Using Siro FAST System to Measure Handle Properties of Outerwear Woven from monofilaments Polyester yarn

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Abstract: Fabric hand attributes can be obtained through subjective assessment or objective measurements. In this study, handle of outerwear woven from monofilaments polyester yarn was obtained objectively using FAST evaluation system. The effect of weave factor and weft yarn density were intended to be studied on extensibility, formability, compressibility, and bending and shear rigidities of such fabrics. The experimental results were assessed using Two –way analysis of variance (ANOVA) in order to detect the significance influence of both independent variables on fabric properties at 0.05 and 0.01 significant levels. The findings of this paper showed that both variables, i.e. weave factor and weft density were found to have a profound impact on the most of fabric handle properties.

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Key Words: Siro Fast, Outerwear, polyester, monofilaments, weave factor, weft density, woven fabrics, shear rigidity.

1-Introduction

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. [1] Subjective assessment is the traditional method of describing fabric handle based on the experience and variable sensitivity of human beings [2]. Textiles are touched, squeezed, rubbed or otherwise handled to obtain information about physical parameters. In the clothing industry, professional trained handle experts sort out the fabric qualities. Objective assessment has a different primary goal: it is to predict fabric hand by testing relationships between sensory reactions and instrumental data. The two primarily used fabric objective measurement systems are the Kawabata Evaluation System for Fabrics (KES-F) and the Fabric Assurance by Simple Testing (SiroFAST) [3]. Based on the results from KESF measurement regression equations have been deduced for calculation of Primary hand values and Total hand value, which can be compared to the subjective assessment results [4]. However, although objective assessments are precise from a mechanical point of view, these methods have not been commonly used in the textile and clothing industry. Even today, many companies still use subjective evaluation to assess fabric properties. The main reason for this situation is the repetitive and lengthy process of measurement and the lack of knowledge for a good interpretation of the test results.

Touching a fabric is the first action that buyers perform in order to evaluate the fabric quality to choose a suitable fabric for garments and to estimate the performance of the fabric for the end use. Many studies have reported the results of judging the objective hand of fabrics based on their mechanical properties [5-10]. Others have reported that the mechanical properties of woven fabrics vary according to weave structure, yarn structure, warp and weft setting, warp and weft counts and densities, which in turn affect fabric's hand significantly [11-18].

This study sheds light upon the handle properties of woven polyester filaments fabrics used for outerwear. The effects of weave type and weft density on extensibility, formability, bending rigidity, shear rigidity and compressibility were investigated.

2.Materials

Commercially available texturized polyester multi filament yarn having 36 denier, with the fiber denier of 1.1 was used in both warp and weft directions to prepare fabric samples of different weaves such as check, crepe, reversed and broken twill weaves with 65 ends per inch and 68, 78 and 88 picks per inch respectively. All fabric samples were woven by a Dornier loom with an electronic dobby shedding mechanism and rapier weft insertion at a loom speed of 470 r.p.m. Figure 1 shows the repeat units of the weave structures for the fabric samples under study.

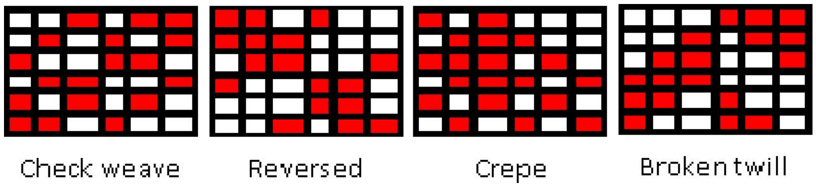

Figure 1: Weave repeat units of different weave studied

Weave factor

The weave factor is a number that accounts for the number of interlacements of warp and weft in a given repeat. It is also equal to average float and is expressed as [19]:

$$M = \frac{E}{I} \quad \text{---------- (1)}$$

where E is number of threads per repeat and I is number of intersections per repeat of the cross-thread. The weave interlacing patterns of warp and weft yarns may be different. In such cases, weave factors are calculated separately with suffixes 1 and 2 for warp and weft respectively. Therefore, $M_1 = E_1/I_2$; E_1 and I_2 can be found by observing individual pick in a repeat and $M_2 = E_2/I_1$; E_2 and I_1 can be found by observing individual warp end in a repeat.

In some weaves, the number of intersections of each thread in the weave repeat is not equal. In such cases the weave factor is obtained as under:

$$M = \frac{\sum E}{\sum I} \quad \text{---------- (2)}$$

Using equation 2, the weave factors of a six-end weave shown in Fig. 1 is calculated and listed in table 1.

