LABORATORY MEASUREMENTS FOR PREDICTING CARPET BEHAVIOUR IN USE

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ABSTRACT

A laboratory dynamic walker machine has been constructed. It simulates the repeated compression and shearing effect at the edge of the shoes of a walker on a carpet. The effect of some carpet parameters on the carpet thickness loss due to walking has been studied. The relation between carpet thickness and the number of walking cycles has been represented by an exponential equation which fits the experimental results well and has a good physical meaning of carpet behaviour in use.

Keywords: Dynamic walker machine, Carpet flattening.

1. INTRODUCTION

Carpet laboratory testing is very important to give a comparative guide of several carpet physical and mechanical properties to predict its behaviour in use. There are many trials of carpet laboratory tests to evaluate carper performance and wear life. Lamb and others (1) built a laboratory walker to study the appearance retention of carpets. Jose and others (2) developed an instrumental techniques to quantify textural change in carpet. Also Wood and Hodyson (3) developed a method to replace human walkers and used the image analysis to evaluate the loss of carpet appearance. While Clegg and Anderson (4) described a carpet abrasion tester to measure the wear life of the carpet. They proved that the results are correlated with the corridor wearing trials. Also Onions (5) found a satisfactory correlation between the inter- laboratory trials of the WIRA dynamic loading machine and the ranking on the floor for the loss of a carpet thickness or flattening.

II. EXPERIMENTAL WORK

II. 1. *Design of the dynamic walker machine*

A dynamic walker machine has been built to apply repeating walking cycles in the laboratory. It has the same principle as the British standard machine (BS 4051) although there are some modifications in the construction. Figure (1) shows the dynamic walker machine in which the carpet specimen (A) (12.5 x 12.5 cm) is subjected to a cyclic loading by a weight piece (B) with two steel feet (C) of a rectangular cross-section. The weight (B) repeatedly drop freely on the carpet specimen by an electric magnet (D). The number of the impacts are counted by a counter. The base plate (E) is traversed slowly by a grooved cam (F) to ensure the movement of its follower in the grooved path of the cam. This gives the specimen a shearing force produced by the edge of the feet (C). The total mass of the impact assembly (B) is 3200 gm and it drops from a height of 1" to give about the same impact as the British standard. The foot (C) dimensions are 0.6 x 5.0 cm width and length respectively, it resembles the normal human foot pressure; and has 1 cm depth and 3.8 cm inside distance between feet. By using an electrical resistance * the frequency is 50 impact/min the base plate traverses 3.2 mm forward and 1.6 mm backward every impact giving a uniformly compressed area of 5 cm wide and about 9 cm long every 25 impacts.

II.2 *Sample specifications*

Ten commercial tufted carpets have been tested. Table (1) shows the carpet specification. They have differences in pile height and density. Also the pile yarn count, material and pile type (cut or loop pile) are different.

Table 1. Constructional details of (Tufted carpet) Samples.

Sample No.	Pile yarn material	Pile Type	height of pile (mm)	pile yarn count (metric)	Pile Density				Samples original Thickness (mm)
					Long wise	width wise (per 10 cm)	(gange)	piles/ cm^2	
1	Nylon/BCF	Loop	4	4/1	29	31.5	1/8	9	6.194
2	Nylon/BCF	Cut	6	4/1	25	39.4	1/10	10	6.84
3	Polypropylene/polyester 50%,50%	Cut	9	3/1	28	31.5	1/8	9	9.55
4	Nylon	Cut	15	6/2	29	31.5	1/8	9	12.54
5	Nylon	Cut	14	7.5/2	54	39.4	1/10	21	12.60
6	Nylon/BCF	Cut	8	5/1	42	39.4	1/10	17	8.87
7	Nylon	Loop	4	3/1	29	31.5	1/8	9	7.29
8	Nylon	Cut	6	4/1	54	39.4	1/0	21	8.71
9	Wool/Nylon 80%, 20%	Cut	8	4/2	50	31.5	1/8	16	10.15
10	Spinning Nylon	Cut	12	3.5/1	41	25.2	5/32	10	9.72

Note: All primary backing is spun bounded & secondary backing is jute except No (8) is polypropylene.

