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A Preliminary Report on the Use of Raw Wool Measurements to Predict Fibre End Characteristics of Top

By

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SUMMARY

A Draft Test Method concerned with measurement of the mean fibre diameter (MFD) of fibre ends was accepted at the most recent IWTO Congress held in Nice, 2001. The new Method, entitled 'Measurement of Fibre End Characteristics in Wool Slivers as a Guide to Fabric Skin Comfort', incorporates an index of skin comfort, the Fibre Ends Fineness Index (FEFI). This paper reports on the distribution of the FEFI observed in 163 commercial tops from the TEAM-3 project.

The MFD of fibre ends in a top is closely related to the MFD of the top. Fitting the MFD of fibre ends based on Raw Wool measurements resulted in a correlation coefficient, R^2 , of 97% and a Standard Error of 0.27 μm . Similarly, fitting FEFI on the basis of Raw Wool measurements gave an R^2 of 35% and a Standard Error of 0.23 μm .

In addition, a preliminary investigation is made into the predictability of FEFI from raw wool measurements. The incorporation of results from further commercial and sale lot processing may lead to more reliable predictions of both the MFD of fibre ends in top and the FEFI. These predictions may well incorporate a significant mill factor.

INTRODUCTION

A new Draft Test Method¹, 'Measurement of Fibre End Characteristics in Wool Slivers as a Guide to Fabric Skin Comfort', was accepted at the most recent IWTO Congress held in Nice, 2001. AWTA Ltd is currently involved in two trials concerned with the prediction of top characteristics from greasy wool measurement, viz., TEAM-3² and a trial processing individual grab samples from sale lots.

Research by CSIRO³ has highlighted the importance of the diameter and frequency of fibre ends in determining the skin comfort of wool fabrics worn close to the skin. The skin comfort is largely independent of the handle of a fabric, which is related to such characteristics as fabric smoothness, stiffness, softness etc.

It is thus important for designers of wool fabrics that are to be worn next to the skin to have some indication of the diameter and frequency of fibre ends in the tops from which the fabrics are to be constructed. Knowledge of the fibre ends MFD or the skin comfort index (FEFI)¹ may allow for improved skin comfort attributes to be selected from tops of the same MFD, or for the use of a top with a coarser MFD to obtain similar skin comfort attributes, all other things being equal. As expected, the MFD of fibre ends in a top was shown in 1995 to be very closely related to the MFD of the top⁴. However, subsequent close examination of a range of tops by Naylor⁵ highlighted differences in individual tops from the general

relationship established in 1995. Some tops had differences between the top MFD and the fibre ends MFD of up to 2 μm .

It was therefore accepted that the measurement of the diameter characteristics of fibre ends could add commercial value to top specifications. The new Draft Test Method was established to provide a means of measuring the relevant fibre ends characteristics.

It is important to realise that a difference between the MFD of fibre ends and the MFD of the top does not necessarily imply that the ends of the fibres are different in diameter to the main body of the fibres. Since the measurement of the MFD of the top is based on a length-biased sample, and the fibre ends measurement is not length-biased, a difference between top MFD and fibre ends MFD could occur if all fibres were cylindrical in shape and there was a relationship between the length and the diameter of the fibres. For example, if the coarse fibres were selectively longer than the finer fibres in a top, then the fibre ends diameter would be expected to be finer than the MFD of the top. It is generally accepted that the longer fibres in a top are coarser than the shorter fibres, and this observation has been supported by a number of analyses^{6,7} of tops made from both Australian and New Zealand wools.

Naylor and Stanton⁸ reported on the relationship between the diameter of the fibre ends and the MFD of the top in a study of time of shearing and geographic locality, and suggested that the largest differences were related to time of shearing and geographic location of the sheep. This data set consisted solely of lots constructed to a single specification, and was thus very restrictive in the range of some of the raw wool attributes, e.g. the MFD of each of the 64 lots was $21.5 \pm 0.4 \mu\text{m}$.

Preliminary work by Couchman (unpublished) using this restricted data set ($n = 64$) showed very little relationship to either location or time of shearing, but a relationship existed with an interaction of the Coefficient of Variation of Staple Length (CVL) and Position of Break (PoB(M)). Couchman suggested that an index based on the interaction of CVL and PoB(M) showed some promise for prediction but cautioned that the evidence was based on a small and biased data set and needed to be validated.

