Mohsen Shanbeh, Arash Ataeian, Mohammad Sheikhzadeh, Hasan Zare
Isfahan University of Technology, Textile Engineering Department, Isfahan

Effect of Fibre Fineness on Colour and Reflectance Value of Dyed Filament Polyester Fabrics after Abrasion Process

Izvirni znanstveni članek

Poslano *julij 2010* • Sprejeto *november 2010*

Učinek finosti filamentov na barvne vrednosti in odbojnost svetlobe barvanih poliestrskih filamentnih tkanin po drgnjenju

Original Scientific Paper

Received *July 2010* • Accepted *November 2010*

Abstract

Fineness is one of the most important properties of fibres constituting textile products. The aim of the research was to evaluate the effect of fibre fineness of multifilament weft yarns on the change in colour (ΔE) and reflectance factor (R-value) of dyed woven polyester fabrics before and after the abrasion process, which is one of the major phenomena affecting the use-life of a garment. The effect of filament fineness of weft yarns was assessed on samples with five different weft densities. The polyester yarns used were 150den/48filaments and 150den/144filaments. The abrasion was performed at 3000, 6000, 10000 and 15000 abrasion cycles.
The research showed that the fibre fineness of weft yarns affected the colour and reflectance factor of woven fabrics after the abrasion process. The woven fabrics with 150den/144f showed a greater change in the colour and reflectance factor at lower weft densities, while by increasing weft density, the trend was reversed. There were also some fluctuations in the reflectance value of samples at different numbers of abrasion cycles, which was a consequence of different sample surface characteristics after the abrasion process. The statistical evaluations using a three-way analysis of variance showed a significant effect of fibre fineness, weft density, and the number of abrasion cycles on the colour and reflectance factor of woven samples after the abrasion process.

Keywords: reflectance value, colour difference, weft density, polyester, multifilament yarn

Izvleček

Finost vlaken je ena najpomembnejših lastnosti vlaken. Namen raziskave je bil oceniti vpliv finosti filamentov multifilamentnega votka na spremembo v barvni vrednosti (ΔE) in na faktor odbojnosti svetlobe (R-vrednost) obarvanih poliestrskih tkanin pred in po postopku drgnjenja – pojav, ki pomembno vpliva na življenjsko dobo oblačil. Raziskano je bilo pet tkanin z različno gostoto votka. Uporabljena je bila poliestrska preja 150den/48f in 150den/144f. Drgnjenje je bilo izvedeno pri 3000, 6000, 10000 in 15000 ciklih. Izkazalo se je, da finost filamentov v votku vpliva na barvne vrednosti in faktor odbojnosti svetlobe tkanin po drgnjenju. Tkanine s 150den/144f so pokazale večjo spremembo pri nižjih gostotah votka, medtem ko je bilo s povečevanjem gostote obratno. Zaradi različnih površinskih lastnosti vzorcev po drgnjenju so se pojavljala nihanja v vrednosti odbojnosti svetlobe vzorcev pri različnem številu ciklov drgnjenja. Statistična obdelava s trismerno analizo variance je pokazala pomembnost vpliva finosti filamentov, gostote votka in števila ciklov drgnjenja na barvne vrednosti in faktor odbojnosti svetlobe tkanih vzorcev.

Ključne besede: odbojnost svetlobe, barvne vrednosti, gostota votka, poliester, multifilamentna preja

Vodilni avtor/corresponding author:
Mohsen Shanbeh
tel.: +98 311 (391) 50 37
e-mail: mshanbeh@cc.iut.ac.ir

1 Introduction

All over the world, the synthetic fibre industry has been tremendously growing and developing technologically. The introduction of finer fibres by the manufacturers of manmade fibres for the use in the apparel industry has created limitless possibilities to achieve improved physical, mechanical and aesthetic properties of apparel fabrics. The fabrics manufactured from these fibres have better softness, drape, dimensional stability and wicking, thus ensuring better mechanical and comfort properties. A study by Srinivasan et al [1] was conducted to evaluate the physical and mechanical properties of knitted fabrics from polyester micro-denier fibres. The results of their study showed better drapability, wicking behaviour and water-drop absorbency of microfibre fabrics than of normal denier fabrics. The bursting strength of microfibre fabrics was slightly better than that of normal denier fabrics. However, the pilling resistance and abrasion resistance of microfibre fabrics did not vary significantly compared with normal denier fabrics. The effect of fibre fineness on the comfort characteristics of polyester woven fabrics was studied by Pouriamehr et al [2]. They found that by increasing fibre fineness, the friction coefficient and bending modulus reduce, while the wicking and tensile properties on the other hand improve.

