# Effect of Weave Structure and Weft Density on the Physical and Mechanical Properties of Micro polyester Woven Fabrics

Gadah Ali Abou Nassif

Fashion Design Department, Design and Art College, King Abdul Aziz University, Jeddah, kingdom of Saudi Arabia
gadah1395@gmail.com

**Abstract:** In this paper, micropolyester woven fabrics with plain, twill and satin weave structures and five different weft densities were produced. Using ANOVA statistical analysis, the effects of weft density and weave structures on the physical and mechanical properties of these fabrics were investigated. The findings of this study revealed that increasing weft density leads to an increase in fabric breaking load, stiffness and crease recovery. On the contrary, the increase in weft density decreased air permeability, and tearing strength. The effect of weft density on fabric breaking elongation and abrasion resistance are similar to each other. Plain weave fabrics were superior to other structures in fabric breaking load, breaking elongation and fabric stiffness. Satin weaves have higher air permeability, whereas twill weaves have higher crease recovery.
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**Key words**: micro fiber, weave structure, weft density, polyester, physical properties, mechanical properties, woven fabric.

## 1. Introduction

Polyester fibers poly (ethylene terephthalate) (PET)) fibers dominate the world synthetic fibers industry. A polyester fiber is composed of any long-chain synthetic polymer including at least 85 wt % of an ester of a dihydric alcohol (HOROH) and terephthalic acid (p-OOCC6H4COOH) [1, 2].

A very important property of polyester is that its mechanical properties in the wet state and under standard conditions are practically the same. PET fibers have excellent resistance to acids, alkalis and microbial attack. They also have good resistance to light and actinic degradation [3-5].

For comparison, microfibers are half the diameter of a silk fiber, one-third the diameter of cotton fiber, one-quarter the diameter of fine wool fiber and one hundred times finer human hair. In order to be called a microfiber, a fiber must be less than one denier which is the weight in grams of a 9000m length of fiber or yarn. Many microfibers are 0.5 to 0.6 denier [6-8].

Besides having a luxurious body and drape, microfiber fabrics are also lightweight and 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 [9-13].

## 2-Experimental Work

### 2.1-Materials

Throughout this study, 15 mcropolyester woven fabric samples were produced with different weft densities and weave structures. The details of the fabric samples were listed in table 1. Weft yarns were spun from drawn textured polyester yarn (DTY) with count 150 denier and 288 filaments. This means that weft yarns spun from micro polyester fibers with fineness 0.52 denier per filament. Warp yarns were produced from DTY whose fineness 150 denier with 208 filaments, i.e. denier per filament is 0.72. All woven fabric samples were produced on Sulzer weaving machine with the following particulars:

- Warp yarn count: 150 denier /208 filaments.
- Weft yarn count: 150 denier/288 filaments
- Warp density: 110 ends / inch.
- Weft density: 61, 65, 71, 75 and 80 picks / inch
- Fabric Width: 160 cm.
- Number of Harness Frames: 4
- Weave structure: 1/1 plain, 2/2 twill, and 4-satin weaves
- Machine speed: 420 ppm

Weave structures of the woven fabrics in this study were shown in figure 1

**2.2-Laboratory Testing**

Since the variation in all fabric samples were conducted in weft yarns, all fabric properties were evaluated in the weft direction. Before testing, all micro polyester woven fabrics were conditioned for 24 hours in a standard atmosphere i.e., 20 $^{o}$C±2 temperature and 65% ±2 Relative humidity. Ten individual readings were taken and averaged for each fabric property. Micro polyester woven fabrics were tested for the following properties: fabric tensile strength, breaking elongation, tearing strength, air permeability, fabric stiffness, crease recovery and abrasion resistance. The standard test methods followed for testing micro polyester woven fabric properties are listed in Table 2.

