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Influence of fibre diameter and medullation on woollen spun yarns and their products

N P Gupta, D B Shakyawar & R D Sinha
Central Sheep & Wool Research Institute, Avikanagar 304 501, India

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The influence of fibre diameter and medullation on mechanical processing and quality performance of yarns, blankets and carpets has been studied. The correlation coefficients between fibre diameter, medullation and properties of yarns, blankets and carpets are presented. The multiple regression equations for yarn, blanket and carpet properties have also been established. A positive correlation has been found between fibre diameter and medullation of fibres in the yarn. The thickness and bulk of blankets and the bulk, compressibility and resiliency of carpets show positive correlations with fibre diameter and medullation while the tenacity of yarns and blankets and the thermal conductivity of blankets show negative correlation with fibre diameter and medullation. These relationships have been found to be statistically significant.

Keywords: Carpet pile, Fibre diameter, Medullation, Resiliency, Thermal conductivity, Woollen spun yarn

1 Introduction

Fibre diameter is one of the important characteristics of wool fibre and plays a vital role in deciding its utilization and processing system to be used. Wool is generally classified into three major grades, viz. fine (20-24 μm), medium (25-34 μm) and coarse (≥35 μm), according to fibre diameter. Fine wool is mainly used for apparel fabrics, whereas medium and coarse wool fibres are utilized to manufacture hand-knotted carpets, blankets, felts, etc.

Hollow or nearly hollow tubular space within the cortex of wool fibre is known as medulla[1]. Wool fibre whose medulla has a width equal to or less than half the width of the fibre is known as partially-medullated or hetero fibre. If the width of medulla is more than half the width of the fibre, the fibre is known as coarsely medullated or hairy, and if the width of medulla is more than three quarters of the width of fibre, the fibre is known as Kemp. Wool fibres without medulla or having medulla up to 5% are known as non-medullated or can be considered as pure fibres. Fine wools generally have no medulla, whereas medium and coarse wools have medulla and it depends on fibre diameter.

A positive correlation exists between fibre diameter and medullation of wool fibre. Medullation in wool fibre significantly influences the performance of end products[2]. Blakey *et al.*[3] reported that Magra (carpet wool breed) was able to attain complete recovery, while Merino wool (apparel wool breed) was not able to do so because of medullation. Ince and Rydes[4] concluded that correlation exists between medullation and carpet appearance. According to Burns *et al.*[5], 15% hetero typical and 2% kemp fibres by count are essential in carpet wool. The carpet yarns generally have fibres with 33.3-38.5 μm average fibre diameter and 36.6-69.1 % medullation[6,7].

This paper deals with the influence of fibre diameter and medullation on mechanical processing and quality performance of yarns, blankets and carpets. Bharat Merino (fine or non-medullated) and Kekri-Chokla (coarse or medullated) wools were used in the present study. The correlation coefficients and multiple regression equations have also been worked out.

2 Materials and Methods

2.1 Materials

Bharat Merino (apparel type) wool developed at

CSWRI, Avikanagar, through cross breeding of Chokla, Nali, etc. sheep with Rambouillet and Soviet Merino, and Kekri-Chokla wool (carpet type) were used in the present study. These wools had 21.24±0.78 μm and 35.58±0.56 μm fibre diameter and 0 and 53.83% medullation respectively.

2.2 Methods

2.2.1 Preparation of Yarns

Kekri-Chokla and Bharat Merino wools were blended in different proportions (40:60, 50:50, 60:40, 70:30, 80:20 and 90:10) at willowing machine. The blends were processed on woollen spinning system of TORIGOE make carding and spinning frame. The yarns of 4 Nm were spun out of these blends. The yarns were dyed as per the standard method.

2.2.2 Preparation of Blanket and Carpet

The yarns were divided into two lots. One lot was converted into blanket on a handloom (pit type). The 2/2 twill weave effect was developed keeping both ends/in. and picks/in. at 18. Single yarn of 4 Nm was used as warp whereas two parallel yarns of 4 Nm were used as weft. The other lot of blended yarns was converted into hand-knotted carpet of 18 mm pile height and 144 knots/in pile density.

The blankets and carpets were finished as per the standard procedures.

2.2.3 Test Methods

The yarns were evaluated for physical and mechanical properties. Average fibre diameter (μm) and medullation (%) were examined with the help of a projection microscope. Yarn tenacity (g/tex) and elongation (%) at break were determined using the computer-aided tensile testing machine (Instron). Yarn evenness, thick and thin places and neps were examined by the Uster evenness tester.

