(REFEREED RESEARCH)

HVI LİF ÖZELLİKLERİNİ KULLANARAK KOMPAKT İPLİKLERİN MUKAVEMET VE DÜZGÜNSÜZLÜKLERİNİN TAHMİNLENMESİ

ESTIMATION OF TENSILE STRENGTH AND UNEVENNESS OF COMPACT-SPUN YARNS BY USING HVI FIBER PROPERTIES

Memik Bünyamin ÜZÜMCÜ[1*], Hüseyin KADOĞLU[2]

[1]Bartın University, Department of Textile Engineering, Bartin, Turkey
[2]Ege University, Department of Textile Engineering, Bornova / İzmir, Turkey

Received: 13.07.2018 Accepted: 24.09.2018

ABSTRACT

Compact spinning system, which has begun to gain an important place in textile industry, thanks to its desired yarn characteristics, was developed in the early 2000s. Less hairy yarns can especially be produced with this system, as stated in the literature. Moreover, the system has significant advantages in terms of tensile strength. In this study, yarns were produced with different yarn counts (Ne 40 - Ne 90) and different twist coefficients (αe 3.8, αe 4.2 and αe 4.6) using the compact spinning system. Regression analysis was carried out using the test results of the yarns produced and HVI fiber properties which were measured before the production. It was investigated whether the properties of the yarns can be estimated before production by using specified fiber properties. As a result of the analysis, the derived equations were used to estimate tensile strength and unevenness values of the yarns.

Keywords: Compact spinning system, fiber properties, HVI, yarn properties, estimation.

ÖZET

Tekstil endüstrisinde, sunmuş olduğu farklı iplik karakteri sayesinde, önemli bir yer edinmeye başlayan kompakt iplik eğirme sistemi 2000'li yılların başında geliştirilmiştir. Bu sistem ile, literatürde de belirtildiği üzere, özellikle daha az tüylü iplikler üretilebilmektedir. Bunun yanı sıra, mukavemet açısından da sistemin önemli avantajları bulunmaktadır. Bu çalışmada kompakt iplik eğirme sistemi kullanılarak farklı numaralarda (Ne 40- Ne 90 aralığında) ve farklı büküm katsayılarında (αe 3.8, αe 4.2 ve αe 4.6) iplikler üretilmiştir. Üretimler öncesinde ölçülen HVI lif özellikleri ile üretilen ipliklerin test sonuçları kullanılarak regresyon analizi yapılmıştır Analiz sonucunda lif özellikleri belirlenmiş olan ipliklerin, özelliklerinin üretim öncesinde tahminlemelerinin yapılıp yapılamayacağı incelenmiştir. Analiz sonucunda türetilen denklemler ile mukavemet ve düzgünsüzlük değerlerinin tahminlemesi yapılmıştır.

Anahtar Kelimeler: Kompakt eğirme sistemi, lif özellikleri, HVI, iplik özellikleri, tahminleme

Corresponding Author: Memik Bünyamin Üzümcü, muzumcu@bartin.edu.tr

1. INTRODUCTION

Compact spinning system was developed at the beginning of the 2000s and has become a preferred system in the market, due to characteristics of the yarns it produces. This system enables the production of yarns with lower hairiness and higher tensile strength, as described in the literature (1-4). As is known, major reason of hairiness is spinning triangle which occurs at the exit of the delivery cylinders (5).

Compact spinning system was developed with modifications made to the drafting zone of ring spinning system and the aim of this was to eliminate the spinning triangle. Although it is not completely possible to eliminate the spinning triangle, the base length of the spinning triangle can be reduced by compacting the fiber bundle with the parts added to the drafting zone. Thus, the fibers which increase the hairiness by joining the yarn at one end are totally joined to the yarn body and that way the tensile strength can also be increased.

There are different types of compact spinning systems in the market. While most of them perform compacting using negative air pressure, some systems uses magnetic mechanical principles (6). In literature, there are studies comparing systems using negative air pressure, as well as comparing them with systems using magnetic mechanical principles (7-9). However, as a general result, most of the studies concluded that all of these compact spinning systems are superior to conventional ring spinning system, especially in terms of tensile strength and hairiness.

