Hand – Related Characteristics of micro polyester woven fabrics

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Abstract: Fabric hand is a generic term for descriptive characteristics of textiles obtained through tactile comparison. Fabric hand attributes can be obtained through subjective assessment or objective measurements. In this study, handle of micro polyester woven fabrics was obtained objectively using FAST evaluation system. The effect of weft density on handle properties of micro polyester woven fbrics were studied . The experimental results of handle properties were statistically analyzed using ANOVA.The findings of this study revealed that weft density of micro polyester fabrics greatly affected the handle properties of this type of fabrics except for hygral expansion and relaxation shrinkage. It is observed that with increase in weft density, the fabric thickness, surface thickness, formability, bending rigidity and fabric shear rigidigty increased. By the contray, with the incresae in weft density fabric extensibility was reduced in warp and weft directions.

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Key words: Handle characteristics, Bending rigidity, shear rigidity, extensibility, Formability, micro fiber, micropolyester fabrics.

1. Introduction

Fabric handle, which is simply defined as "all feelings when you touch a fabric", is the outcome of a complex phenomenon determined by fabric mechanical and surface properties, and it is very important for a customer in assessing fabric quality while shopping, as well as for the end-use and prospective performance of a textile product **[1]**.

Traditionally, scientists working in the area of textile fabric engineering evaluate fabric handle subjectively. On the basis of judges knowledge, experience and senses a priori trial models are constructed only for the quantitative evaluation of textile hand. This situation occurred in default of one opinion and simple reliable direct method suitable to evaluate textile hand. Textile hand usually was evaluated on the basis of separate values or the sum of the parameters of simply understandable fabric properties. The scientists, who earlier investigated textile hand, were stating that fabric properties mostly influencing textile hand are: fabric smoothness (28 %), softness (22 %), stiffness (8 %), roughness (7 %), thickness (5 %) and weight (5 %). Such fabric properties as warmth, hardness, elasticity, nap, creasing propensity, drape and 6 – 7 other properties less influencing the textile hand enter the residual part of 25 % **[2].** Nowadays, the parameters of these properties are determined objectively using two well-known fabric testing systems KES and FAST **[3 – 5]**.

Fabric handle is dependent on several parameters such as fiber and yarn characteristics, fabric construction, and finishing treatments **[6].** It was found that aforesaid parameters have a statistically significant effect on handle properties of the fabrics woven with compact spun yarns **[7].** The effect of hairiness on surface roughness and fabric compression was studied **[8].** The effect of bleaching on the mechanical properties of yak fabrics was investigated and it was found that bleached yak fabrics have a coarser handle than the unbleached yak fabrics although bleached yak fabrics are easily bent and softer than unbleached ones **[9].** Finishing effects on the compression of woven fabrics were examined and it was observed that finishing lead to a more fully, dimensionally stable and more relaxed fabric structure **[10].** The effect of washing/ironing cycles on the properties of cotton weaves was investigated and it was found that due to the deformation and change in bulkiness, the range of hand rating in washed/ironed samples is higher **[11].**

Microfibers refer to fibers ranging from 11.1 to 6.4 microns in diameter, which is the diameter of silk and smaller (there are also ultrafine and superfine microfibers) **[12]**. The fineness and the increased number of filaments required to produce the yam allow for a tight weave that provides windproof and water-resistant qualities to fabrics that are soft, washable and that breathe. Also, the microfiber fabrics are lighter in weight yet more opaque than other fabrics. They recover from wrinkling, and they are easy to wash and dry. These features will make the fabrics popular with consumers despite their higher price **[13-16].**

The objective of this study was to investigate the handle characteristics of micro polyester woven fabrics. The effect of weft density on the handle – related properties was detected.

