(REFEREED RESEARCH)

EVALUATION OF AIR PERMEABILITY OF FABRICS WOVEN WITH SLUB YARNS

ŞANTUK İPLİKTEN ÜRETİLMİŞ DOKUMA KUMAŞLARIN HAVA GEÇİRGENLİĞİNİN İNCELENMESİ

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ABSTRACT

The aim of this research was to analyse the influence of slub yarn structure on air permeability of woven fabrics. Slub length, slub distance, amplitude of slub and yarn linear density were used as control factors to produce slub yarns with varying properties according to Taguchi L9 orthogonal design. Twill 1/3 woven fabrics were produced with these slub yarns and air permeability results were statistically analysed. Optimum yarn parameters were determined for air permeability which was considered as nominal-the-better property according to the end-use purposes of the fabric. The analysis results showed that slub thickness had the most significant effect on air permeability.

Keywords: Slub Yarn, Air Permeability, Woven Fabric, Taguchi, Orthogonal Design

ÖZET

Bu çalışmadaki amaç, şantuk iplik yapısının dokuma kumaşın hava geçirgenliği özelliği üzerindeki etkisini incelemektir. Bu amaçla, şantuk uzunluğu, şantuk mesafesi, şantuk kalınlığı ve iplik numarası kontrol faktörleri olarak belirlenmiş ve Taguchi L9 ortogonal dizaynına göre farklı özelliklerde şantuk iplikler üretilmiştir. Bu ipliklerden 1/3 dimi kumaşlar dokunarak hava geçirgenliği özellikleri istatistiksel olarak analiz edilmiştir. Kumaşın son kullanım amacına göre "hedef değer en iyi" olarak değerlendirilen hava geçirgenliği için optimum iplik parametreleri tespit edilmiştir. Analizler, şantuk kalınlığının hava geçirgenliği üzerinde en etki faktör olduğunu göstermiştir.

Anahtar Kelimeler: Şantuk İplik, Hava Geçirgenliği, Dokuma Kumaş, Taguchi, Ortogonal Dizayn

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1. INTRODUCTION

Comfortability as well as physiological, mechanical and end-use properties is very important for many flat textile products, such as weaving or knitting fabrics, outerwear etc. [1, 2]. Fabrics with fancy yarns can also be included in this group. Fancy yarns present deliberate, decorative and also programmed effects of colour and/or form, and they are used to create certain variations in their aesthetic appearance. These variations in their forms also change their comfort properties as well as their appearance [3].

Air permeability is one of the important parameters that affect the apparel comfort. The permeability of textiles used in clothing influences thermal regulation of the human body and comfort during wearing and also plays a role regarding health issues [4]. Air flow through textiles is mainly affected by the pore characteristics of fabrics. If there is no possibility of air flow through the pores of the fabric or the flow is difficult, very soon it will cause feeling of discomfort. For this reason, air permeability might be considered as a feature of fabric which has a great contribution in overall clothing comfort. Most of the literature published regarding air permeability has focused on the study of properties of knitted, woven and coated fabrics [1, 2, 5, 6, 7], but there have been few investigations on fabrics with fancy yarns [8, 9].

Studies of slub yarn are critically important because fabrics woven from slub yarn have special aesthetic properties [10]. These properties are due to the slub effects formed by the variation in linear density in the slub yarn. A simple slub yarn structure is composed of two parts, the base part and the slub part. The repetition pattern of slub yarn is determined by: slub length, slub distance and amplitude of slub. In previous studies the effects of descriptive parameters on the breaking force and elongation of slub yarn were determined [11], slub yarn breaking strength has been numerically analysed [12]. Furthermore, various methods were used and developed in order to visualise and determine the geometrical parameters of slub yarns [13, 14, 15]. However, there is a gap in the studies about the slub yarn fabric parameters and how they are affected by the slub yarn properties. Most of the previous studies were focused on simulation and modelling of slub yarn fabrics [16, 17]. Thus in this study, slub length, slub distance and amplitude of slub were chosen as control factors with yarn linear density in order to analyze the influence of slub yarn structure on the air permeability of woven fabrics.

2. MATERIAL AND METHOD

In the experimental part of the study 100 % combed, 738 tex cotton roving with 48 T/m twist were provided from a yarn spinning mill. The average values for the cotton fiber length, fineness and tenacity values were 29.80 mm, 4.32 micronaire and 30.7 cN/tex, respectively. Basic slub yarns were produced with Merlin spinning frame. In order to achieve the slub effect, the intermittent acceleration of the middle and back feeding rollers was applied to obtain the varying degrees of draft in yarn spinning. The spindle speed was constant at 8000 r.p.m. The twist coefficient of basic slub yarn was chosen the same for all experimental samples; α_{tex} =114 (α_e = 3.8), since yarns were used as weft threads. The control factors and their levels were shown in Table 1. Selection of control factors and their levels were chosen on the basis of literature review on the subject.