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Table 1: Details of the woven fabric samples

| Sample No. | Weave structures | Weft density (ppi) |
|---|---|---|
| 1 | Plain 1/1 | 61 |
| 2 | Plain 1/1 | 65 |
| 3 | Plain 1/1 | 71 |
| 4 | Plain 1/1 | 75 |
| 5 | Plain 1/1 | 80 |
| 6 | Twill 2/2 | 61 |
| 7 | Twill 2/2 | 65 |
| 8 | Twill 2/2 | 71 |
| 9 | Twill 2/2 | 75 |
| 10 | Twill 2/2 | 80 |
| 11 | Satin 4 | 61 |
| 12 | Satin 4 | 65 |
| 13 | Satin 4 | 71 |
| 14 | Satin 4 | 75 |
| 15 | Satin 4 | 80 |

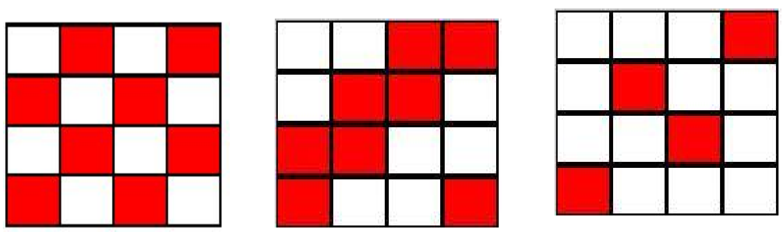

Fig.1- Weave structures of woven fabric samples

Fabric tensile strength and breaking elongation of all fabric samples in weft direction were performed on an Instron 4411 Tester ( Instro Inc., U.S.A), which was shown in fig. 2. The tensile testing speed was 100 mm/min. Shirley Air permeability Tester was used to evaluate the air permeability of the fabric samples.

Tearing force of the woven fabric samples was measured using an intensity tearing tester (Elmendorf type), which shown in fig. 3. A Nu-Martindale Abrasion Tester (James H. Heal, UK) was used to evaluate the abrasion behavior of the micro polyester fabrics. The fabrics were abraded under a pressure of 12 kPa (795 ± 7 g). At the end of 1000 rubs, the abrasion cycle was ended. The abrasion resistance of the fabrics was evaluated according to their weight loss (%) after 1000 rubs. For each fabric sample, the abrasion tests were carried out 10 times, and the average weight loss was calculated. The photograph of Martindale abrasion tester was depicted in fig.4.

Fabric stiffness was evaluated using fabric stiffness tester model UASUDA SEIKI Japan, which shown in fig.5. The crease recovery angles of the fabrics were measured. The tests were performed in weft directions for five replicas for each fabric sample. High crease recovery angle means better crease recovery of the fabric.

Table 2- Standards Test methods of the properties measured in this study

| Fabric Property | Standard Test Method |
|---|---|
| Fabric tensile strength and breaking elongation (strip method) | ISO 13934-1 |
| Air permeability | D737 |
| Fabric tearing strength | D1424 |
| Fabric stiffness | D1388 |
| Fabric abrasion resistance | BS 5690 |
| Crease recovery | AATCC 66-1975 |

**Fig. 2: Instron 4411 Tester**

**Fig. 3: Elmendorf Type Tearing Tester**

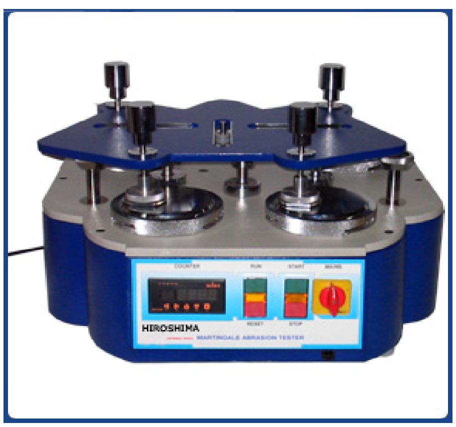


**Fig. 4: Martindale Abrasion Tester**

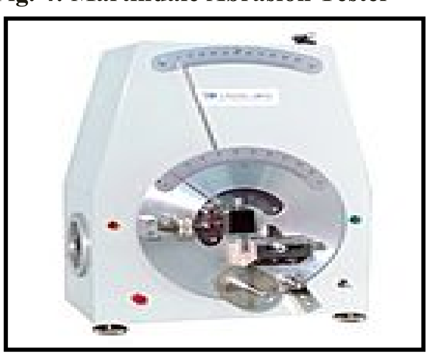

**Fig. 5. Fabric Stiffness Tester**

**2.3- Statistical Analysis**

In this study, five different weft densities were applied to three different weave structures. The results were tested for significant difference using a 3 × 5 mixed factorial design. The Minitab statistical package was used to execute the statistical analysis. All test results were statistically assessed at significance level, p-value, $0.05 \leq$ p-value $\leq 0.01$. If the p-value is smaller than or equals 0.05, the effect of weave structure and weft density are considered to be significant.