The life of garments depends on different parameters which affect the garments during their application. There are different processes, e.g. abrasion, cutting action, laundering, light and etc, which change the garment properties. Among these processes, abrasion is defined as the phenomenon that reduces the serviceable life of garments. Therefore, the abrasion resistance of fabrics is the major criterion taken into consideration when choosing the type of a fabric.

According to the ASTM standard [3], abrasion is defined as the wearing away of a part of material by rubbing against another surface. There are several ways in which a fabric can be abraded. Abrasion ultimately results in the loss of performance characteristics, such as strength and the appearance of a fabric [4]. Different factors have been found to affect the abrasion of a fabric, including fibre type, fibre properties, yarn twist and fabric structure [5]. Different abrasion test methods have been introduced, e.g. Martindale abrasion tester [3], oscillatory cylinder [5] and rotary platform double-head methods [6]. Among the test parameters which can affect the results of an abrasion test, the type of abrasion, type of abradant, pressure, speed tension and direction of abrasion should be mentioned [7].

There are many researches related to the abrasion process, e.g. studying the effect of increasing abrasion cycles on the reflectance value and the difference between cotton and wool fabrics [4, 8]. Fatma Kalaoglu et al [9] studied the influence of various structural parameters of 50/50 wool/polyester blended fabrics on the abrasion characteristics. The abrasion resistance of cotton/flax fabrics on the basis of computer simulations of fabric wear geometry was studied by Koltysheva et al [10]. Another paper evaluated the effect of abrasion on the stress-strain properties of two polyester/cotton fabrics [11]. The effect of the cross-section shape of polyester fibres on the values of woven fabrics after the abrasion process was studied by Becerir et al [12].

The literature shows that there are not any studies about the evaluation of the effect of fibre fineness on the colour change and reflectance value of multifilament polyester woven fabrics after the abrasion process. Therefore, apart from better mechanical and physical properties of woven fabrics by using finer fibres, in this experiment, the effect of fibre fineness on the reflectance factor and the effect of differences on the use-life of fabrics after the abrasion process are evaluated. Finally, a statistical evaluation based on a three-way analysis of variance was used to compare the difference between the change in colour and reflectance factor of woven samples after the abrasion process.

2 Materials and methods

For the purpose of this study, fabrics were woven in 5 different weft densities with two kinds of polyester weft yarns, i.e. 150den/144f and 150den/48f DTY filament yarns, with a Z-twist. The fibre cross section was round in these yarns. The tensile properties are presented in Table 1. The selected weft densities were 11, 14, 17, 20 and 23 per centimetre. The warp yarn was 150den/48f DTY filament yarns and its density was 24 per centimetre. 10 different samples were produced.

The dyeing procedure and the auxiliaries applied in the dyeing of polyester woven fabrics are shown in

Table 2. A computerized laboratory dyeing machine called Polymat from Data was used (cf. Figure 1). The reduction cleaning of samples was performed using hydro and alkali according to Table 3. The construction parameters of samples before and after the dyeing process, and specified codes for each of them are listed in Table 4.

The abrasion tests were performed on a Martindale abrasion tester in accordance with the ASTM D4966 standard [3] at 4 different numbers of abrasion cycles, i.e. 3000, 6000, 10000 and 15000 cycles.

The thickness values of samples after the abrasion process are presented in Table 5.

The reflectance factors of samples (before and after the abrasion process) were measured with a Texflash spectrophotometer from Datacolor. The CIE L*a*b* colour system was used to evaluate the colour deviations by means of ΔE*ab values.

The wavelength of 640 nm (between 400–700 nm) was found as the minimum reflectance of samples; hence, the reflectance values were recorded at this wavelength.

