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Staple Strength as a Measure of the Soundness of Wool — A Preliminary Note

by

E. Gee

SOUTH AFRICAN
WOOL AND TEXTILE RESEARCH
INSTITUTE OF THE CSIR

P.O. BOX 1124
PORT ELIZABETH
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STAPLE STRENGTH AS A MEASURE OF THE SOUNDNESS OF WOOL — A Preliminary Note

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ABSTRACT

Using the techniques developed by other workers experiments have been made which demonstrate the usefulness of staple strength as a reflection of wool soundness. A good topmaking style of wool gave a higher strength and lower spread of results than an inferior topmaking wool. A significant negative correlation was found between the mean strength and its CV. The suspected inferior style of a certain wool was confirmed by its low staple strength value. Wools subjectively assessed as tender gave very low strength values (less than 2,3 cN/tex). A high correlation (93%) between the combing tear and staple strength, and lower correlations with decrease in length were found for the data of seven commercially processed wools.

A tentative scale suggests that sound wool has a staple strength greater than 4 cN/tex while an unsound wool gives less than 3 cN/tex.

INTRODUCTION

The wool industry has learned by experience to recognise and subjectively appraise those properties of greasy fleece wool which influence the processing performance and quality of the end product. These properties include yield, fineness, length, crimp, soundness and style. In recent years the development and use of scientific measurements for yield, fineness and length (and crimp) has taken place. These are considered to be the more important properties.

Although the soundness of wool is of lesser importance it does have an important effect on the value of the wool. Onions[1] describes the soundness of a wool staple as its capacity to withstand tension. He reports that a wool is unsound when the breaking tension is about one quarter of that of sound or normal wool, that is, when the maximum finger tension of about 5 kgf or 50N will break a staple. The subjective assessment of the soundness of wool is made by gripping a staple between thumb and finger of each hand and applying an extension force and a lateral impulse with the third or fourth finger to the staple. The quality of the staple is judged from its response which can range from the highly resilient resonant response of sound wool to the dull slow response or even breakage of fibres for unsound wool. Lack of soundness, which is usually associated with thin places along the fibre (reflecting inferior growth due to such factors as poor nutrition or ill-health), can give excessive breakage of the fibres during carding and combing[2]. The ensuing extra noil and the reduced mean fibre length adversely affect the economics of production.

Workers[3-10] in New Zealand have shown a linear relation between breaking load and hand-assessed grade. They also showed that the hand test developed a force of about 50N.

Bratt, Ross and Story in New Zealand and Roberts, James and Burgmann[11] in Australia have developed test methods similar to the one reported here. The breaking load of a cleaned weighed staple, having a length of about 4 cm between the grips and whose fibres are roughly evenly tensioned, is measured. Serrated grips to ensure non-slippage of the test piece are necessary. Although this method only measures the strength in the middle 50% of the staple, it is believed that this is the important region. Centre breakage leads to large reductions in mean fibre length while end breakage gives higher noil which may be of lesser importance.

Holdaway[12] has developed a "wisp" test, which records the breaking load of about 100 fibres from a staple while Samson and White[13] have reported a ballistic or impact pendulum method which correlated well with the extension test and was a rapid method. Onions *et al*[14] describe a machine to rapidly measure the strength of fibre bundles.

Techniques for measuring the extension breaking strength of staples have been examined in the work reported here. Some typical values for sound and tender wools and their relations to other properties are given.

EXPERIMENTAL AND DISCUSSION OF RESULTS

Sample Grips

The capstan principle using interleaved V-shaped plates, as suggested by Caffin[15], is used as the basis for holding the staple test piece while its strength is measured in an Instron tensile tester. Each half of the jaws consist of four V-slotted plates of three mm thickness and spaced three mm apart to allow interleaving with the other half. The jaws sit in an open rectangular cage which has walls of six mm thickness. Side screws through the wall enable the jaws to be forced together. One face of the cage is open to give space for the wool staple and the opposite face is able to be coupled to the Instron machine. The lower jaws are held against the upper side of the lower cage by two metal blocks.

The gauge length is made as long as possible consistent with non-slippage in the jaws. The arrangement is such that if the full depth of jaw is used to clamp a staple then the minimum staple length that can be used is 60 mm — made up of 24 + 6 + 6 + 24 mm . By using less than the full jaw depth the limits can be reduced to about 45 mm . This is about equal to the shortest staple that can be hand tested. The breaking length i.e. that between the upper and lower jaws at worst is 25% of the staple length. For longer staples a higher proportion of the length is subjected to the breaking force.

