31G04

Effect of Fiber Fineness and Silicone Softener Treatment on Hand and Abrasion Resistance of 100% Polyester Knitted Fabrics

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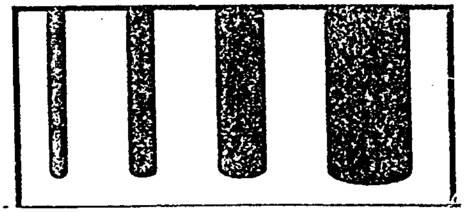
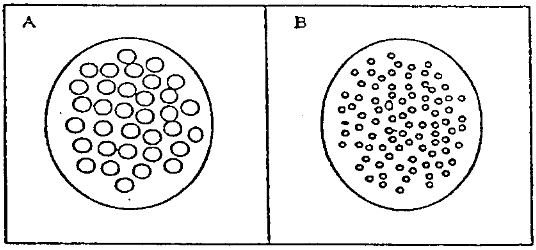
1. Introduction

Consumption of synthetic fibers has been declining in the past ten to 20 years, even though synthetic fibers have many advantageous properties over natural and non-synthetic manufactured fibers. Consumer taste and fashion trend have preferred natural fibers, which have soft, smooth hand and comfort properties[1]. In response to this trend, the synthetic fiber industry came up with microfibers, which have silk-like appearance and hand properties. The exquisite hand of microfiber can be accomplished by reduction of filament denier size[2]. Figure 1 shows a comparison of fiber size with different deniers, and Figure 2 shows a comparison of corss-section of yarns with filaments of different deniers[3].



0.3dpf 0.7dpf 1.0dpf 2.0dpf

Fig. 1. A comparison of Fiber Fineness



2.0 dpf 0.7 dpf

Fig. 2. A comparison of Yarn Cross-Section with Filaments of Different Deniers.

Research has shown that microfiber fabrics have better hand properties than conventional denier fabrics. Most research, however, dealt with microfiber fabrics in commercial production. In the current research design the test fabrics were controlled in fabric structure and yarn size other than the independent variables concerned. Silicone softeners have been applied to woven, knit, and nonwoven fabrics of regular denier fabrics to improve pliability, softness, and tactile properties[4]. With the advent of microfiber fabrics, which shows poorer abrasion resistance, tear strength, and wrinkle resistance than conventional denier fabrics, softener applicants to the new fabrics are being attempted to compensate for the disadvantageous properties of microfiber fabrics[5]. How different silicone softener chemicals affect hand and these physical-mechanical properties had not been thoroughly investigated, especially in conjunction without different denier sizes. The specific research objective was to determine the effects of filament fineness and silicone softener treatment on fabric hand and abrasion resistance.

2. Methodology and Procedures

The test fabrics were made of filament fibers of three different deniers per filament (0.75, 1.0, and 2.0 dpf). The silicones selected for testing included amide, epoxy glycol, and amide glycol. Finishes were applied from a pad bath containing 1.0% silicone solids based on the weight of the fabrics. Eight expert judges evaluated the hand of the fabrics by a sensory method, using nine polar adjective pairs as semantic differential on an 11-point certainty scale (Table 1). In addition, instrumental measures of eleven parameters were made as physical-mechanical attributes of hand, using the Kawabata Evaluation System. During testing, some problems and limitations which were similar to Finnimore[6]'s were encountered. Because of the limitation friction and roughness testes were done in the wale directions only, and tensile and shear test could not be done in this study. Some of the characteristic values have been normalized for statistical analysis by taking their logarithmic values[7]. The parameters tested on fabrics are listed in Table 3. Abrasion resistance of the fabrics was also performed, using a Taber abrasion tester. Statistical significance tests, Pearson products correlation coefficients were used to determine the effects of fiber fineness hand and abrasion resistance. Regression analysis[8] was used to predict fabric softness.

