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Investigation of Performance Properties of Dyed and Raised Twill Woven PES/VIS Fabrics by Full Factorial and Taguchi Experiment Design Methods

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Abstract

In this study, full factorial experimental design and Taguchi experimental design for the optimization of selected fabric quality parameters were examined comparatively with an experimental study. The aim of the study is to show that Taguchi Experimental Design can be used instead of Full Factorial Experimental Design, which is a classical experiment plan in textile engineering studies. In the experimental study developed in outerwear woven fabric dyeing-finishing enterprises; The woven fabric in three different twill forms, having the same blend, was dyed at three different rates and produced in three different raising conditions. The fabrics were woven 100 m in factory conditions and dyed and raised under the same conditions. The selected twill texture is 3/1, 2/1, 2/2, dyeing ratio, 1%, 3%, 5% and raising status-no raising, single passage raising, two passage raising (shearing process is included in all raising). Selected woven fabric performance tests were applied to the fabrics. In the study, 27 fabric samples were used for the Full Factorial Experiment Design and 9 fabric samples were used according to the Taguchi Experiment Design. The results of the performance tests obtained according to both experimental designs were compared. As a result, it has been shown with this study that 9 samples according to the Taguchi method can be used instead of 27 samples according to the full factorial experimental design for optimum results. Experimental design based on Taguchi Method can be used effectively with less experiments in experimental studies where production is very difficult and costly in the field of textile engineering.

Keywords: Woven fabric, Raising, Full factorial experimental design, Taguchi experimental design

Boyanmış ve Şardonlanmış Dimi Dokuma PES/VIS Kumaşların Performans Özelliklerinin Tam Faktöriyel ve Taguchi Deney Tasarımı Yöntemleriyle İncelenmesi

Öz

Bu çalışmada, seçilmiş kumaş kalite parametrelerinin optimizasyonu için tam faktöriyel deney tasarımı ve Taguchi deney tasarımı karşılaştırmalı olarak deneysel bir çalışma ile incelenmiştir. Çalışmanın amacı, tekstil mühendisliği çalışmalarında klasik bir deney planı olan Tam Faktöriyel Deney Tasarımı yerine

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Taguchi Deney Tasarımı'nın kullanılabileceğini göstermektir. Dış giyim dokuma kumaş boya-terbiye işletmelerinde olmak üzere, geliştirilen deneysel çalışmada; aynı harmana sahip olan, üç farklı dimi formdaki dokuma kumaş, üç farklı oranda boyanmış ve üç farklı şardon koşulunda üretilmiştir. Kumaşlar fabrika koşullarında 100'er m olarak dokunmuş ve aynı koşullarda boyanmış ve şardonlanmıştır. Seçilen dimi doku, 3/1, 2/1, 2/2, boyama oranı, %1, %3, %5 ve şardon durumu-şardonsuz, tek pasaj şardon, iki pasaj şardon (şardonların hepsinde makaslama prosesi dahildir) şeklindedir. Kumaşlara seçilmiş dokuma kumaş performans testleri uygulanmıştır. Çalışmada Tam Faktöriyel Deney Tasarımı için 27 kumaş numunesi ve Taguchi Deney tasarımına göre de 9 kumaş numunesi kullanılmıştır. Her iki deney tasarımına göre elde edilen performans testlerinin sonuçları karşılaştırılmıştır. Sonuç olarak, bu çalışma ile optimum sonuçlar için, tam faktöriyel deney tasarımına göre 27 adet numune yerine, Taguchi yöntemine göre 9 adet numunenin kullanılabileceği gösterilmiştir. Taguchi Metoduna dayalı deney tasarımı, tekstil mühendisliği alanında üretimin oldukça zor ve maliyetli olduğu deneysel çalışmalarda, daha az deneylerle, etkin şekilde kullanılabilir.

Anahtar Kelimeler: Dokuma kumaş, Şardon, Tam faktöriyel deney tasarımı, Taguchi deney tasarımı

1. INTRODUCTION

The performance of a textile material determines the behavior of the material under force [1]. These forces can be in the form of tensile, tearing, stiffness, pilling, wearing and bursting. The direction of these forces may be in the direction of the fabric warp and weft or perpendicular to the plane of the fabric. Fabric performance tests are applied to estimate the behavior of textile material under forces. There are many factors that determine the strength of textile material; fiber type and properties, yarn formation parameters and fabric formation parameters, finishing processes etc. as.