The tenacity and elongation at break of blankets were determined by RKM tensile testing machine. Thickness was measured on WIRA carpet thickness gauge at a pressure of 0.25 lb/in^2 and the bulk was calculated in terms of specific volume (cm^3/g). The thermal conductivity of blankets was determined with the help of SASMIRA thermal conductivity apparatus and calculated in terms of cal/°C m h.

The carpets were evaluated for bulk, compressibility and resiliency with the help of Instron tensile testing machine. Abrasion loss (%) was determined on carpet abrasion tester. Thickness loss after loading at different periods was measured by WIRA carpet dynamic loading testing instrument and thickness gauge.

2.2.4 Statistical Analysis

The correlation coefficients among fibre diameter, medullation and properties of yarns and carpets were worked out at $P<0.01$ and $P<0.05$ significant levels.

The multiple regression equations were worked out between fibre diameter and medullation with dependent variables i.e. properties of yarns and carpets. The regression coefficients for fibre diameter (b_1) and medullation (b_2) and the regression constant (a) are presented in Table 1. The multiple correlation coefficient (R^2) and F-value (variance of analysis) for the regression equations are also presented.

3 Results and Discussion

3.1 Average Fibre Diameter and Medullation

Average fibre diameter and medullation percentage of fibre in different yarns are shown in Figs 1 and 2. It is observed that the average fibre diameter shows a positive correlation with medullation of fibre in the yarn. With increase in average fibre diameter, the number of medullated fibres in yarn increases significantly ($P<0.01$).

3.2 Yarn Properties

3.2.1 Yarn Linear Density

The linear density of yarn shows an increasing trend with increase in fibre diameter and

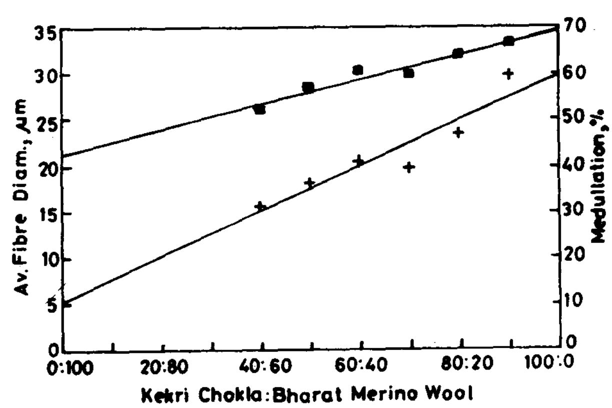

Fig. 1—Average fibre diameter and medullation *vs* blend ratio of Bharat Merino and Kekri-Chokla wools [(–■–) Av. fibre diameter, and (+) medullation]

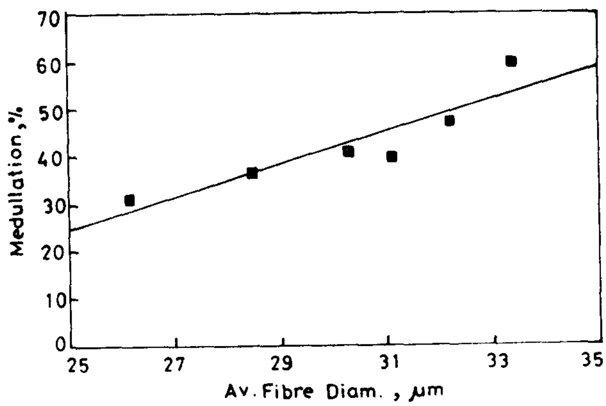

Fig. 2—Average fibre diameter *vs* medullation of Bharat Merino and Kekri-Chokla blended yarns