Test Sample Preparation and Strength Measurement

A portion (about 0,50 g), is gently split from a selected greasy staple and is secured in the test jaws on the machine. The length of staple between the jaws (L cm) is measured when the preload is 100 g . After the test piece has been broken in the machine using a crosshead speed of 500 mm/min the fibres exposed by the jaws are cut, solvent scoured, dried and conditioned in a standard atmosphere and then weighed (M grammes). From the maximum recorded force (F kg) the breaking stress is calculated by the formula

$$\text{Breaking Stress} = \frac{F\,L\,D}{M}\ \text{Kgf/cm}^2$$

where D = density of fibre (1,31 g/cm^3 for wool)

The strength is expressed in units of cN/tex using the relation

$7{,}48 \times 10^{-3}$ cN/tex = 1 Kg/cm^2

The high CV of the results suggests that 25 or preferably 49 or more replicates are to be tested.

Experiment 1

Three grease wools classed as of Good, Average and Inferior Topmaking style respectively were used to investigate the influence of the speed of the crosshead on the breaking strength. Ten tests from each sample, at each of 100, 50 and 20 cm/min cross head speed, were measured.

The results obtained are given in Table I.

TABLE I

STRENGTH (cN/tex) OF WOOLS AT VARIOUS CROSSHEAD SPEEDS OF TESTS

SAMPLE STYLE \ SPEED, CM/MIN		100	50	20	AVERAGE VALUES AND 95% Confidence Limits
Good	cN/tex	4,79	4,26	5,38	4,81 ± 2,9%
	CV %	7	6	11	8
Average	cN/tex	3,06	3,78	3,66	3,50 ± 6,2%
	CV %	23	15	14	17
Inferior	cN/tex	3,27	2,75	3,39	3,47 ± 8,4%
	CV %	17	15	18	23
Average	cN/tex	3,70	3,93	4,14	
Average	CV %	16	15	18	

These results suggest a slight trend towards higher values at lower speeds. As the speed was reduced from 100 cm/min to 20 cm/min, the strength was increased by about 10%.

The Average and Inferior Topmaking wools gave lower strength results than the Good Topmaking wool (3,5 versus 4,8 cN/tex). The CV values showed that the lower quality wools had higher variations in strength, (8% to 23%).

Experiment 2

Twenty test pieces were prepared and tested from each of twelve grease wools which were used in the work reported by Turpie[16]. Their mean strength and CV are given in Table II.

This table shows that a range of values for strength and their CV's were obtained. It is interesting to note that the strength or tenacity of the outsorts tended to be lower than the values for the fleeces. The data shows that a high strength correlates with a low CV, the relation being CV = 63,3 − 11,1 cN/tex with a correlation coefficient of 0,933. Results obtained by other workers[8] show that similar correlation exists.

This equation can be interpreted by assuming that a good wool contains staples of uniformly high strengths and that inferior quality wools contain a higher proportion of weak staples.

TABLE II

STAPLE STRENGTH (TENACITY) OF A SELECTION OF GREASY WOOLS

DESCRIPTION		BREAKING STRENGTH (cN/tex)	
Style	Classing Length (Month)	Mean	CV %
Spinners Fleeces	8/10	4,1	19,4
Good Top fleece	8/10	4,4	14,4
Av. Top fleeces	8/10	4,4	15,6
Av. Top backs	8/10	3,8	20,9
Av. Top broken	8/10	3,5	25,1
Av. Top lambs	8/10	4,0	16,6
Av. Top bellies	8/10	4,0	17,9

Experiment 3

Two commercial samples of grease wool were tested, one of which was believed to be of inferior quality. Five staples were selected from each of four clumps (part fleeces) from each sample. Each set of results had a CV of 12% and their mean strength values were 3,42 cN/tex and 2,62 cN/tex which confirmed the inferior character of the one sample.

Experiment 4

Nineteen samples of wools, subjectively classed as tender, were obtained from a farm. Their measured strengths were all less than 2,3 cN/tex. The range was 0,70 to 2,27 cN/tex and with an average value of 1,63 cN/tex.

These values suggest that wools of inferior quality have a staple strength of less than about 3 cN/tex.

