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Studies on animal fibre blended hand made felts: Part I– Physical and mechanical properties[a]

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Wool fibre has been blended separately with camel hair and angora rabbit wool in different proportions and felts of different thicknesses and densities produced as per Indian standards. The felts developed from medium type wool and rabbit hair give lowest density and thickness as required for extra soft quality (64s) felt. It is also observed that the performance characteristics of felt, i.e. tensile strength and splitting resistance, mainly depend on thickness of felt. The correlation between these two is also very high. The felts developed with pure camel hair give highest tensile strength and quite comparable splitting resistance and density with pure wool felt for making soft quality (48s) felt; however, it gives higher abrasion loss.

Keywords : Abrasion loss, Hand made felt, Tensile strength, Splitting resistance, Wool
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1 Introduction

The scaly structure of wool fibre due to the directional frictional effect (DFE) helps in the formation of an irreversible structure, i.e. felt by entanglement of wool fibre scales. In size the epithelial scales are 25-30 micron (average 28 μ) in length, 35 μ in width, and 0.05-0.5 μ in thickness. In very fine wools, one scale only encircles the body of the fibre, so called 'coronal scale' but normally fine wools have two or three and with coarse wools, even more (four or five) scales are necessary for the encirclement. Not only there is lateral overlapping of the scales which surround the fibre, but there is also overlapping along the length. Longitudinally, the scales fit into one another like a stack of ice-cream cones or flowerpots, and this leaves the rims projection, which on the wool fibre takes the form of imbrications or serrations caused by the free tips of scales.

The scales of the fine fibres stack within each other to greater depth (16 micron or so) than the coarse fibre, leaving only one third of their length exposed (about 8 micron). On the other hand, the coarse wool expose two thirds or even more (about 20-25 micron) and less than one third (5-10 micron) is submerged into the body of the fibre. The free tips of scales, which are more numerous along the length of finer rather than the coarse fibre, are said to affect its behaviour in processing, particularly in spinning and in shrinkage.[1]

Indian standards cover a range of soft to extra hard type felts for different applications.[2,3] The major applications of felts include filtration, sound absorption, thermal insulation, shock absorption, cushioning, padding, packing, surfacing, spacing, etc.[4] Sheep wool is mostly used for manufacturing of hand made felts. The use of wool in machine made paper makers felts is very limited due to the use of needle punching system with synthetic or resin coated multifilament use.[5] Handmade felts are produced in small-scale sector by local artisans in Rajasthan, Himachal Pradesh, Jammu & Kashmir, etc. The products are utilized as floor covering for protection against cold as well as for decoration. Such felts contain either embroidery or patchwork of coloured felt pieces over the felt sheet of single colour. Since hand made felt is manufactured manually, the control on its quality needs to be monitored very carefully. Some work about the performance of such felts was carried out by Gupta *et al.*[6] but it was confined to the use of sheep wool only, particularly to study the effect of medullated fibres on the quality of felts. In the present work, the felts made with wool and its blend

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with rabbit hair, camel hair and coarse quality wool in different proportions have been studied with respect to their tensile strength, splitting resistance and abrasion loss.

2 Materials and Methods

2.1 Materials

Wool, rabbit hair and camel hair were collected from Kekri wool mandi, NTRS Garsa substation of CSWRI, Avikanagar and National Research Centre on Camel (NRCC), Bikaner respectively.

2.2 Processing of Materials

The wool purchased from Kekri mandi was first sorted for black, burry, short and matted, and the main fleece was utilized for opening, carding and subsequent felt making. Camel hair was sorted into light brown, brown, black and white spotted. Light brown coloured camel fibre was used for making felts. Rabbit hair of low quality was used without any sorting.

2.3 Felt Preparation

Blends of rabbit hair/camel hair with wool in the increasing proportion of 10% were prepared (Table 1). The blend level for rabbit hair was restricted to 40%. The experimental lots were carded on TORIGOE woollen card. The carded web was used for felt making. The carded web of individualized fibres was laid down manually in the form of a bed keeping in view that almost equal density of fibres was laid down per unit area. The total quantity of web taken for rabbit hair and camel hair blends was about 1500 g and 2000 g respectively to prepare a felt of approximately 1.20 m × 1.80 m size. The thickness was maintained at around 3 mm for rabbit hair blends and 6 mm for remaining other blends as per Indian standard (IS 1719- 2000). This bed was impregnated with an emulsion of soap in water by sprinkling the emulsion by hand and rolling the bed. The fibre bed was left for about 4 h so as to allow all the fibres to absorb the desired moisture. After this, the bed was rigorously rubbed for a period of 60 min with the help of hands. Simultaneously mending of thin places was done by putting extra tuft of carded web wherever needed and rubbing till a compact strong structure was achieved. The prepared felts were washed to remove extra alkali present in the felt.

