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The Mechanical Properties and Abrasion Behavior of Warp Knitted Fabrics for Footwear

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Abstract: The abrasion behavior of three kinds of warp knitted fabrics, which are normally used for upper sole of footwear, was evaluated. We measured the changes of mechanical and structural properties of each sample as abrasion cycle increased. Each sample showed similar trends in compression and surface properties but there were significant differences in abrasion rate among the samples. The mechanical properties showed remarkable differences with directions. The frictional coefficient (MIU) of fabric surface increased at the beginning of abrasion and decreased as abrasion cycles increased. The weight and thickness of the fabric linearly decreased with abrasion cycles. The surface roughness (SMD) and the compressional resilience (RC) decreased as abrasion cycles increased while compressional energy (WC) increased.

Keywords: Warp knitted fabric, Surface property, Compression property, Tensile property, Abrasion behavior

Introduction

Warp knitted fabrics are widely used for footwear industry because of their numerous advantages such as excellent moisture permeability, air permeability, attractive shoes appearance and appropriateness for foot. This also means that the shoes made of warp knitted fabrics can maintain comfort condition of foot while wearer moves dynamically.

Compared with other types of knitted fabrics, warp knitted fabrics tend to be less resilient and lighter in weight. They have low formability and dimensional stability with freedom of threads composing loops. By controlling the knitting stitch, stability in both directions of wale and course can be obtained. It is, however, very important that these properties stand in long use. Especially, the circumstance where the footwear is being used is very severe. That is why the testing standards of the warp knitted fabric for footwear are even stricter than those of garments.

Earlier studies have shown the abrasion resistance between yarns inside cloth. And they reported that the pilling property of fabric was mainly affected by the mechanical property of the yarn composition [1,2]. Using the Martindale abrasion tester, Manich reported that the abrasion kinetics was identified by the sharpness of the weight loss curve versus abrasion cycles up to yarn breakage [3,4]. Ramkumar examined the influence of structural variables on the frictional properties of knitted cotton fabrics. Both the loop length and the yarn linear density influenced the fabric frictional properties [5]. Also, there were various researches on corona treatment, solvents treatment and so on, to improve the abrasion resistance of fabric [6-10]. It is thought that the factors which affect on the abrasion property are the surface features of fabric, the crossover region to be wear, thread count, chemical and physical characteristics of fabric, construction of fabric, weight, processing condition, the material of abradant and the environmental conditions and so on. Abrasion behavior is an important property of textile materials that governs the quality and efficiency of processing and the performance of products. Although many researches were done, it is still considered to be one of the most complex, least understood, and least controllable properties [11]. Most researches are related to the fabrics for garment. So, the reports have limitation to analyzing the warp knitted fabric for footwear.

In this study, we measured abrasion behavior of three types of warp knitted fabrics which are normally used for producing footwear. Specimens have differences in yarn composition, construction and density.

Experimental

Materials

The specimens used in this study were several kinds of warp knitted fabrics in common use for footwear, and three kinds of the specimens were selected to compare with the mechanical and abrasion properties. The specifications of the specimens are shown in Table 1.

Abrasion Property

Abrasion property was measured according to BS-5690 using Martindale abrasion tester [12], which is designed to give a controlled amount of abrasion between specimens surface and abradant in continuously changing directions. To fit the wearing condition of footwear, we used sand paper for abradant. The abradant used in this test was 320 J grit sandpaper of Nike standard, and the specimens were abraded under the pressure of 12 kpa. The abrading was continued until a hole was occurred, and it was investigated at suitable intervals until a predetermined end-point.

