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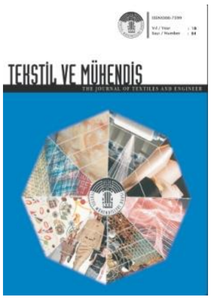

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The Determinants of the Comfort and Aesthetic of Shawls Fringes

Şalların Saçakları: Konfor ve Estetiğinin Belirleyicileri

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THE DETERMINANTS OF THE COMFORT AND AESTHETIC OF SHAWLS FRINGES

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ABSTRACT: Shawl's comfort has been evaluated from the subjective and objective points of view concerning the effect of the twisted style of the rope fringe yarns. Objectives results have been achieved by designing special machines for twisting yarn fringes at different settings. Focused on finding the optimum twisting parameters as "pressure," "linear speed of rubbing jaws," and "tension" has been made. Thirty observers evaluated subjective results by checking the fringes' aesthetic regard to total TPM and twist loss. While observers believe more shawl comfort could be achieved with the lower twist loss of fringes after a period of use, testers try to describe more aesthetics by words like elegance, precision, finesse, and fine-spun. Taguchi's method has been used as the experimental design method, and objective (the optimum twisting parameters) and subjective (the evaluation of Expert Choice software) results have been presented. Constraint analyses are done by response surface methodology to draw the optimum points and desirability function.

Keywords: Comfort; aesthetic; shawl fringe; twist.

ŞALLARIN SAÇAKLARI : KONFOR VE ESTETİĞİNİN BELİRLEYİCİLERİ

ÖZ: Bu çalışmada, saçak iplikleri büküm stillerinin etkisine ilişkin objektif ve sübjektif bakış açıları yardımıyla şal konforu değerlendirilmiştir. Farklı ayarlarda saçak iplikleri üretebilecek özel makinelerin tasarlanması ile hedef sonuçlara ulaşılmıştır. "Basınç", "sürtünme çenelerinin doğrusal hızı" ve "gerginlik" gibi optimum büküm parametrelerinin belirlenmesine odaklanılmıştır. Otuz gözlemci, saçakların toplam büküm ve büküm kaybı ile ilgili estetik özelliklerini kontrol ederek öznel sonuçları değerlendirmiştir. Gözlemciler, daha fazla şal konforunun belirli bir süre kullanım sonrasında saçak ipliklerindeki düşük büküm kaybı ile sağlanabileceğine inanırken, test uzmanları, zariflik, hassasiyet, incelik ve ince büküm gibi kelimelerle estetik özelikleri tanımlamaya çalışmışlardır. Deneysel tasarım yöntemi olarak Taguchi metodu kullanılmıştır ve nesnel(optimum büküm parametreler), öznel(Expert Choice yazılım değerlendirmeleri)değerlendirmelere ilişkin sonuçlar sunulmuştur. Optimum nokta ve fayda fonksiyonları çizmek amacıyla değerlendirmelere ilişkin kısıtların analizleri, yüzey tepki yöntemi kullanılarak yapılmıştır.

Anahtar Kelimeler: Konfor; estetik; şal saçağı; büküm.

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1 INTRODUCTION

Many attempts have been made to define the term "Comfort" in the physical state [1]. Bekesius [2] has surveyed the literature and quotes such definitions as "the absence of unpleasantness or discomfort" or "a neutral state compared to the more active state of pleasure" initially made by authors during the previous twenty years. These tries were made concerning fabrics, cloth, shawl, shoes, and all textile goods that touch the human body. Slater [1] reviewed all causative factors on the comfort of textile goods include "Physical aspects of comfort," "Thermal properties and comfort," "Moisture-Vapor Transmission," "Liquid-Moisture Transmission," "Air Permeability," "Size and Fit," "Aesthetic Comfort," "Static Electricity" and "Noise." Regarding the unique usage of scarves and shawls (the human body's contact time and a commonly human head are about some hours), so between all above causative mentioned factors, the "Physical Aspects of comfort" has the most important compared to the others. Norton et al.[3] uses an instrument for testing the impact test and collected both the impact results and subjective data from pedestrians to capture a relationship between floor comfort and impact aspects. They suggest that instrumental simulation of heel-strike is an indicator of carpet comfort. Although Norton suggests monitoring the physical properties, such a low rate of strain modulus might well be essential in other categories of user-surface interactions like standing or in considering wheelchair mobility. Whittle et al.[4], in other research work, try to present the best high and the weight of the missile (178 mm and 2.27kg, respectively) in impact testing for simulating the foot impact. Whittle et al. and some other researchers [5-10] investigated the relationship between the mechanical properties of carpet and the subjective comfort of walking on the carpet. In Whittle's research, 48 person user panel walked on the samples of four types of carpets and ranked them in order of comfort. Two different mechanical tests were applied to the same samples: an impact test, designed to simulate the heel strike transient, and measurement of the twist loss at a low rate of deformation. According to Whittle's result, there was a general agreement between the subjects regarding which carpet was the least comfortable and the most comfortable. These observations were corresponded to the carpets giving the highest and the lowest values, respectively, for the peak deceleration in impact testing. The other two carpets were intermediate in both user response and impact testing. Most users preferred the carpet in these two tests, which had lower compression modules when measured by slow deformation. The walking surface's subjective comfort may relate to the measurable parameters, such as force in joints, muscles, ligaments, energy expenditure, or the presence (or absence) of microtrauma. Moreover, some other research works about the relationship between plantar pressure distribution under the foot and insole comfort or the shoe construction limitation to achieve more comfort [11]. There are many types of comfort research in the field of fabric and yarns [12-20], and also some outstanding Hearl' work [21] that focuses on forming wrapped-ribbon structure or Bennett' researches [22] that explore on torsional stability in plied yarns or other massive researches in the filed of yarns and twisting by different techniques and machinery [23-27].