Experiment 5

Thirty tests for each of seven commercial lots of raw wool were tested and their average staple lengths were measured. Table III lists the staple strengths and lengths obtained and some properties of the tops which were processed commercially.

Correlations of strength with each of several other parameters were calculated. Correlations with % fibres shorter than 25 mm in the top, with % length change (using the ratio of H or B to staple length) and with combing tear gave

% fibres shorter than 25 mm = – 1,8 x strength + 9,0;
r = 0,53, not significant at the 80% level
% H = 3,4 x strength + 63,9; r = 0,64, significant at the 83% level
% B = 4,5 x strength + 77,0; r = 0,61, significant at the 80% level
tear = 10,5 x strength – 11,7; r = 0,71, significant at the 93% level

TABLE III

STRENGTH, COMBING TEAR AND PROPERTIES OF THE TOP FOR SOME COMMERCIAL SAMPLES

Sample	Staple Strength (cN/tex)	Staple Length unstretched (mm)	Hauteur (H) (mm)	Barbe (B) (mm)	% Fibre less than 25 mm	Combing tear
1	3,50	92	74,5	91,3	2,0	27,8
2	3,02	91	67,5	81,7	3,4	19,4
3	3,36	82	68,1	83,5	4,1	20,2
4	2,89	90	72,6	88,5	3,3	22,0
5	3,16	86	70,3	85,8	3,2	20,8
6	2,88	83	66,5	81,7	4,2	16,4
7	3,08	91	72,6	88,5	4,1	21,1

There are therefore objectively described indications that the quality of the processed material can be affected by the strength of the staples. This is especially true of tear which had a higher value for stronger staples. Higher strength could also give a better length when processing raw wool into top.

A tentative scale of staple strength or tenacity values can be made from the above results. A value greater than 4 cN/tex can be expected for sound wool, while a wool having a strength of less than 3 cN/tex can be regarded as unsound.

Henderson[17], quoting W. von Bergen, gives a value of about 12 cN/tex for the tenacity of single wool fibres of 20 µm diameter. This value is considerably higher than the values of staple strength measured in this work. The difference can probably be attributed to the progressive breaking of fibres in the staple during testing. The peak force will be less than could be expected if all the fibres broke at the same time. Nevertheless, the test does appears to discriminate between wools of different soundness.

SUMMARY

Using the techniques developed by other workers experiments have been made which demonstrate the usefulness of the staple strength measurement as a reflection of wool soundness. Good topmaking style wool gave a higher strength and lower spread of results than inferior topmaking style wool. A significant negative correlation was found between the mean strength at its CV.

Other findings were that wool suspected to be of inferior quality had a low staple strength value, that wools subjectively assessed as tender gave very low strength values (less than 2,3 cN/tex) and that a high correlation (93%) between the combing tear and staple strength, and lower correlations for % loss in length existed in the data for seven commercially processed wools.

APPENDIX

Some theoretical considerations of fibre weakness

Assume that weak regions in fibres reflect only volume changes and not inherent strength changes.

Consider three cases. For case 1, assume that the test staple contains uniform fibres of length L and radius R1. For case 2 assume the fibres of case 1 each contain a weak region of smaller fibre radius R2 which occupies virtually no length. In the third case assume that the weakness of case 2 extends for a fraction K of the length. Thus we have the basic shapes of a cylinder, a notched cylinder and a dumbell shaped cylinder.

For a given mass M of fibres of density D, each fibre having a strength S per unit cross-section, we have:-

Case 1

Cross-sectional area of sample $= \dfrac{M}{DL}$

Cross-sectional area of 1 fibre $= \pi R1^2$

$\therefore$ number of fibres $= \dfrac{M}{DL \pi R1^2}$

Breaking force of 1 fibre $= S \; R1^2$

Breaking force of sample $= \dfrac{SM}{DL}$

Case 2

Assume all fibres break at the notch.

