STUDIES ON THE TENSILE PROPERTIES AND THEIR INTERRELATIONSHIP OF HASHTNAGRI WOOL FIBRES

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Hashtnagri wool samples were collected from the various parts of Charsadda and Mardan tehsils. Tests on breaking strength, elongation, stress, tenacity and tensile strength were conducted on the four types of wool viz. true, medullated, heterotypical and kempy. The relationship between diameter to the strength, stress and tensile strength was investigated.

Introduction

The behaviour of wool fibre, i.e., its ability to stretch when a load is applied and also to recover when unloaded is of considerable interest, since wool fibre is subjected to frequent stresses of this kind during the processes of carding, combing and spinning, etc.[1] Moreover, the strength of the fibre has a direct effect upon the strength of the finished product, whether yarn or fabric.[2] So far little work seems to have been done on the strength of Pakistani wools, and the present paper deals with the mechanical properties, i.e., strength, elongation, stress, tenacity and tensile strength of Hashtnagri wool.

Hashtnagri wool samples were collected from the breed home tract, i.e., Charsadda tehsil. Some samples were also collected from Mardan district. Great difficulty was encountered in measuring the strength as Hashtnagri wool contains very fine as well as very coarse wool fibres within one staple. Tests were, therefore, conducted separately on these four types—true, medullated, heterotypical and kempy. Lack of strength in wool is caused by the presence of what is called 'tender wool'[3] and also because of some weak spots on the fibre. The majority of heterotypical and some medullated fibres have weak spots which cause the fibre to break on the application of load.

Experimental

Medullation.—Since the average staple length of Hashtnagri wool is about 3.9″, representative portions were drawn from each of the 50 samples of wool and cut into 3″ length[4] and 0.09 g. of each were taken. The wool samples were then separated into the four types, i.e., true, medullated, heterotypical and kempy, with the help of benzene test.[5]

Dynamometric Measurement.—A Schopper dynamometric apparatus 1 cm. apart and a pre-tension of 200 mg. weight were used. One end of the single fibre was suspended from the upper clamp of the hydraulic type single fibre testing machine, while the pre-tension was suspended freely from the other end of the fibre and then tightened. The flow of water was maintained in such a way that the time to break the fibre was at least 20 seconds. There are two scales on the testing machine, the upper scale representing strength and the lower scale showing elongation in percentage. Measurements were always made at 20°C. and 65% relative humidity, since moisture affects strength and elongation.

Measurement of Diameter.—The diameter was always measured at the breaking point. The fibres were aligned on a slide and were covered by a coverslip, which was secured by glycerine. The magnification of lanameter was × 500.

Calculation

Due to excessive calculation required, it is very difficult to find out the tensile strength of all the 50 samples of three types of wool. It was therefore arranged in order of increasing diameter so as to cover the whole limit.[6] Breaking strength was measured at the time of rupture as well as elongation (%) on the elongation scale. The breaking stress,[7] tenacity[8] and tensile strength were calculated as follows:—

$$\text{Breaking stress} = \frac{\text{Breaking force in mg. wt.}}{\text{Area of cross section in } \mu^2}$$

Tensile strength (p.s.i.) =

$$\text{g./denier} \times 12800 \times \text{sp. gr.}$$

where tenacity (g./denier) = Breaking strength in g./900000 × area of cross section × density.

Density of true wool = 1.304; density of heterotypical = 1.172; and density of medullated = 1.160.

Discussion

It appears from Tables 1 and 2 that there is large variation in strength and elongation of the true, medullated and heterotypical wool fibres stemming from the variation in diameter. Since the percentage of kempy fibres is very low (about 1%), it is not included in the table. It should be noted that the presence of small percentage of kempy fibres in Hashtnagri wool is allowed, as it is suitable for carpet manufacture. On the other hand in woollen and worsted manufacture it is undesirable. The mean strength of kempy fibres has been found to be 23.3 g. and diameter 72.6μ. It has a very low elongation (14.3%). The mean elongation percentage of true, medullated and heterotypical wool were found to cluster, whereas their strength differ widely from one another. Medullated wool is about four times stronger than true wool, while heterotypical wool occupies an intermediate position.

TABLE 1.—DISTRIBUTION OF STRENGTH OF TRUE, HETEROTYPICAL AND MEDULLATED HASHTNAGRI WOOL FIBRES.

Strength g. wt.	True %	Heterotypical %	Medullated %
3-6	26.71	—	—
6-9	36.60	—	—
9-12	21.65	4.28	—
12-15	8.90	5.71	—
15-18	4.08	19.71	4.63
18-21	2.04	20.00	8.73
21-24	—	18.42	11.49
24-27	—	11.71	12.30
27-30	—	5.71	17.82
30-33	—	4.57	10.69
33-36	—	4.71	10.62
36-39	—	1.85	9.35
39-42	—	2.00	4.00
42-45	—	1.28	3.20
45-48	—	—	1.78
48 and above	—	—	5.34
Mean	8.6	21.7	30.6

TABLE 2.—DISTRIBUTION OF ELONGATIONS (%) OF TRUE, HETEROTYPICAL AND MEDULLATED HASHTNAGRI WOOL FIBRES.