2. Materials

Throughout this study four polyester fabric samples were woven on rapier weaving machine. In all woven fabrics, the warp yarns were remained constant. Warp yarns were produced from 100% polyester with count 75 denier/ 144 filaments, i.e. 0.52 dpf. The weft yarns were also produced from 100% polyester with count 70 denier / 144 filaments (the fineness of the monofilament is 0.48 denier). The warp yarn density was 24 ends/cm, whereas the weft yarns were produced with four densities, i.e. 21, 24, 27 and 31 picks / cm. All fabric samples were woven with plain 1/1 weave structure. After weaving, the polyester woven fabrics were bleached.

Laboratory Testing

The handle properties of micro polyester woven fabrics were measured objectively. All fabric samples were tested for their extensibility, bending rigidity, shear rigidity, compression and formability using FAST evaluation system.

SiroFAST is a set of instruments and test methods for measuring mechanical and dimensional properties of fabrics. These measurements allow the prediction of fabric performance in garment manufacture and the appearance of the garment during wear **[17].** The instruments were developed by the Australian CSIRO Division of Wool Technology. The system was designed to be relatively inexpensive, reliable, accurate, robust and simple to operate. A simple method of interpreting the data to predict fabric performance is an integral port of the system.

SiroFAST consists of three instruments and a test method:

FAST-1: Compression meter that measures fabric thickness.

FAST-2: Bending meter that measures fabric bending length.

FAST-3: Extension meter that measures fabric extensibility.

FAST-4: It is a test method to measure dimensional stability: relaxation shrinkage and the hygral expansion of fabrics.

Using the FAST system, 14 parameters can be measured and calculated. The FAST-1, FAST-2, and FAST-3 instruments are shown in order from left to right in Figure 1.

Figure 1: CSIRO FAST Instruments

FAST-1 measures the thickness of a fabric under two fixed loads, T_2 (2 g/cm^2) and T_{100} (100 g/cm^2). The difference in fabric thickness at the two loads is defined as fabric surface thickness. Figure 2 is a visual description of this fabric property.

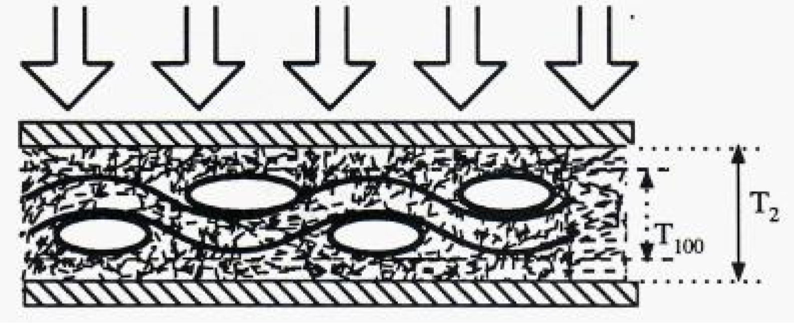

Figure 2: FAST-1 Thickness Measurement [18]

The surface thickness, and released surface thickness of the fabrics were calculated according to the following formulas.

Surface thickness (T) = T_2- T_{100} in mm

Released fabric thickness= T_2 R- T_{100}R

Dimension Stability

FAST-4 consists of a test method rather than a specialized instrument. The test uses an oven and consists of a cycling series of drying and wetting stages. After each of these stages, fabric dimensions are recorded in both warp and weft directions. Two properties are calculated from this method, relaxation shrinkage and hygral expansion [**19**]. The procedure is as follows:

Three pairs of reference points are made on 30 cm x 30 cm specimens in both the warp and weft directions using a template. Marks are made with a Texpen, similar to liquid paper. Fabric specimens are placed on racks in a laboratory convection oven for 1 hour at 105°C. Changes in the distance between warp and weft dots on the fabric are measured within 30 seconds of taking a sample out of the oven. These provide the initial measurements, L_1.

Samples are then soaked in a solution of water (25-30°C) and 1% wetting agent for 30 minutes. Samples are taken out of the water, placed on flat surface, blotted with a towel, and re-measured. These provide the second set of measurements, L_2.

