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Changes in Tensile Strength and Stiffness of Selected Durable Nonwoven Fabrics due to Abrasion and Laundering*

Charles J. Kim and Evelyn Hargett

Department of Textiles and Clothing, Iowa State University, U.S.A.

耐久性 不織布의 摩擦 및 洗濯에 의한 引張強度 및 剛軟度 變化

김 철 주·애브린 하게트

미국 아이오아 주립대학교 의류학과

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Abstract

This research explored the effects of abrasion, laundering, and abrasion/laundering interaction upon wear of 15 durable nonwoven fabrics. Wear was measured in terms of changes in tensile strength and stiffness. The test materials consisted of nine different dry-laid commercial interfacing fabrics of various fiber contents and six spunbonded poyester and polypropylene fabrics. Three fixed levels of abrasion and four fixed levels of laundering made up the 3×4 factorial analysis used for the experiment and the analysis of variance.

Findings revealed that abrasion had a greater effect than laundering on strength and stiffness of the tested fabrics. Laundering seemed related to the particular fibers used and to the fixation quality of fiber bonds. Spunbonded webs performed better than dry-laid webs in retaining tensile strength. Stiffness change occurred more readily than strength change. Lighter, flexible, stretchable fabrics seemed less easily abraded than heavier, stiff, less stretchable fabrics. The interfacing fabrics of 70/20/10% nylon/polyester/rayon blends with high crosswise stretchability effectively resisted wear caused by abrasion and laundering.

Further research is recommended to study the effects of longer abrasion periods and additional laundering cycles on wear qualities of nonwoven fabrics. Additional factors such as amount and fixation methods of bonding agents, the effect of shear distortion, seam construction, and drycleaning solvents could also be studied.

I. Introduction

A nonwoven fabric is defined as a flexible, porous, flat textile structure consisting of a web or mat of fibers held together by adhesive bonding, heat welding, mechanical entanglement, or any combination of these. Nonwovens are classified either as disposables or durables according to the anticipated duration of their usage. Durable nonwovens can be reused after cleaning, whereas disposable nonwovens are used once or twice and then discarded.

Forming a nonwoven structure involves selection of fibers, web formation, consolidation of

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the web, and finishing. Synthetic fibers of polyester, nylon, olefin, and acrylic are used to produce durable nonwovens because of their outstanding inherent properties such as strength, resiliency, and abrasion resistance[1]. The fiber plays an important role in durability of a nonwoven product; therefore, the required end use properties suggest the fiber used in the product[2].

Nonwoven fabric structures can be classified by their method of production, either the web formation method or the web consolidation method. Web formation methods include wet-laying(papermaking) and drylaying. Web consolidation methods include chemical bonding, heat welding, needle-punching, and felting. To consolidate the fiber webs, binders (bonding agents) are universally used. The type of binder and its application method also affect nonwoven fabric properties. Finally, a finish is applied which is consistent with the end use of the nonwoven product.

Most durable nonwovens are produced by spunbonding or dry-laying. Spunbonding is a method that combines the web formation and consolidation process. In the spunbonded process, bonding takes place as the molten fibers cross over one another and fuse as they are laid down on a moving conveyor in a random arrangement. Spunbonded fabrics are used for primary and secondary carpet backings, carpet underpads, upholstery underlays, bedspreads, mattress pads, and wall coverings. Dry-laid webs are formed by carding or air-laying and consolidated by chemical, thermal, or mechanical methods. In the carding process, fibers in the web can be arranged in a specific manner; however, air-laying produces a random web. Many of the nonwoven interfacing fabrics, wiping cloths, and limited-use apparel are produced by the dry-laid process[2].

Although disposable nonwovens are now more widely used, durable products are expected to show the largest growth[3] because consumers are now beginning to realize the many advantages of durable nonwovens. Despite their many advantages, nonwovens have not been used as ordinary apparel materials due to their inherent characteristics of poor strength, poor drape, and dimensional instability[4]. Research conducted to alleviate the disadvantages has been focused mainly on the industry level, because industry is the main user of nonwoves; however, nonwoven durable goods are steadily coming to the consumer market as well as the industrial sector[1].