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Table 1. Physical characteristics of the warp knitted fabrics for footwear

Sample	Characteristics					
	Gauge/ Bar	Weight (kg/m^2)	Thickness (mm)	Stitch density		Yarn composition (%)	
				W.P.I.[a)]	C.P.I.[b)]		
A Tricot	28/4	86	0.47	30.5	37.8	Bar1: PET 75/36 SD[c)] Bar2: PET 75/36 BRTR[d)] Bar3: PET 150/48 SD Bar4: PET 150/48 SD	22.0 % 42.8 % 17.6 % 17.6 %
B Tricot	28/2	82	0.53	8.0	14.2	Bar1: PET 75/36 SD Bar2: PET TEX[e)] 50/48 SD	28.1 % 71.9 %
C Tricot	20/4	177	0.94	7.1	8.7	Bar1-4: PET 250/48 SD	100 %

[a)]W.P.I.: wale per inch, [b)]C.P.I.: course per inch, [c)]SD: semi dull yarn, [d)]BRTR: bright triangle yarn, [e)]TEX: textured yarn.

Mechanical Properties

Compression and surface properties were measured by KES-FB system to examine the changes with abrasion cycles.

Tensile strength was measured according to KS K 0521 using the DW-5 Instron tester (Kyungsung Testing Machine, Korea). This test was performed with full scale load of 200 kgf, test speed of 50 mm/min, and the sample size of 7.6 cm x 2.5 cm.

Surface morphologies were observed using the Optical Microscope (Sometech, Mirero Inc.) to examine the changes with knitting structures and abrasion cycles.

Results and Discussion

The abrading with different knitting structure, knitting density, yarn composition was carried out until a hole was occurred by using the abradant. Three samples with change in abrasion cycles were selected and divided with suitable interval of abrasion cycles. Several kinds of warp knitted fabrics for footwear were selected to investigate the compression property, surface property, and tensile property with abrasion cycles.

Table 2. Weight loss and thickness of the sample with abrasion cycles

Specimens	Abrasion cycles	Weight loss (%)	Thickness (mm)
Sample A	0	0	0.47
	100	0.058	0.45
	200	0.105	0.42
	300	0.163	0.41
	400	0.221	0.38
	500	0.256	0.36
Sample B	0	0	0.53
	2 000	0.184	0.52
	4 000	0.343	0.49
	6 000	0.649	0.46
	8 000	0.991	0.45
	10 000	1.102	0.43
Sample C	0	0	0.94
	1 000	0.955	0.90
	2 000	2.282	0.87
	3 000	3.378	0.80
	4 000	4.299	0.75
	5 000	4.874	0.73

Changes on Weight and Thickness

Table 2 shows the results that weight loss increases and thickness decreases with abrasion. It was due to the fact that pilling was removed after the abrasion test in the initial stages of abrasion, which resulted in a weight loss. Abrasion cycles until the first hole was occurred were different with the samples because of fabric specifications. Especially, abrasion cycle of sample B was about 20 times as much as that of sample A. Since knitting density of sample A was higher than that of sample B, there were many crossover regions on surface, so much more portion of the specimen was exposed and abraded. Therefore, pilling formation was fast and there were many pills. Sample B had less capacity of pills, because loop structure of knitting was weak. On the other hands, the slippage of loop crossover region was happened, so sample B was relatively loose. Comparing sample B with C on fixed abrasion cycles (4000 cycles), weight loss of sample C was twelve times as much as that of sample B, because sample C was weaved by coarse yarns. Sample C was stiff, and a lot of crossover region of sample surface was exposed to abradant, so there was a lot of weight loss with abrasion cycles.

Surface Properties

The results of MIU, which is the frictional coefficient of specimens surface, are shown according to abrasion cycles by logarithms scale in Figure 1. MIU increased in initial stage, and then progressively decreased with abrasion cycles. Also, MIU of sample A was lower than those of sample B and C.

Figure 2 is the photographs of the sample surface with abrasion cycles of sample A. The photographs show that the

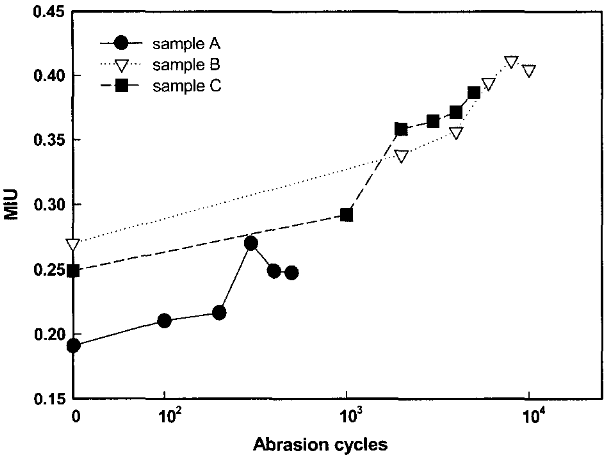

Figure 1. Frictional coefficient (MIU) with abrasion cycles.

