INTERNATIONAL WOOL TEXTILE ORGANISATION

TECHNOLOGY & STANDARDS COMMITTEE — **SHANGHAI MEETING**

Sliver Group — **November 2004**

Chairman: DR. G.S.SINGH (India) — **Report No: SG 02**

Modelling of Length Distributions in the OFDA 4000

By

R C Couchman

Capronex Services Pty.Ltd. PO Box 247, N.Carlton, 3054, Australia

BRIEFING PAPER

SUMMARY OF FINDINGS

The OFDA 4000 instrument measures fibre length and length distributions by optical scanning and then calculates a capacitance distribution with a mathematical model to produce values to approximate Hauteur and Barbe capacitance based distributions. To date, data presented suggests that the models used have some difficulties, particularly in the L1 (length at 1%) levels for Hauteur in particular. The instrument developer sought comment from the author on a draft of Report SG01 presented at this (Shanghai 2004) meeting by them which prompted preliminary investigations on the application of different Capacitance models used in the development of the OFDA 4000.

Preliminary results for the major attributes of Ha, CVHa, Barbe and CVB appear to be reasonably close approximations of values obtained from the Almeter. However, there appears to be a systematic bias in the length distributions. The latest “capacitance” model used appears to be a closer approximation than the initial model based on diameter^2 but it appears that the length distribution bias still exists. This paper examines these differences in an attempt to offer suggestions of where improvements in the capacitance model may exist.

COMMERCIAL IMPLICATIONS – CURRENT AND FUTURE

Spinners, in particular rely on length distribution parameters from the Almeter to set spinning machines and thus any instrument seeking “equivalence” will need to be able to demonstrate that the length distribution statistics also show equivalence.

Report SG01 (this meeting) clearly illustrates that Hauteur is both cross-sectional biased but also Capacitance biased. It is therefore necessary to accurately model capacitance. A further complication is that associated with distributions, altering one end of the distribution to fix a problem in that area is likely to force errors in another part of the distribution. Modelling length distributions is therefore not an easy task.

It is recommended further that the definition of Hauteur and Hauteur distributions be amended in IWTO17-04 and IWTO 26-98 to the following to assist in defining more precisely what Hauteur and its distributions are affected by. The following changes to the definition to include the words “*and capacitance*” is therefore recommended for inclusion in IWTO17-04 and IWTO 26-98:-

“Hauteur = cross-section <u>and capacitance</u> biased length”.

This is the subject of a separate Submission; SG-01 (this meeting).

NOTE

This report will be discussed in the Sliver Group meeting on Sunday 20th November.

INTERNATIONAL WOOL TEXTILE ORGANISATION

TECHNOLOGY & STANDARDS COMMITTEE **SHANGHAI MEETING**

Sliver Group **November 2004**

Chairman: DR. G.S.SINGH (India) **Report No: SG 02**

Modelling of Length Distributions in the OFDA 4000

By

R C Couchman

Capronex Services Pty.Ltd. PO Box 247, N.Carlton, 3054, Australia

SUMMARY

The OFDA 4000 instrument measures fibre length and length distributions by optical scanning and then, using a mathematical model, calculates a capacitance distribution to produce values to approximate Hauteur and Barbe capacitance based distributions. To date, data presented suggests that the models used provide reasonably close approximations for the major "length" parameters but have some difficulties, particularly in the "length @ %" distributions, L^1 (length at 1%) levels for Hauteur in particular.

Depending on the modelling conventions used, it could also be possible to calculate the Barbe distribution directly from the OFDA's "Length" and diameter distribution without using a capacitance model. Capacitance models are therefore only likely to affect Hauteur as the "Length" parameter reported by the OFDA is unaffected by capacitance. It is, however, pointed out that calculating the Barbe distribution, independent of a capacitance model, may compromise the level of agreement between Hauteur and Barbe as the Almeter determines the Hauteur capacitance values first before calculating Barbe and thus the nexus between the two parameters (Hauteur and Barbe) could be broken under such circumstances.

The instrument developer sought comment from the author on a draft of Report SG01 by them to be presented at this (Shanghai 2004) meeting which prompted preliminary investigations on the application of different Capacitance models used in the development of the OFDA 4000.

