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Optimization of the Yarn Slippage at the Seam in Chenille Upholstery Fabrics Including Recycled and Virgin Polyester Yarns

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ABSTRACT

In this study, it is aimed to establish an optimization model that minimizes the seam slippage in chenille upholstery fabrics using recycled and virgin polyester yarns. For this purpose, 32 chenille yarns were produced in two different pile lenghts by using r-PET and virgin polyester yarns in binder and / or pile structure and then, these chenille yarns were used as weft to produce chenille upholstery fabrics. Tests have been performed in accordance with the standards to determine the physical and performance properties of woven fabrics. Statistical analyzes were made using the data obtained as a result of the tests, and equations that express each variable mathematically were created with the help of regression analysis of performance characteristics. Lingo 18.0 software was used to solve the optimization model. In the solution of the model, while the amount of seam slippage was minimized within the constraints, optimum values of some physical and performance properties of the fabrics such as count of binder and pile yarn, pile length, weft tensile strength, weft tear strength, stiffness were obtained. The use of recycled (r-PET) yarns in binder and/or pile yarns of chenille in fabrics did not affect the warp seam slippage values.

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KEYWORDS

Recycled polyester, r-PET yarn, seam slippage, upholstery fabrics, optimization model

1. INTRODUCTION

The development of technology and the increase in the production of value added products, changing fashion trends and the increase of competition in the domestic and foreign markets have affected not only the ready-to-wear sector but also the upholstery fabric sector, which is included in the home textiles. The production of fabrics of different designs with different raw materials in upholstery, the application of different finishing processes, and the widespread use of fancy yarn have been observed more frequently in recent years due to these reasons. Chenille yarns, a type of fancy yarn, are widely used in upholstery fabrics today. The soft touch, beautiful outer appearance and low cost of the fabrics obtained with these yarns are the reasons why they are frequently preferred in the upholstery fabric sector.

The production and consumption amounts are increasing with the increasing population. It is becoming more and more inevitable to reduce consumption and turn to more environmentally friendly and sustainable products. Nowadays, waste PET bottles can be recycled with the open-loop recycling method to obtain r-PET (recycled polyethylene terephthalate) fibers. The product can be recycled in a different production system and has a different usage area with this method [1]. The open loop recycling system provides great environmental benefits. With this method, the life cycle of the products extends and the disposal processes are delayed. r-PET fibers can be accepted as eco-friendly because of their contributions to the reduction of energy and raw material costs [2].

Today, r-PET yarns are used in textile, fashion and apparel industry. In chenille upholstery fabrics, which are widely used in home textiles, it has been observed that sufficient performance properties are achieved with the use of r-PET

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yarns. Thus, it can be said that more sustainable production can be made with lower raw material costs in the sector [3].

Some of the studies on seam slippage in chenille upholstery and chenille upholstery in general, the use of r-PET yarns in the textile industry are summarized below.

