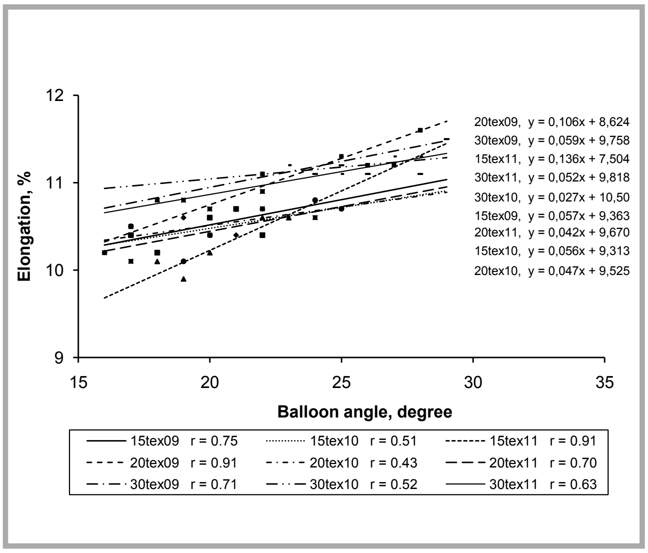

Figure 11. *Yarn elongations at different balloon angles and spindle speeds.*

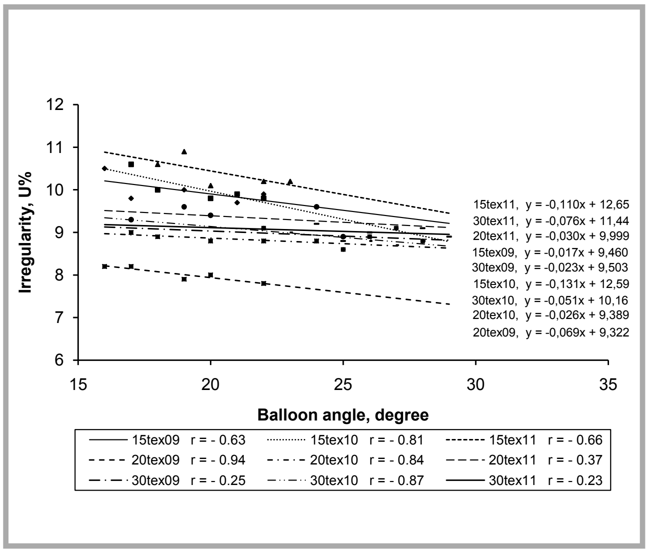

Figure 12. *Yarn irregularity at different balloon angles and spindle speeds.*

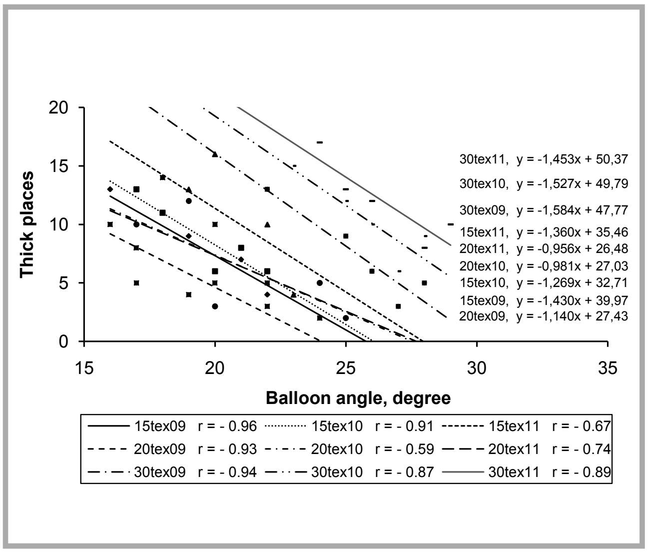

Figure 13. *Thick places at different balloon angles and spindle speeds.*

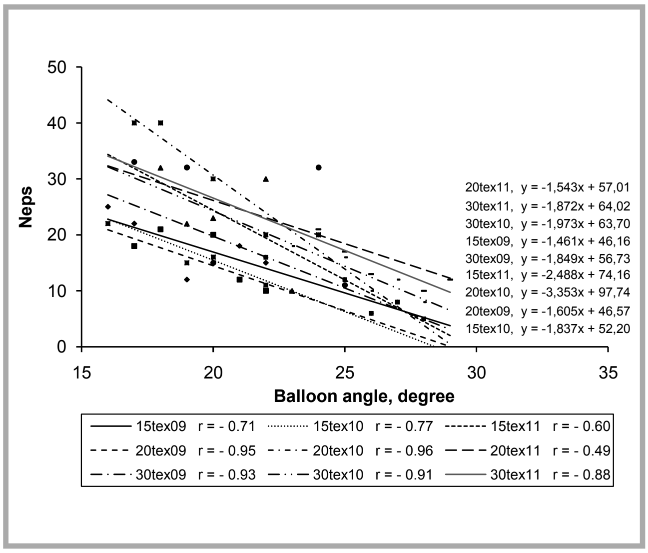

Figure 14. *Neps at different balloon angles and spindle speeds.*

In ***Figure 8*** it can be understood that as the balloon angle increases, yarn counts (tex) increase slightly, and thus the yarn gets marginally thicker. On the other hand, when spindle speeds are taken into consideration, 30 tex yarn, especially, shows a remarkable count difference. This difference is thought to be caused by the increase in the number of fibres depending on the yarn count.

Figure 9 shows that as the balloon angle increases, the yarn twist increases, which is greatly affected by the balloon angle. Widening of the yarn balloon angle is caused by the decrease in traveller weight and also by a decrease in spinning tension. Because of this the length of yarn between the front roller and the traveller increases and less yarn is wound onto the cone. In other words, fora wider balloon angle, more spindle speed is required for a certain set length of yarn, but less spindle speed is applied for the winding. This in fact results in higher twist at a wider balloon angle and lower twist at a narrow balloon angle. A higher spindle speed also widens the spinning balloon angle, which also results in higher twist in yarn.

In ***Figure 10***, as a result of the increase in the balloon angle, the yarn strength increases considerably. As mentioned above, an increase in the balloon angle results in an increase in twist . It is clear that an increase in twist causes an increase in the yarn strength. With the increasing balloon angle, the fibres are wound in the yarn body with a wider surface helix angle. The increasing surface helix angle puts the fibres on the upper points in the direction of the yarn with frictional forces. These