Preliminary results for the major attributes of Ha, CVHa, Barbe and CVB appear to be reasonably close approximations of values obtained from the Almeter. However, there appears to be a systematic bias in the length distributions. The latest "capacitance" model used appears to be a closer approximation than the initial model based on $diameter^2$ but it appears that the length distribution bias still exists. This paper examines these differences in an attempt to offer suggestions of where improvements in the capacitance model may be possible.

Spinners, in particular rely on length distribution parameters from the Almeter to set spinning machines and thus any instrument seeking "equivalence" will need to be able to demonstrate that either the length distribution statistics also show equivalence or are well correlated so that a mathematical conversion is possible between the two.

Report SG01 (this meeting) clearly illustrates that Hauteur is cross-sectional biased but it is also capacitance biased. It is therefore necessary to accurately model capacitance. A further complication is one associated with distributions; altering one end of the distribution to fix a problem in that area is likely to force errors in another part of the distribution. Modelling length distributions is therefore not an easy task.

Introduction.

Length distribution parameters of wool tops are used by spinners to make machinery settings. They use both L values (length of fibres @ x%) and their corollary, K values (% of fibres @ x length).

Of particular interest are the L^1 or L^5 values as it is this area of the distribution curve that spinners use to set drafting distances to ensure that long fibres do not get caught between the top and bottom drafting rollers and break during drafting, causing subsequent yarn unevenness.

Similarly, at the other end of the distribution, the L^{95-90} area, (the length of 95 - 90% of fibres) i.e. the short fibre area is an important top attribute. This corresponds approximately to the K^{15-25} area in most tops, but values are dependant on mean top length and are thus variable hence the commercial use of the corollary, K values, as a more finite parameter in this part of the distribution. K values (% fibres < x mm) are used in normal trading because of the fixed nature of the definition for each top when the user wishes to know the proportion of short fibre in the top rather than the length of a proportion of short fibres. It is the quantity of these short fibres that define top quality for spinners and it quantifies the number of short fibres entering the uncontrolled area of the twisting cone, between the drafting roller and when twist starts to take hold and control fibres in the yarn development.

Differences in both these areas of the distribution should therefore be of interest and concern to spinners.

This paper reports on L values as it, to some degree, simplifies the discussion and analysis of any effects observed. However, as pointed out above, any effects observed in one distribution (L values) will be manifest in the corollary K distribution. It is equally legitimate to undertake an analysis on the K values and derive similar conclusions.

The tops used in this investigation were those used in the Almeter 2ooo equivalence trials (5). They were originally Interwoollab tops that had been measured by some 80+ laboratories world-wide and in some cases they were in a number of Interwoollab series measured by the Almeter AL100. Some of these tops, therefore, have been measured by the Almeter some 240+ times in Interwoollab round trials. They therefore represent a very stable measurement platform from which to base comparisons.

Access to OFDA 4000 instruments has been through a commercial mill and a research laboratory during pre-commercialisation proving trials of the instrument. Results obtained are compared to the reference AL100 values because of easy access to AL100 instruments and the large body of background reference data from the tops used and measured by that instrument.

Brims (1) reported that the OFDA Hauteur calculation model was originally based on length x diameter^2 and results of such trials have been reported earlier (Brims 2 & 3). These trials clearly showed differences in both K and L values with a particular difference showing up in the L^1 values.

As a consequence, of differences observed in the earlier length x diameter^2 model (Model 1), there has been an update of the capacitance model that clearly shows an improvement in Ha, CVH Barbe and CVB values and many of the distribution statistics (Brims 6). This new model uses a length x $\text{diameter}^{>1.5<2.0}$ model (Model 2). The details of the power function being undisclosed for commercial reasons.

The author was asked to review the draft of that paper for the OFDA developers and it became evident that the L^1 value discrepancy still existed in Model 2 and that there appeared to be an observable but not significant difference at the L^5 level (see table 1 below). This prompted further examination of the data available from the earlier mill trial data on the AL2ooo equivalence tops to ascertain if this situation existed over the entire L distribution (Length @ x%) range as differences of a similar nature had been observed from the work undertaken using the length x diameter^2 model (Model 1). The new model using a length x $\text{diameter}^{>1.5<2.0}$ model (Model 2) and the AL2ooo equivalence tops was also examined in another laboratory to confirm findings of Brims and to extend the range of L values analysed in his study.

Table 1. Differences in L values between the Almeter AL100 and Two Capacitance Models in the OFDA 4000.

