(REFEREED RESEARCH)

PARAMETERS AFFECTING THE PROPERTIES OF THE S PLICED COTTON/ELASTANE BLENDED CORE YARNS

UÇ BİRLEŞTİRME İŞLEMİ GÖRMÜŞ PAMUK/ELASTAN KARIŞIMLI ÖZLÜ İPLİKLERİN ÖZELLİKLERİNİ ETKİLEYEN PARAMETRELER

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ABSTRACT

In this study, cotton/elastane blended core yarns in the yarn count of 20 tex with different twist factors and elastane linear densities were produced in order to determine the parameters which affect the properties of the splicing zone in winding process. After several trials, it is observed that the parameters affecting the breaking strength are splicing air pressure, splicing time, twist factor and elastane linear density for cotton/elastane yarns spliced with the elasto-splicer. The parameters which affect breaking elongation and the diameter of the spliced yarn are splicing air pressure and twist factor.

Key Words: Cotton/elastane blended yarns, Splicing, Strength, Elongation, Yarn diameter.

ÖZET

Bu çalışmada, bobinleme işleminde uç birleştirme bölgesinin özelliklerini etkileyen parametrelerin belirlenmesi amacıyla, iki farklı büküm katsayısı ve elastan numarası kullanılarak 20 tex iplik numarasında pamuk/elastan karışımlı özlü iplikler üretilmiştir. Elasto uç birleştirme mekanizması ile yapılan denemeler sonucunda uç birleştirme bölgesinin kopma mukavemeti özelliğini, üfleme havası, üfleme süresi, pamuk/elastan karışımlı ipliklerin büküm katsayısı ve elastan numarası etkilemektedir. Kopma uzaması ve uç birleştirme işlemi görmüş ipliğin çapı üfleme havası ve büküm katsayısından etkilenmektedir.

Anahtar Kelimeler: Pamuk/Elastan karışımlı iplik, Uç birleştirme, Mukavemet, Uzama, İplik çapı.

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1. INTRODUCTION

In weaving process, it is necessary to carry out winding process because of the bobbin size coming from the ring spinning mill. The length of the yarn in a bobbin is not adequate to run the downstream processes efficiently. The winding process therefore has the basic function of obtaining a larger package from several ring bobbins. This conversion process provides possibility of cutting out unwanted and problematic objectionable faults. The process of removing such objectionable faults is called as yarn clearing.

When the objectionable faults are cut out, to maintain continuity of the yarn in the wound package, two yarn ends have to be joined together by means of splicing which is carried out on automatic winding machines. Till now, a lot of yarn end joining methods have been developed because of the difficulties in joining yarn ends based on the usage of various materials in yarn production. Besides standard splicer, elasto-splicer and injection-elasto-splicer which have been developed especially for cotton elastane blends of core yarns can be used in winding process. In standard splicing, the cut yarn ends are overlapped in a turbulence air chamber and joined by an air blast that is adjustable in duration and consumption of compressed air to produce quality spliced yarns.

The elasto-splicer is a further development of the standard splicer, functioning on the pneumatic principle, especially designed for efficiently splicing core yarns via designing of the yarn opening tube. For the blends of elastane/cotton core yarns when standard splicer is used in splicing process, elastane yarn ends remain free between the cotton fibres and the ends of elastane yarn are not joined together. However, using elasto-splicer is an advantage while elastane yarn ends are kept close by in splicing zone, thus physical properties of the spliced area gets better. In injection splicing, the splicer type is different from the basic pneumatic principle only in that a small quantity of water is added to the splicing air. Injection splicer can also be combined with elasto-splicer. The thermo-splicer is used for splicing yarns of wool and wool blends. In thermo-splicer, temperature of the splicing air is adapted exactly to the properties of the animal fibres to be spliced. Localized heating in the splicing zone allows making good use of the thermoplastic properties of the fibres, resulting in the spliced joints.