Samples are then placed in the oven for 1 hour at 105°C for a second time. Fabrics are taken out and measured for the last time, providing measurements L_3. To calculate the results, the averages were taken for each sample's L_1, L_2, and L_3 values, for both warp and filling. Relaxation shrinkage and hygral expansion can be evaluated according to the following formulas:

Relaxation Shrinkage, % = $100 (L_1-L_3) \div L_1$ (%)

Hygral Expansion, % = $100 (L_2-L_3) \div L_3$ (%)

Fabric Extensibility

FAST-3 is an extensibility meter, providing a direct measure of fabric extension under selected loads. Warp, weft and bias directions are tested on woven fabrics strips. Warp and weft strips are subjected to three loads (5, 20, and 100 gf/cm). Bias strips are used to calculate shear rigidity and are subjected to only 5 gf/cm load **[20].**

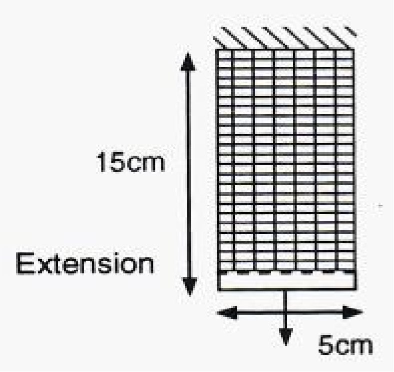

Figure 3: FAST-3 Extension

Extension properties of the woven polyester fabrics are calculated as follows:

Extension, % is calculated by the average values for a specimen in the warp and weft direction at specific weight loads.

Bias Extension, EB_5, % is the average of all of the bias samples at 5 gf / cm

Shear Rigidity, G, in N/m is calculated from the following formula:

$G = 123 \div EB_5$

Formability, F, in mm^2 is calculated from the following formula:

$F = ((E_{20} - E_5) * B) \div 14.7$

Where,

- E_5, Extension at 5 gf/cm, in %
- E_{20}, Extension at 20 gf/cm, in %
- B, Bending Rigidity, in μN.m

Fabric Bending Rigidity

FAST-2 measures two bending properties of a fabric, fabric bending length and fabric bending rigidity. Bending length is related to the ability of a fabric to drape, and bending rigidity is related more to the quality of stiffness felt when the fabric is touched or handled [21].

FAST-2 is a bending meter which works on the cantilever principle, meaning a fabric strip is pushed over a vertical edge until it has bent under its own weight to a specified angle, in this case 41.5° from the horizontal. The instrument uses photocells to detect the edge of the fabric and the bending length; thus calculating the bending rigidity based on the bending length and the fabric weight [20]. Figure 4 depicts this principle:

The bending rigidities in the warp and weft directions were calculated according to the following formula:

$G = W * C^3 * 9.81 * 10^{-6}$

Where,

G: fabric bending rigidity in μN.m.

W: fabric mass per unit area in g/cm^2, and

C: the bending in mm.

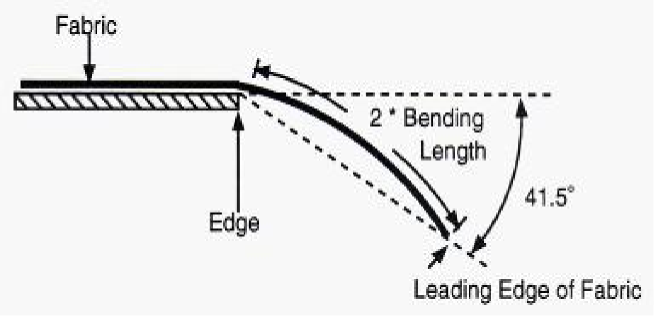

Figure 4: FAST-2 Cantilever Bending [20]