Table 1. Semantic Differential Corresponding to the mechanical properties.

Polar Adjective	Mechanical Attributes Represented
Light - Heavy	Weight
Smooth - Rough	Frictional
Flexible - Stiff	Bending
Crisp - Limp	Bending
Fine - Coarse	Frictional
Slippery - Waxy	Frictional/surface contour
Soft - hard	Compression
Thin - Thick	Thickness
Stretchy - Firm	Tensile

Table 2. Mechanical Hand Attributes Used in the KES Method.

Property	Hand Attributes	Description
Bending	log B	Bending rigidity
	log H.5	Hysteresis at 0.5 degree
	log H1.5	Hysteresis at 1.5 degree
Compression	LC	Compressional linearity
	log WC	Compressional energy
	RC	Compressional resilience
Surface	MIU	Coefficient of friction
	log MMD	Mean deviation of MIU
	log SMD	Geometrical roughness
Weight	log W	Weight per unit area
Thickness	log T	Thickness at 0.5 $gf cm^{-2}$

3. Results and Discussion

Sensory hand of the knit fabrics differed significantly ($p<0.01$) by fiber fineness in all of the nine polar adjective pairs. Sensory hand, however, did not differ significantly by silicone softener treatment. Correlation analyses showed that smooth-rough and soft-hard showed the highest correlation coefficient ($r = 0.84$). suggesting that the two adjective pairs measured similar sensory characteristics.

Instrumental measure of hand, as measured by the KES, differed significantly by fiber fineness, except for the parameter mean deviation of coefficient of friction (MMD). This result could lead to a conclusion that the KES instrumental measures of hand can detect the difference of fiber fieneness as did the subjective sensory hand evaluation by expert judges. Instrumental measure of hand differed significantly by silicone softener treatment for the following physical-mechanical hand attributes: bending hysteresis at $k = 1.5$ (H1.5), compressional linearity (LC), weight (W), and thickness (T). in general, the effect of silicone softener treatment was more significant in the KES hand measures than in the sensory hand measures by the expert judges.

Correlation analyses revealed that all KES bending parameters were highly associated with all adjective pairs of sensory hand. A conclusion was made that expert judges' sensory perception of fabric hand was in good agreement with instrumental measures of bending properties of the fabrics as measured by the KES system. Other KES parameters that showed high correlations with all adjective pairs of sensory hand were compressional energy (WC), geometrical roughness (SMD), and fabric weight (W).

Strong correlations that existed between the sensory hand measures and some of the KES physical-mechanical hand attributes suggested that instrumental measures of KES hand attributes can be used to predict fabric hand without the use of sensory hand judging, provided that a representative adjective pair of sensory hand is selected and a predicative equation is developed using appropriate KES hand parameters. By use of a stepwise regression method (Kawabata, 1980), a predictive equation was developed by stepwise elimination of parameters of no importance without sacrificing the accuracy of the regression equation:

$$\text{Soft-hard} = -12.06 - 20.79 \log (WC) - RC \; (92\%)$$

For the research fabrics made of three fiber fineness, this equation showed the best fit between predicted and observed values of fabric hand in terms of soft-hard. Predicted hand using this equation and observed sensory hand by the soft-hard polar adjective pair with respect to fiber fineness is shown in Fig. 3. Fig. 3 also shows that as fiber fineness increased, softness increased in both the predicted and observed hand.

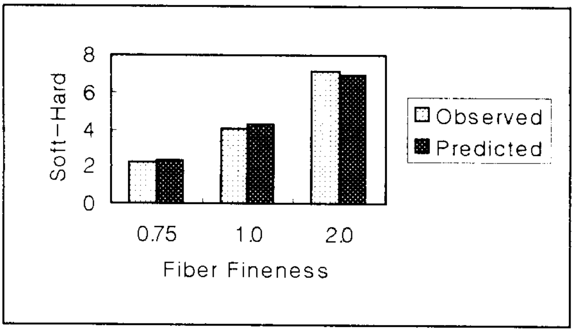


Fig. 3. Comparison of Predicted and Observed Fabric Softness for Each of the Three Fiber Types.

