Evaluation of Floorcovering Abrasion Resistance by Means of Image Processing Technique

Fatemeh Mokhtari, Seyed Mohammad Hosseini Varkiyani and Masoud Latifi

Abstract— **An important factor in material quality is the time duration that materials are used (known as substance lifetime). Lifetime is a function of several factors, and among them wearing and abrasion resistances are more important than the other aspects. In addition, to the physical and mechanical properties, abrasion has a significant effect on the textiles appearance. This phenomenon considerably influences the texture of floor coverings in which continuous abrasion are applied. While the texture retention of the floorcovering during lifetime usage is quite desirable and leads to consumer satisfaction, it is necessary to evaluate the abrasion resistance of floor covering before its application. In this paper, the abrasion resistance for three types of floorcoverings (100% polypropylene(pp), 100% polyester(p) and 50/50% polypropylene-polyester(pp/p)) are tested with four kinds of steel abrasives with different coefficients of friction during three steps of abrasion cycles (1000,3000 and 5000). Their images were assessed by image processing method with two different functions. The results approved the procedure of the abrasion during 5000 cycles in the experimental condition. Weight changes of the floor-covering samples were evaluated as an index to illustrate the abrasion process.**

Keywords: Abrasion, floorcovering, image processing, intensity profile.

I. INTRODUCTION

Physical properties of textiles in all possible forms are a very important issue in production and trade. Characteristics of industrial textiles and fabrics which depend on the geometry and structure of the surface are a very complex structure of the fibers and yarns. The care of textiles is directly tied to their lifetime and application. As a result of erosion, a fabric may lose its beauty due to some factors such as abrasion and pressure force in wet and dry conditions [1]. The abrasion resistance of the fabric is influenced to a great extent by the geometry of its structure. The most important factors which affect the abrasion resistance are fiber type, frictional pressure and geometry of the textile, yarn diameter, crimp distribution, wave and their effect on protrusion, twist as well as dyeing and finishing treatments [1]. Variables such as wear direction, wet or dry samples, pressure, fabric tension, abrasive type, abrasive erosion and loss of transparency are recognized as wearing phenomena. The floorcoverings are subjected to abrasion by heavy mechanical forces and washing by chemical detergents. Farlane evaluates all discussed and reviewed the methods of evaluation, testing and characterization of the floorcoverings and analyzed them from different points of view. He also introduced the test methods for dynamic compressibility properties, abrasion resistance and anti-static properties [2]. Lehnen et al. presented some experimental tests to evaluate the carpets abrasion in a bridge by riding a motorcycle on it as well as in the main corridor of a school to perform the walking test. They showed that the fibers thicknesses play the most important and effective role in the erosion characteristics while the pile height and texture densities are also very effective [3]. Carnaby evaluated the mechanical processes that lead to changes in the textiles and loss piles. He plotted the diagrams of the total carpet thickness versus the number of wearing cycles and then investigated the results based on decreasing the thickness under physical processes. He proposed specific steps to reduce the thickness which contains fibrous internal friction, relaxation of pile fibers, fiber fatigue and fiber rupture. He also evaluated the experimental results with the mathematical diagrams. He claimed that the mathematical method is an appropriate method for carpet grading [4]. Slate found that the loop and cut pile show significant differences in the appearance after being abrasive. This is while they reported a similar damage to the fibers at the microscopic level, and they found that in all cases the damaged fibers are uniformly distributed in a pile and the space in which the damage occurs is often associated with a strong local or regional impact of inner fibers bending [5]. Changing the color of the carpet abrasion test are the most important carpet abrasion tests [6]. The tests are done on certain grades and evaluate the intensity of light which is reflected from the surface of the carpet with the help of mathematical equations. There are different methods for assessing the abrasion resistance, i.e. abrasion resistance of nonwovens with thermal connections, evaluation of abrasion resistance by characteristics of the stress - strain, abrasive machine for estimation of single fiber, the non-planar scenes, the bending and abrasion, the screen wire method, and etc. [1]. Changes in the appearance of textiles due to mechanical abrasion are possible to be assessed by the changes of texture images. In fact, by preparation of suitable images, the abrasion of textiles could be evaluated [8]. Shady *et al.* used image processing to extract the

F. Mokhtari, S. M. Hosseini Varkian and M. Latifi are with the Department of Textile Engineering of Amirkabir University of Technology, Tehran, Iran. Correspondence should be addressed to S. M. Hosseini Varkiyani (e-mail: varkiyan@aut.ac.ir).