FAST Output Plot

The main output of FAST is a control chart that specifies upper and lower acceptable limits for each fabric property. The actual values of the fabric are plotted and a line connects the values to generate what is called a snake plot. [22]. The existing FAST Control Chart, showing a plot for one fabric, is shown in Figure 5:

Statistical Analysis

One – Way Variance analysis was performed in order to determine the differences between the values of the dependent variables regarding to weft density. The significance value, p value, was compared with α = 0.05. If the p value is greater than α, it means that there is no difference within the groups whereas in case of p value is lower than α, it means there is a difference between the groups. In order to predict the dependent variables at the different levels of the weft density of micro-polyester fabric, the regression analysis was conducted. With the regression test, a linear or non-linear regression models were derived. The validation of the regression models was performed using the coefficient of determination, i.e. R^2 value.

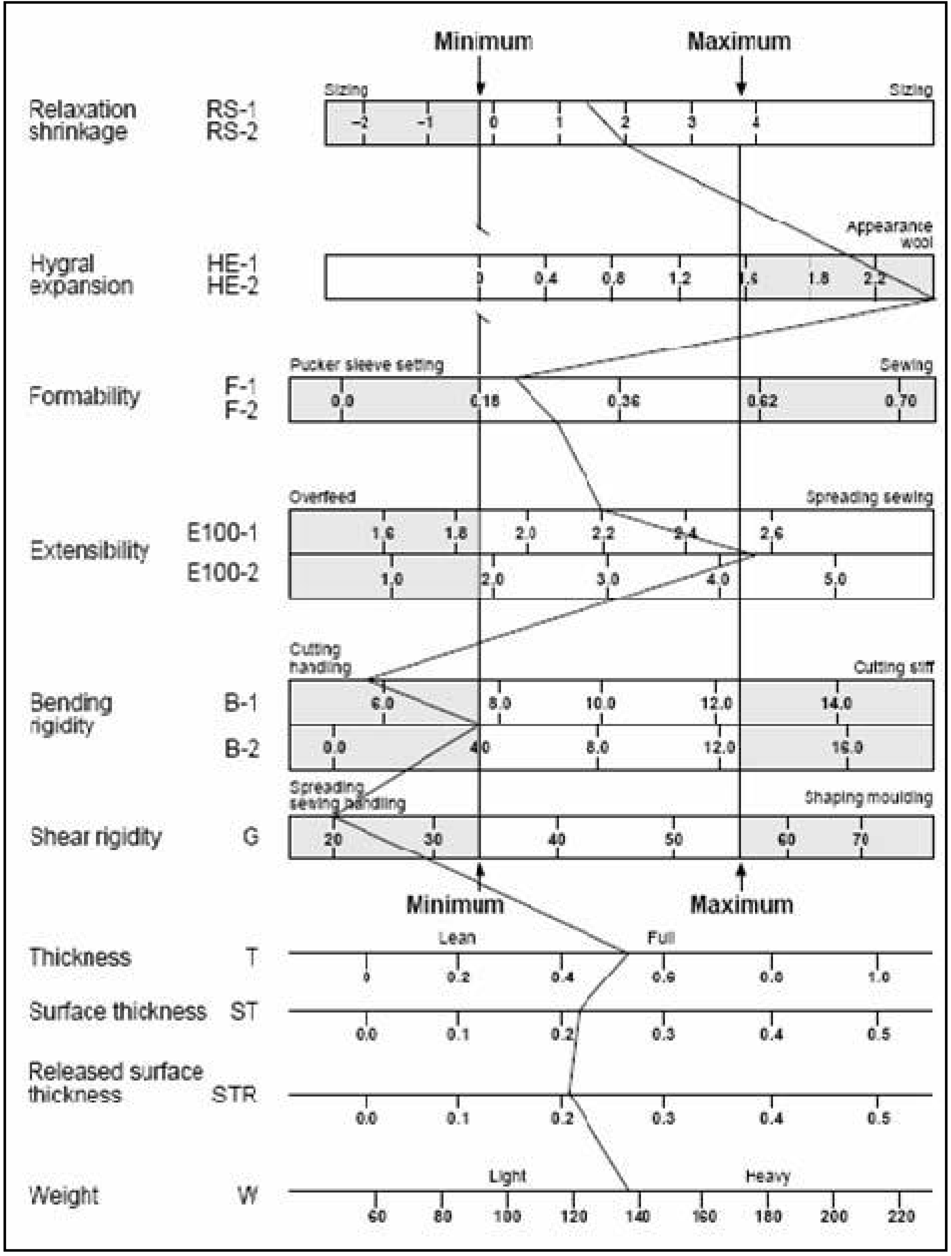

Figure5: FAST Control Chart

3. Results and Discussion

Thickness

Thickness changing of the fabrics gives an idea about the bulkiness of the fabric under different pressures. The released surface thickness is often a measure of the stability of a fabric finish. The surface layer is measured before and after the fabric is subjected to steam, as this is indicative of what would occur during garment manufacture [21]. Generally, a greater variation in surface thickness can be tolerated with thick fabrics than with thin fabrics.

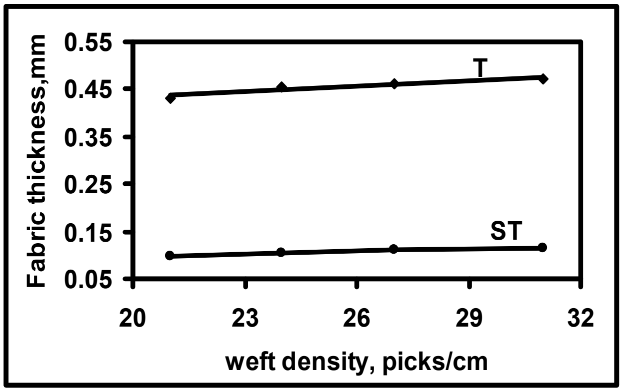

Figure 6: Thickness, T, and surface thickness, ST, of micr polyester woven fabrics at different weft densities