In this research, wear properties of 15 durable nonwoven fabrics frequently used in apparel components, home furnishings, and other household items were examined. Wear of a nonwoven fabric is complicated and many factors contribute to the wearing process. However, it is not known exactly to what extent various physical characteristics of a nonwoven fabric are degraded due to wear, although a number of performance characteristics of nonwoven products have been studied[5]. For this study, wear of the nonwoven fabrics was measured in terms of changes in tensile strength and stiffness. Among factors that cause wear of durable nonwovens, mechanical abrasion and laundering were assumed to be the two most crucial.

Specific objectives of this research were to 1) measure tensile strength and stiffness as evidence of property changes caused by mechanical abrasion and laundering, 2) determine the effects of mechanical abrasion, laundering, and their interaction upon the changes in tensile strength and stiffness, and 3) relate the measured data to a suggested wear model of a nonwoven fabric.

Ⅱ. Experimental Procedure

1. Material

Durable nonwoven fabrics used in this investigation are described in Table 1. They were selected for the wide usage in their respective end use areas, and are mainly spunbonded and dry-laid webs consolidated by heat welding and by chemical binders, respectively.

Table 1. Physical properties of durable nonwoven fapric samples

Fabric sample	Fapric trade name	Fiper conten	Web construction method	Fabric weight (oz/yd²)
F 1	Typar	100% Polypropylene	Spunbonded, random	1.97
F 2	Typar	100% Polypropylene	Spunbonded, random	1.57
F 3	Reemay	100% Polyester	Spunbonded, random	0.57
F 4	Reemay	100% Polyester	Spunbonded, random	0.79
F 5	Reemay	100% Polyester	Spunbonded, random	1.04
F 6	Reemay	100% Polyester	Spunbonded, random	1.35
F 7	Interlon	75/25% Rayon/nylon	Dry-laid, random	2.78
F 8	Easy Shaper	70/20/10% Nylon/polyester/rayon	Dry-laid, parallel*	2.02
F 9	Add Shape	70/20/10% Nylon/polyester/rayon	Dry-laid, parallel	1.43
F 10	Interlon	75/25% Rayon/nylon	Dry-laid, random	1.86
F 11	Shape Flex	100% Rayon	Dry-laid, random	1.99
F 12	Interlon	100% Polyester	Dry-laid, random	2.29
F 13	Easy Shaper	70/20/10% Nylon/polyester/rayon	Dry-laid, parallel	1.48
F 14	Pellon	100% polyester	Dry-laid, random	1.29
F 15	Add Shape	70/20/10% Nylon/polyester/rayon	Dry-laid, parallel	1.18

*Parallel to the length direction

2. Experimental Design

A wear model is proposed for durable nonwovens:

Wear = Abrasion + Laundering + Abrasion/Laundering interaction

Wear is measured in terms of changes in tensile strength and stiffness at specific levels of abrasion and laundering. A statistical design of 3×4 factorial analysis[6] was used to conduct the experiment and the analysis of variance(ANOVA): three fixed levels of abrasion (0, 2, and 3 minute abrasion) and four fixed levels of laundering (0, 1, 5, and 10 washings). The experimental design can be expressed mathematically as follows:

$$X_{ijk}=\mu+(AB)_i+(LD)_j+(AB/LD)_{ij}+e_{(ij)k}$$

where

$i=1, 2, 3$; $j=1, 2, 3, 4$; $k=1, 2, \dots, 8$; and

X_{ijk} = value of the variable (tensile strength or stiffness)