Sample	Almeter			OFDA 4000 $um^{>1.5<2.0}$ Model 2			OFDA 4000 um^2 Model 1		
	L50	L5	L1	L50	L5	L1	L50	L5	L1
1	41.1	82.9	108.3	42.2	85.1	109.3	40.9	79.2	101.5
2	43.9	92.1	114.6	44.1	91.6	114.4	43.0	85.2	106.9
3	90.8	139.7	154.8	92.0	135.8	145.8	91.7	130.3	138.3
4	85.5	125.1	141.6	85.2	121.4	132.5	84.5	116.7	125.6
5	41.8	73.9	88.5	42.2	74.6	88.4	41.2	69.8	81.6
6	93.5	147.1	165.9	93.0	142.4	156.7	93.0	136.6	148.7
7	64.7	134.1	150.3	64.6	133.3	147.2	61.9	126.0	137.6
8	78.7	121.9	136.9	77.4	121.6	135.5	77.0	115.9	127.8
9	60.9	114.5	131.1	59.6	111.0	126.9	58.9	104.4	118.0
10	91.1	163.8	200.2	94.4	166.7	189.4	95.5	159.8	179.4
Av.Diff*				***-0.27mm***	***1.2mm***	***4.6mm***	***0.44mm***	***7.1mm***	***12.7mm***

*Note * Difference from AL100 values.*

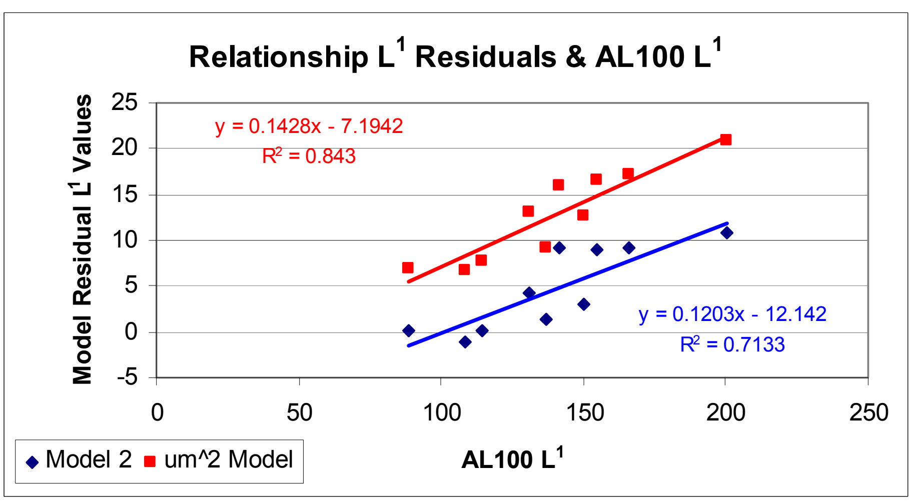
The differences above clearly indicate an incremental difference as the L values move towards the long fibre end of the distribution for both, Model 1 & 2, OFDA capacitance models despite the fact that the latter model (Model 2) shows significant improvement.

Recent repeat testing of the *AL2ooo* tops (5) using the length x diameter $^{>1.5,<2.0}$ model was undertaken to determine if this situation extended over the whole distribution, as Report SG01 only provides data on the L^1, L^5 and L^{50} values.

Data is presented below to compare the two model distributions against the Almeter AL100 values of the reference tops.

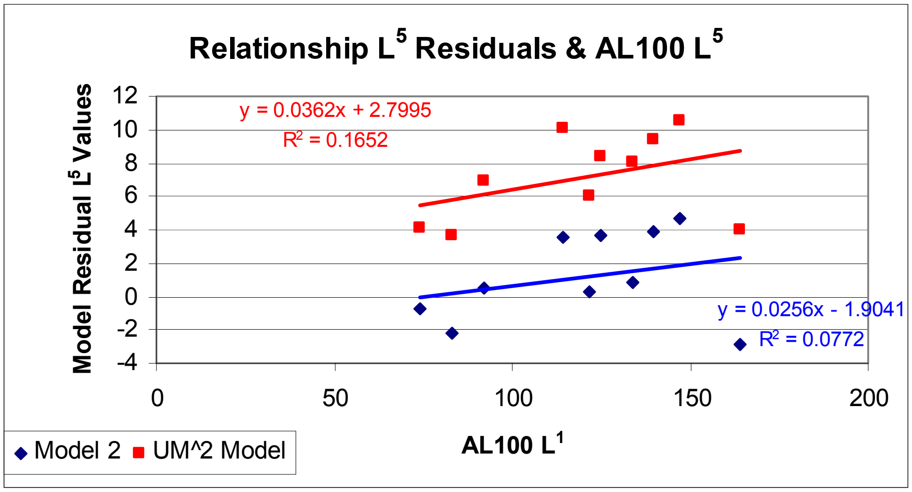
Examination of the relationship of the residual values and the L^1 values clearly indicates a strong relationship with the fibre length at 1%. This further suggests that a systematic bias exists.