There are many studies about strength tests as being one of the quality performance indicators of fabrics. Ünal and Taşkın, produced plain and twill fabrics having different polyester weft and warp yarns. Before and after washing, the weft and warp direction tensile strength values of the fabrics were measured. The tensile strength was higher in fabrics than in fabrics prior to washing and in fabrics after washing [2]. Kumpikaite examined the effect of the fabric on the tensile strength and elongation at break [3]. Tayyar et. al., the cotton/PES blend of fabric, 2/2 twill and 6 knitted satin braided, 70 denier semi - matt weft warp yarn and Ne 30/1 cotton weft yarn were subjected to the abrasion of the shirting woven fabrics and examined the effects of structural parameters on surface wear. It was observed that the knitting structure had no effect on fabric weight at the end of 10000 rpm but had a significant effect after 20000 revolutions [4]. Kaloğlu et. al. investigated the abrasion properties of 2/2 and 2/1 twill weave fabrics produced from polyester/wool blend yarns with different densities. It was found that the warp 2/1 twill fabrics were more resistant to abrasion than 2/2 twill fabrics. It was also found that the dense fabrics were appraised less than loose fabrics [5]. Kaynak and Topalbekiroğlu investigated the effect of fabric on the abrasion and pilling strength of the weaving pattern. They used 7 different fabrics produced with 30/1 100% combed cotton yarn. It was observed that the texture of the fabric affected the wear and pilling and the weight loss of the fabrics increased in direct proportion to the number of connections [6]. Doba Kadem and Oğulata inspected the tear resistance of plain weave and twill weave cotton fabrics, and they detected that the tear resistance of plain weave fabrics were superior to the twill ones [7]. Özdil and Özçelik measured the fabric tear resistance values of 100% Cotton and 50-50% Cotton-PET blend plain, twill, sateen and ribs weave fabrics by employing four different test methods. It was detected that the plain weave had higher tear resistance, 50-50% Cotton-PET blend fabrics yielded higher values than 100% Cotton fabrics for all of the tear resistance test methods employed [8]. Sabır and Doba Kadem manufactured tree different polyester/vis denim fabrics as reference, raised fabric and laminated fabric using standard processes. and subjected to mechanical and chemical finishing treatment. Researchers have shown that the thermal resistance of raising fabrics is better than coated fabrics [9].

Sabır and Maralcan investigated the effects of the raising drum speed and the raising passage number, as being one of the mechanical textile finishing processes, on various fabric properties [10]. They observed that the drum speed had effect on pilling properties whereas number of passages was not significant. Carfagi et. al. developed a system for their study for observing the raising process which measured the length and frequency of fibers protruding from the raised fabric surface. This system enabled to predict the less than 2 percentile defects [11]. Table 1 shows the difference between the Taguchi method and full factorial design in terms of number of experiments.

Table 1. The difference between Taguchi Method and Full Factorial Design [12]

Ortogonal series	Factor and number of level	Experiment number for Full Factorial Design
L4	3 Factor 2 levels	8
L8	7 Factor 2 levels	128
L9	4 Factor 3 levels	81
L16	15 Factor 2 levels	32768
L27	13 Factor 3 levels	1594323

In experimental studies, a full factorial experiment design is generally used to determine the effects of inputs on the outputs. This is an approach where all combinations of selected levels of selected dependent variables (inputs) are applied. In recent years, Taguchi experiment design has also been used in applied engineering research to examine the effects of input variables on output variables. The Taguchi experiment design shows that reliable results can be obtained by performing less experiments than the full factorial experiment design. In order to demonstrate the reliability of the use of Taguchi Experimental design in engineering research and the reliability of the results, studies comparing both approaches have been made [13,14]. Taguchi method is used by conscious and educated people in a textile mill to a high rate of 97% of the average yield as a method that can help the managers showed increased [15].

Alhalabi and Sabır examined the effect of lubricant used in synthetic fiber spinning on the ring yarn quality parameters by using the Taguchi L4 test setup. They have determined the optimum comb speed and optimum amount of lubricant by Taguchi method [12]. Ömeroglu et. al. examined the bending, draping and wrinkling resistance of fabrics made of hollow and filled fibers. It was observed that different fabric structures did not affect bending strength with Taguchi Experiment Design [16].

Kazmi et. al. used the multi-purpose Taguchi method to determine the optimum comfort properties of terry knitted fabrics made of different materials [17].

It is seen that the Taguchi method is used in the studies carried out for the optimization of performance properties such as Bursting Strength and air permeability of knitted fabrics and optimum results can be achieved [18,19].

