The Influence of Number of Filaments on Physical and Mechanical characteristics of Polyester Woven Fabrics

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Abstract: In this paper different polyester woven fabrics having different number of filaments in its filling yarns were woven. The effect of the number of filaments on the fabric properties was analyzed. The experimental results were assessed using analysis of variance and regression methods via SPSS statistical package. The statistical analysis revealed that properties of polyester fabrics have affected significantly by the number of filaments. As the number of filaments in the cross section of filling yarns increases, fabric thickness, tensile strength, fabric elongation and crease recovery increases. By the contrast, increasing number of filaments leads to a reduction in fabric air permeability, weight loss due to abrasion and fabric tearing strength.

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Key words: polyester fabrics, denier per filaments, fabric tensile strength, air permeability, tearing strength, abrasion resistance, crease recovery.

1. Introduction

Polyester fiber (polyethylene terephthalate) becomes more popular due to its unique properties such as excellent mechanical characteristics, good resiliency, chemical inertness and heat resistance. The micro polyesters have been more focal point in research during the past decade because of its aesthetic and highly soft touch [1, 2]. Microfibers are the fibers with fineness below 0.1 tex. This is the general definition of microfibers, although the Japanese have already made a fiber with fineness below 0.01 tex [3, 4]. The development of microfibers with fineness below 0.1 tex began in the seventies in Japan, and in the eighties and nineties in Europe and America. In 1992, about 10000 tons microfibers, mostly as microfilaments, were spent in USA [5]. PES microfilament yam, PA microfilament yam, microstaple fibers, acryle microfibers, viscose microfibers and polypropylene microfibers are mainly produced nowadays. In 1992, about 35000 t microfibers were produced all over the world [6]. Asahi, Kanebo, Kuraray, Mitsubishi, Rayon, Teijin, Toray, Toyobo and Unitika are the Japanese companies that produce microfibers, filament and staple fibers [7].

Besides having a luxurious body and drape, microfiber fabrics are also lightweight resilient. They can retain their shape and resist pilling. Compared to other fabrics of similar weight, they are relatively strong and durable. Since fine yarns can be packed tightly together, microfiber fabrics have good wind resistance and water repellency. As the number of filaments in a yarn of given linear density increases, the surface area of all the fibers increases and the spaces between the fibers get smaller. Liquid water is prevented by surface tension from penetrating the fabric, which will have a degree of water repellency. On the other hand, the spaces between the yarns are porous enough to breathe and wick body moisture way from the body [8-11].

Some examples for microfiber application are sports wear, medical, and protective wear, different filter material upholstery etc. It can be assumed that their uses will increase due to their outstanding aesthetic, physical and textile properties [12-15].

In the present study, the effect of the number of filaments on physical and mechanical properties of polyester woven fabrics was investigated. The physical and mechanical characteristics of five different 150 denier polyester filament yarns containing different number of filaments were studied with respect to fabric thickness, fabric strength, breaking elongation, air permeability, tearing strength, crease recovery and abrasion resistance.

2. Materials

In this study five different polyester continuous filament yarns of 150 denier supplied by the same manufacturer from the same lot. It contained 34 filaments (4.4 denier per filament), 48 filaments (3.13 denier per filament), 108 filaments (1.39 denier per filament), 144 filaments (1.04 denier per filament), and 208 filaments (0.72 denier per filament) were selected. The fabric sample having 208 filaments is considered a micro polyester fabric, but the other samples represent normal polyester fabrics.

The polyester filament yarns were woven on Water-Jet weaving machine with the following particulars:

Warp density: 156 ends / inch
Weft density: 60 picks / inch
Fabric width: 165 cm
No. of harness frames: 4

Warp yarn count: 150 denier
Weave structure: 1/1 plain.

After weaving, all the polyester fabric samples were hot washed, thermal fixed, bleached and dyed.

Laboratory Testing

Physical and mechanical tests were carried out in weft direction after conditioning of the fabrics for 24 hours under the standard atmospheric conditions (20 ± 2 °C temperature, 65 ± 2% relative humidity). Ten individual readings were averaged for each fabric property. The fabrics were tested for the following characteristics; Fabric thickness, fabric strength, breaking elongation, air permeability, tearing strength, crease recovery and abrasion resistance.