Galuszynski (1985) investigated seam slippage in plain woven fabrics theoretically and revealed that seam slippage or the resistance of the fabric to seam slippage depends on the yarn-to-yarn friction, yarn-to-sewing thread friction, yarn flexural rigidity and stitch and fabric geometry [4]. Kalaoğlu and Demir (2001) investigated the effect of chenille yarn properties on abrasion resistance and seam slip properties of chenille upholstery fabrics. They concluded that yarn raw material, twist and pile length are effective on abrasion resistance and fabric construction and design on seam slippage [5]. Babaarslan and İlhan (2005) compared the effects of pile yarn type and linear weight levels commonly used in chenille yarn production on abrasion resistance of upholstery fabric produced using 100% polyacrylic dralon chenille yarn. As a result of the study, it was observed that less mass loss occurred in samples using ring yarn as pile yarn compared to OE-Rotor yarns; It has been stated that longer pile yarns cause increased frictional forces during abrasion and thus increased pile losses [6]. Miguel et al. (2005) aimed to design fabrics that give optimum seam slippage values by examining the effects of structural parameters on seam slippage in wool and wool blended fabrics. They stated that the most influential variables on seam slippage were opacity, blend ratio, finish type, and cover factor [7]. Yücel (2006) investigated sewing efficiency and slippage in gabardine fabrics depending on various fabric and sewing thread properties. It was stated that the highest values were obtained in fabrics sewn with cotton / polyester sewing threads, and the lowest in fabrics sewn with mercerized cotton threads [8]. Pasayev et al. (2012) examined the effects of sewing direction and the number of interlaced of chenille yarns over warp yarns on seam slippage [9]. Özdemir and Yavuzkasap (2012) investigated seam slippage, Martindale abrasion and pilling properties of the double woven upholstery fabrics. They concluded that the seam slippage strength of upholstery double fabrics has increased by increasing weft density and by decreasing sateen number of face weave. They also stated that the seam slippage strength along both warp and weft directions and the abrasion resistance of upholstery double fabrics woven with wefts of staple polyester yarn have been higher than those of upholstery double fabrics woven with cotton wefts [10]. Namiranian et al. (2014) investigated the effects of fabric extensibility and stitch density on seam slippage and strenght behavior of elastic woven fabrics. The results show that increase in fabric extensibility leads to decrease in seam slippage load and seam strenght in weft direction. Also, in the warp direction, while the seam slippage load decreases with the increase in the fabric weft extensibility, the seam strength remains invariant [11]. Vadicherla and Saravanan (2014) discussed sustainability in the textile industry in their study. They have classified textile wastes and explained their recycling methods [12]. Payne (2015) examined open and closed loop recycling approaches for the textile, apparel and fashion industry [1]. He et al. (2015) examined the similarities and differences between the surface morphology, mechanical properties and fiber structures of recycled PET (r-PET) and standard PET (virgin PET / v-PET) fibers. They stated that r-PET fibers among the fibers selected at the same thickness and length (1.6 dtex, 38 mm) had higher tensile strength and elongation than v-PET fibers, and that there was no difference in surface morphology. In the study, it was emphasized that the structure and yarn properties of the fabrics, sewing thread properties and sewing conditions caused seam slippage [13].

The most common problems encountered in chenille upholstery are pile losses and seam slippage problems, which can be caused by low abrasion resistance. The yarn slippage at the seam in the woven fabrics significantly influences the product quality and appearance. Seam slippage is defined as the tendency of the warp and weft yarns in a woven fabric to slip over one another. A fabric is considered faulty due to seam slippage when there is a displacement of the yarn used for the fabric due to a force exerted perpendicularly to the seam, which produces an opening parallel to the seam. It is known that the yarn slippage at the seam in the woven fabrics depends on the woven fabrics' structure parameters, such as: fabric density, yarn linear density, composition and others, on fabric finishing, on sewing parameters and on seam type.

In this study, it is aimed to establish an optimization model within the scope of minimizing the seam slippage problem seen in chenille upholstery. Thus, some parameters of the optimum physical and performance properties of the fabrics can be determined by minimizing the seam slippage value before mass production and without the need for trial production. At the same time, the cost and time loss arising from trial productions in the plant can be prevented. In addition, the aspect that makes this study different from the others is to investigate the effects of r-PET use on seam slippage in chenille upholstery fabrics.

2. MATERIAL AND METHOD

Within the scope of the experimental study, r-PET yarns obtained from waste PET bottles and standard (virgin) PES yarns were used as binder and pile for production of chenille yarns. The properties of the yarns used in chenille yarn structure in the study are given in Table 1 and Table 2.

Chenille yarn machine with 128 heads was used to produce in 32 types and with two different pile lengths (0.8 and 1.2 mm). The properties and production parameters of the chenille yarns are given in Table 3 [3].