The availability of data from TEAM-3 enabled a preliminary investigation to be made of the relationships between fibre ends characteristics and Raw Wool measurements. In addition, it allowed for earlier work by Couchman (unpublished) to be validated over a much larger data-set with a wider range of Raw Wool characteristics.

This report examines the relationships for three parameters measured on the fibre ends of tops and the measured Raw Wool characteristics of the wool used to produce the tops. The three variables were:

1. Fibre Ends Fineness Index (FEFI)¹
2. Fibre Ends Mean Fibre Diameter
3. Fibre Ends Comfort Factor

MATERIALS AND METHODS

The data used for the following analyses were derived from 163 consignments from the TEAM-3 database, as detailed by Lindsay et al². Raw Wool measurements were conducted at AWTA Ltd following procedures defined in the relevant IWTO Standards⁹. All tops were measured for fibre ends characteristics following the method of Naylor¹ using an AL-100 Almeter and a SirolanTM Laserscan at AWTA Ltd Textiles Division. The MFD of each top was determined as per IWTO-12-00⁹.

FEFI was calculated from the following formula¹:

$$\text{FEFI} = 1.7 + 0.87 * \text{MFD}(\text{Top})_{\text{measured}} - \text{MFD}(\text{Ends})_{\text{measured}}$$

The data were analysed using the MLR function in Excel 2000; only those terms with a significant coefficient (5% level) are reported.

In addition, the data set was used to validate earlier models by Couchman.

RESULTS AND DISCUSSION

The results have been separated into three sections:

1. Fibre Ends Fineness Index
2. Fibre Ends Mean Fibre Diameter
3. Fibre Ends Comfort Factor

1. FIBRE ENDS FINENESS INDEX

1.1 Relationships FEFI and Raw Wool Characteristics

Table 1 summarises the relationship between fibre ends variables in commercial tops and the Raw Wool characteristics of the greasy wool used.

Table 1 Regression Coefficients of Raw Wool Parameters

Dependent Variable	Independent Raw Wool Regression Variables	Coefficients of Raw Wool Variables							SE [#]	R ^{2#}
		MFD	CVD	CF	CVL	SS	Mid %	MFC		
FEFI	CVD + CF + CVL + SS		0.17	0.08	-0.03	0.04			0.23	0.35
Fibre Ends CF	CF			0.88					0.42	0.94
Fibre Ends MFD	LSN MFD	0.98							0.31	0.96
Fibre Ends MFD	LSN MFD + Mid%	0.97					0.02		0.28	0.97
Fibre Ends MFD	LSN MFD + Mid% + MFC	0.87					0.01	-0.02	0.27	0.97

[#]SE: Standard Error; R: Correlation Coefficient

The average and range of FEFI and Fibre Ends MFD results for the 163 commercial tops are shown in Table 1. The values of FEFI occur within a narrow band with 94% of the values within $\pm 0.4 \mu\text{m}$.