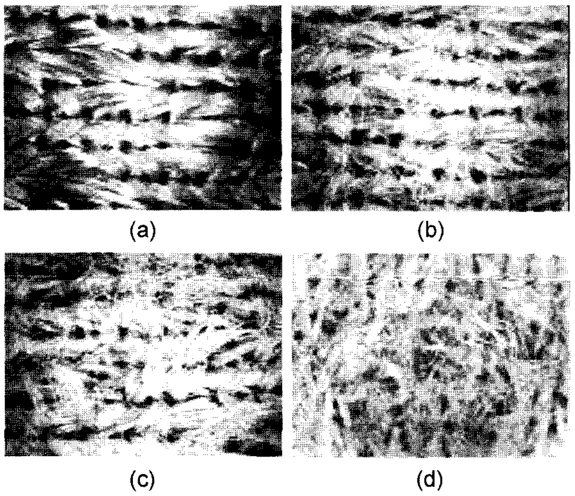

Figure 2. Surface photographs of the sample A with abrasion cycles obtained by optical microscope: (a) before abrasion, (b) 200 cycles, (c) 400 cycles, (d) 500 cycles.

filament yarns of surface loops are cut according to abrasion progress. Sample surface on initial stage became rough, and it was gradually smooth with abrasion. So it is thought that MIU decreases, and there are not significant changes between wale and course directions. The frictional coefficient of sample A was smaller than those of sample B and C, because sample surface was smooth with knitting arrangement, and yarn was equally arranged with coarse and fine yarn.

