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Investigation of the Properties of Selected Blended Yarn Produced in Air Jet Spinning (Vortex) Technology

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Abstract
In this study, selected air-jet blends of cotton, polyester, viscose and modal fibers were used. The quality values of the yarns produced in the air-jet spinning (Vortex) system were investigated. In the Vortex spinning system, yarns with a mixture ratio of 65/35% Polyester/Viscose, 65/35% Cotton/Polyester and 50/50% Cotton/Modal were produced. Cotton fibers grown in Şanlıurfa region were used in the study. Since polyester, viscose and modal average fiber lengths are longer than cotton fiber, they can be better positioned to the core of the yarn during spinning. Since air-jet spinning technology is a system where spinning is done very quickly, the short average fiber length makes it difficult to place the fibers in the yarn core.

Keywords: Fiber, Vortex, Yarn, Fabric, Air Jet

1. Introduction

In recent years, the expected developments in the spinning systems, as in all production systems, are mostly realized in the direction of increasing the production speed. The Air-jet spinning (Vortex) system is the last system that has become globally accepted and widespread among the spinning systems developed for this purpose. This system was first introduced by the MURATA Company in 1997. Among other mainstream spinning systems, 21 m/min in Ring spinning system and 350 m/min in Open-End Rotor spinning system can be reached, whereas in Vortex Air-Jet spinning system 500 m/min yarn production speed has been reached today. However, increasing yarn production speeds cannot be achieved at the same extent in yarn quality values. The system that best meets the expectations in terms of basic yarn properties such as strength, evenness and hairiness is the Ring spinning system, followed by the Open - End Rotor spinning system and after these the Vortex Air Jet spinning system comes. Studies on the yarns produced with the Vortex Air-Jet spinning system, which is increasingly preferred due to the advantage of production speed, and the improvement of the properties of the fabrics obtained from them, are continuing increasingly [1-2].

Core yarn production in Murata Vortex System has a significant effect on mechanical properties and Vortex core elastane yarns provide higher breaking elongation than Vortex yarns without elastane [4]. The cost of knitted fabric varies depending on the length of the yarn loop, hence its density and weight [1]. In cost calculations of fabrics with and without elastane, element costs can be calculated in a very short time with simple computer coding [5]. Different fibers such as tencel, modal, cotton, viscose and bamboo are used in summer seasons because they affect the fabric touch properties [6]. The fabrics produced using double-ply vortex and ring yarns in the warp and weft directions are statistically different [7].

Cotton (Co), Polyester (Pes), Viscose (Cv) and Modal (Cmd) fibers were used as raw materials within the scope of the study. Industrially, 65/35% Polyester/Viscose, 65/35% Cotton/Polyester, 50/50% Cotton/Modal blends are used in products that are frequently preferred by consumers. The yarns in these blends were used to obtain woven and knitted fabric surfaces [15].

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2. Material and Method

2.1. Properties of Fibers Used

Basic properties of polyester, viscose, cotton and modal fibers used in the study are given in Table 1 [15].

Table 1. Properties of Used Fibers in Application

Fiber Type	Fiber Fineness (mic./dtex)	Fiber Length (mm)	Fibers Tensile Strength (cN/tex)	Fiber Elongation at Break (%)
Cotton	4 mic - 1.57 dtex	29	32.54	5.4
Polyester	1.30 dtex	38	58.40	39.0
Viscose	1.30 dtex	38	19.00	24.0
Modal	1.30 dtex	38	34.00	17.0

2.2. Production Parameters of Vortex Yarns

The selected yarn production speed (450 m/min) for this study is in the range of values that are commonly suitable for weaving (400-500 rpm) and knitting (25-30 rpm) machines. The air pressure has been determined according to the fiber mixture type. Spindles and clips were selected according to the type of raw material (fiber) produced. The production parameters of Polyester/Viscose, Cotton/Polyester and Cotton/Modal blended yarns are given in Table 2. Among the needle holders specified in the given yarn production parameters, Orient type is used for the production of 100% synthetic yarns and Crown type used for the cotton/synthetic blended yarns [15].

