Pakistan J. Sci. Ind. Res., Vol. 13, Nos. 1–2, August 1970

STUDY ON THE LOAD-ELONGATION CURVE AT LOW EXTENSION OF KAGHANI WOOL FIBRES

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(Received February 1, 1969)

In order to study the tensile properties of dry and wet wool fibres of Kaghani wool, 50 samples were tested for breaking strength and elongation. Moreover, strength at 20% elongation as well as Hookean slope of dry and wet wool fibres, were determined in the case of the three types of fibres. i.e. true, heterotypical and medullated. The variations in cross sectional area were also examined and the relationship between the various parameters were perused.

The behaviour of wool fibres as regards their ability to stretch when a load is applied to them and also to recover when unloaded is a subject of considerable practical interest, since wool fibres are subjected to frequent stresses of just this kind during processing as carding, combing and spinning etc.[1]

Some work has been done in these Laboratories on the force and elongation at breaking point of Pakistani wools on dry fibres (65% R.H. and 20°C) only,[2] but no attention has been given to the mechanical properties of wet wool fibres or at low extension. Since in practice the load is not so high which breaks the fibres, but rapid extension and contraction of the fibre occurs, a study at the low extension is more relevant to the practical conditions in processing. In the present study, 50 samples of Kaghani wool fibres were collected from the home tract of the Kaghani breed which extend from Balakot to Babusar top in the North-Western area of West Pakistan. This breed is considered superior to other Pakistani breeds due to its low medullation content.[3]

If a wool fibre is loaded, it will extend by a certain percentage of its original length. The relationship between load and elongation can be determined experimentaly, over a range of loads up to breaking point and expressed graphically as load-elongation curve. The present study is confined to the breaking force and elongation (%) of dry (65% R.H. and 20°C) and wet (immersed in distilled water for 24 hr) wool fibres. Major emphasis was placed on fibre before rupture i.e. 20% elongation. In this connection force at 20% elongation of dry fibres (F_{20} air) and wet wool fibres (F_{20} wet) as well as Hookean slope of dry fibres (H. air) and wet fibres (H. wet) of true, heterotypical and medullated wool fibres were recorded. The variation in cross-sectional area (A) was also determined and the relationships between the various parameters were examined.

Materials and Methods

The three types of fibres i.e. true, heterotypical and medullated were separated each from 50 samples of Kaghani wool with the help of benzene test.[4] A Schopper dynamometer apparatus[5] (constant rate of loading) which traces the load-elongation curve was employed. About 10 fibres were withdrawn at random from each sample and the length of the fibre was fixed at 3 cm. Breaking strength and elongation of dry (65% R.H. and 20°C) and wet wool fibres (immersed in distilled water for 24 hr) of true, heterotypical and medullated fibres of the 50 samples were determined. In another experiment, fibres of different cross-sections were extended to 20% and the force and Hookean slope determined. The fibre was immediately released and allowed to stand for 10 to 15 mins. Then it was immersed in water for 24 hr and the load-elongation curve was drawn. Thus force at 20% elongation of dry fibres (F_{20} air) and wet fibres (F_{20} wet) as well as Hookean slope of dry fibres (H. air) and Hookean slope of wet fibre (H. wet) were determined as explained by Burte.[6] The diameter of the same fibre of 3 cm length was found at 15 points by a Lanameter (×500) and the cross-sectional area (A) calculated. The coefficient of variation (C.V.) was determined by the rapid method.[7]

Results

Table 1 shows the mean breaking strength and elongation (%) of true, heterotypical and medullated dry Kaghani wool fibres. It is clear that the strength and elongation of medullated fibres have the highest values, while those of true fibres, the lowest. Table 2 shows breaking strength and elongation of wet wool fibres. As compared to dry fibres the breaking strength is slightly lower and elongation greater.

Table 3 shows $\sqrt{A}$, $\sqrt{F_{20}}$ air, $\sqrt{F_{20}}$ wet, $\sqrt{H.}$ air, $\sqrt{H.}$ wet and C.V. ($\sqrt{A}$) of true wool fibres,

TABLE 1.—BREAKING STRENGTH AND ELONGATION (%) OF DRY KAGHANI WOOL FIBRES.

