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Instrumental Measurements of Hand Attributes on Microfiber Polyester/Cotton Blend Fabric Finished with Silicone Mixed Fluorochemical+

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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 fabric hand attributes. Fabric hand was evaluated by instrumental measures using Kawabata KES-F system instruments. Silicone-only finishes did not change the bending properties significantly from those of the control fabric. The fluorochemical-only finish made the fabric stiffer and crisper. When the two chemicals were mixed they tended to offset this adversary effect. Most of the chemical finishes made the surface finer and smoother. Fluorochemical-only finish improved fabric strength. Likewise, dimethylpolysiloxane silicone improved fabric strength. Amino -functional hydrophilic and diamino-functional silicone softeners, on the other hand, reduced fabric strength. However, when mixed with the fluorochemical, the adversary effect was diminished.

Key Words : Fabric Hands, Microfiber, Silicone Finish, Fluorochemical

I. Introduction

Microdenier yarns are generally made from fibers of less than 1 dpf(denier per filament). They are four times finer than wool, three times finer than cotton and more than twice as fine as the finest silk. 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.

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.

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Silicones have been used as finishes and textile processing aids for conventional fabrics and apparels for many years. Literature shows that silicone can greatly improve fabric hand[1)-6)]. Sabia demonstrated that silicone softener treatments enhanced softness and physical properties of 100% polyester microfiber fabrics[8)]. 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[9)-17)].

The general purpose of this study was to evaluate performance characteristics of a 60% polyester microfiber/40% cotton blend woven apparel fabric, finished with silicone softeners, a fluorochemical, and their mixtures. The specific objective was to examine the effects of finishing chemicals on fabric hand of the test fabric.

II. Experiments

1. Test fabrics

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.

2. Finishing Chemicals

Based on a preliminary study[1)], 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 (F) : 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.

3. 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 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

<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.

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

<Table 3> Fabric Hand Attributes Used in the Kawabata KES-F System.

Property	Parameters	Description	Unit	Apparatus
Bending	log B	Bending rigidity	$gfcm^2/cm$	KES-FB2
	log H.5	Hysteresis at 0.5 degree	$gfcm^2/cm$	
	log H1.5	Hysteresis at 1.5 degree	$gfcm^2/cm$	
Surface	MIU	Coefficient of friction	None	KES-FB4
	log MMD	Mean deviation of MIU	None	
	log SMD	Geometrical roughness	㎛	

under standard laboratory conditions, 21±1℃ and 65±2% RH for at least 24 hours before testing.

4. Instrumental Measurements of Hand Attributes

The Kawabata hand attributes[7] and tensile strength testings were conducted at the laboratory of the Department of Textile Products Design and Marketing at the University of North Carolina at Greensboro. All measurements were carried out at 21±1℃ and 65±2% RH standard laboratory conditions. Bending and surface/frictional properties were measured by a Kawabata KES-F system under the conditions of high sensitivity. The specimens were cut into 20×20 cm along both warp and filling directions and conditioned. One specimen for each chemical finish and control fabrics were tested. For each specimen, three different positions of both warp and filling directions were measured. Some of the KES values had been normalized for statistical analysis by taking their logarithm values as shown in Table 3.

The tensile breaking strength was measured by an Instron tensile tester interfaced with a computer according to the ASTM Standard Test Method D-5035, Breaking Force and Elongation of Textile Fabrics, Strip Method. For each finish type, three 6 x 2 inch specimens were cut along the warp direction and three for the filling to test the breaking strength. The gauge length was 3 inches and the Instron crosshead speed was 12 inch/min.

The maximum breaking strength was calculated by the interface computer and set at 500 lbs.

III. Results and Discussion

The results of measurements on the fabric performance characteristics, fabric hand were analyzed using appropriate statistical procedures to determine the effects of the ten different chemical finishes.