Fiber properties need to be known, as yarn producer have to adjust some machine parameters according to them besides quality of raw material. According to spinning system, some fiber properties become more important in terms of spinning quality. Fiber length is crucial in ring and airjet spinning while fiber strength has more importance in open-end spinning system (10). HVI and AFIS systems are devices developed by Uster, which are used for determination of fiber properties. In fiber standardization, the HVI device has a great importance. Before this device; fiber properties such as strength, elongation and fineness were measured with Pressley tester, Stelometer and Fibronaire (11). After the development of the device, it became possible to obtain more detailed information about fiber in one device and to standardize it accordingly. With current technology, the device can test properties such as fiber fineness, length, strength, elongation, lightness, yellowness, trash and nep number (12). Some of these features were also used in our study.

Producers make a number of production experiments while developing new products or improving existing products. These experiments cause additional raw material, energy and labor costs. Estimation takes place at this point. By using the features of the inputs used in production, it is possible to estimate the results with statistical methods. There are studies in the literature where these methods are used for the textile industry. Some of these studies focus on estimation of yarn strength, breaking extension, unevenness, hairiness and IPI faults as well as fabric properties. Üreyen and Kadoglu used regression analysis for estimation of ring spun yarns' tensile strength, breaking elongation, unevenness and hairiness values by using HVI and AFIS fiber properties (13,14). Faulkner et al also investigated the effects of fiber properties (used HVI and AFIS test results) to ring-spun yarn properties by using regression analysis (15). Üreyen and Gürkan used regression analysis and artificial neural network, in order to predict hairiness and unevenness values of ring-spun yarns (16). Furferi and Gelli used artificial neural network for predicting tensile strength of ring-spun yarns produced from different fibers by using fiber properties (17). Bedez Üte and Kadoglu used regression analysis to estimate tensile strength and unevenness of siro-spun yarns by using HVI and AFIS properties of the fibers used in productions (18,19). Uzumcu and Kadoglu used HVI fiber values for predicting IPI fault values of compact-spun yarns (20). Gurkan Unal used artificial neural network and response surface methods for evaluating the effects fiber properties on spliced yarn characteristics (21,22). For predicting the pilling tendencies of cotton interlock knitted fabrics, Kayseri used both regression analysis and artificial neural network methods in their studies (23,24). Sari and Oglakcioglu also used regression analysis in their study about pressure characteristics of medical stockings (25). Not only for cotton yarns, cotton waste containing yarn properties were also tried to be explained by using correlation with fiber properties by Telli and Babaarslan (26). Positive results were obtained in most of these studies where various methods such as regression analysis and artificial neural networks were used for estimation.

In this study, it was investigated that how fiber properties effect yarn properties and if it is possible to determine yarn properties before production, in case of using compact spinning system. For this purpose, yarns were produced by compact spinning system using rovings produced from different blends. Data gathered from previous studies about predicting yarn properties indicated that various types of analysis were performed for properties of coarse (≤Ne 40) yarns produced with ring, rotor, siro and vortex spinning systems. In our study, fine yarns (≥Ne 40) were produced by using compact spinning system and regression analysis was performed by using the properties of the fibers measured by HVI and some yarn parameters (yarn count, twist coefficient) and as a result the estimation equations were developed.

2. MATERIAL AND METHODS

In this study, it was aimed to estimate the properties of cotton compact-spun yarns. For this reason, cotton fibers of different properties were used and initially properties of these fibers were tested. Uster HVI was utilized in determining the fiber properties. Fiber tests were carried out after combing process, because resultant fiber properties were needed for our estimation equations.

Rovings from different cotton blends were produced in Söktaş Dokuma İşletmeleri San. Ve Tic. A.Ş. Rovings were produced with two different counts (Ne). These roving counts were Ne 1.3 (for 7 blends) and Ne 2.0 (for 4 blends). Thus, yarn productions were started by using 11 different blend types. Unevenness values of the rovings used in the productions were measured with Uster Tester 5 device.

Machine settings which should be used in the production were determined before the yarn productions started. For this purpose, we interviewed industrialists and moreover, made a preliminary experiment using Taguchi experimental design, which included the factors of spacer type, spindle speed and ISO of traveller. In this preliminary experiment, three different types of spacers, three weights of traveller and three speed for spindle were used in the range suggested by the machine manufacturer, and the levels that provided the highest strength and the lowest unevenness / hairiness values according to the Taguchi method were preferred in the productions. By the means of yarn count, yarns were produced starting from the thinnest yarn number that can be produced with the rovings in hand, to thicker numbers. Productions of six different yarn counts (Ne 40, Ne 50, Ne 60, Ne 70, Ne 80 and Ne 90) were intended, after preliminary tests for both roving counts (Ne 1.3 and Ne 2.0). However, due to technical limitations of the machine, yarns finer than Ne 70 could not be produced by using rovings with Ne 1.3 count. The final production plan created as a result of the preliminary studies is given in Table 1 and the machine settings used in the productions are given in Table 2. Productions were carried out using Rieter K45 compact spinning machine.