Few researches have been done about the parameters affecting the spliced yarn's properties. The effect of material type on the spliced yarn properties was investigated and found that increasing of fibre to fibre friction increases the strength properties of the spliced yarns due to the compact yarn structure (1). Adding of polyester fibre in the blended yarns also cause an increase in the strength properties (2). The effect of twist factor on the strength properties of yarns was investigated and it is found that if the high twisted yarns aren't untwisted sufficiently in case of inadequate opening air pressure which will cause a decrease in the strength values (3,4). The effect of different spinning methods was investigated and the best results were obtained from the ring spun spliced yarns (4,5). It was found that opening air pressure has an effect on the yarn properties of the spliced yarns (5,6). Increasing of the splicing air pressure increases the strength properties of the cotton/polyester blended yarns (1) whereas in an another study it was found that splicing air pressure affects the strength properties of the yarns in a nonlinear way which means after a threshold value it causes a decrease (4). Overlapping length of the yarn ends participating in the splicing zone has an also significant effect on the spliced yarn properties (3,5,7). In another study, the effects of the opening air pressure, splicing air pressure and time of splicing air pressure were investigated in detail (8). A review about the effects of the splicing parameters on the spliced yarn properties was written in detail (9). Injection splicer and standard splicer was investigated and found that using low levels of splicing pressures with a little amount of water gave better results than the standard splicer (10). In order to obtain maximum tenacity, elongation and diameter after splicing of the yarns which have different fibre properties, yarn counts and yarn twists, optimum splicing settings were tried to be determined. The effects of splicing parameters, fibre and yarn properties on the tenacity and elongation of the spliced yarns were investigated in detail (11-13).

The present work is focused on the examination of the parameters affecting the properties of spliced cotton/elastane core yarns. For material parameters, twist factor and elastane yarn linear density were chosen and for the splicing device parameters, opening air pressure, splicing air pressure and time of splicing were chosen.

2. MATERIALS AND METHODS

In the scope of this study, cotton/ elastane core yarns in the yarn count of 20 tex with different twist factors and elastane linear densities were produced in order to investigate the parameters affecting the spliced cotton/elastane core yarns' properties such as breaking strength, breaking elongation and diameter. The twist factors of the tested yarns were chosen to be α_{tex} 33.7 and 43.4. To see the effect of the elastane linear density on the spliced yarn properties, 44 dtex and 78 dtex were chosen which are widely used for the yarn count of 20 tex. The widespread used elastane draft ratio "3.47" was chosen for the yarn production. Specifications of the yarns are given in details in Table 1.

In this study DZ3 prism type was used on the winding machine. The distance between the cover plates whose function is proper feeding of the yarns through the prism was set to 1.9 mm. The distance between the scissors supporting the cut of the yarns coming from the package and bobbin was set to 73 mm. This distance also determines the length of the yarns in

Table 1. Yarn specifications

Material	Cotton/Elastane (Lycra)			
Yarn Count (tex)	20 tex			
Elastane Draft Ratio	3.47			
Twist Factor (α_{tex})	33.7	33.7	43.4	43.4
Elastane Linear Density (dtex)	44	78	44	78
Parent Yarn Breaking Strength (cN/tex)	13.09	11.78	14.51	12.76
Parent Yarn Breaking Elongation (%)	6.38	5.64	6.04	6.48
Winding Machine	Schlafhorst Autoconer 338			

Table 2. Levels of each parameter used in the study and technical data of the tester

Splicing Air(bar)	**Opening Air(bar)**	**Splicing Code**	**Total Time of Splicing (ms)**
4.5	3 4	6-0-0	120
6		5-0-5	200
7.5		7-0-7	280
Technical Data of the Tester			
Claw Distance	:	500 mm	
Load Cell	:	10 N	
Test Speed	:	5000 mm/min	
Pre-Load	:	0.50 cN/tex	

$$\boxed{TTS = (SC_1 + SC_2 + SC_3) \times 20 \quad (ms)} \tag{1}$$

the opening and intermingling zones. Due to the Z twist direction of the yarns used in this study, Z-saw-toothed opening tubes were used. The feeding arm was adjusted to first level degree considering the yarn count and raw-material of the yarn to ensure the best spliced yarn appearance. Opening air blowing time was set to maximum value “7” (700 ms) in order to guarantee the effective opening of the elastane blended yarn ends.