Finally, there is a lack of research the same as the present work to investigate the relationship of shawl fringe rope and comfort while fringes have a significant role in the beauty and aesthetic of textile goods, and no research work has been done to investigate how it should be to be pleasant and more comfort. So, in the present research, it has been tried to investigate the effect of fringe shawl yarns on the two main aspects ("Physical Aspects of Comfort" and "Aesthetic Comfort"). For achieving this goal in the experimental phase, Taguchi's design is used, and 25 samples prepared in a different twist and twist loss were measured. Afterward, the subjective inspection was done by 30 people[28-30], and subjective data evaluated by Expert Choice software (version 11), thanks to pair comparison mode. In the next step for evaluating the aesthetic index of shawl fringes, another subjective evaluation process with 30 people's aid has been done to understand whether folding yarns increases or decreases the shawl grace.

Consequently, Taguchi analysis has been explored, and the optimum pressure, speed, and yarn tension as the main object that affects the twisting and twist loss are presented with all aspects. This article aims to make the first reference to fill the lack of researches on the beauty and comfort of the scarf fringes and be the first step for researchers to focus on the comfort factor for goods that are more in contact with the body. Also, there is a vast technological lack to produce machines with better capabilities and easier to use in this field, based on the results of this research and other researchers' results to achieve production variety and employment development.

2 MATERIALS AND METHODS

2.1. Experimental design

Taguchi's experimental design was used [31] to estimate the optimum process conditions and examine each of the controllable factors' effects on a particular response. In Taguchi design, it is possible to select a suitable design regarding the factors and their levels. L25 is a suitable case for three factors, which include five levels as primary inputs. Taguchi reports the signal to noise ratio for estimating factor, calculated by equation (1). In these equations, where "n" is the number of observations and "Y" is the measured data, it could be used to calculate the signal to noise for both cases; "smaller is better" and "larger is better."

$$SN = -10 \times \log_{10}\left(\frac{sum(Y^2)}{n}\right) \quad \text{(Smaller is Better)}$$

$$\mathrm{SN} = -10 \times \log_{10}\left(\frac{\mathrm{sum}\left(\frac{1}{\mathrm{Y}^2}\right)}{\mathrm{n}}\right) \quad \text{(Larger is Better)} \qquad (1)$$

The signal to noise ratio is one of the critical indices for analyzing Taguchi's design. Noise signal could be calculated concern to the goal optionally. "Larger is better," "Smaller is better," and "Nominal is better" are selectable for the calculation. For instance, because more comfort is parallel to the lowest level of twist loss, "smaller is better" has been used for the twist loss analysis, while it is logical to use "larger is better" for the subjective evaluation of comfort.

2.2. Decision-making technic for subjective assessment

Analytical Hierarchy Process (AHP) method is a multi-criterion decision-making system. Thus, it is a valuable technique for subjective assessment in different fields, especially management, engineering, biology. Expert Choice (EX) software is one of the analytic hierarchy process software (AHP) that analyzes a questionnaire's result. In this research, observers made a pair of comparisons to reach better accuracy [32]. Hierarchical structure has benn done base on figure 1. The samples were kept in standard conditions for 24 hours and subjective evaluation was performed in one day (with a temperature of 25 ° C and a relative humidity of 42%) by the observers. In evaluating the beauty of each sample, the observer can visually observe the specimen for 5 minutes while the shawl fringe ropes positioned in the Wooden embroidery hoops. To assess the comfort of the specimen, observers can touch the specimens while set inside the wooden workshop and also wear the specimen scarf on their head for ten minutes. To find out whether the aesthetic has an increasing or decreasing effect by changing the parameters, another survey of 30 observers (including girls and women between the ages of 15 and 45 with different occupations) used by expert choice software and the "Paired Comparison" method. Another point that should be considered in this test is the number of experts who will be consulted. To achieve the number of people, the "T-Test Hoteling" distribution is used [33, 34], according to which, at least the examiner must be one more than the number of samples that want to be arranged in order. Therefore, as a precaution, 30 people responded to the survey.

2.3. Response surface methodology

Response surface methodology (RS M) combines mathematical and statistical techniques useful for empirical modeling and optimizing several independent variables' effects on the response [35, 36]. The optimum condition of the three independent processing parameters, namely vertical pressure of twisting jaws (bar), the horizontal linear speed of twisting jaws (m/min), and yarns (fabric fringes yarns) tension (kg), on comfort and aesthetic properties, were investigated using RSM [37].

3. EXPERIMENTAL

3.1. Preparing the shawl fringe yarns

Objective and subjective evaluation is not possible; else, to do all the final product steps. It means, first of all, shawls should be woven, and then fringes twisting should be done. So, machines for running weaving and twisting are necessary. Besides these laboratory instruments for measuring TPM, the twist loss fringe template for observers viewing (for getting the observer's idea easier and more accurate) is necessary. After designing the model, the prediction will be accessible by the model without sample preparation. Hence, shawl samples should be prepared to compare the effect of rope twist fringes yarns for comfort. In this research, a certain number of fringes rope is placed in the one centimeter defined as the "fringe rope density" or briefly named "shawl fringe density."

3.2. Sample preparation/ Weaving shawl

The Sulzer machine has been used to weaves the required numbers of shawls, twill weave structure, fabric width 120 cm, and yarn count and density according to model A, Table 1, the most popular shawl density in the present market.

The vital point in shawl's fabric weaving is weaving a length of about 220 millimeters without weft insertion process between the two shawls (after weaving 140 cm shawl length, give up 220 mm without weft insertion and then weave the next shawl) so that in the feature it divided to two shawls. It will do for all fabric roll. The schematic view has been depicted in figure 2.

