INTERNATIONAL WOOL TEXTILE ORGANISATION

TECHNOLOGY & STANDARDS COMMITTEE | BUENOS AIRES MEETING

Commercial Technology Forum | May 2003

Chairman: A.G.DE BOOS (Australia) | Report No: CTF 03

The Examination of Decrimped Staple Length to Differentiate Atypical Wool Types as a Potential Aid to Purchasing and Processing Prediction.

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SUMMARY

AWTA Ltd has commenced a trial to examine the processing characteristics of individual sale lots comprised of ‘atypical’ wool types. Such an investigation complements the commercial processing of consignments in the TEAM3 trial. Initial analyses of Hauteur prediction using the current TEAM2 formula have highlighted under-prediction of belly-wool types. Other results indicate that a new parameter, Decrimping Ratio, has the potential to differentiate between wool lots with extreme levels of staple crimp. For example, belly-wool types typically have high levels of staple crimp and high Decrimping Ratios. The incorporation of Decrimping Ratio into future prediction formulae is being evaluated as a means of improving prediction accuracy for wools with atypical Decrimping Ratios.

INTRODUCTION

Raw wool measurements are used to provide both a definition of a wool lot for trading purposes and a basis for determining the expected performance of the wool in subsequent processing (eg Schlumberger Dry Yield[1)]. The usefulness of prediction of Hauteur parameters and Romaine based on Raw Wool measurements has been established for commercial consignments by TEAM[2,3] in the mid 1980’s. Subsequently, a survey[4] in 1997 revealed that the TEAM formulae remain the accepted benchmarks for processing prediction within the wool industry.

The 1997 survey[4] also highlighted concerns that some specific wool types may not predict accurately, e.g. short strong wools, variable length lots, weaner’s wool and some superfine lots. Subsequent to the survey, belly wools with extraordinary stretch, commonly termed “stretchy bellies”, that contain some staples capable of extension over 40% in length without any apparent fibre breakage, have also been identified as a wool type that may be poorly predicted[9]. However, it is difficult to commercially quantify such concerns because consignments composed entirely of these specific wool types are not generally processed; these types typically being included as blend components with other wool types. It is difficult therefore to investigate the processing performance of these specific wool types using commercial processing.

Since the replacement of Airflow measurement by Laserscan as the default method for measurement of Fibre Diameter, two new measurements of Raw Wool properties are routinely available; the Coefficient of Variation of Fibre Diameter (CVD) and Mean Fibre Curvature (MFC). There is evidence from research trials[5,6] that MFC may influence early stage processing performance. Research trials have demonstrated a predictable relationship between CVD and the Coefficient of Variation of Fibre Strength[7], a fibre parameter that may also influence processing performance. Prediction accuracy may therefore be improved by inclusion of MFC and CVD in prediction formulae. Partly in recognition of the impact of these new measurements on early stage processing, AWTA Ltd is currently engaged in TEAM3[8], a project to determine if an update to the TEAM formulae would improve the prediction accuracy of commercial processing consignments.

To complement the commercial processing of TEAM3 and to assess the effect of specific wool types (called ‘atypical’ types in this report) on processing performance, AWTA Ltd has undertaken a parallel project in which individual sale lot display samples (grab samples of approximately 5 kg) previously tested by AWTA Ltd, are being processed as individual sale lot consignments by CSIRO Textile and Fibre Technology[10,11,12]. This is in part to address the concerns expressed by wool buyers. Orders may define a TEAM2 length which raw wool measurements exclude due to a sale lot being of atypical nature, however experience has shown processors that some atypical wool types process much longer than their TEAM2 predicted value. These atypical sale lots are being selected to include wool types that have been subjectively assessed as being poorly predicted, as well as wools with a wider range of Raw Wool properties than is generally found in commercial consignments. Processing of these individual sale lots allows for the full expression of the wool characteristics associated with atypical wool types, characteristics that would normally be lost in the processing of a blended consignment.

To provide further information from Raw Wool testing a modification has been made to the data collection software on the ATLAS machine[13]. This modification captures more information about the length and strength characteristics of a staple than the current ATLAS testing, while not affecting the performance of the ATLAS itself.

This report introduces a new Length parameter, Decrimped Staple Length (DSL) and describes the design of the Sale Lot processing trial. Some discussion of the initial results of the trial is included.