Table 2. Yarn Production Parameters

Yarn Type / Production Parameters	Ne 28/1 65/35% PES/VIS	Ne 30/1 65/35% CO/PES	Ne 30/1 50/50% CO/CMD
Spindle Speed (m/min)	450	420	450
Vortex Clips	GRAY	GRAY	GRAY
Needle holder	ORIENT	CROWN	CROWN
Spindle type	M1	M1	M1
Spindle Distance (mm)	22	22	22
Pressure (bar)	0.50	0.50	0.54
Thread Ne	28	30	30
Sliver Ne	0.140	0.140	0.140

In the production, the yarns of Cotton, Polyester, Viscose and Modal fibers at the mixture ratios of 65/35% Pes/Cv, 65/35% Co/Pes and 50/50% Co/Cmd are produced at a production speed of 450 m/min, gray spinning clip, M1 type spindle and with 22 mm spindle distance.

The selected yarn properties for vortex yarn analysis are listed below.

- % Cvm; Coefficient of Variation of Mass
- -50%; Thin Place/km,
- +50%; Thick Place/km,
- +280%; Neps /km numbers,
- H; Yarn Hairiness,
- Rkm (Resistance of kilometer); for yarn strength, it is the length in kilometers at which the sample breaks with its own weight.

2.3. Statistical Analysis

In this study, the tests applied to textile products were analyzed by statistical method, model summary, analysis of variance and coefficient values in regression analysis. Each type was evaluated within itself. In the model summary results, R is a measure of the linear relationship between the two observed variables. The R value is an indicator of how well the model created fits the observed values. R^2 is used to compare regression models with the same number of explanatory variables. R and R^2 need to be close to 1. Thus, the reliability of the type falling into the rejection zone in the mixtures is analyzed. The analysis of variance analyzes the hypothesis between the variables by stating the importance of the regression analysis.

F test statistical value is calculated for these hypotheses. The calculated significance level of the test was evaluated. When the significance value is less than and equal to 0.025, the calculated F test statistical value falls into the rejection region. Evaluations were made in the mean squares value residual model. The non-standardized coefficients were calculated as the standard error in the B constant term parameter. T test statistic value calculated for B constant term parameter was analyzed. The significance level was evaluated. If the significance value is less than or equal to 0.025, the test value falls into the rejection region.

3. Results and Discussion

Parameters such as the distance between the front roller and the spindle, air nozzle angle, nozzle pressure, spindle diameter and yarn speed used in the vortex yarn production system affect yarn evenness. High nozzle angle and pressure, low yarn speed and small spindle diameter reduce hairiness. Low yarn speed causes low yarn diameter and increases the strength by taking more twist of the yarn. These production parameters are also valid for the production of microfilament yarns. The important factors affecting the relationship between the number of fibers in the yarn cross section, fiber tensile properties, twist stiffness and fiber friction forces are the machine process variables [8-11].

The yarn spun in the vortex spinning system reduces the pressure values on the swirl chamber wall and the sub-atmospheric pressure values in the inlet duct by approximately 50%, thereby reducing the value of the peripheral component of the air velocity. In woven fabrics where vortex yarns are used, low breaking force, low elongation and tensile properties are almost non-existent [12-13]. Specifically, processes with lower feed rate, larger spindle size and lower air pressure should be applied to produce softer and more voluminous yarn for knitted fabrics. More rigid and compact yarns can be produced for weaving while pursuing a higher feed rate, narrow spindle size and high pressure [14].

In Table 3, the test results of unevenness (CVm %) control, averages, standard deviations and coefficient of variation (CV %) of Polyester/Viscose, Cotton/Polyester and Cotton/Modal blended yarns measured in the physical textile laboratory are given. Yarn evenness (CVm %) is an important parameter that needs to be examined in order to determine the origin of the defects that occur during the vortex yarn production stages. It is seen that the test results of these three mixtures are close to each other. According to these results, the level of unevenness in the yarns is low. Accordingly, the winding of the fibers to each other in the core of the yarn was been regular. It has been determined that the average unevenness value of Cotton/Polyester yarns (16.83) is higher than Cotton/Modal blend yarn (13.30) and Polyester/Viscose blend yarn (14.28). The reason for this is that the average length of cotton fiber in Cotton/Polyester blends is shorter than other fibers.