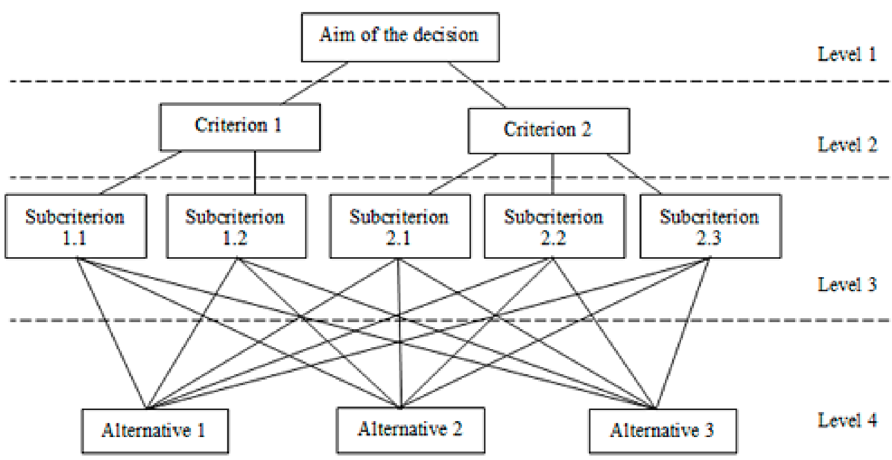


Figure 1. Hierarchical structure in the analytic hierarch process method for aesthetic and comfort evaluation[32]

Table1. Specifications of usual shawls in the market (100% viscose yarn)

Shawl Model	Weft yarn count Ne	Warp yarn count Ne	Weft density (Pick/cm)	Warp density (end/cm)	Fringe rope density(/cm)
A	30/2	30/2	20	20	1
B	30/2	30/2	10	20	1.5
C	30/2	30/2	10	10	0.5

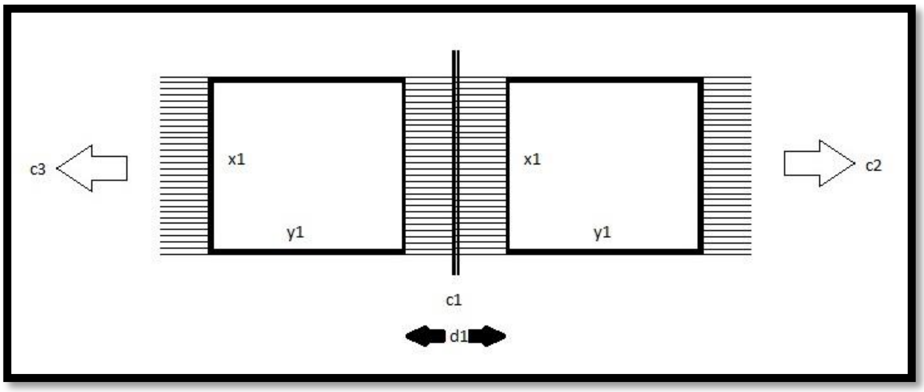
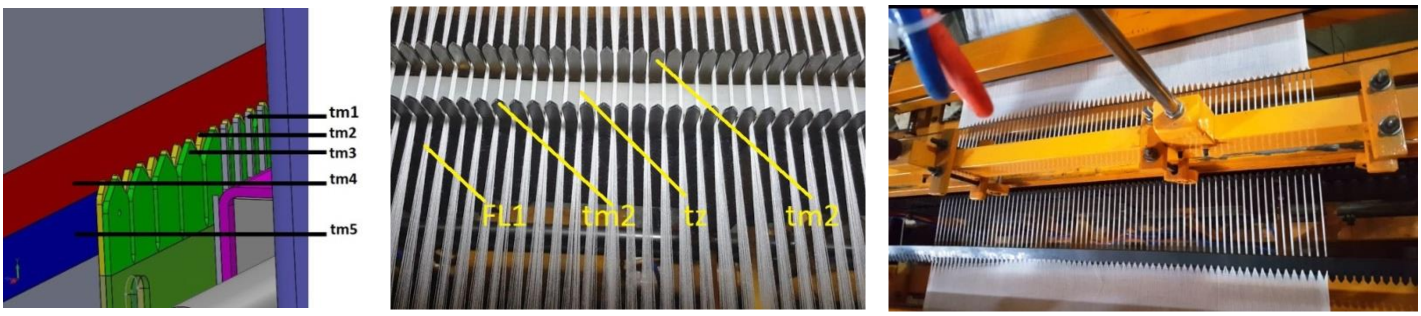


Figure2. The schematic view of weaving shawls continually; x1: The shawl's width, y1: length of the shawl; c1: cutting line, c2: continues to the next shawl, c3: continues to next shawl, d1: length of fabric without weft insertion.

3.3. Sample preparation/ Twisting

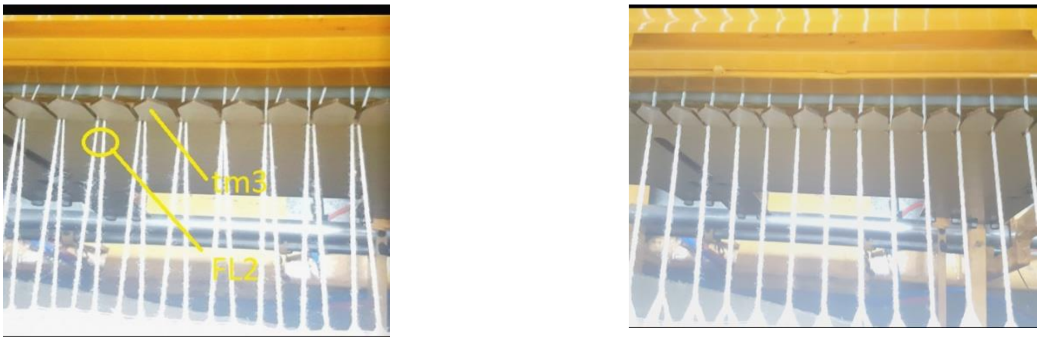
After weaving the fabrics, the machine for twisting these shawls' fringes is designed and made (figure 3). The two jaws (constructed on both sides of the machine, pull out the holder shawls) and all connected-shawls are fed to the machine in a roll. These two jaws apply their force on both sides of the fabric thanks to 4 springs so that the fabric is stretched and the fringes take flat with enough tension so that the two rubbing jaws can perform the twisting operation. This tension force is one of the factors studied in this research. On the surface of the two rubbing jaws, soft material is used to twist the fringes. The two rubbing jaws' pressure over each other is supplied by the pneumatic air jacks and is one of the examined parameters. The two rubbing jaws move in a linear state in opposite directions to get the best twisting on the fringes, and this horizontal linear speed (Supplied with two racks and one pinion gears between two racks) is another factor studied in this research work.