The experiments were designed according to Taguchi's orthogonal array (OA) technique which is a powerful tool for improving quality and simultaneously reducing development time [18]. Experimental design refers to the determination of the experimental conditions run in order to decide design parameters or manufacturing conditions for stable quality. The method uses a special design of OAs in order to study the entire parameter space with a small number of experiments. The experimental results are then transformed into an S/N (signal to noise) Ratio. Taguchi $L_9 \; (3^4)$ orthogonal array was selected; slub distances, slub length, amplitude of slub and yarn linear densities were chosen as factors with three levels. The main effects were determined; all other interactions were considered as negligible in the analyses. The experimental layout using orthogonal array (L_9) for sample production was given in Table 2.

Twill 1/3 woven fabrics were produced with Dornier air jet weaving machine in the experimental part of the study. Nine different characterized 100 % combed slub yarns were used as weft yarn in the production of fabric. Warp yarns having Ne 10 yarn linear density was the same for all fabrics.

QT-4 software was used for the design and analysis of Taguchi Experiments. In the design of the study, Taguchi L_9 Orthogonal arrays were selected and the analysis of variance (ANOVA) was utilized.

3. RESULTS AND DISCUSSION

Analysis of the Response

The experimental results of abrasion results were transformed into S/N Ratios. The S/N Ratio is used to measure quality in terms of the reciprocal of variability per unit. Regardless of the category of quality characteristic, a greater S/N Ratio corresponds to better quality characteristic. The method of calculating the S/N Ratio depends on whether the quality characteristic is smaller-the-better, larger-the-better or nominal-the-best. Air permeability is a nominal-the-better property since it depends on the end-use purpose whether air permeability is needed as low or high. For nominal-the-better characteristics, the S/N Ratio in decibel units is calculated with the formula which is given below;

$$S/N = \frac{10 \log \bar{y}^2}{\sigma^2} \qquad (1)$$

where $\bar{y}$ is the mean value and σ is the variance from the experimental observations. Average air permeability values and S/N Ratios calculated with Equation 1 were given in Table 3. Air permeability values were measured by using Textest Fx 3300.

Table 1. Control factors and their levels

		Levels		
Factors	Designation	1	2	3
Slub distance (mm)	A	100	200	300
Slub length (mm)	B	50	75	100
Amplitude of slub	C	1.5	2	2.5
Yarn count (Ne)	D	8	14	20

Table 2. Experimental layout using orthogonal array (L_9) for sample production

Sample No	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Table 3. Average air permeability values and S/N ratios of air permeability results

Sample No	A	B	C	D	Air permeability ($l/m^2/s$)	S/N ratio (dB)
1	1	1	1	1	178	25.18
2	1	2	2	2	333	24.86
3	1	3	3	3	599	26.69
4	2	1	2	3	991	27.56
5	2	2	3	1	137	14.24
6	2	3	1	2	610	31.55
7	3	1	3	2	578	24.95
8	3	2	1	3	1105	28.14
9	3	3	2	1	162	26.32

For each control factor, average effect of each factor on the yarn tensile strength at different levels was determined (Table 4). This is equal to the sum of all S/N Ratios corresponding to a factor at a particular level divided by the number of repetitions of each factor level. The delta value was calculated by subtracting the highest value from the lowest in each row. A higher delta value means that the level change of this factor has an impact on the yarn tensile strength. As shown in Table 4 amplitude of slub had greater effect than the other control factors. Slub length and yarn count could be shown as the other effective parameters for the air permeability.

The factor level corresponding to the maximum average effect of each factor was selected as the optimum level. As seen in Tablo 4 the highest S/N Ratio for each factor was determined as A3B3C1D3. The main effects plots for the S/N ratio for air permeability were shown in Figure 1 and the corresponding factor levels for the optimum air permeability were given in Table 5.

Table 4. Response table for S/N ratios

	Average S/N ratios (dB)			
Factor	**Level 1**	**Level 2**	**Level 3**	**Delta**
Slub distance	25.57	24.45	26.47*	2.02
Slub length	25.89	22.41	28.18*	5.77
Amplitude of slub	28.29*	26.25	21.96	6.33
Yarn count	21.91	27.12	27.46*	5.55