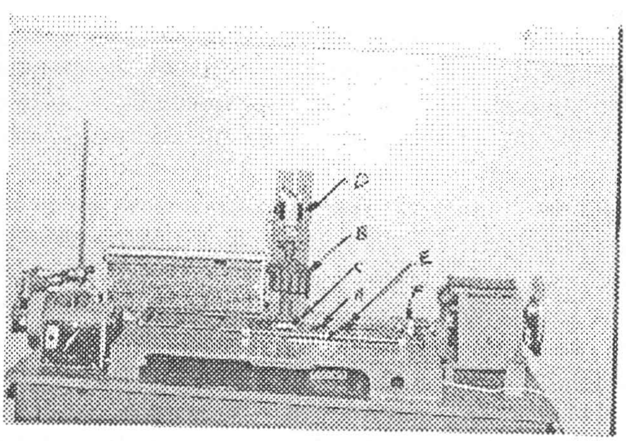

Figure 1. Photo of the dynamic walker machine.

II. 3 *Testing procedure of the dynamic walker tests*

A square carpet sample of 12.5 x 12.5 cm with a marked side parallel to the machine production direction is clamped on the base plate after its original thickness is measured. Precaution should be taken to held the carpet flat without any buckling. The carpet thickness is measured after applying 50, 100, 200, 500 and 1000 impacts to measure the carpet thickness loss or flattening due to walking.

III. RESULTS AND DISCUSSION

Table (2) and Figure (2) illustrate carpet behaviour under the dynamic walker machine. They show the change of carpet thickness by the increase of the number of impact walker cycles for the different types of carpet samples. From Figure (2) it can be generally realized that by increasing the number of impacts, the thickness of the sample decreases gradually for all samples. The rate of decreasing of the thickness is fairly high at the start. This is mainly due to the compacting of the pile without much actual wear. Then the rate of decrease in the thickness becomes low with more number of impacts. This is mainly due to the wearing away of the pile. The carpet thickness loss or flattening depends on the different carpet constructional parameters.
The following shows the effect of some parameters:-

III. 1 *The effect of pile yarn count*

Comparing samples (1) & (7) which have the same construction except pile yarn count, it is clear that the coarser the pile yarn the higher thickness loss. This is mainly due to three mechanisms: the potential energy and the friction of the pile helps flattening while the stored elastic bending helps recovery. Thus the coarser the yarn diameter the more the potential energy and the more the tuft to tuft friction, accordingly the more carpet flattening. While the finer yarn diameter has more elastic bending which helps in recovery and decreases flattening.