Table 1: Tensile properties of weft yarns

Parameter	Breaking strength (cN/tex)		Breaking elongation (%)	
	Mean	CV (%)	Mean	CV (%)
150den/48f	27.30	6.49	24.32	3.87
150den/144f	29.70	4.20	29.91	8.77

Table 2: Dyebath contents

Dye	CI Disperse	Acetic acid	Carrier (DI-300, Dongin Texchem Co., Ltd)	Dispersing agent (Donasisi NWA-1DD, Dongin Texchem Co., Ltd)	L : G
1%	Blue 56	30 ml/lit	6 g/l	1.3 g/l	30 : 1

Table 3: Reduction cleaning of samples

Sodium hydrosulphite	Ammonia	Dispersing agent	Temperature (°C)	Time (min)
3 g/l	4 g/l	1 g/l	50	30

Table 4: Construction parameters of woven fabrics after dyeing

Fabric code	Weft density (1/cm)		Weft number	Warp density (1/cm)	Weight (g/m²)	Thickness (mm)
	Nominal	After dyeing				
A	11	17.3	150den/48f	31.3	118.50	0.45
B	14	18.5	150den/48f	31.7	124	0.44
C	17	22.8	150den/48f	30.3	122.75	0.33
D	20	25.2	150den/48f	32.0	125.5	0.30
E	23	27.3	150den/48f	31.0	128.5	0.29
F	11	17.1	150den/144f	31.3	116.75	0.43
G	14	18.9	150den/144f	29.5	121.5	0.43
H	17	22	150den/144f	31.7	121.0	0.36
I	20	25.2	150den/144f	32.0	135.25	0.31
J	23	26.7	150den/144f	31.2	136.5	0.26

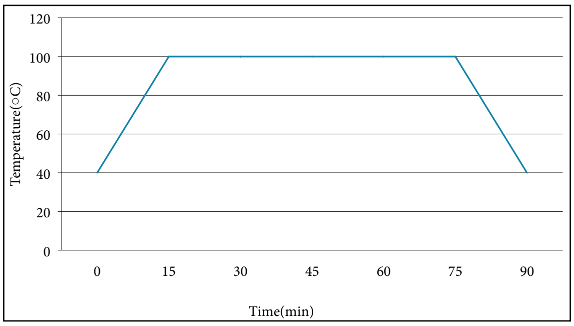


Figure 1: Dyeing process of samples

Table 5: Thickness values (mm) of woven fabrics after abrasion process

Sample code	Abrasion cycles				
	0	3000	6000	10000	15000
A	0.45	0.42	0.45	0.43	0.43
B	0.44	0.38	0.37	0.38	0.42
C	0.33	0.33	0.31	0.32	0.32
D	0.30	0.30	0.30	0.31	0.32
E	0.29	0.27	0.27	0.27	0.27
F	0.43	0.45	0.44	0.44	0.44
G	0.43	0.42	0.43	0.47	0.46
H	0.36	0.33	0.33	0.35	0.34
I	0.31	0.29	0.29	0.33	0.34
J	0.26	0.28	0.27	0.28	0.26

3 Results and discussion

Figure 2 (a–e) shows the effect of fibre fineness of weft yarns on the difference in colour after the abrasion process.

The colour differences of Fabrics F, G and H were higher than that of Fabrics A, B and C, respectively. The largest change in this value occurred until the 6000th abrasion cycle for Fabrics A and F, B and G, and C and H. On the other hand, it could be observed that by increasing weft density up to 20 wefts per centimetre the colour difference of Sample I was almost equal to Sample D, and in the maximum weft density, this trend was reversed, thus Sample J woven with finer fibres displayed a lower colour difference compared to Sample E. For these samples, i.e. Samples I and D, and Samples E and J, the largest change in colour difference was observed at 10000–15000 abrasion cycles. In consequence, the fabrics woven with 150den/144f weft yarn were more affected by the abrasion process in lower weft densities, although by increasing weft densities, these samples showed lower distortion.

The above mentioned parameters, i.e. weft density and fibre fineness, obviously had a tremendous effect on the abrasion resistance of fabrics in this study. According to the literature [7], by increasing weft density up to a specific level, the abrasion resistance increases, since each individual thread has to take less force. However, there are some optimum values for increasing weft density, since the jamming of yarns and more movement restriction during the abrasion process by increasing weft density could cause more distortion of the fabric structure. On the other hand, the flexural rigidity of a filament depends on its shape, tensile modulus, density and most of all, its thickness. The flexural rigidity varies with the second power of the linear density of a filament as shown in Equation 1 [13]:

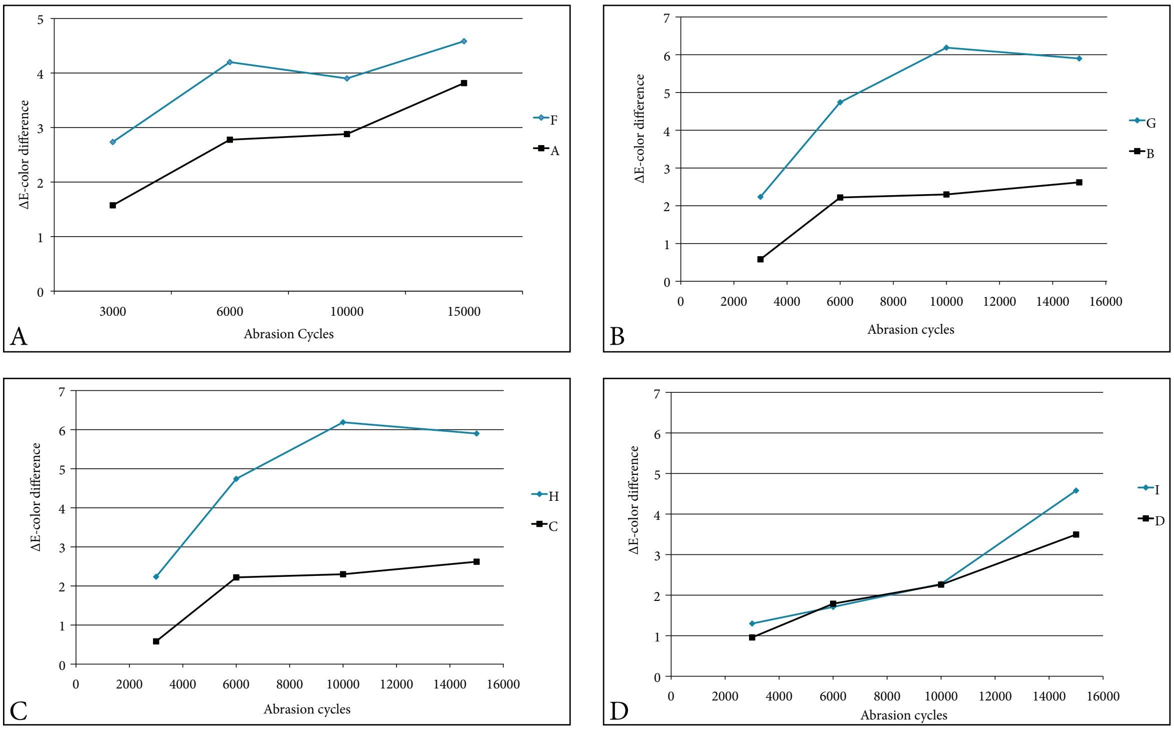
$$\text{Flexural rigidity (Nmm}^2\text{)} = \frac{1}{4\pi}\frac{\eta E T^2}{\rho} \qquad (1)$$

where T (kgm^{-1}) is the linear density of a filament, ρ (kgm^{-3}) is density, E (Nkg^{-1}m) is a specific modulus and η is the shape factor.

The finer fibres which had a lower breaking load could be more affected by the cyclic rubbing actions during the abrasion process in lower weft densities due to the more space available for their movement and displacement. On the other hand, by increasing weft densities, there is not as much space for the fibre movement as it is in lower weft densities. This causes fibre breakage and more fabric distortion under cyclic rubbing actions especially in higher weft densities with regard to the coarser fibre which had higher rigidity than the finer fibre according to Equation 1.

The decrease in the colour difference of woven fabrics containing 150den/144f weft yarn in 23 wefts per centimetre (Samples J and E) could be more influenced by fibre fineness than weft density. Thus, the distortion of the woven Fabric J was lower than of the woven Fabric E.