Thickness is the distance between one surface to its opposite in textiles, the distance between the upper and lower surface of the material, measured under a specified pressure. The specimens were tested as directed in ASTM test method D. 1777. Tensile strength and elongation measurements of the plain fabrics in weft direction were performed on an Instron 4411 Tester (Instron Inc., USA) according to TS EN ISO 13934-1; and the air permeability tests were conducted on Shirley Air Permeability tester in accordance with ASTM D737.

For tearing test, an Intensity tearing tester (Elmendorf type) was used according to ASTM D1424. The abrasion resistance measurements were carried out with the help of a Martindale abrasion tester. At the end of 2000 rubs, the abrasion cycle was ended. The abrasion resistance of the fabrics was evaluated according to their weight loss (%) after 2000 rubs. For each fabric sample, the abrasion tests were carried out 3 times, and the average weight loss was calculated. The abrasion resistance was measured according to the relevant standard BS 5690. Crease recovery of polyester fabric samples having different levels of continuous filaments was evaluated using the measurement of crease angle. Crease angle of the woven samples was measured via Wrinkle Recovery tester according to AATCC Test method 66-1975.

Statistical Analysis

To explore the effect of the number of filaments in yarn cross section on the physical and mechanical properties of the woven polyester fabrics, One – Way ANOVA statistical analysis was performed using SPSS statistical package. All test results were assessed at significance level $0.05 \leq \alpha \leq 0.01$. To predict the mechanical property of each woven fabric sample at different levels of number of filaments, a linear or non-linear regression models was executed via a regression analysis.

The regression non- linear models which correlate the number of filament in the yarn cross section to the woven fabric properties has the following form:

$Y = a X^2 + b X + c$

Where,

Y= Fabric properties such as (tensile strength, elongation, air permeability, -- etc.)

X= Number of filaments in the yarn cross section.

C= constant

a, b = Regression coefficients.

In the case of linear models, the value of regression coefficient, a – value, equals zero. The validation of the regression models was performed using the coefficient of determination, R^2, R-square (the coefficient of determination), measures the reduction in the total variation of the dependent variable (fabric properties) due to the independent variable (total number of filaments in the yarn cross section).

3. Results and Discussion

In order to study the effect of filament fineness on physical and mechanical properties of woven polyester fabrics such as thickness, tensile strength, breaking elongation, air permeability, tearing strength, crease recovery and abrasion resistance, five different fabrics containing 150 denier polyester yarns were used and the effect of the number of filaments in the yarn cross section was studied.

Fabric Thickness

Some properties of fabrics like keeping warm and bulkiness, are depends on the thickness of the fabrics. Since thick and porous fabrics contain more air, form a thicker layer between human body and surrounding and make the heat transfer difficult, they keep warmer.

The values of fabric thickness versus the levels of the number of filaments in the yarn cross section were demonstrated in figure 1. An increasing trend is detected assuring that as the number of filaments increases the fabric thickness follows the same trend. It is also noticed that the thickness of microfiber polyester fabric is more than those woven from normal polyester fibers. This means that micro polyester fabrics is more efficient in thermal insulation and give warmth to the man's body. Increasing fabric thickness value with the increase in number of filaments may be due to compactness of the finer filament yarn in the fabric.

The regression model which correlates the fabric thickness to the number of filaments has a linear model with the following form:

Thickness (mm) = 0.0002 X + 0.274

The coefficient of determination for this model equals 0.94, which means that this model fits the data very well.

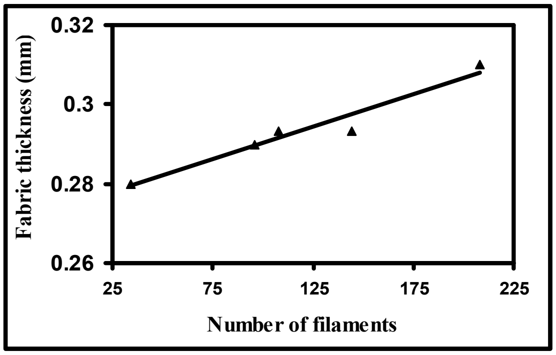

Figure 1: Effect of number of filaments on fabric thickness

Tensile Strength

Fabric tensile strength is the force in Newton which is used to break the fabric sample. The results of the analysis of variance and comparison of individual means for fabric strength revealed that the effect of number of filaments is highly significant. From figure 2 it is seen that as the number of filaments in the yarn cross section increases the tensile strength of the woven polyester fabrics also increases. This means that the tensile strength of micro polyester fabric is more than those woven from normal polyester fibers.