In Table 4, thin place -50% test results, averages, standard deviations and coefficient of variation (CV%) of Polyester/Viscose, Cotton/Polyester and Cotton/Modal blended yarns measured in the physical textile laboratory are given. It is desired that the measurement results are low at -50% thin place values. It has been determined that the measurement result of Cotton/Modal yarns is lower than the other two blends. When the CV% results were checked, it was determined that the Polyester/Viscose and Cotton/Modal values were higher than the Cotton/Polyester values. The reason for this is that the cotton ratio was high and the yarn was produced as carded. The combing process ensures a reduction in all errors that may pass into the yarn with repeated combing processes. The CV% value in statistical results is generally requested not to exceed 10% in textiles. However, in mass unevenness types (thin place, thick place, neps etc.), this value can be much higher. Since values close to zero are desired in these error values, even a low number of mass uneven places in a different sample of the yarn can cause high CV% results. For this reason, the high CV% value in mass unevenness types is not considered as a problem.

Table 3. Test Results of Yarn Unevenness (CVm %)

Measurement	Ne 28/1 65/35% PES/VIS	Ne 30/1 65/35% CO/PES	Ne 30/1 50/50% CO/CMD
1.	14.010	16.290	13.110
2.	14.110	17.280	13.440
3.	14.900	16.940	13.080
4.	15.270	16.400	13.300
5.	15.350	16.860	13.250
6.	14.160	16.680	13.410
7.	13.320	17.150	13.880
8.	14.180	17.310	12.800
9.	13.960	16.480	13.420
10.	13.580	16.860	13.340
Average	14.280	16.830	13.300
Minimum	13.320	16.290	12.800
Maximum	15.350	17.310	13.880
St. Deviation	0.679	0.360	0.283
CV%	4.753	2.143	2.127

Table 4. Thin Place Test Results (-50%)

Measurement	Ne 28/1 65/35% PES/VIS	Ne 30/1 65/35% CO/PES	Ne 30/1 50/50% CO/CMD
1.	7.500	60,000	7.500
2.	2.500	125.000	5.000
3.	30.000	122.500	7.500
4.	15.000	77.500	7.500
5.	20.000	105.000	17.500
6.	7.500	90.000	5.000
7.	7.500	117.500	15.000
8.	7.500	125.000	0.000
9.	7.500	92.500	15.000
10.	7.500	112.500	0.000
Average	11.250	102.750	8.000
Minimum	2.500	60.000	0.000
Maximum	30.000	125.000	17.500
St. Deviation	8.186	22.187	6.101
CV%	72.766	21.594	76.262

In Table 5, thick place +50% test results of Polyester/Viscose, Cotton/Polyester and Cotton/Modal blended yarns measured in the physical textile laboratory are given as averages, standard deviations and coefficient of variation (% CV). Cotton/Polyester thick place measurements high results in all tests is due to the fact that the yarn was produced as carded and short fibers were high. The fact that the values in Cotton/Modal thick place control are close to each other and at low values is due to the fact that the yarn was produced as combed.

Table 5. Thick Place Test Results (+50%)

Measurement	Ne 28/1 65/35% PES/VIS	Ne 30/1 65/35% CO/PES	Ne 30/1 50/50% CO/CMD
1.	32.500	225.000	7.500
2.	52.500	310.000	10.000
3.	92.500	242.500	5.000
4.	82.500	185.000	5.000
5.	62.500	290.000	12.500
6.	60.000	285.000	12.500
7.	25.000	275.000	30.000
8.	80.000	332.500	5.000
9.	40.000	280.000	15.000
10.	20.000	295.000	17.500
Average	54.750	272.000	12.000
Minimum	20,000	185.000	5.000
Maximum	92.500	332.500	30.000
St. Deviation	25.233	43.265	7.710
CV%	46.088	15.906	64.250

In Table 6. Neps +280% test results of Polyester/Viscose, Cotton/Polyester and Cotton/Modal blended yarns measured in the physical textile laboratory are given as averages, standard deviations and coefficient of variation (CV%). Neps as well as other types of error of + 280% value is targeted to low. It has been determined that the average neps value of the Cotton/Polyester blend yarn was higher than the average value of the Polyester/Viscose and Cotton/Modal blend yarn. The high cotton/polyester tests are due to the fact that the yarn was produced as carded. The low Polyester/Viscose neps values are due to the fact that Polyester and Viscose fibers are longer than cotton fibers and that the fibers are better placed in the yarn structure. The low values of Cotton/Modal neps are due to the use of cotton as combed cotton.