Since the values of the released surface thickness of the micro polyester woven fabrics are zero, the results of fabric thickness, T, and surface thickness, ST, were only depicted in Figure 6. The statistical analysis proved that filling yarn density has a significant influence on both fabric properties. It is shown that weft density has a positive effect on fabric thickness and surface thickness. As the weft density increases, both fabric properties follow the same trend. The statistical analysis also revealed that increasing filling yarn density from 21 to 31 picks/ cm leads to an increase of fabric thickness and surface thickness by 9% and 17% respectively. Higher thickness and surface thickness of micro polyester woven fabrics may be related to increasing the float height with the increase in weft density. The null values of the released surface thickness of the micro polyester fabrics may be ascribed to the very slight change in its dimensions when exposed to steam.

The regression relationship which correlates fabric thickness to filling yarn density is as follows:

Fabric thickness, mm, = 0.0036 × weft density + 0.3614

Whereas in the case of surface thickness of the woven polyester fabrics, the regression line has the following form:

Fabric surface thickness, mm, = 0.0017 × weft density + 0.0616

The statistical analysis proved that the coefficient of determination for the two models is 0.87 and 0.98 for both fabric properties, which means that these models fit the data very well.

Extensibility

The ability of a fabric to stretch at low loads is critical to garment and other sewn products' making-up procedures. FAST-3 is an extensibility meter, providing a direct measure of fabric extension under selected loads. In this study fabric extensibility was evaluated at load 100 gf/cm.