The parameters of opening air pressure, splicing air pressure and splicing code (time of splicing air) were changed and the effects of these parameters on the spliced yarn properties were investigated. The levels of each parameter used in this study are given in Table 2. Full-factorial experimental design was used according to the levels of each parameter. Thus, 3x2x3 trials for each yarn were done which means 72 experiments totally. In the splicing code, every value has a meaning. The first value means the pre-air blowing time code whereas second one means the waiting time code and the third one means the second air blowing time code. Total time of splicing (ms) can be calculated from the following equation:

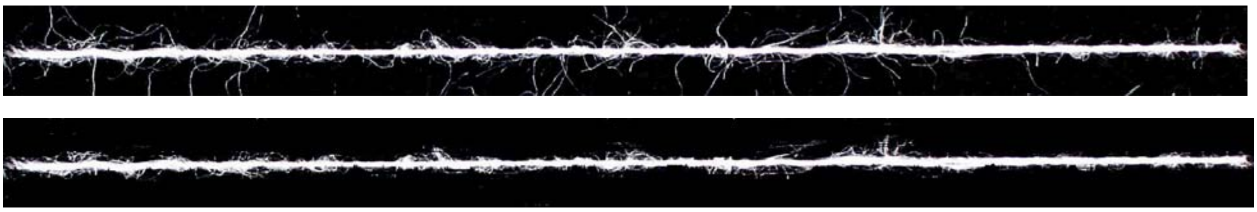
where, SC_1 denotes the pre-air blowing time code, SC_2 waiting time which is zero, SC_3 the second air blowing time code and TTS the total time of splicing.

To eliminate any variations during winding process, all the splicing tests were done in the same unit of the winding machine and the trials were done using the same bobbin. Regression analysis was conducted via using Minitab Statistical Program. In order to perform regression analysis firstly best subset were done. Best subsets regression identifies the best-fitting regression models that can be constructed with the predictor variables specified. Best subsets is performed by examining all possible subsets of the predictors, beginning with all models containing one predictor, and then all models containing two predictors, and so on. Subset models may actually estimate the regression coefficients and predict future responses with smaller variance than the full model using all predictors.

The breaking strength of the parent and spliced yarns was tested on Statimat-M instrument (Table 2). The purpose of the study is to estimate the mean values of retained spliced strength, retained spliced elongation and retained spliced diameter. For every sample, 15 trials were done and in statistical evaluation of the obtained data from the trials, the effect of each parameter on the mean values of breaking strength and breaking elongation was investigated. The diameter measurements were done via using Image Analysis. Firstly, images of each yarn have been taken and after diameters of each yarn have been calculated via a special designed program which was developed with Borland Delphi Developer Studio IDE environment. In the program, acceptable limits of hairs on horizontal and vertical lines have been set and cleared. The remaining hairs were being counted pixel by pixel. Thus, the yarn body diameter has been measured. The given result from the program about the diameter means the mean number of pixels along the diameter. In order to designate the diameter of the spliced yarns, 5 images were taken for each sample.

3. RESULTS AND DISCUSSION

Cheng and Lam has already investigated the breaking strength of the spliced yarn and used the term “retained spliced strength” (RSS) for the expression of this issue. In this study, the RSS and RSE (retained spliced elongation) express the strength and elongation of the spliced yarn as the percentage of the parent yarn in which the splice is inserted (1,2). Retained spliced diameter (RSD) also expresses the diameter of the spliced yarn as the percentage of the parent yarn in which the splice is inserted.



(a)

(b)

Figure 1. Images of yarn samples (a) before and (b) after image analysis

$$
\begin{aligned}
RSS\,(\%) &= \frac{Breaking \quad Strength \quad of \quad the \quad Spliced \quad Yarn}{Breaking \quad Strength \quad of \quad the \quad Parent \quad Yarn} \times 100 \\
RSE\,(\%) &= \frac{Breaking \quad Elongation \quad of \quad the \quad Spliced \quad Yarn}{Breaking \quad Elongation \quad of \quad the \quad Parent \quad Yarn} \times 100 \\
RSD\,(\%) &= \frac{Diameter \quad of \quad the \quad Spliced \quad Yarn}{Diameter \quad of \quad the \quad Parent \quad Yarn} \times 100
\end{aligned} \tag{2}
$$

Tables 3 represents the mean values of RSS, RSE and RSD of the spliced yarns by using elasto-splicer considering the splicing air pressure, opening air pressure and total time of splicing, respectively. The effects of these parameters on the breaking strength, breaking elongation and diameter were analysed systematically.

The effects of yarn properties and splicer settings on RSS, RSE and RSD were analysed by using regression analysis.