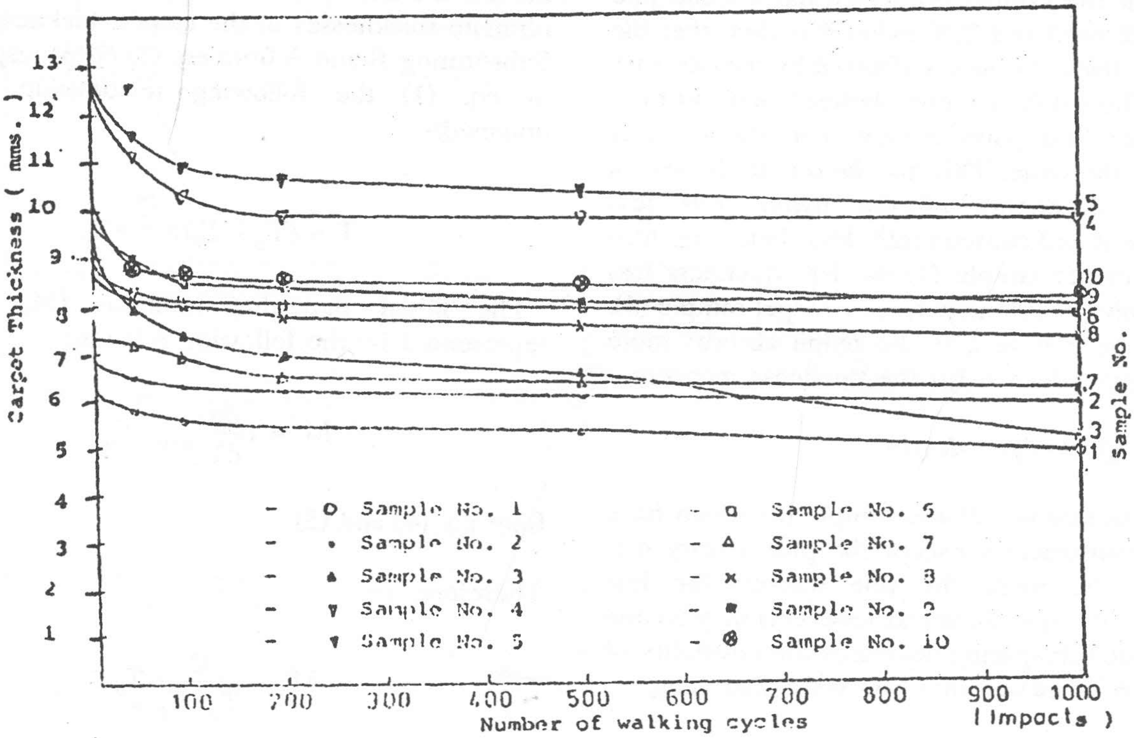

Figure 2. Loss of carpet thickness under dynamic walker machines.

Table 2. Carpet thickness loss after different walking impact cycles.

Samples No.	Original Thickness (mm)	Thickness after impacts mm (Thickness loss %)				
		impacts 50	impacts 100	impacts 200	impacts 500	impacts
1	6.19	5.78(6.7)	5.63(9.1)	5.45(12.0)	5.26(15.1)	4.27(23.7)
2	6.84	6.44(5.8)	6.30(7.9)	6.20(9.4)	6.04(11.7)	5.60(18.1)
3	9.55	7.89(18.3)	7.39(22.6)	6.89(27.9)	6.50(31.9)	5.01(47.5)
4	12.54	11.12(11.3)	10.28(18.0)	9.92(20.9)	9.87(21.3)	9.69(22.7)
5	12.60	11.58(8.0)	10.88(13.7)	10.68(15.2)	10.49(16.8)	9.86(21.7)
6	8.87	8.29(6.5)	8.12(8.5)	7.91(10.9)	7.71(13.2)	7.00(21.1)
7	7.29	7.18(1.5)	6.90(5.3)	6.49(11.0)	6.28(13.9)	6.17(15.4)
8	8.71	8.17(6.2)	8.10(7.0)	7.79(10.6)	7.67(10.9)	7.50(12.9)
9	10.15	8.87(12.6)	8.73(14.0)	8.54(15.9)	8.43(16.9)	7.82(23.0)
10	9.72	8.88(8.6)	8.54(12.1)	8.47(12.9)	8.00(17.7)	7.97(18.0)

III. 2 *The effect of pile height*

Comparing samples (4) & (7) which have the same construction except the pile height, it is clear that the higher the pile height the more carpet thickness loss. This may be due to that the higher the tuft height the more the potential energy which helps flattening and resisting recovery.

III. 3 *The effect of fibre type*

Comparing the behaviours of sample (6), which is

100% nylon and sample (9), which has a blend pile yarn of 80% wool and 20% nylon it is clear that the percentage thickness loss is affected by the pile yarn material. The nylon yarn gives better behaviour from the thickness loss point of view, keeping all other parameters the same. This may be due to the less of the frictional energy of the nylon thus less entanglement and consequently less flattening. Also the nylon carpet sample (4) has less thickness loss than the poly-propylene/polyester carpet sample (3). This may be due to that the nylon absorbs more elastic energy which helps the thickness recovery.