2.4 Evaluation

Samples for fibre fineness testing were drawn from the raw wool, brown colour camel hair fibre and rabbit hair. Fineness was measured with the help of a projection microscope, following the standard procedure.[7] Similarly, fibre fineness of blends was measured by drawing the samples from the blended felts. The felt thickness, density, tensile strength and splitting resistance tests were also conducted as per standard procedures of BIS. Abrasion loss was calculated at 1000, 2000 and 4000 cycles of rubbing on WIRA abrasion tester. Correlation coefficients between fibre fineness, density of experimental felts and other performance properties were worked out using SPSS software.

Table 1—Various wool blended hand made felts

Sample	Blend ratio	Code
Camel hair: Chokla wool	00:100	CH00
Camel hair: Chokla wool	40:60	CH40
Camel hair: Chokla wool	50:50	CH50
Camel hair: Chokla wool	60:40	CH60
Camel hair : Chokla wool	100:00	CH100
Rabbit hair: Chokla wool	10: 90	RH10
Rabbit hair: Chokla wool	20: 80	RH20
Rabbit hair: Chokla wool	30: 70	RH30
Rabbit hair: Chokla wool	40: 60	RH40
Rabbit hair :Chokla wool	100:00	RH 100
Malpura wool: Chokla wool	30:70	MW30
Malpura wool: Chokla wool	40: 60	MW40
Malpura wool: Chokla wool	50:50	MW50
Malpura wool: Chokla wool	70:30	MW70

3 Results and Discussion

3.1 Fibre Properties

Fibre properties, such as fineness and medullation, significantly influence the felting properties. The fibre diameter and medullation per cent of experimental materials, i.e. Chokla wool, Malpura wool, camel hair and rabbit hair, are found to be 30.3, 36, 25.5 & 12.5 μm and 45, 56, 30 & 78 respectively. Ladder type medulla is observed in rabbit hair. The distribution of fibre diameter for four experimental wools is shown in Fig. 1. It is observed that the fibre diameter distribution ranges 9-102, 9-76, 5-72 and 5-48 μm in Malpura wool, Chokla wool, camel hair and rabbit hair respectively. The variability in fibre diameter is highest in Malpura wool followed by Chokla wool, camel hair and rabbit hair. The variability is directly influenced with average fibre diameter. Chokla wool possesses desired fibre diameter and medullation required for a good quality hand made felt. Malpura wool is coarsest in diameter having highest numbers of medullated fibres. Considering the fineness

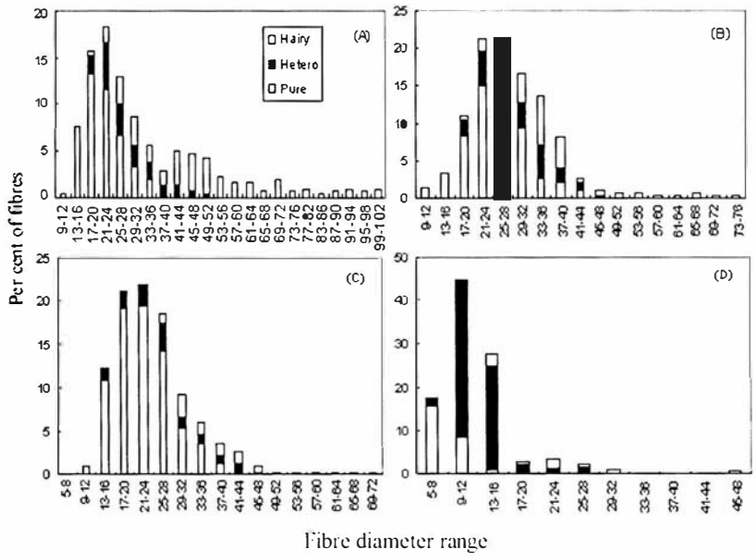

Fig. 1—Distribution of fibre diameter [(A)- Malpura wool; (B) – Chokla wool; (C)- Camel hair; and (D)- Rabbit hair]