Table 1. Properties of r-PET and PES ring yarns [14]

Fiber properties	Yarn count, raw material	Twist level (tpm)	Tensile strenght (cN/tex)	Breaking elongation (%)
1.2 dtex, 38 mm	Nm 68/1, r-PET	860	17.6	12.02
1.2 dtex, 38 mm	Nm 47/1, r-PET	750	18.2	11.90
1.3 dtex, 38 mm	Nm 68/1, PES	896	29.5	11.70
1.3 dtex, 38 mm	Nm 47/1, PES	725	30.3	11.35

Table 2. Properties of r-PET and PES filament textured yarns [3]

Yarn count and raw material	**Tensile strenght (cN/tex)**	**Breaking elongation (%)**
150 denier/36 filament, PES	36.20	19.76
300 denier/72 filament, PES	35.52	19.79
150 denier/36 filament, r-PET	35.00	24.20
300 denier/72 filament, r-PET	33.79	28.87

Table 3. Chenille yarn properties and machine parameters

Raw materials of binder yarns	r-PET
	PES
Raw materials of pile yarns	r-PET
	PES
Counts of binder yarn	Nm 68/2
	Nm 47/1
Counts of pile yarn	Nm 68/1
	150 denier
	300 denier
Pile lengths (mm)	0.8
	1.2
Spindle speed (r/min)	6460
Production speed (m/min)	7.6

The caliber circumference in the chenille yarn machine changes depending on the pile lenght. Caliber circumference; it can be calculated with the help of the following equation using the caliber thickness (c_t), blade thickness (c_{kt}) and caliber width (c_w) values [15]:

$$k = 2c_w + 4c_t + 2c_{kt} \quad (1)$$

It is expressed as follows;

k: Caliber circumference (m)

c_t: Caliber thickness (m)

c_{kt}: Blade thickness (m)

c_w: Caliber width (m)

Since the caliber width determines the pile lenght of chenille, in the production of chenille with 0,8 mm pile lenght in the study, k_1; In the production of chenille with 1.2 mm pile lenght, k_2 caliber circumference value (m) was obtained.

$$k_1 = (2\times0,8\times10^{-3}) + (4\times0,5\times10^{-3}) + (2\times0,6\times10^{-3}) = 4,8\times10^{-3} \quad (2)$$

$$k_2 = (2\times1,2\times10^{-3}) + (4\times0,5\times10^{-3}) + (2\times0,6\times10^{-3}) = 5,6\times10^{-3} \quad (3)$$

The counts of these yarns used in the chenille yarn structure were determined depending on the product range of the company where upholstery fabric was produced. Therefore, since Nm 34/1 PES and r-PET yarns with similar production parameters could not be supplied to be used in binder yarn, Nm 68/1 yarn was folded and used as Nm 68/2. In addition, in order to work at a fixed count of chenille yarns, the number of pile yarns fed to the rotor was determined as 3 for staple fiber types, and 2 for the filament types. The production plan with coded chenille yarns is shown in Table 4 [3]. When the table is examined, in type A chenille yarns, r-PET yarn is used in binder and pile yarn; in type B chenille yarns, PES and r-PET yarns are used in binder and pile yarn, respectively; in type C yarns, r-PET and PES yarns are used in binder and pile yarn, respectively; in type S yarns, PES yarn is used in binder and pile yarn.

These chenille yarns were used as weft for the woven upholstery fabrics. The production parameters of the weaving machine are shown in Table 5 [3].

Weight, yarn density, crimp ratios, tensile strength and elongation, tear strength, stiffness and abrasion resistance of upholstery fabrics were determined according to TS 251, TS 250 EN 1049-2, TS 254, TS EN ISO 13934-1, TS EN ISO 13937-3, ASTM D 4032-08 and TS EN ISO 12947-3 standard procedure, respectively [16-22].