1. Instrumental measurements of hand attributes

The raw data of instrumental measurements of Kawabata hand attributes (see Table 3) and tensile strength by an Instron tensile tester are presented in Table 4 and Table 5. The hand attributes and tensile strength were measured and statistically analyzed separately for warp and filling directions. To determine if these hand attributes and tensile strength differed significantly by the chemical finishes,

<Table 4> Bending Properties of Fabric Specimens

Parameter Chemical	B(slope)		2H(HY.5)		2H(HY1.5)	
	Warp	Filling	Warp	Filling	Warp	Filling
Control	0.1147 0.1013 0.1110	0.0996 0.0984 0.0707	0.1634 0.1585 0.1502	0.1446 0.1356 0.1626	0.1438 0.1415 0.1361	0.1254 0.1203 0.1237
Silicone 1	0.1903 0.1186 0.1241	0.1789 0.1101 0.1045	0.1414 0.1106 0.1159	0.0982 0.1172 0.0926	0.1856 0.1185 0.1218	0.1677 0.0984 0.0908
Silicone 2	0.1974 0.2623 0.1797	0.1495 0.1384 0.1481	0.1757 0.1766 0.1350	0.1338 0.1167 0.1261	0.1798 0.2447 0.1635	0.1157 0.1069 0.1108
Silicone 3	0.1332 0.1159 0.1206	0.0960 0.1155 0.1064	0.1648 0.1349 0.1738	0.1249 0.1283 0.1152	0.1653 0.1457 0.1668	0.1327 0.1220 0.1103
Fluorochemical	0.2864 0.2713 0.1988	0.2186 0.2293 0.2191	0.3478 0.3165 0.2536	0.2519 0.2466 0.2340	0.3600 0.3469 0.2763	0.2550 0.2531 0.2499
0.5%S1+F	0.2714 0.3539 0.3154	0.2964 0.4383 0.3978	0.2862 0.3174 0.3033	0.2652 0.4348 0.3161	0.3161 0.3839 0.3371	0.2778 0.3455 0.3466
0.5%S2+F	0.2656 0.3989 0.2538	0.3272 0.3059 0.2844	0.2544 0.3140 0.1845	0.2335 0.2202 0.1890	0.2879 0.3022 0.2209	0.2994 0.2589 0.1940
0.5%S3+F	0.2145 0.2700 0.2511	0.2465 0.2460 0.2321	0.3041 0.3150 0.2709	0.2856 0.1987 0.2476	0.3095 0.3718 0.3413	0.2918 0.2469 0.2895
1.0%S1+F	0.1802 0.2350 0.2350	0.2290 0.2006 0.2006	0.2251 0.2099 0.2099	0.1696 0.1254 0.1254	0.2199 0.1908 0.1908	0.1862 0.1845 0.1157
1.0%S2+F	0.2476 0.4542 0.2501	0.3512 0.3414 0.2849	0.2203 0.4329 0.1868	0.2304 0.2427 0.2041	0.2335 0.2966 0.2132	0.2841 0.2744 0.2436
1.0%S3+F	0.1626 0.1462 0.1520	0.1648 0.1141 0.1403	0.2533 0.1856 0.1993	0.2726 0.1410 0.1577	0.2458 0.1813 0.2024	0.1606 0.1416 0.1567

an F-test of significance was performed as shown in Table 6.

There were significant differences ($p<0.01$) among the chemical finishes in Kawabata hand attributes and Instron tensile strength in both warp and filling directions, except for geometrical roughness (SMD) in both directions. The null hypothesis that finishing chemical type has no effect on fabric hand was therefore rejected. A multiple t-test of ANOVA was performed to determine between which two chemical finishes among the ten there was a significant difference in fabric hand. To accomplish this, the ten finishing chemical types (see Table 2) were divided into four groups as shown in Table 7.

<Table 5> Surface/Friction and Instron Tensile Properties of Fabric Specimens.