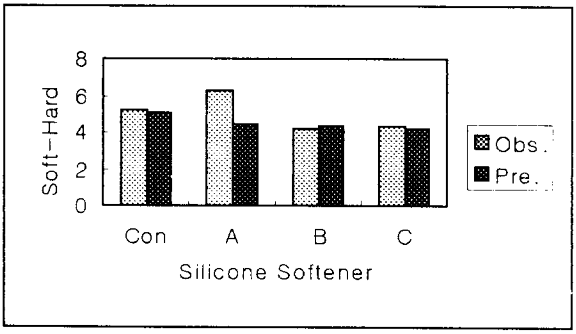


Fig. 4. Comparison of Predicted and Observed Fabric Softness for Each of the Four Silicone Softener Treatment.

Fig. 4 shows the predicted and observed hand for each of the fours silicone softener treatment across all fiber fineness types. The predicted and observed hand values were in good agreement, except in the silicone A treatment. Unlike in Fig. 3, however, Fig. 4 does not show any trend of increasing or decreasing softness, depending on silicone softener treatment. Fabric abrasion resistance differed significantly by fiber fineness. Fabric abrasion resistance differed significantly by fiber fineness (Fig. 3). The data indicated that fiber denier reduction in microfibers could bring an abrasion wear problem. The efect of silicone softener treatment is shown in Figure 6. Generally, fabric abrasion resistance improved with silicone softener treatment as compared with the control fabric. These results implicated that reduced fabric abrasion resistance is one of the disadvantages of microdenier fiber fabrics[9] and that abrasion wear problem of the microfiber fabrics can be improved by silicone softener treatment.

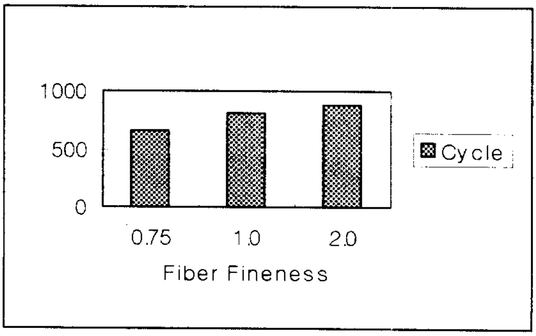


Fig. 5. Effect of Fiber Fineness on Fabric Abrasion Resistance.

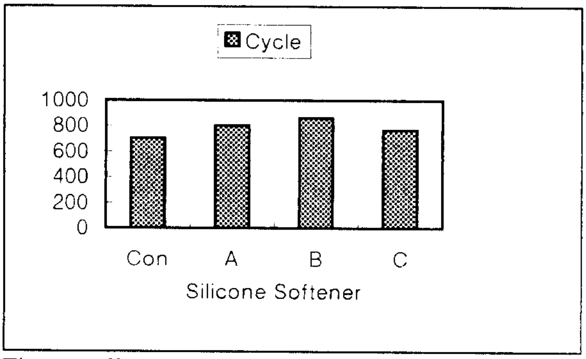


Fig. 6. Effect of Silicone Softener Treatment on Fabric Abrasion Resistance.

4. Conclusion

The research objective was to determine the effects of filament fineness and silicone softener treatment on fabric hand and abrasion. Sensory hand of the fabrics and KES measurements of hand differed significantly by fiber fineness. Unlike the results of sensory hand, some of the KES parameters differed significantly by silicone softener treatment. Fabric compressional energy and compressional linearity were hand attributes that correlated with fabric softness the most. Fabric abrasion resistance test indicated that fiber denier reduction in microfibers could bring an abrasion wear problem; however, silicone softener treatment improved fabric abrasion resistance.

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