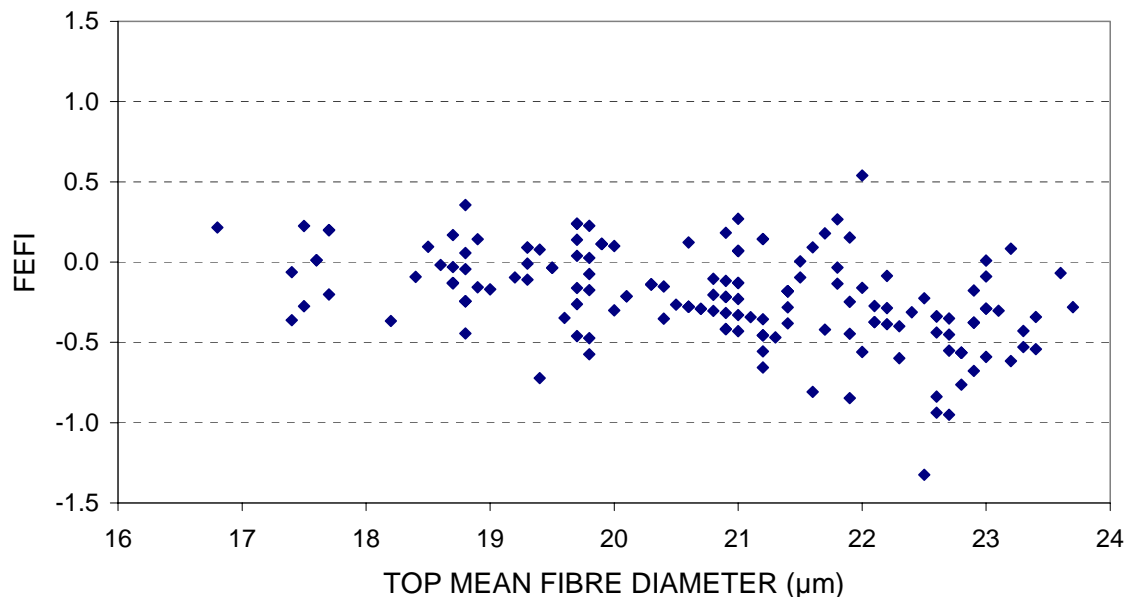
Table 2 Range and Average of FEFI Results

	Average	Minimum	Maximum
FEFI	-0.21	-1.33	0.54
Fibre Ends MFD	20.0	16.1	22.6

Average FEFI values show differences for the different mills in the data set. Differences in mean values of FEFI for individual mills range from -0.62 to approximately 0. These comparatively large differences between mills indicate that mills may be an important factor in the prediction of FEFI. Examination of the mean Raw Wool values for each mill would suggest that processing effects rather than differences in Raw Wool attributes are influencing the FEFI.

The relationship between FEFI and top Mean Fibre Diameter can be seen in Figure 1.

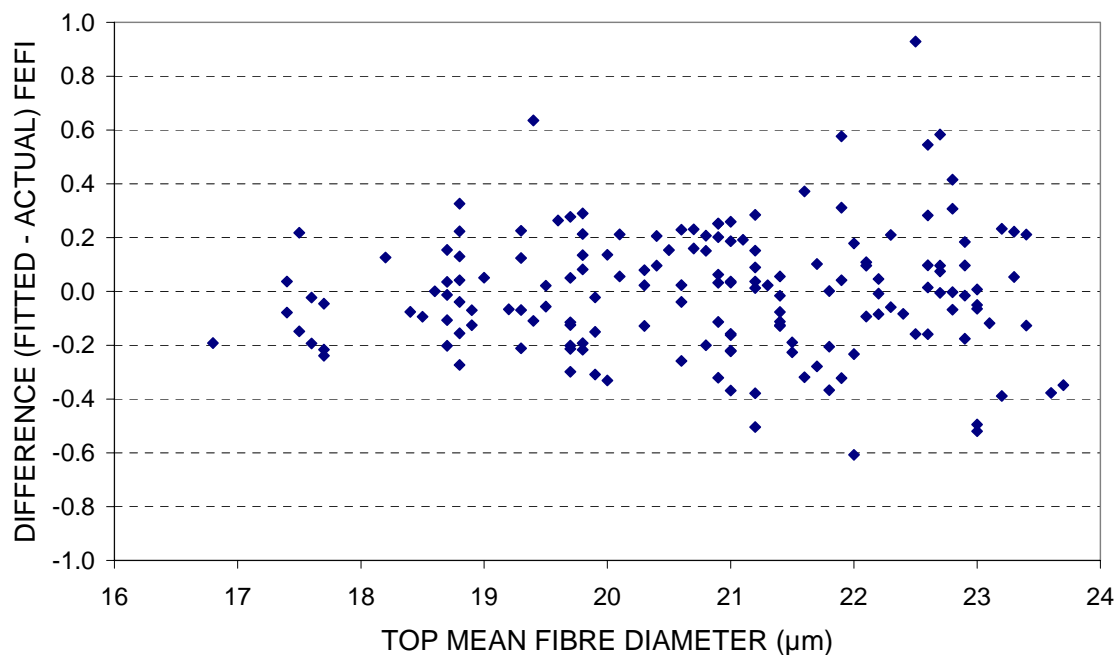
Figure 1 Relationship Between Top MFD and FEFI



FEFI was not highly related to any of the Raw Wool parameters tested. However, the FEFI values can be calculated from Coefficient of Variation of Fibre Diameter (CVD), Comfort Factor (CF), Coefficient of Variation of Staple Length (CVL) and Staple Strength (SS) ($R^2 = 0.35$; Standard Error = $0.23 \mu\text{m}$).