Figure 3 (a–b) shows the effect of weft density on the colour change in different abrasion cycles. In the samples woven with 150den/48f, the colour



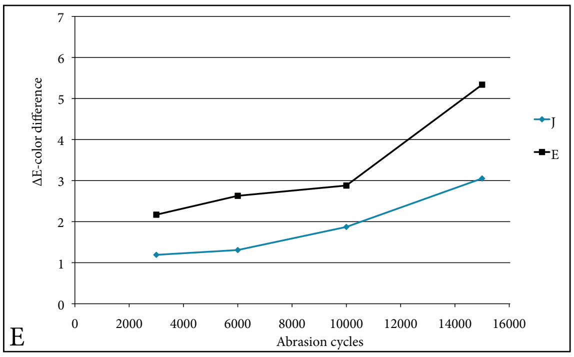


Figure 2: Colour differences of woven fabrics with different weft density: (a) 11 per cm, (b) 14 per cm, (c) 17 per cm, (d) 20 per cm and (e) 23 per cm.

difference was reduced up to the optimum values of weft density and then increased in most cases. This trend was not observed with woven fabrics with 150den/144f weft yarns. In these samples, it was clear that by increasing weft density in all abrasion cycles, the colour difference reduced. The prominent effect of variation of weft density on the abrasion resistance and then the colour change of the fabric could be the reason for the observed trend on the samples woven with 150den/48f weft yarns. On the other hand, irrespective of the increase in weft density and less free space for fibre displacement, a higher flexibility of finer fibres in 150den/144f yarns has a dominant effect on the abrasion resist-

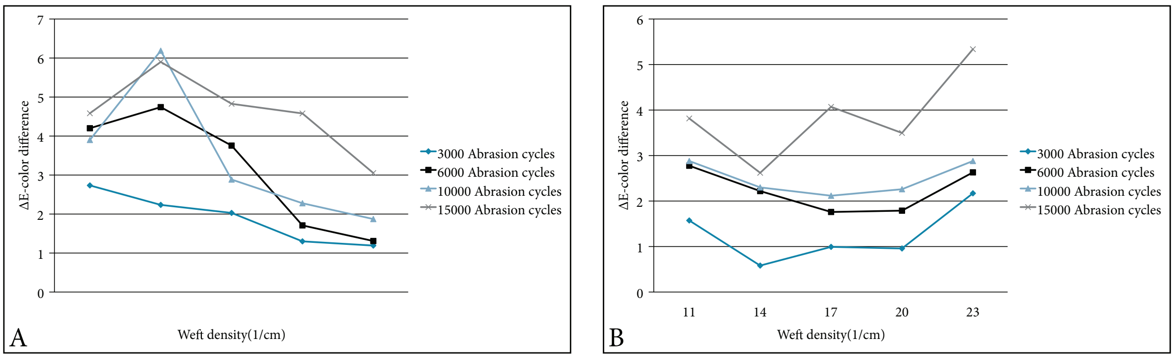
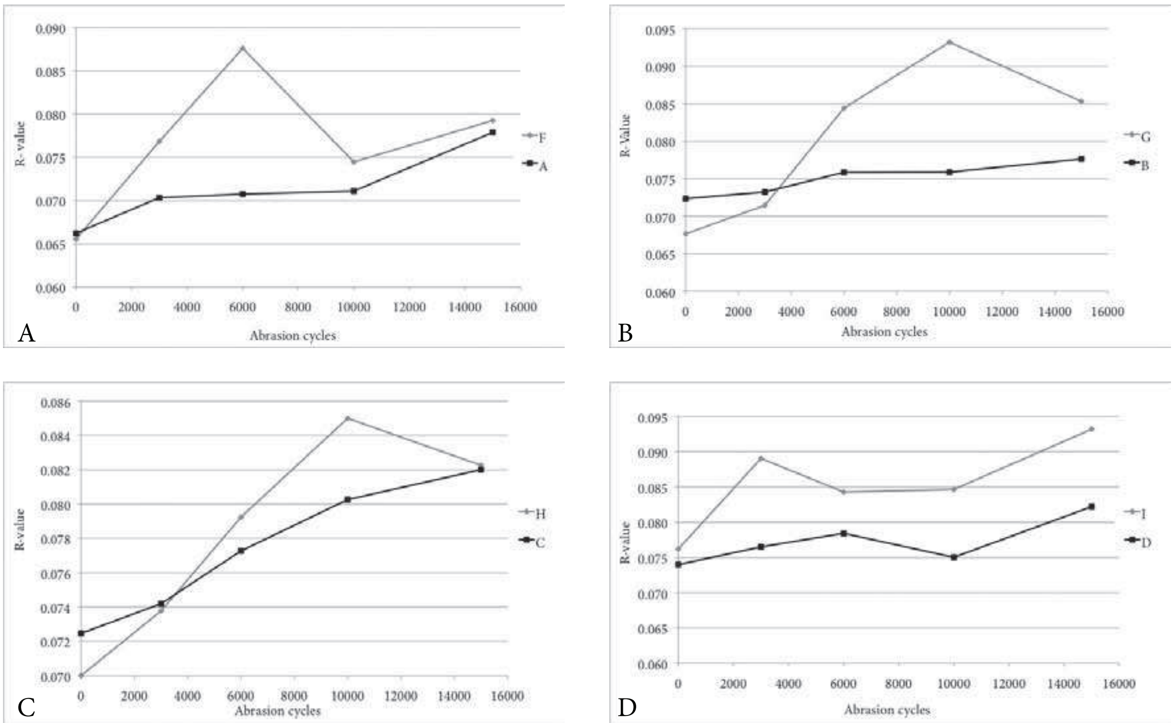