The resistance of fabric yarns against slipping was determined according to TS EN ISO 13936-2 standard [23]. Firstly, test specimens in accordance with the standard were prepared, and then the seam opening amounts that emerged under 180 N load applied between the jaws of the Instron 4411 tensile tester in vertical direction to the sewing threads were determined with the help of a caliper. Figure 1 shows the schematic view of the samples prepared in accordance with the relevant standard and sizes are in mm [9]. The Instron 4411 tensile tester with the test sample is also shown in the Figure 1.

Table 4. Chenille yarn production plan

Chenille yarn types	Binder (lock) yarn	Pile yarn	Pile length (mm)
1A	Nm 68/2 r-PET	Nm 68/1 r-PET	1.2
1B	Nm 68/2 PES	Nm 68/1 r-PET	1.2
1C	Nm 68/2 r-PET	Nm 68/1 PES	1.2
1S	Nm 68/2 PES	Nm 68/1 PES	1.2
2A	Nm 68/2 r-PET	Nm 68/1 r-PET	0.8
2B	Nm 68/2 PES	Nm 68/1 r-PET	0.8
2C	Nm 68/2 r-PET	Nm 68/1 PES	0.8
2S	Nm 68/2 PES	Nm 68/1 PES	0.8
3A	Nm 68/2 r-PET	150 denier r-PET	1.2
3B	Nm 68/2 PES	150 denier r-PET	1.2
3C	Nm 68/2 r-PET	150 denier PES	1.2
3S	Nm 68/2 PES	150 denier PES	1.2
4A	Nm 68/2 r-PET	150 denier r-PET	0.8
4B	Nm 68/2 PES	150 denier r-PET	0.8
4C	Nm 68/2 r-PET	150 denier PES	0.8
4S	Nm 68/2 PES	150 denier PES	0.8
5A	Nm 47/1 r-PET	300 denier r-PET	1.2
5B	Nm 47/1 PES	300 denier r-PET	1.2
5C	Nm 47/1 r-PET	300 denier PES	1.2
5S	Nm 47/1 PES	300 denier PES	1.2
6A	Nm 47/1 r-PET	300 denier r-PET	0.8
6B	Nm 47/1 PES	300 denier r-PET	0.8
6C	Nm 47/1 r-PET	300 denier PES	0.8
6S	Nm 47/1 PES	300 denier PES	0.8
7A	Nm 47/1 r-PET	Nm 68/1 r-PET	1.2
7B	Nm 47/1 PES	Nm 68/1 r-PET	1.2
7C	Nm 47/1 r-PET	Nm 68/1 PES	1.2
7S	Nm 47/1 PES	Nm 68/1 PES	1.2
8A	Nm 47/1 r-PET	Nm 68/1 r-PET	0.8
8B	Nm 47/1 PES	Nm 68/1 r-PET	0.8
8C	Nm 47/1 r-PET	Nm 68/1 PES	0.8
8S	Nm 47/1 PES	Nm 68/1 PES	0.8

Table 5. Weaving machine production parameters for upholstery fabrics

Weaving machine	Dornier HTV Jacquard Loom
Loom speed	400 r/min
Width of weaving machine	190 cm
Width of fabric	140 cm
Total ends	9600
Weave type	5/5 Warp rib
Weft yarn type	Chenille yarn
Warp yarn type	Polyester yarn
Weft yarn count	Nm 3.60 - Nm 3.99
Warp yarn count	150 denier / 48 filament
Weft density	10 ends/cm
Warp density	69 ends/cm
Weight of chenille fabrics	369.3 – 478.3 g/m^2