There are two fine and two coarse comb teeth in the machine. A coarse comb has a tooth density equal to half (teeth per cm) of a fine comb. Also, for tm1, tm2, and tm3, there is the mirror one on the other side of the machine, as shown in Figure 3B. After twisting the first strand, two folded yarns will twist together (Figure 4), and the result will be a combination of two folded yarns that every of which is included of n yarns. For locking the final folded yarn together, the first folded yarn and the second one have the opposite twist direction, so the plied yarns of two folded step locked and not open, or on the other hand, do not happen twist loss.



A B C

Figure 3. A: Main elements of twisting machine include the tm1,tm2,tm3,tm4,tm5, where tm1 is a holder of selvage fabric that hold both sides of shawls for applying the necessary tension, tm2 is a fine comb with more density of teeth, tm3 is a coarse comb with the half density of a fine comb, tm4 is up rubbing jaw, tm5 is down rubbing jaw. B: actual condition before starting the folding process, FL1 is a bundle of yarns that will be one rope, tz is the twisting zone that applies the twist. C: a complete view of the twisting section.



A B

Figure 4. A: Two folded yarns (FL2) plied together by dividing the coarse comb (tm3) and twisting by rubbing jaws. B: Complete secondary folded before cutting the fringes from the middle point of fringes.

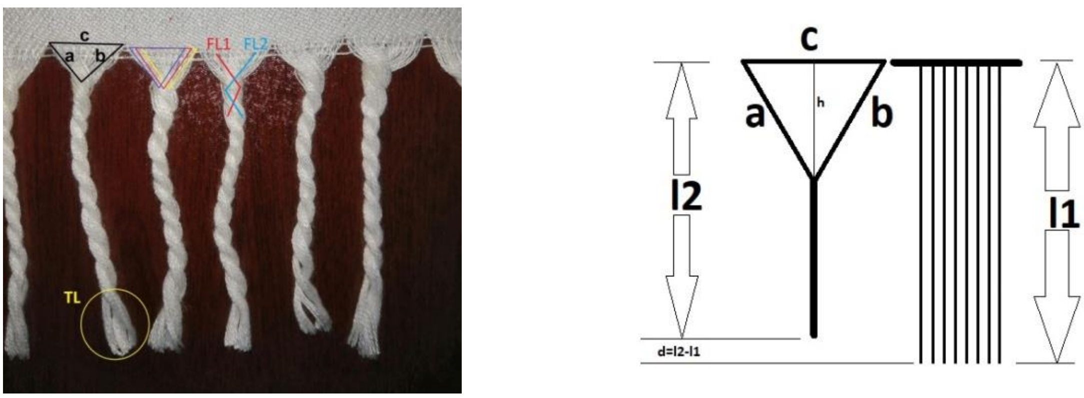
3.4. Sample preparation/ Twisting and TPM

For applying the twisting, some points are essential. The torsional stability in plied yarns [22] plays an essential role in the twisted fringes open. In some goods, twist loss is unwanted and defining the untwisting after finishing the twisting process. Also, minimum tensions must be such enough that it does not cause the snarling of two yarn' strands that rub against each other, and it can hold the twisted threads parallel to each other so that the twisting operation can be performed on the yarns bundle [23, 24],[25, 26] while should not be high that happens the slippage on the rubbing surfaces [23, 24]. [25]. Regarding increasing the yarn diameter in the second step of strand winding, maybe a little decreasing the second winding pressure reduces the slippage [23, 24]. Considering the research in twisting and end-use goods reveal necessary to a particular machine for twisting. Parameters were detected as essential factors by more than 50 random tests and causative items highlighted in table 2. The final expectation is that software finds the optimum point that finding by try and error is tedious. The twisting is done in two directions, S and Z, respectively, for one strand fringes, and secondary twisting creates the rope. The twisting system base is the same as the finisher machine that twists the silver of fibers, while here, twisting the yarns is the primary process.

Table 2. Causative factors and levels in twisting shawl fringe yarns

Row No.	Pressure (bar)	Speed (m/min)	Tension Force (kg)
1	1	1	2
2	2	2	4
3	4	3	6
4	5	4	8
5	6	5	10

Measuring twist efficiency is an important section, so an average of TPM is measured for ten fringe ropes. Hence, to compare the effect of twisting parameters on comfort is necessary to know the minimum and maximum TPM that could be applied to the fringe rope. Let to assume some parameter in figure 5.



A B

Figure 5. A: is simple shawl twisted fringes, a, b and c are triangle sides that repeat in sequentially triangles (blue, red, yellow) during the twisting process, TL is twisted loss zone at the end of folded fringes yarn, FL1 is first folded yarn, and FL2 is second folded yarn. B: schematic diagram of twisted and untwisted shawl fringes include the base of the fringe twist triangle (c), The triangle's sides (a,b), length of untwisted fringe yarns (l1), length of twisted fringe yarns (l2), and the difference of twisted and untwisted length (d=l2-l1).