The study uses the Taguchi experimental design, which is an optimization technique frequently encountered in recent studies. Studies on full factorial experimental design are still common in scientific and experimental research publications in the field of engineering. In the field of textile manufacturing, it is difficult to make production under operating conditions in order to see the results of experimental studies. Stopping production for a long time and allocating it for the work done cause problems such as loss of production. For this reason, studies that use the Taguchi method, which reduces the number of experiments, and examine its effect on quality values, especially in the field of product production, are considered important. For researchers, this study will contribute to whether the Taguchi technique will give appropriate results in fabric performance in woven fabric dyeing and finishing processes, instead of the classical experimental design. To illustrate the importance of this issue, both experimental designs were used and compared in the same study

The study uses the Taguchi experimental design, which is an optimization technique frequently encountered in recent studies. The Taguchi method was compared with other experimental design methods (such as Artificial Neural Network, full factorial experimental design, fuzzy theory) and the advantages of the Taguchi method were tried to be demonstrated [20-22]. Studies on full factorial experimental design are still common in scientific and experimental research publications in the field of engineering. In the field of textile manufacturing, it is difficult to make production under operating conditions in order to see the results of experimental studies. Stopping production for a long time and allocating it for the work done cause problems such as loss of production. For this reason, studies that use the Taguchi method, which reduces the number of experiments, and examine its effect on quality values, especially in the field of product production, are considered important. For researchers, this study will contribute to whether the Taguchi technique will give appropriate results in fabric performance in woven fabric dyeing and finishing processes, instead of the classical experimental design. To illustrate the importance of this issue, both experimental designs were used and compared in the same study.

In this study, the effects of woven fabric structure, dyeing and raising process on fabric performance were investigated separately with Taguchi test design method and Full factorial design. In this study, it is aimed to compare the results of Full factorial experimental design, which is the classical experimental design method, and Taguchi experimental design, in which fewer experiments are performed. Fabrics produced for this purpose; Three different woven fabric structures, dyeing process with three different shades of the same color and three different raising conditions were selected. The results were statistically evaluated with both approaches. As a result, it has been tried to show that Taguchi experimental design can be used instead of full factorial experimental design in experimental and applied research in the field of textile.

2. MATERIAL AND METHOD

2.1. Material

In this study, gabardine fabric is used for male outerwear. It is woven, dyed and finished under fabric operating conditions. Sample raw fabrics on the 2006 model Picanol Gamma Max loom, 500 rpm. At machine speed, 160 cm. fabric width, 120/2 scallop number, 196 cm comb width, 100 m long and three different fabric structure; Twill 3/1, 2/2 and 2/1 (Z) were weaved. The weft and warp yarns of the fabrics are the same and they are Ne 28/2 number and 63/32/5% PES/Viscose/Elastane blend yarn. The warp frequency is 34 wire/cm and the weft density is 22 wire/cm. The weight of the fabrics is 306 g/m^2. Dyeing-finishing operations of the fabrics; Boiling test, incineration (Machine: Osthoff - Senge machine), washing (Machine: Ramisch Kleinewefers), untensioned drying (Machine: Dilmenler), fixing (Machine: Dilmenler), dyeing, drying-emulsion (Machine: Monforts), Crown (Lafer-Turk) and scissors. Fabrics 1%, 3% and 5% in three different dyeing ratio of the sample dyeing jet dyeing machine. Since all of the samples are polyester/viscose, disperse dye is used for polyester and reactive dyeing is done for viscose. The fabrics were used in three different ways for the raising condition in the finishing process in the experimental study. These are non-raising fabric, single-pass raising (1.Passage raising) fabric and two-pass raising (2.Passage raising) fabric. Shearing is also included in the raising fabrics.

2.2. Method

In this study, the effect of woven fabric structure, dyeing and raising woven fabric performance was investigated with two different experimental study plans. The input variables (factors) and their levels created for this experimental plan are given in Table 2. There are three factors and each is three levels. There are 3 factors (code: k = 3) and 3 levels of factors (n = 3). The tests given in Table 3 were applied to the sample fabrics.

Design of Experiment (DOE)*:* Experimental design is a quality improvement technique defined as the observation and interpretation of variability on the response variable by systematically making the desired changes on the input factors in a process. Two different experimental designs were used in this study: Full Factorial Experimental Design and Taguchi Experimental Design.

Full Factorial Experimental Design FFED: The method of full factorial experimental design is the case where all parameters and all levels related to these parameters match each other.

Taguchi Experiment Design (TED): Taguchi uses Orthogonal Arrays (OD) to perform multivariate experiments with a small number of experiments. The orthogonal sequence is the Taguchi approximation, which is expressed as L, while the next number represents the number of experiments.

The main purpose of the Taguchi method; decreasing the variability around the target value. The test results obtained in Taguchi Experiment Design method are evaluated by converting to signal / noise (S/N) ratio (Eq.1). The value of the signal /noise ratio is small, the value is good, the good value is good, the nominal value is well calculated and analyzed in different ways according to the value of the quality values. No the confirmation test was included in the study.