Figure 3: Effect of weft density on difference of samples after abrasion process; (a) 150den/144f weft yarn, (b) 150den/48f weft yarn

Table 6: Statistical evaluation of difference of samples after abrasion process using ANOVA at 0.05 significance level

Source	Sum of squares	df	Mean square	F	Sig.
Corrected model	469.305	39	12.033	4.798	0.000
Intercept	1775.216	1	1775.216	707.780	0.000
Abrasion cycle	247.061	3	82.354	32.834	0.000
Weft density	65.846	4	16.461	6.563	0.000
Yarn type	16.817	1	16.817	6.705	0.011



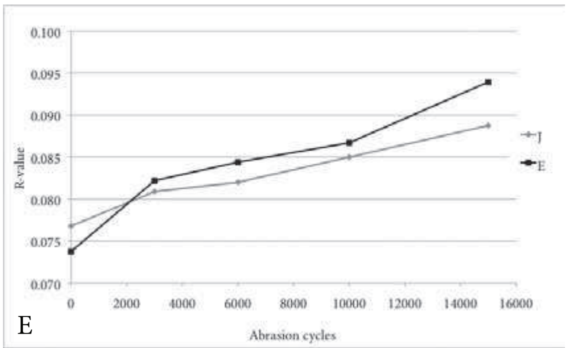


Figure 4: Reflectance value of woven fabrics with different weft density:
(a) 11 per cm, (b) 14 per cm, (c) 17 per cm, (d) 20 per cm and (e) 23 per cm

ance, which could be the reason for the observed trend in Figure 3a.

The photos of fabrics after 3000 and 15000 abrasion cycles, respectively, taken with a Light Microscope (Stereo Microscope) are given in Figure 5, where the surface changes are visible. The photos were taken with the magnification 30×. The figures show that the number of ruptured and pulled out fibres on the surface of fabrics in 15000 abrasion cycles was more than 3000. These distortions were in most cases more visible for the samples with 150den/144f weft yarns.

The difference between the colour changes of samples after the abrasion process using a three-way analysis of variance was performed at the 0.05 significance level using the SPSS software. As shown in Table 6, it was clear that all three parameters, i.e. the number of abrasion cycles, weft density, and yarn type (fibre fineness of yarn) had a significant effect on the colour change of samples at the 0.05 significance level (sig. value < 0.05).

The effect of fibre fineness and weft density on the reflectance value of samples is presented in Figure 4 (a–e).

The reflectance values of all abraded samples in different abrasion cycles were higher than of the unabraded samples. Moreover, it seems that the reflectance value of fabrics with 150den/144f weft yarn was higher than with the 150den/48f ones in all cases except for the sample woven with 23 wefts per centimetre. As shown in Figure 4 (a–e), some fluctuations could also be observed in the reflectance value of samples in certain abrasion cycles.

It can be observed from the photographs (cf. Figure 5) that filaments are ruptured or pulled out due to the abrasion process. The change in the light reflection characteristics of the surface could be associated with the condition of filaments on the surface after the abrasion.