Figure 2 shows the differences between FEFI values and estimates of FEFI based on the MLR algorithm shown in Table 1. The fit of the data is more precise for the tops finer than $21 \mu\text{m}$ than for the coarser tops.

Figure 2 The Difference Between Fitted and Actual FEFI



1.2 Validation of the CVL:PoB(M) Interaction Index

Figure 3 shows the relationship between Couchman's PoB(M) and CVL interaction model and FEFI for the TEAM-3 data set. Whilst a relationship exists ($R^2 = 0.49$), it is not strong and the residuals are evenly distributed at random around the mean (Figure 4).

Figure 3 Relationship Between Interaction Model and FEFI

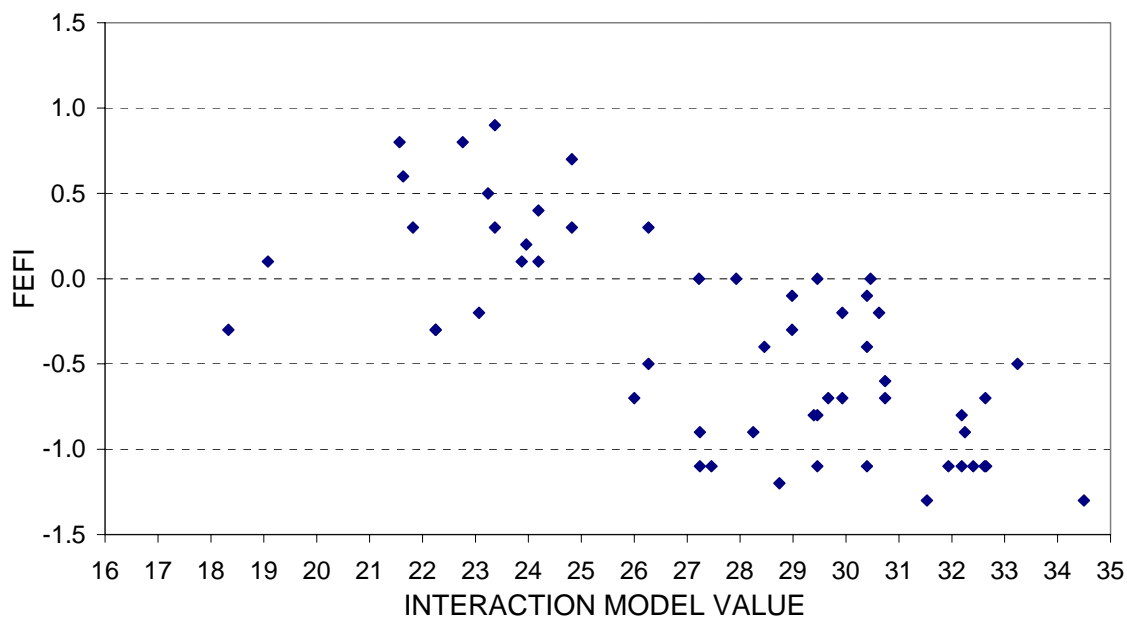
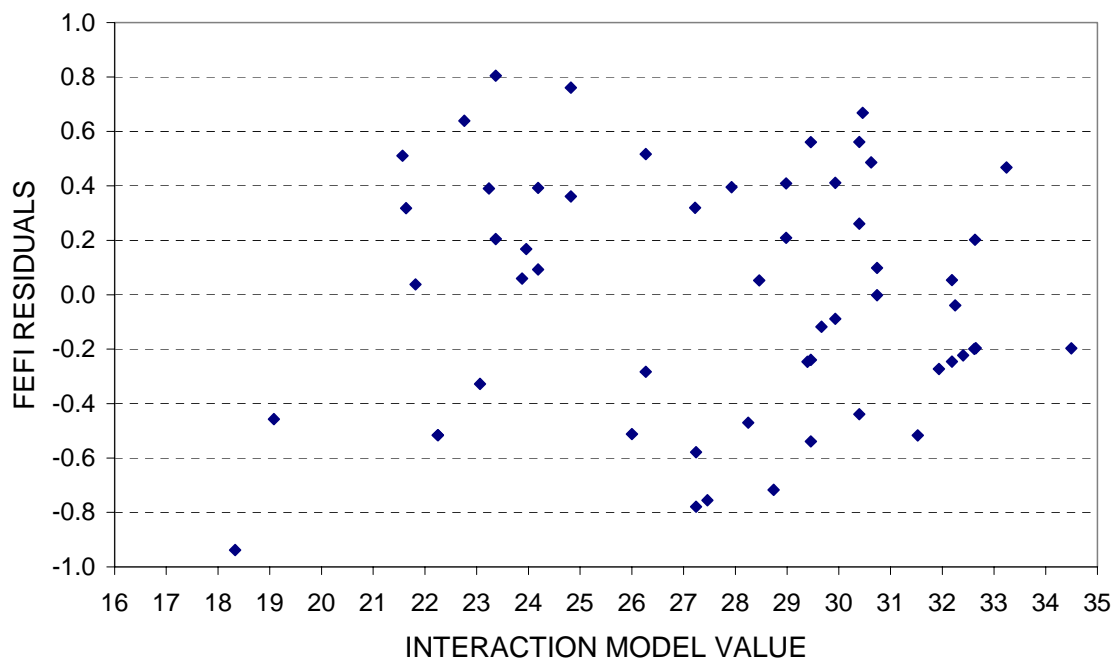