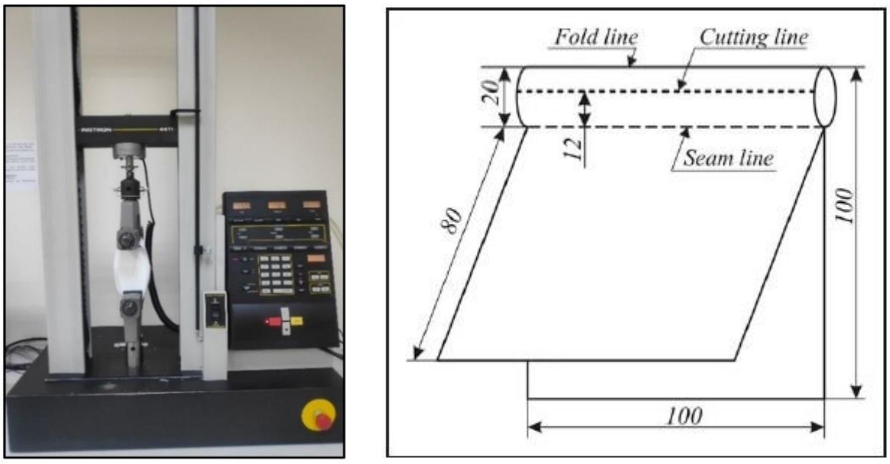

Figure 1. Instron 4411 tensile tester used in seam slippage determination and schematic view of the samples prepared for seam slippage test

The measurement results obtained from these tests were analyzed with the help of SPSS 24 Statistical Analysis Package Program. First of all, the suitability of the data to normal distribution and their randomness were analyzed before applying the regression analysis. Histogram graphics, Shapiro-Wilk normality tests, Skewness-Kurtosis values and Runs test (random test) were examined. It is understood that regression analysis can be performed after these tests. In the study, regression analysis was performed to determine the constraining equations and objective function of the mathematical model. In addition, performance results for each chenille upholstery fabric type were calculated using the equations obtained from regression analysis in the study and the relationship between these values and the values measured in the tests was also examined. The relationship between results calculated using regression equations and performance measurement results was found to be significant with 99% reliability. In the study, the equation to be used as the objective function in the seam slippage minimization model and the equations obtained from the regression analyzes to be used in the constraints were defined in accordance with the open form of Lingo and solved.

3. RESULTS AND DISCUSSION

The objective function and restrictive equations in the model, obtained form the statistical analyses, are shown in Table 6. As can be seen in Table 6, only the seam slippage of warp direction has been considered as the objective function. Since many parameters in the warp direction in the fabric samples were kept constant, the independent variables affecting the weft direction seam slippage dependent variable could not be fully determined and the explanatory power of the model (R = 0.609) was found to be low. Changes in chenille yarn production parameters generally affected the warp direction seam slippage values due to the contact of warps with wefts. Therefore, the regression equation of weft seam slippage dependent variable is not included in the optimization model. The warp seam slippage equation obtained by the regression analysis was selected as the objective function. The rest equations were included in the model as constraints. However, while determining the lower and upper limit values seen in the Table 6, test standards and literature reviews were used.

As seen in Table 4, two different raw materials, r-PET and PES, have been studied in the pile yarns of chenille in upholstery. Independent Samples t-test was applied to determine the relationship between raw material of pile yarn and fabric performance characteristics, and according to the t-test results, it was observed that there was no statistically significant relationship since the Sig. (2-tailed) value was greater than 0.05. In other words, it was determined that the pile yarns being r-PET or PES had no effect on fabric performance properties. Therefore, raw material of pile yarn was not taken as a constraint in Table 6.

Average seam slippage values of fabrics in weft direction are given in Figure 2, and average seam slippage values in warp direction are given in Figure 3 in graphical form.

According to the graphs of the seam slippage values in Figure 2 and 3, it is seen that seam slippage values decrease as the pile lenght decreases in most types. When both graphs are examined, it can be said that the seam slippage values in the weft direction are generally higher than the values in the warp direction. Type 1 and 3; Type 2 and 4; Type 5 and 7; and Type 6 and 8 are compared among themselves, when the finer pile yarn is used and the number of pile yarns fed to the rotor increases, the warp direction seam slippage values decreased.