One of the most important things taken into consideration in yarn production was that productions were always done using the same spindles. For this reason, firstly, a code number was given to rovings which were tested according to the standard. In the second stage, 20 spindles of which had non-problematic drafting and twisting zones were selected and given code numbers. These code numbers of roving and spindles were written on each of the produced cops. Therefore, the results obtained from the tests were evaluated considering which roving and which spindle was used in the production of the yarn. As a precaution against errors that may occur in tests, backup for every single cop was produced.

Table 1 Production plan

Roving count (Ne)	Yarn count (Ne)	Twist coeeficient (α_e)		
		3.8	4.3	4.8
1.3	40	+	+	+
	50	+	+	+
	60	+	+	+
	70	+	+	
2.0	40	+	+	+
	50	+	+	+
	60	+	+	+
	70	+	+	+
	80	+	+	+
	90	+	+	

Table 2 Machine settings

Yarn count (Ne)	Spindle speed (rpm)	Spacer (mm)	Traveller (ISO)
40	17000	3.25	31.5
50		3.25	25
60		3.00	22,4
70		3.00	20
80		2.75	18
90		2.75	16

For each yarn type, ten cops were used in the tests. These cops were conditioned and subjected to yarns tests according to the standards. Unevenness tests were performed using Uster Tester 5 and Uster Tensorapid 4 was used for tensile strength tests.

Data gathered from the tests were used for correlation analysis by using SPSS and for regression analysis using GRETL. Correlations between the fiber properties were determined and fiber properties with least correlation with other fiber properties were selected in order to be used in further analysis. In the regression analysis part, control tests were performed after analysis. With these tests, heteroscedasticity, collinearity and distribution of residuals were examined. The validity and reliability of the estimation equations were ensured by making necessary corrections according to results of these tests.

3. RESULTS

In this study, blends with different mean fiber properties were used and the effects of fiber properties on yarn properties were investigated. Initially, fiber properties were obtained by using Uster HVI. Test results are given in Table 3.

In accordance with the aim of the study, ANOVA test was conducted to determine whether the fiber test results of blends were statistically different. Results of this test showed that differences between blends were statistically significant ($p=0.00 <0,05$).

Correlations between fiber properties and yarn properties (yarn count and twist coefficient) which were planned to be used as independent variables were also examined. The results of this analysis are given in Table 4. According to the correlation in between fiber properties (if they were high), some of them were not used in regression analysis, as mentioned before. The reason for this was that the use of two highly correlated fiber values together in the regression analysis would have caused a virtual rise in the relationship between fiber properties and yarn property which was aimed to be estimated. Then, correlation between the fiber properties and the measured yarn properties was investigated. What is important here is that generally, fiber properties which had a relatively high correlation with the yarn property that would be estimated were used. The results of the analysis are shown in Table 5.

Table 3 HVI results of 11 different blends

Blend	UHML	UI	Str	Elg	SFI	Mst	Mat	Mic	Rd	+b	SCI
B1	30.57	83.35	39.50	5.3	5.95	5.70	0.870	4.105	79.65	10.10	171
B2	31.57	84.50	43.40	5.3	5.60	5.90	0.885	4.840	78.15	11.70	182.5
B3	31.53	84.10	39.10	5.5	5.70	5.80	0.880	4.650	77.10	11.70	169
B4	31.19	84.00	40.80	4.9	5.75	5.55	0.880	4.610	75.05	11.25	172
B5	30.28	84.30	41.00	5.2	5.90	5.25	0.890	4.965	82.80	9.45	173
B6	26.42	83.30	28.30	4.7	7.50	6.00	0.895	5.230	80.30	11.35	121
B7	26.87	83.20	29.85	4.6	7.35	5.65	0.890	4.895	79.75	11.05	129
B8	31.67	83.95	39.80	5.4	5.90	6.00	0.880	4.750	77.90	11.35	171
B9	30.38	82.30	40.10	5.1	6.50	5,50	0.890	4.900	73.30	12.10	158
B10	30.36	83.75	39.65	4.9	5.85	5.50	0.880	4.585	80.35	10.85	170
B11	27.70	84.05	30.60	5.2	6.40	5.65	0.880	4.810	80.65	10.85	138