Figure 4 Residuals from Regression of Interaction Model and FEFI



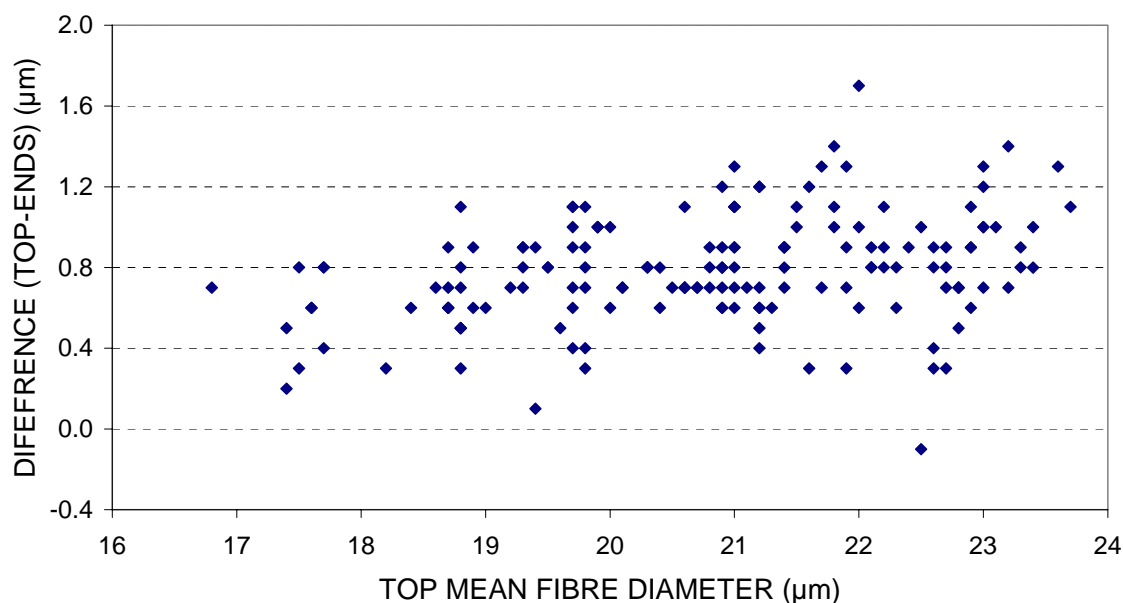
Whilst the relationship is not as strong as observed in the original limited split data-set, used to both develop and separately validate the model, these plots clearly illustrate that such a relationship exists and shows promise for further refinement of this interaction model.