According to correlation analysis, the relationship between the warp seam slippage and the number of pile yarns fed into the rotor, count of pile yarn, fabric abrasion resistance, is statistically significant (Sig. (2-tailed) <0.05). Correlation analysis results are shown in Table 7.

Table 6. Objective function and restrictive equations used in the model

Constraints		Lower Limit	Upper Limit
Weft tensile strength	WTSS = 171.460 – 2.598*Nm_c – 0.092*Nm_p + 16.905*BR	25.49	-
Weft tear strength	WTRS= 86.523 – 1.405*Nm_c + 4.941*BR	15	-
Stiffness	S= 3.790 – 0.037*Nm_c – 0.359*h	0.1	-
Abrasion Resistant	AR = -12.716 + 0.098*Nm_c + 0.080*Nm_p + 909.297*k + 8.676*PT	-	35
Count of binder yarn	Nm_c	34	47
Count of pile yarn	Nm_p	30	68
The number of pile yarns fed into the rotor	h	2	3
Caliber circumference	k	0.0048	0.0056
Raw material of the binder yarn	BR	0	1
Pile yarn type	PT	0	1
	Objective function		
Warp seam slippage	WSS = 2.029 + 150*k – 0.238*h		

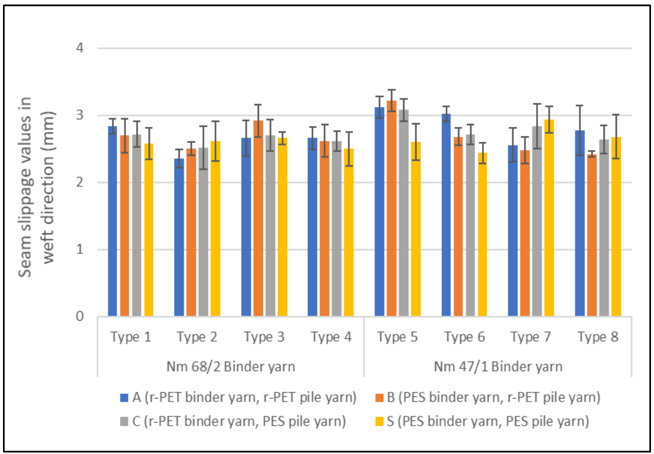

Figure 2. Seam slippage in weft direction

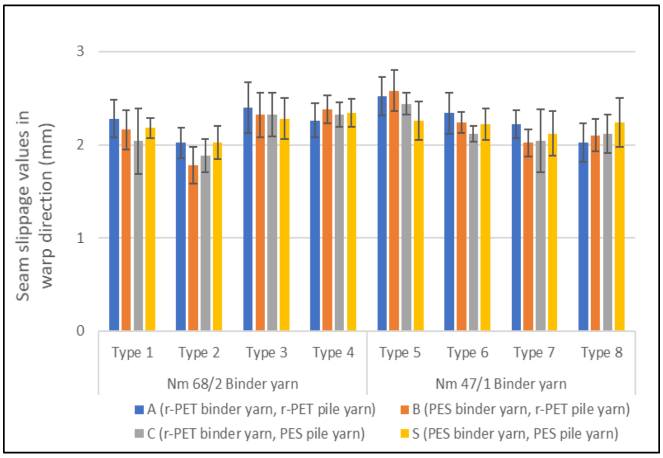

Figure 3. Seam slippage in warp direction

Table 7. Correlation analysis results

Correlations		**The number of pile yarns fed into the rotor**	**Count of pile yarn**	**Fabric abrasion resistance**
Seam slippage in warp direction	Pearson Correlation	**-0.651****	**- 0.495***	**0.670****
	Sig. (2-tailed)	0.000	0.004	0.000
	N	32	32	32

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Correlation analysis was performed to determine the direction, strength, and significance of the relationship between the variables. The relationship between seam slippage in warp direction and the number of pile yarns fed into the rotor, count of pile yarn is negative and moderate since the Pearson correlation coefficients are -0.651 and -0.495 respectively. Since the number of pile yarns in one twist of chenille yarn is less in types (Type 5 and 6) where the number of pile yarns fed to the rotor is less, it is thought that the friction coefficient between the fabric yarns decreases and thus the stitch opening amount increases.