Parameter Chemical	MIU		MMD		SMD		Breaking load	
	Warp	Filling	Warp	Filling	Warp	Filling	Warp	Filling
Control	1.145	1.150	0.174	0.162	35.300	27.500	198.20	126.20
	1.145	1.135	0.160	0.164	29.800	26.951	188.20	142.50
	1.130	1.140	0.158	0.158	28.600	32.900	191.20	137.20
Silicone 1	0.962	0.902	0.136	0.159	26.400	30.550	162.70	125.70
	0.859	0.835	0.144	0.173	25.800	22.650	164.20	126.20
	0.854	0.855	0.120	0.160	29.350	23.350	157.50	122.50
Silicone 2	0.822	0.822	0.158	0.124	27.950	26.900	166.70	123.00
	0.797	0.820	0.147	0.146	26.100	29.150	152.20	123.20
	0.790	0.827	0.168	0.144	35.500	28.600	164.70	124.50
Silicone 3	0.940	0.174	1.008	0.144	37.150	26.100	180.50	140.50
	0.946	0.967	0.152	0.159	29.850	26.350	189.50	139.70
	0.977	1.041	0.165	0.163	34.500	25.800	177.00	136.70
FC-251	1.004	1.092	0.160	0.190	34.800	29.000	192.00	151.00
	0.942	1.110	0.226	0.239	35.050	26.450	184.00	151.00
	0.991	1.140	0.167	0.179	43.100	23.450	184.20	149.70
0.5%S1+F	1.054	1.016	0.202	0.188	38.250	26.900	175.50	137.20
	1.008	1.003	0.149	0.198	33.000	30.550	177.50	133.70
	1.037	0.981	0.191	0.191	35.800	29.700	174.70	139.20
0.5%S2+F	0.982	1.095	0.188	0.193	33.950	31.100	178.70	128.20
	1.064	1.083	0.200	0.191	34.400	30.650	176.70	128.50
	1.052	1.045	0.233	0.190	35.050	26.800	173.70	131.70
0.5%S3+F	1.120	1.100	0.222	0.188	38.450	28.800	182.20	151.50
	1.150	1.110	0.204	0.152	30.300	27.200	180.70	146.00
	1.095	1.044	0.175	0.146	35.050	27.900	187.50	150.70
1.0%S1+F	0.955	0.893	0.163	0.165	35.900	28.350	162.50	123.70
	0.913	0.925	0.151	0.194	29.050	26.450	173.70	130.70
	0.944	0.909	0.212	0.181	32.750	26.800	172.50	126.00
1.0%S2+F	1.035	0.989	0.197	0.193	39.050	33.000	173.00	129.50
	1.031	1.021	0.214	0.192	39.100	27.150	171.20	129.00
	1.033	1.032	0.218	0.195	40.100	35.100	165.20	124.70
1.0%S3+F	1.300	1.165	0.254	0.217	37.500	29.550	184.70	151.50
	1.145	1.160	0.213	0.215	32.850	34.750	184.00	144.20
	1.165	1.125	0.216	0.241	29.900	26.500	189.20	151.20

<Table 6> Statistical Results of Instrumental Measurements of Hand Attributes.

Parameters		Warp		Filling	
		F-value	p-value	F-value	p-value
Bending	log B	12.07*	.0001	32.32*	.0001
	log 2H.5	7.37*	.0001	13.07*	.0001
	log 2H1.5	15.65*	.0001	19.61*	.0001
Surface	MIU	27.08*	.0001	60.84*	.0001
	log MMD	3.17*	.0002	7.18*	.0001
	log SMD	6.72	.0015	1.45	.2221
Tensile	Breaking load	14.54*	.0001	25.43*	.0001

* Significant at 0.01 level

<Table 7> Finishing Chemical Groups and Their Symbols.