Table 2. Factor (input) parameters and level of the study [23]

Code	Factor (inputs)	Unit	Level	Explanation of the levels
A	Fabric structure	-	3	Twill 3/1(Z), Twill 2/2(Z), Twill 2/1 (Z)
B	Dyeing ratio	%	3	1,3,5
C	Raising condition (Mechanical finishing type)	-	3	no-rised fabric, 1th passage rised fabric (shered), 2th passage rised fabric (shered)

Table 3. Selected Fabric Performance Properties for the samples

No	Test	Standard	Method
1	Tensile Strength and Elongation%	TS EN ISO 13934-1	Strip method/ TITAN® Device
2	Tearing Strength	TS EN ISO 13937-1	Ballistic pendulum method
3	Stiffness	TS 1409/October1974	Fixed Angle Bending
4	Thermal Stability	BS 4323	WIRA®
5	Abrasion Resistance	TSE EN ISO 12947-1/2	Martindale / According to mass loss principle up to 10000 cycles

Bigger-the-Better
$$\frac{S}{N}_{(Bigger)} = -10\log\left(\frac{\sum\left(\frac{1}{y_i^2}\right)}{n}\right)$$

Smaller-the-Better
$$\frac{S}{N}_{(Smaller)} = -10\log\left(\frac{\sum y_i^2}{n}\right)$$

Nominal-is-Best
$$\frac{S}{N}_{(Nominal)} = 10\log\left(\frac{\bar{Y}^2}{s^2}\right)$$

The design of full factorial experimental design is the classical experimental design approach and the number of experiments with this approach is found by multiplying the three levels of three factors. Since there are three factors and each of them has three levels, the number of experiments will be 3x3x3=27. In Taguchi method, the number of experiments varies according to the number and level of factors. A 3-factor 3-level test pattern is expressed in the Taguchi Experimental Design as 3^3, and Taguchi then suggests the L9. Table 4 shows the number of experiments with both experimental designs. As can be seen, there is a big difference between the number of experiments.

Table 4. Number of experiments for the experimental design methods

Experimental design code	Experimental design Name	Number of experiment
FFED	Full factorial experimental design	27
TED	Taguchi experimental design	9

The test set prepared according to both experimental plan is given in Table 5. There are 27 complete factorial test sets (FFED) and 9 Taguchi test sets (TED). The data obtained from the tests were statistically analyzed. In order to select the appropriate type of analysis, the characteristics of the data must first be determined [24]. Minitab15® software was used for statistical analysis.

Table 5. Experimental plan for statistical analysis [23]

Experiment No	Dyeing ratio	Fabric structure	Raising condition	FFED	TED , **L9**
1	1%	2/1	No Raising	√	L1
2	1%	2/1	1. Passage raising	√	-
3	1%	2/1	2. Passage raising	√	-
4	3%	2/1	No Raising	√	-
5	3%	2/1	1. Passage raising	√	L2
6	3%	2/1	2. Passage raising	√	-
7	5%	2/1	No Raising	√	-
8	5%	2/1	1. Passage raising	√	-
9	5%	2/1	2. Passage raising	√	L3
10	1%	2/2	No Raising	√	-
11	1%	2/2	1. Passage raising	√	L4
12	1%	2/2	2. Passage raising	√	-
13	3%	2/2	No Raising	√	-
14	3%	2/2	1. Passage raising	√	-
15	3%	2/2	2. Passage raising	√	L5
16	5%	2/2	No Raising	√	L6
17	5%	2/2	1. Passage raising	√	-
18	5%	2/2	2. Passage raising	√	-
19	1%	3/1	No Raising	√	-
20	1%	3/1	1. Passage raising	√	-
21	1%	3/1	2. Passage raising	√	L7
22	3%	3/1	No Raising	√	L8
23	3%	3/1	1. Passage raising	√	-
24	3%	3/1	2. Passage raising	√	-
25	5%	3/1	No Raising	√	-
26	5%	3/1	1. Passage raising	√	L9
27	5%	3/1	2. Passage raising	√	-

3. RESULTS AND DISCUSSION

Comparison of statistical analysis for full factorial design and Taguchi experimental design:

When the fabric performance test results were analyzed statistically, it was seen that the data were homogeneous. Accordingly, two-way ANOVA was applied to tensile strength and elongation, tear strength, stiffness, thermal stability tests. Abrasion resistance test results were applied Kruskal-Wallis Test. 95% confidence interval was chosen in the analyzes (significance level p, 0.05). At the end of the tests, it was analyzed statistically whether the production parameters had an effect on fabric performance. "Sig." if statistically it has an effect on a parameter. means "significant" and this statistical evaluation is given collectively in Table 6. Table 6 shows the effects of the performance of fabric production parameters can be revealed. According to this, the twist strength of the twill weave structure has no effect, but the dyeing intensity and the shrinkage effect. There is no effect on the tear strength of the twill weave structure and the dyeing intensity. However, the raising does not affect the tearing strength in the direction of the warp, but in the weft direction. This is an expected result due to the fiber removal of the fabric from the weft-directional yarns of the fabric by raising. This is also an expected result because it affects the stiffness of the fabric due to fiber removal from the fabric structure by raising. Thermal stability performance of the fabrics is not affected by the change in the twill weave structure but it is also affected by all three types of dyeing. This effect was found to be significant because the dyeing process was performed under heat. The process of thermal stabilization was also found to be ineffective on the warp effect on the weft, since the process was a process to effect the weft direction.