It is seen from the mass loss graphs, given in Figure 4 and Figure 5, of the fabrics, the total mass loss value at the end of 70000 cycles is less in the types of staple fibers in pile yarns (Types 1, 2, 7 and 8) compared to the fabrics with pile filament yarn (Types 3, 4, 5 and 6). In the types using filament as pile, the abrasion and pile losses occur more due to the lower friction force between the binder and pile yarns. In addition, when the types with the same pile yarn counts (Types 1, 2, 7 and 8) are compared among themselves, it is seen that the mass losses decrease with the decrease in the binder yarn count (thickening of the binder yarn). With the thickening of the binder yarn, the pile ratios decrease. Thus, less mass loss occurs as a result of abrasion compared to chenille yarns with thinner binder yarns.

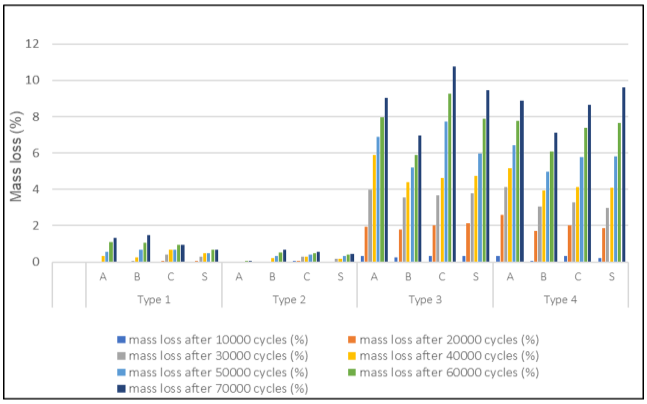

Figure 4. Mass loss values of fabrics (containing chenille yarns with Nm 68/2 binder)

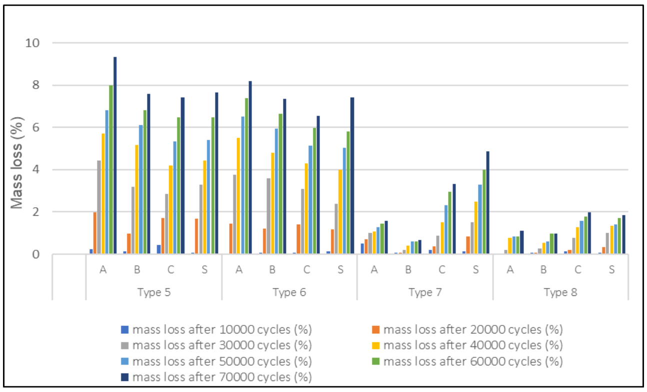

Figure 5. Mass loss values of fabrics (containing chenille yarns with Nm 47/1 binder)

The statistical analysis of the data, obtained as a result of applied seam slippage and other fabric tests (tensile strength, tear strength, stiffness and abrasion resistance), was made and a mathematical model was created to minimize seam slippage of warp direction with the help of regression equations.

Using all the data, it was written in accordance with the writing format of Lingo 18.0 optimization program. The seam slippage minimization model of chenille upholstery was written in open form. The problem resulted in 'Global Optimum' solution. This result means that the best solution is obtained in line with the constraints. The result of the solution (objective value) or the minimum warp seam slippage value is 2.035 mm.