μ = population mean

$(AB)_i$ = variance due to abrasion effect

$(LD)_j$ = variance due to laundering effect

$(AB/LD)_{ij}$ = variance due to abrasion/laundering interaction effect

$e_{(ij)k}$ = error effect in replications

3. Wearing Procedure

Wear of nonwoven fabrics was simulated by different levels of laboratory abrasion and laundering. Abrading was done according to AATCC Test Method 93—1978, using an Atlas Accelerotor. Four 1×6 inch specimens were crumpled in a random manner and placed inside the abrading chamber lined with a No. 250 abrasive liner. The rotor speed was maintained at 2,000 rpm for the 2 or 3 minute abrasion periods. In Accelerotor abrasion, a combination of flat, flex, and edge abrasion occurs, simulating actual wear and cleaning processes.

Laundering was per formed according to AATCC Test Method 135-1978[7] A home-model Speed Queen washer was used with wash-water temperature set at 41±3°C. Tumble drying followed at the normal temperature setting in a home-model Speed Queen dryer.

4. Testing Procedure

Tensile strength of the nonwoven samples was measured according to ASTM D11170-80[7], using a 1×6 inch cut-strip method with an Instron Tensile Tester at a 3 inch gauge length and a 12 inch/min crosshead speed. Fabric stiffness was measured by the bending length of a 1 inch wide specimen, according to ASTM D1388-64[8]. The slope of the bending length tester was set 41.5°. Data on tensile strength and bending length are the mean of tests along parallel and crosswise directions of the fabric.

Ⅲ. Results and Discussion

Data from each testing on tensile strength and bending length for each of the 15 nonwoven fabrics are shown in Table 2 and Table 3.

1. Hypotheses Stated

The following null hypotheses were set up according to the objectives of this research and tested against the mean values of fabric tensile strength and stiffness at different levels of wear:

1) $H_{01,04}$: Wear caused by Accelerotor abrasion has no effect on tensile strength or stiffness of the tested fabrics.

2) $H_{02,05}$: Wear caused by laundering has no effect on tensile strength or stiffness of the tested fabrics.

3) $_{03,06}$: Wear caused by abrasion/laundering interaction has no effect on tensile strength or stiffness of the tested fabrics.

2. Analysis of Wear Factors

Results of the ANOVA analyses for the 15 nonwoven fabrics are shown in Table 4.

2.1 Change in tensile strength

The null hypothesis that wear caused by Accelerotor abrasion had no effect on tensile strength of the fabrics was rejected at $p \leq .01$ level in fabrics F2, F7, F10, F11, and F12; and at $p \leq .05$ level in F1, F4, F6, and F14 (Table 4). The three fabrics with rayon fibers predominant (F7, 10, F11) were affected the most by abrasion (multimode), as would be expected. However, 100% polypropylene (F2, spunbonded) and 100% polyester (F12, drylaid) fabrics also showed significant ($p \leq .01$) reduction in tensile strength caused by abrasion. This suggested that factors other than fiber content were more important in relation to abrasion wear. The strength loss might be due to the abrading action on the bonding agent or melt seal. In F2, the random array of the fibers in the melt-spun web and the insufficient melt bonding, in addition to high fabric stiffness, seemed the cause of abrasion damage. F12, also a stiff, heavy fabric with dry-laid random fiber arrangements, was significantly affected by abrasion.

It is noteworthy that all four 70/20/10% nylon /polyester/rayon drylaid nonwovens (F8, F9, F13, F15) were among the six fabrics that were not affected significantly by abrasion Table 3 shows that these four fabrics had bending lengths (stiffness) in the range of 4. 18cm to 5.29cm, a lower level of stiffness for durable nonwoven fabrics, which ranges typically between 4 cm to 10 cm[9]. This suggested that flexible nonwovens are less likely to lose strength by abrasion[10]. also reported that fabrics possessing good abrasion resistance had a low value of bending moment or fabric stiffness.