TABLE I
SPECIFICATION OF FIBERS

Cross section	Crimp /cm	Elongation(%)	Ruptureforce, (CN)	Fineness, (Denier)	Length, (millimeter)	Parameters	Fiber type
circular	1.76	131.25	37.64	15.18	100.5	average	polyester
	21.8%	25.4%	11.4%	12.8%	5.7%	Coefficient of variation	
circular	2.11	318.3	34.09	16.8	93.5	average	polypropylene
	14.8%	17.2%	11.6%	17.4%	3.03%	Coefficient ofvariation	

TABLE II
WEIGHT PER SQUARE METER OF PREPARED SAMPLES (G/M^2)

Type	Sample							
	1	2	3	4	5	Average	Standard deviation	Coefficient of variation
Polyester	1022	971	976	1039	998	1001.2	28.6	2.86%
Polypropylene/Polyester	836	764	848	793	838	817	35.8	4.38%
Polypropylene	782	807	751	870	857	813.4	49.8	6.13%

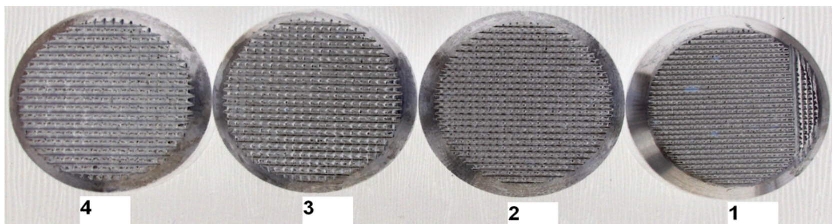

Fig. 1. Four steel abrasives.

image features for six different knitted fabric defects [9]. Yeung *et al.* analyzed the images of sixteen bagged fabrics and their properties by the image processing method and predicted fabrics bagging and presented a predictive model [10]. In this paper, the abrasion resistances for three types of floorcoverings are tested with four kinds of steel abrasives in different friction coefficients during three steps of abrasion cycles, i.e. 1000, 3000 and 5000 cycles. The captured images from samples are evaluated by the image processing method with two different functions to show the satisfied procedure of abrasion cycles in experimental conditions. In addition, the weight changes of the floorcovering samples are evaluated and used as an index to illustrate the abrasion process.

II. EXPERIMENTAL

A. Material

1) Fibers Characteristics

Floorcoverings are nonwovens and all the samples are produced in the same condition of manufacturing. Characteristics of the used fibers are illustrated in Table I. For the evaluation of each parameter, 30 specimens were tested. According to the information given in Table I, there are differences between these two types of fibers. With regard to these properties, the final cost of the product is another factor which should be mentioned in choosing the raw materials.