Lingo program gives the solution report of the model by grouping in 4 separate sections as Value, Reduced Cost, Slack or Surplus and Dual Price. All variables of the model are included in the "Variable" section in the solution report. In the 'Value' section, there are values that the variables in the model take in the global optimum solution, in other words, the optimum values obtained as a result of the solution of the model are given. In the solution report, the binder yarn count (Nm_c) Nm 47/1; pile yarn count (Nm_p) Nm 68/1; weft tensile strength (WTSS) 60.003 kgf; stiffness (S) 0.97 kg etc. and seam slippage value (value of objective function) becomes 2.035 mm. Table 8 shows the optimum values of all variables included in the model in seam slippage minimization.

Table 8. Solution results of the WSS minimization model

Variables	**Optimum values**
WTSS (Weft tensile strength)	60.003 kgf
WTRS (Weft tear strength)	25.429 N
S (Stiffness)	0.97 kg
AR (Abrasion Resistance-loss of mass)	% 10.37
Nm_c (Binder yarn count)	Nm 47/1
Nm_p (Pile yarn count)	Nm 68/1
h (The number of pile yarns fed into the rotor)	3
k (Caliber circumference)	0.0048 m
Pile length (mm)	0.8
BR (Raw material of binder yarn)	PES
PT (Pile yarn type)	Filament
Minimum WSS (Warp seam slippage) value: 2.035 mm	

4. CONCLUSION

The aim of the study was to minimize the seam slippage value in chenille upholstery with recycling and virgin polyester yarns content and to obtain optimum values of some physical and performance properties of the fabrics such as count of binder and pile yarn, pile length, weft tensile strength, weft tear strength, stiffness. The results of the study are summarized below.

- Seam opening in fabrics is generally affected by the properties of fabric yarns and fabric structure, sewing yarn properties and sewing type and sewing machine [9]. In this study, since the weft and warp densities, which are among the important parameters that will affect the seam opening, were kept constant, the other parameters were taken into consideration.

- It is seen that lower seam slippage values are obtained as the pile lenght decreases in most of the type groups.

- It can be said that generally the seam slippage values in the weft direction are higher than the values in the warp direction. The slippage of the seam in the weft direction under the influence of mechanical forces is greater than the seam in the warp direction. When the seams are in the warp direction, lower seam openning values occur. For this reason, it is recommended to use the seam in the warp direction as much as possible on chenille upholstery fabrics [24].

- The use of recycled (r-PET) yarns in binder and/or pile yarns of chenille in fabrics did not affect the warp seam slippage values. At the same time, the Independent sample t-test performed within the scope of statistical analysis confirmed that the use of r-PET or standard PES yarn in binder and pile yarns did not have a significant effect on seam slippage of warp direction (Sig. (2-tailed)> 0.05).

- According to the results of the correlation analysis, it was seen that there was a negative and moderate relationship between warp seam slippage and the number of pile yarns fed into the rotor, count of pile yarn. The relationship between seam slippage in warp direction and fabric abrasion resistance was positive and moderate.

- According to the solution report of the optimization model, the best value of the warp seam slippage aimed to be minimized was obtained as 2.035 mm. For chenille in an upholstery fabric having this warp seam slippage value, the binder yarn count Nm 47/1; pile yarn count Nm 68/1; The number of pile threads fed into the rotor is 3; The caliber circumference that changes depending on the pile lenght is 0.0048 m; binder yarn raw material and pile yarn type are determined as PES and filament, respectively. In addition, the weft tensile strength of chenille upholstery produced with these properties is 60.003 kgf; the weft tear strength of 25.429 N; 0.97 kg of stiffness; It can be predicted with high reliability before production that the abrasion resistance (mass loss) value will be 10.37%.

- In this study, a mathematical optimization approach has been applied to the problem of seam slippage, which is an important problem in chenille upholstery. Based on the created model, new models can be easily developed for different purposes. Since some physical properties and fabric performance properties of upholstery fabrics can be predicted before production with the developed model, cost increases and time losses that may be caused by trial productions in plants can be prevented.

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