## 3- Results and Discussion

### 3.1- Fabric breaking load

The tensile behavior of woven fabrics is known to be affected by its sett and construction. This influence, when clearly understood, would make engineering of fabrics for tensile properties easier. In this study, tensile properties of micropolyester woven fabrics were characterized by fabric breaking load and elongation.

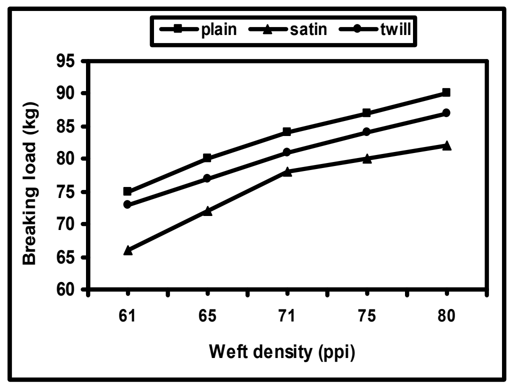


Fig. 6- Variations of fabric breaking load at different levels of weft density and weave structure.

The results of fabric breaking load were depicted in Figure 6. According to the statistical analysis, filling yarn density and weave structure were found to have a significant influence on breaking load of fabrics woven from micropolyester fibers. An increasing trend is detected confirming that as the weft density increases, the breaking load of the fabric samples follow the same trend. It is also shown that weave structure has a profound effect on fabric breaking load. Micropolyester fabrics woven from plain structure showed the highest breaking load followed by fabrics with twill weaves and satin weaves respectively. Generally, increasing weft density from 61 to 80 picks / inch leads to an increase in fabric breaking load by 20%, 24% and 19% for fabrics with weave structures plain, satin and twill respectively. The significant impact of weft density on fabric breaking load may be related to the increase of yarns which bears the load in fabric structure. Fabric samples with plain structure showed higher breaking load; this is because the higher intersections associated with this structure.

### 3.2- Fabric breaking elongation

In determining the effect of weft density and weave structure type on breaking extension of fabrics woven from micropolyester fibers, the results were plotted in figure 7. From this figure, it is verified that there is a negative correlation between weft density and breaking elongation. Fabric breaking elongation was increased by the increase in weft density from 61 to 71 picks/ inch, and then decreased with the increase in weft density up to 80 picks /inch.

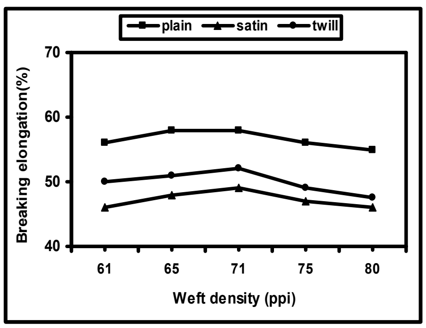


Fig. 7- Variations of fabric breaking elongation at differentlevels of weft density and weave structure.

It is also apparent that woven micropolyester fabrics with weave structure plain 1/1 are associated with higher breaking elongation followed by twill weave and satin weave respectively. The higher elongation of plain fabrics can be ascribed to the higher intersections between warp yarns and weft yarns in the fabric structure. The lower breaking elongation of satin weave fabrics may be related to the higher float length of the weft yarns in this type of fabrics.

### 3.3- Fabric air Permeability

The air permeability is very important factor in the performance of some textile materials. Especially, it is taken into consideration for clothing, parachutes sails, vacuum cleaners, fabric for air bags and industrial filter fabrics. The air permeability is mainly dependent upon the fabric's weight and construction (thickness and porosity). Air permeability of micropolyester woven fabrics at different levels of weft densities and weave structures was plotted in figure 8.

From this figure it is seen that when the number of weft yarns per inch increases, the air permeability of the woven fabrics decreases. The higher the values of filling numbers cause decreases the air permeability of the woven fabrics. As known, increasing number of weft yarns per inch results a tightly woven structure. So, it is thought that the air permeability of the woven fabric is reduced.