Table 3. Mean values of RSS, RSE and RSD of spliced core yarns according to the different parameters of splicing settings

			Yarn Count: 20 tex											
			Elastane Draft Ratio: 3.47											
			Twist Factor (α_{tex}): 33.7						Twist Factor (α_{tex}): 43.4					
			Elastane Linear Density						Elastane Linear Density					
			44 dtex			78 dtex			44 dtex			78 dtex		
a*	b*	c*	RSS	RSE	RSD	RSS	RSE	RSD	RSS	RSE	RSD	RSS	RSE	RSD
4.5	3	120	86.13	83.77	111.12	82.17	89.54	91.79	84.77	90.23	99.30	88.01	93.52	107.80
4.5	3	200	83.22	84.26	99.28	80.98	89.54	108.28	85.87	94.37	104.45	88.87	95.99	109.77
4.5	3	280	86.37	86.72	101.42	86.25	90.78	93.52	84.22	90.56	109.25	87.54	96.14	107.49
4.5	4	120	88.26	94.26	117.58	79.71	87.94	100.61	87.39	99.01	114.70	89.26	89.81	122.17
4.5	4	200	87.55	95.57	105.35	77.59	87.23	99.84	88.56	98.34	105.78	85.74	86.88	117.56
4.5	4	280	85.82	91.48	108.56	80.81	91.49	106.16	84.08	92.88	104.89	88.79	94.44	117.36
6	3	120	85.97	85.90	119.56	83.28	92.91	109.19	87.53	95.36	114.51	88.56	97.07	120.17
6	3	200	81.17	80.49	109.81	76.40	82.98	117.22	89.25	97.85	106.80	85.58	93.21	114.02
6	3	280	85.19	89.67	99.68	76.66	79.43	110.68	88.35	99.80	107.76	84.40	92.28	125.48
6	4	120	85.97	85.25	102.78	86.50	99.47	106.69	93.31	98.81	107.37	87.30	89.97	117.47
6	4	200	88.26	90.33	100.23	82.34	94.15	95.98	88.35	96.19	107.34	86.60	89.81	126.25
6	4	280	85.50	86.39	107.33	78.69	85.46	99.28	88.08	96.52	115.49	84.56	85.03	125.10
7.5	3	120	88.65	89.34	104.52	85.31	88.48	92.36	88.70	93.87	101.24	87.15	94.44	118.38
7.5	3	200	77.70	75.08	105.66	82.09	85.46	91.60	87.04	92.88	101.18	86.21	87.50	109.62
7.5	3	280	79.28	78.85	112.99	79.03	86.70	92.41	83.60	87.42	101.32	80.49	81.64	111.85
7.5	4	120	79.43	77.38	105.18	81.58	84.40	96.73	86.97	93.05	100.88	80.88	84.57	111.36
7.5	4	200	80.77	76.72	85.09	76.66	83.16	98.45	87.59	90.07	101.30	81.97	88.73	109.48
7.5	4	280	82.51	80.66	79.85	80.73	90.07	80.65	86.49	96.52	97.36	83.46	85.19	95.45

a*: Splicing Air Pressure (bar) b*: Opening Air Pressure (bar) c*: Total Time Of Splicing (ms)

Analysis of RSS

According to the regression analysis, the coefficient of the affecting parameters and their significance values are shown in Table 4.

Table 4. Results for regression analysis of RSS

Parameters	Abbreviation	Coefficient	T	*P (Significance Value)*
Constant		59.519	7.83	*0.000*
Elastane Linear Density	(dtex)	-62.06×10^{-3}	-4.73	*0.000*
Twist Factor	(α_{tex})	405.24×10^{-3}	8.76	*0.000*
Splicing Air Pressure	(SP)	6.619	2.63	*0.011*
(Splicing Air Pressure)^2	(SP^2)	-62.43×10^{-2}	-2.98	*0.004*
Total Time of Splicing	(TTS)	-14.22×10^{-3}	-4.16	*0.000*
S=17.4467		R^2=69.0 %		*R^2 (Adjusted)=66.7 %*

Analysis of Variance

Source	DF	SS	MS	F	*P*
Regression	5	44806.3	8961.3	29.44	*0.000*
Residual Error	66	20089.5	304.4		
Total	*71*	*64895.8*			