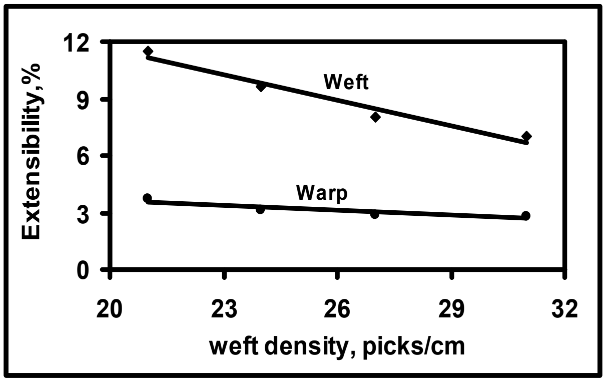

Figure 7: Extensibility of micro polyester woven fabrics at different weft densities.

In determining the effect of filling yarn density on extensibility of fabrics woven from micro polyester yarns in warp and weft directions, the results (Figure 7) verify that there is a negative correlation between filling yarn density and extensibility of such fabrics. As the filling yarn density increases the fabric extensibility decreases. The statistical analysis proved that fabric samples woven from densely weft yarns gave lower extensibility in warp and weft directions. This is because the increase in weft density leads to a restricted movement of the weft yarns inside the fabric cross section during tensile processing. The effect of weft density on fabric extensibility is more pronounced in weft direction than in warp direction.

The statistical analysis proved that extensibility of micro polyester woven fabrics reduced by 39% with the increase in the weft density from 21 picks/ cm to 31 picks / cm for the weft direction. Whereas, in the warp direction the fabric extensibility diminished by 24% with the increase in weft yarn density.

The regression model that correlates extensibility of micro polyester woven fabrics to filling yarn density was found to be of the first order and of the following form:

Fabric extensibility, (%) = - .4507 × weft density + 20.63

This regression model demonstrates a very good fit with high R^2 values of 0.96. This statistical model can be used to predict extensibility of micro polyester woven fabrics at different levels of filling densities.

Dimensional Stability

Poor dimensional stability has a negative impact on the final appearance of textile products, including size changes, poor matching of seams, and puckering. The dimensional stability of micro polyester woven fabrics was expressed in two properties namely: relaxation shrinkage and hygral expansion. Hygral expansion is defined as the reversible change in fabric dimensions that occur when the moisture content of the fabric is altered [4]. While, the relaxation shrinkage is the irreversible change in dimensions that occurs when a fabric is relaxed in steam or water [20].

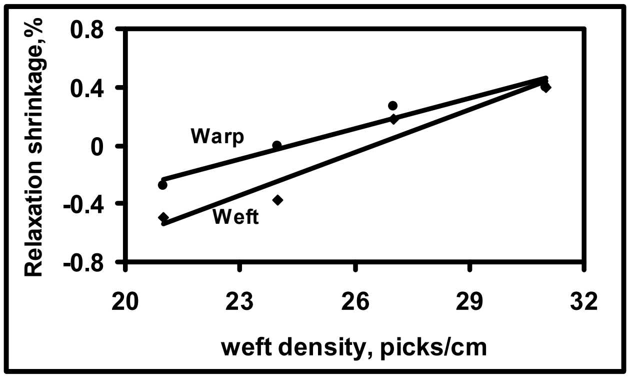

Figure 8: Relaxation shrinkage of micro polyester woven fabrics at different weft densities.

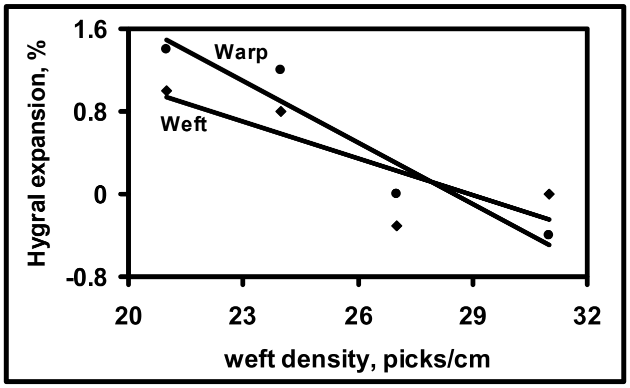

Figure 9: Hygral expansion of micro polyester woven fabrics at different weft densities.