Fig 1. Relationship of Residuals with AL100 L^1 Values using two Capacitance models



A similar pattern but not statistically significant, exists for the L^5 relationship.

Fig 2. Relationship of Residuals with AL100 L^5 Values using two Capacitance models

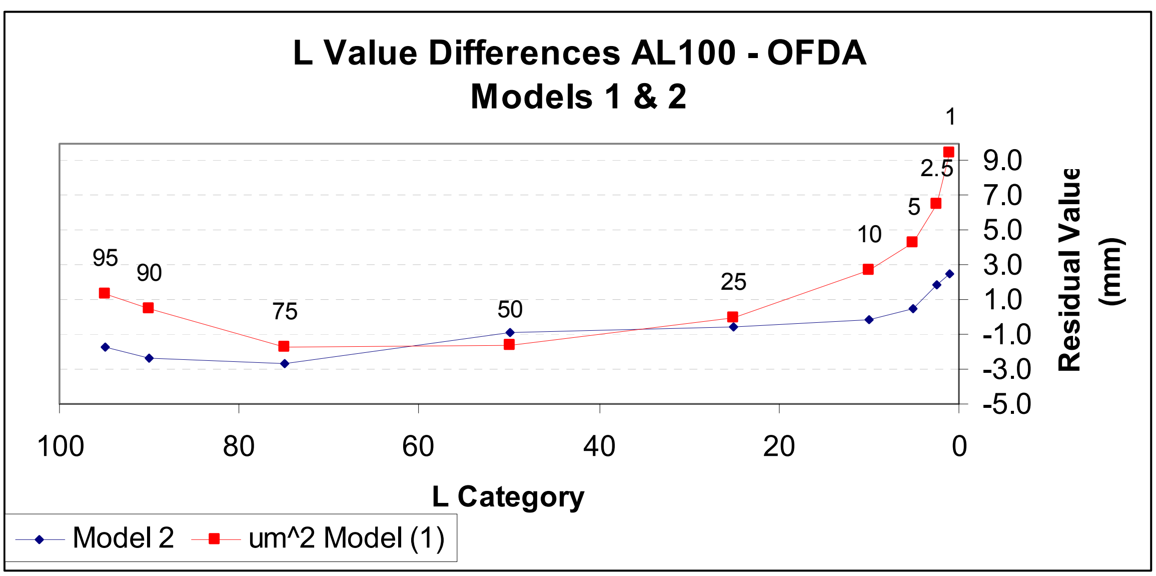


This analysis suggested that there was a need to investigate the full distribution statistics for these tops at other L% values to determine if any trend existed over the full length of the distribution.

Figures A1-A5 (Appendix A) provide graphic representations of the comparisons of the full L value distributions for the two different OFDA models used to date and the AL100 capacitance values for the 5 reference tops used. They clearly show differences in the distributions which appear to increase as the L value decreases. i.e. in the long fibre region of the top. Similarly there appears to be a length dependant bias in the differences with larger differences at each end of the distributions as the average top length (Hauteur) increases.

The mean difference values of the OFDA – Almeter distribution statistics for the two OFDA capacitance models are presented below.

Fig.3 Length Residual Values from Diameter^2 Model (1) & 2



This figure is presented in reverse format to correspond with the Almeter's cumulative distribution printout format. It shows a clear trend in the diameter^2 model (Model 1). It is however clear that whilst the relationship has changed as a consequence of the change to Model 2 there still appears to be a systematic trend towards increased differences as the Length % of fibres increases.

The differences at the L^5 and L^1 levels in this study (0.5mm and 2.5mm respectively) are of the same order as that observed by Brims for capacitance Model (2) and it is therefore likely that similar effects are observable in Brim's unreported data for the other L values reported above for this study.