The cross-sectional area at the notch $= \pi R2^2$

The number of fibres $= \dfrac{M}{DL \pi R1^2}$

The breaking force of one fibre $= S \pi R2^2$

The breaking force of the sample $= S \pi \dfrac{R2^2 \; .M}{D.L \pi R1^2} = \dfrac{SM.}{DL} \dfrac{R2^2}{R1^2}$

Case 3

Volume of one fibre $= (1 - K) L \pi R1^2 + KL \pi R2^2$

Volume of sample $= \dfrac{M}{D}$

Therefore number of fibres $= \dfrac{M}{\pi LD [(1\text{-}K) R1^2 + KR2^2]}$

Breaking force on one fibre $= S \pi R2^2$

Breaking force on one sample $= \dfrac{MS \pi R2^2}{\pi LD [(1\text{-}K) R1^2 + KR2^2]}$

$$= \frac{SM.}{LD} = \frac{R2^2}{(1\text{-}K) R1^2 + KR2^2}$$

$$= \frac{SM.}{LD} \; F$$

where F is the breaking force of the sample as a fraction of that of a sound sample. Incidentally, the value of F as K tends to zero equals $\dfrac{R2^2}{R1^2}$

which corresponds to case 2.

Let $f = \frac{R2}{R1}$ the fractional ratio of the two radii,

then $F = \frac{f^2}{1 - K + Kf^2} = \frac{f^2}{K(f^2 - 1) + 1}$

Tabulated values of F for various K and f values are given in Table IV.

TABLE IV

FRACTIONAL BREAKING FORCE FOR "WEAK FIBRES" OF VARYING DIMENSIONS

K / f	0,1	0,3	0,5
0,9	0,83	0,86	0,90
0,7	0,52	0,58	0,66
0,5	0,27	0,32	0,40

Thus if the neck or notch extends for one tenth of the test length of the fibres and the diameter is 0,7 of the normal value then the breaking force of such a sample (of given mass) will be about half (0,52) of an equivalent good sample and will be two thirds if the neck extends over half of the fibre length.

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REFERENCES

1. Onions, W. J., Wool: An Introduction to its Properties, Varieties, Uses and Production, Ernst Benn Ltd (1962), p.116.
2. Walls, G. W., Wool Characteristics of Processing Importance, *Wool Technol. Sheep Breed,* **21,** 27 (1974).
3. Ross, D. A., New Zealand 48s Count Romney Crossbred Wool, *N.Z. J. Agric. Res.,* **2,** 214-228 (1958).
4. Ross, D. A., Staple Strength, I: The measurement of Staple Strength, *N.Z. J. Agric. Res.,* **2,** 503-525 (1960).

5. Ross, D. A., The Strength of Fibre Bundles and Tops, *J. Text. Inst.,* **51,** T240-259 (1960).
6. Ross, D. A., Staple Strength III: Variations through the Wool Selling Season, *N.Z. J. Agric. Res.,* **4,** 523-37 (1961).
7. Ross, D. A., Staple Strength II: Some Factors Affecting the Measurement of Staple Strength, *N.Z. J. Agric. Res.,* **4,** 57-71 (1961).
8. Story, L. F. and Ross, D. A., Effect of Shearing Time on Wool, IV: Effect on Fleeces, *N.Z. J. Agric. Res.,* **2,** 1096-1103 (1959).
9. Ross, D. A., Bratt, R. L. and Story, L. F., The Effect of Staple Strength on Carding and Combing, *J. Text. Inst.,* **51,** T907-921 (1961).
10. Bratt, R. L., Ross, D. A. and Story, L. F., The Effect of Staple Strength on Worsted Processing, *J. Text. Inst.,* **55,** (3), T165-174 (1964).
11. Roberts, N. F., James, J. F. P. and Burgmann, V. D., Tenderness in Fleece Wool, *J. Text. Inst.,* **51,** T935-952 (1960).
12. Holdaway, H. W., A "Wisp" Test for Mechanical Properties of Raw Wool, *Text. Res. J.,* **39,** (3), 228-233 (1969).
13. Samson, A. and White, M. A., A Ballistic Determination of the Toughness of Wool Staples, *Text. Res. J.,* **40,** (9), 803-809 (1970).
14. Onions, W. J., Oxenham, W., Townhill, P. A., The Rapid Measurement of the Tensile Properties of Fibre Bundles, *J. Text. Inst.,* **68,** (11), 370 (1977).
15. Caffin, R. N., A Clamp for the Tensile Testing of Fibre Bundles, *J. Text. Inst.,* **67,** (1), 33 (1976).
16. Turpie, D. W. F., The Processing Characteristics of South African Wools, Part VI: The Influence of Style, Length and Class Description on the Processing Performance up to Combing of Mixtures of South African Wools, *SAWTRI Techn. Rep.* No. 250 (1975).
17. Henderson, A. E., Growing Better Wool, A. A. and A. W. Reed, Sydney, 1968, p.40.

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