Further attempts were made to improve the original model by investigating predictability by MLR techniques. This improved the R^2 value slightly. However, when seeking validation with the larger TEAM-3 data set, this model also proved less efficient than the interactive model. The poor relationship between the model prediction and the TEAM-3 FEFI values shows that this model is inappropriate to use, and confirms concerns regarding the use of a restricted data set to develop a model.

3. FIBRE ENDS MEAN FIBRE DIAMETER

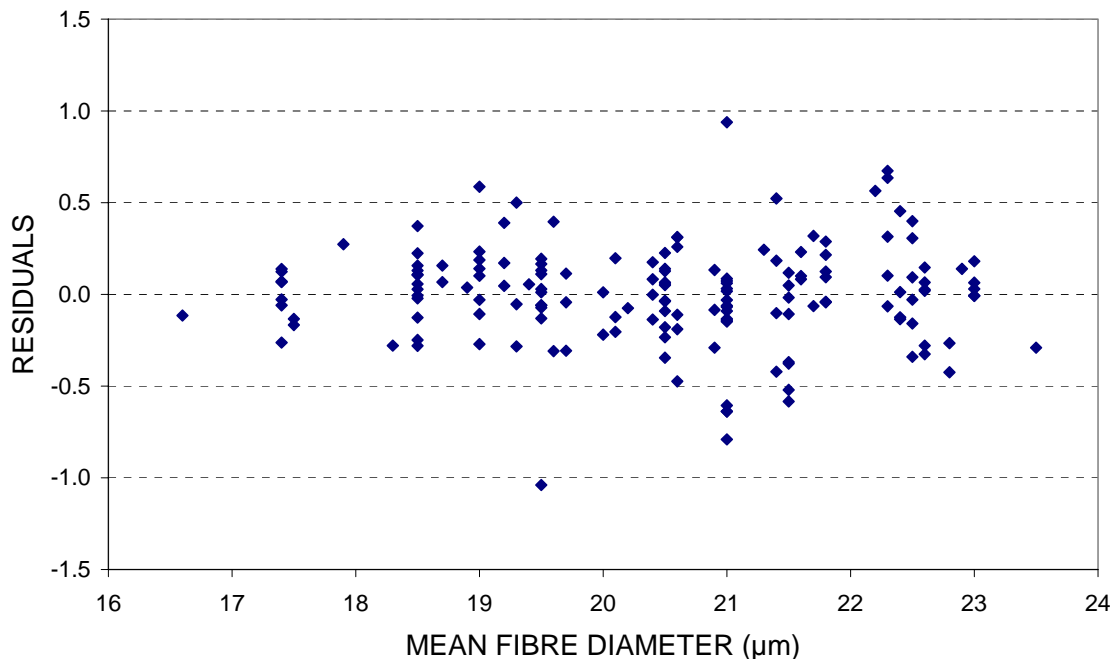
As noted in earlier work by Naylor⁷ the MFD of tops is consistently higher than the MFD of fibre ends, as shown for the TEAM-3 data in Figure 5. For the 163 tops in this investigation the diameter of the fibre ends was, on average, $0.8 \mu\text{m}$ finer than the MFD of the top, with this difference increasing with increasing MFD. The range of fibre ends MFD can be seen in Table 2 for the 163 tops. Again, the values of the MFD of fibre ends can be fitted from greasy MFD, percentage Mid-breaks and Mean Fibre Curvature (MFC) ($R^2 = 0.99$; Standard Error = $0.27 \mu\text{m}$). However, greasy MFD alone accounts for 97% of the variation in diameter of fibre ends.

Figure 5 The Relationship Between the Top MFD and the Fibre Ends MFD



Examination of Figure 6 shows that, for 11 of the 163 lots, the calculated diameter of the fibre ends is more than $0.5 \mu\text{m}$ from the measured value.