Table 1: Weave factor for studied weaves

Weave type	Weave factor
Check weave	1.29
Crepe weave	1.38
Reversed weave	1.8
Broken twill	3

Laboratory testing

The handle properties of outerwear woven from polyester filaments were measured using Siro Fast measuring system. In this study, compressibility, extensibility, formability, shear and bending rigidities were measured in weft direction.

Hayam Demerdash and co-authors [18] stated that 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. 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 part 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 2.

Figure 2: CSIRO FAST Instruments

Fabric Extensibility

FAST-3 is an extensibility meter, providing a direct measure of fabric extension under selected loads. Weft and bias directions are tested on woven fabrics strips. 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 [18].

In this study, Extension, % is calculated by the average values for a specimen in the weft direction at specific weight loads. Bias Extension, EB5, % is the average of all of the bias samples at 5 gf / cm

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

$$G = \frac{123}{EB_5}$$

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

$$F = \frac{(E_{20} - E_5) \times B}{14.7}$$

where,

- E5, Extension at 5 gf/cm, in %
- E20, Extension at 20 gf/cm, in %
- B, Bending Rigidity, in µN.m

Bending rigidity

FAST-2 measures two bending properties of a fabric, fabric bending length and fabric bending rigidity. Figure 3 shows the principle of measuring bending length using this system. The bending rigidity in the weft direction was calculated according to the following formula:

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

Where,

G: fabric bending rigidity in µN.m.

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

C: the bending in mm.

Compressibility

In this study, the results of fabric thickness at loads 2 g/cm^2 and 100 g/cm^2 were used to evaluate fabric compressibility according to the following formula:

$$\text{Fabric compressibility,\%} = \frac{T_2 - T_{100}}{T_2} \times 100$$

Statistical analysis

Since the independent variables in this study were weave factor and weft density, the entire data were assessed using Two –Way analysis of variance. The experimental results were investigated at significance level $0 \le \alpha \le 0.05$. To predict each dependent variable such as extensibility, compressibility, --etc at the various levels of the independent ones, a multiple non-linear regression model was used. The regression model has the following form:

$$Z = a + b x + c y + d x^2 + e y^2 + f xy$$

Where,

Z= dependent variable, i.e. extensibility, compressibility,--etc.

a = constant

x= weft density, ppi

y= weave factor, and

b, c, d, e, and f= regression coefficients.

The validation of this regression model was conducted using the coefficient of determination, R^2. This coefficient ranges between zero and one; as it approaches one, this means that the predicted regression model fits the data very well and it can be used to predict the fabric properties effectively.

3.Results and Discussion

Extensibility

The plot of woven fabric extensibility versus both weft yarn density and weave factor was depicted in figure3. From this figure and statistical analysis, it can be seen that both independent variables have a profound influence on the woven fabric extensibility. It was found that weft density has a significant effect at 0.05 significant level on fabric extensibility. A decreasing trend is detected assuring that as the weft density increases, the woven fabric extensibility decreases. The statistical analysis proved that increasing weft density from 68 to 88 picks / inch leads to a decrease of fabric extensibility by about 25%. In contrast to the effect of weft density, weave factor was found to have a significant influence on the woven fabric extensibility at 0.01 significance level. An increasing trend was detected assuring that as the weave factor increases the fabric extensibility behaves the same trend.

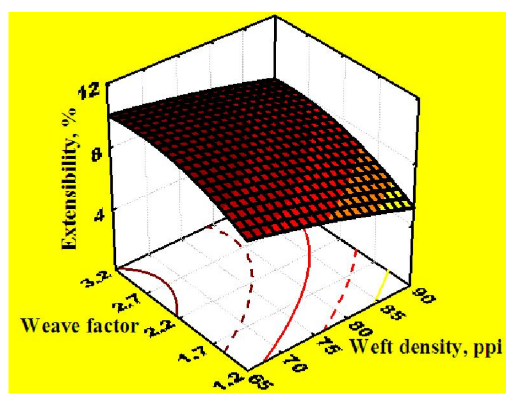

Figure 3: Response surface of weave factor and weft density on extensibility of woven fabrics

Irrespective of the values of weft density, extensibility of weave structures has the following order: broken twill > reversed twill > check weave> crepe. It was found the extensibility of the woven fabric of broken twill weave equals 9.1%, while the value of extensibility of crepe weave is about 5.6%.