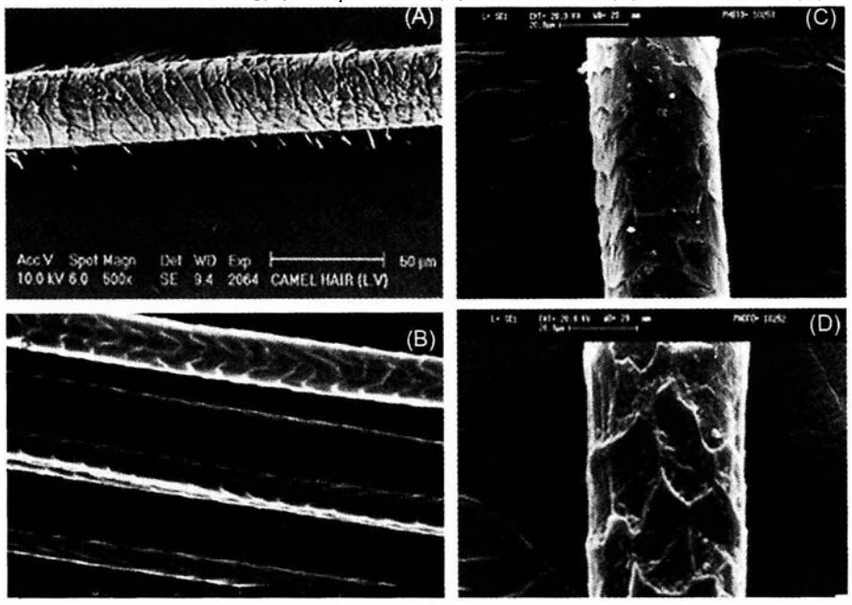

Fig. 2—SEM photographs of (A) Camel hair, (B) Rabbit hair, (C) Chokla wool, and (D) Malpura wool

parameters, it is observed that a blend of Chokla sheep wool with Malpura sheep wool can be used for the production of 48s quality felts. The rabbit hair is finest and its blending with Chokla wool is suitable for the production of extra soft type (64s quality) felt. Camel hair is one of the cheapest alternate sources of wool and can be blended with Chokla wool for the manufacture of soft type (48s quality) felt.

3.2 Morphology of Fibre

The morphology of surface of fibre plays an important role in deciding the felting process. The shape and size of the scale of fibre vary with species and breed of animal.[8] The morphology of fibres as studied on scanning electron microscope is shown in Fig. 2. It is observed that the wool has got irregular weaved mosaic reticulate structure, whereas camel hair and rabbit hair have got more regular scales. The density of scales as counted from photograph shows that Malpura, Chokla, camel hair and rabbit hair have got approximately 50, 100, 120 and 150 scales per mm respectively. These are more or less similar as reported earlier.[9] Further, the scales of rabbit hair are

found to be stacking more within each other than the scales of camel hair and wool. This stacking or overlapping of scales leads to a smoother surface.

3.3 Characteristics of Hand Made Felts

3.3.1 Fibre Characteristics

The relative felting property of wool depends on the distribution of fibre diameter as well as medullation. The fineness and medullation per cent of fibres obtained from different felt samples are shown in Fig. 3. The results reveal that the wool blends are coarsest while rabbit hair blends possess lowest fibre fineness and medullation. Camel hair blends lie in between. The fibre fineness decreases with the increase in proportion of rabbit hair and camel hair in the blended felts. Medullation content has shown an increasing trend with the increase in rabbit hair content in the blend which is obviously due to the very high number of medullated fibres present in rabbit hair. No significant difference is observed in felts prepared from blends of wools of different micron. It may be because of the preferential removal of coarse kempy fibres during the preparation of felt.

3.3.2 Constructional Parameters

The physical properties of felts such as thickness, weight per unit area and density play an important role in determining the end-use suitability. The thickness of wool and wool blended felts is higher than that of camel hair blended felts. This is due to the comparative coarseness of wool than camel hair (Fig. 4). The area density of wool and camel hair blended felts in term of weight per unit area is varying from 800 g/m^2 to 1200 g/m^2 whereas the same is varying from 400 g/m^2 to 600 g/m^2 for felts prepared from rabbit hair blend (Fig. 4). The density of camel blended felts is higher than that of wool blended felts (Fig.4). This is due to the hollowness of wool fibre, i.e. higher extent of medulla which makes it comparatively lighter than camel hair. As per Indian standards, according to density, all the felts come under soft and extra soft types having the density of 0.15-0.18 g/cm^3. The density of felts prepared from rabbit hair blend is lower (~ 0.15-0.16 g/cm^3), however it satisfies the need of extra soft quality (64s) felt as per BIS.