B. Method

1) Floorcover Production

Fiber carding is the first step of the producing process. Afterwards, fibers pass to the cross lapping machine. Then several layers are put on each other and sent for the needle punching machine. The needle punching machine makes a strong layer by involving the web layers. To create the desired continuity, needle punching was done in 2 steps. In the first step, the Dilo machine carried out needle punching with a speed of 320pick/min, penetration depth of 17mm and output speed of 1.9 m/min. In the second step, the Asselin machine did needle punching from bottom of substrate. This machine applies 227 picks to penetration of 14mm and its speed output is 2.2 m/min. The second step in floorcovering production is the design of the plane. In this step, two plates with a distance of 5mm stay in front of each other. The needling speed is 600pick/min, penetration depth is 7.5 mm and output speed is 2m/min. Finally, for making the web more stable, the finishing process is carried out. A coating layer is an additional layer that is attached to the bottom side of the floorcovering. The purposes of this final layer are mainly in accordance to strengthening the attachment of the pile, improving the dimensional stability of the carpet and providing the floorcovering with properties such as anti-slip, heat isolation, stepping elasticity or even flame retardancy. In this step, material such as polyvinyl alcohol and carbonate sodium powder are added to the bottom of the floorcovering. The finishing machine speed is 4.3 m/min. the weight per square meter of the floorcovering is shown in Table II.

2) Abrasive Design

To determine the abrasion resistance, the Martindale instrument was equipped with four special designed steel abrasives (Figure 1).Their different coefficients of frictions are shown in Table III. Their coefficients of frictions are based on their height and the ivory angle. To create these properties, the sand blast method was used for their surfaces modification. Three types of floorcoverings made of 100% polypropylene, 100% polyester and 50/50% polyester - polypropylene were abraded by the abrasives at 1000, 3000 and 5000 cycles.

To apply more abrasion in a shorter time, weightlifting was used on the Martindale instrument (Figure 2) for all samples during abrasion cycles, because it leads to ivories percolating in more depth. To gain more abrasion in a shorter time, additional vertical loading block was used on the Martindale instrument for all samples during abrasion cycles, because it leads to ivories penetrating in more depth.

Fig. 2. Martindale instrument.

TABLE III
ABRASIVE CHARACTERISTICS

Abrasive number	1	2	3	4
Groove depth(mm)	1	1.25	1.50	1.75
Coefficient of friction	0.61	0.7	0.74	0.783

C. Measurements

Based on the standard number ASTM-D6242, for each floorcovering, 5 samples in 10*10 cm were selected and by multiplying its weight by 100, the weight per square meter of the floorcovering was calculated (Table II). For measuring friction coefficient of abrasives, place them on a sloping plane (Figure 3) and increase the slope angle until the abrasives begin to slip. The coefficient of friction is simply the tangent of the critical slope angle (measured with respect to the horizontal plane).The capturing device was a LaserJet scanner because of its uniform light distribution. This uniformity is desirable because it can appropriately show texture surface roughness. There are no shades in images so accurate results are obtained from image processing.

In this paper, two different methods were used for analyzing abrasion resistance of floorcovering. One is the evaluation weight variation of samples. In this test, the raw samples without abrasion were initially weighed and then during each of the abrasion cycles, the samples are weighed again and the percentages of these variations are calculated too. The other way is using the image processing method in two different functions. Both methods can be used as a way to evaluate the abrasion resistance.

III. IMAGE PROCESSING METHODS

A. Image Processing System

1) Gradient Function

In this method, the program had initially made a comparison between the pictures taken from the samples. After calling the images by the program, the original image (image without abrasion) was selected by the user. With regards to this note that samples were abraded in the middle sections (because of circular movement of the abrasive) by removing the round of the images, the desired level of abraded area was achieved. Since the images were taken by a scanner, there was no need to use any filter because of its uniform light distribution. To simplify the image processing method, two-dimensional color images are converted to a gray scale. The main work was learning the texture by the program. In this section, the distance is defined first. Using the trial and error methods, the distances were chosen between 10 and 15 dots respectively and then the gradient function was applied between these distances. In this step by using a gradient function, the images were taught to the program. It should be considered that for each parameter defined in the program, a number was assigned to the images. In later stages, the images were requested to be opened sequentially in the program by the user. By this method, each image is assigned to a number. Finally, the numbers obtained from each image are compared to the base number (original image number). This comparison is obtained through using the gradient function and each image within the 10 or 15 dots basis points are compared with the base number (number related to the image without abrasion). From this comparison, a number is obtained by subtracting each number from a base number which shows the texture difference between samples. It revealed that the greater number results in more changes in the structure of floorcovering appearance.