The regression relationship which correlates fabric extensibility to filling yarn density and weave factor has the following non-linear form:

Fabric extensibility = 6.8+ 0.03 x +3.4 y - $0.01x^2$+ 0.02xy-$0.8y^2$

The statistical analysis proved that the R^2 for this model is 0.0.81. This means that the regression model fits the data very well.

Compressibility

Compressibility of outerwear fabrics against weave factor and weft density was plotted in figure 4. The statistical analysis proved that both variables have a significant effect on fabric compressibility at 0.05 significance level. From this figure it can be seen that as the weave factor increases, the compressibility also increases. Compressibility increases by approximately 7% with the increase of weave factor from 1.29 to 3. With regard to the effect of weft yarn density on fabric compressibility, a decreasing trend was detected assuring that as the weft density increases the fabric compressibility deceases. Increasing weft yarn density from 68 to 88 picks / inch leads to a reduction of fabric compressibility by approximately 10%.

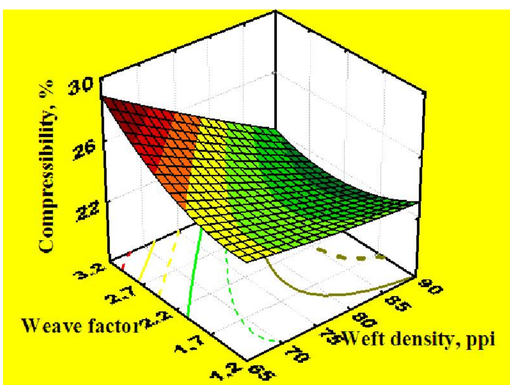

Figure 4: Response surface of weave factor and weft density on compressibility of woven fabrics

The regression relationship which correlates fabric compressibility to weft yarn density and weave factor has the following non-linear form:

Fabric extensibility = 27.13 - 0.07 x +3.6 y + 0.11xy + $1.3y^2$

The statistical analysis proved that the R^2 for this model is 0.0.85. This means that the regression model fits the data very well.

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 [18].

The response surface of the effect of weft density and weave factor on the bending rigidity of woven fabrics is illustrated in figure 5. The statistical analysis showed that both independent variables have a profound effect on the fabric bending rigidity. Weft density was found to give a significant impact on bending rigidity at 0.01 significant level. An increasing trend was detected assuring that as the weft density increases, the woven fabric bending rigidity also increases. Increasing weft density from 68 to 88 picks / inch leads to an increase of fabric bending rigidity from 4 to 6.8 µN.m. The statistical analysis also proved that weave factor has a significant impact on fabric bending rigidity at 0.05 significant level. A decreasing trend is detected assuring that as the weave factor increases the fabric bending rigidity decreases. It was found that woven fabric with weave structure crepe has the highest value with regard to bending rigidity, whereas the broken twill weave has the lowest value.

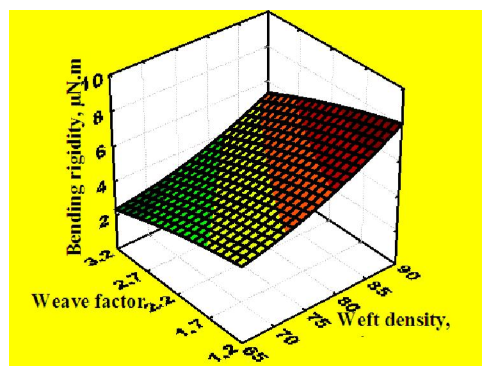

Figure 5: Response surface of weave factor and weft density on bending rigidity of woven fabrics

The regression relationship between fabric bending rigidity and both weft density and weave factor has the following form:

Bending rigidity, µN.m = 11.6 - 0.3 x + 0.9 y + $0.03x^2$ - 0.02 xy - 0.2 y^2

The statistical analysis proved that the R^2 value for this model is 0.9. This means that the regression 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. As a tailoring parameter, it related to the amount of overfeed possible in eased seams (sleeve cap, neckline) [18].