Hygral expansion or contraction is caused by the swelling or deswelling of hygroscopic fibers in atmospheres of changing humidity. Relaxation shrinkage is due to the recovery of fibers strained during manufacturing processes [21]. Some relaxation shrinkage is necessary, for reducing bulk in eased seams (armholes etc.), though high levels cause problems.

Relaxation shrinkage and hygral expansion of micro polyester woven fabrics were measured in warp and weft direction. The experimental values of the both properties versus filling yarn density were plotted in figures 8 and 9.

The statistical analysis proved that neither relaxation shrinkage nor hygral expansion was significantly affected by the filling yarn density. This is because polyester fibers are hydrophilic fibers. From the above figures, it is noticed a positive correlation between weft density and relaxation shrinkage, while a negative correlation between weft density and hygral expansion was very clear.

As the weft density increases the relaxation shrinkage increases and the hygral expansion decreases for both warp and weft directions. The regression relationship between weft density and relaxation expansion of the micro polyester fabrics in warp direction has the following linear form:

Relaxation shrinkage= 0.069 × weft density -1.67

While in the weft direction the same relationship is as follows:

Relaxation shrinkage= 0.097 × weft density -2.62

The coefficients of determination for these models are 0.92 and 0.94 for warp and weft directions respectively. The regression models which correlate hygral expansion to weft density of micro polyester fabrics in warp direction has the following form:

Hygral expansion = -0.19 × weft density +5.65

Whereas in the weft direction the relation between the two variables is as follows:

Hygral expansion = -015 × weft density +4.3

The coefficients of determination of the above models are 0.91 and 0.89 for warp and weft directions.

Bending Rigidity

Bending properties of a fabric are determined by the yarn bending behavior, the weave of the fabric and the finishing treatments applied. Bending length is related to the ability of a fabric to drape, and bending rigidity is related more to the quality of stiffness felt when the fabric is touched or handled [21].

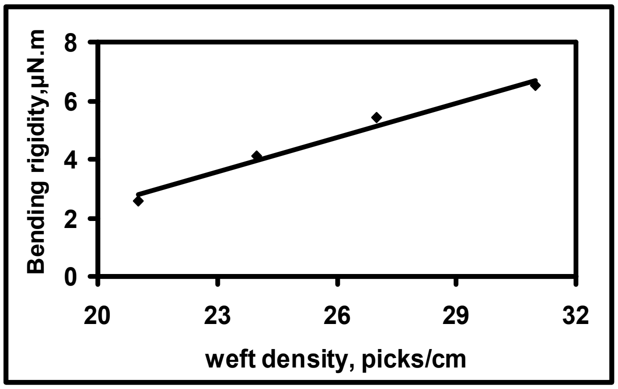

Figure 10: Bending rigidity of micro polyester woven fabrics atdifferent weft densities.

The results of bending rigidity of micro polyester woven fabrics in weft direction are introduced in figure 10. It is noticed that filling yarn density had a profound effect on fabric bending rigidity in weft directions. The positive correlation between the two variables is very clear. In fact, the fabric bending rigidity increases swiftly with the increase in the weft density. The significant influence of weft density on the fabric bending rigidity can be attributed to the increase in fabric weight with the increase in weft density. The statistical analysis proved that increasing weft density leads to increasing of fabric bending rigidity from 2.6 µN.m to 6.5 µN.m.

The relationship between weft density and fabric bending rigidity is as follows:

Bending Rigidity = 0.39 × weft density – 5.4

The R^2 value of this model is 0.98 which means this model fits the data very well.

Formability

Formability is a term derived by Lindbergh, relating to the relationship between fabric properties and performance in garment manufacture. Formability is a measure of the extent to which fabrics can be compressed in-plane before buckling and thus can be used to predict seam pucker. Formability is related to bending rigidity and extensibility [23]. As a tailoring parameter, it related to the amount of overfeed possible in eased seams (sleeve cap, neckline) [21].