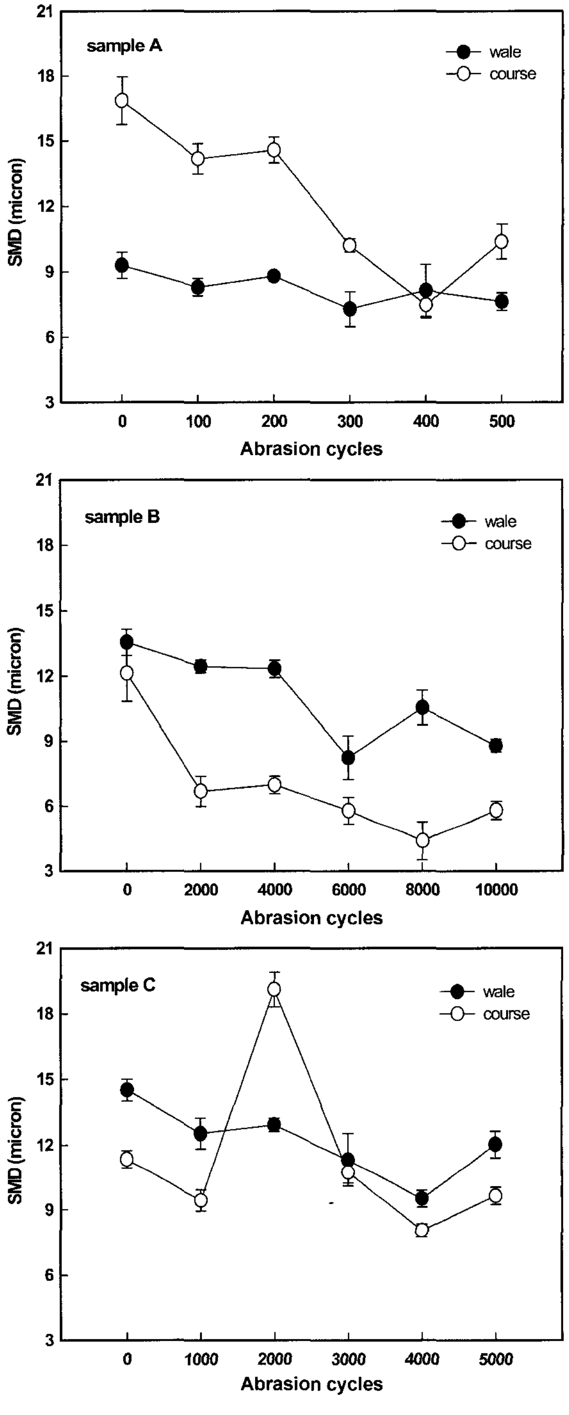

Figure 3. Surface roughness (SMD) with abrasion cycles.

Figure 3 shows surface roughness (SMD) according to abrasion cycles. SMD gradually decreases with abrasion cycles. It is thought that sample surface becomes smooth because surface loop filaments are eliminated according to abrasion behavior. SMD shows significant change between wale and course directions of the sample, because of thickness and loop height of the sample. In the case of sample A, the decrease of SMD was little in wale direction with abrasion cycles. On the contrary, decrease of SMD was great in course direction with abrasion cycles. The reason is due to the location of two kinds of guide bar 3 and 4 with coarse yarn in the course direction. The geometrical constructions of sample A, B, and C are shown in Figure 4. Also, sample B and C show similar trends, and there are significant

Sample A

BAR	Arrangement	Chain notation
1	Solid	10 12
2	Solid	45 10
3	2XXXX2XXXX[a]	10 12 23 21
4	XX2XXXX2XX	21 10 12 23

[a] X: unthreaded in partly threaded bar

Sample B

BAR	Arrangement	Chain notation
1	Solid	10 12
2	Solid	10 23

Sample C

BAR	Arrangement	Chain notation
1	1X	10 23
2	X1	23 10
3	1X	00 44
4	Solid	10 01

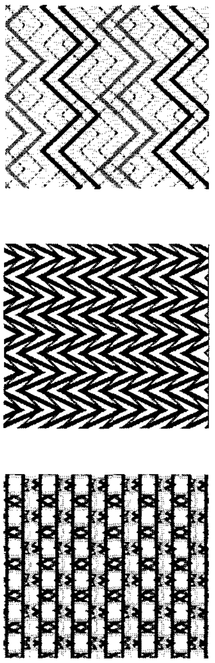

Figure 4. Geometrical construction of warp knitted fabrics.

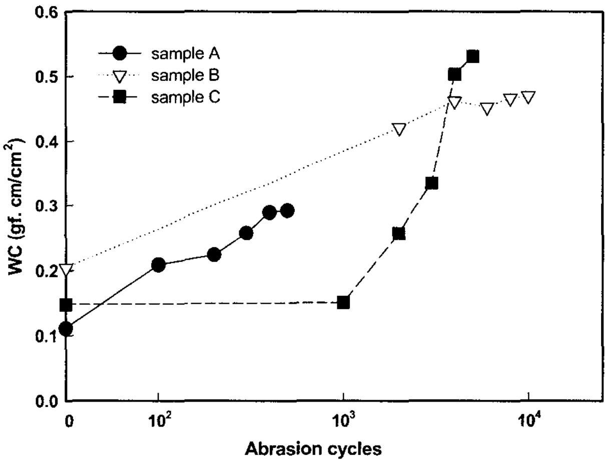

Figure 5. Compressional energy (WC) with abrasion cycles.

differences between wale and course directions according to thickness and arrangement of yarn composition.

Compression and Tensile Properties

The changes of compressional energy (WC) and compressional resilience (RC) with abrasion cycles are shown in Figures 5 and 6. WC gradually increased as abrasion cycles increased. Since the filament yarns of surface loops were cut with abrasion cycles, the thickness became thin, and fabric structure became irregular and rough. So WC increased.