Type of wool	Strength (g wt)		Elongation (%)	
	Mean	Range	Mean	Range
True	12.8	4.6–17.2	34.3	22.8–43.2
Heterotypical	26.2	16.2–37.2	37.5	21.5–50.4
Medullated	29.6	22.1–40.4	41.5	30.8–52.2

TABLE 2.—BREAKING STRENGTH AND ELONGATION (%) OF WET KAGHANI WOOL FIBRES.

Type of wool	Strength (g wt)		Elongation (%)	
	Mean	Range	Mean	Range
True	11.3	4.2–13.4	35.9	25.2–48.6
Heterotypical	23.5	14.1–30.8	39.8	23.2–53.6
Medullated	25.3	17.5–32.3	45.4	24.0.57.6

TABLE 3.—TRUE WOOL FIBRES.

Fibre No.	$\sqrt{A}$ (μ^2)	$\sqrt{F_{20}}$ air (g wt)	$\sqrt{F_{20}}$ wet (g wt)	$\sqrt{H.}$ air	$\sqrt{H.}$ wet	$\sqrt{H.}$ wet/ $\sqrt{H.}$ air	C.V. in $\sqrt{A}$
1.	16.3	1.89	1.71	9.13	8.33	0.91	16.6
2.	16.6	1.90	1.73	9.31	8.44	0.90	10.4
3.	18.9	2.23	2.14	9.25	8.77	0.94	13.9
4.	19.7	2.36	2.23	9.35	8.85	0.94	18.0
5.	20.2	2.68	2.23	9.43	8.94	0.94	18.6
6.	20.9	2.64	2.44	9.89	9.72	0.98	17.2
7.	22.5	2.75	2.44	9.64	9.41	0.97	19.3
8.	23.2	2.89	2.71	9.90	9.81	0.99	15.2
9.	23.7	3.09	2.82	9.79	9.49	0.96	7.4
10.	24.4	3.25	3.06	9.60	9.27	0.96	10.9
11.	25.2	2.82	2.70	9.59	9.42	0.98	13.8
12.	26.5	3.10	2.90	9.86	9.71	0.98	6.6
13.	27.4	2.89	2.75	9.80	9.60	0.97	6.4
14.	28.3	3.47	3.31	10.07	10.00	0.99	10.0
15.	29.1	3.16	2.89	9.71	9.65	0.99	21.2
16.	31.2	3.46	3.34	9.93	9.77	0.98	2.7
17.	32.2	3.74	3.49	10.28	10.24	0.99	8.3
18.	33.5	3.63	3.52	9.85	9.60	0.97	19.2
19.	34.2	3.92	3.49	10.02	10.02	1.00	13.0
20.	34.9	3.84	3.49	9.96	9.72	0.97	12.0
Mean	25.2	2.98	2.75	9.91	9.43	0.96	12.80

TABLE 4.—HETEROTYPICAL WOOL FIBRES.

Fibre No.	$\sqrt{A}$ μ^2)	$\sqrt{F_{20}}$ air (g wt)	$\sqrt{F_{20}}$ wet (g wt)	$\sqrt{H}$. air	$\sqrt{H}$. wet	$\sqrt{H}$. wet/ $\sqrt{H}$. air	C.V. in $\sqrt{A}$
1.	27.1	3.74	3.53	9.76	9.57	0.98	16.3
2.	28.2	3.74	3.31	9.81	9.36	0.94	12.4
3.	28.9	3.87	3.67	9.58	9.36	0.97	17.1
4.	30.3	4.35	4.00	9.78	9.50	0.98	11.3
5.	31.2	4.74	4.52	9.66	9.64	0.99	11.3
6.	32.0	4.35	4.00	10.00	9.42	0.94	11.8
7.	32.9	4.58	4.30	9.71	9.38	0.96	16.1
8.	33.8	5.09	4.35	9.83	9.63	0.97	15.2
9.	34.5	5.00	4.58	9.88	9.81	0.96	15.2
10.	35.3	4.89	4.47	9.85	9.82	0.99	29.6
11.	35.6	4.18	4.00	9.85	9.40	0.95	25.2
12.	36.3	4.47	4.35	9.80	9.70	0.98	9.9
13.	37.0	5.47	5.04	9.85	9.60	0.98	10.9
14.	38.3	4.58	4.30	9.97	9.62	0.96	13.8
15.	39.0	5.24	5.00	9.89	9.72	0.98	13.8
16.	39.9	4.74	4.63	9.86	9.59	0.97	14.0
17.	40.6	4.89	4.63	9.91	9.76	0.98	15.2
18.	43.2	5.47	5.00	9.89	9.64	0.97	16.8
19.	43.9	4.94	4.58	9.97	9.50	0.95	16.2
20.	46.8	5.83	5.33	10.22	9.85	0.96	10.3
Mean	35.7	4.70	4.37	9.85	9.64	0.97	15.1

TABLE 5.—MEDULLATED WOOL FIBRES.