Purpose of Trial

This processing trial has three main objectives:

1. To evaluate if Decrimped Staple Length (DSL) can provide additional guidance in the purchase of sale lots of atypical wool types.

2. To determine whether or not an enhanced set of Raw Wool parameters, including Decrimped Staple Length (DSL), Coefficient of Variation of Fibre Diameter (CVD) and Mean Fibre Curvature (MFC), can improve processing prediction at the Sale Lot level; and

3. To determine the prediction accuracy of specific wool-types that have been identified as being poorly predicted, for example short/strong wool types, variable length lots, weaner’s wool, “Stretchy” bellies.

The objectives of this trial necessitate that each sale-lot is processed as a one-lot consignment.

MATERIALS AND METHODS

Lot Nomination

Prior to the commencement of the trial, a matrix of desired wool-types was devised with the assistance of the Northern Wool Auction Buyers Association. Desired wool-types were allocated across selling centres (Northern, Southern and Western), and across strata allocated for Mean Fibre Diameter (MFD), Staple Length (SL) and Staple Strength (SS). The use of stratified sampling is designed to target wool-types that are of particular interest to this trial. To date, a total of 20 wool-types has been isolated for inclusion as shown in Table 1; 15 fleece types and 5 non-fleece types. Control lots have been included in the processing comparisons over the full period of the trial.

Table 1: Sale lots included in this trial.

Wool Type	Code	Sale-Lots Required	Sale-Lots Included
Control Fleece	FLC	26	29
Fine Fleece	FFC	13	9
Superfine Fleece	SFF	13	6
Low CV(D) Fleece	LCD	13	3
High CV(D) Fleece	HCD	13	3
Low MFC Fleece	LFC	13	10
High MFC Fleece	HFC	13	1
SRS® Type Wool	SRS	12	0
Elite Type Wool	ELT	13	3
Lambs Wool	LMB	17	5
Long & Strong Fleece	LST	8	0
Short & Strong Fleece	SAS	13	9
High Staple Strength & High Midbreak % Fleece	HSM	7	3
Weak Fleece	WEK	10	0
Cotted Fleece	COT	7	2
Control Pieces	PCS	16	22
Variable Length Pieces	MLP	16	22
Belly Wool	BLS	16	11
"Stretchy" Belly Wool	SBL	24	15
Total		278	153

Processing and Measurement

Presale Raw Wool test data (MFD, CVD, MFC, SL and SS) were used to select lots for inclusion in the trial and subsequently to predict processing performance. Prior to processing, 120 tufts were removed from the sample for measurement on ATLAS utilizing modified software. This software allowed for the measurement of Decrimped Staple Length (DSL) as defined in the next section, and for the storage of measurement data for each individual staple.

Lots were processed into top at CSIRO Textile and Fibre Technology, Geelong. AWTA Ltd Textile Testing measured tops for Regain, Hauteur and Barbe.

Determination of Decrimped Staple Length (DSL) and Decrimping Ratio (DR)

The measurement of Staple Strength by ATLAS is a measurement of the peak force required to break a staple, divided by the staple mass of wool/unit length of the staple. The force exerted on a staple is detected by a strain-gauge load-cell while the staple is extended at 300mm/s[14]. Software changes were made to enable monitoring of the force versus displacement relationship on two ATLAS machines.

Figure 1 shows the Extension versus Strength relationship for a typical staple. Note that there is no registrable force (Strength) on the staple until nearly 14mm of displacement, followed by a dramatic increase in force (Strength) with further displacement until the majority of fibres in the staple break at approximately 35mm. It is likely that the fibres in the staple are being straightened, or decrimped, during the first 14mm of extension of this staple, since the force required to decrimp a wool fibre is very much smaller than the force required to extend the fibre itself[15].