The relation between the number of filaments in the yarn cross section and the fabric tensile strength has the following form:

Tensile strength (Newton) = $0.012\ X^2 – 0.85\ X + 413.8$

The statistical analysis proved that the R^2 value for this model equals 0.99, which means that this model fits the data very well.

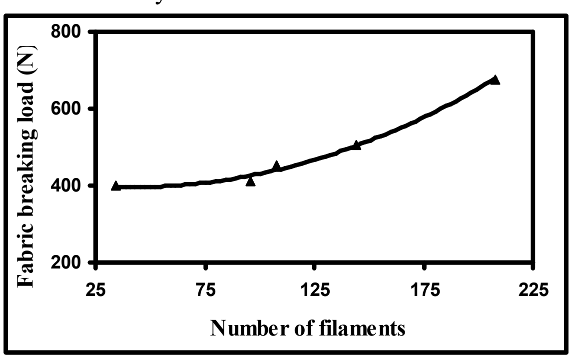

Figure 2: Effect of number of filaments on fabric tensile strength

Breaking Elongation

Breaking elongation of the polyester woven fabrics at the different levels of the number of filaments in the yarn cross section was illustrated in figure 3. The same trend was detected as the above figure, assuring that as the number of filaments increases the fabric breaking elongation follows the same trend. It also noticed that the micro polyester fabric has higher breaking elongation compared to the normal polyester fabrics. This is because the higher number of filaments in their cross section.

The relation between the number of filaments in the yarn cross section and the fabric breaking elongation is as follows:

Breaking elongation (%) = $0.005\ X^2 – 0.019\ X + 16$

The coefficient of determination of this regression model is 0.97, which means this model fits the data very well.

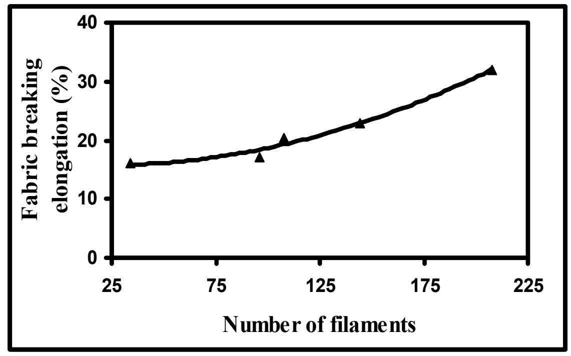

Figure 3: Effect of number of filaments on fabric breaking elongation

Air Permeability

The impact of the number of filaments in the yarn cross section on the air permeability of the polyester woven fabrics was depicted in figure 4. The statistical analysis proved that fabric air permeability has significantly affected with the number of filaments. A decreasing trend is detected confirming that as the number of filaments increased the air permeability of the polyester woven fabrics decreased. It is also shown that the air permeability of micro polyester woven fabrics is lower than those woven from normal polyester fibers. This means that micro polyester fabric is suitable for making wind resistant fabrics and filter fabrics

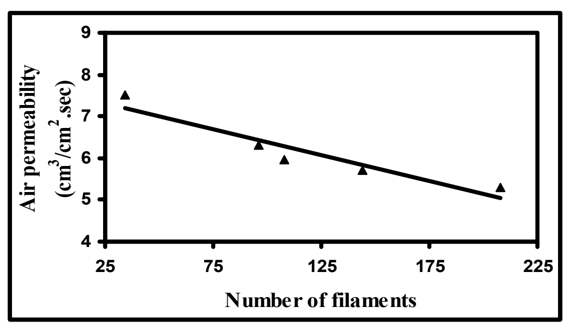

Figure 4: Effect of number of filaments on fabric air permeability.

The relation between air permeability and the number of filaments in the cross section of the weft yarns has the following linear form:

Air permeability (cm^3/cm^2.sec) = $-\ 0.012\ X + 7.6$

The R^2 value for this model equals 0.87.

Tearing strength

Fabric tearing strength is related to its serviceability and depends on its weave structure and the strength of the constituent warp and weft yarns. The fabric tearing strength versus the number of filaments in the weft yarn cross section was shown in figure 5. It is noticed that the number of filaments has a profound effect on fabric tearing strength. A decreasing trend is detected assuring that as the number of filaments increases the fabric tearing strength decreases. This means that the tearing strength of micro polyester fabric had lower tearing strength compared to other woven fabrics. This is because the higher number of filaments in the yarn cross section. Under tearing force, the higher number of filaments in yarn cross section behaves as single filament. On the contrary, for the fabrics having lower number of filaments, these filaments withstand the tearing load individually.