As a quality control rule, the increasing twist should not create selvage damage, so it has a limitation point. The maximum twist should be under the point that damages the fabric selvage (of hanging the fringes) begin or appear. So it could be seen that, If a=b=c, there is normal condition without damage in fabric selvage; if a,b<c then fringe rope twisted more than usual and the fabric selvage will damage, while If a,b>c then fringe rope twisted but TPM is not sufficient. Finally, the "length of the twist loss zone" and TPM are determined as two main factors of fringe rope twisting.

3.5. Sample preparation/ Fringe template for observers viewing

The observer's opinion was collected in stable condition with a wooden embroidery hoop (Figure 6), and 25 samples have been prepared and showed to observers.

3.6. Sample preparation/ Measuring

Till this point, all instruments and necessary has been prepared to begin the measuring. Measuring has been done according to the below factors and levels (Table 3.), and responses are the twist (TPM) and length of twist loss zone (mm). The machine setting was the pressure of 1,2,4,5,6 bar, the linear speed of 1,2,3,4,5 m/min, and tension of 2,4,6,8,10 kg and produced results compared together. Taguchi design and the sample codes are present in column one table 3. Pressure, linear speed, and tension are mentioned, respectively, with an underline character as a spacer in column one in table 3. A final twist and twist loss are measured by calculating the twist in fringe rope and measuring the twist loss zone's length. Finally, subjective evaluation of comfort and aesthetic has been done separately by 30 observers [33, 34] include expert and non-expert that were chosen of ages in the range of 15-45 females. In comfort evaluation, observers should test the samples by hand and look carefully. Then reply which one has better comfort than the other one, and the results were processed in the Expert choice software. One of the exciting feedback on the testers' wear experience is that they announce that the untwisted fringes are disturbed in the head and tied together. For subjective evaluation of the aesthetic terms, 25 wooden embroidery hoop templates (figure 6) were used to create the same conditions for fringes, and observers made the paired comparison. The objective and subjective tests and the signal-to-noise ratio has been done and depicted in table 3.

Figure 6. Wooden embroidery hoop for positioning the shawl fringe ropes

Table 3 Subjective and objective results

Sample code Pressure_speed_tension	Twist	Twist Loss	Aesthetic	Comfort	SNRA4_ Twist	SNRA5_ TwistLoss	SNRA1_ Aesthetic	SNRA2_ Comfort
1_1_2	0	11	1.00	0.37	0.00	-20.83	0.00	-8.54
1_2_4	0	12	0.74	0.38	0.00	-21.58	-2.66	-8.47
1_3_6	0	11	0.66	0.38	0.00	-20.83	-3.56	-8.47
1_4_8	0	12	0.68	0.38	0.00	-21.58	-3.41	-8.43
1_5_10	0	12	0.62	0.41	0.00	-21.58	-4.12	-7.70
2_2_2	1	11	0.63	0.41	0.00	-20.83	-3.96	-7.66
2_3_4	2	10	0.59	0.42	6.02	-20.00	-4.63	-7.50
2_4_6	4	7	0.55	0.45	12.04	-16.90	-5.18	-6.84
2_5_8	10	2	0.53	0.46	20.00	-6.02	-5.52	-6.72
2_1_10	2	9	0.51	0.49	6.02	-19.08	-5.86	-6.23
4_3_2	0	11	0.49	0.50	0.00	-20.83	-6.16	-5.97
4_4_4	1	11	0.47	0.53	0.00	-20.83	-6.50	-5.49
4_5_6	0	12	0.46	0.56	0.00	-21.58	-6.81	-5.10
4_1_8	0	11	0.43	0.58	0.00	-20.83	-7.25	-4.68
4_2_10	2	10	0.42	0.61	6.02	-20.00	-7.63	-4.31
5_4_2	2	10	0.40	0.64	6.02	-20.00	-7.94	-3.92
5_5_4	0	11	0.38	0.66	0.00	-20.83	-8.39	-3.57
5_1_6	3	8	0.36	0.69	9.54	-18.06	-8.95	-3.19
5_2_8	10	2	0.34	0.72	20.00	-6.02	-9.26	-2.85
5_3_10	0	11	0.33	0.75	0.00	-20.83	-9.65	-2.46
6_5_2	0	11	0.31	0.79	0.00	-20.83	-10.12	-2.10
6_1_4	1	11	0.30	0.82	0.00	-20.83	-10.46	-1.72
6_2_6	10	2	0.29	0.86	20.00	-6.02	-10.76	-1.33
6_3_8	4	8	0.28	0.90	12.04	-18.06	-11.15	-0.89
6_4_10	11	1	0.26	1.00	20.83	0.00	-11.63	0.00

4. RESULTS AND DISCUSSIONS

4.1. Statistical analyzes/ Objective results/ ANOVA results

Regarding the literature, there is no research to define the twisting level and comfortable. So this question will reply by analyzing the results of AHP output. Checking the validation of data, the homogeneity of variances, and the ANOVA test calculated to understand whether there are any differences between the samples from a comfort point of view. Results show that there are differences between groups for each "twist" and "twist loss." The Sig-value of homogeneity of variances depicts that assume H_1 is rejected, and H_0 is accepted. H_0 has based the assumption of the equality of variances. Now is the time to claim the ANOVA results are certified for use.

4.2. Statistical analyzes/ Objective results/Taguchi analyzing twist level

As checking an objective parameter, the twist against the main three factors has been evaluated by the rule "higher is better.". The signal to noise ratio requested based on the larger is better because observers' opinions confirmed more twist-level bring more aesthetic and the result of analyzing depicted in figure 7.

