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STUDIES ON THE CRIMP FORM OF DIFFERENT TYPES OF WOOL

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An attempt was made to investigate the relationship between crimp form and other crimp parameters, such as crimp frequency and amplitude, but no correlation was found. However, % length (% increase in length on straightening based on crimped length) gave highly significant partial regression coefficient on crimp form, crimp frequency and amplitude. Variations in crimp form are associated with differences in fleece density. In high density fleeces, the crimp configuration is planar, whereas in low density fleeces, the fibres have a helical form.

Introduction

In addition to the overall staple crimp, individual wool fibres also possess a number of crimps of various configurations. Considerable work has been done on the causes of crimp and the measurement of crimp in the staple form, but little attention has been given to the crimp form of the individual fibre itself, although spiral form in wool fibres was reported as early as 1926.[1]

Three different spatial configurations for single wool fibres have been suggested, namely a twisted sine wave, a helix and a sine wave.[2-4] However, in recent years,[5] it has been shown that no single form can suitably describe all crimped wool fibres and that different samples have significantly different crimp forms. It is, therefore, impossible to assume in general, a typical crimp form for a particular sample. Variations in this form have marked effects on the handle, felting and compressional properties of loose wool.[6] The present study was undertaken with the following objectives:

(1) Relationship between crimp form, frequency and amplitude were investigated. The study was further extended to include the relationship of % length to crimp form, frequency and amplitude.

(2) Speakman and his co-workers[7-9] have investigated the relationship between fibre substance and end use. It was considered necessary to invesigate the influence of crimp parameters in the case of wools for different end use, demonstrated by these workers to be differing in "plasticity".

(3) It has been observed[6] that the crimp configuration of low density fleeces have helical form, whereas that of high density are planar. It was felt that an examination of these types could provide some further support for the view that fleece density is a significant factor in crimp form determination.

Materials and Methods

Wool Samples.—The following wool samples were included in the present study. Most of these have been used in previous studies[6,10] and have, therefore, been described by the same identification numbers.

(a) Low plasticity
- (i) Pinda
- (ii) Sample 109
- (iii) Sample B

(b) High plasticity
- (i) Sample 127
- (ii) Sample C

(c) Low density mutant
- (i) Sample 218-H
- (ii) Sample 291-H

(d) Merino
- (i) 64's
- (ii) Sample A

(e) Helical
- (i) Southdown

(f) Sine
- (i) Merino lambs

(g) Carpet wool
- (i) Hashtnagri
- (ii) Lohi
- (iii) Harnai

The above samples were purified by Soxhlet extraction with diethyl ether, followed by soaking in ethyl alcohol and finally washed with distilled water.

Method.—About 3 cm lengths of fibre were taken at random from the root ends of the staples and mounted with gummed paper at each end. After conditioning at 65% R.H. and 21°C for 24 hr, 10-12 fibres were measured from each sample.

The apparatus[5] consists of a clamping device for the wool fibre, which can be rotated at varying speeds or stationed at any desired angle of rotation. The clamps have centering screws and are attached to a frame which is used to extend the fibre to any required length. An optical system produces an image of the fibre and clamps at a magnification of ×10 and rotation produces a 'solid of revolution'. When the fibre is properly centered and rotated at a constant speed, the 'buckling length,' l_0, which is the crimped length when buckling just disappears, can easily be determined and the various parameters such as crimps/mm, mean amplitude and straight length measured. The straight length is then compared with the theoretical straight length for a fibre with similar wave length and frequency, obtained from graphs, prepared separately for both helical and sine form equations. An arbitrary value for the crimp form (score) is given by

$$\text{Score} = \frac{(S - S_S) \times 100}{S_H - S_S}$$

Where S_H = Theoretical straight length from the helical equation.

S_S = Theoretical straight length from the sine equation.

S = Experimental straight length.

A zero score represents a perfectly sinusoidal form, while a score of 100 represents a perfectly helical form.

Statistical Analysis.—Regressions of crimp form (score) on crimp frequency, amplitude and % length (% increase in length on straightening, based on buckled length) were calculated for individual samples. The total and pooled regressions were also calculated. To test further whether the slopes differed significantly or not, analyses of co-variance were employed.