Table 6. Neps Test Results (+280%)

Measurement	Ne 28/1 65/35% PES/VIS	Ne 30/1 65/35% CO/PES	Ne 30/1 50/50% CO/CMD
1.	0.000	90.000	5,000
2.	7.500	90.000	0.000
3.	7.500	97.500	5.000
4.	12.500	87.500	5.000
5.	10.000	85.000	2.500
6.	2.500	70.000	2.500
7.	2.500	82.500	7.500
8.	5.000	140.000	0.000
9.	7.500	70.000	0.000
10.	2.500	87.500	0.000
Average	5.750	90.000	2.750
Minimum	0.000	70.000	0.000
Maximum	12.500	140.000	7.500
St.Variance%	3.917	19.578	2.751
Cv	68.131	21.754	100.045

In Table 7, hairiness test results, averages, standard deviations and coefficient of variation (CV%) values of Polyester/Viscose, Cotton/Polyester and Cotton/Modal blended yarns measured in the physical textile laboratory are given. When the standard deviation and CV% values of the hairiness results of the blended yarns were checked, it was determined that the Cotton/Modal values were higher than the Cotton/Polyester and Polyester/Viscose values. It has been determined that all blends (Polyester/Viscose, Cotton/Polyester and Cotton/Modal blended yarns) have low hairiness values. The reason for this is that in the Vortex spinning system, the fibers are wrapped around themselves with the effect of the air vortex, significantly reducing the hairiness.

Table 7. Yarn Hairiness Test Results (H)

Measurement	Ne 28/1 65/35% PES/VIS	Ne 30/1 65/35% CO/PES	Ne 30/1 50/50% CO/CMD
1.	3.820	3.830	3.900
2.	3.840	3.960	3.900
3.	3.770	3.910	3.690
4.	3.830	3.910	4.140
5.	3.860	3.930	3.950
6.	3.900	3.890	3.950
7.	3.880	3.900	3.840
8.	3.840	3.950	3.650
9.	3.920	3.960	3.900
10.	3.870	3.940	3.870
Average	3.850	3.920	3.880
Minimum	3.770	3.830	3.650
Maximum	3,920	3,960	4.140
St. Deviation	0.042	0.039	0.137
CV%	1.114	1.012	3.540

Yarn strength test results are given in Table 8. Polyester/Viscose blend yarn strength measurement result of Cotton/Polyester and Cotton/Modal mixture was maintained higher than the yarn. This is due to the fact that Polyester and Viscose fibers can contribute more to yarn strength by being longer than cotton fibers, and the number of Polyester/Viscose blended yarn was at higher linear density than other yarns. When the individual tensile strength values of the fibers are examined, it is seen that the strength value of Polyester fiber is 58.4 cN/Tex and the strength value of Viscose fiber is 19 cN/Tex. For this reason, it is a natural result that the strength of the mixture increases as the polyester fiber ratio increases.

Table 8. Yarn Strength Test Results (Rkm)

Measurement	Ne 28/1 65/35% PES/VIS	Ne 30/1 65/35% CO/PES	Ne 30/1 50/50% CO/CMD
1.	25.800	11.160	12.850
2.	25.890	11.860	12.410
3.	23.270	13.500	13.050
4.	24.590	13.380	14.980
5.	21.090	12.690	16.050
6.	25.020	13.590	15.690
7.	24.720	14.300	14.450
8.	25.420	12.420	15.040
9.	28.000	12.280	14.620
10.	27.890	11.780	13.260
Average	24.570	12.700	14.240
Minimum	21.090	11.160	12.410
Maximum	28.000	14.300	16.050
St. Deviation	2.026	0.979	1.263
CV%	8.247	7.714	8.866

In Figure 1, images were taken from three randomly selected regions in Ne 28/1 65/35% Polyester/Viscose blended yarn, and the placement of the fiber in the yarn is presented. Although polyester and viscose fibers are long fibers, not all of the fibers can be placed in the yarn core in the air-jet yarn production system. In image (a), it is seen that the ends of the fibers remain on the yarn surface. In cases where the air circulation in the air jet was not at sufficient pressure, it causes less false twist. For this reason, the strength is low in such regions and the Neps is high. Yarn properties such as thin place, thick place and yarn unevenness show irregularity in this region. In image (b), it is seen that the fibers were placed regularly in the yarn core. On the other hand, in image (c), it is seen that the fibers did not settle in the yarn core sufficiently and were placed irregularly. For this reason, high hairiness is obtained in knitted fabrics woven with these yarns.

a) b) c)

Figure 1. Ne 28/1 65/35% Polyester/Viscose Yarn Images.