Table 4 shows that abrasion affected tensile strength at the $p \leq .01$ level for proportionally fewer fabrics that had spunbonded web structures than dry-laid webs. It seemed that material characteristics such as fabric weight, strength, and stiffness were more closely associated with adrasion wear than fiber contents, because, in general, heavy (Table 1), strong (Table 2), and stiff (Table 3) fabrics (F2, F7, F10, F11, F12) among the 15 nonwovens tested in this research seemed to be more subject to abrasion.

Table 2. Mean vlues of tensile strength*

(unit: kg)

	Accelerotor abrasion											
Laundering	0 Minute				2 Minute				3 Minute			
0 Cycle	F 1	7.68	F 9	3.01	F 1	6.11	F 9	2.73	F 1	4.70	F 9	2.49
	F 2	6.70	F 10	4.46	F 2	4.50	F 10	2.69	F 2	3.50	F 10	2.09
	F 3	1.65	F 11	3.09	F 3	1.45	F 11	0.89	F 3	1.11	F 11	0.64
	F 4	2.20	F 12	5.44	F 4	1.75	F 12	5.19	F 4	1.36	F 12	3.95
	F 5	2.49	F 13	2.43	F 5	2.91	F 13	2.30	F 5	2.63	F 13	2.03
	F 6	4.46	F 14	1.79	F 6	3.53	F 14	1.66	F 6	2.79	F 14	1.53
	F 7	5.56	F 15	2.56	F 7	4.98	F 15	2.40	F 7	3.48	F 15	2.16
	F 8	5.05			F 8	3.39			F 8	3.16		
1 Cycle	F 1	8.28	F 9	3.19	F 1	5.79	F 9	2.76	F 1	6.54	F 9	2.70
	F 2	5.99	F 10	4.71	F 2	5.04	F 10	2.49	F 2	2.71	F 10	2.19
	F 3	1.79	F 11	3.08	F 3	1.54	F 11	1.30	F 3	1.58	F 11	0.61
	F 4	2.04	F 12	6.21	F 4	1.63	F 12	4.10	F 4	1.65	F 12	3.31
	F 5	2.76	F 13	2.61	F 5	2.74	F 13	2.18	F 5	2.80	F 13	2.00
	F 6	2.71	F 14	2.13	F 6	2.78	F 14	1.50	F 6	2.51	F 14	1.39
	F 7	5.13	F 15	2.71	F 7	3.44	F 15	2.14	F 7	2.93	F 15	2.04
	F 8	4.65			F 8	3.03			F 8	3.41		
5 Cycle	F 1	5.99	F 9	2.73	F 1	5.73	F 9	2.50	F 1	6.91	F 9	2.34
	F 2	4.50	F 10	2.69	F 2	3.83	F 10	2.11	F 2	3.10	F 10	1.69
	F 3	1.45	F 11	0.89	F 3	1.50	F 11	1.31	F 3	1.38	F 11	0.95
	F 4	1.75	F 12	5.19	F 4	1.64	F 12	4.04	F 4	1.64	F 12	3.15
	F 5	2.91	F 13	2.30	F 5	2.79	F 13	2.09	F 5	2.58	F 13	1.88
	F 6	3.53	F 14	1.66	F 6	3.15	F 14	1.69	F 6	2.60	F 14	1.40
	F 7	4.98	F 15	2.40	F 7	3.31	F 15	2.20	F 7	2.25	F 15	2.03
	F 8	3.39			F 8	3.69			F 8	3.06		
10 Cycle	F 1	8.21	F 9	2.78	F 1	5.43	F 9	2.53	F 1	5.89	F 9	2.56
	F 2	5.48	F 10	4.26	F 2	4.84	F 10	2.18	F 2	3.40	F 10	2.41
	F 3	1.55	F 11	2.56	F 3	1.38	F 11	1.25	F 3	1.58	F 11	1.11
	F 4	1.90	F 12	5.19	F 4	1.55	F 12	3.95	F 4	1.79	F 12	3.63
	F 5	2.76	F 13	2.60	F 5	2.83	F 13	2.15	F 5	2.30	F 13	2.11
	F 6	2.83	F 14	2.06	F 6	2.84	F 14	1.70	F 6	2.43	F 14	1.48
	F 7	5.55	F 15	2.14	F 7	3.01	F 15	2.05	F 7	2.55	F 15	2.25
	F 8	3.71			F 8	3.81			F 8	3.10		