Table 4 Correlation analysis results for HVI fiber properties

	(Ne)	(T/m)	SCI	MIC	STR	LEN	UNF	SFI	ELG	Rd	B	Mat
(Ne)	1	0.751*	0.148*	-0.101*	0.177*	0.173*	-0.077*	-0.097*	0.153*	-0.174*	0.106*	-0.069*
(T/m)	0.751*	1	0.142*	-0.090*	0.167*	0.162*	-0.056	-0.095*	0.131*	-0.145*	0.079*	-0.061
SCI	0.148*	0.142*	1	-0.492*	0.969*	0.955*	0.437*	-0.950*	0.693*	-0.179*	-0.086*	-0.454*
MIC	-0.101*	-0.090*	-0.492*	1	-0.375*	-0.443*	-0.028	0.519*	-0.393*	-0.004	0.371*	0.931*
STR	0.177*	0.167*	0.969*	-0.375*	1	0.956*	0.262*	-0.868*	0.630*	-0.348*	0.049	-0.314*
LEN	0.173*	0.162*	0.955*	-0.443*	0.956*	1	0.321*	-0.908*	0.744*	-0.390*	0.126*	-0.447*
UNF	-0.077*	-0.056	0.437*	-0.028	0.262*	0.321*	1	-0.581*	0.404*	0.490*	-0.273*	-0.142*
SFI	-0.097*	-0.095*	-0.950*	0.519*	-0.868*	-0.908*	-0.581*	1	-0.755*	0.096*	0.112*	0.561*
ELG	0.153*	0.131*	0.693*	-0.393*	0.630*	0.744*	0.404*	-0.755*	1	-0.091*	-0.040	-0.494*
Rd	-0.174*	-0.145*	-0.179*	-0.004	-0.348*	-0.390*	0.490*	0.096*	-0.091*	1	-0.780*	-0.036
B	0.106*	0.079*	-0.086*	0.371*	0.049	0.126*	-0.273*	0.112*	-0.040	-0.780*	1	0.364*
Mat	-0.069*	-0.061	-0.454*	0.931*	-0.314*	-0.447*	-0.142*	0.561*	-0.494*	-0.036	0.364*	1

*Significant for p=0,01

Table 5 Correlation analysis results for yarn and HVI fiber properties

	Tensile Strength (cN/tex)	Breaking Elongation (%)	Unevenness	Thin Places (-50%)	Thick Places (+50%)	Neps (+200%)	Hairiness (H)
Measured Ne	0.003	-0.672*	0.652*	0.583*	0.438*	0.468*	-0.723*
Measured T/m	0.074*	-0.265*	0.477*	0.369*	0.305*	0.304*	-0.795*
MIC	-0.358*	-0.064*	0.179*	0.165*	0.286*	0.225*	0.084*
STR	0.851*	-0.029	-0.420*	-0.348*	-0.549*	-0.508*	-0.277*
LEN	0.827*	-0.038	-0.416*	-0.348*	-0.564*	-0.538*	-0.287*
UNF	0.292*	0.026	-0.382*	-0.198*	-0.326*	-0.302*	-0.051
SFI	-0.772*	-0.059	0.531*	0.404*	0.641*	0.595*	0.256*
ELG	0.581*	-0.091*	-0.276*	-0.239*	-0.486*	-0.501*	-0.260*
Rd	-0.165*	0.084*	-0.112*	0.037	0.037	0.068	0.197*
B	-0.152*	-0.146*	0.235*	0.087*	0.151*	0.119*	-0.069*

*Significant for p=0.01

Ordinary least squares method was used in regression analysis. The results of this multiple regression analysis technique, in which the effects of many independent variables to a single dependent variable can be examined, were obtained [27]. As a result of the analysis made for tensile strength, only statistically significant value was found to be the fiber strength. Tests were also carried out to determine the validity of the regression. The “White’s test” was used to evaluate heteroscedasticity and because of negative result of this test, analysis was repeated with heteroscedasticity corrected option of GRETL. R^2 value was found to be 0.82 and Akaike criterion was 4896.96 (Table 6). The graph of measured vs estimated yarn strengths is given in Figure 1.