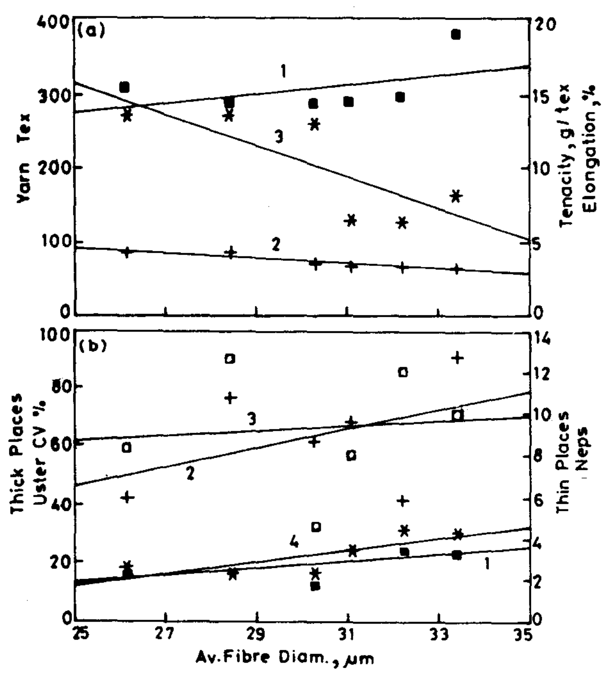

Fig. 3—Influence of fibre diameter on the properties of blended yarns: (a) [(–■–) yarn tex (1); (+) tenacity (2); (–*–) elongation (3)] and (b) [(–■–) Uster CV% (1); (+) thick places (2); (–□–) thin places (3); (–*–) neps (4)]

medullation in the blends (Figs 3a and 4a). A multiple regression equation shows that these two parameters influence the yarn linear density significantly ($P< 0.05$) (Table 1), indicating that the spinnability of the fibre (reduction in yarn fineness) deteriorates with increase in average fibre diameter and medullation percentage.

3.2.2 Yarn Tenacity and Elongation at Break

Yarn tenacity shows a negative correlation with average fibre diameter and medullation percentage of fibre in the yarns (Figs 3a and 4a). The

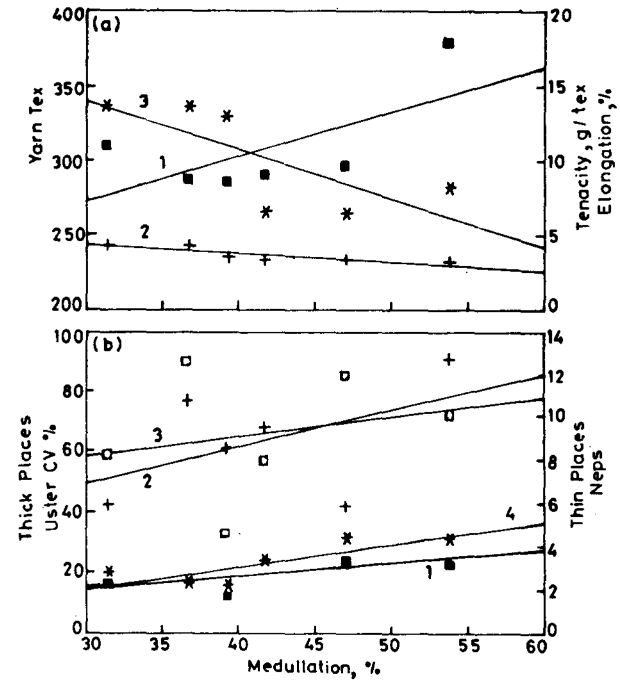

Fig. 4—Influence of medullation on the properties of blended yarns: (a) [(–■–) yarn tex (1); (+) tenacity (2); (–*–) elongation (3)] and (b) [(–■–) Uster CV% (1); (+) thick places (2); (–□–) thin places (3); (–*–) neps (4)]

correlation coefficients are –0.9277 and -0.7353 respectively. It is inferred that the yarn tenacity decreases with increase in average fibre diameter and fibre medullation in the yarns. It is further confirmed by multiple regression. These two parameters influence the yarn tenacity significantly ($P<0.05$). The results are in conformity with the finding of Gupta *et al*[2].

The elongation at break shows a negative trend, but non-significant, with average fibre diameter and medullation percentage (Figs. 3a and 4a). Multiple regression is also found non-significant.

3.2.3 Uster CV%

Uster CV% shows a positive trend, but non-significant, with fibre diameter and medullation of fibre in the yarns (Figs 3b and 4b). It is clearly observed that both fibre diameter and medullation of fibre affect the spinnability of the blends. As medullated and coarser fibres increase in the blends, the regularity of the yarn is reduced. The influence of these parameters are non-significant.