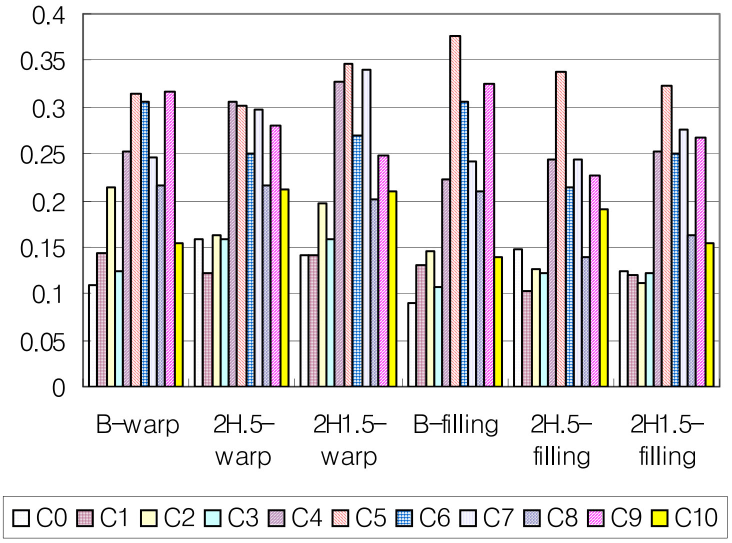
Chemical Group	Description	Symbol
Group 1	Silicone-only	S1 (C1), S2 (C2), S3 (C3)
Group 2	Fluorochemical-only	F (C4)
Group 3	0.5% Silicone + Fluorochemical mixtures	0.5S1+F (C5), 0.5S2+F (C6), 0.5S3+F (C7)
Group 4	1.0% Silicone + Fluorochemical mixtures	1.0S1+F (C8), 1.0S2+F (C9), 1.0S3+F (C10)

2. Bending Property

All bending parameters differed significantly by the chemical finishes (Table 6). Thus the null hypothesis was rejected in the bending property. Figure 1 illustrates the mean differences in both warp and filling directions among the chemical finishes for bending rigidity (B), and hysteresis of bending moment at both 0.5 degree (2H.5) and 1.5 degree (2H1.5). The control fabric (C0), silicone-only (C1, C2, C3) and 1.0%S+F group (C8, C9, C10) had relatively smaller means in all bending parameters. The fluorochemical (C4), silicone + fluorochemical mixtures - 0.5S1+F (C5), 0.5S2+F (C6), 0.5S3+F (C7), and 1.0S2+F (C9) –had higher means in most of the bending parameters.

In order to distinguish statistical significant differences among the chemical finishes,a multiple t-test of ANOVA was performed. The analysis showed that there was an agreement in bending rigidity (logB) between the warp and filling directions: the silicone-only finishes (C1, C2, C3) had lower values; 0.5S1+F (C5), 0.5S2+F (C6), 0.5S3+F (C7), and fluorochemical-only finish (C4) had higher values. The difference between these values was significant. These results implied that the fluorochemical imparted an adversary effect on bending rigidity–the fabric became stiffer. The finishes, 1.0S1+F (C8), 1.0S2+F (C9), and 1.0S3+F (C10), however, showed no significant differences from all other finishes.

Further, the comparisons of bending rigidity within each group of chemical finishes indicated



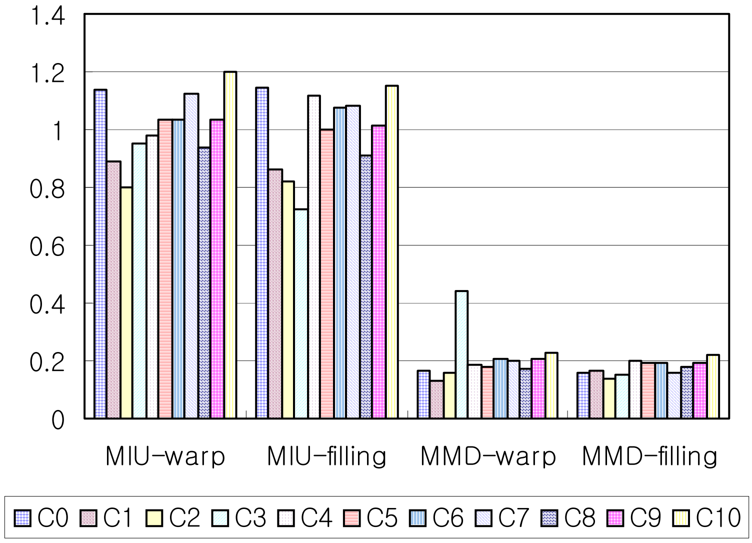
<Figure 1> Means of Instrumental Bending Attributes.