types of fibre gathering that occur as a result of the widening of the yarn balloon increase the tenacity of yarn.As far as the spindle speed is concerned, it is clear that it increases the yarn balloon, and as a result the balloon angle increases. The increase in balloon angle allows for the case mentioned above, which increases the yarn strength.

Figure 11 shows the elongation at break values of the yarn increase with the widening balloon angles. The increase in elongation at break is seen as insignificant for 15 tex10, 20 tex10, 30 tex10 and 30 tex11yarns. The increase in elongation can be explained in terms of the fibre being wound at a wider helix angle as a result of the yarn balloon angle having a higher twist. When a force is applied on yarn, as the surface helix angle increases, the fibres hold onto each other at higher points, which delays breaks in the yarn and the elongation at break.

When ***Figure 12*** is examined, it can be seen that yarn irregularities decrease as a result of the increase in the balloon angles. Meanwhile, the increase in spindle speed seems to be effective with respect to the irregularity in the widening yarn balloon as well as lower spinning tension and results in surface fibres being tightly forced into the yarn body . Such fibre settlement causes less fibre movement and decreases the irregularity in a set unit length of yarn.

When the effect of the spindle speed on the irregularity of yarn is considered, an increase in spindle speed increases yarn irregularity. In addition to the tension that results from the traveller weight, the increase in spindle speed brings about an increase in tension , which makes the yarn thicker or thinner and changes the fibre place of the fibre in the yarn and produces higher irregularities in the yarn structure.

Figure 13 shows that an increase in the balloon angle degree decreases the number of thick places on the yarn. Here again there is tighter placement of fibres on the body of the yarn with lower spinning tension, due to wider balloon angles, which is the cause of less thin and thick places on the yarn.

