MEDULLATION FINENESS AND STRENGTH CHARACTERISTICS OF THE HETEROTYPICAL FIBRES OF BIBRIK WOOL

MUHAMMAD ASHRAF ALI AND S. MUMTAZ FATIMA

North Regional Laboratories, Pakistan Council of Scientific and Industrial Research, Peshawar

(Received February 15, 1965; revised June 3, 1966)

A sample of a Bibrik fleece of West Pakistan was sorted into the true, heterotype and kemp classes. Forty heterotypical fibres were studied for medullation, fineness, breaking stress, extension and toughness etc. The turnable knob provided for the to-and-fro motion of the slide clips in a Reichert projection microscope was graduated to measure the length of medullary fragments inside a fibre. The analysis of the results provided a significant positive correlation between the breaking force and the fibre diameter as also between the diameter and the medullation, and significant negative coefficients of the correlation between the diameter and the breaking stress, between the breaking stress and the medullation, between the breaking stress and the cross-sectional area, and between toughness and medullation. But the negative correlation between medullation and extension at break was not significant. Regression equations corresponding to the significant coefficients of correlation were derived statistically. Analysis shows that medullation adversely affectsthe processing efficiency and the durability of the wool product.

Introduction

The spinning performance of any wool depends on its various characteristics such as fibre fineness, length, friction, breaking stress and extension. A knowledge of these properties is essential for the commercial utilisation of various wools.

Like most carpet wools the Bibrik wool is highly medullated. It is thus desirable that the relationships, if any, between medullation and other wool characteristics should be known. With this end in view, the relationships between the following paired qualities have been investigated, employing the heterotypical fibres.

1. Medullation and fineness.
2. Medullation and breaking stress.
3. Medullation and extension at break.
4. Medullation and toughness.
5. Fineness and breaking stress.
6. Breaking stress and cross-sectional area.
7. Breaking force and fineness.

Thoughness is defined as the product of the breaking stress and the extension at break expressed in percent of the original fibre length. It is an approximate measure of durability of the finished product[1] obtained from the fibres concerned. The approximation stems from certain chemical changes brought about by the treatment with alkalis during scouring and some reorientation of α-keratin molecules during the severe stress involved in carding, combing and drafting. Breaking stress is defined as the breaking force per unit area of a fibre. Its importance in processing can be realised in view of its relationships to "end downs" in spinning and yarn breakages during weaving. Moreover, in the yarn of highly extensible fibres small tension variation from spindle to spindle in a spinning frame can produce appreciable irregularity.

Medullation is estimated as percentage by volume of a fibre or a class of fibres. Fineness, in this work, is given by root mean square radius of a fibre. It is closely related to spinning behaviour of a fibre.

Experimental

SORTING

Twenty subsamples each of 0.06 g were drawn by random sampling to represent a fleece of a Bibrik breed from West Pakistan. Each subsample was sorted by the benzene method[2] into three main classes, namely, true, heterotype and kemp. The number of so-called medullated fibres was too small to make a distinctly separate class in the breed. These fibres were, therefore, added to heterotypical class of fibres.

MEASUREMENT OF DIAMETER AND MEDULLATED LENGTH

The measurement of the fibre diameter and strength was carried out at 20°C and 65% relative humidity. During strength testing a fibre usually undergoes what is known as the "temporary set" which may mask the diameter of the true fibre. To avoid this error diameter measurement preceded the strength test in our experiments. A fibre was aligned on a slide and covered with 4 cm long coverslip which was secured by cedar wood oil in order to get a sharp definition of medulla. Special care was taken to straighten the fibre as far as possible, and to exclude the air layer from the fibre surface inside the slide oil. The magnification of the lanameter was × 500. Its movable circular knob allowing for the movement of the slide-clips was graduated to measure the length L_m of the medullated pieces in a fibre. The length of a fibre thus studied was marked by a china-glass pencil. The interval was selected at random at different positions along the length of the fibres.

Usually more values of the fibre radius γ_f and medulla radius γ_m were recorded as their relative heterogeneity increased. The number of observations per fibre was within ranges 4-47 and 21-66 for L_m and γ_f respectively. The frequency of γ_m over a fragment of medullation ranged from 2 to 42. The approximate length interval between successive observations of γ_f and γ_m were 0.9 mm and 0.15 mm respectively.

DYNAMOMETRIC MEASUREMENT

A Schopper dynamometer with the two jaws set 4 cm apart and a pre-tension of 50 g weight was used to evaluate the strength characteristics of each fibre. One pencil-marked end of a fibre was fastened to the upper clamp of the hydraulic type single fibre testing machine, while the pre-tension weight was suspended freely from the other end of the fibre and the jaws were then tightened. The continuous rate of water flow was adjusted to break the fibres in about 20 seconds. The upper scale of the dynamometer gave the breaking force in g weight while, the lower one registered elongation in mm. Fibres cut by the jaws or broken adjacent to the jaw ends were discarded.