2) Intensity Profile

The intensity profile of an image is the set of intensity values taken from the regularly spaced points along a line segment or multiline path in an image. For the points that do not fall on the center of a pixel, the intensity values are interpolated. Here this method is used as an implement to show softness of floorcovering that occurs on the surface during an abrasion. The results show that by applying more abrasion cycles, the amount of abrasion increases and variation of peaks decreases [11].

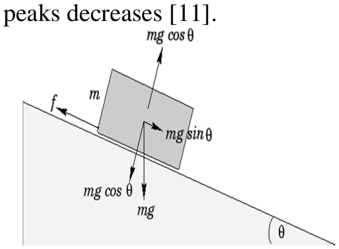

Fig. 3.Tilted plane test for measuring coefficient of friction.

IV. RESULTS AND DISCUSSION

The weights and weight differences (a, b, c) after abrasion cycles show that variations of weight loss in the polyester floorcovering in comparison with other types have smaller values and the polypropylene floorcovering has the greatest value of weight loss during abrasion cycles(Table IV). In other words, polyester floorcoverings have the best abrasion resistance due to the greater resistance of their fiber against pulling out force during abrasion.

TABLE IV
WEIGHT AND WEIGHT DIFFERENCES OF FLOORCOVERING DURING ABRASION (IN GRAMS)

Samples Weight				Samples Weight Differences		
P						
No Abrasion	After 1000 cycles	After 3000 cycles	After 5000 cycles	a	b	c
13.63	13.43	13.34	13.28	0.2	0.09	0.06
13.72	13.37	13.16	12.96	0.35	0.21	0.2
13.86	13.67	13.57	13.49	0.19	0.1	0.08
13.71	13.53	13.44	13.35	0.18	0.09	0.09
PP				a	b	c
13.49	13.06	12.87	12.71	0.43	0.19	0.16
13.51	12.71	11.97	11.03	0.8	0.74	0.94
13.59	13.18	12.98	12.84	0.41	0.2	0.14
12.83	12.58	12.36	12.18	0.25	0.22	0.18
pp/p				a	b	c
12.86	12.52	12.4	12.27	0.34	0.12	0.13
12.94	12.21	11.76	10.76	0.73	0.45	1
12.68	12.36	12.21	12.05	0.32	0.15	0.16
12.54	12.3	12.12	11.92	0.24	0.18	0.2

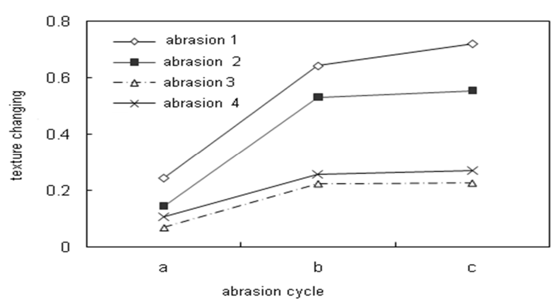

Fig. 4. Texture changing of 100% polyester during abrasion cycle increment

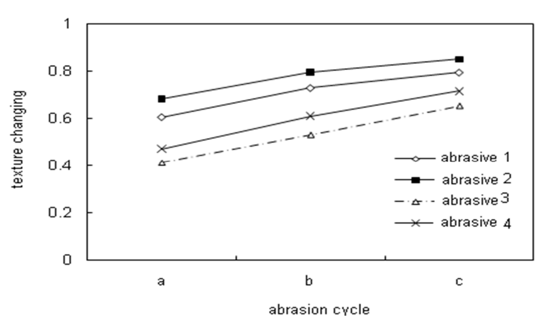

Fig. 5. Texture changing of mixture of polyester and polypropylene during abrasion cycle increment.

Although both polyester and polypropylene floor covering are produced in the same conditions and their initial coherences are the same, what make fibers come out of the surface are their intrinsic properties.

