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Short Communications

Performance of wool-nylon cut pile carpets in relation to their structural parameters

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The change in performance parameters of hand-tufted cut-pile carpets has been studied with respect to variation in their constructional parameters. Carpet samples are prepared from 80/20 wool-nylon blended pile yarn by varying pile density and pile height. The influence on deformation, abrasion and tuft withdrawal force properties has been investigated. Carpet samples are evaluated for compression, abrasion and tuft withdrawal force. The experimental results are statistically analyzed using general linear model through regression analysis and analysis of variance. From the statistical analysis of test results, it has been established that the carpet structural parameters, such as pile height and pile density, have a significant influence on thickness loss, recovery under compression and durability properties of hand-tufted carpets.

Keywords: Compression, Cut pile, Pile yarn, Resilience, Tufted carpets, Wool-nylon carpet

Carpet is a three-dimensional textile structure and one of the most widely used floor coverings in both residential and work places. Pile yarns in the form of cut, loop, or cut-loop are perpendicular to the carpet backing and create carpet surface[1]. Life time of a carpet is usually determined by deterioration in its appearance and mechanical performance of surface pile yarns. Surface pile yarns are mainly exposed to forces among axial compression, bending and extension during such human daily activities like standing and walking and also static & dynamic pressure by massive goods such as moving furniture and other household goods[2,3].

Carpet compression is the most important property that manifests wear and abrasion characteristics. A number of studies has been conducted theoretically and experimentally to understand carpet performance properties bearing the influence of structural parameters. A mathematical model established by Carnaby and wood suggests that carpet's surface is suffered by pile loss as a result of abrasion due to fatigue mechanism. According to this fatigue mechanism, pile weight of carpet left after dynamic loading, such as walking depends on the number of repetition cycles, pile density, linear density of fibers and the percentage of damaged fibers[4,5].

Further, effect of structural parameters mainly pile height and pile density has been studied with the help of a mathematical orthogonal plan for compression deformation in wool-polyamide blended carpets by Dubinskaite *et al*[6]. and established that in elastic deformation pile density is the major influencing parameter while in case of unrecovered deformation, both pile height and density are significant contributors to deformation under compressive deformation.

Ozdil *et al*[7]. have suggested that wool carpets having higher pile mass and densities have higher compressibility and recovery after dynamic loading and unloading. Thickness loss values of wool carpets are generally lower after long term static loading. The resistance to dynamic compression is higher for the carpets, which have higher number of loops per unit area and therefore recovery properties are better.

The most common fibre used for producing pile yarn is wool. Wool fibre can be used as pile yarn when its resiliency, length, number of crimps, percentage of vegetable trash, tenacity, elongation and fineness are suitable[11]. Apart from structural parameters of carpets, performance of carpets is affected by several other factors such as raw material, linear density of fibres, cross-section of fibres, diameter and structure of pile yarn[8,10,12]. However, these factors are found to have relatively lesser and distinct influence than the structural parameters, i.e. pile height and pile density.

Use of blended yarns in the carpets has drawn attention of the technologists in pursuit of up gradation of performance. Various blends are being tried out in the industry. but information related to carpets made of nylon blended wool is scanty. In this study, the compression, recovery, abrasion and tuft withdrawal force properties of hand- tufted cut pile

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nylon-wool blended carpets have been discussed by taking into account the structural parameters, such as pile height and pile density.

Experimental

The raw material used for the carpet was spun pile yarn of linear density 4 Nm and TPM approx. to 95, blended from 80% wool and 20% nylon6 and used to prepare nine hand-tufted cut pile carpet samples of size 24 × 24 inch. Pile yarn was subjected to test blend ratios using wool and nylon fibres test methods IS 2006:1988 (wool) & IS 2005:1988 (nylon) respectively. Tufted carpet samples were prepared with three different pile heights (10 mm, `12mm, 14 mm) and pile densities (145000, 170000, 195000 no. of tufts /m²) using a tufting gun for pile yarn insertion in the primary backing. The warp and weft raw material used in the primary backing was 100% cotton woven fabric. Specifications of hand-tufted cut-pile carpets samples and matrix of general linear model are given in Table 1.