To determine the relative significance of crimp form, crimp frequency and amplitude, a multiple regression model was used with % length (Y) as dependent variable and crimp form (n_1), crimp frequency (n_2) and amplitude (n_3) as independent variables.[11]

Results

Table 1 shows the mean values of crimp form (score), crimps/mm, amplitude and % length of the samples.

Regression of crimp form on crimp frequency was calculated for individual samples as shown in Table 2. Only two samples were found with significant regression coefficients having opposite slopes and the total and pooled regressions were found to be non-significant. Analysis of co-variance shows that there is no significant difference between the slopes. The regression of crimp form on amplitude gives three samples with significant regression coefficients and one sample with opposite slope. The pooled regression gives a significant result and the analysis of co-variance shows a significant difference between the slopes. The regression of crimp form on % length shows six samples with significant regression coefficients and the total and pooled regressions give significant results. Analysis of co-variance shows significance only for total regression.

Multiple regression of 124 fibres comprising 11 samples shows that crimp score, crimp frequency and amplitude account for 52% of the variations in %length. Reduction in variation accounted for, by dropping crimp form, is 33%, while when crimp frequency and amplitude are dropped, the reduction in variation accounted for is 31% and 28% respectively. Regression of % length on the three parameters i.e. crimp score, crimp frequency and amplitude taken together gives significant results. However, the test of significance on parameters taken separately (Table 3) showed that whereas crimp form and frequency were significant (at the 1% level) amplitude was not. Multiple regressions were also found for the 11 samples taking % length as the dependent variable. It was found that 81% of the variation was accounted for by the three parameters namely crimp form, amplitude and crimp frequency. Individually the variation accounted for by crimp form was 68% and the reduction in variations accounted for by dropping amplitude and crimp frequency were 30% and 31% respectively. Regression of % length on these three parameters was found to be significant but individually only crimp form was found to be significant (Table 3). However, the significance of the partial regression coefficient of % length on crimp form, crimps/mm and amplitude gives highly significant results for the means as well as for all the 124 fibres (Table 4).

Discussion and Conclusions

It is important to note that the majority of the fibres are quite irregular in shape (Fig. 1) along their length and that the crimp scores are approximate. Types I, II, III are found in Southdown and low density mutant, with type II, the most

TABLE 1.—MEAN VALUES OF CRIMP PARAMETERS.

Sample	Crimp form (Score)	Crimps/ mm	Amplitude (mm)	Length %
Low plasticity				
(i) Pinda	57.1	0.351	0.441	30.7
(ii) 109	42.0	0.408	0.339	22.6
(iii) B	61.9	0.428	0.293	21.2
High plasticity				
(i) 127	19.7	0.296	0.329	10.1
(ii) C	31.4	0.516	0.244	17.6
Low density mutant				
(i) 218-H	137.4	0.283	0.380	23.6
(ii) 291-H	141.1	0.279	0.366	21.0
Merino				
(i) 64's	29.2	0.215	0.588	16.9
(ii) A	–1.4	0.233	0.480	10.1
Helical				
(i) Southdown	149.2	0.354	0.339	28.6
Sine				
(i) Merino lamb	–8.9	0.362	0.305	10.2

TABLE 2.—REGRESSION OF CRIMPS FORM (SCORE) ON CRIMPS/mm, AMPLITUDE AND % LENGTH.

Sample	" t " Values		
	Crimps/mm	Amplitude mm	Length %
Pinda	–0.05	0.68	1.45
109	–2.61*	0.60	0.48
B	0.01	–0.89	3.19**
127	0.84	–1.14	5.10**
C	0.65	–2.74*	2.54*
218-H	–1.88	3.90**	3.37**
291-H	3.44**	–1.28	3.50**
Merino 64's	0.79	–3.57**	–0.30
Merino A	0.42	–0.93	1.84
Southdown	–0.29	–1.07	0.19
Merino lamb	–0.59	–1.65	6.22**
Total regression	–0.65	–1.57	5.23**
Pooled regression	–0.52	–3.19**	6.82**

* Significant at 5% level. ** Significant at 1% level.