Images of samples during the abrasion cycles were compared with the main image and the results were reported as the difference number in Table V based on Gradient function. As can be seen from Figures (4), (5) and (6), by increasing the abrasion cycles number, the intensity changes of texture structure will be increased. Although three types of textures are faced with three abrasion cycle processes in the same conditions, the rate of changes varies from type to type.

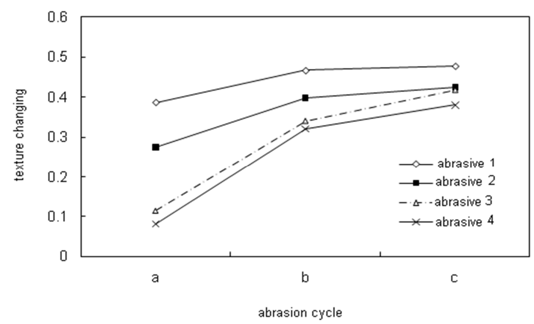

Fig. 6. Texture changing of 100% polypropylene during abrasion cycle increment

TABLE V
NUMBER OF TEXTURE CHANGES DURING THREE ABRASION CYCLES

	a	b	c
polyester	0.2437	0.6424	0.7209
	0.1446	0.5317	0.5554
	0.0908	0.222	0.231
	0.117	0.2554	0.2691
	a	b	c
polypropylene-polyester	0.607	0.7297	0.7948
	0.6833	0.7975	0.852
	0.4127	0.5322	0.664
	0.470	0.6119	0.717
	a	b	c
polypropylene	0.387	0.466	0.4779
	0.2646	0.398	0.4245
	0.1246	0.3405	0.4167
	0.0814	0.3207	0.3805

For polyester fibers a continuous increase in intensity changes is obvious. However, this continuous trend decreased with an increase in the abrasion cycles and the overall surface structure damage. This descending trend is more specific for the polyester fiber. It is explained that the floorcovering of polyester (in assessing the weight loss) shows better abrasion resistance. The initial abrasion cycle pulls out fibers from the surface. This causes absolute changes on the appearance of floorcovering because of the fiber ends out of the surface. In the next cycle, by an increase in the abrasion process, due to the surface fibers removing, changes in texture have an increasing trend.