Table 6. Comparison of statistical analysis results of fabric performance properties for FFED and TED methods

Performance properties of the samples	Fabric direction	**Fabric structure**		**Dyeing ratio**		**Raising condition**	
		FFED	TED	FFED	TED	FFED	TED
Tensile strength	Weft	non	non	**Sig.***	**Sig.**	**Sig.**	**Sig.**
	Warp	non	non	**Sig.**	**Sig.**	**Sig.**	**Sig.**
Elongation %	Weft	**Sig.**	**Sig.**	**Sig.**	**Sig.**	**Sig.**	**Sig.**
	Warp	**Sig.**	**Sig.**	**Sig.**	**Sig.**	**Sig.**	**Sig.**
Tear	Weft	non	non	non	non	Sig.	Sig.
	Warp	non	non	non	non	non	non
Stiffness	Weft	non	non	non	non	**Sig.**	**Sig.**
	Warp	non	non	non	non	**Sig.**	**Sig.**
Thermal stability	Weft	non	non	**Sig.**	**Sig.**	**Sig.**	**Sig.**
	Warp	non	non	**Sig.**	**Sig.**	**non**	**non**
Abrasion resistance		non	non	**Sig.**	**Sig.**	**Sig.**	**Sig.**

**: "Sig", Significant (For less than 0.05 significant value, p<0.05).*

In order to investigate the effect of three different production parameters on the performance of six fabrics, 9 experiments were performed instead of 27 experiments and the same statistical results were obtained. In this experimental study, it is suggested that Taguchi method can be used instead of full factorial method in experimental design.

Determination of optimum production parameters by Taguchi Experimental Design (TED):

With Taguchi experiment design, optimum results can be achieved with less experimentation. The results of the experiments conducted according to the standards were analyzed with L9 Taguchi test design and the equation (S/N) was given in equation (1). It is desirable to have the lowest value of rupture, tear strength, fabric softness and thermal stability as the highest value and the abrasion resistance value shows the % mass reduction from the fabric.

Table 7. Signal/Noise (S/N) ratio of performance properties of the samples

No	Test	Signal / noise (S / N) ratio
1	Tensile Strength	Bigger-the-Better
	Elongation %	Bigger-the-Better
2	Tearing Strength	Bigger-the-Better
3	Stiffness	Bigger-the-Better
4	Thermal Stability	Bigger-the-Better
5	Abrasion Resistance	Smaller-the-Better

Taguchi Method shows the production parameters that will make the selected fabric performance values optimum with "Main Effects Plot for Means" graphs (Figure 1-5). Optimum values are marked on the graphs in accordance with the "Highest Best" in Figure 1-4 and "Lowest Best" in Figure 5. Since the production parameters selected in the warp direction tear strength have no effect, the S/N figure is not given.

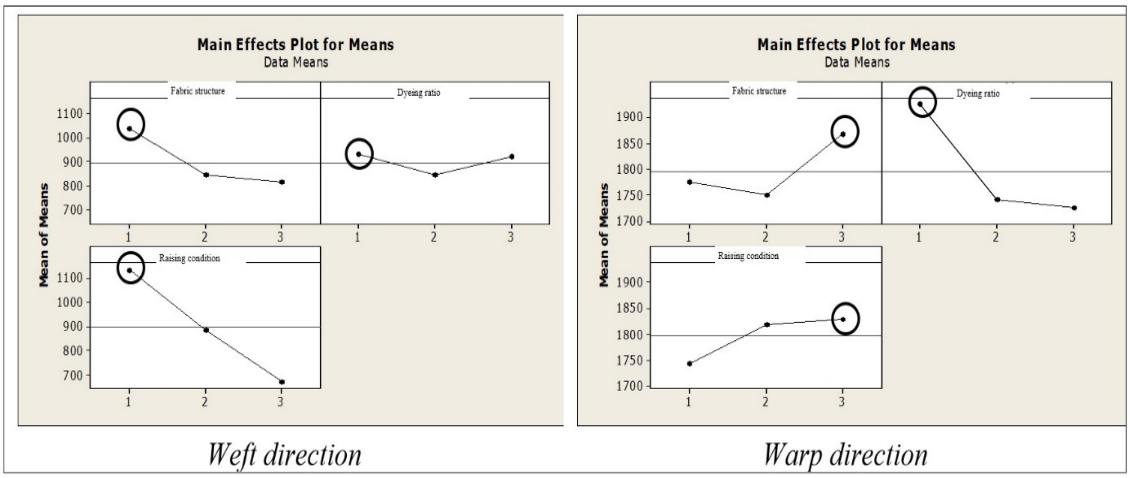

Figure 1. Optimum production parameters for tensile strength (Highest Best)

