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Effects of Silicone Mixed Fluorochemical Finishes on Fabric Performance Characteristics of a Microfiber Polyester/Cotton Blend Fabric

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Abstract : The purpose of this study was to examine the effects of chemical finishes on performance characteristics of microfiber blend fabrics. A 60% polyester microfiber/40% cotton blend woven fabric was finished by ten chemicals: three silicone softeners, one fluorochemical, and their mixtures. Performance characteristics examined were abrasion resistance, and oil/water repellency. Chemical finishes containing dimethylpolysiloxane silicone performed better in fabric abrasion resistance than other chemicals. The correlation between abrasion wear and instrumental measures of fabric hand indicated that the breaking strength loss by abrasion related negatively to the coefficient of friction. This implied that the finished fabrics with lower surface frictional coefficient (slipperier) had higher breaking strength loss by abrasion. The microfiber structure of polyester did not appear to help in oil/water repellency due to the larger surface areas of the microfibers. The fluorochemical finished fabric had the most significant improvement on oil/water repellency. The silicone-only finishes, however, did not improve oil/water repellency. When mixed with the fluorochemical, silicone finishes showed improved oil/water repellency.

Key words : silicone softener, fluorochemical, microfiber, abrasion, oil repellency, water repellency, breaking strength

INTRODUCTION

Microdenier yarns, often called low dpf (denier per filament) yarns, are generally made from fibers of less than 1 dpf. They are four times finer than wool, three times finer than cotton and more than twice as fine as the finest silk (Isaacs, 1991). Fabrics containing these fibers have come into increasing favor in the apparel design community over the past few years due to their silk-like soft hand and excellent drapability (Rozelle, 1993).

The advantages of a microfiber fabric include washandwear properties, wind and weather resistance, waterproof quality, and vapor permeability. Furthermore, the outlook for microfiber fabrics appears excellent because they provide the consumer with lightweight, easy care, dimensional stability and outstanding hand (Goldstein, 1993). With the benefits of improved hand and comfort, fashionable outerwear will definitely be the largest end-use market. Functional sportswear, including ski outfits, sailing outfits and raincoats, will also play an important role in the microfiber fabric marketplace because of the ability of microfibers to repel water, yet remain air permeable.

However, microfibers have their drawbacks. The drawbacks include higher filament price and processing cost; greater care and expertise required especially in finishing; and reduced fiber strength, abrasion resistance and wrinkle resistance of the fabric (Behera, 1995). Carding is more difficult in the manufacturing process for a fine denier yarn, and drafting becomes more difficult in the ring spinning process. The microfibers are easily damaged if the spindle speed is increased. For this reason the speed must be low, and this means lower productivity (Murata, 1994). The fineness of cotton fibers, if not the same with that of the microfiber polyester, could cause problems in fiber mixing in the yarn spinning process of blending. Due to the greater number of filaments and greater surface area available in a microfiber yarn, the static problem appears to be greater (Behera, 1995). Additionally, the small radius of the fiber causes many problems with the dyeing process and color fastness of dyed fabrics (Nakamura, 1995). In order to obtain a specific color, it is often necessary to use twice as much dye for a microfiber fabric as for a conventional one (Lallam, 1997).

It is possible to broaden and upgrade microfiber fabric's usefulness by enhancing certain characteristics through finishing. Types of effects that can be achieved by chemical finishing include hand modification, sewing lubrication, oil/water repellency, soil release, comfort, antipilling, antistatic and durable press properties (Goldstein, 1993).

Silicones have been used as finishes and textile pro-

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cessing aids for conventional fabrics and apparels for many years. Literature shows that silicone can greatly improve fabric hand. Sabia (1995) demonstrated that silicone softener treatments enhanced softness and physical properties of 100% polyester microfiber fabrics. In addition, the utility of silicone softeners of varying chemical structures, when padded to a 50/50% cotton/polyester microfiber woven fabric was also evaluated. The silicone treatments improved fabric softness and hand but to a different degree, depending on the chemical structure of the silicone. Tear resistance and wrinkle recovery were also increased by a silicone treatment (Sabia, 1995).

Fluorochemicals are known for their oil/water repellency when used on fabrics. If they were applied to a microfiber fabric with a dense structure, the fabric can be made into waterproof quality. The waterproof effect can be markedly superior to that of regular polyester/cotton blends or 100% cotton fabrics, also treated with fluorochemicals. Microfiber fabrics with a fluorochemical finish can have resistance to water penetration equivalent to a water column of 350700 mm, which is sufficient for ordinary rainwear or skiwear (Jerg, 1990).