Fibre No.	$\sqrt{A}$ (μ^2)	$\sqrt{F_{20}}$ air (g wt)	$\sqrt{F_{20}}$ wet (g wt)	$\sqrt{H}$. air	$\sqrt{H}$. wet	$\sqrt{H}$. wet/ $\sqrt{H}$. air	C.V. in $\sqrt{A}$
1.	39.0	4.69	4.30	9.90	9.78	0.98	18.0
2.	42.0	4.35	4.24	9.90	9.56	0.96	23.8
3.	44.6	5.74	5.52	9.94	9.56	0.96	19.8
4.	46.2	4.74	4.00	9.92	9.41	0.94	31.8
5.	47.3	5.24	5.00	10.02	9.84	0.98	14.7
6.	48.4	5.56	5.00	9.91	9.75	0.98	18.2
7.	49.6	5.91	5.76	9.90	9.49	0.95	25.9
8.	50.5	4.58	4.35	10.00	9.76	0.96	16.0
9.	51.5	5.47	5.32	10.04	10.00	9.99	20.0
10.	53.3	5.47	5.38	10.00	9.94	0.99	18.2
11.	54.6	5.00	4.69	10.14	9.68	0.95	23.0
12.	56.1	5.47	5.24	10.06	9.81	0.97	16.6
13.	57.6	5.09	4.94	10.00	9.92	0.99	15.4
14.	58.6	5.09	4.47	10.00	9.77	0.97	15.2
15.	62.0	5.00	4.30	9.82	9.48	0.96	26.0
16.	64.0	5.83	5.83	10.09	9.84	0.97	12.6
17.	67.2	5.56	5.43	10.05	10.00	0.99	17.3
18.	74.7	5.47	5.24	10.00	9.77	0.97	10.6
19.	76.0	5.87	5.47	10.57	9.90	0.93	11.9
20.	78.0	5.47	5.09	10.14	9.83	0.96	19.0
Mean	56.1	5.28	4.97	10.24	9.75	0.97	18.8

arranged according to the ascending order of cross-sectional area. Similarly Tables 4, 5, show the various parameters of load-elongation curve of heterotypical and medullated wool fibres.

Discussion

A complete load-extension curve of the wool fibre can be obtained by stretching the fibre upto breaking point (Fig. 1). There are three main regions in the fibre i.e. Hookean region, yield region and post yield region as described by Speakman.[8,9] Apart from this there is also a region which is called decrimping region which is very small and depends upon the crimp in the fibre. The initial Hookean region upto 2% extension (OB) is followed by yield region upto 30% extension) (BC) and a post yield region upto 70% extension (CD). In the Hookean region, extension is proportional to the load which has been attributed to the straining of hydrogen bonds in the α-helices.[10] In yield region a rapid extension occurs which is due to unfolding of the α-helical structural units of the wool fibre. It should be noted that if a fibre is stretched upto 30% in water and put in water for 24 hours, the load-extension curve is reproducible. In post yield region disulphide bonds break.[11] It may be noted that previously Astbury[12] had shown that at about 20% extension, the diffraction pattern remains virtually unchanged, but recently Bendit has shown that the α-pattern begins to change from a few percent extension.[13,14]

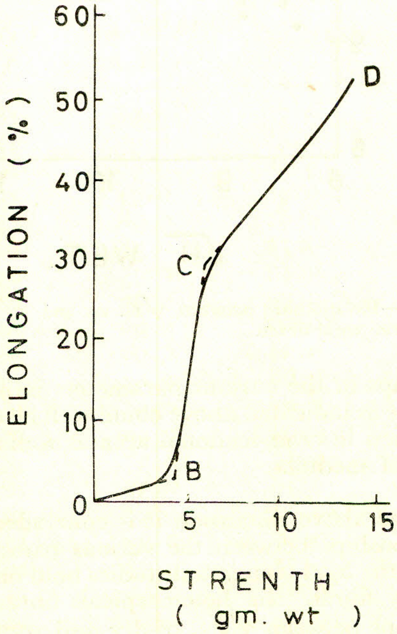

Fig. 1.—A typical load-extension curve showing different regions.