In the analysis for unevenness, the relation between the fiber properties and Uster % CV values of yarns was investigated, initially. For this purpose, curve fitting was used in the study, like Ureyen performed in his study and fiber properties, which were not in a linear relationship with the dependent variable, were converted into new variables to provide linearity (28). Fiber strength, micronaire and short fiber index, which had statistically significant role according to the analysis, were used in estimation equation. In order to reach the highest R^2 values, uniformity was excluded.

Foretold conversions were done and new independent variables were defined as follows:

- Quadratic fiber strength (QSTR)= 34.35 – 1.031 x fiber strength (STR) + 0.01305 x fiber strength^2 (STR^2)
- Cubic short fiber index (CSFI)= 286.3 – 130.6 x short fiber index (SFI) + 20.62 x short fiber index^2 (SFI^2) – 1.070 x Short fiber index^3 (SFI^3)

Regression analysis was performed using new independent variables obtained with conversions. Estimation equation was gathered by regression analysis and this equation and R^2 values are given in Table 7. The graph of measured and estimated unevenness values is given in Figure 2.

Table 6 Estimation equation for tensile strength

Estimated Value	Estimation equation	R^2	Adj. R^2
Tensile Strength (cN/tex)	1.57153 – 0.0342010 x Ne + 0.123803 x α_e + 0.149382 x CVm + 0.542162 x STR	0.82	0.82

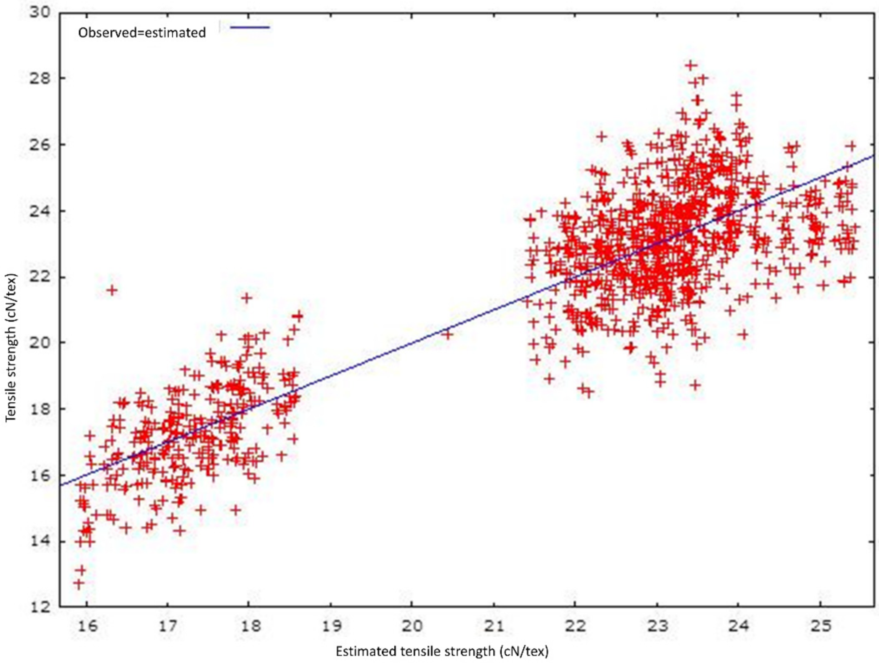

Figure 1 Estimated-Observed Tensile strength values

Table 7 Estimation equation for unevenness

Estimated Value	Estimation equation	R^2	Adj. R^2
Unevenness (cN/tex)	-6.29767+ 0.0583889 x Ne - 0.594462 x Mic + 0.815532 x CSFI + 0.598781 x QSTR	0.82	0.82