Consumer tastes in the clothing sector have fluctuated over the past ten to 15 years. The fashion trend toward soft, smooth, and natural fiber textiles was paralleled by a decline in the popularity of 100% synthetic textiles, despite advantages of synthetic fibers as wash-wear, durability and dimensional stability. Unfortunately, the results obtained from natural fiber textiles often fell short of requirements in terms of dimensional stability and wash-wear performance. Therefore, microfibers with their versatile potential were able to fill an attractive and promising textile niche, particularly in blends (Jerg, 1990).

Blends play an important role in the use of polyester microfibers. Suitable blends can be used to reduce the cost, yet retain the advantages microfibers offer (Partin, 1991). However, this may reduce some of the desirable characteristics of the microfiber that make microfiber fabrics special, such as softness, hand and water repellency. It is possible to impart a variety of functional and aesthetic effects by chemical finishing of the microfiber blend fabrics. These effects include hand modification, oil/water repellency, soil release, antistatic, antipilling and durable press properties.

Silicones have been demonstrated to be able to enhance fabric hand, tear resistance, wettability and wrinkle recovery of a 50/50 cotton/polyester microfiber woven fabric (Sabia, 1995). Likewise, fluorochemicals will undoubtedly improve oil/water repellency, but the application of fluorochemicals may have an adversary effect on other performance properties such as softness and hand. Weather the poorer abrasion resistence of microfiber fabrics than that of regular denier fabrics can be improved by chemical finishes has not been shown in the literature.

Industries are seeking the effects of the combination of these two chemicals in order to optimize their function and reduce the cost. The combined effects of silicone/fluorochemical finishes on hand, softness and other fabric performance characteristics have not been systematically investigated. The chemical mixture at which level it might give optimum fabric performance properties as well as economic advantages is not known.

EXPERIMENT

Materials

Test fabric : The test fabric was made of blended spun yarns of 60% polyester microfiber and 40% cotton in woven construction, and unfinished and undyed. The fabric was acquired through Dow Corning Corporation of Greensboro, North Carolina. The characteristics of the test fabric are shown in Table 1.

Finishing chemical

Based on a preliminary study (Goldstein, 1993), four chemicals supplied by Dow Corning Corporation, Greensboro, were selected for this study:

Chemical 1 (S1) : Amino-functional hydrophilic prototype silicone softener fluid (20% solids)

Chemical 2 (S2) : Diamino-functional siloxane silicone softener (20% solids)

Chemical 3 (S3) : Dimethylpolysiloxane hydrophobic silicone softener (40% solids)

Chemical 4 (F1) : 30% fluoroaliphatic ester emulsion (Scotchguard TM FC-251).

In addition to the four base chemicals, six more chemical mixtures of the base chemicals were prepared. The total ten finishing chemical types are shown in Table 2.

Fabric finishing

One yard of the test fabric was finished with each chemical type in the Dow Corning Corporation research laboratory in Greensboro, North Carolina. Finishes were applied to the fabric by a pad/bath system at the speed of 1.0 m/min. The wet pick up (wpu) of the control fabric

Table 1. Characteristics of the test fabric

Characteristic	60% polyester microfiber/40% cotton blend woven apparel fabric
Weight	197 g/m^2
Weave	plain weave rib
Fabric Count	50× 60 yarns/inch
Thickness	0.48 mm

Table 2. Finishing chemical description

Finishing chemical type	Symbol	Description
silicone 1 (S1)	C1	S1 at 1.0% fabric wet pick up (wpu)
silicone 2 (S2)	C2	S2 at 1.0% wpu
silicone 3 (S3)	C3	S3 at 1.0% wpu
fluorochemical (F)	C4	F at 1.5% wpu
0.5% S1 + F mixture (0.5S1+F)	C5	S1/F blend at 0.5%/1.5% wpu
0.5% S2 + F mixture (0.5S2+F)	C6	S2/F1 blend at 0.5%/1.5% wpu
0.5% S3 + F mixture (0.5S3+F)	C7	S3/F1 blend at 0.5%/1.5% wpu
1.0% S1 + F mixture (1.0S1+F)	C8	S1/F1 blend at 1.0%/1.5% wpu
1.0% S2 + F mixture (1.0S2+F)	C9	S2/F1 blend at 1.0%/1.5% wpu
1.0% S3 + F mixture (1.0S3+F)	C10	S3/F1 blend at 1.0%/1.5% wpu

was 42%. The finished fabrics were dried/cured at 150°C and at the speed of 0.465 m/min for 3 minutes, and then conditioned under standard laboratory conditions, 2± 1°C and 65± 2% RH for at least 24 hours before testing.