Pile height was measured according to test method ASTM-D5823-00. Pile density was calculated as number of tufts per square meter. In order to determine the compression and thickness properties, carpets samples were tested in accordance with test method BS 4908, which is equivalent to ISO 2094. In the method, the initial thickness of the conditioned carpet specimens was measured under a pressure of 2 kPa. Thickness of specimens at various loads (2-200 kPa) and corresponding compression and recovery values of thickness were measured. The pile thickness of the unworn and worn carpet specimens was measured with a WIRA digital thickness gauge and all these observations were carried out under standard conditions of 22 ± 2 °C and 65 ± 2% RH. The pressure was taken in kilopascal (kPa) and the deformation occurred was in millimeter (mm). Numerically, the compression parameters were calculated and obtained using the following equations:

Table 1 — Specifications of hand-tufted cut-pile carpets samples and matrix of general linear model

Sample code	Pile density (X1)		Pile height (X2)	
	Value in matrix	Value, no. of tufts/m^2	Value in matrix	Value, mm
S1	-1	145000	-1	10
S2	-1	145000	0	12
S3	-1	145000	1	14
S4	0	170000	-1	10
S5	0	170000	0	12
S6	0	170000	1	14
S7	1	195000	-1	10
S8	1	195000	0	12
S9	1	195000	1	14

Thickness recovery (%) = (Tr/T2) *100 … (1)

Compression recovery = (Tr – T200/ T2 – T200) *100 … (2)

where T2 is the initial thickness at pressure 2kPa; T200, the thickness when specimen is compressed at pressure 200kPa; and Tr, the amount of thickness recovered after releasing the pressure from 200 kPa to 2 kPa.

The abrasion resistance characteristics of carpets were determined on a WIRA carpet abrasion tester machine following test method IWS TM-283:2000 known as weight loss method. Specimens mounted on the holder were abraded against the standard abradant fixed in the abradant holder on the abrasion tester. Initial weight of the specimen before abrasion cycles was measured and then final weight of specimen is recorded after 5000 abrasion cycles. Difference in the initial and final weight is expressed as rate of weight loss of pile yarn surface in milligrams per 1000 cycles, as shown below:

Absolute weight loss (WL) = Initial weight – Final weight

Rate of weight loss = mg/1000 cycles

For each of above parameters, such as thickness recovery, compression recovery and abrasion, five tests were made for each carper sample. The withdrawal force to remove tuft (or pile) from the carpets was determined with the help of WIRA Tuft with drawl Tensometer, WIRA, England following the test method BS 5229: 1975, which is equivalent to test method IS: 5884.One end of a tuft was gripped and pulled upwards out of the structure, and the force required to pull the tuft off the backing structure was recorded. Twenty tests were made for each carpet type, keeping the specimen of size 200mm×200mm. Tuft withdrawal force (TWF) is measured in kilogram force (kgf).

Results and Discussion

With the help of general linear model through regression analysis the experimental results of carpet compression, recovery, abrasion and tuft withdrawal force are statistically analyzed. Table 2 indicates that how both the structural parameters pile height and pile density influence these properties. Discussion on results in detail is given hereunder.

Compression Recovery, Thickness Recovery, Abrasion and Tuft Withdrawal Properties

The carpet properties, such as compression recovery, thickness recovery, abrasion (weight loss) and tuft withdrawal properties, versus pile height and pile density are illustrated through contour curves (Figs 1-4).

Through statistical regression analysis, following regression equations are obtained:

$$TR = 81.252 - 1.122*X1 + 0.827*X2 + 0.198*X1*X2 \quad ... (3)$$

$$CR = 64.564 + 2.132*X1 - 2.455*X2 + 0.293*X1*X2 \quad ... (4)$$

$$WL = 67.233 + 1.367*X1 - 1.033*X2 - 0.175*X1*X2 \quad ... (5)$$

$$TWF = 1.801 - 0.026*X1 + 0.015*X2 + 0.002*X1*X2 \quad ... (6)$$

From Table 3, it is clear that small values of standard error, zero p-values and square multiple values of R close to 1 for all the carpet properties indicate that both pile height and pile density have significant effect with almost nil interactional effect at 5 % level of confidence.

As in Fig. 1(a), it is shown that with increase in pile density, the thickness recovery increases but the trend gets reversed with respect to pile height. Raising pile height brings down the thickness recovery values. This happens because of the fact that a greater number of tufts per unit area and smaller length of pile offer more resistance to bending during compression, causing less entanglement of fibres in tufts which help the fibres to recover more and vice-versa. On the contrary, as the pile height increases, more length of fibres is subjected to compression, which leads to more bending and ultimately more permanent deformation occurs in fibres which results in lesser recovery[2-4]. Thickness recovery refers to work done on a carpet when the pressure is released from 200 kPa to 2 kPa.