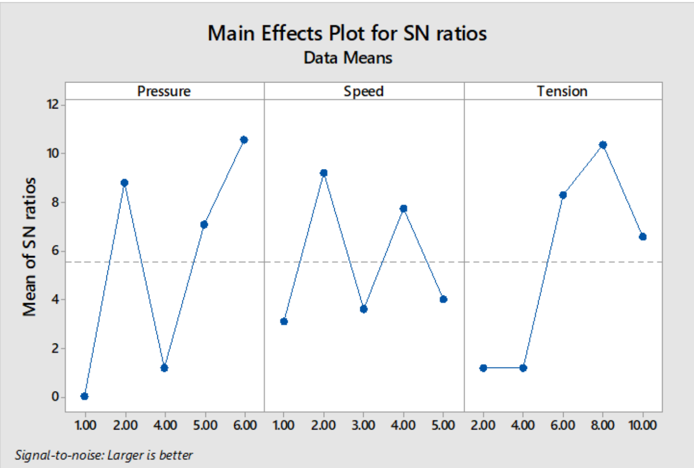


Figure 7. Taguchi results of twist against the three primary parameters

Mean of mean and mean of SN ratios outputs confirm the best state captured by handling pressure of 6 bars and speed of 2 m/min and 8 kg tension. Analyzing results confirmed that a higher level of tension and pressure are relevant factors.

4.3. Statistical analyzes/ Objective results/ Taguchi analyzing twist loss

As an objective checking, the twist loss against the main three factors has been evaluated. The effect of twisting conditions on twist loss is investigated by Taguchi analysis. Concerning the observers' results from table 3, a lower level of twist loss means more comfort of shawls; hence the Taguchi has been analyzed based on "Smaller is better" for twist loss factor and result depicted in figure 8.

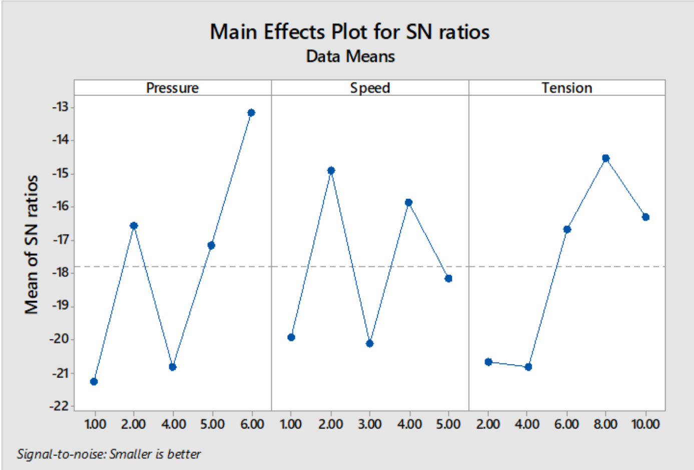


Figure 8. Taguchi results for twist loss signals based on changing the three main factors

Smaller twist loss is defined as the base guideline for Taguchi analysis to achieve the best state if twist loss level is the minimum. The Mean of Means and Mean of SN Ratios confirms that a pressure of 6 bars, speed of 2 m/min, and a tension of 8 kg push the results in the minimum twist loss. It could be seen that the results of twist level and twist loss are the same because those responses are linked together and have a vice versa relation between twist loss and twist level.

4.4. Statistical analyzes/ Subjective Results/ ANOVA results for Both Comfort and Aesthetic

The ANOVA test has been done for the subjective evaluation results too. ANOVA results indicate that observers believed differences between groups from both comfort and aesthetic points of view. This result has good confirmation of the ANOVA results of objective tests. Therefore, it would be an acceptable result that samples' comfort varies between the groups, and the Kolmogorov-Smirnov test confirms it. The Kolmogorov-Smirnov test shows that aesthetic and comfort data are standard data because Sig (0.944 and 0.846) are more prominent than 0.05, which means the H_1 assumption has been rejected, and H_0 is accepted and confirmed that the data have a normal distribution. Now is the time to test the variances are equal or not. Test of homogeneity of variances confirmed variances is homogeneous, and ANOVA results could be accepted.

4.5. Statistical analyzes/ Subjective Results/ Taguchi Analyzing of Comfort Results

Since more comfort is a favorable change, the Taguchi results are drawn based on the "Larger is Better.". Signal to noise depicted in table 3 and figure 9 shows that the most comfort belongs to the samples with the highest level of pressure and speed of 4 m/min and 10 kg tension. It is observed that speed has not shown a significant role in comfort than pressure or tension. The role of speed in combining the tension and pressure of the rubbing jaw seems to diminish.

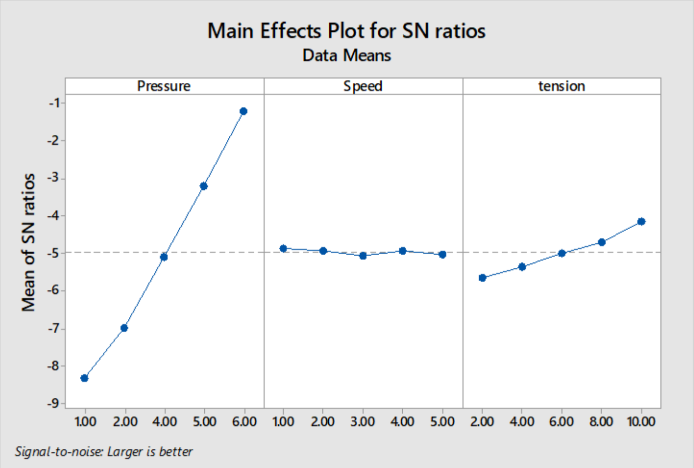


Figure 9. Taguchi results of comfort based on the three base parameters (more comfort is better.)

4.6. Statistical analyzes/ Subjective Results/ Taguchi Analyzing of Aesthetic properties

Based on the presented data (table 3), the signal to noise has been depicted in Table 3 for an aesthetic based on the main factors. This analysis is depicted based on "Larger is better" because more aesthetic properties are needed for textile goods. Signal to noise presents that more favorable effect achieved by minimizing pressure and speed and maximum tension. Increasing the tension and decreasing pressure has created a good appearance for the customers, while speed change has no remarkable effect on beauty (figure 10).