Abrasion resistance

ASTM Standard Test Method D-3884, Abrasion Resistance of Textile Fabrics: Rotary Platform, Double-Head Method (ASTM, 1997a) was used to measure abrasion resistance of the test fabrics. The test was conducted in the standard laboratory of the Department of Textile Products Design and Marketing at the University of North Carolina at Greensboro. Three specimens of 6 × 6 inches in size were cut. The wheel and platform position were calibrated according to the test standard. Calibrase CS-17 resilient rubber-base wheels were selected and purchased form Taber Industries, North Tonawanda, NY., in order to reduce the variations of abrasive quality. Due to the uneven wear and clogging of the surface, the wheels and specimens were resurfaced and cleaned with a brush at an interval of every 200 revolutions.

The method of percentage loss in breaking load was used to interpret the abrasion results. After 600 revolutions, three stripes of 5 × 1 inches were cut along the warp and filling directions of the abraded specimens and tested for breaking strength using an Instron tensile tester to compare with that of unabraded specimens. The percentage loss in breaking strength was calculated using the following equation:

$$L\ (\%) = 100\ (A - B)/A$$

where:

L = loss in breaking strength,
A = breaking strength before abrasion, and
B = breaking strength after abrasion.

Oil repellency test : AATCC Test Method 118, Oil Repellency: Hydrocarbon Resistance Test (AATCC, 1997-a) was used for the oil repellency test. The specimens were tested in the laboratory of Dow Corning Corporation, Greensboro, NC. According to the test standard, two specimens of 8 × 8 inches for each test fabric were cut and conditioned. AATCC standard test liquids used are shown in Table 3. The test liquids were dropped covering an area approximately 5 mm in diameter on the test specimen in five different locations along the filling direction, beginning with the lowest-numbered test liquid (No. 1). After 30± 2 seconds, if no penetration or wetting of the fabric took place at the liquid-fabric interface and no wicking around the drops occurred, the next higher-numbered test liquid would be dropped at the same manner, until one of the test liquids showed obvious wetting or wicking of the fabric. A pass occurs if three or more of the five drops showed clear well rounded appearance with a high contact angle. The oil repellency grade was measured on two specimens with the same chemical finish. The value was reported if the two grades agreed. Otherwise, a third determination was made to match either of the first two determinations. The median value was reported if the three determinations disagreed to one another.

Table 3. AATCC standard test liquids

AATCC oil repellency grade number	Composition
0	none (Fails Kaydol)
1	kaydol
2	65:35 Kaydol: n-hexadecane by volume
3	n-hexadecane
4	n-tetradecane
5	n-dodecane
6	n-decane
7	n-octane
8	n-heptane

Water repellency test : Water repellency of test fabrics was measured using AATCC Test Method 22, Water Repellency: Spray Test (AATCC, 1997b). The test was conducted in the standard laboratory of the Department of Textile Products Design and Marketing at the University of North Carolina at Greensboro. One specimen of 7 × 7 inches from each test fabric was cut and conditioned before testing. AATCC Spray Tester was used. After testing, the test specimen was compared with the rating chart in the test method and assigned a rating corresponding to the nearest standard in the rating chart.

RESULTS AND DISCUSSION

The results of measurements on abrasion resistance, and oil/water repellency, were analyzed using appropriate statistical procedures to determine the effects of the ten different chemical finishes

Abrasion resistance

The abrasion resistance of the test fabrics was measured separately in warp and filling directions by measuring the strength loss (Instron breaking strength) after abrasion. To determine if there were significant differences in abrasion resistance attributed by the chemical finishes, an F-test was performed and the results are shown in Table 4. The abrasion resistance differed significantly ($p<0.01$) by the chemical finishes in both warp and filling directions. Therefore, the null hypothesis that finishing chemical type has no effect on abrasion resistance was rejected.

A multiple t-test was performed to determine the significant levels of difference by chemical finishes. The percentage breaking strength loss in the warp direction was more prominent than that in the filling direction as shown in Fig. 1. In the warp direction, 0.5S3+F (C7), 1.0S3+F (C10), and 0.5S1+F (C5) showed significantly improved abrasion resistance from the control fabric. In the filling direction, S3 was the only chemical that showed significantly different abrasion resistance from the control fabric. It had the lowest mean value of percentage breaking strength loss.

Table 4. Statistical results of f-test on abrasion resistance

Strength loss	F-value	p-value
Warp	6.31*	0.0002
Filling	29.47*	0.0001

*Significant at 0.01 level

Fig. 1. Mean percentage of breaking strength loss after abrasion.