III. 4. *The effect of pile density*

Comparing sample (2) and sample (8) which have the same construction except the pile density it is clear that the more the pile density the less percentage of carpet thickness loss. This may be due to that as the tuft spacing decreases the possibility of deformation decreases thus pile resist flattening.

IV *Empirical formula for the prediction of carpet behaviour*

The thickness of a carpet as a function of the number of impact cycles for the different samples is fitted according the to following equation:

$$T = A\, e^{\frac{-n}{C}} + B \qquad (1)$$

where:
T is the carpet thickness
n is the number of walking cycles

A,B,C are constants and can be defined as follows:- from eq (1) at infinite cycling the ultimate carpet thickness (T_f) will be equal to the constant B
Therefore, $B = T_f$ i.e. B is the carpet ultimate thickness.
If T_o is the initial carpet thickness at zero walking cycles;

$$T_o = (T)_{n=o} = A + B.$$

Therefore;

$$A = T_o - T_f$$

i.e. A is the difference between the carpet initial and ultimate thicknesses or the carpet thickness loss. Substituting B and A from eq. (2) & (3) respectively in eq. (1) the following relationship can be obtained:-

$$T = (T_o - T_f)\, e^{\frac{-n}{C}} + T_f \qquad (4)$$

The initial flattening modulus (M_i) can be represented by the following relation:

$$M_i = \left(\frac{dn}{dT}\right)_{n=o} . T_o \qquad (5)$$

from eq. (4) and (5)

Therefore;

$$M_i = \frac{C}{T_o - T_f} . T_o \qquad (6)$$

Since the flatting strain (S) is the ratio of thickness loss therefore;

$$S = \frac{T_o - T}{T_o};$$

and when

$$T = T_f \quad ; \quad S = S_f = \frac{T_o - T_f}{T_o} = \frac{A}{A+B} \qquad (7)$$

Substituting eq. (7) in eq. (6)

Then;

$$M_i = \frac{C}{S_f} = C(A+B)/A \qquad (8)$$

Thus, the constant C can be defined as the number of cycles at which the carpet will reach its ultimate thickness if it allways behaves as it does initially, for this range of cycles.