The thick places, thin places and neps show positive trends with fibre diameter and medullated fibre content in the blends (Figs 3b and 4b). More thick and thin places and neps are developed in

Table 1—Regression coefficients and constants of equations for average fibre diameter and medullation with physical and mechanical properties of yarns, blankets and carpets

Dependent variable	Multiple correlation coefficient (R^2)	Regression coefficients: Medullation (b_1)	Regression coefficients: Fibre diam. (b_2)	Constant (a)	F-value
Yarn Properties					
Tex	0.8556	13.112	−31.6900	720.3	0.0500[a]
Tenacity,g/tex	0.8987	0.0456	−0.3129	11.22	0.0324[a]
Elongation,%	0.6344	0.1448	−1.4697	48.63	0.2221[c]
Uster CV%	0.5596	0.2235	0.6086	8.053	0.2921[c]
Blanket Properties					
Tenacity, g/tex					
Warp	0.9383	−0.00954	0.0123	1.130	0.0153[a]
Weft	0.9260	−0.01809	0.0198	1.526	0.0200[a]
Elongation, %					
Warp	0.1172	−0.1270	0.0890	12.662	0.8266[c]
Weft	0.1812	0.0970	−0.1341	21.178	0.7407[c]
Bulk	0.2701	0.0042	0.0181	3.329	0.6200[c]
Thermal conductivity	0.9846	−0.1088	0.1197	5.775	0.0019[b]
Thickness	0.8834	0.0400	−0.0449	2.891	0.0397[a]
Carpet Properties					
Bulk	0.9264	−0.0236	0.1819	0.799	0.0199[a]
Compressibility	0.9547	1.1819	−1.9438	73.70	0.0100[b]
Resiliency	0.9501	0.3247	0.0565	28.46	0.0100[b]
Abrasion loss	0.6565	0.1334	0.0052	9.551	0.2012[c]
Thickness loss	0.4851	−0.4410	0.6520	19.04	0.3694[c]

[a]$P<0.05$, [b]$P<0.01$ and [c]Non-significant.

highly medullated fibre blends. Further, these increase with increase in average fibre diameter in the blends. The effect of fibre properties is non-significant.

3.3 Properties of Blankets

3.3.1 Thickness and Bulk

The thickness and bulk of blankets are the functions of fibre and yarn diameter used to manufacture the blankets. From Figs 5a and 6a, it is observed that the fibre diameter and medullated fibre content in the blends show positive correlation with thickness and bulk. The correlation coefficients are 0.9026 and 0.8332 for thickness and 0.5164 and 0.5129 for bulk respectively. Table 1 shows that the combined effect of average fibre diameter and medullated fibre content has positive correlation with thickness and bulk. The multiple correlation coefficient R^2 for thickness is significant (0.8834) while for bulk it is non-significant (0.2701).

3.3.2 Thermal Conductivity

The thermal conductivity is a function of the thickness of blanket. It decreases significantly with increase in average fibre diameter and medullated fibres in the blends (Figs 5a and 6a). The correlation coefficients are −0.9000 and −0.9806 for fibre diameter and medullated fibre content respectively. The combined effect of fibre diameter and medullation percentage further improves the dependency of thermal conductivity. The test of significance for multiple regression has been found to be highly significant ($P<0.01$). The blanket having more coarser and medullated fibres shows low thermal conductivity. A similar trend was observed by Gupta *et al.*[2]

3.3.3 Tenacity and Elongation

The tenacity and elongation at break of blankets are shown in Figs 5b and 6b. It is observed that the tenacity in both the warp and weft directions

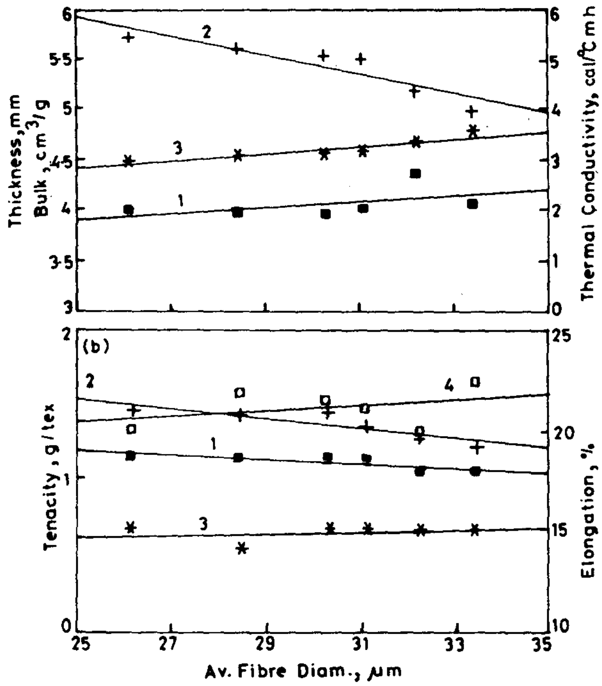

Fig. 5—Influence of fibre diameter on the properties of blankets: (a) [(–■–) bulk (1); (+) thermal conductivity (2); (–*–) thickness (3)] and (b) [(–■–) tenacity (warp) (1); (+) tenacity (weft) (2); (–*–) elongation (warp) (3); (–□–) elongation (weft) (4)]