Elongation %	True %	Heterotypical %	Medullated %
9-12	1.84	—	—
12-15	2.95	—	—
15-18	5.64	3.61	—
18-21	7.68	5.65	5.11
21-24	10.88	7.80	7.74
24-27	10.60	11.61	9.97
27-30	18.17	18.68	18.76
30-33	18.54	27.47	24.80
33-36	13.83	13.50	17.97
36-39	7.65	8.84	10.82
39-42	2.13	2.82	4.67
Mean	25.5	27.0	28.4

TABLE 3.—DIAMETER, SINGLE FIBRE STRENGTH, BUNDLE (K.G.) STRESS, ELONGATION, TENACITY AND TENSILE STRENGTH OF HASHTNAGRI WOOL FIBRES (TRUE WOOL). MEAN DIAMETER, 25.0 μ.

Diameter μ	No. of fibres	Breaking strength		Stress	Elongation %	Tenacity	Tensile strength
		Bundle kg.	Single fibre g.				
19.2	343	1.81	5.3	18.2	26.4	1.56	1850
21.1	461	3.08	6.7	18.4	21.2	1.67	1981
21.5	377	2.63	7.0	19.2	23.0	1.61	1910
22.6	347	2.42	7.2	17.8	29.0	1.50	1664
24.6	279	2.03	7.3	15.3	29.3	1.31	1553
24.8	277	2.04	7.4	16.2	22.6	1.30	1542
26.5	237	2.06	8.7	15.3	30.4	1.34	1590
26.6	395	3.47	8.8	15.2	30.4	1.35	1602
28.3	509	4.93	9.7	16.2	28.0	1.31	1553
28.4	175	1.71	9.8	16.2	33.3	1.32	1566
29.1	185	1.95	10.6	16.0	32.0	1.36	1613
29.5	260	2.80	10.8	15.8	33.0	1.34	1590

The load/elongation curve drawn by tensile testing machine is shown in Fig. 1. From the point A to point B the curve obeys Hooke's law and is called the Hookean region.[9] It should be noted that there is no decrimping region in Hashtnagri wool, as the crimps/inch is 0.8. In the Hookean region the extension is proportional to the load as demanded by Hooke's law. The slope of the straight line of the Hookean region gives Young's modulus. The slope is practically the same for the three types of wool. The load is the greatest in medullated fibres while least in true wool, which conforms with the readings taken. The part of the curve from B to C is called the yield region. The yield region represents a rapid extension of the

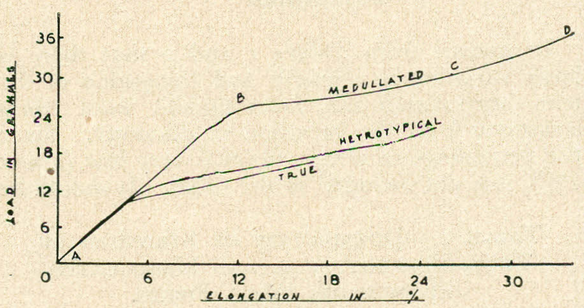

Fig. 1.—Relationship between load and elongation traced by tensile testing machine.

TABLE 4.—DIAMETER, SINGLE FIBRE STRENGTH, BUNDLE (KG.) STRESS, ELONGATION, TENACITY AND TENSILE STRENGTH OF HASHTNAGRI (HETEROTYPICAL) WOOL FIBRES. MEAN DIAMETER, 38.8 μ.

Diameter μ	No. of fibres	Breaking strength		Stress	Elongation %	Tenacity	Tensile strength
		Bundle kg.	Single fibre g.				
33.5	49	0.56	11.5	11.6	24.0	1.10	1175
35.1	90	1.51	16.8	17.2	30.2	1.40	1495
38.2	137	2.54	18.6	13.7	31.4	1.40	1495
39.0	37	0.66	18.0	14.4	30.8	1.30	1388
40.2	238	4.40	18.5	14.5	31.0	1.50	1498
40.2	154	3.03	20.1	12.5	20.6	1.35	1442
40.2	148	3.10	21.0	16.5	30.6	1.29	1378
40.8	175	3.64	20.8	15.9	27.4	1.34	1432
42.2	167	3.50	21.0	14.9	28.2	1.41	1495
44.0	185	4.21	22.8	14.9	31.3	1.29	1378
45.6	240	6.50	27.2	16.6	29.0	1.42	1495
47.0	132	3.40	25.8	14.8	31.3	1.22	1300

TABLE 5.—DIAMETER, SINGLE FIBRE STRENGTH, BUNDLE (KG.) STRESS, ELONGATION, TENACITY AND TENSILE STRENGTH OF HASHTNAGRI (MEDULLATED) WOOL FIBRES. MEAN DIAMETER, 74.8 μ.