* Mean of lengthwise and crosswise data

Table 3. Mean values of bending length (stiffness)*

(Unit: cm)

Laundering	Accelerotor abrasion: 0 Minute				2 Minute				3 Minute			
0 Cycle	F1	11.03	F9	5.00	F1	7.26	F9	5.65	F1	5.96	F9	4.59
	F2	10.19	F10	9.90	F2	6.15	F10	7.16	F2	5.74	F10	6.06
	F3	7.58	F11	6.26	F3	5.69	F11	5.40	F3	4.51	F11	4.25
	F4	7.93	F12	9.91	F4	5.75	F12	8.71	F4	4.35	F12	5.23
	F5	10.46	F13	4.18	F5	6.18	F13	4.56	F5	5.44	F13	3.95
	F6	10.45	F14	5.10	F6	6.38	F14	4.84	F6	5.41	F14	3.98
	F7	11.16	F15	4.65	F7	9.76	F15	5.48	F7	7.16	F15	4.48
	F8	5.29			F8	5.54			F8	4.66		
1 Cycle	F1	8.61	F9	5.51	F1	5.84	F9	4.26	F1	9.03	F9	5.13
	F2	8.48	F10	6.94	F2	4.66	F10	5.04	F2	7.00	F10	5.71
	F3	6.80	F11	5.98	F3	5.01	F11	4.59	F3	5.15	F11	4.53
	F4	6.73	F12	9.16	F4	5.50	F12	6.10	F4	5.40	F12	5.55
	F5	7.91	F13	4.93	F5	6.11	F13	3.66	F5	6.08	F13	4.68
	F6	7.45	F14	4.99	F6	5.28	F14	3.99	F6	5.99	F14	4.08
	F7	7.43	F15	5.53	F7	5.45	F15	3.94	F7	5.81	F15	5.05
	F8	6.16			F8	4.88			F8	5.33		
5 Cycle	F1	6.42	F9	5.56	F1	5.70	F9	4.85	F1	7.59	F9	4.98
	F2	6.56	F10	6.09	F2	5.69	F10	5.03	F2	5.43	F10	5.13
	F3	5.35	F11	5.63	F3	5.31	F11	4.93	F3	5.19	F11	4.94
	F4	5.83	F12	8.39	F4	5.15	F12	6.03	F4	5.13	F12	5.20
	F5	6.43	F13	5.01	F5	5.61	F13	4.79	F5	5.53	F13	4.53
	F6	6.59	F14	4.54	F6	5.80	F14	4.31	F6	5.56	F14	4.26
	F7	7.18	F15	5.18	F7	5.93	F15	5.01	F7	5.33	F15	4.93
	F8	6.04			F8	5.45			F8	5.40		
10 Cycle	F1	5.49	F9	5.19	F1	5.76	F9	4.65	F1	5.41	F9	4.51
	F2	5.70	F10	5.31	F2	5.83	F10	4.66	F2	4.65	F10	4.08
	F3	5.25	F11	5.29	F3	5.18	F11	5.20	F3	4.20	F11	4.26
	F4	5.71	F12	6.01	F4	5.04	F12	5.36	F4	4.53	F12	5.08
	F5	5.25	F13	4.00	F5	5.26	F13	4.50	F5	4.50	F13	4.14
	F6	5.28	F14	4.34	F6	5.18	F14	3.88	F6	4.53	F14	2.98
	F7	6.40	F15	4.00	F7	5.33	F15	4.69	F7	5.10	F15	3.61
	F8	5.65			F8	4.88			F8	4.81		

* Mean of lengthwise and crosswise data

Table 4. ANOVA results on the effects of abrasion, laundering, and abrasion/laundering interaction