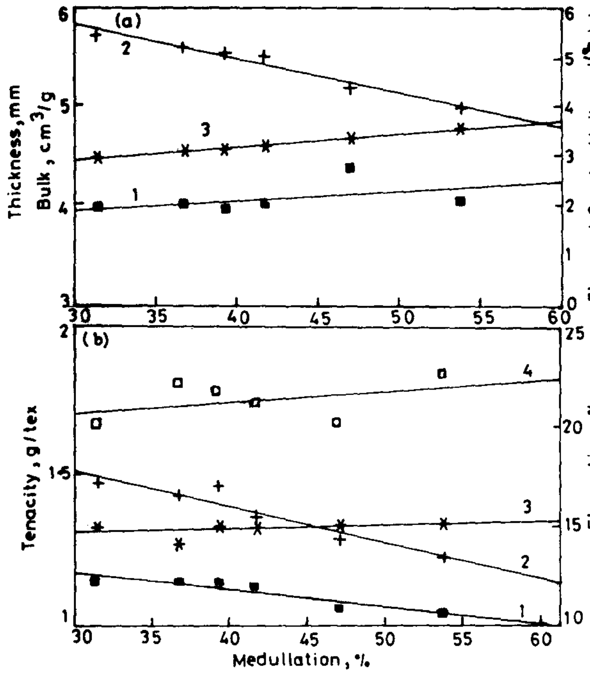

Fig. 6—Influence of medullation on the properties of blankets: (a) [(–■–) bulk (1); (+) thermal conductivity (2); (–*–) thickness (3)] and (b) [(–■–) tenacity (warp) (1); (+) tenacity (weft) (2); (–*–) elongation (warp) (3); (–□–) elongation (weft) (4)]

decreases with increase in the average fibre diameter and medullation content in the blends. The correlation coefficients for average fibre diameter and medullation have been found to be –0.8600 and –0.9240 for tenacity along the warp and –0.8737 and –0.9510 for tenacity along the weft respectively. The relationship further improves for tenacity when the affects of average fibre diameter and medullated fibre content are combined together. The multiple R^2 are 0.9383 and 0.9260 for tenacity along the warp and weft respectively. This is quite obvious because the coarser and medullated wool have low tenacity. Also, the number of fibres in the yarn cross-section decreases which influences the yarn tenacity adversely.

The elongation at break of blanket in both the warp and weft directions does not show any significant change with the change in blend composition.

3.4 Properties of Carpet

3.4.1 Bulk and Compressibility

The bulk of the carpets is shown in Figs 7a and 8a. The bulk shows positive correlation with fibre diameter and medullation. The correlation coefficients are 0.9685 and 0.8669 respectively. Due to the higher medullated fibre and large fibre diameter, the more space could be occupied and as a result, more volume per unit mass of carpet will be produced. The test of significance for the multiple regression equation has been found to be significant (P<0.05).

The compressibility of the carpets (Figs 7a and 8a) indicates that it depends highly on fibre diameter and medullated fibre content in the carpet. The multiple regression equation (Table 1) indicates that the combined effect of fibre diameter and medullation percentage has positive influence on compressibility. The test of significance for the multiple regression equation has been found to be significant (P<0.01).

3.4.2 Resiliency

The resiliency shows good relationship with fibre diameter and medullation percentage of fibre in the carpet (Figs 7a and 8a). The correlation coefficients are 0.9318 and 0.9651 for average fibre diameter and medullated fibre percentage respectively. The combined effect of fibre diameter and medullation shows that the resiliency significantly increases with increase in average fibre diameter and medullation percentage in the carpet. The multiple R^2 has been found to be 0.9501 which is highly significant ($P<0.01$).