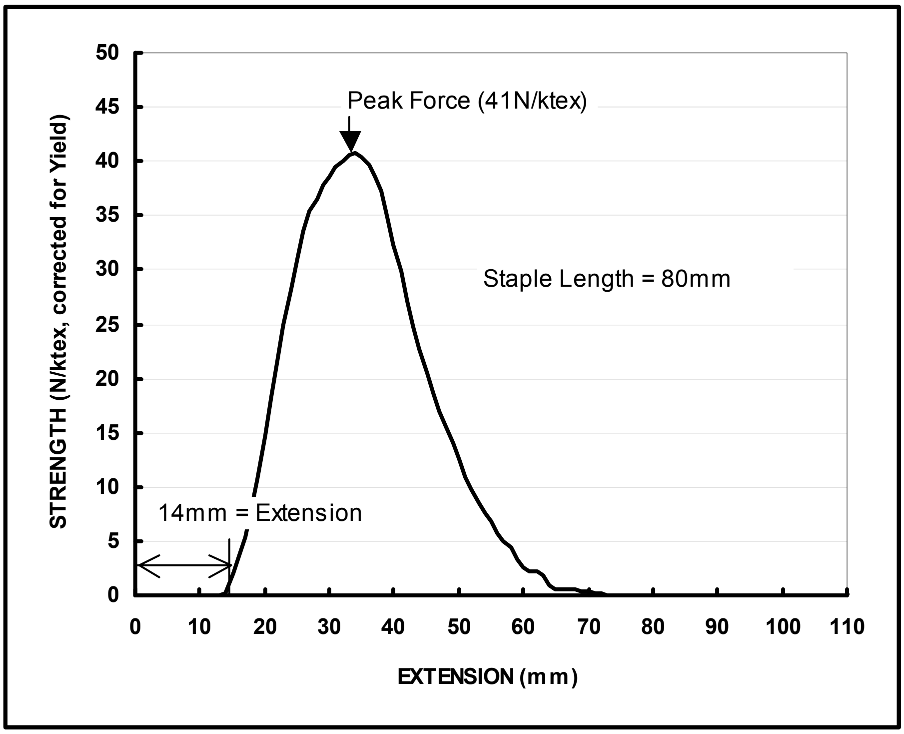

Figure 1: A typical force versus extension relationship for a staple test on ATLAS.

The only information from the relationship shown in Figure 1 that is currently recorded in a standard ATLAS test[14] is the peak force (shown as strength) of approximately 41/ktex. For the purposes of this trial, further parameters are being monitored, including Decrimped Staple Length. DSL is defined as the extended length of the staple not held by the ATLAS jaws and corrected for initial SL using Equation 1 below. DSL is the only new parameter from ATLAS measurement included in this analysis.

$$DSL = \frac{(SL - Jaw + Extension) \times SL}{SL - Jaw} \qquad \text{Equation 1}$$

Where, DSL = Decrimped Staple Length value expressed in millimetres,
SL = initial length of the staple not under tension,
Jaw = a constant (20mm), the length of staple that the ATLAS jaw covers when straining a staple,
Extension = the distance the staple is extended before an extension force is registered.

Using the staple in Figure 1 as an example,

$$DSL = \frac{(80mm - 20mm + 14mm) \times 80}{80mm - 20mm}$$

= 98.6mm

DSL has limited application as a comparative measure between sale lots because it is a unit dependant measurement. Decrimping Ratio (DR) is potentially more useful because it is unit independent, and can be used as a comparison across all wool-types.

The value of Decrimping Ratio for a Sale Lot is defined by Equation 2:

$$Decrimping\ Ratio = \frac{Mean\ Decrimped\ Staple\ Length}{Mean\ Staple\ Length} \qquad \text{Equation 2}$$

Using the above example, the DR for a single staple would be calculated as

$$DR = \frac{98.6mm}{80mm}$$

= 1.23 for an individual staple.

This value can be confirmed by stretching a staple by hand, and to compare the Staple Length with the Decrimped Staple Length, then performing the above calculation in equation 2.

Decrimping Ratio is potentially affected by the frequency, depth and uniformity of the Staple Crimp. A staple that is highly crimped would be expected to exhibit a high DR. However, if there is little uniformity of crimp in the staple, the DSL, and thus the DR, will be relatively low because the straighter fibres within the staple may break before the majority of other fibres have been decrimped.

RESULTS AND DISCUSSION

Relationships between Raw Wool Parameters

Table 2 summarises the Raw Wool characteristics for the first 153 lots processed for the trial. A comparison is made with the original TEAM datasets consisting of 603 consignments, and TEAM3, which currently includes 453 consignments. The Sale Lot trial has finer, shorter, weaker and stronger lots than the TEAM datasets. The extreme Raw Wool parameter values for this trial are a direct reflection of the diversity of wool types used in this analysis, and serve the purpose of testing the TEAM2 prediction in the areas beyond the scope of the TEAM datasets.