that finishes containing Silicone 2 (S2) generallyhad a higher logB value than S1 and S3, indicating that S2 made the fabric stiffer. The mixture 1.0S2+F (C9) differed significantly from 1.0S1+F (C8) and 1.0S3+F (C10) in the filling direction, and S2 (C2) differed significantly with S3 (C3) in the warp direction. However, the 0.5S+F mixtures (C5, C6, C7) showed no such difference; they all had relatively high values of logB. Finally, the mean logB values for the control fabric (C0) were the lowest in both warp and filling directions, but they were not significantly different from the silicone-only finishes (C1, C2, C3). Similar results were found in the other two bending parameters: hysteresis at 0.5 degree and hysteresis at 1.5 degree, in both warp and filling directions.

Overall, silicone softener finishes did not change the bending properties significantly from those of the control fabric. The fluorochemical -only finish (C4, Group 2 in Table 7) exhibited an adversary effect on fabric bending properties, making the fabric stiffer and crisper. However, 1.0% silicone-fluorochemical mixtures (Group 4 in Table 7) offset this adversary effect significantly: the microfiber fabric gained more pliable, soft, springy, and elastic hand. On the contrary, S2, a diamino -functional siloxane softener did not exhibit a promising performance in bending properties when used alone or in mixtures with the fluorochemical.

3. Surface Property

All Kawabata surface properties differed significantly by the chemical finishes ($p<0.01$), except geometrical roughness (SMD) inboth warp and filling directions (Table 6). The non -significant data in fabric surface roughness may be due to the fact that the control microfiber fabric seemed smooth enough and chemical finishes did not change it. Figure 2



<Figure 2> Means of Instrumental Surface Attributes.

shows the mean differencesof all significantly different parameters by the chemical finishes. In both directions, the means of coefficient of friction (MIU) were lower by most of the chemical finishes when compared with the control fabric. As in bending properties, the silicone-only finishes (Group 1 in Table 7) had relatively low mean values, that is, they provided the finished fabric with improved slipperiness and smoothness; the 0.5S2+F mixture (C6) was in the middle; 1.0S3+F (C10) had the highest values in both directions.

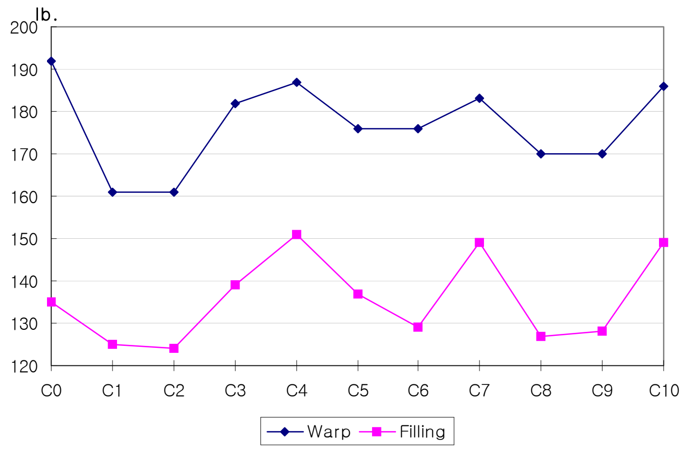
Significant difference between any two finishes was evaluated by the multiple t-test of ANOVA. All finishes improved coefficient of friction (MIU) significantly, except by 1.0S3+F (C10) in both directions and 0.5S3+F (C7) in the warp direction. SiliconesS1and S2, and the mixture 1.0S1+F (C8) had the best performances in MIU. They exhibited lower values, meaning that the finishes provided additional slipperiness and smoothness. The 0.5S+F mixtures (Group 3 in Table 7), except 0.5S3+F (C7) in the warp direction also were significantly different from the control fabric and showed lower values, though the level of significance was not as great as that of the silicone-only finishes. Within the silicone-only finishes (Group 1 in Table 7), S3 had the highest value and was significantly different from S1 and S2. Within Group 4, S3+F (C10) had the highest value and the three chemicals in the group differed significantly from each other. In Group 3, 0.5S1+F (C5) had the lowest value and differed significantly from the other two chemicals in the group. The same trends were observed for mean deviation of MIU (MMD), except that the mean value of the control fabric was lower than those of most chemicals in Group 3 and 4.