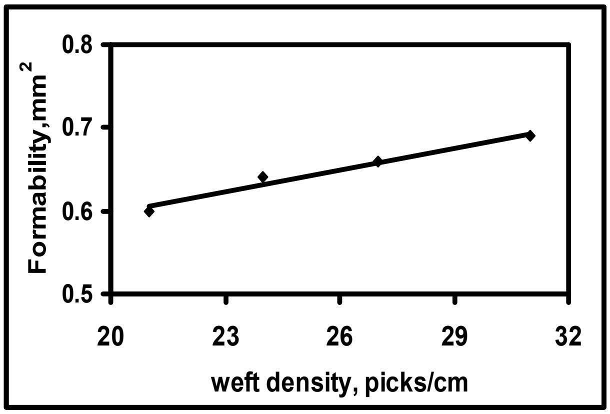

Figure 11: Formability of micro polyester woven fabrics at different weft densities.

The plot of formability of micro polyester woven fabrics versus filling yarn density was presented in Figure 11. It is shown that the positive correlation between the two variables is very clear. As the weft density increase the formability reacts in the same manner. Fabric formability in weft direction has augmented by 15% with the increase in weft density. The regression relationship which correlates fabric formability to weft density is as follows:

Formability = 0.0087 × weft density + 0.423

The coefficient of determination for this model equals 0.98.

Shear Rigidity

The ability of a two-dimensional fabric to form a three-dimensional product is related to the ability of the fabric to be sheared in its plane. This is characterized by shear rigidity, a parameter derived from bias extensibility. Shear rigidity values of micro polyester fabrics at different levels of weft densities are illustrated in figure 12.

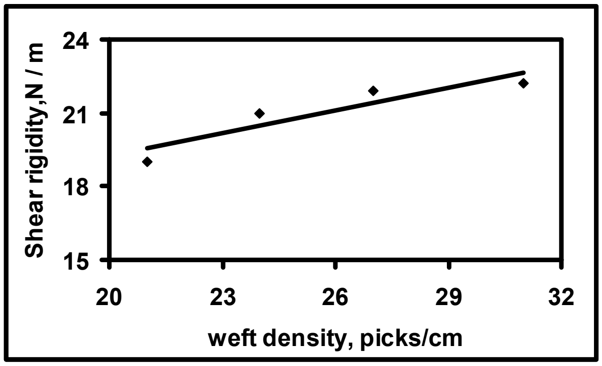

Figure 12: Shear rigidity of micro polyester woven fabrics at different weft densities.

The statistical analysis proved that weft density has a significant influence on fabric shear rigidity. A positive correlation between the two variables is detected. As the weft density increases the fabric shear rigidity follows the same trend. Increasing weft density from 21 to 31 picks / cm leads to the increase in shear rigidity by 16.8%.

The regression relationship between the fabric shear rigidity and weft density has linear following form:

Shear Rigidity =0.31 × weft density + 13.07

The calculated R^2 value for this model is 0.84.ring fabrics respectively.

Conclusion

The aim of this paper was to study the effect of weft density on handle properties of micro polyester fabrics. The handle characteristics of the woven fabric samples were measured objectively using Fast evaluation system. The experimental data was analyzed statistically using One- Way ANOVA. The results showed that weft density of the woven polyester fabrics was effective factor on handle characteristics of such fabrics. With the increase in weft density, thickness and surface thickness of woven fabric samples increased. Also fabric bending rigidity, formability and shear rigidity swiftly increased with the increased weft density. By contrast, Fabric extensibility in warp and weft directions significantly diminished with the increase in weft density. Finally, hygral expansion and relaxation shrinkage did not significantly affected by the weft density of micro polyester fabrics.

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