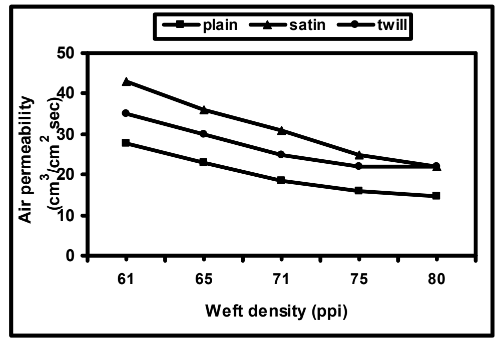


Fig. 8- Variations of fabric air permeability at different levels of weft density and weave structure.

It is also shown that woven fabrics with weave structure plain 1/1 showed lower air permeability compared with other fabric structures. Fabric samples with satin weaves had higher air permeability followed by will weaves and plain weaves. At higher weft density, the air permeability of woven fabrics with twill and satin weaves are close to each other. The lower values of air permeability of plain weave structures can be attributed to its compactness due to the higher intersections of warp and weft yarns.

### 3.4- Fabric Stiffness

Stiffness is one of the most widely used parameters to judge bending rigidity and fabric handling. Fabric stiffness and handling is an important decision factor for the end users. The degree of fabric stiffness is related to its properties such as fiber material, yarn and fabric structure. In this work, the effects of weft density and weave structure of micropolyester woven fabrics on fabric stiffness were investigated. The results of fabric stiffness were depicted in figure 9.

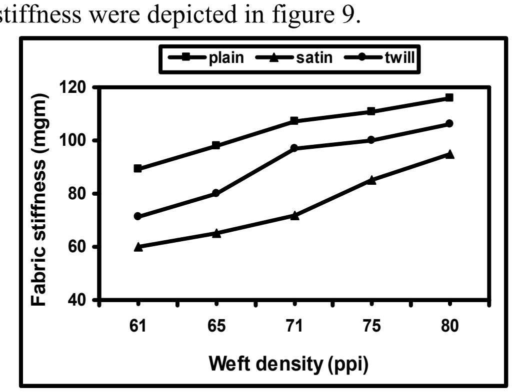


Fig. 9- Variations of fabric stiffness at different levels of weft density and weave structure.

The statistical analysis proved that stiffness of micropolyester woven fabrics has been affected significantly at 0.01 significance level by both weave structure and weft density. Weft density has a profound influence on fabric stiffness. An increasing trend was detected assuring that as the weft density increases fabric stiffness increases. This is because the increase in fabric tightness with the increase in weft density, which in turn increases fabric stiffness. Increasing weft density from 61 to 80 picks / inch leads to an increasing of fabric stiffness by 30%, 58% and 48% for plain, satin and twill weaves respectively.

From this figure it is also shown that the stiffness of micropolyester fabrics woven from plain weaves is higher than those woven from other structures. Associated higher stiffness of plain weaves can be ascribed to the higher tightness which characterizes this type of fabrics.

### 3.5- Fabric Tear Strength

The values of tearing strength according different levels of weft density and weave structure were plotted in figure 10. The statistical analysis proved that this fabric property has affected significantly with weave structure and weft density. From this figure, it is shown that as the weft density increases fabric tearing strength decreases. Tearing strength of micropolyester woven fabrics decreased by 20%, 9.4% and 17.4% for plain, satin and twill weaves respectively. It is also shown that higher tearing strength was associated with satin weaves followed by twill and plain weaves respectively. The higher tearing strength of satin weaves may be related to the longer flats in this type of fabrics which make yarns to be free under tearing load.

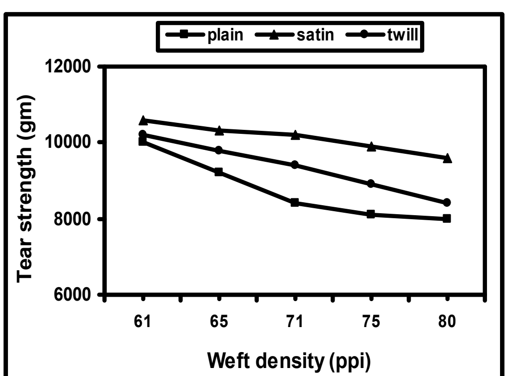


Fig. 10- Variations of fabric tear strength at different levels of weft density and weave structure.