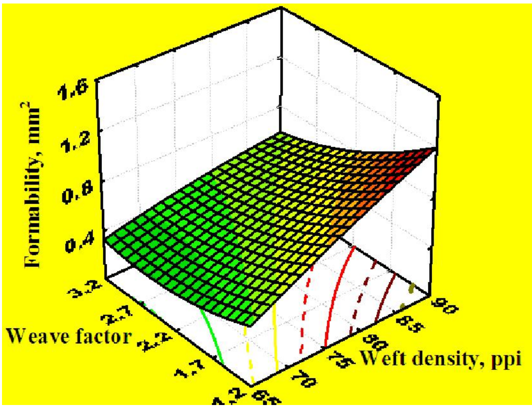

Figure 6: Response surface of weave factor and weft density on formability of woven fabrics

Figure 6 shows the response surface of the effects of weave factor and weft density on the formability of the woven fabrics. The statistical analysis showed that both factors has a significant influence at 0.01 significance level on fabric formability. As the weft density increases, the fabric formability reacts in the same manner. Increasing weft density from 68 to 88 picks / inch leads to an increase of formability by approximately 88%. It is also noticed that weave factor has a significant influence on woven fabric formability. A decreasing trend is detected conforming that as the weave factor increases the formability decreases. The statistical analysis proved that the weave structure of type check has the lowest formability values, whereas the broken twill structure has the highest value.

The regression relationship which correlates the woven fabric formability to both weft density and weave factor has the following non-linear form:

Fabric formability= $-2.7 + 0.07\ x + 0.1\ y - 0.02\ x^2 - 0.09\ xy + 0.1y^2$

The statistical analysis proved that the coefficient of determination for this model equal to 0.97. This means that the regression model fits the data very well.

Shear rigidity

Shear rigidity values of the woven fabrics according to the variations of weft density and weave factor are depicted in figure 7. The statistical analysis proved that both variables have a significant effect on fabric shear rigidity. Weft density was found to have a significant effect at 0.01 significant level on fabric shear rigidity. An increasing trend was detected assuring that as the weft density increases the fabric shear rigidity react sin the same trend. Increasing weft density from 68 to 88 picks / inch leads to an increase of fabric bending rigidity from 19.3 to 27.5 N/.m. It is also found that weave factor has a significant effect on fabric shear rigidity. As the weave fabric increases, shear rigidity increases up to weave factor 1.8 and then decreases with the increase of weave factor. It was found that the fabrics with weave structure check has the highest value of shear rigidity, whereas the weave structure broken twill was found to have the lowest value.

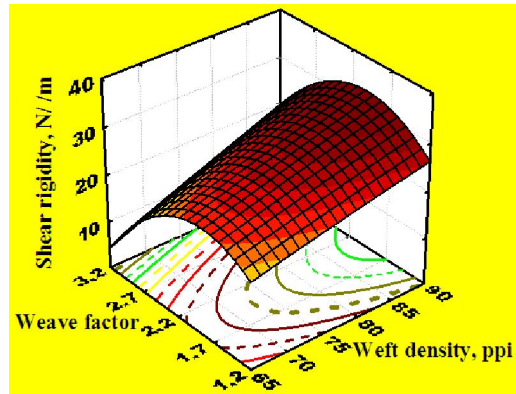

Figure 7: Response surface of weave factor and weft density on shear rigidity of woven fabrics

The statistical analysis proved that the relationship between shear rigidity and both weft density and weave factor has the following non-linear form:

Shear rigidity, N/m = $-27.4 - 0.3\ x + 27.2\ y - 0.01\ x^2 + 0.2\ xy - 10\ y^2$

The coefficient of determination for this model is 0.79, which means that this model fits the data very well.

Conclusion

The findings of this study can be sum up as follows:

- It was found that weft yarn density has a tremendous influence on fabric handle properties. As the weft yarn density increases, fabric formability, shear rigidity and bending rigidity also increases. By contrast, a decreasing trend was detected with respect to the impact of weft density on the other fabric properties. As the weft density increases the extensibility and compressibility of the studied woven fabrics decreases.
- The statistical analysis proved that increasing the weave factor leads to an increase of the fabric extensibility. It was found that extensibility of woven fabrics have the following order: broken twill > reversed twill > check weave> crepe
- As the weave fabric increases, shear rigidity increases up to weave factor 1.8 and then decreases with the increase of weave factor.
- It is also found that weave factor has a profound impact on formability and bending rigidity

of the woven fabrics, a decreasing trend was detected conforming that as the weave factor increases the values of the both variables deceases.

- Finally, non-linear regression models were used to correlate each handle property of the studied fabrics to both weave factor and weft densities. These regression models can be used to predict these handle properties effectively according the value of coefficient of determination.

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