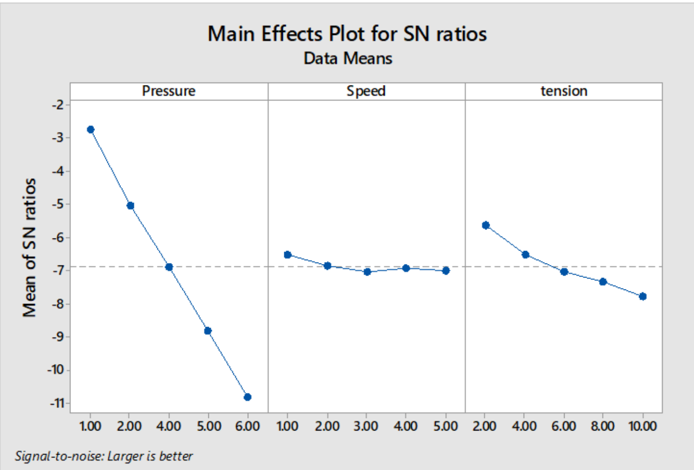


Figure 10. Taguchi results for Asethic against the three factors (more aesthetic is better)

5. PROFICIENCY

5.1. Determination R^2 for Comfort from a subjective and objective point of view

Understanding whether the subjective and objective results (twist) confirm each other is essential and draw linear regression subjective results of comfort and twist calculated and depicted in figure 11.

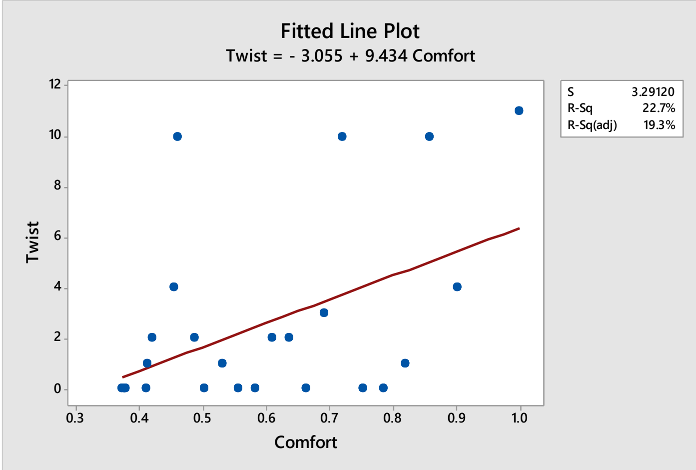


Figure 11. Regression plot of comfort and twist (X and Y axis, respectively)

Twist = - 3.055 + 9.434 Comfort (2)

Equation (2) presents the relationship between subjective comfort and twist, where X and Y are the values of subjective evaluation of comfort and twist, respectively. The relationship between the un-normalized values of the twist (Y) and subjective comfort (X) has R-sq(adj)=19.3%, and this relationship is statistically significant (P=0.016 <0.05) [28, 38].

5.2. Determination R^2 for Comfort from a subjective point of view and twist loss

Linear regression between subjective results of comfort and twist loss has been depicted in (figure 12) As it could be seen, this graph depicted by [28, 38] R-Sq = 23.2%, R-Sq(adj) = 19.9%, and P_value=0.015 between comfort sense of human being and twist loss.

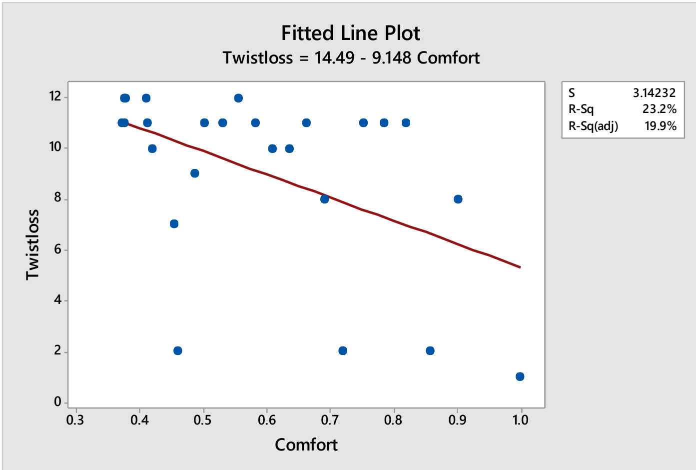


Figure 12. Regression plot between "comfort" and "twistLoss," (X and Y axis respectively)

Equation 3 shows the fitted Line between twist losses and comfort.

Twistloss = 14.49 - 9.148 Comfort (3)

5.3. The optimum condition for twisting

Shawl users and producers are interested in having more comfort and more aesthetics. Because there was a good correlation between "physical aspects of comfort from an objective point of view" and "twist and twist loss," it is enough to find the best conditions that have good aesthetic and good comfort for a shawl. On the other hand, a good correlation confirms that it was not different if the judgment was based on objective or subjective results. Moreover, more twist means less twist loss, and consequently, it has been tried to find suitable conditions that satisfy both comfort and aesthetic properties. RSM method has been used to find better desirability in considering the optimum condition. This numerical optimization method searches the design space, using the model created to find factor settings that meet the defined goals. In this work, our goal is to maximize both comfort and aesthetics. Initial parameters for the optimization set are pressure (bar), Speed (m/min), and tension (kg). These constraints must apply so that the minimum defect and process cost-benefit obtain, while it should satisfy the product necessary. In this work, total desirability has been presented in equal importance and weight. Also, the start point limitation for pressure and linear speed should be defined for achieving the actual result. These limitations come from twisting knowledge based on this test's experiences regarding the designed and manufactured machine for this research [39, 40]. The RSM method finds the optimum point based on constraints and limitations. The limitation for every parameter has been depicted in Table 4. In this table, the constraints are mentioned in the first column. Also, the goal for every ingredient has been defined that the favorable effect is created. The lower and upper range has been defined in the next column, and the start point is the defined point that the optimization problem may be solved in this domain. The start point has fluctuated in the lower and upper range of every factor. Although in this software (Expert Design version 2011), it is possible to calculate the optimum point based on the weight for upper and lower points and different importance levels of every factor, it assumes to be the same and equal.