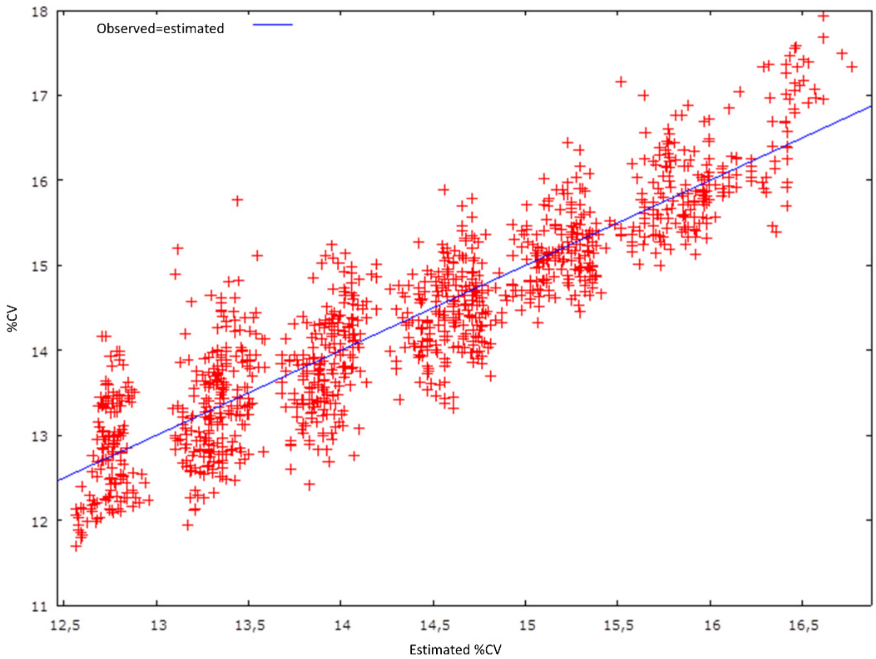

Figure 2 Estimated-Observed unevenness values

Both tensile strength and unevenness analysis were examined via controlling variance inflation factors (VIF). Collinearity was controlled by this way and in both analyzes, results of this test were found to be within the necessary limits.

4. DISCUSSION

The aim of this work was to determine the yarn properties by using raw material properties, before spinning. The estimation equations obtained for this purpose as result of the regression analysis were given. The data obtained in these analyzes (approximately R^2 = 0.82 for both) were found at a satisfactory level.

When the studies of Bedez Üte on estimation of siro-spun yarn properties and Ureyen's on estimation of ring-spun yarn properties were examined, it was seen that both studies can determine the yarn strength and unevenness values well, by using the estimation equations developed by regression analysis (12,28). However, when these two studies were compared, it was found that regression analyzes for the ring-spun yarns resulted with higher R^2 values. Moreover, this value (R^2) seems to be even lower, in comparison with both studies, in our study. Though more investigation will be made in this matter, our first thought was that the siro spinning system, compared to the ring spinning system, brought yarn properties closer to the theoretically expected values by minimizing the problems caused by the system. Since this effect is more valid in the compact spinning system, our R^2 value was thought to be lower than the siro system. In other words, it was believed that the effect of the spinning system on the yarn is higher in these cases. In Siro spinning system, the two pre-yarns are twisted together and form a yarn, so that a problem that may occur in each yarn caused by any fiber property may be eliminated randomly. Likewise, in the compact spinning system, due to compacting, fibers that normally would not be able to join might be added to the yarn body and caused changes in yarn properties. That is to say, although the fiber properties were different from each other, system reduced effects of some of them which may normally have a negative effect on yarn properties. This topic is planned to be examined in detail in following studies.

In this study, it was also aimed to estimate hairiness, one of the most important yarn properties. However, as mentioned before, the correlation between fiber properties and hairiness was very low due to the effect of the system. Correlations of hairiness with fiber length and short fiber ratio which were normally expected to be high, were at the Pearson coefficient levels of 0.287 and 0.256, respectively, as can be seen from Table 3. For this reason, the estimation equation for hairiness value could not be developed with HVI data.

5. CONCLUSION

With this work, it was aimed to develop estimation equations which we hope to lead the industrialists who produce yarn and piled a lot of fiber and yarn data. It is believed that having prior knowledge of the yarn without increasing costs of additional raw materials, labor and energy may increase the competitiveness of the yarn producers. Positive results were obtained for tensile strength and unevenness (R^2 = 0.82). Yarns were produced to examine the estimation precision and their test results and the results obtained from the estimation equations were compared. Estimations had close results to tests of the yarns produced, and this helped us to state that these estimation equations can be usable for spinners.

6. ACKNOWLEDGEMENT

Authors would like to thank Söktaş Dokuma İşletmeleri San. Ve Tic. A.Ş,, Göl İplik Şeremet Tekstil San ve Tic. A.Ş. and Mr. Ali Galip BAYRAKTAR for their valuable helps during the study.

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