In Figure 2, images were taken from three randomly selected regions in Ne 30/1 65/35% Cotton/Polyester blended yarn, and the placement of the fiber in the yarn core was presented. Cotton fibers are short fibers. Due to this feature, the fibers cannot fully adhere to each other in the yarn core. Thus, the yarn strength is low; neps, thin places, thick places and yarn unevenness are high. In image (a), it was seen that some of the polyester fiber remains on the yarn surface. In images (b) and (c), it is seen that the fibers were regularly placed in the yarn core compared to (a).

a) b) c)

Figure 2. Images of Ne 30/1 65/35% Cotton/Polyester Yarn.

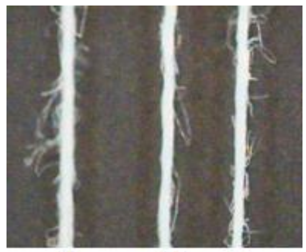
In Figure 3, Ne 30/1 50/50% Cotton/Modal yarn placement images of the fibers in the core of the yarn were given from three randomly selected regions. Cotton fibers are in the short staple fiber group. For this reason, the fibers cannot fully adhere to each other in the yarn core. Thus, the yarn strength was low. The cotton fiber used in this mixture was produced by the sensitive combing process in the combing machine. For this reason, low neps, thin places, thick places and yarn unevenness were obtained. In images (a), (b) and (c), it is seen that the yarn properties were regular.

a) b) c)

Figure 3. Images of 50/50 Cotton/Modal Yarn.

In Figure 4, the layout images of the fibers in the blended vortex yarn were given. Images of (a) yarn Cotton/Polyester, (b) yarn Polyester/Viscose and (c) yarn Cotton/Modal blended yarns were given. In polyester/viscose blended yarn, the fibers were better attached to the yarn core. In Cotton/Polyester yarn, the fibers could not be fully embedded in the yarn core. It was seen in the images that the fibers are regularly attached to the yarn core in Cotton/Modal yarn.

In Table 9, Table 10 and Table 11 the results of model summary, analysis of variance and coefficient values in regression analysis are given. In the model summary, analysis of variance and coefficient analysis results, the reliability is low by falling into the Cotton/Modal rejection region. The reliability of the other two mixtures is high.



a) b) c)

Figure 4. Blended Vortex Yarn Images

Table 9. Statistical Analysis of Yarn Unevenness

			28/1 % 65/35 Pes/Cv	30/1 % 65/35 Co/Pes	30/1 %50/50 Co/Cmd
Model Sumary	R		0.181	0.161	0.411
	R^2		0.033	0.026	0.169
Analysis of Variance	Sum of Squares	Regression Model	2.704	2.130	13.947
		Residue Model	79.796	80.370	68.553
	Average Square	Regression Model	2.704	2.130	13.947
		Residue Model	9.974	10.046	8.569
	F		0.271	0.212	1.628
	Meaningfulness		0.617	0.657	0.238
Coefficient	Unstandardized Coefficients	B	2.613	1.868	-2.440
		Standard Error	5.018	4.057	1.913
	Beta		0.181	0.161	-0.411
	T		0.521	0.460	-1.276
	Meaningfulness		0.617	0.657	0.238