Fabric sample	Tensile strength			Bending length		
	H_{01} $(AB)_i=0$	H_{02} $(LD)_j=0$	H_{03} $(AB/LD)_{ij}=0$	H_{04} $(AB)_i=0$	H_{05} $(LD)_j=0$	H_{06} $(AB/LD)_{ij}=0$
F 1	.0294*	.8181	.5063	.0001**	.0001**	.000**
F 2	.0001**	.1679	.5542	.0001**	.0001**	.0001**
F 3	.2278	.3687	.6001	.0001**	.0008**	.0004**
F 4	.0184*	.9231	.5044	.0001**	.0026**	.0017**
F 5	.5233	.9305	.8967	.0001**	.0001**	.0001**
F 6	.0132*	.0114*	.5735	.0001**	.0001**	.0007**
F 7	.0001	.0014**	.2471	.0001**	.0001**	.0133*
F 8	.5662	.9579	.9579	.2547	.7535	.9471
F 9	.7744	.9533	.9999	.5889	.8971	.7268
F10	.0001**	.0001**	.0001**	.0001**	.0001**	.0026**
F11	.0001**	.0001**	.0001**	.0001**	.2973	.0346*
F12	.0001**	.0015**	.0042**	.0001**	.0001**	.0001**
F13	.5774	.9805	.9997	.8173	.5646	.5250
F14	.0258*	.8738	.8626	.0001**	.0001**	.0001**
F15	.7747	.9779	.9977	.6435	.1181	.1976

* Reject the null hypothesis at $p \leq .05$
** Reject the null hypothesis at $p \leq .01$

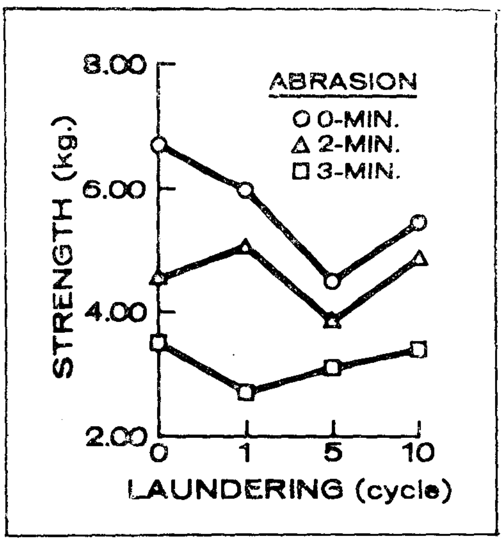

Fig. 1. Significant effect of Accelerotor abrasion on tensile strength of Fabric 2 (F 2)

Figure 1 shows the significant effect of abrasion in F2 by the three separate curves at different levels of abrasion. Laundering and abrasion/laundering interaction effects were not significant as shown by the varying slopes of the curves at different laundering cycles and the lack of crossover of curves that would show any definite interaction effect.

The second null hypothesis that wear caused by laundering had no effect on tensile strength was rejected at $p \leq .01$ for F7, F10, F11, and F12, and at $p \leq .05$ for F6 (Table 4). These five fabrics were also the ones that were affected by abrasion at the same significance levels. The number of fabrics significantly affected in tensile strength by laundering was fewer than in the case of abrasion; this and data in Table 2 suggested that laundering was a less severe cause of strength loss than abrasion.