Table 2: Range of Raw Wool parameters for this trial versus TEAM data.

Characteristic	This Trial	TEAM	TEAM2	TEAM3 (to date)
MFD (µm)	15 - 26	17 - 31	18 - 28	16 – 25
VMB (%)	0 - 19	0 - 10	0 - 8	0 – 6
SL (mm)	53 - 114	59 - 123	65 - 108	71 – 104
SS (N/ktex)	18 - 65	23 - 60	26 - 56	24 – 49
Hauteur (mm)	47 - 92	48 - 97	50 - 95	58 – 91
CV(H) (%)	27 - 63	31 - 61	31 - 61	33 - 58

Table 3 summarises the mean Raw Wool parameter values for the 153 processed sale-lots, and then partitions these values according to wool-type for types with 3 or more sale-lots.

Table 3: Mean Raw Wool Parameter values for 153 Processed Lots.

Wool Type	MFD (μm)	CV(D) (%)	MFC (deg/mm)	SL (mm)	SS (N/ktex)	Midbreaks (%)	Number of Lots
All Sale-lots	19.7	21.5	95	77	36	63	153
Control Fleece	21.4	21.5	89	90	39	61	29
Fine Fleece	18.5	21.1	102	82	37	66	9
Superfine Fleece	15.7	21.0	112	70	36	77	6
Low CV(D) Fleece	20.0	17.8	101	82	47	58	3
High CV(D) Fleece	21.1	24.8	88	82	31	37	3
Low MFC Fleece	21.5	22.0	79	91	33	65	10
High MFC Fleece	20.5	22.0	99	85	27	19	1
Elite Type Wool	16.4	18.8	95	73	49	58	3
Lambs Wool	18.6	22.6	96	63	43	55	5
Short & Strong Fleece	20.6	21.3	95	63	50	63	9
High Staple Strength & High Midbreak % Fleece	21.7	20.1	86	85	49	95	3
Cotted Fleece	21.1	24.0	83	87	31	47	2
Control Pieces	19.5	22.0	93	75	33	62	22
Variable Length Pieces	18.8	22.5	97	71	34	63	22
Belly Wool	20.2	20.6	97	71	24	61	11
"Stretchy" Belly Wool	18.7	20.3	110	70	28	68	15

Initial inspection of the raw wool parameter values shows that sale-lots are described appropriately by their raw wool measurements. *Superfine fleeces* are characterised by low MFD (15.7μm) and high MFC (112 deg/mm). *Elite-type wool* exhibited low MFC (95 deg/mm). The *Short & Strong* fleece types were found to be short (63mm) and strong (50N/ktex). The *Belly wool* and "*Stretchy" belly wool* categories showed higher than average MFC's of 97 deg/mm and 110 deg/mm respectively.

Care should be taken with the interpretation of these values due to the preliminary nature of this analysis. However, there are sufficient data to assess the potential usefulness of the Decrimped Staple Length software modification.

Relationship of Decrimping Ratio to Raw Wool Parameters

Table 4 summarises the Decrimping Ratio (DR) values for Sale Lots for all represented wool types. It is premature to make definitive statements about the relationship between wool-type and DR, especially for wool types in which there are fewer than 10 lots. However, broad relationships can be observed.

Table 4: Comparison of Mean and Range of Decrimping Ratio (DR) Values for wool-types.

Wool Type	Mean DR	Number of Lots	Min	Max
Control Fleece	1.27	29	1.22	1.32
Fine Fleece	1.29	9	1.27	1.33
Superfine Fleece	1.34	6	1.29	1.39
Low CV(D) Fleece	1.30	3	1.28	1.32
High CV(D) Fleece	1.28	3	1.26	1.31
Low MFC Fleece	1.27	10	1.24	1.29
High MFC Fleece	1.27	1	1.27	1.27
Elite Type Wool	1.29	3	1.29	1.31
Lambs Wool	1.31	5	1.29	1.32
Short & Strong Fleece	1.30	9	1.25	1.39
High Staple Strength & High Midbreak % Fleece	1.24	3	1.15	1.29
Cotted Fleece	1.28	2	1.28	1.29
Control Pieces	1.31	22	1.14	1.39
Variable Length Pieces	1.32	22	1.27	1.38
Belly Wool	1.37	11	1.31	1.45
"Stretchy" Belly Wool	1.44	15	1.38	1.52
All Sale-lots	1.32	153	1.14	1.52