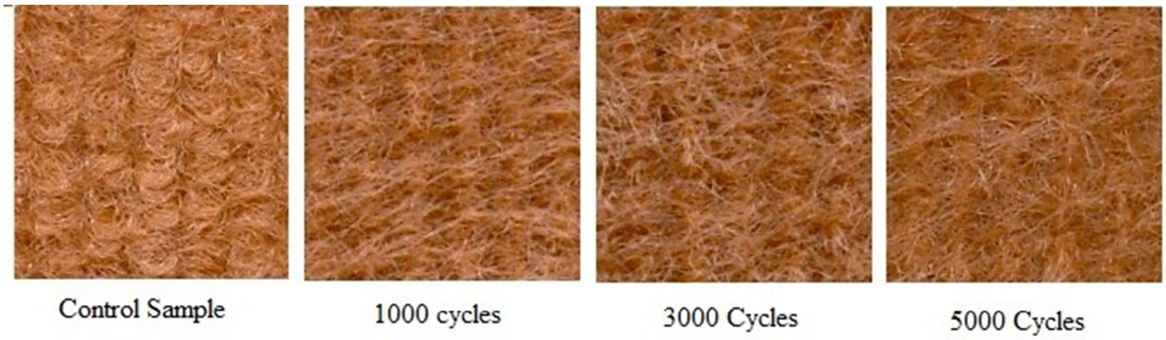

Fig. 7 .Image of polyester floorcovering after abrasion

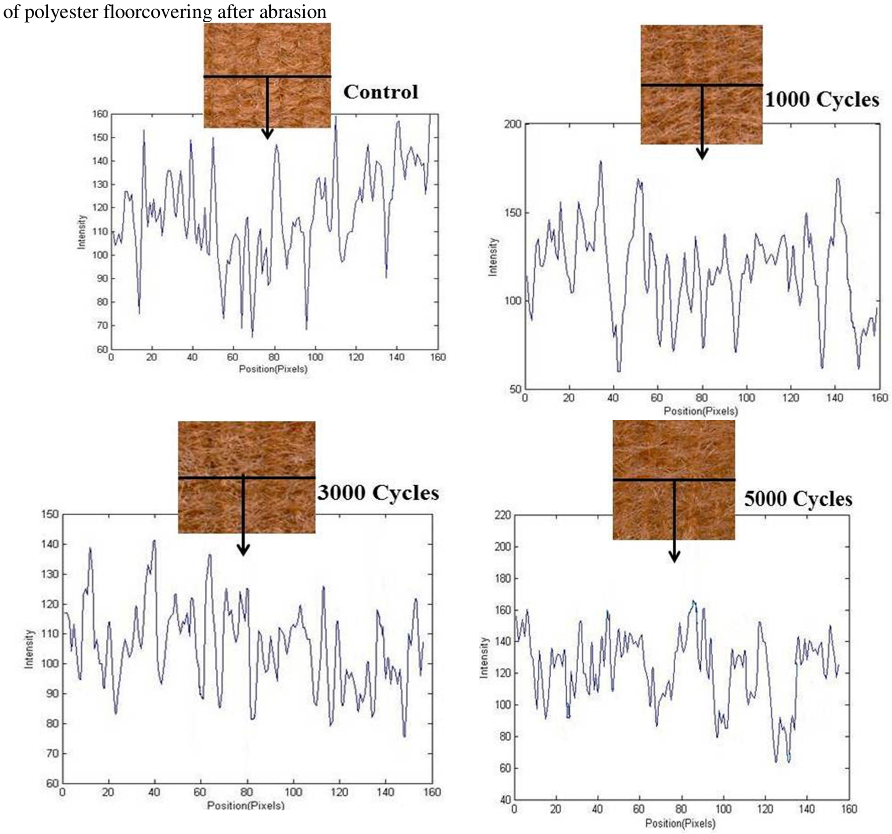

Fig. 8. Intensity profile for floorcovering

Polypropylene floorcovering in Figure 6 has high growth in changes. This growth may be related to the intrinsic properties of polypropylene fibers because the abrasion resistance of this floorcovering is very weak. Therefore, changes in the first cycle are more than the second cycle. However, it does not indicate any increase in changes. It simply means that in comparison with the first cycle, this amount is less.

In polyester floorcovering, the texture changing rate is rising and by increasing the abrasion cycle floorcovering, the surface is damaged. This means that after lots of damage in the first abrasion cycle and loss of fibers in the unstable surface structure, texture changes occur to the lower levels. Evaluation of texture variation for each abrasion indicates that the abrasive rate for each abrasive during the abrasive cycles was the same. The images for various levels of abrasion for polyester floorcovering are shown in Figure 7.

The magnitude of the intensity peaks has become smaller and as a result of abrasion, this fact is shown in Figure 8. Floorcovering samples have striped lines in their longitudinal direction, which gradually disappears during the abrasion process and the entire surface becomes uniform. As a result, the intensity peaks get smaller (Figure 8).

V. Conclusions

The goal of this paper is to assess the suitability of image processing methods to determine texture abrasion and its weight loss. For both polyester and polypropylene floorcovering, the abrasion descending trend is upward but these trends are different in various steps as the polypropylene floor covering degradation trend becomes less after losing unstable fiber on the surface in the first cycle. Similarly, the intensity profile can be an index in determining the appearance abrasion of the floor coverings. Polyester floorcoverings have the best abrasion resistance due to the greater resistance of their fiber against pulling out force during abrasion. Although this is the predicted base of intrinsic properties of polyester fibers, this paper reaches this fact by the use of image processing method. Therefore, this method can predict the abrasion of various floorcoverings with different fiber properties.

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