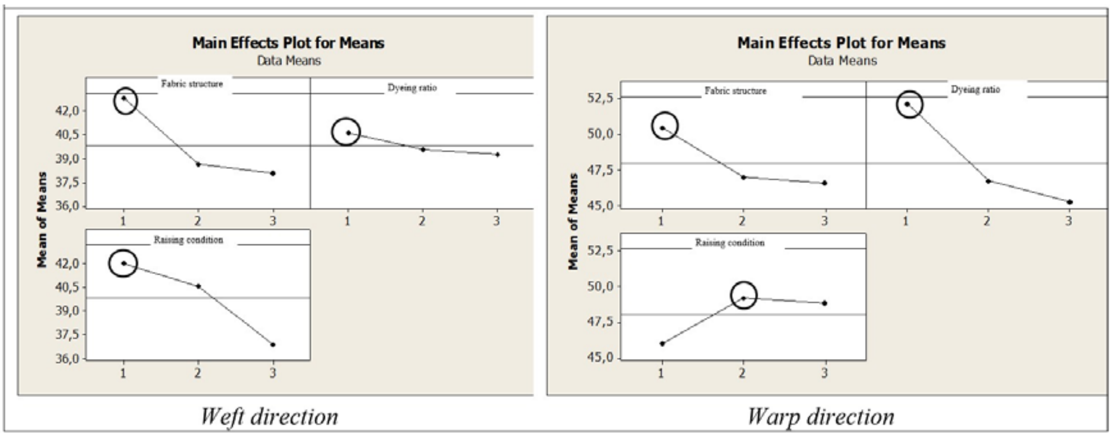

Figure 2. Optimum production parameters for elongation at break% (Highest Best)

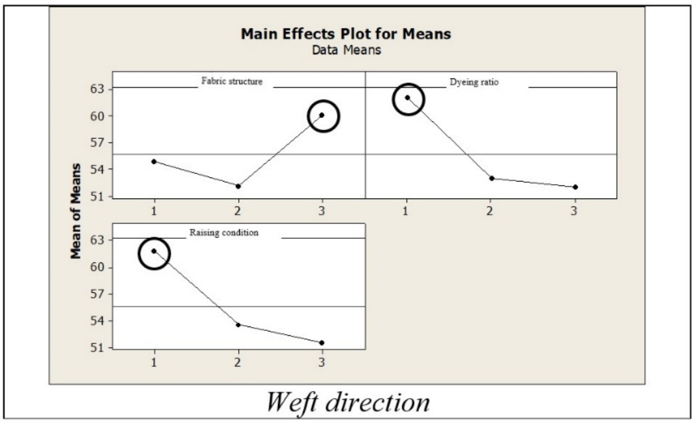

Figure 3. Optimum production parameters for tearing strength (Highest Best)

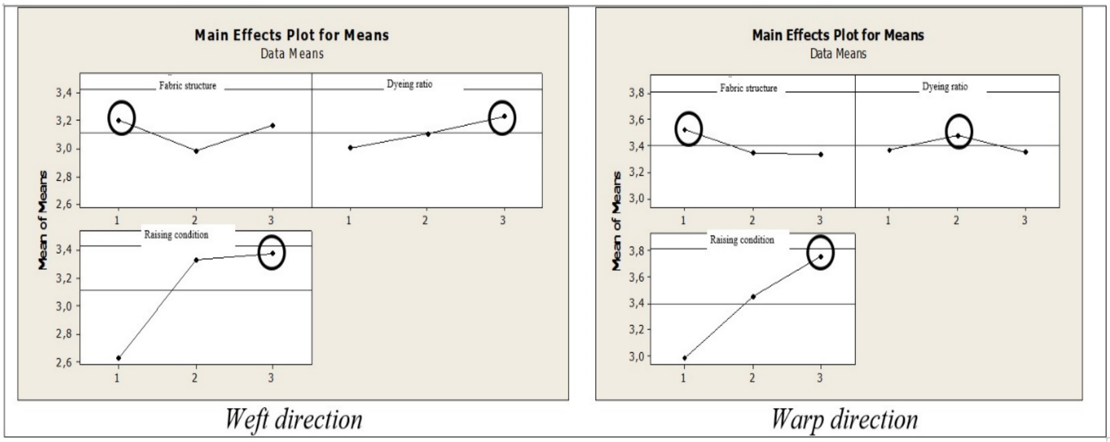

Figure 4. Optimum production parameters for stiffness (Highest Best)