The large range in breaking force and elongation(%) of Kaghani dry and wet wool fibres (Tables 1,2) indicates that there are large variations in force and elongation. It is also clear that there are some differences in breaking force and elongation in dry and wet wool fibres, the values for the latter being lower. It is very difficult to stretch these dry fibres beyond 30% extension, whereas the wet fibre stretched upto 60%. From Table 2, it is evident that some fibres break before 30% (wet state) which indicate some damage.

The various parameters of load-extension curve, arranged according to the ascending order of $\sqrt{A}$ of true wool are given in Table 3. $\sqrt{F_{20}}$ is plotted against $\sqrt{A}$ for both dry and wet cases. In both the cases, a linear relationship is revealed (Fig. 2). This confirms the results of Lindberg.[15] The same trend is evident in heterotypical wool fibres, although there is some increase in the scatter. (Fig. 3). In medullated wool, the scatter increases further and the overall relation is very poor. Thus it is clear that with the increase of medullation, the relationship between $\sqrt{F_{20}}$ and $\sqrt{A}$ diminishes.

An attempt was made to correlate $\sqrt{A}$ with $\sqrt{H.}$ air and $\sqrt{H.}$ wet true wool fibres. It is evident (Fig. 4) that a linear relationship exists between $\sqrt{A}$ and $\sqrt{H.}$ air confirming previous work of Lindberg.[16] However, when $\sqrt{H.}$ wet is plotted against $\sqrt{A}$ (Fig. 5), there is a slight increase in the scatter, the trend being the same. It is also interesting to note that a strong linear relationship exists between $\sqrt{H.}$ air and $\sqrt{H.}$ wet in the case of true wool fibres (Fig. 6) as reported in previous

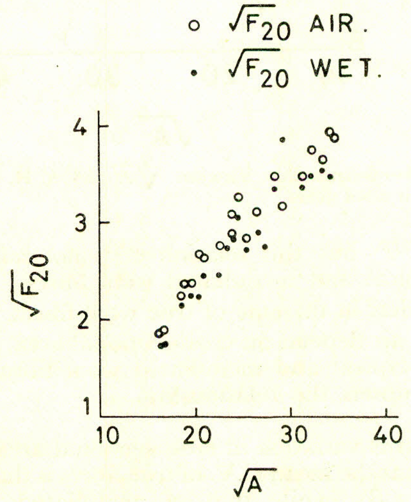

Fig. 2.—Relationship between $\sqrt{A}$ and $\sqrt{F_{20}}$ of dry and wet Kaghani true wool fibres.

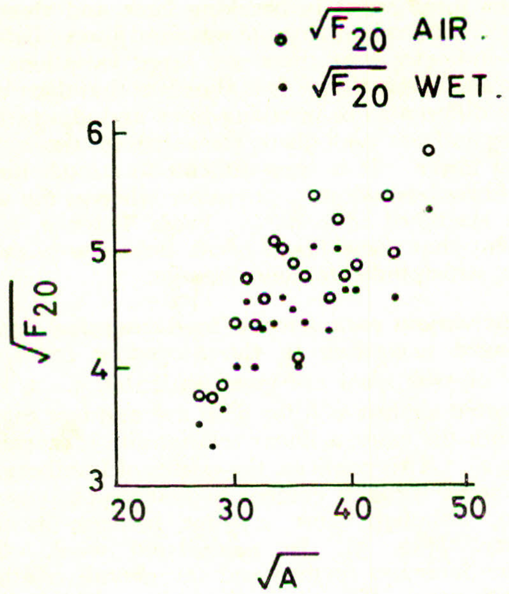

Fig. 3.—Relationship between $\sqrt{A}$ and $\sqrt{F_{20}}$ of dry and wet heterotypical Kaghani wool fibres.