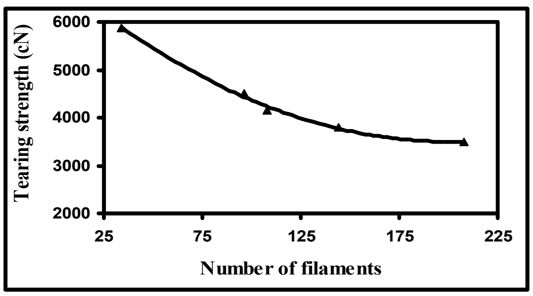

Figure 5: Effect of number of filaments on fabric tearing strength.

To predict the fabric tearing strength at the different levels of the number of filaments, the following regression model can be used:

Tearing strength (cN) = $0.086 X^2 - 34.6 X + 6964$.

This regression models fits the experimental data very well with a higher value of R^2, 0.99.

Abrasion resistance

In this study, abrasion resistance of the woven fabric samples was evaluated by the percentage of fabric weight loss. As the weight loss decreases the abrasion resistance of the woven fabrics increases. The weight loss of the woven fabric sample according to different number of filaments was plotted in figure 6. The statistical analysis showed the huge influence of the number of filaments on the weigh loss. As seen from this figure, the amount of weight loss decreased as the number of filaments in the yarn cross section increased. The highest improvement in terms of weight loss was observed on microfiber polyester fabrics. This can be attributed to the higher frictional forces between fibers in the yarn cross section in the fabrics having micro polyester fibers. As a result, it became more difficult for the fibers to be removed from the fabric structure.

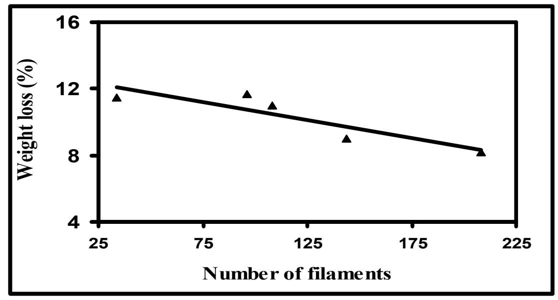

Figure 6: Effect of number of filaments on fabric abrasion resistance.

The regression model which correlates weight loss of woven fabrics due to abrasion to the number of filaments has the following linear form:

Weight loss (%) = $- 0.0219 X + 11.843$

The R^2 value for this model is 0.75.

Crease Recovery

The crease recovery is one of the fundamental properties of fabrics which affects product performance. Crease recovery refers to the ability of the fabric to return to its original shape after removing the folding deformations. The crease recovery of fabrics is determined by measuring the crease recovery angle. As the crease angle increases the fabric crease recovery increases.

Crease angle of polyester woven fabrics at different levels of number of filaments was plotted in figure 7. It is shown that number of filaments in the weft yarn cross section has a significant influence on the crease angle. An increasing trend is detected, conforming that as the number of filaments increases the fabric crease angle increases. This means that fabric crease recovery enhanced with the higher number of filaments in the yarn cross section.

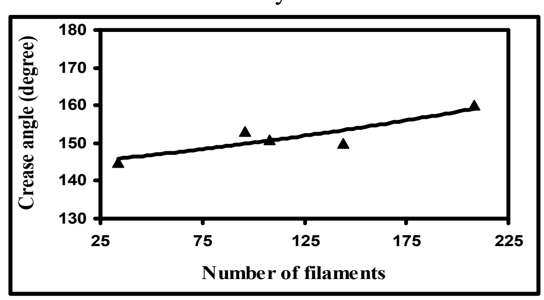

Figure 7: Effect of number of filaments on fabric crease recovery.

To predict the crease angle of polyester fabric at different levels of number of filaments, the following linear model can be used:

Crease angle (degree) = $0.076 X + 142.8$

The R^2 for this model is 0.79.

Conclusion

Thickness, tensile strength, breaking elongation, air permeability, crease recovery, abrasion resistance, and tearing strength of polyester woven fabrics at different number of filaments have been investigated. The statistical analysis showed that increasing the number of filaments enhanced the fabric tensile strength and its elongation, crease recover and abrasion resistance. But polyester woven fabrics having higher number of filaments had lower air permeability, which means that these fabrics suitable for fabric filters and wind proof garments.

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