According to these results, for 20 tex yarn count, the regression equation for estimating RSS is as follows:

$$\boxed{\begin{aligned} RSS = {} & 59.519 - (62.06 \times 10^{-3} \times dtex) + (405.24 \times 10^{-3} \times \alpha_{tex}) + (6.619 \times SP) \\ & - (62.43 \times 10^{-2} \times SP^2) - (14.22 \times 10^{-3} \times TTS) \end{aligned}} \quad (3)$$

The dominant parameters that affect RSS of cotton/elastane core yarns are linear density of elastane, twist factor, splicing air pressure, and total time of splicing. Since the opening air blowing time was set to maximum value, it is adequate to open the fibres. Effect of opening air pressure in selected boundary values on the breaking strength of the spliced zone is statistically insignificant. Thus, opening air pressure wasn't included in the analysis.

Elastane linear density has the influence on the RSS in a negative way. Increasing of this parameter, in other words increasing of elastane linear density, causes decrease in RSS. This is due to the decrease of cotton fibre number in yarn cross sectional area by increasing of elastane linear density for the same yarn count. It is thought to be that due to the low bending rigidity of fine elastane compared to coarse elastane, elastane in the splicing zone makes more crimp and because of this, the friction between cotton fibres increases and RSS increases.

If the twist factor increases, the RSS would increase due to the time of opening air which was set to maximum value. In case of low twisted core yarn, this maximum time of opening air is excess, so the fibres may leave the yarn and also may cause an over-twisting of fibres in the opposite direction. By increasing the twist factor, it is almost enough to untwist the yarn. In the past studies it was reported that if high twisted yarns aren't untwisted sufficiently in case of inadequate opening air pressure which will cause a decrease in the strength values (1,5).

There is a nonlinear relation between splicing air pressure and RSS. The increasing of splicing air till a value causes an increase in RSS. After that optimum value, the effect changes to a decrease in the RSS. Using low splicing air pressures will be insufficient for fibre to fibre adhesion due to the less twist, whereas in case of using high splicing air pressures the breaking strength decreases due to the loss of fibres in the yarn cross section. More recently Das et.al reported that increasing of splicing air pressure till a value increases the strength values of the spliced yarns. after this threshold value strength values of the spliced yarns deteriorate (4). Our results support this finding.

Total time of splicing also affects the RSS values in a negative way. Increasing of TTS will cause fibre loss in the yarn cross section thus the RSS values will decrease. For this reason, total time of splicing should be chosen neither much nor less.

Analysis of RSE

According to the regression analysis, the coefficient of the affecting parameters and their significance values are shown in Table 5.

Table 5. Results for regression analysis of RSE

Parameters	**Abbreviation**	**Coefficient**	**T**	***P (Significance Value)***
Constant		70.744	16.28	*0.000*
Twist Factor	(α_{tex})	62.66 x10^{-2}	5.88	*0.000*
(Splicing Air Pressure)^2	(SP^2)	-145.03 x10^{-3}	-4.13	*0.000*
S=4.38733		R^2=42.8 %		*R^2 (Adjusted)=41.1 %*

Analysis of Variance

Source	DF	SS	MS	F	*P*
Regression	2	993.75	496.87	25.81	*0.000*
Residual Error	69	1328.16	19.25		
Total	*71*	*2321.9*			

The dominant parameters that affect RSE of cotton/elastane core yarns are twist factor and splicing air pressure respectively. The effect of the other parameters could not be determined so they weren't included in the regression analysis.

According to these results, for 20 tex yarn count, the regression equation for estimating RSE is as follows:

$$\boxed{RSE = 70.744 + (62.66 \times 10^{-2} \times \alpha_{tex}) - (145.03 \times 10^{-3} \times SP^2)} \quad (4)$$

Increasing of splicing air pressure causes a decrease in the RSE values due to the excess air which would cause fibre loss in the cross section of the spliced yarn. The RSE values increase with the increase in twist factor. Fibre adhesion decreases in case of increasing of splicing air pressure and decreasing of twist factor which will cause a decrease in RSE.