Calculation

Data on 40 fibres representing the whole range of medullation in heterotype class were analysed. The average values typical of the distributions of the observed L_m, γ_m and γ_f were used to find P_5,

APPENDIX A.—METHOD OF CALCULATING PERECENT MEDULLATION OF SINGLE FIBRES.

Dimensions of medullation				Fibre radius	
L_m micron	$\bar{\gamma}_m$ micron	$\bar{\gamma}_m^2$ (micron)^2	$L_m \times \bar{\gamma}_m^2$ (micron)^3	$\bar{\gamma}_f$ micron	$\bar{\gamma}_f^2$ (micron)^2
0960	3.0	9.00	8640	14.0	196.00
1760	3.5	12.25	21560	14.0	196.00
0120	2.5	6.25	750	15.3	234.09
1520	4.0	16.00	24320	13.3	176.89
0400	3.3	10.89	4356	15.7	246.49
0920	4.5	20.25	18630	15.0	225.00
0320	5.0	25.00	8000	16.7	278.89
0220	5.5	30.25	6655	17.3	299.29
0220	6.0	36.00	7920	14.0	196.00
7000	9.9	98.01	686070	19.3	372.49
10800	9.8	96.04	1037300	19.7	388.09
0140	5.7	32.49	4549	17.7	313.29
6720	11.2	125.44	842800	16.3	265.69
				21.7	470.89
				17.0	289.00
				21.0	441.00
				15.0	225.00

$\Sigma L_m = 31100$ $\quad \Sigma (L_m \bar{\gamma}_m^2) = 2671550$ $\quad \Sigma \bar{\gamma}_f^2 = 4814.10$

$\bar{\gamma}_m$ is the arithemetic mean over a medullary piece showing mostly symmetrical distribution of r_m

$$P = \frac{\Sigma(L_m \times \bar{\gamma}_m^2)}{400\, \bar{\gamma}_f^2} \quad (3)$$

$$= 23.58$$

$$\bar{\gamma}_f^2 = 283.2$$

Table 2.—MICROSCOPIC DATA AND STRENGTH CHARACTERISTICS OF SINGLE FIBRES.

Fibre No.	$\pi \bar{\gamma}_f^2$ (micron)^2	B.F. Breaking force, g. wt	B.S. Breaking stress, CGS gravitation unit $\times 10^4$	Elongation %	To, toughness CGS gravitation unit $\times 10^4$	P% porosity index	$\sqrt{\bar{\gamma}_f^2}$ micron
1.	1152	15.00	130.2	23.25	30.27	26.64	19.15
2.	1172	13.00	111.0	13.00	14.43	02.23	19.34
3.	0982	13.00	132.4	10.00	13.24	08.14	17.69
4.	1462	25.00	171.0	26.00	44.45	00.57	21.56
5.	0739	10.50	142.1	18.25	25.93	23.36	15.34
6.	0759	11.00	144.9	18.25	26.44	08.76	15.55
7.	1575	12.00	076.2	14.50	11.05	45.50	22.40
8.	1197	19.00	158.7	29.50	46.82	02.24	19.53
9.	0949	10.50	110.6	05.00	05.53	06.73	17.38
10.	0970	12.00	123.7	07.50	09.28	00.35	17.59
11.	1002	10.00	099.8	06.00	05.99	27.84	17.86
12.	1174	13.00	110.7	19.50	21.59	08.72	19.34
13.	1138	18.00	158.2	35.00	55.36	12.36	19.04
14.	1064	17.00	159.8	18.00	28.76	00.07	18.41
15.	0836	14.00	167.4	31.50	52.73	00.77	16.32
16.	1223	13.50	110.3	15.00	16.54	27.10	19.74
17.	0783	10.50	134.1	29.50	39.56	03.19	15.79
18.	1119	27.50	245.8	37.50	92.17	08.68	18.87
19.	0806	15.50	192.3	30.00	57.69	06.65	16.02
20.	0760	11.00	144.7	25.00	36.18	02.69	15.55
21.	1096	17.50	159.7	30.00	47.91	09.09	18.70
22.	0773	13.00	168.2	17.75	29.86	00.36	15.70
23.	0804	15.50	192.8	31.00	59.76	07.72	16.00
24.	1040	11.50	110.6	10.75	11.89	11.47	18.20
25.	1323	19.00	143.6	14.25	20.46	00.02	20.52
26.	1164	14.50	124.6	27.00	33.64	02.10	19.25
27.	1046	16.50	157.8	22.00	34.72	00.64	18.24
28.	0815	14.00	171.8	32.50	55.86	19.69	16.11
29.	1316	16.00	121.6	12.50	15.20	10.00	20.46
30.	1248	11.00	088.2	07.50	06.61	01.56	19.47
31.	0939	13.50	143.8	25.00	35.95	03.33	17.26
32.	0948	08.50	089.7	08.25	07.40	19.19	17.37
33.	1174	12.00	102.2	15.00	15.33	01.14	19.33
34.	0919	17.00	185.0	30.00	55.50	14.64	17.11
35.	0890	12.00	134.8	17.50	23.59	23.58	16.82
36.	0735	13.00	176.9	30.00	53.07	01.59	15.31
37.	0993	11.00	110.7	14.50	16.05	39.33	17.78
38.	0899	11.00	122.4	10.00	12.24	03.14	16.91
39.	0733	16.00	218.3	30.00	65.49	11.38	15.27
40.	1159	15.50	133.7	23.25	31.09	10.21	19.21