TABLE 3.—TEST OF SIGNIFICANCE OF % LENGTH ON CRIMP FORM, CRIMPS/mm AND AMPLITUDE.

	Crimp Parameter	Source of variation	Degree of freedom	Sum of squares	Mean square	F
124 fibres	Crimp form	Regression	1	1605.2	1605.2	27.39**
		Deviation	122	7156.1	58.6	
	Crimps/mm	Regression	1	404.1	404.1	5.89**
		Deviation	122	8357.2	68.5	
	Amplitude	Regression	1	88.1	88.1	1.24
		Deviation	122	8673.2	71.0	
Mean of 11 samples	Crimp form	Regression	1	254.6	254.6	8.95*
		Deviation	9	256.0	28.4	
	Crimps/mm	Regression	1	25.8	25.8	0.48
		Deviation	9	484.8	53.8	
	Amplitude	Regression	1	50.1	50.1	0.88
		Deviation	9	510.6	56.7	

* Significant at 5% level. ** Significant at 1% level.

TABLE 4.—SIGNIFICANCE OF PARTIAL REGRESSION COEFFICIENTS OF % LENGTH ON CRIMP FORM, CRIMPS/mm AND AMPLITUDE.

	Source of Variation	Degree of freedom	Sum of squares (Regression)	Mean square	F
Mean of 11 samples	Crimp form	1	358.4	358.4	26.1**
	Crimps/mm	1	169.6	169.6	12.3**
	Amplitude	1	162.8	162.8	11.8**
	Deviation	7	96.3	13.7	
124 fibres	Crimp form	1	2858.0	2858.0	81.6**
	Crimps/mm	1	2723.3	2723.3	77.8**
	Amplitude	1	2452.0	2452.0	70.1**
	Deviation	120	4198.8	34.9	

** Significant at 1% level.

common and the so-called 'sine' portion, not perfectly planar, but rather 'dished'.[12] In fact, the perfect helix is more common in Down wool but the perfect sine (type IV) is common in lamb's wool and some fine Merino wool. In ordinary Merino, type IV is common.

Marked differences between high and low plasticity wools have been found. Low plasticity wools tend to be helical in crimp configuration and harsh in handle, while high plasticity wools have planar or sine forms with high lustre and smooth, soft handle.

Mean results of Table 1 show that in low density mutant and Southdown wools, the crimp score is very high, while on the other hand, in Merino and lamb's wool, the fibres have low score i.e. sinusoidal shape. The reason for helical fibres in low density mutant would appear to be that the fibres, after emergence from the follicles, have enough space to coil and are not restrained to a sinusoidal shape.[6] It is also evident that the fibres with helical form have no staple crimp, whereas sine fibres tend to be derived from staples of high 'character'. These conclusions assume firstly that the natural crimping mechanism in the follicle will produce a coiled fibre and secondly that the lack of 'character' in the staple appears to be a useful guide to crimp form and, in fact, the attention given to 'character' by sheep classers and wool experts seems justified from this viewpoint. It should be pointed out that large variations in single fibre crimp occur within single staples[13] and most fibres assume an irregular form which is roughly approximated.[14]

Crimp Form of Carpet Wool.—Pakistani carpet wool consists of three types of wool, i.e. true, heterotypical and medullated wool fibres in different percentage in a staple.[15–17] Usually true wool fibres range between 40–60%. A visual examination of carpet wool reveals that medullated and heterotypical wool fibres are of the straight type (Fig. 1), while majority of true wool fibres are of type V and have sinusoidal shape. Carpet wool being more irregular in crimp form due to the presence of the above 3 types of fibres was not included in the analysis.

Regression of Crimp Form on Crimp Frequency Amplitude and Length.—Regression in individual samples shows opposite trends. In some samples, the crimp frequency increases with crimp form, while in others it decreases. This may be expected in view of the wide range of wool fibre population studied, each with its own characteristics of density, rate of growth and mean fibre dimensions.[18] In the case of crimp form and amplitude (Table 2) only three samples show significant regression coefficients. However, two of them have negative and one positive slope. The pooled regression is negative and highly significant. In this case, as might be expected, the slopes are significantly different as shown by analysis of co-variance.