Analysis of RSD

Table 6. Results for regression analysis of RSD

Parameters	Abbreviation	Coefficient	T	*P (Significance Value)*
Constant		-29.94	-0.97	*0.333*
Twist Factor	(α_{tex})	0.8599	4.59	*0.000*
Splicing Air Pressure	(SP)	38.17	3.71	*0.000*
(Splicing Air Pressure)^2	(SP^2)	-3.3652	-3.93	*0.000*
S=7.70171		R^2=40.1%		*R^2 (Adjusted)= 37.4%*

Analysis of Variance

Source	DF	SS	MS	F	*P*
Regression	3	2697.02	899.01	15.16	*0.000*
Residual Error	68	4033.51	59.32		
Total	*71*	*6730.52*			

According to the regression analysis, the coefficient of the affecting parameters and their significance values are shown in Table 6.

According to these results, for 20 tex yarn count, the regression equation for estimating RSD is as follows:

$$\boxed{RSD = -29.9 + (0.86 \times \alpha_{tex}) + (38.2 \times SP) - (3.37 \times SP^2)} \quad (5)$$

The effects of opening air pressure, elastane count and total time of splicing couldn't be found thus these three parameters weren't included in the regression analysis. However, it is recommended that these parameters should be kept at the minimum levels.

According to the equation (4), increasing of twist factor causes an increase in the RSD.

Splicing air pressure has a polynomial effect on the retained spliced diameter. Increasing of this parameter to a certain level causes an increase in the diameter. However, excess air pressure would cause fibre loss in the cross section of the yarn and unfold the crimp of fibres, thus the diameter would be less than the parent yarn's diameter.

4. CONCLUSIONS

In this study, the elastane/cotton blended core yarns in the yarn count of 20 tex with different twists and different linear densities of elastane were used in the trials considering elasto-splicer settings such as opening air, splicing air and splicing code. The breaking strength, elongation and diameter of the spliced yarns were analysed. The obtained results led to the following conclusions:

- *Elastane linear density* has the influence on the RSS in a negative way. Increasing of this parameter causes a decrease in RSS. The effect of this parameter on RSE wasn't found statistically significant. Elastane linear density has the influence on the RSD in a negative way. However the elastane is in the splicing zone of the cotton/elastane core yarns, especially the cotton fibres intermingle and the splicing zone's elasticity decreases due to the breaking of elastane part. Increasing of elastane linear density, that is, decreasing of the amount of cotton fibres in cross section of yarn leads less intermingling of cotton fibres which will cause a decrease in RSS and RSD.
- Increase in *twist factor* which was chosen as 33.7 and 43.4 causes an increment in the values of RSS, RSE and RSD. This parameter affects the values of RSS and RSE positively; on the other hand it has a negative effect on RSD values. Using low splicing air pressures will be insufficient for fibre to fibre adhesion due to the less twist, whereas in case of using high splicing air pressures the breaking strength decreases due to the loss of fibres in the yarn cross section.
- *Splicing air pressure* has a nonlinear effect on RSS. Increasing of splicing air pressure causes a decrease in the RSE values. Splicing air pressure has a polynomial effect on RSD values. Since the splicing air pressure increases to a certain level, fibres are more intermingled. As a result of this, the diameter of the spliced zone increases (in other words RSD increases) as well as RSS and RSE values increase. After this certain level of splicing air pressure, due to the fibre loss in the splicing zone RSS and RSD values decrease. The effect at excess air pressure would cause not only the fibre loss also unfolding of fibre crimps. However similar effect is expected from TTS, this effect is not statistically significant.
- *Total time of splicing (TTS)* affects the RSS values in a negative way. Increasing of TTS will cause fibre loss in the yarn cross section thus the RSS values will decrease. For this reason, total time of splicing should be chosen at the minimum level. This parameter doesn't have any effects on neither RSE nor RSD in the selected boundaries within the study.
- *Opening air* doesn't have any effects on any of the spliced yarn properties due to the observed range. The reason of this result is thought to be the minimum level of opening air pressure is enough for optimum splicing of 20 tex cotton/ elastane blended yarns.

- As a result of the study it is found that the splicing air pressure is the most important adjustment parameter. This parameter should be chosen at the optimum level according to the yarn properties processed. The results show that low or high levels of this parameter might cause negative effects on the yarn properties of spliced zone.

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Bu araştırma, Bilim Kurulumuz tarafından incelendikten sonra, oylama ile saptanan iki hakemin görüşüne sunulmuştur. Her iki hakem yaptıkları incelemeler sonucunda araştırmanın bilimselliği ve sunumu olarak ***"Hakem Onaylı Araştırma"*** *vasfıyla yayımlanabileceğine karar vermişlerdir.*