The mean DR value for the whole data set was 1.32. This value was substantially higher than the Control Fleece value (1.27) due to the high DR values of the non-fleece wool categories, which contribute 46% of the dataset. *Superfine fleeces* demonstrated a substantially higher DR (1.34) than the *Control Fleece* (1.27) and *Fine Fleece* (1.29) categories, indicating the *Superfine fleece* category exhibited substantially more staple crimp than the *Control* and *Fine fleece* categories. *High Staple Strength with High Percentage Midbreak* Wool is characterised by the lowest DR value (1.24), though there are only 3 samples in this category to date.

Differentiation of wool types by DR shows promise; this is demonstrated by the high DR values of the belly wool types. The usefulness of DR is further confirmed by the differentiation between Belly and Stretchy Belly wool types. The Belly and Stretchy Belly wool types are characterised by high levels of staple crimp, and this is reflected in their DR values; 1.37 and 1.44 for Belly and Stretchy Belly wool types respectively.

Table 5 shows the correlations between Decrimping Ratio and, MFC and SL. DR is negatively correlated with SL (-0.47), indicating that an increase in SL is associated with a decrease in DR, though there is considerable scatter about the relationship as shown in Figure 2. This relationship suggests longer wool types tend to "stretch" less. The Standard Error of Regression (STEYX) for SL against Ratio was 0.05.

Table 5: Pearson's Product-moment correlation between Decrimping Ratio and Raw Wool parameters.

Parameter	Correlation	p-Value	Significance
MFC	0.62	0.000	✳✳✳
SL	-0.47	0.000	✳✳✳

✳✳✳ significant at the 0.01% level

In Figure 2 there is a cluster of data points above a DR of 1.4 and with Staple Lengths from 62mm to 77mm. This cluster which consists solely of "Stretchy" Bellies and Belly wool types, represents a population separate from the majority of lots which have an approximately linear relationship between SL and DR. The two 'outlier' points below a DR of 1.2 are unrelated (Control Pieces and High Staple Strength & Midbreak %).

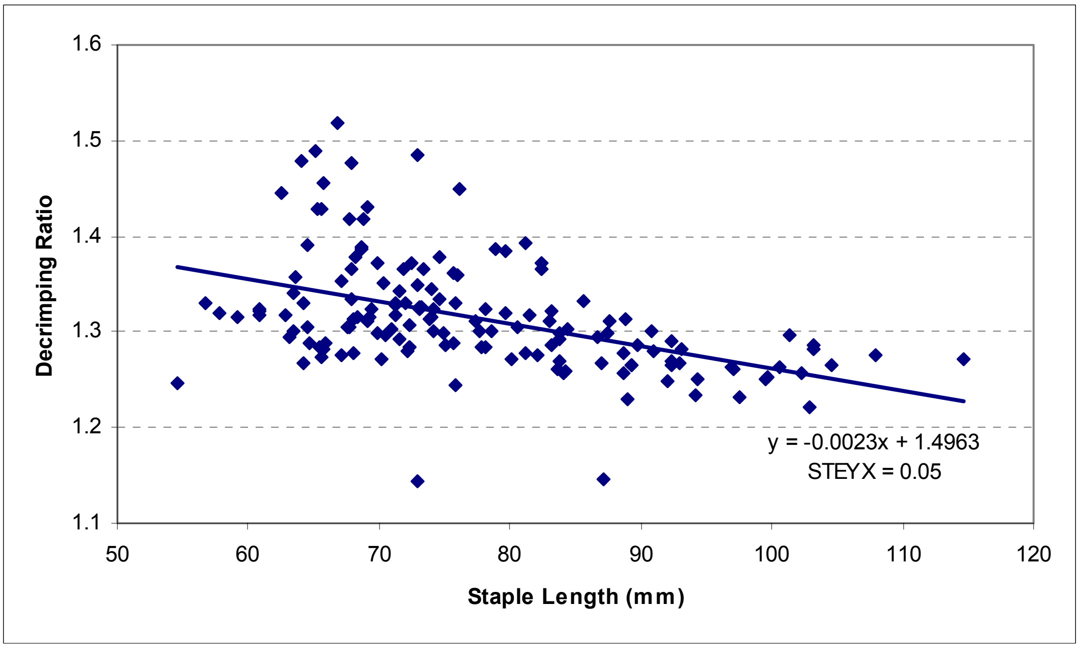

Figure 2: Relationship between Staple Length and Decrimping Ratio for 153 Sale Lots.