Table 10. Yarn Hairiness Statistical Analysis

			28/1 % 65/35 Pes/Cv	30/1 % 65/35 Co/Pes	30/1 %50/50 Co/Cmd
Model Sumary	R		0.329	0.492	0.183
	R^2		0.108	0.242	0.034
Analysis of Variance	Sum of Squares	Regression Model	1.084	2.425	2.772
		Residue Model	8.916	7.575	79.728
	Average Square	Regression Model	1.084	2.425	2.772
		Residue Model	2.972	2.525	9.966
	F		0.365	0.960	0.278
	Meaningfulness		0.588	0.399	0.612
Coefficient	Unstandardized Coefficients	B	15.487	16.164	-4.046
		Standard Error	98.058	16.496	7.673
	Beta		0.329	0.492	-0.183
	T		0.604	0.980	-0.527
	Meaningfulness		0.588	0.399	0.612

Table 11. Yarn Strength Statistical Analysis

<table>
<tr><td colspan="3"></td><td>28/1 % 65/35 Pes/Cv</td><td>30/1 % 65/35 Co/Pes</td><td>30/1 %50/50 Co/Cmd</td></tr>
<tr><td rowspan="2">Model Sumary</td><td colspan="2">R</td><td>0.048</td><td>0.127</td><td>0.399</td></tr>
<tr><td colspan="2">R^2</td><td>0.002</td><td>0.016</td><td>0.159</td></tr>
<tr><td rowspan="6">Analysis of Variance</td><td rowspan="2">Sum of Squares</td><td>Regression Model</td><td>0.187</td><td>1.331</td><td>13.104</td></tr>
<tr><td>Residue Model</td><td>82.313</td><td>81.169</td><td>69.396</td></tr>
<tr><td rowspan="2">Average Square</td><td>Regression Model</td><td>0.187</td><td>1.331</td><td>13.104</td></tr>
<tr><td>Residue Model</td><td>10.289</td><td>10.146</td><td>8.674</td></tr>
<tr><td colspan="2">F</td><td>0.018</td><td>0.131</td><td>1.511</td></tr>
<tr><td colspan="2">Meaningfulness</td><td>0.896</td><td>0.727</td><td>0.254</td></tr>
<tr><td rowspan="5">Coefficient</td><td rowspan="2">Unstandardized Coefficients</td><td>B</td><td>-0.071</td><td>0.393</td><td>0.955</td></tr>
<tr><td>Standart Hata</td><td>0.528</td><td>1.084</td><td>0.777</td></tr>
<tr><td colspan="2">Beta</td><td>-0.048</td><td>0.127</td><td>0.399</td></tr>
<tr><td colspan="2">T</td><td>-0.135</td><td>0.362</td><td>1.229</td></tr>
<tr><td colspan="2">Meaningfulness</td><td>0.896</td><td>0.727</td><td>0.254</td></tr>
</table>

In the model summary analysis, the Cotton/Modal blends fall into the rejection region and the reliability is low. The reliability of the other two mixtures is high. In variance analysis and coefficient analysis, no mixture fell into the rejection region and its reliability is high.

In the model summary analysis, all mixtures fall into the rejection region and the reliability is low. In the analysis of variance and coefficient analysis, no mixture fell into the rejection region and its reliability is high.

4. Conclusions

Average fiber length was shorter than other fiber types used in cotton fiber blends. It has been observed that all quality values give better results when yarn linear density increases in blended yarns. This is in terms of strength-related properties; the linear density of the strains in the yarn structure is due to the fact that the strain per unit fiber occurs at a lower level due to the high number of fibers in the cross section in higher yarns. In addition, the excess number of fibers in the cross-section contributed to the increase in the number of fibers that can be properly placed in the yarn core, resulting in an improvement in other yarn quality values.

As the ratio of polyester, viscose and modal fibers in the mixture increased, positive developments were observed in the yarn test results. Since polyester, viscose and modal average fiber lengths are longer than cotton fiber, those can be better positioned to the core of the yarn during spinning. Since air-jet spinning technology is a system where spinning is done very quickly, the high average fiber length makes it easier for the fibers to settle into the yarn core. In addition, since the strength value of (58.4 cN/Tex) polyester fibers is higher than cotton (58.4 cN/Tex) fibers, the strength of cotton-free polyester blends was higher than those containing cotton in the test results.

By looking at the test and image results of the blended yarns, it was determined that the best results of Yarn Evenness, Thin Place, Thick Place and Neps yarn properties were in Cotton/Modal yarn. By looking at the test and image results of these yarns, it has been determined that the best results of Hairiness and Strength yarn properties are in Polyester/Viscose yarn.

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