** Optimum factor level*

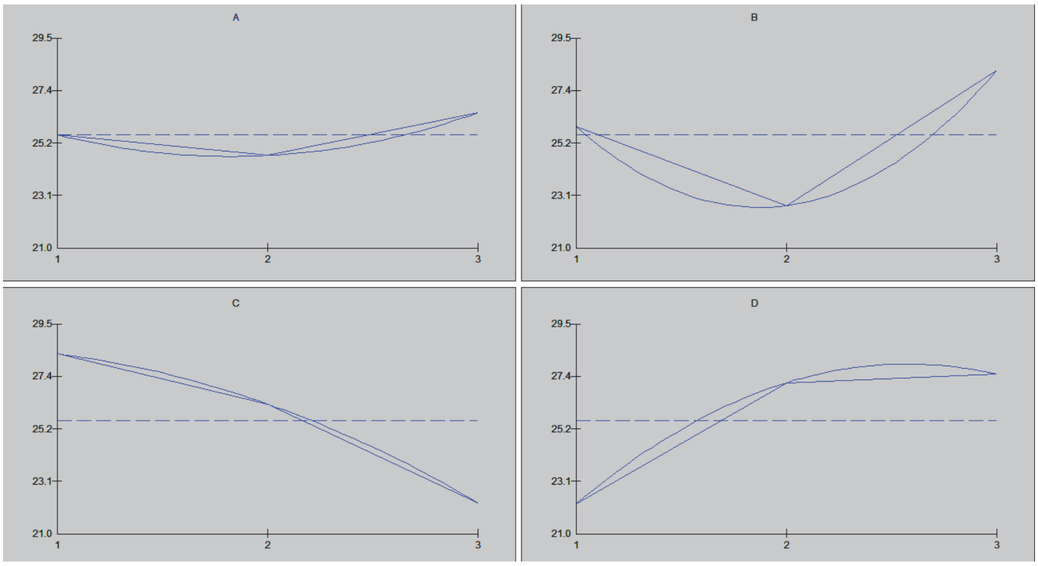

Figure 1. Average effect plots of control factors for S/N ratios

Table 5. Optimum factor levels

Factor (level)	Level type
A 3	300 mm
B 3	100 mm
C 1	1.5
D 3	Ne 20

ANOVA Analysis

ANOVA is a one of the most frequently used statistical methods to measure the influence of individual factors and to determine the relative importance of various parameters. ANOVA analysis was made with SPSS 18 and Qualitec 4. The results of ANOVA and regression analysis were given in Table 6 and Table 7, respectively.

According to the statistical analysis, all control factors has significant effect on air permeability. Slub thickness had the most significant effect with 35.28 % contribution percentage. The increase of slub thickness decreased air permeability. Yarn count and slub length had the contribution percentages of 32.73 % and 28.52 %, respectively. According to regression analysis results, the increase in yarn count increased the air permeability whereas the increase in slub length decreased the results, since slub length had negative coefficient as slub thickness did. As indicated in previous studies when the fabric is considered to be less compact, interyarn spacing will be more, which allow the air to pass through more freely [19, 20]. Finally, slub distance had a minor influence on air permeability results with the contribution percentages of 3.47 %. It can be seen from Table 7 that slub distance had positive coefficient which indicated an increase in the air permeability values.

4. CONCLUSIONS

As a result of the evaluations, slub thickness, yarn linear density, and slub length were designated as the important factors affecting the air permeability. Based on the Anova results for the S/N ratios, slub thickness was the most important parameter for air permeability. During the transport of the air through the porous of woven fabrics part of the energy of the air is used to overcome the friction of the fluid on the fabric and the rest to surmount the inertia forces. When the size of the pores decreased, the fluid friction of the fabric increased. Since higher slub thickness significantly lowered the pore sizes, it decreased the air permeability of the fabric. Slub distance found as the least effective parameter on air permeability value comparing to the other parameters.

It can be concluded from this study that using the Taguchi method, the optimum factors for maximizing air permeability can be determined from few experiments with low cost. Taguchi's approach provides a systematic, simple and efficient methodology for the optimization of design parameters with only a few well-defined experimental sets and helps determine the main parameters that affect the process. The optimum factor levels were found as A3B3C1D3; this corresponds to Ne 20 yarn with 300 mm slub distance, 100 mm slub length and 1.5 slub amplitude.

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Table 6. ANOVA analysis results for air permeability

Factor	Degree of freedom (n)	Sum of squares (S)	Mean Square	F-Ratio (F)	Sig.	Percentage (%)
Slub distance	2	1059199,40	529599,70	705,48	0.000*	3.47
Slub length	2	235301,26	117650,63	156,72	0.000*	28.52
Slub thickness	2	579586,46	289793,23	386,03	0.000*	35.28
Yarn count (Ne)	2	8169637,06	4084818,53	5441,39	0.000*	32.73

**Statistically significant at 0.05 level*

Table 7. Regression analysis results

Factor	Coefficient	t	Sig.
Slub distance	0.299	17.102	0.000
Slub length	-0.152	-8.716	0.000
Slub thickness	-0.233	-13.320	0.000
Yarn count (Ne)	0.899	51.442	0.000