Decrimping Ratio was more highly correlated with MFC (0.62) than with SL. The positive correlation between MFC and DR indicates that lots with high MFC generally have a high DR and vice versa, as shown in Figure 3. This correlation supports the previous suggestion that higher values of DR may be determined, in part, by high Staple Crimp, that is highly crimped wool may "stretch" more than wool exhibiting a lower level of crimp. The Standard Error of Regression for this relationship was 0.05.

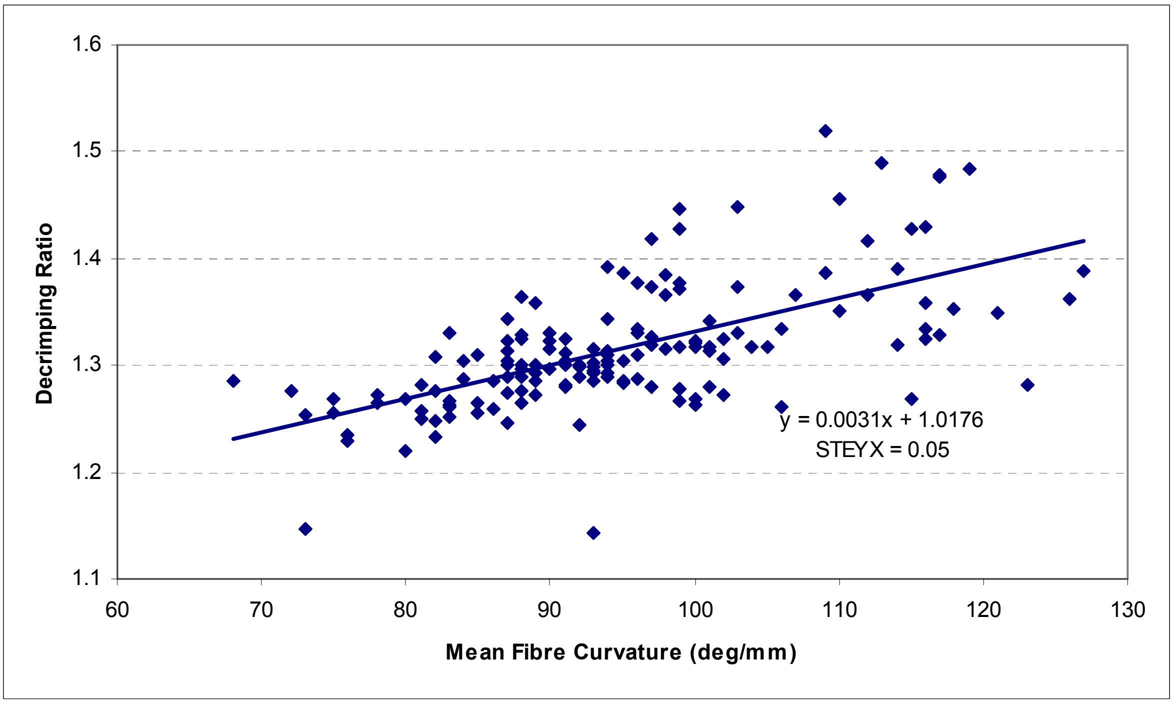

Figure 3: Relationship between Decrimping Ratio and Mean Fibre Curvature for 153 Sale Lots.

Processed Results

Hauteur

Estimates of Hauteur based on the TEAM2 equation were generated for the 153 sale-lots. Table 6 compares the average values for the TEAM2 predicted Hauteur and the measured Hauteur grouped by wool-types. The single mill correction factor for the CSIRO mill was estimated to be 5mm, which is the value of the difference between Actual and Predicted Hauteur for the Control Fleece and Control Pieces types.