Again, the three predominantly rayon-fiber fabrics (F7, F10, F11) were weakened the most by laundering, because rayon loses strength readily as it absorbs water and swells. Even after drying, the slipped molecules may not rearrange to take the stress. The other two affected fabrics were

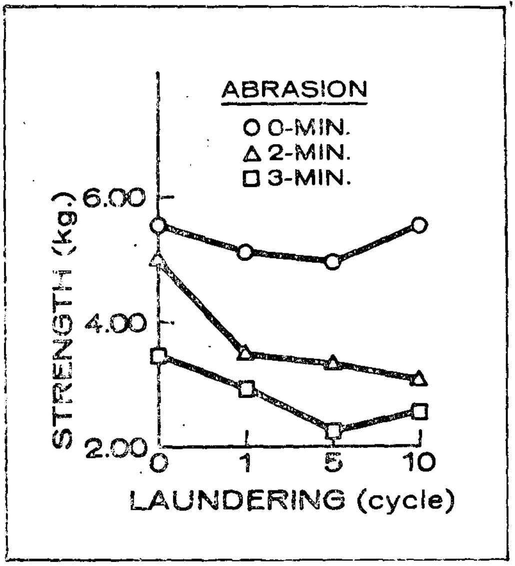

Fig. 2. Significant effects of Accelerotor abrasion and laundering on tensile strength of Fabric 7 (F 7)

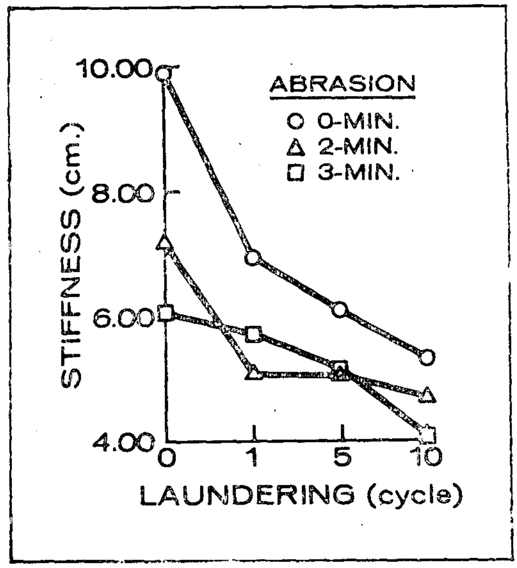

Fig. 3. Significant effects of Accelerotor abrasion, laundering, and abrasion/laundering interaction on stiffness of Fabric 10 (F 10)

F12 (100% polyester, dry-laid) at $p \leq .01$ and F6 (100% polyester, spunbonded) at $p \leq .05$. Strength loss in F12 might be caused by degradation of chemical bonding agents in laundering, as hydrophobic polyester fibers were unlikely to lose strength in laundering. The 100% polypropylene-fiber fabrics were not significantly affected by laundering, as would be expected from the hydrophobic nature of the fiber. All four fabrics (F7, F10, F11, F12) affected by laundering at $p \leq .01$ were dry-laid webs (Table 1); the only spunbonded web affected was F6 (100% polyester), but at $p \leq .05$. This led to the conclusion that web construction method affected tensile strength in both abrasion and laundering wear, since spunbonded webs performed far better than dry-laid webs (Table 2, 4).

The abrasion/laundering interaction effect on tensile strength was seen only in three fabrics (F10, F11, F12) at $p \leq .01$ (Table 4). These three were the only fabrics that were affected significantly at $p \leq .01$ level by all three factors of abrasion, laundering, and abrasion/laundering interaction among the 15 nonwoven samples. Fabrics F10 and F11 were basically rayon fabrics; F12, 100% polyster, was a heavy, strong, and stiff fabric (Tables 1, 2, 3). None of the spunbonded nonwovens was significantly affected by the abrasion/laundering interaction.

In Figure 2, the three separate curves with generally descending slopes toward the positive abscissa show the significant effects of abrasion and laundering in F7; the lack of crossing of the curves denotes the nonsignificant effect of the abrasion/laundering interaction.

2.2. Change in stiffness

Effects of abrasion, launbering, and abrasion/laundering interaction on the loss of fabric stiffness are shown in the last three columns of Table 4. Stiffness loss by abrasion was significant ($p \leq .01$) in all fabrics except F8, F9, F13, and F15. These four fabrics were 70/20/10% nylon/polyester/rayon dry-laid nonwovens. These and F11 were also the fabrics that did not change significantly in stiffness when laundered. The abrasion/laundering interaction had more significant associations with stiffness than with strength of the fabrics. The interaction effect on bending length was similar to both abrasion and laundering effects. As was the case in strength change, the four three-fiber-blend fabrics showed exceptional durability to abrasion and laundering.