3.3.3 Tensile Strength

As per Indian standards IS 1719-2000, the felts of extra soft category having density of 0.15 g/cm^3 need

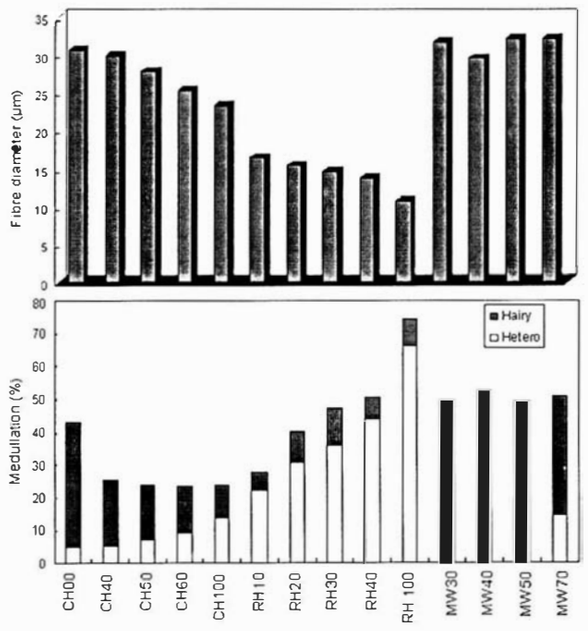

Fig. 3—Blends composition *vs.* fibre diameter and medullation

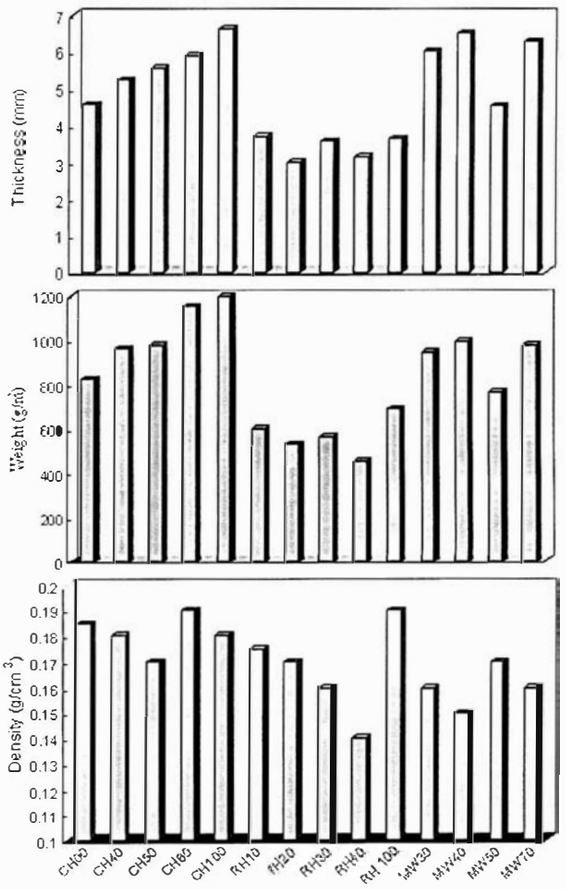

Fig. 4—Blend composition *vs.* thickness, weight and density of felts

not undergo this test. However, the tensile strength results of 0.18 g/cm^3 density are meeting the standards of 900 kPa. Figure 5 reveals that the felt made from pure Chokla wool is weakest and the felt made from pure camel hair is strongest. It is further observed that different blends do not show any trend. This may be due to the combined effect of fibre fineness, length, number of scale and their nature, and limited control over constructional parameters at the times of making the felt by hand operation.

3.3.4 Splitting Resistance

The splitting resistance (N/cm) of felts (Fig.5) reveals that the pure camel hair felt gives highest splitting resistance followed by wool-camel hair blends. This phenomenon is mainly because of the higher scale frequency and reticulate scale structure of camel hair. Among the felts made from wool blends of Malpura and Chokla, the value of splitting resistance has shown a decreasing trend with the increase in proportion of Malpura wool in the blends. The value of splitting resistance is found lower in rabbit hair and its blends with wool. This is mainly because of lesser thickness of felt. However, this test is not essential for extra soft variety of felts as per BIS.