the medullation percentage by volume employing the following equation:

$$P_s = \frac{\bar{N}_m \bar{L}_m \bar{\gamma}_m^2}{40000\, \bar{\gamma}_f^2} \times 100 \qquad (1)$$

where N_m is the mean number of medullary pieces inside the fibre length, and the factor 4000 has been employed to convert length (4 cm) units from microns to cm. In a symmeterical distribution, as is the case in all the characteristics of the heterotypical fibres, the mean is highly affected by extreme observations and so the either median or mode is the representative class average. However, equation(1) is in conformity with a relation[3] commonly employed in the microscopic measurements of sample medullation by cutting the fibres into short fragments.

The percent medullation P, the cross-sectional area α, the breaking stress S and the toughness T of each fibre were estimated as below:

$$P = \frac{\Sigma L_m \times \Sigma (L_m \gamma_m^2)}{40000 \times \Sigma L_m \times \bar{\gamma}_f^2} \times 100 \qquad (2)$$

$$d = \pi \bar{\gamma}_f^2 \qquad (3)$$

$$S = \frac{F}{\alpha} \qquad (4)$$

$$T = \frac{S \times E}{100} \qquad (5)$$

where $\bar{\gamma}_m$ =mean of the observed γ_m in each medullary piece; $\bar{\gamma}_f^2$ =mean of $\bar{\gamma}_f^2$ over each fibre; $\bar{\gamma}_f^2$ =mean of 3 successive readings of γ_f;

F =breaking force of a fibre; and E=breaking extension per 100 cm fibre length.

The method of calculating P in individual fibres is illustrated in Appendix A. The results of Appendix B are grouped into 12 class intervals to find the relevant coefficients of correlation by the product-moment method. Their levels of significance were estimated on the assumption that the coefficients of correlation in all heterotypical fibres are normally distributed. Where the coefficients of correlation were significant, the equations of regression lines were also derived from the emperical data.

Results and Discussion

The mean values of sample medullation (P_s) obtained by substituting the mean and typical class averages of the parameters in equation(1) are compared with the corresponding value of P_s found by a gravimetric study[4] in Table 2. This comparison, when extended to consider the mean P, *i.e.*, P_s in Table 2, shows that the new method of equation(2) provides more reliable estimates of P. This method is also useful for the assessment of the quantitative relationships between P and other characteristics of single fibres. Such data are given in Table 2.

The parameters in Table 4 are arranged in the order of decreasing variability as indicated by their coefficient of variation. Medullation shows the highest, and fineness the lowest coefficient of variation. A comparison of the mean breaking force and breaking stress (Table 2) with the corresponding values 18.19 gm wt. and 1904 kg/cm², of foreign woosl shows the Bibrik sample to be weaker. This may be largely attributed to the differences in the extent of medullation and in the nuitritional and environmental conditions.

Table 3 gives the coefficients of correlation and regression equations corresponding to significant relationships. These equations are useful in roughly predicting fibre characteristic from the knowledge of an easily measurable parameter. The positive slope (0.9462) of breaking force and the negative slope (–10.27) of breaking stress

TABLE 1.—STATISTICS OF MEDULLATED LENGTH L_m, AND RADIUS γ_m FIBRE RADIUS γ_f AND SAMPLE MEDULLATION P_s.

	L_m	γ_m	γ_f	P_s (%)	Method of finding P_s
Range (μ) ..	60–30660	1–24	10–33	8.65	Gravimetric study
Frequency ..	861	2786	1595		
Mean (μ) ..	3391	6.79	18.10	25.66	Putting mean parameters in Equation 1.
Median (μ) ..	2027	6.54	18.10		
Mode (μ) ..	1000	5.04	19.30	12.50	Putting median L_m and γ_m, mode γ_f in Eq. 1 since mean γ_f =median γ_f
Standard deviation ..	2780	3.08	1.74		
Coefficient of variation	82.00	45.40	9.60		