(NB: only results for the six (6) Wool Types with 10 or more Sale Lots are discussed in this section.)

For four (4) of these types, TEAM2 correctly estimated Hauteur to within 2mm for the TEAM2 predicted value. After accounting for the CSIRO mill factor (5mm), the two poorly predicted types, Stretchy Bellies and Belly wool types, showed differences between Actual Hauteur and TEAM2 predicted Hauteur of 9mm and 6mm respectively. This result supports the data generated for the Decrimping Ratio, because TEAM2 uses SL to predict Hauteur, however the fibres in the Top are decrimped. A high DR value is generated when there is a large difference between the Staple Length and the Staple Decrimping Length. As a result, this is reflected in the difference between the TEAM2 predicted Hauteur value and the actual Hauteur value (approximately 8mm).

Table 6: TEAM2 Predicted Hauteur and Actual Hauteur values for 153 Sale-lots, arranged by wool-type.

Wool Type	TEAM2 Hauteur	Actual Hauteur	Diff (Actual - TEAM2)	Diff (Actual – (TEAM2+Mill Factor))
Control Fleece	70	75	5	0
Low MFC Fleece	67	73	6	1
Control Pieces	55	61	5	0
Variable Length Pieces	54	57	3	-2
Belly Wool	50	61	11	6
"Stretchy" Belly Wool	50	64	14	9
All Sale-lots	59	65	6	1

Due to the limited numbers of lots within the Wool Type groupings, it is premature to discuss other results, except for the two Pieces Types, which have 22 lots for both the control and Variable Length groups. Variable Length Pieces were only 2mm shorter than TEAM2 predictions compared to the Control Pieces, which were as per the TEAM2 prediction. Such a closely predicted Hauteur was unexpected, based on responses to the 1997 survey[4].

Figure 4 shows the relationship between TEAM2 predicted and actual Hauteur for 153 lots. This result is similar to that reported by TEAM3[16] which noted that TEAM2 predictions increasingly underestimated Hauteur as Hauteur increased. The CSIRO processing mill is therefore processing in a manner comparable to commercial mills.

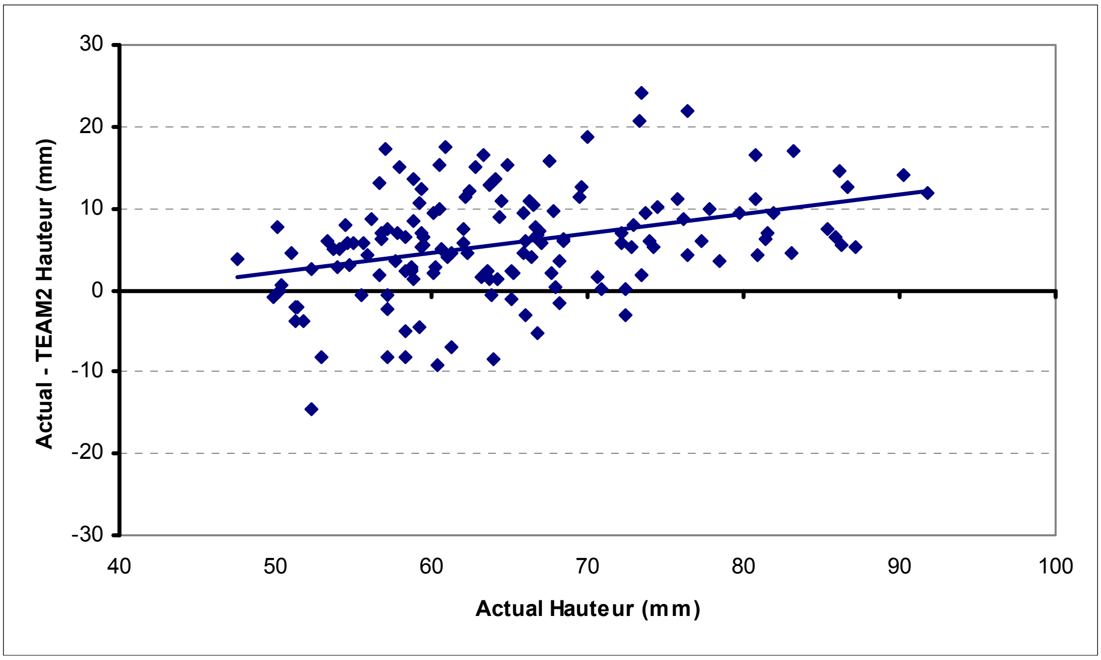

Figure 4: Comparison of actual Hauteur against the difference between Hauteur and TEAM2 predicted Hauteur.