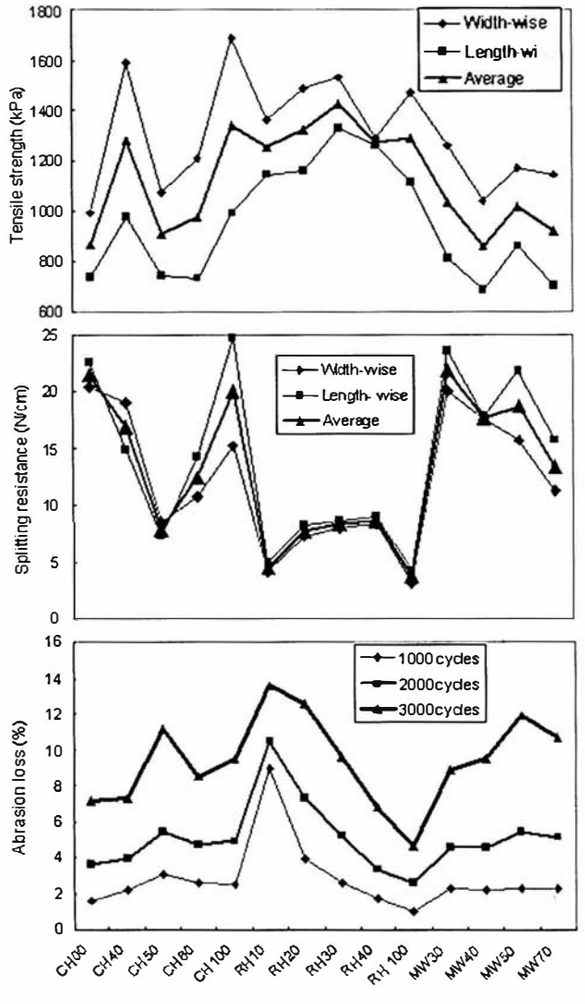

Fig. 5—Tensile strength, splitting resistance and abrasion loss of felts

3.3.5 Abrasion Loss

Figure 5 shows that the abrasion loss increases with number of rubs which is quite obvious. Further, it is observed that the abrasion loss is less in the felts made from pure wool, pure rabbit hair and pure camel hair as compared to their blends. This indicates that the entanglement of fibres is better when they are alike and it is not so strong when two fibres differing in surface characteristics are milled/felted together. The surface of wool, camel hair and rabbit hair is different due to their different scaly structures and their numbers[8]. The scale angle with respect to main body of the fibre is less in case of rabbit hair and camel hair as compared to that in case of wool fibre. Further, it is also revealed that with the increase in rabbit hair content, the abrasion loss is reducing, indicating better felting property of rabbit hair due to its fineness than other two experimental fibres. No such trend is observed in case of camel hair blends. However, in case of wool blends, it is observed that the abrasion loss is more upto 50% level and thereafter it is reduced. The corresponding values of felt density and abrasion loss per cent are shown in Fig. 6. It is observed that the abrasion loss increases initially, reaches to its peak at 0.17 g/cm^3 density and then comes down. It is minimum at around 0.19 g/cm^3. This trend indicates that to have minimum of

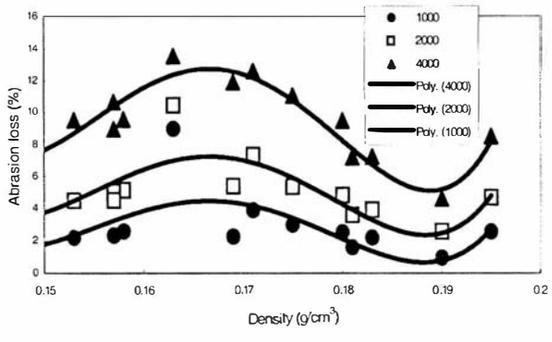

Fig. 6—Density *vs.* abrasion loss

Table 2—Correlation coefficients among physical and performance characteristics

Parameters	Correlation coefficient
Fibre diameter and weight	0.69
Thickness and splitting resistance	0.68
Thickness and tensile strength	0.59
Tensile strength and splitting resistance	0.94

abrasion loss, the optimum density of the felts should have been 0.19 g/cm^3 instead of 0.18 g/cm^3 as recommended under IS: 1719-2000.

3.4 Relationship Among Physical Attribute and Performance Characteristic

The correlation coefficients were worked out for different performance characteristics with physical attributes. The correlation coefficients are presented in Table 2. It is observed that with the increase in thickness of felt, both tensile strength and splitting resistance increase; the correlation being better with splitting resistance than tensile strength. It is also observed that the two parameters have got very high correlation, i.e. with tensile strength the splitting resistance increases. This is very obvious since phenomenon of fibre entanglement is responsible for both the characters.

4 Conclusions

4.1 Extra soft quality felt can be prepared from rabbit hair and its blends with wools, whereas soft quality felt can be prepared from camel hair and its blends with medium quality wools as per Indian standards IS: 1719-2000.

4.2 The performance characteristics of felt, i.e. tensile strength and splitting resistance, are influenced by thickness of felt and surface characteristics of fibres used for making felts.

4.3 The abrasion loss is dependant on the density of felt. The optimum density of felt to have minimum abrasion loss should be 0.19 g/cm^3.

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