When ***Figure 14*** is examined, as a result of the increase in the balloon angle, the number of neps gets lower. As is known, neps are fibre bundles caused by the entanglement of fibres . A widening balloon angle, as was examined above, means lower spinning tension and lower friction. The yarn between the top roller and traveller is subjected to tensions at these points: the yarn guide, balloon control ring and traveller. Here the strongest yarn friction occurs in the traveller, where the yarn changes direction at an angle of 900. At higher tensions fibres are subjected to higher friction, more closely touching each other, whereas as the friction decreases, this tension related to the touch decreases. As a result fewer neps are observedat lower spinning tension and more neps at higher spinning tension.

Statistical analysis

Variance analysis was applied to check whether the results obtained are important statistically. Significance were conducted at 95% and 99% confidence limits.

The test results for the balloon angle, spinning tension and hairiness obtained during spinning were investigated using two-way variance analysis, depending the traveller weight and spindle speed. The results of analysis are given in ***Table 4*** see page 46.

When ***Table 4*** is examined, it can be found that at a $\alpha_{0.05}$ significance level, balloon angles, spinning tension and hairiness are affected during the yarn production by both the traveller weight and spindle speed. These effects at a $\alpha_{0.01}$ significance level, except at the balloon angle during the production of 30 tex yarn, were all proved to be important. This shows that the traveller weight and spindle speed play an important role during the yarn production process.

Yarn properties obtained following the production of the yarns were investigated by two-way variance analysis depending on the balloon angle and spindle speed. All the analysis results are given in ***Table 5*** see page 46.

When ***Table 5*** is examined, it can be seen that the balloon angle, except for 20 tex yarn, has an important effect at both significance levels. Except for 15 tex yarn, the effect of spindle speed on hairiness was found to be significant. When the YSHA is examined, it can be seen that both the balloon angle and spindle speed have an important effect on the YSHA. The yarn count effect of the balloon angle is seen to be negligible at both significance levels. When the effect of spindle speed on yarn count is examined, while it is not important for 15 tex yarn at a $\alpha_{0.01}$ significance level, nor for 20 tex yarn at both significance levels, for the other counts and significance levels, the spindle speed effect is important. When yarn twists are examined, the effect of the balloon angle seems to be important at both significance levels. As regards the effect of spindle speed on twist , while it is important for both significance levels in 30 tex yarn, the effect was found to be unimportant at either of the significance levels. When the effect of the balloon angle and spindle speed on the yarn strength is examined, it can be seen that the balloon angle has an important effect, except for 20 tex yarn at a $\alpha_{0.01}$ significance level. When the effect of the spindle on the strength is consid-

Table 4. Variance analysis of yarn properties using different weights of ring travellers during spinning.

Properties	Variation sources	15tex		20tex		30tex	
		$\alpha_{0.05}$	$\alpha_{0.01}$	$\alpha_{0.05}$	$\alpha_{0.01}$	$A_{0.05}$	$\alpha_{0.01}$
Balloon angle	Traveller weight Spindle speed	s s	s s	s s	s s	s s	s n.s.
Spinning tension	Traveller weight Spindle speed	s s	s s	s s	s s	s s	s s
Hairiness	Traveller weight Spindle speed	s s	s s	s s	s s	s s	s s

s – significant, and n.s. – not significant

Table 5. Variance analysis of yarn properties at different balloon angles and spindle speeds in the cops.

Properties	Variation Sources	15tex		20tex		30tex	
		$\alpha_{0.05}$	$\alpha_{0.01}$	$\alpha_{0.05}$	$\alpha_{0.01}$	$\alpha_{0.05}$	$\alpha_{0.01}$
Hairiness, H/m	Balloon angle Spindle speed	s n.s.	s s	n.s. s	n.s. s	S s	s s
YSHA, degree	Balloon angle Spindle speed	s s	s s	s s	s s	s s	s s
Yarn count, tex	Balloon angle Spindle speed	n.s. s	n.s. n.s.	n.s. n.s.	n.s. n.s.	n.s. s	n.s. s
Twist, T/m	Balloon angle Spindle speed	s n.s.	s n.s.	s n.s.	s n.s.	s s	s s
Strength, cN	Balloon angle Spindle speed	s s	s s	s s	n.s. s	s s	s s
Elongation, E%	Balloon angle Spindle speed	n.s. n.s.	n.s. n.s.	n.s. n.s.	n.s. n.s.	s n.s.	n.s. n.s.
Irregularity, U%	Balloon angle Spindle speed	n.s. n.s.	n.s. n.s.	n.s. s	n.s. s	s n.s.	n.s. n.s.
Thick places, in km	Balloon angle Spindle speed	s n.s.	n.s. n.s.	s n.s.	n.s. n.s.	s s	s s
Neps, in km	Balloon angle Spindle speed	n.s. n.s.	n.s. n.s.	s s	n.s. n.s.	s s	s s