Coefficient of Variation of Hauteur

The relationship between TEAM2 predicted and measured CV(Hauteur) shows a similar trend to that noted in TEAM3[16]. The general negative relationship between actual and TEAM2 predicted CV(Hauteur) is shown in Figure 5.

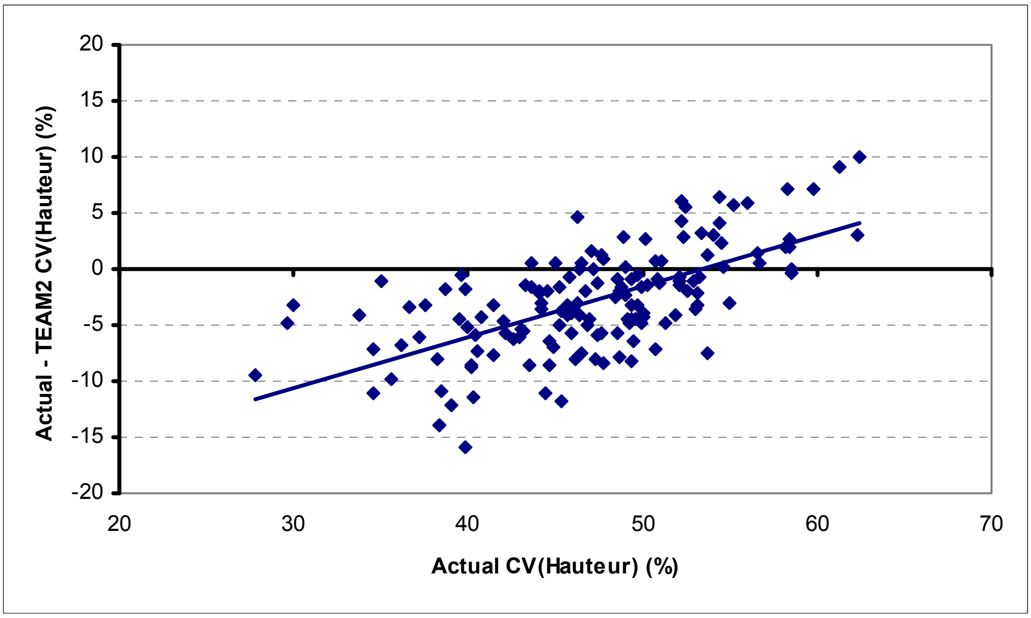

Figure 5: Comparison between TEAM2 Predicted CV(Hauteur) and Actual CV(Hauteur) for 153 Sale Lots.

CONCLUSION

A modification to the data collection from a standard ATLAS test for Staple Length and Strength has produced a new parameter, Decrimping Ratio, which appears to have successfully characterised the decrimping behaviour of wool staples. This preliminary paper has explored the processing performance of individual sale lots that can be considered difficult to predict or "atypical" when compared to most sale lots.

The new statistic, Decrimped Staple Length, has been extracted from modified ATLAS software. From this DSL, a unit-independent ratio DR, can be derived, allowing comparisons across sale lots of different lengths.

DR clearly shows differences for Belly and Stretchy Belly wool types and indications are that it is highlighting differences in other wool types also. Processing results show DR may predict sale lots that do not perform as expected according to existing prediction formulae (for example Bellies). There is potential that DR may add value to prediction formulae, however further analysis will be required to confirm this.

On completion, the single Sale Lot processing trial will cover extended ranges of Raw Wool parameters compared with the TEAM2 and TEAM3 data sets. The trial has already included lower values for Mean Fibre Diameter, Staple Length and Staple Strength than were obtained in these TEAM data sets.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the contribution of the Northern Wool Auction Buyers Association to the design of this trial. The contribution of Phillip Semmel also requires special acknowledgement for the development of the mathematical model and the software that was used to extract the decrimping data from ATLAS. Gratitude is also expressed to Martin Prins and his staff at TFT, CSIRO for processing of the lots reported in this paper.

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