The ruptured and pulled out fibres on the fabric surface may act as light-scattering points. This phenomenon causes a decrease in the reflectance value of Samples H and G at 15000 abrasion cycles, of Sample F at 10000, Sample I at 6000 and Sample D at 10000 abrasion cycles. On the other hand, the surface uniformity of one fabric might be improved by the ruptured and pulled out fibres, since

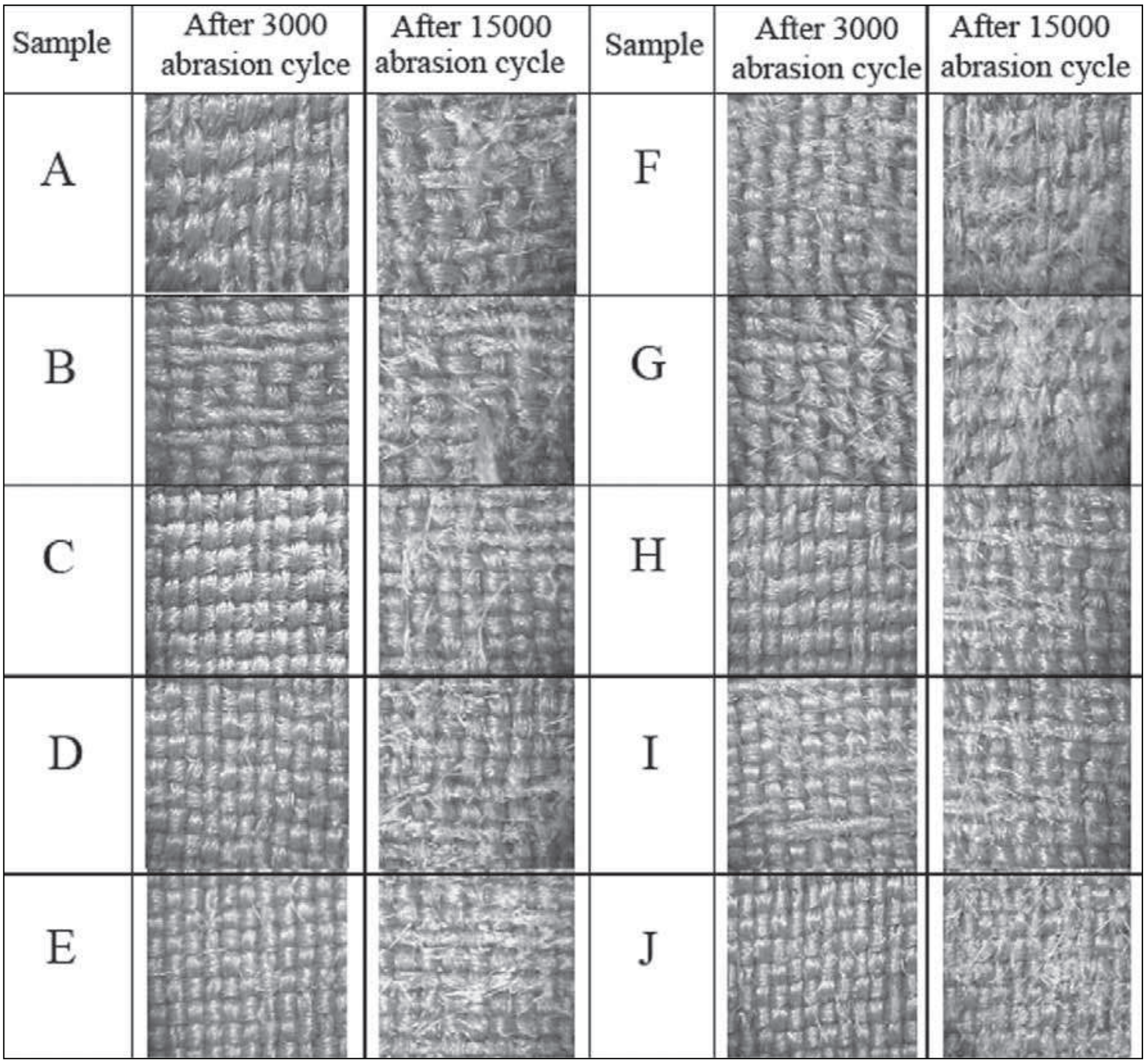


Figure 5: Surface structure of samples after abrasion process

Table 7: Statistical evaluation of reflectance factor of samples after abrasion process using ANOVA at 0.05 significance level

Source	Sum of squares	df	Mean square	F	Sig.
Corrected model	1.122E-02	49	2.289E-04	4.589	0.000
Intercept	1.539	1	1.539	30865.424	0.000
Abrasion cycle	3.493E-03	4	8.732E-04	17.508	0.000
Weft density	2.854E-03	4	7.135E-04	14.305	0.000
Yarn type	4.684E-04	1	4.684E-04	9.392	0.002

their parallel alignment creates a combing effect which increases the reflectance value [4]. The results of reflectance values of samples show that in most cases the fabrics woven with 150den/144f in weft had a higher reflectance value due to a greater distortion and modification of the fabric surface so that a smoother surface was obtained, while the reflectance values of Fabric J were higher than that of Fabric E in all abrasion cycles. As mentioned before, the distortion of Sample E was higher than that of Sample J, which could be the reason for this trend.