From Fig. 1(b), it is clear that the trend for compression recovery is opposite to that of thickness recovery as shown in Fig. 1(a). This phenomenon is just opposite to that of thickness recovery because compression is a factor of pile height. As pile height increases, fibres in pile yarn bend easily and consequently deformation in fibres takes place easily and compress comparatively to a larger extent. But recovery from its compressed state can be attributed

Table 2 — Experimental results of carpet properties

Sample code	Thickness recovery (TR), %	Compression recovery (CR), %	Weight loss (WL), mg/1000 cycles	Tuft withdrawal Force (TWF), kgf
S1	81.58	65.12	66.7	1.816
S2	80.64	67.2	68.4	1.785
S3	78.94	68.92	69.9	1.761
S4	82.38	62.48	65.8	1.825
S5	81.47	64.35	67.2	1.796
S6	80.14	66.50	68.3	1.774
S7	82.95	59.65	64.9	1.841
S8	82.07	62.24	66.5	1.816
S9	81.1	64.62	67.4	1.792

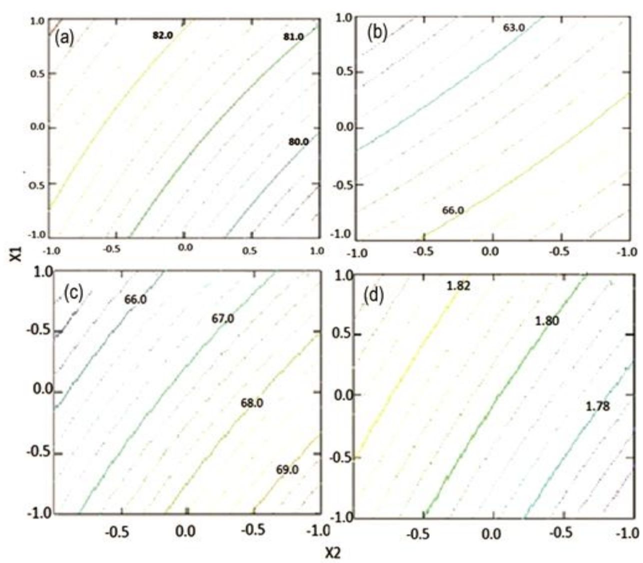

Fig. 1 — (a) Thickness recovery (TR), (b) compression recovery, (c) abrasion and (d) tuft withdrawal force *vs.* pile height and pile density

Table 3 — Simple regression analysis of experimental results

Parameter	Squared multiple coefficient (R^2)	Standard error	F-ratio	P-value (up to 3 decimal places)
Thickness recovery (TR)	0.987	0.176	127.556	0.000
Compression recovery (CR)	0.998	0.175	697.240	0.000
Weight loss (WL)	0.988	0.212	131.865	0.000
Tuft withdrawal force (TWF)	0.992	0.003	212.688	0.000

to dissipation of frictional energy during compression which happens to be lesser in case of longer piles because of higher surface contact points. This ultimately lowers the total energy of deformation during recovery from compression. As a result, longer piles exhibit temporary and elastic deformations, while shorter piles are subjected to permanent deformations relatively plastic in nature[4,6,9]. Therefore, compression recovery is more for higher pile heights. Similarly, if pile density increases, a greater number of fibres in tufts per unit area are subjected to deformation, which provides greater resistance to the fibres in pile yarns in recovering from compression deformation and consequently less compression recovery occurs. This means that if a carpet has lower compressibility, it has higher resistance against recovery, resulting in a harder carpet.

From Fig.1(c), it is observed that weight loss is decreasing with increase in pile density, but increasing with increase in pile height. Higher the weight loss of pile yarn, the lesser is the abrasion resistance. Abrasion resistance depends much on pile density and pile height. As the pile density increases, compression in fibres is decreased due to strong cohesive forces and more contact points between fibres. Hence, fibres remain integrated and affected lesser by abrasive surface[1,3,6,9]. Therefore, abrasion resistance will be higher for denser carpets. As the pile height increases, there is often slight variation in pile height due to which surface of the carpet becomes less uniform; and when such a less uniform surface is exposed to abrasion, there is higher loss of pile weight. Hence, there is more weight loss and less abrasion resistance as the pile height increases.

As shown in the Fig. 1(d), tuft withdrawal force is increasing with increase in pile density. As pile density increases, a greater number of fibres are interlocked within same space and provides higher frictional resistance while withdrawal force is applied[2,11,12]. Hence, more tuft withdrawal force is required to pull the tuft off the surface at a given pile height for denser carpets.

Further, it is also observed that tuft withdrawal force is decreasing with increase in pile height at a given pile density. Tuft withdrawal force is a type of pulling force being applied along the length of the tuft to pull it off the primary backing. Pulling force is inversely proportional to the magnitude of length. Therefore, the higher the length of the tuft, the lesser force is required to withdraw the tuft.

Based on the experimental results, it is concluded that both the structural parameters, viz pile height and pile density, have significant effect on carpet properties. Thickness recovery is higher for carpets which are denser and having low pile height. Compression recovery is higher for carpets having high pile height and lower pile density. Weight loss or wear is more in case of carpets having higher pile height and low pile density. Tuft withdrawal force which determines the durability of carpet is higher for denser carpets having low pile height. It is one of the parameters determining the carpet durability along with carpet compression, recovery, abrasion etc. It is expected that, this study would give useful information to both manufacturers and researchers about wool-nylon cut-pile carpets made with above-said range of parameters.

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