Consequently, these settings are applied (Table 4), and the results have been depicted in Table 5. The nature of this work is such that some limitations in work must be taken into account. For example, if the tension is high, it will harm the fabric's quality, whose edge is held by the considered comb (part tm1 at figure 3A.). Also, if the jaws' pressure is too high, it will cause excessive amortizement of the device and more air consumption, so the jaws' pressure is set to a minimum and finally force the software to find the best state with these constraints.

The optimization problem has been solved based on the input data (which those depicted in table 4) and the desirability function present to achieve the 0.67 total values (Table 5). It can be seen that the numerical optimization finds a point that maximizes the desirability function. In this research, the maximum possible value for the desirability function is approximately 0.67 (Table 5).

This desirability corresponds to the pressure of 2.69 (bar), speed of 4.99 (m/min), and tension of 2.07 (kg), which depicts is the best desirability. Of course, Figure 13 shows good points for marketing and manufacturing. It shows that increasing the pressure will increase the desirability value. In some cases, the manufacturer and customers need to produce particular goods for unique usage, which demands changes in the weight of essential parameters for calculating the desirable goal.

Table 4. Constraints for the optimization process

Lower	Upper	Lower	Upper			
Name	Goal	Limit	Limit	Weight	Weight	Importance
Pressure	Minimize	1	6	1	1	3
Speed	Maximize	1	5	1	1	3
Tension	Minimize	2	10	1	1	3
Twist	Maximize	0	10	1	1	3
Twist loss	Minimize	0	12	1	1	3
Better comfort(Subjective)	Maximize	0.374211	1	1	1	3
Better Aesthetic(Subjective)	Maximize	0.262105	1	1	1	3

Table 5. Suggested desirability

Number	*Pressure*	*Speed*	*tension*	*Twist*	*Twist loss*	*Better comfort (Subjective)*	*Better Aesthetic (Subjective)*	*Desirability*	
1.000	*2.679*	*4.999*	*2.077*	*10.000*	*0.000*	*0.524*	*0.567*	*0.677*	*Selected*

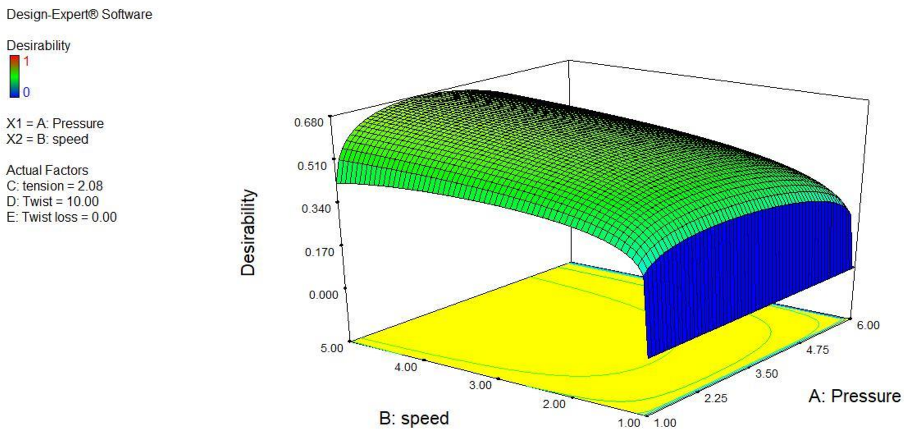


Figure 13. The 3D plot of desirability against pressure and speed

Hereupon, according to the advantages and disadvantages of parameters, regard to the all limitation mentioned above and wanted effect, 2.69 (bar), speed of 4.99 (m/min), and tension of 2.07 are the best parameters, respectively

6. CONCLUSION

In this paper, the effect of twisting parameters on shawls' comfort and aesthetic properties has been investigated. First of all, the fabric weaved by weaving looms and necessary instruments includes twisting machines and preparatory instruments designed and manufactured. Tests and experiences have been investigated to define the best range that satisfying the main twisting parameters (vertical force for pressing the rubbing jaws(bar), the horizontal speed of the rubbing jaws(m/min), and both sides of fabric tension (kg)). Then objective and subjective judgments of fringes are evaluated based on the independent factors. The unique method (wooden embroidery hoop) for presenting the prepared fringes is presented for taking a more accurate opinion of observers. TPM and twist loss are calculated, and the subjective evaluation results (analyzed by AHP software) are compared to the objective results. The results were analyzed by the Taguchi analysis method and regression plots. The results present a good correlation between twist and comfort, while twist loss decreases shawl fringes' comfort. The subjective evaluation also presents that twisting increases the aesthetic of shawls. Consequently, 2.69 (bar), speed of 4.99 (m/min), and tension of 2.07 (kg) defined as the best pressure, speed, and tension range, respectively, that achieved by drawing the disabling function with the help of the RSM method (thanks to Design expert software) to find the optimum point based on constraints and limitations.

As mentioned in the introduction, there is not much research about comfort in textile goods' fringes. It is one of the obstacles for researchers in creating the first paper in such fields, and this research hopes that it serves as a basis for further research by researchers to improve the configuration of related machines or even open solutions to design new machines for fringe twisting for textile products. Because according to the mentioned parameters, a machine with better quality and smaller dimensions can be designed for home businesses to solve jobless problems. So it is necessary to do more research like this example to discover solutions to build more economical, favorite machines to increase textile goods' novelty.

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