$\overline{N_m}$= 21.5

TABLE 2.—DISTRIBUTION OF MEDULLATION P, TOUGHNESS T, EXTENSION E, BREAKING FORCE F, BREAKING STRESS S, CROSS-SECTION α AND FINENESS. $\sqrt{\bar{\gamma}_f^2}$

	P (%)	T g cm$+10^4$	E(%)	F g wt	S $\frac{\text{g wt}\times 10^4}{\text{cm}^2}$	α (μ^2)	$\sqrt{\bar{\gamma}_f^2}$ (μ)
Range ..	0.02– 45.50	5.53– 92.17	5.0– 37.5	8.5– 27.5	76.2– 245.8	733– 1575	15.27– 22.40
Frequency ..	40	40	40	40	40	40	40
Mean ..	10.30	31.56	20.50	14.40	141.5	1029	17.94
Median ..	7.10	28.75	22.00	13.63	138.5	1015	17.95
Mode ..	3.00	14.91	29.80	12.89	138.5	1139–788	19.21
Standard deviation ..	9.67	19.51	9.00	3.66	34.35	170.8	1.57
Coefficient of variation (%) ..	93.9	61.20	43.90	25.42	24.27	16.60	8.80

TABLE 3.—COEFFICIENTS OF CORRELATION BETWEEN FIBRE CHARACTERISTICS, THEIR LEVEL OF SIGNIFICANCE AND EQUATIONS OF REGRESSION.

Fibre characteristics	Coefficient of correlation	Level of signifficance	Equations of regression lines
F and $\sqrt{\bar{\gamma}_f^2}$	+ 0.5201	0.01	$F = 2.57 + 0.9462\sqrt{\bar{\gamma}^2}$ (A)
S and α	− 0.5082	0.01	$S = 246.7 - 0.1022\ \alpha$ (B)
S and $\sqrt{\bar{\gamma}_f^2}$	− 0.4696	0.01	$S = 325.7 - 10.27\sqrt{\bar{\gamma}_f^2}$ (C)
S and P	− 0.3666	0.01	$S = 154.9 - 1.302\ P$ (D)
$\sqrt{\bar{\gamma}^2}$ and P	+ 0.2549	0.05	$\sqrt{\bar{\gamma}_f^2} = 17.55 + 0.0381\ P$ (E)
T and P	− 0.2512	0.05	$T = 36.38 - 0.4677\ P$ (F)
E and P	− 0.1717	Non-signifficant	

regression lines on fibre fineness are in agreement with that in the Hashtnagri wool.[6] Similar reverse slopes of the regression lines of the breaking force and stress on the fibre diameter were found in the Australian[7] and South African[8] merino wool, even though disagreement might exist on the issue. [9]

The regression equations (A) and (C) in Table 3 show that, as the fibre diameter increases, the breaking stress decreases much more rapidly than the corresponding increase of breaking force. This may be attributed to the increase in medullation with the increase in diameter. Thus the breaking stress falls off slightly with an increase of fibre cross-section (equation B) and declines sharply with the increase of fibre medullation (equation D). Similarly, toughness diminishes as the fibre medullation increases (equation F), but the fibre extension at break seems independent of its medullation (non-significant coefficient of correlation –0.1717).

Conclusions

1. The breaking force of the heterotypical fibres increases with diameter but the breaking stress declines with the increase of the diameter. Increment of the fibre cross-section is associated with a slight diminution in its breaking stress.
2. Medullation increases with fibre diameter.
3. While the breaking extension is independent of fibre medullation, both the breaking stress and the toughness decrease with the increase in medullation in a fibre. Eventually, medullation in wool diminishes the durability of the product.

Acknowledgement.—The authors are highly grateful to Dr. S.A. Warsi, Director, North Regional Laboratories, P.C.S.I.R., Peshawar, for his interest and inspiration in this work. They are also thankful to Dr. S.M.A. Shah for many suggestions regarding the improvements in the manuscript.

References

1. John H. Skinkle, *Textile Testing*, (Chemical Pub. Inc. New York, 1949), p. 145.
2. *Wool Science Review* (International Wool Secretariat, London) No. 13, p. 38-39.
3. *Ibid*, p. 43.
4. M.A. Ali and Mumtaz Fatima, *Gravimetric Study of Yield and Medullation of Bibrik Wool* (Submitted to the Editor, Pakistan J. Sci. Ind. Res., for publication).
5. Herbert R. Mauersberger, *Mathews' Textile Fibres* (John Wiley and Sons., Inc., New York, 1947), p. 538.
6. Mumtaz Ahmad, Pakistan J. Sci. Ind. Res., **6,** 11 (1963).
7. J. Meybeck and G. Gianola, Procedings of the International Wool Textile Research Conference, Australia, Vol. D, p. 137.
8. Reference 5, p. 537.
9. S.M.A. Shah (Thesis for the Doctorate of Philosophy, University of New South Wales, 1965).