Overall, chemical finishes containing dimethylpolysiloxane silicone (S3), especially 0.5S3+F (C7), performed better in fabric abrasion resistance. The warp direction showed a much higher percentage breaking strength loss than the filling direction. This may be due to the fact that the warp yarn count was fewer than the filling count (see Table 1).

Correlation between abrasion resistance and instrumental hand measures: To determine the correlation between abrasion resistance and those Kawabata instrumental hand attributes and tensile breaking strength that showed significant differences by the chemical type, Pearson's correlation coefficient analysis was performed separately in warp and filling directions as shown in Table 5.

The breaking strength loss by abrasion related negatively to the coefficient of friction (MIU) and mean deviation of MIU (MMD) in the warp direction. These significant correlations implied that fabrics with lower surface frictional coefficient (slipperier) had a higher breaking strength loss by abrasion. In other words, the slipperier the fabric surface, the poorer in abrasion resistance. In the filling direction, however, no significant correlation was observed between abrasion resistance and any of the Kawabata hand attributes and tensile breaking strength.

Oil/Water repellence properties

Oil/water repellency tests were performed qualitatively

Table 5. Correlation coefficients between abrasion resistance and instrumental hand attributes

	Loss of breaking strength by abrasion (%)	
Instrumental hand attributes	Warp	Filling
Bending		
logB	0.11	0.02
log H5	-0.12	0.04
log H15	-0.07	-0.10
Surface		
MIU	-0.62**	-0.05
logMMD	-0.44*	0.23
Tensile		
Breaking Load	-0.26	-0.01

*Significant at 0.05 level.
**Significant at 0.01 level

Table 6. Results of oil/water repellency

Finishes	Oil Repellency rating	Water repellency rating
control Fabric		
C0	1	50
silicone Only		
C1	1	0
C2	1	0
C3	1	50
fluorochemical		
C4	7	100
0.5% Silicone + Fluorochemical		
C5	6	90
C6	6	100
C7	6	100
1.0% Silicone + Fluorochemical		
C8	6	100
C9	5	90
C10	5	100

under the guidance of AATCC test methods 118, Oil Repellency: Hydrocarbon Resistance Test, and AATCC 22, Water Repellency: Spray Test. The results are presented in Table 6.

The data on oil and water repellency tests showed similar results. The control fabric (C0) had poor oil/water repellency. This seemed to be due to the presence of hydrophobic but oleophilic polyester (60%) for the poor oil repellency and hydrophilic cotton (40%) for the poor water repellency in the fiber blend. The microfiber structure of polyester did not appear to help in oil/water repellency due to the larger surface areas of the microfibers.

The fluorochemical finish (C4) had the most significant improvement on oil/water repellency (Table 6). Oil/water repellency, however, did not differ significantly by the silicone-only finishes (C1, C2, C3). When mixed with the fluorochemical, silicone finishes showed improved oil/water repellency; among these finishes there were no significant differences although a small decrease of oil repellency was observed when compared with that of the fluorochemical treatment.

CONCLUSIONS

The abrasion resistance differed significantly by the chemical finishes in both warp and filling directions. The null hypothesis that finishing chemical type has no effect on fabric abrasion resistance was rejected. Chemical finishes containing dimethylpolysiloxane silicone performed better in fabric abrasion resistance than other chemicals. The warp direction showed a much higher percentage breaking strength loss by abrasion than the filling direction. This may be due to the fact that the warp yarn count was fewer than the filling count. The correlation between abrasion wear and instrumental measures of fabric hand indicated that the breaking strength loss by abrasion related negatively to the coefficient of friction and its mean deviation in the warp direction. This implied that the finished fabrics with lower surface frictional coefficient (slipperier) had higher breaking strength loss by abrasion. In other words, the slipperier the fabric surface, the poorer in abrasion resistance as measured in percentage breaking strength loss. In the filling direction, however, no significant correlation was observed.

The control fabric had poor oil/water repellency. This seemed to be due to the presence of hydrophobic but oleophilic polyester (60%) for the poor oil repellency and hydrophilic cotton (40%) for the poor water repellency in the fiber blend. The microfiber structure of polyester did not appear to help in oil/water repellency due to the larger surface areas of the microfibers. The fluorochemical finished fabric had the most significant improvement on oil/water repellency. Oil/water repellency of fluorochemical mixed finishes, however, did not differ significantly by the silicone-only finishes. When mixed with the fluorochemical, silicone finishes showed improved oil/water repellency to be able to reduce the hand value, the abrasion resistance and also cost.

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