### 3.6- Fabric 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 recovery angle increases the fabric crease recovery increases.

The values of crease angle of polyester fabrics according to different levels of weft densities and weave structures were depicted in figure 11. From this figure it is seen that both variables have a huge effect on fabric crease recovery.

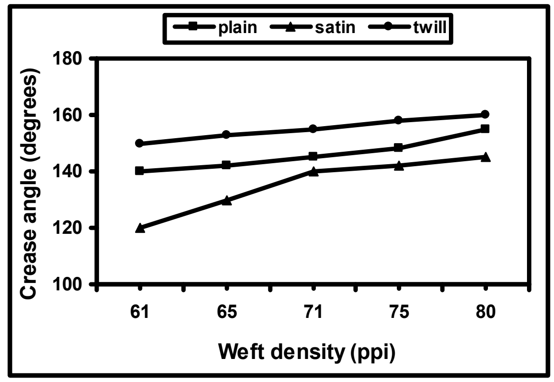


Fig. 11- Variations of fabric tear strength at different levels of weft density and weave structure.

Weft density was found to have a profound effect on crease angle. An increasing trend is detected assuring that as the weft density increases the crease angle increases. Crease angle of micropolyester fabrics increased by 11%, 21% and 7% for plain, satin and twill weaves with the increase in weft density from 61 to 80 picks/inch. It is also shown that twill fabrics exhibited higher crease recovery followed by plain and satin weaves respectively.

### 3.7- Fabric 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 weave structure type and weft density was plotted in figure 12. The statistical analysis showed the huge influence of the weft density and weave type on the weigh loss of micro polyester woven fabrics. As seen from this figure, the amount of weight loss increased as the weft density increased from 61 to 71 picks/ inch and decreased as the number of weft yarns in the fabric structure increased to 80 picks / inch.. This is because the fabric tightness will increase with the increase in weft density up to 81 picks / inch. The highest improvement in terms of weight loss was observed on microfiber polyester fabrics with plain structure followed by twill and satin structures respectively.

The higher abrasion resistance associated with plain weaves can be attributed to the higher frictional forces between warp and weft yarns in the fabric cross section.

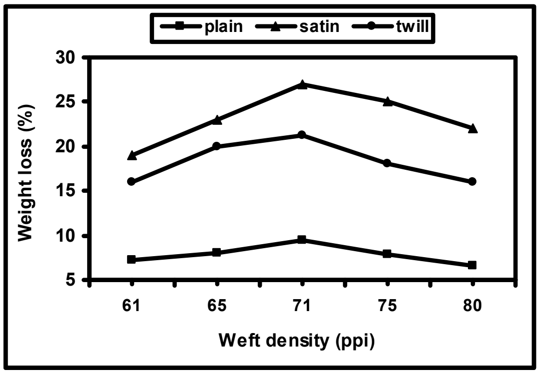


Fig. 12- Variations of fabric weight loss of fabric samples at different levels of weft density and weave structure.

**4- Conclusion**

Physical and mechanical properties of micropolyester woven fabrics with different weft densities and plain, twill and satin weave structures were investigated. The results of the research can be summarized as follows:

- Fabric breaking load and breaking elongation were significantly affected by weft density and weave structure. Breaking load increases with weft density but breaking elongation increase with the increase of weft density from 61 to 71 picks/inch and then decreased with the increase in weft density. Plain fabrics associated with higher breaking load and elongation followed by twill and satin weaves respectively.
- The effect of weft density on weight loss % of the woven fabrics is similar to its effect on breaking elongation. The order of abrasion resistance of woven fabrics is as follows: plain > twill > satin.
- As the weft density increases fabric air permeability and tearing strength decreases. Satin fabrics have the highest air permeability and tearing strength. Whereas plain fabrics have the lowest air permeability and tearing strength.
- The increase in weft density leads to an increase in crease angle and fabric stiffness. - Plain fabric showed higher fabric stiffness, while twill fabrics exhibited higher crease recovery.

**Corresponding author**
**Gadah Ali Abou Nassif**
Fashion Design Department, Design and Art College, King Abdul Aziz University, Jeddah, kingdom of Saudi Arabia
gadah1395@gmail.com

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