RC gradually decreased with abrasion cycles. Because the thickness became thin with abrasion cycles, compressional elasticity got worse. RC has some relation with thickness and stitch density. Compared sample A with B, RC of sample A was about 10 % higher than that of sample B. Since the thickness of sample A and B were similar, and stitch density of sample A was much higher than that of sample B, RC of sample A was high.

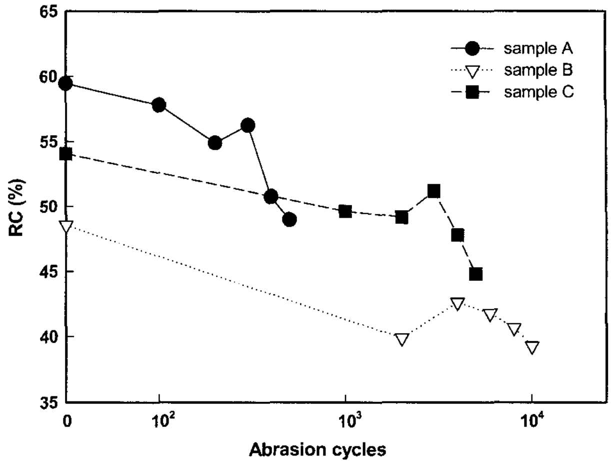

Figure 6. Compressional resilience (RC) with abrasion cycles.

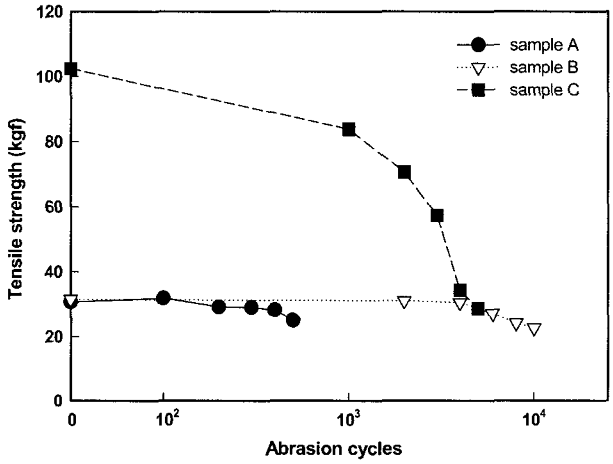

Figure 7. Maximum load of tensile strength with abrasion cycles.

Figure 7 shows tensile strength with abrasion cycles. Tensile strength decreased with abrasion cycles. Compared sample A with B, tensile strength decreased a little with abrasion cycles when the hole was occurred. And there were many tight crossover regions of fabric structures, so surface area of abrading was wide. On the other hands, the knitting density of sample B was low, so fabric structure was more loose and slipped inside loops. Therefore, abrasion resistance was improved. The sample C was knitted with coarse yarn, and guide bar 3 and 4 were densely arrayed in a line of knitting loop, so crossover regions in knitting structure were more wide than those of other samples. The weight loss of sample

C was more than those of other samples with abrasion cycles, so its tensile strength also decreased.

Conclusions

In this study, we investigated the mechanical properties of warp knitted fabrics for footwear which had differences in knitting structure, knitting density and yarn composition.

Fabric weight showed the tendency of gradually decreasing as the number of abrasion cycles increased. It was due to the fact that pill was removed after the abrasion cycles. MIU increased at the beginning and decreased after a little later. The surface of the fabric was rough, but immediately made to be smooth with abrasion as the abradant forced the fiber to separate from fabric. SMD decreased with abrasion cycles, but the tendency was different according to the direction of abrasion in sample fabrics. It depended mainly on the kinds of yarn knitted which had arranged by the guide bar.

WC gradually increased according to abrasion cycles, because the filament yarns of surface loops were cut with abrasion cycles. So fabric structure became irregular and rough. RC gradually decreased with abrasion cycles, because the thickness became thin and compressional elasticity got worse. Tensile strength to rupture decreased with increasing the number of abrasion. The arrangement of yarn input to the machine principally affected this property.

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