Overall, most of the chemical finishes did improve the surface property of the microfiber blend fabric significantly, and made the fabric surface finer and smoother. Specifically, S1 and S2 showed the best performances on fabric surface friction. The 1.0S1+F mixture (C8) was recommended for improvement in fabric surface properties. Dimethylpolysiloxane softener (S3) blended with Scotchgard™ FC-251 (F) did not improve fabric surface properties and even showed an adversary effect. The 0.5% silicone blended with fluorochemical (Group 3 chemicals) may also be used fabric hand since it can improve surface properties. The amino-functional hydrophilic silicone softener (S1) was recommended to blend with the fluorochemical.

4. Tensile Breaking Strength

The tensile breaking strength differed significantly ($p<0.01$) by chemical finishes in both warp and filling directions. Figure 3 shows mean comparisons of the tensile breaking strength. Chemicals S1, S2, 1.0S1+F (C8) and 1.0S2+F (C9) had the lowest breaking strengths. On the other hand, fluorochemical-only (C4) and finishes containing Silicone 3 – 0.5S3+F (C7), 1.0S3+F (C10), and S3 – had the highest mean values of breaking strength. These results suggested that Silicone 1 and Silicone 2 (see Table 2) showed an adversary effect on fabric breaking strength.

A multiple t-test of ANOVA showed that all finishes except fluorochemical-only (C4) andfinishes containing Silicone 3 reduced fabric breaking strength significantly in the warp direction, compared with that of the control fabric (C0). In the filling direction, fluorochemical finish (C4) and finishes containing Silicone 3 increased breakingstrength significantly. On the contrary, finishes containing Silicone 1 and Silicone 2 lowered breaking strength from that of the control fabric; however, the difference was not statistically significant. Fluorochemical-only (C4) and finishes containingSilicone 3 (C3, C7, C10) showed the highest values. S1 and S2 had the lowest breaking strengths and when blended



<Figure 3> Means of Tensile Breaking Strength.

with the fluorochemical the breaking strength did not increase significantly. However, when silicone wet pick up was reduced from 1.0% to 0.5% breaking strength started to increase.

Fluorochemical-only finish improved fabric strength significantly. Likewise, Silicone 3, dimethylpolysiloxane softener, improved fabric strength. Amino-functional hydrophilic (S1) and diamino-functional silicone softeners (S2), on the other hand, showed an adversary effect on fabric strength. However, when mixed with the fluorochemical, the adversary effect was reduced.

V. Conclusions

To the benefits of improved hand and comfort, lower cost and easy care, microfiber blend fabrics have been used largely in high-performance apparel and other apparel end uses. These beneficial characteristics of microfiber blend fabrics can be enhanced through chemical finishing. 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 selected. Ten chemicals - three different silicone softeners, one fluorochemical, and their mixtures -were applied to the fabric through a pad/bath method. Performance characteristics were examined by the change of fabric hand properties.

Fabric hand was evaluated by instrumental measures using Kawabata KES-F system instruments and by sensory judges. Six Kawabata hand attributes and tensile strength were measured for instrumental hand evaluation. For sensory hand eight expert judges evaluated the hand using an evaluation form of nine polar adjective pairs as semantic differential on an 11-point certainty scale. Abrasion resistance was measured using a Taber abrasion tester and abrasion wear was determined by loss in breaking strength using an Instron tensile tester. Oil/water repellency was tested according to AATCC Test Methods 22 and 112. Statistical analyses of ANOVA significance test and multiple t-test were performed to determine the effects of chemical finishes on fabric performance characteristics. Pearson's correlation coefficient was analyzed between abrasion resistance and instrumental hand measures.