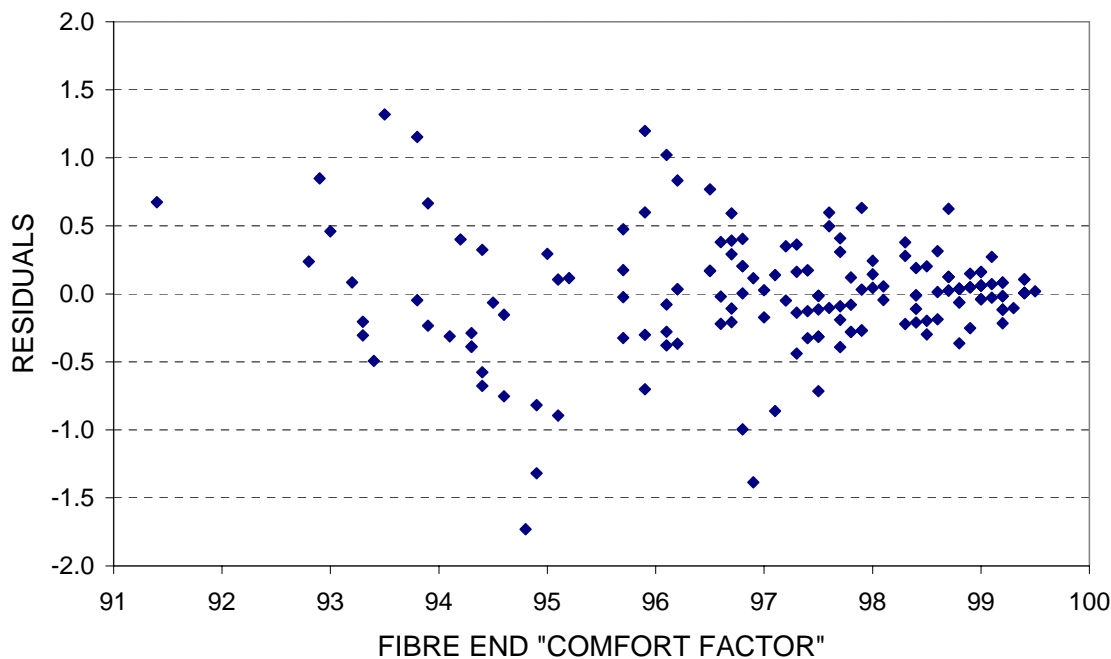
Figure 6 Residuals from the Fitting of Fibre Ends Diameter Data Using Mean Fibre Diameter, Percentage Mid-Breaks, and Mean Fibre Curvature



4. FIBRE ENDS COMFORT FACTOR

The only significant greasy wool parameter in the multiple regression for Fibre Ends CF was the greasy CF ($R^2 = 0.94$; Standard Error = 0.42%). As can be seen in Figure 7, the error of the fit is relatively low for values of CF greater than 98%.

Figure 7 Residuals from the Fitting of Fibre Ends Comfort Factor Using Greasy Wool Comfort Factor



CONCLUSIONS AND FUTURE WORK

The MFD of fibre ends in a top is closely related to the MFD of the top. A MLR between the MFD of fibre ends in a top and Raw Wool measurements had a Standard Error of 0.27 μm and an R^2 of 97%. A similar relationship for FEFI had a Standard Error of 0.23 μm and an R^2 of 35%.

The indicators of predictability for models developed from a limited data set failed to realise their earlier promise. However, there is a strong indication that prediction of a skin comfort index, or FEFI, will be mill dependant, and this is being investigated further. There are commercial benefits to be obtained if a suitable prediction can be derived.

This preliminary report demonstrates that the FEFI and the Fibre Ends MFD in top should be predictable from Raw Wool measurements to within $\pm 0.30 \mu\text{m}$. Improved predictions may be possible through incorporation of a mill factor.

The incorporation of results from further commercial and sale lot processing may lead to reliable predictions of both the fibre ends diameter in top and the FEFI. AWTA Ltd and The Woolmark Company plan further work on a larger set of data, including further lots from TEAM-3 and up to 250 sale lot grab samples that are being processed for AWTA Ltd. Information from the set of 20 sale lots currently available was considered too limited to be reported here. However, these sale lots contained a wider range of values of some Raw Wool parameters, especially Staple Strength and % Mid-breaks, than did the currently available TEAM-3 data set. Also, the Woolmark Company is continuing investigations into the predictability of this index and its association with comfort attributes of knitwear.

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