Adjusted R^2 0.973

REFERENCES

1. Tokarska, M., 2008, "Analysis of Impact Air permeability of Fabrics", Fibres and Textiles in Eastern Europe, Vol. 16, No. 1, pp. 76-80.
2. Milašius, V., Milašius, R., Kumpikaitė, E., Olšauskienė, A., 2006, "Influence of Fabric Structure on some Technological and End-use Properties", Fibres and Textiles in Eastern Europe, Vol. 11, No. 3, pp. 49-52.
3. İlhan, İ., Babaarslan, O., & Vuruşkan, D., 2012, "Effect of descriptive parameters of slub yarn on strength and elongation properties", Fibres & Textiles in Eastern Europe, Vol. 20, pp. 33-38.
4. Veselá D, Kůs Z., 2016, "Device for Measurement of Static and Dynamic Air Permeability and Deformation Changes in Textile Materials", Fibres & Textiles in Eastern Europe, Vol. 24, 1(115): 120-126.
5. Čiukas, R., Abramavičiūtė, J., 2010, "Investigation of the Air Permeability of Socks Knitted from Yarns with Peculiar Properties", Fibres & Textiles in Eastern Europe, Vol. 18, No. 1 (78), pp. 84-88.
6. Ogulata, R.T., 2006, "Air Permeability of Woven Fabrics", Journal of Textile and Apparel, Technology and Management, Vol. 5, No. 2, pp. 1-10.

7. Asanovıc et al., 2015, “Quality of clothing fabrics in terms of their comfort properties”, Indian Journal of Fibre & Textile Research, Vol. 40, pp. 363-372.

8. Kumpikaite, E., Ragaišiene, A., Barburski, M., 2010, “Comparable Analysis of the End-Use Properties of Woven Fabrics with Fancy Yarns. Part I: Abrasion Resistance and Air Permeability”, Fibres & Textiles in Eastern Europe, Vol. 18, No. 3 (80), pp. 56-59.

9. Seyam, Aly El-Shiekh, 1995, “Mechanics of Woven Fabrics Part V: Impact of Weavability Limit Parameters on Properties of Fabrics from Yarns with Thickness Variation”, Textile Research Journal, Vol. 65, No. 1, pp. 14-25.

10. Liu, J., Xie, Z., Gao, W., Jiang, H., 2010, “Automatic Determination of Slub Yarn Geometrical Parameters Based on an Amended Similarity-based Clustering Method”, Textile Research Journal, Vol. 80, No. 11, pp. 1075-1082.

11. Ilhan, I., Babaarslan, O., Vuruskan, D, 2012, “Effect of Descriptive Parameters of Slub Yarn on Strength and Elongation Properties”, Fibres & Textiles in Eastern Europe, Vol. 20, No. 3, pp. 33-38.

12. Su, XZ., Gao, WD., Liu, XJ., Xie, CP., Zhu, Y., 2014, “Numerical analysis of the slub yarn breaking strength using finite element method”, Indian Journal Of Fibre & Textile Research, Vol. 39,No. 4, pp. 437-440.

13. Liu, J., Xie, Z., Gao, W., et al., 2010, “Automatic Determination of Slub Yarn Geometrical Parameters Based on an Amended Similarity-based Clustering Method”, Textile Research Journal, Vol. 80, No. 11, pp. 1075-108.

14. Liu, J., Li, Z., Lu, Y., et al., 2010, “Visualisation and Determination of the Geometrical Parameters of Slub Yarn”, Fibres & Textiles In Eastern Europe, Vol. 18, No. 1, pp. 31-35.

15. Gao, R., Gong, RH., 2004, “3D modelling of fancy yarn”, Quality Textiles For Quality Life, Vol. 1-4, pp. 1290-1293.

16. Xu, BJ., Yu, CW., 2004, “Cad and simulation for fabric appearance effect woven by slub yarn”, Quality Textiles For Quality Life, Vol. 1-4, pp. 1380-1383.

17. Kowalski, K., Ledwon, J., 1999, “Computer modelling of patterns on fabrics made from fancy yarns on weft knitting machines and of slub repeats of the yarns”, Fibres & Textiles In Eastern Europe, Vol. 7, No. 1, pp. 42-44.

18. Taguchi G., Taguchi Methods Design of Experiments, Quality Engineering Series 4, American Supplier Institute Inc., Michigan, 1993.

19. Umair, M., Hussain, T., Shaker, K., Nawab, Y., Maqsood, M., & Jabbar, M., 2016, “Effect of woven fabric structure on the air permeability and moisture management properties”, The Journal of The Textile Institute, Vol. 170, No. 5, 596–605.

20. Vimal, J. T., Murugan, R., Subramaniam, V, 2016, “Effect of Weave Parameters on the Air Resistance of Woven Fabrics”, Fibres & Textiles in Eastern Europe, Vol. 24, No. 1(115), pp. 67-72.