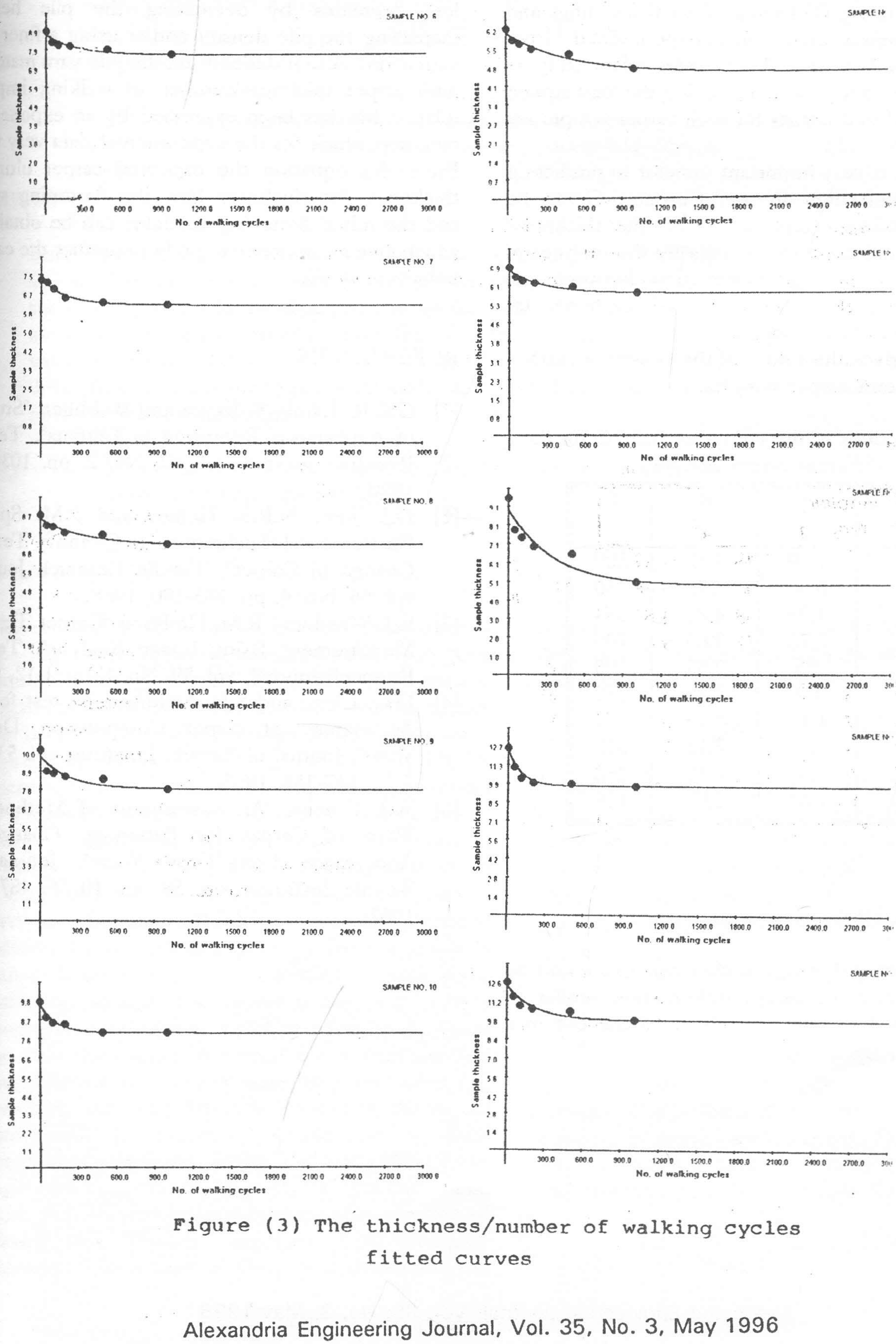

Figure (3) The thickness/number of walking cycles fitted curves

It is clear that all the constants in the suggested relationship in eq. (1) have a physical meanings and it is a good representation of th experimental carpet thickness/number of walking cycles relationship or carpet flatting due to walking. Using the least square method the fitted curves for each carpet sample are given in Figure (3).

constant C is very important indictor to predicting the carpet behaviour in use. Constant C can be easily determined graphically from the thickness/ number of walking cycles curves by the number of cycles at the point of intersection between the tangent to the curve at the start and the horizontal line at the end of the curve.

Table (3) gives the values of the constants A,B&C for the different carpet samples.

Table 3. Values of the constants A,B&C for the different carpet samples.

Samples No.	A	B	C
1	1.49	4.57	500
2	0.94	5.78	250
3	4.08	4.81	333
4	2.72	9.69	100
5	2.5	9.85	200
6	1.1	7.58	250
7	1.19	6.16	200
8	1.41	7.12	333
9	1.95	7.18	250
10	1.64	7.97	125

V. CONCLUSION

The laboratory dynamic walker machine could be used to predict the carpet deformation similar to those obtained by contact walkers in use but in a shorter time.

The carpet deformation as percentage thickness loss decreases by decreasing the pile height, increasing the pile density and/or using a finer pile yarn count. Also it depends on the pile yarn material. The carpet thickness/number of walking impacts relationship has been expressed by an exponential equation which fits the experimental data very well. From this equation the expected carpet ultimate thickness, the thickness loss, the flattening strain and the initial flattening modulus can be obtained, which give a comparative guide to predict the carpet behaviour in use.

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