Kawabata instrumental hand attributes and Instron tensile strength differed significantly by the chemical finishes in both warp and filling directions, except for geometrical roughness (SMD). The null hypothesis that finishing chemical type has no effect on fabric hand as measured by instruments was therefore rejected. Among the finishing chemicals, silicone finishes did not change the bending properties significantly from those of the control fabric. The fluorochemical-only finish exhibited an adversary effect on fabric bending properties, making the fabric stiffer and crisper. It seemed that when the two chemicals were mixed (1.0% silicone-fluorochemical mixtures) they tended to offset this adversary effect: the microfiber fabric gained more pliable, soft, springy, and elastic hand.

Most of the chemical finishes improved the surface property and made the fabric surface finer and smoother. The reason for non-significance of surface roughness may be due to the fact that the control microfiber fabric seemed smooth enough and thus chemical finishes did not change it. Fluorochemical -only finish improved fabric strength. Likewise, Silicone 3, dimethylpolysiloxane softener, improved fabric strength. Amino-functional hydrophilic and diamino-functional silicone softeners, on the other hand, reduced fabric strength. However, when mixed with the fluorochemical, they showed an improved fabric strength.

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References

1) Ahn Young-Moo, Li Bin and Kim Charles (2001), "Effects of Silicone Mixed Fluorochemical Finishes on Fabric Performance Characteristics of a Microfiber Polyester/Cotton Blend Fabric", *Journal of the Korean Society for Clothing Industry*, 3(5), 486-491
2) Kim Jong-Jun and Son Yang-Kug (2006), "Physical Properties of Ultra-fine Denier Filament Yarn Fabric", *Journal of Fashion Business*, 10(3), 23-30
3) Mun S. H., Kim Jong-Jun and Jeon Dong-Won (2003), "Application of the Multi-Focusing Composite Image for the Cotton Fiber Luster Analysis and Cotton Fabric Luster Analysis, *Journal of Fashion Business*, 7, 108-118
4) Kim Charles and Piromthamsiri K. (1984). "Sensory and physical hand properties of inherently flame-retardant sleepwear fabrics". *Textile Research Journal*, 54(1), 61-68.
5) Kim Charles, Hamouda H., Shalev I., and Barker R. L. (1993). "Instrumental methods for measuring the surface fictional properties of softener treated fabrics". *Textile Chemist and Colorist*, 25(8), 15-20.
6) Kim Charles, Winakor G., and Wolins L. (1980). "Fabric hand: tactile sensory assessment". *Textile Research Journal*, 50, 601-610
7) Kawabata S., and Niwa M. (1991). "Objective measurement of fabric mechanical property and quality: its application to textile and clothing manufacturing". *International Journal of Clothing Science and Technology*, 3(1), 7-18.
8) Sabia, A. J. (1995). "Modification of the tactile and physical properties of microfiber fabric blends with silicone polymers". *Textile Chemist and Colorist*, 27(9), 79-81.
9) Goldstein, H. B. (1993). "Mechanical and chemical finishing of microfiber fabrics". *Textile Chemist and Colorist*, 25 (2), 1621.
10) Isaccs, M. (1991). "Microdenier fibers create latest rage for apparel". *Textile World*, 142(3), 48-50.
11) Jerg, G., & Baumann, J. (1990). "Polyester microfibers: a new generation of fabrics". *Textile Chemist and Colorist*, 22 (12), 1214.
12) Lallam, A., Michalowska, J., Schacher, L., & Viallier, P. (1997). "Diffusion and adsorption of dye by polyester microfibers". *Journal of Society of Dyers & Colorist*, 113(3), 107-110.
13) Murata Machinery Ltd. (1994). "Murata: Spinning microfiber yarns on the MJS system". *Textile World*, 144(4), 42-48.

14) Nakamura, T., Ohwaki, S., & Shibusawa, T. (1995). "Dyeing properties of polyester microfibers". *Textile Research Journal*, 65(2), 113-118.
15) Partin, R. A. (1991). "Wet processing of polyester microfiber fabrics". *American Dyestuff Reporter*, 80(11), 4549.
16) Rozelle, W. N. (1993). "How to size microdenier yarns". *Textile World*, 143, 51-55.
17) Behera, B. K. (1995). "Microfibres – outlets and challenges". *Textile Asia*, 26(3), 36-38.

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