It is generally observed that helical fibres have lower amplitude as compared to sine fibres. This is not necessarily a causal relationship. But if follicles produce a naturally coiled fibre, those with smaller amplitudes which have a greater chance of coiling, will become helical. This relationship might be expected not to hold in abnormal wools such as the low density mutants which give positive regression coefficients (Table 2).

Regression analysis of crimp form on % length show 6 out of 11 samples to give significant regression coefficients. The pooled and multiple regressions are also significant but in one Merino sample, the slope is in the opposite direction (Table 2). As our measurement of crimp form is based on this % length, these deviations may occur due to abnormal fibre shape. Thus if the fibres are uniform, then as the form measurement depends on % length, one would expect highly significant results for all the 11 samples.

Causes of Variations in Straight Length.—The following are the main causes of variation in % length (Fig. 2).

(1) Same number of crimps but different amplitude.

(2) Same amplitude, but different crimp frequency.

(3) Different crimp forms.

(4) Combinations of the above.

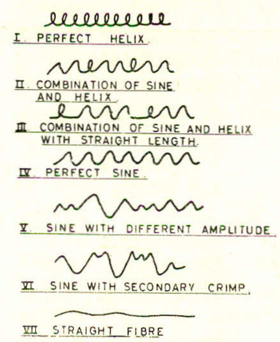

Fig. 1.—Different types of crimps.

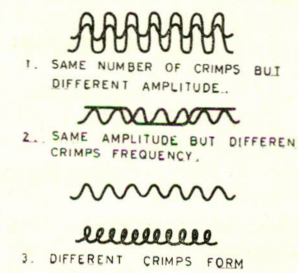

Fig. 2.—Causes of variation in straight length.

Multiple regression of % length on crimp form, crimp frequency and amplitude, shows that these independent variables accouted for only 52% taking 124 fibres. For the mean samples, however, these variables accounted for 81%. In taking mean samples, the variation increases and a high percentage of the variation is accounted for. Thus these differences can be explained by the above cases.

However, due to the high correlation of amplitude and crimp frequency ($r=0.850$), simple regression does not give accurate results. In fact simple regression gives correct results when the independent parameters are not correlated but in the present case, apart from the correlation between amplitude and crimp frequency, crimp form also depends upon crimp frequency and amplitude, so that the variation in % length due to amplitude may be due to the relation with crimp frequency or crimp form or both. In order to avoid this ambiguity, the partial regression coefficient method was used for finding significant differences of % length on crimp form, crimps/mm and amplitude. In this case % length gives highly significant results on the three crimp parameters in mean as well as in 124 fibres (Table 4). It should be noted that previously only crimp form was found significant in mean samples and in taking 124 fibres, crimp form and crimp frequency gave significant results (Table 3).

It should be pointed out that these analyses including % length as dependent variable and crimp form as the independent variable do not fit the normal multiple regression model as the % length is used in the calculation of crimp form. Consequently it cannot be considered as being independent. The most valid approach is to study the regression of crimp form on % length, frequency and amplitude. From the simple regression (Table 2), it appears that within samples (pooled regression) amplitude and % length both contribute significantly, whereas when samples are ignored (total regression) only % length is significant. This is not surprising, as clearly both amplitude and frequency contribute to % length and all three of them are related to crimp form.

Thus the analysis is unusual in that we have an assumed theoretical basis (i.e. that all crimps can be represented by a combination of sine and helical forms). If the assumptions are correct, then the calculated crimp form and the measured amplitude and frequency should give an almost complete account for the variations in Y. It can be seen that for individual fibres, this does not hold, but 81% of the variations in the mean % length can be accounted for. Excluding crimp form, amplitude and frequency alone accounted for only 13% of the variations in the mean % length and these two parameters cannot, therefore, be considered to give a suitable description of fibre crimp.

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