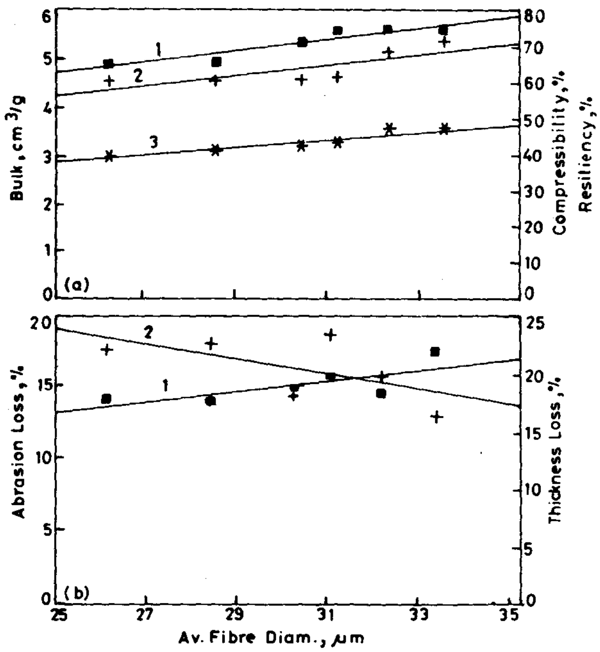

Fig. 7—Influence of fibre diameter on the properties of carpets: (a) [(–■–) bulk (1); (+) compressibility (2); (–*–) resiliency (3)] and (b) [(–■–) abrasion loss (1); (+) thickness loss (2)]

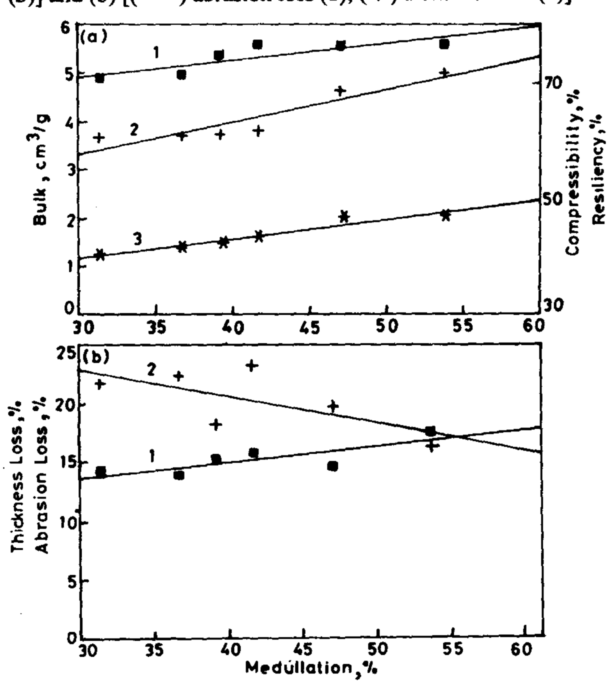

Fig.8—Influence of medullation on the properties of carpets: (a) [(–■–) bulk (1); (+) compressibility (2); (–*–) resiliency (3)] and (b) [(–■–) abrasion loss (1); (+) thickness loss (2)]

3.4.3 Abrasion and Thickness Loss after Dynamic Loading

The effects of fibre diameter and medullation on abrasion and thickness loss are shown in Figs 7b and 8b. The correlation coefficients have been found to be 0.7798 and 0.8103 for abrasion loss and –0.6009 and –0.6747 for the thickness loss after dynamic loading. Though these are non-significant, the trends show that abrasion loss increases with increase in fibre diameter as well as medullated fibre content in the carpet, whereas thickness loss after dynamic loading reduces with increase in fibre diameter and medullated fibre content in the blends. A similar trend is also observed in multiple regression. The test of significance for the multiple regression equation has been found to be non-significant.

4 Conclusions

4.1 The average fibre diameter and medullation percentage of fibre increase with increase of Chokla wool content in the blend.

4.2 Average fibre diameter is highly associated with the medullation of fibre in the blended yarns.

4.3 Yarn linear density is affected significantly and the effect is positive with fibre diameter and medullation percentage in the blend but the tenacity is affected negatively. Uster CV% shows the positive trend but non-significant.

4.4 Bulk and thickness of blankets show positive correlation with fibre diameter and medullated fibre content but tenacity and thermal conductivity show negative trend.

4.5 Bulk, compressibility and resiliency of carpets are highly dependent on fibre diameter and medullated fibre content present in the carpet.

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