The difference between the reflectance factors of samples after the abrasion process using a three-way analysis of variance was also performed at the 0.05 significance level. As shown in Table 7, it was clear that all three parameters showed a significant effect on the reflectance factor of samples at the 0.05 significance level (sig. value < 0.05). The number of abrasion cycles showed the greatest effect on the reflectance factor of samples after the abrasion process.

4 Conclusion

In this study, the effect of fibre fineness of multifilament yarns and weft density on the reflectance values and colour difference values of polyester woven fabrics was studied. By considering the interaction between the two mentioned parameters, the obtained results showed that the largest change in the difference values of samples is between 3000 and 6000, or between 10000 and 15000 abrasion cycles. It could also be concluded that the samples with 150den/144f weft yarns in 11, 14, 17 and 20 weft densities per centimetre were more affected by abrasion, so these samples displayed a greater colour difference, while inversely in 23 weft density per centimetre, the sample woven with 150den/48f weft yarn was more affected by abrasion. Finally, the reflectance value of woven fabrics with 150den/144f was higher in most cases after different cycles of the abrasion process.

5 References

1. SRINIVASAN, J., RAMAKRISHNAN, S., MUKHOPADHYAY, S., MANOHARAN, S. A study of Knitted Fabrics from Polyester Microdenier Fibers. *Journal of the Textile Institute*, 2007, vol. 98, (1), p. 31–35.
2. POURIAMEHR, L., HOSSEINI, S. A., SHANBEH, M., JAFARI, E. An Experimental Study to Assess the Effect of Fiber Denier on Physical and Mechanical Properties of PET Woven Fabrics. *Proceedings of 6th National Conference on Textile Engineering*, Isfahan, Iran, May 8–10, 2007.
3. *Annual Book of ASTM Standards: D4966*. American Society for Testing and Materials, United States, 1999.
4. ALPAY, R., BECERIR, H., AKGUN, M., B. Assessing Reflectance and Differences of Cotton Fabrics after Abrasion. *Textile Research Journal*, 2005, vol. 75, (4), p. 357–361.
5. *Annual Book of ASTM Standards: D4157*. American Society for Testing and Materials, United States, 1999.
6. *Annual Book of ASTM Standards: D3884*. American Society for Testing and Materials, United States, 1999.
7. SAVILLE, B. P. *Physical Testing of Textiles*, 1st ed.. Cambridge : Woodhead Publishing, 1999.
8. ALPAY, R., BECERIR, H., AKGUN, M., B. Assessment of Reflectance and Differences of

Wool Fabrics after Abrasion. *Textile Research Journal***,** 2005, vol. 75, (8), p. 607–615.

9. KALAOGLU, F., ONDER, E., OZIPEK, B. Influence of Varying Structural Parameters on Abrasion Characteristics of 50/50 Wool/Polyester Blended Fabrics. *Textile Research Journal,* 2003, vol. 73, (11), p. 980–984.
10. KOLTYSHEVA, N. G., LOMOV. S. V., TRUEVTZEV, N. N. Abrasion Resistance of Cotton/Flax Fabrics: 3D Computer Simulations of Fabric Wear Geometry. *AUTEX Research Journal,* 2004, vol. 4, (4), p. 182–186.
11. MASTURA, R. Effect of Abrasion on Stress--Strain Properties of Two Polyester/ Cotton Fabrics in Low-Level Laboratory Abrasion and Wear Trials. *Textile Research Journal*, 1980, vol. 50, (6), p. 381–386.
12. BECERIR, B., KARACA, E., OMEROGLU, S. Assessing Color Values of Polyester Fabrics Produced from Fibers Having Different Cross--Sectional Shapes after Abrasion. *Technology,* vol. 123, p. 252–259.
13. MORTON, W. E., HEARL, J. W. S. *Physical Properties of Textile Fibers*, 1st ed. Manchester : The Textile Institute, 1993.