Table 4 shows that more fabrics were affected significantly by abrasion, laundering, abrasion/laundering interaction effects in terms of stiffness loss, as compared with tensile strength loss. This demonstrated that the durable nonwovens tested were more prone to stiffness change by the wear factors studied than to strength change. The implication from stiffness loss is that performance as a stabilizing fabric to preserve shape for garment construction might be reduced as abrasion is incearsed in use or in renovation processes.

Unexpectedly, stiffness of F11(100% rayon, dry-laid, fusible interfacing) was not significantly affected by laundering, although stiffness was significantly ($p \leq .01$) affected by abrasion (Table 4). To make a nonwoven fusible, a chemical adhesive, which works as a glue after being melted by heat, is applied in addition to the chemical bonding agent to consolidate the fiber web. Addition of this extra glue material increases fabric stiffness. Residual glue on the surface of the fabric washes off quite easily in the laundering processes. However, in F11, as abrasion removed the fusible material, laundering did not play a significant role in changing stiffness in the abraded fabric. The other two fusibles were F8 and F13, the durable three-fiber-blend fabrics. Figure 3 shows the significant effects of abrasion, laundering, and abrasion/laundering interaction on bending length of F10.

Ⅳ. Conclusions and Recommendations

Strength of durable nonwovens tested in this study was affected more by mechanical abrasion than by laundering. Nonwovens are more easily damaged by abrasion than woven or knitted fabrics. In woven or knitted fabrics in which yarns form the grain in the fabric, the abrading force may deteriorate surface fibers in the yarn; however, if the severity of abrasion force does not reach the point where the yarn structure is totally disassembled, the fabric retains much of its strength even after some abrasion. Due to the lack of a yarn assembly, however, nonwovens reach the critical point of fabric disintegration much more readily and this results in decreased tensile strength. Also, the bonding agents includingthe heat seals hold the fibers more rigidly in nonwoven fabrics and the fibers, therefore, abrade with the abrading force rather than move to alleviate the abrading force.

Spunbonded webs performed better than dry-laid webs in retaining tensile strength from wear by abrasion and laundering. The predominantly rayon-fiber fabrics succumbed to abrasion and laundering wear and resulted in loss of tensile strength. Effects of laundering seemed related to the particular generic fibers used in the fabric and to the web-construction method.

Nonwoven fabrics showed greater change in stiffness than in strength as a result of abrasion and laundering (Table 4). Fortunately, stiffness loss is a less severe problem than strength loss in most end uses for durable nonwovens; however, the loss of stiffness can result in undesirable shape distortion when nonwovens are used as interfacings and interlinings.

The 70/20/10% nylon/polyester/rayon fabrics with crosswise stretchability performed the best in resisting wear by abrasion and laundering. Strong, abrasion resistant nylon fibers blended with resilient, hydrophobic polyester, and a small amount of absorbent, flexible rayon appeared to resist both the abrasion and laundering actions satisfactorily. Also, flexible, thinner fabrics with higher elongation seemed less easily abraded than thicker, stiffer, and less stretchable fabrics.

As consumers begin to understand the merits of using durable nonwovens in many end uses, the nonwoven market will certainly expand considerably in coming years. Together with the increased use of nonwovens, many consumer problems will also arise. Because wear-related problems are more important in consumer uses of durable nonwovens, a more complete range of abrasion periods and laundering cycles is suggested for study so that broader generalizations can be made with respect to the wear problems. Additional factors such as amount and fixation methods of bonding agents, the effect of shear distortion, seam construction, and drycleaning solvents could also be studied on wear qualities of nonwoven fabrics.

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