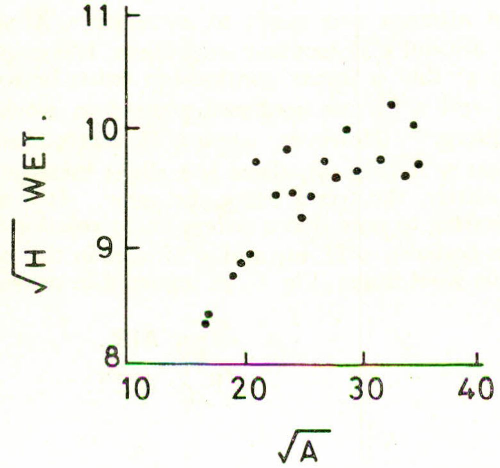

Fig. 5.—Relationship between $\sqrt{A}$ and $\sqrt{H.}$ wet of true Kaghani wool fibres.

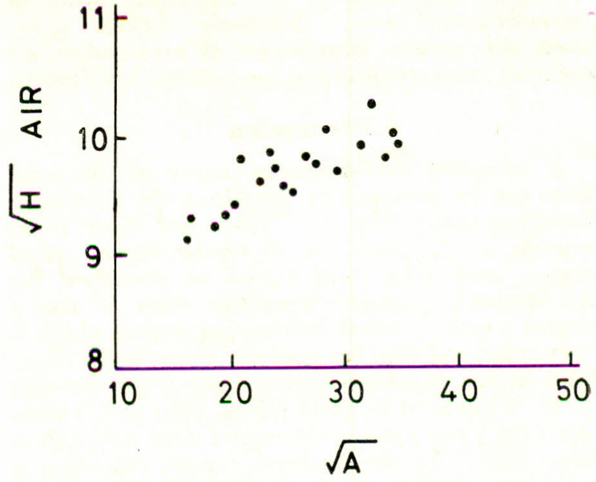

Fig. 4.—Relationship between $\sqrt{A}$ and $\sqrt{H.}$ air at 65% R.H. of true Kaghani wool fibres.

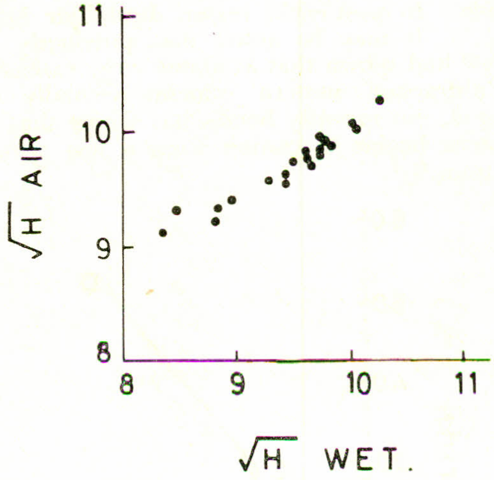

Fig. 6.—Relationship between $\sqrt{H.}$ air and $\sqrt{H.}$ wet of Kaghani true wool fibres.

studies,[17,18] but this relation does not hold for heterotypical and medullated wool fibres. Thus it seems that in the case of true wool fibres, $\sqrt{H.}$ wet $\sqrt{H.}$ air depend on cross-sectional area, while in heterotypical and medullated wool fibres, the medulla upsets the relationship.

As regards variation in cross-sectional area, it is evident that the mean C.V. of true fibres is the least (Mean 12.8), while that of medullated fibres (Mean 18.8) the highest; heterotypical fibres occupy intermediate position. The absence of relationships in the various parameters in medullated fibres as indicated above could well be due to the variation in cross-sectional area as well as the presence of medulla.

From the above discussion it is concluded that the relationships between the various parameters related to the load-elongation studies hold only for true wool fibres. In heterotypical fibres, the relationships between $\sqrt{F_{20}}$ of dry and wet wool fibres and $\sqrt{A}$ still hold but all these patterns practically vanish in the case of medullated fibres.

Acknowledgement.—The authors wish to thank Dr. S.A. Warsi, Director, PCSIR, Laboratories, Peshawar, for the facilities provided to carry out this work. They are also thankful to Dr. S.M.A. Shah of these Laboratories for improvement in the manuscript and to Abdul Rashid for his help in some of the experimental work.

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