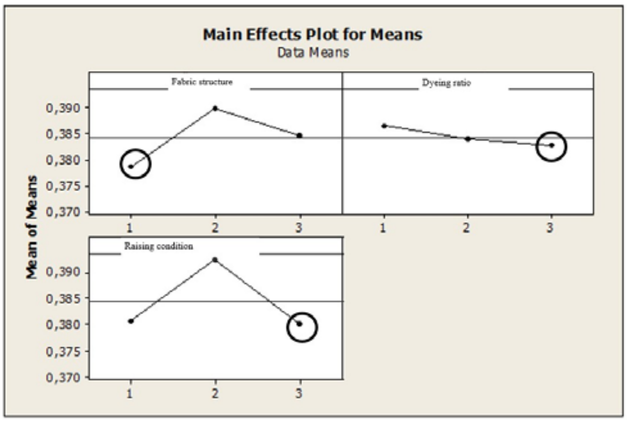

Figure 5. Optimum production parameters for abrasion resistance (Lowest Best)

Optimum values of selected fabric performance properties for TED and FFED Design was found same and was shown in Table 8.

Table 8. Production parameters for optimum fabric performance according to TED and FFED

Tests	Fabric direction	Optimum production parameters of the fabrics		
		Fabric structure	***Dyeing ratio***	***Raising condition***
Tensile Strength	Weft	2/1	%5	no raising
	Warp	3/1	%1	2. Passage raising
Elongation %	Weft	2/1	%1	no raising
	Warp	2/1	%1	1. Passage raising
Tearing Strength	Weft	3/1	%1	no raising
	Warp	Three production parameters are ineffective		
Stiffness	Weft	2/1	%1	2 Passage raising
	Warp	2/1	%3	2 Passage raising
Thermal Stability	Weft	2/2 or 3/1	%1	1. Passage raising
	Warp	2/1	%1	1. Passage raising
Abrasion Resistance		2/2	%1	1. Passage raising

4. CONCLUSION

In this study, dyeing and raising applied twill weave fabrics were subjected to two different statistical analyses methods for determining their effects on preselected fabric performance parameters. Two different experimental designs were arranged for the preselected parameters. One was Full factorial experimental design as being the classical approach and the other was Taguchi experimental design. Full factorial experimental design requires to execute all the combinations of the experimental study. Taguchi experimental design enables to conduct the statistical analysis with less number of experiments. In this study, both of these experimental designs were applied and the obtained results were analyzed for a selected experimental setting.

As a result of the experimental study, it has been revealed that the results obtained with the Taguchi experimental design are compatible with those obtained with the full factorial experimental design. It was observed that, 9 trials instead of 27 trials i.e. 18 less number of trials enabled to achieve highly similar results via Taguchi Method. The Taguchi method was also able to show optimum results. With this study, the possibility of making statistical evaluations with fewer trials without interrupting production for applied research studies in textile factories has been revealed. The validation experiment is the final step of the Taguchi experimental design. The purpose of the validation experiment is to predict and verify the results obtained during the analysis phase. This test was not included in this study, but it is recommended that it be added with future studies.

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6. REFERENCES

1. Tayyar, A.E., 2010. Ev Tekstillerinde Kumaş Özelliklerinin Patlama Mukavemetine Etkileri. Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi, 16(2), 165-172.

2. Ünal, P.G., Taşkın C., 2007. %100 Poliester Kumaşlarda Dokunun ve Sıklıkların Kopma Mukavemetine Etkisi. Tekstil ve Konfeksiyon, 2, 115-118.

3. Kumpikaite, E., 2008. Influence of Fabric Structure on the Character of Fabric Breakage. Fibres&Textiles in Eastern Europe, 16(3), 44-46.

4. Tayyar, E., Sarı, F., Yağız İ., 2011. Gömleklik Kumaşlarda Yapısal Parametrelerin Kumaşın Aşınma Direncine Etkileri. The Journal of Tekstil and Engineer, 18(84): 23-26.

5. Kaloğlu, F., Önder, E., Özipek, B., 2003. Influence of Varying Structural Parametres on Abrasion Characteristics of 50/50 Wool/Polyester Blended Fabrics. Textile Research Journal, 73(11), 980-984.