Diameter μ	No. of fibres	Breaking strength		Stress	Elongation	Tenacity	Tensile strength
		Bundle kg.	Single fibre g.				
50.0	80	2.34	29.3	14.7	33.6	1.27	1343
51.0	66	1.93	29.3	14.2	34.4	1.22	1288
51.9	97	2.86	29.5	13.6	28.8	1.19	1258
56.5	95	2.84	29.9	12.1	32.2	1.01	1068
59.9	33	0.98	29.9	10.6	28.2	0.90	934
61.5	160	5.58	34.9	11.8	36.0	1.00	1057
64.8	198	6.35	32.1	9.7	26.6	0.83	877
65.5	253	7.89	31.2	9.2	32.0	0.79	835
66.2	153	4.63	30.3	8.7	29.2	0.75	793
69.4	133	4.70	37.4	8.9	28.5	0.84	888
71.0	148	4.58	31.0	11.1	30.6	0.66	698
73.5	109	3.38	31.1	7.4	34.2	0.78	825

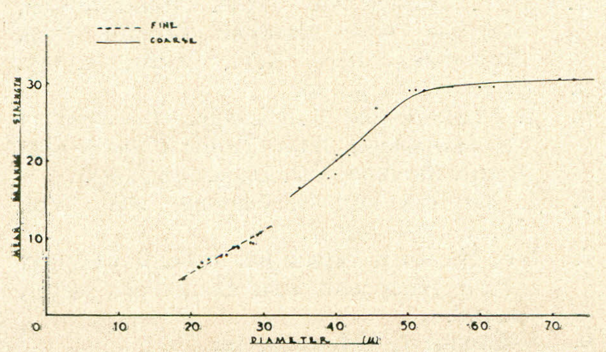

Fig. 2.—Relationship between the breaking strength and diameter of Hashtnagri wool.

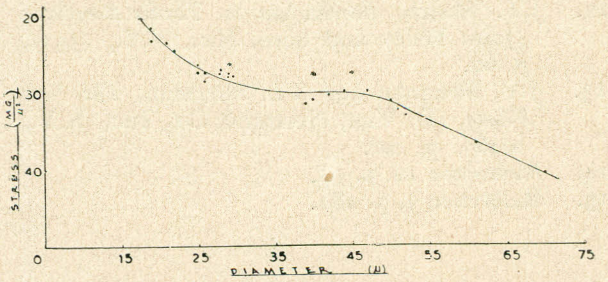

Fig. 3.—Relationship between stress and diameter of Hashtnagri wool.

wool fibres with a relatively small change of load. In this region medullated fibres show greatest extension while true fibres the least. The curve from C to D is called the post-yield region. In this region the fibre again stiffens up and at last the fibre breaks at point D.

If we arrange[10] the three types of wool according to their ascending order of diameter and plot a graph between the diameter and strength, then in the case of true (fine wool) we get a straight line (Fig. 2). The points lie very close to one another. There is also a significant correlation (0.44) between diameter and strength, but in the case of medullated and heterotypical wools (coarse) we get a curve, which is more or less parabolic. The points lie between the first and second power of diameter. The barely significant correlation between diameter and strength of medullated, and heterotypical fibres and their deviation from the ideal curve can possibly be due to morphological differentiation and variation in the quantity of fibre substance of heterotypical and medullated wools. The correlation between strength and diameter is insignificant in the case of medullated and heterotypical wools (Tables 4 and 5).

An attempt was also made to find relation between stress[11] (mg./diameter in μ^2) and diameter. As a rule, stress should decrease as the diameter increases, but here again we face difficulty because the law does not hold good for heterotypical and medullated fibres. True wool obeys the law (Fig. 3). In the case of coarse wool a bend in the curve was observed which shows its roughness. There is also[12] some relation between fineness and extension, but due to variation in individual fibres no clear tendency is evident.

The strength of various fibres may be compared on two different bases—tenacity and tensile strength.[13] The tenacity is generally expressed in g./denier while the tensile strength is measured in terms of strength/unit of cross sectional area. Tenacity[14] is not interchangeable with tensile strength, and the values of tensile strengths are directly comparable but values of tenacities are not. Hence two fibres may have the same tenacity but different tensile strengths, because their tenacities differ, and therefore also their cross sectional areas. As shown in Tables 3, 4 and 5, the tenacity of true wool is the highest and so is its tensile strength, while that of the medullated fibres is the lowest. There is a significant negative correlation (0.31) between diameter and tensile strength in true wool, and negative but insignificant correlation in medullated and heterotypical wools.

Conclusion

From the above discussion it is clear that Hashtnagri wool is divisible into two categories, i.e., fine (true wool) and coarse (medullated and heterotypical wool) which differ considerably from each other. So far as fine wool is concerned we have no trouble when we find relation of diameter to the strength, stress and tensile strength, but in the case of coarse wool it is related to some extent. The following points emerge from the above discussion.

1. Fine wool has a breaking strength varying more closely with the first than with the second power of diameter.

2. Coarse wool[15] has a breaking strength which varies with a figure lying somewhere between the first and the second power of diameter.

3. Tensile strength of wool is negatively correlated with the diameter.

4. In the case of fine wool stress decreases most sharply with the increase of diameter than coarse wool.

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