s – significant, and n.s. – not significant

ered, it was found out that it has an effect on all counts of yarn at both significance levels. The effect of the balloon angle on yarn elongation at break is important for all counts and significance levels except for 30 tex yarn at a $\alpha_{0.05}$ significance level. The effect of spindle speed on the elongation at break has was to be important. The effects of balloon angles on irregularities is of great significance for 30 tex yarn, while it is not important for other counts and significance levels. The effect of spindle speed on irregularities for 20 tex yarn is important for two significance levels, while for 15 tex and 30 tex yarns it is seen to be unimportant for the two significance levels. The effect of the balloon angle on thick places on the yarn is insignificant at the significance level for 15 tex and 20 tex yarns, whereas it is important for other counts and significance levels. The effect of spindle speed on thick places is important for 30 tex yarn at both significance levels, whereas it is not important for 15 tex and 20 tex yarns. When the effect of the balloon angle on neps is examined, for 15 tex yarn at two significance levels and for 20 tex yarn at a $\alpha_{0.01}$ significance level, it is important, whereas for other counts and significance levels, it is not important. As regards effect of spindle speed on neps, it is seen that the same effect exists, as observed for balloon angles .

Conclusions

When the results obtained from this study are taken into consideration, the following conclusions can be drawn.

Conclusions regarding measurements during spinning;

- The traveller weight has an important effect on the spinning balloon and balloon angle. Furthermore, the traveller weight affects the spinning balloon completely by itself. As the traveller weight increases, the spinning balloon and balloon angle get narrower, but when it decreases, the spinning balloon widens and the balloon angle becomes higher. It can be understood that the spindle speed has an effect on the spinning balloon. As the spindle speed increases, the spinning balloon and balloon angle get higher as well.
- Yarn spinning tension increases remarkably as the traveller weight increases. Similarly, the spindle speed increases spinning tension.
- The effects of the traveller weight and spindle speed on yarn hairiness during spinning were observed as significant. As the traveller weight increases, hairiness decreases during the yarn spinning. The spindle speed increases with rising spinning tension, and yarn hairiness decreases during spinning.

Conclusions regarding measurement in cops;

- It is clear that both the balloon angle and spindle speed have an effect on the hairiness of yarn. An increase in the balloon angle has an effect on the hairiness of yarn, except for 20 tex yarn. A rise in the Spindle speed, increases the hairiness in all the yarns tested.
- It is clear that the angle of the fibres on the yarn axes – angle of yarn surface helix (YSHA) – affects the increase in balloon angles and spindle speed.
- Statistically, the effect of balloon angles on yarn counts has been proved to be unimportant. However, the effect of an increase in spindle speed on yarn count is important, except for 20 tex yarn.
- An increase in the balloon angle leads to higher yarn twists. This increase is distinctive for all types of yarn produced. The effect of spindle speed on twist, except for 30 tex yarn, was found to be unimportant.
- It was found that an increase in the balloon angle and spindle speed significantly increases the tenacity in all the yarns produced.
- Generally, it can be said that an increases in the balloon angle and spindle speed increases the elongation at break of yarns. However, this is not considered statistically significant.
- Statistically, it was proved that the effect of the balloon angle on yarn irregularities is unimportant. The effect of spindle speed on yarn irregularities, except for 20 tex yarn, was found to be insignificant. However, considering that yarn irregularities change at short intervals, this irregularity tendency should be taken into account.
- An increase in the balloon angle generally decreases the number of thick places. This decrease, especially for a α0.01 significance level, was found to be important for all the yarns pro-

duced. During an increase in spindle speed, the most important effect on thick places was found in 30 tex yarn.

- An increase in the balloon angle decreases the number of neps. This decrease is significant for 20 tex and 30 tex yarns. The effect of the increase in spindle speed on neps was found to be important in 20 tex and 30 tex yarn, but not in 15 tex yarn.
- According to the measurements carried out, no thin places were observed on the yarn in relation to the sensitivity determined.

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