6. Kaynak, K., Topalbekiroğlu, M., 2007. Dokuma Kumaşlarda Doku Tipinin Aşınma ve Boncuklanma Dayanımı Üzerine Etkilerinin Araştırılması. Tekstil ve Konfeksiyon, 17(1), 40-44.

7. Doba Kadem F., Oğulata R.T., 2009. Boyalı İpliklerden Üretilen Farklı Konstrüksiyonlardaki Pamuklu Kumaşlarda Kumaş Yırtılma Mukavemetinin Regresyon Analizi, Tekstil ve Konfeksiyon, 19(2), 97-101.

8. Özdil N., Özçelik G., 2006. Kumaşlarda Yırtılma Mukavemeti Test Yöntemlerinin Karşılaştırılması Üzerine Bir Çalışma, Tekstil ve Konfeksiyon, 3, 174-179.

9. Sabır E.C., Doba Kadem F., 2016. Comfort and Performance Properties of Raised and Laminated Denim Fabrics, Fibres & Textiles in Eastern Europe, 5(119), 88-94.

10. Sabır E.C., Maralcan A., 2010. 2/1 Z Dimi PES/VIS/EA Dokuma Kumaş Özelliklerine Şardon Parametrelerinin Etkisi. Tekstil Teknolojileri Elektronik Dergisi, 4(2), 1-8.

11. Carfagı M., Furferi R., Governi L., 2005. A Real-Time Machine-Vision System for Monitoring the Textile Raising Process, Computers in Industry, 56, 831-842.

12. Alhalabi K., Sabır E.C., 2011. Antistatik Yağın İplik Parametrelerine Etkisi. Çukurova Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi, 26(2), 19-32.

13. Aytaç A., Yılmaz B., Deniz V., 2008. Kord Bezi Üretiminde Büküm Yönünün Etkilerinin Farklı Deney Tasarımı Yöntemleri ile İncelenmesi, İşletme Fakültesi Dergisi, 9(1), 61-71.

14. Kumar A., Ishtiaque S.M., Salhotra K.R., 2006. Analysis of Spinning Process Using the Taguchi Method. Part III: Effect of Spinning Process Variables on Migration Parameters of Ring, Rotor and Air-Jet Yarn. Journal of the Textile Institute. 97(5), 377-384.

15. Sabır E.C., Özgür, E., 2014. Seçilmiş Dokuma Kumaşların Eğilme Uzunluğuna Boyamanın ve Şardonlamanın Etkisinin İstatistiksel Yöntemlerle Araştırılması, https://fbe.cu.edu.tr/storage/fbeyedek/makaleler/2014/secilmisdokuma.pdf, Access date: April 2023.

16. Ömeroglu S., Karaca E., Becerir B., 2010. Comparision of Bending, Drapabilty and Crease Recovery Behaviours of Woven Fabrics Produced From Polyester Fibers Having Different Cross-Sectional Shapes. Textile Research Journal, 80, 1180-1190.

17. Kazmi K., Javed Z., Salman M., Iftikhar F., Ahmed N., Naeem J., Jabbar A., Karahan M., Naeem M.S., 2023. Optimization of Knitted Fabrics for Better Thermophysiological

Comfort by Using Taguchi-Based Principal Component Analysis. Textilec. 66(1), 18-30.

18. Mavruz, S., Ogulata, R.T., 2010. Taguchi Approach for the Optimisation of the Bursting Strength of Knitted Fabrics. Fibres & Textiles İn Eastern Europe, 18(2), 78-83.

19. Ogulata, R.T., Mezarcioz, S.M., 2011. Optimization of Air Permeability of Knitted Fabrics with the Taguchi Approach. Journal of the Textile Institute, 102(5), 395-404.

20. Zeydan, M., 2008. Modelling the Woven Fabric Strength Using Artificial Neural Network and Taguchi Methodologies. International Journal of Clothing Science and Technology, 20(1-2), 104-118.

21. Shabaridharan, K., Das, A., 2014. Analysis of Thermal Properties of Multilayered Fabrics by Full Factorial and Taguchi Method. Journal of the Textile Institute, 105(1), 29-41.

22. Kuo, C.F.J., Lin, W.T., 2019. Optimum Processing Parameters of Sueding Fabric Comfort by Applying the Taguchi Method and Fuzzy Theory. Textile Research Journal, 89(23-24), 5165-5176.

23. Özgür E., 2013. Dokunmuş Kumaşın Örgü Yapısının Şardonlu Kumaşın Kalite Özelliklerine Etkisinin İstatistiksel ve Taguchi Yöntemiyle Araştırılması, Master Thesis, Department of Textile Engineering, Unviersity of Çukurova, Adana/Turkey, 144.

24. Eymen U.E., 2007. SPSS 15.0 Veri Analizi Yöntemleri. URL: www.istatistikmerkezi.com.