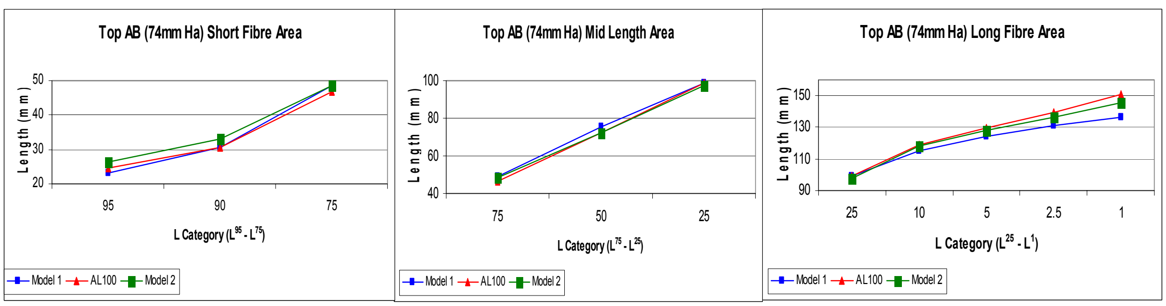
The point of issue here is, however, not the absolute level of difference observed but the systematic pattern that has emerged suggesting a degree of failure of the capacitance model and the influence of another factor or factors not being accounted for in the new model.

It is also interesting to note the negative values in the $>L^{10}$ area. This is providing a counter-balance to the $<L^{10}$ values; the overall average difference across the L values being only 0.1mm. This counter-balancing effect in turn allows for reasonable approximations of Ha, CVH, Barbe and CVB being currently observed from this latest capacitance model. This effect is demonstrated in all the tops measured in this study and is clearly shown in Figures A1 to A5 (Appendix A).

This counter-balance effect is highlighted below with the distribution curve split into 3 sections to clearly illustrate where the differences are occurring. This example is for a 74mm Hauteur top; a commonly available commercial top length, in the middle of the range of tops reported in this study. It can be clearly observed that there are increasing discrepancies in the 2 extreme ends of the distribution but a fairly close approximation in the centre area of the distribution curve. The differences at the extremes counter-balance each other to provide similar Hauteur and Barbe values along with the respective CV values for these attributes.

Fig. 4

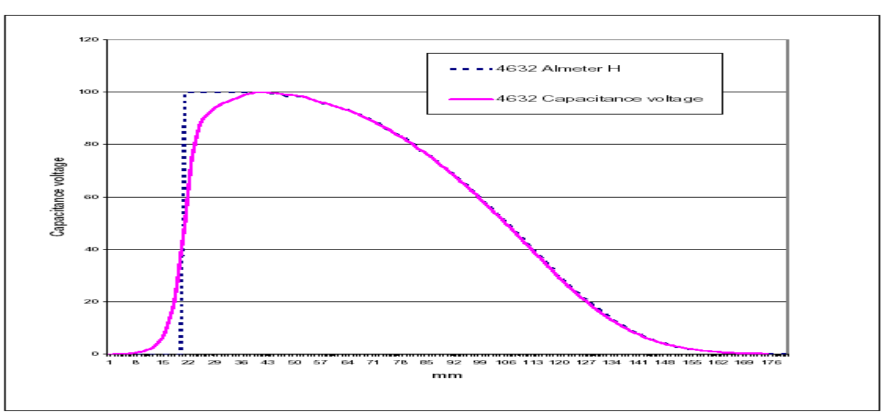
Model Differences in 3 Areas of the Distribution Curve



Top AB = 74mm Ha

One of the critical issues associated with capacitance measurement is the "squaring of the beard". This is discussed with particular clarity in Report SG 01 (this meeting). To recap however, the Almeter determines peak capacitance signal then takes 50% of the remainder at the point of "squaring the beard". It extends the maximum capacitance value to that point as the start of the beard. Any error in setting that point will therefore have significant effects on all the distribution values.

This is demonstrated in Brim's Figure 3 (reproduced below as **Fig.5)**



For example, if the "beard extension" level is too low then L^1 value will be significantly lower, and the K^{25} values will also be lower. This is the joint scenario currently being presented in the OFDA 4000 data. It is therefore worth inspecting that area of the modelled capacitance curve to observe if there are any likely affects occurring in that region of the distribution curve.

The OFDA 4000 MES file records a value called "tip to 1st scan" and it is understood that this value has a significant effect on the extrapolation algorithms used to normalise the length and Hauteur distributions.

In a bid to see if there was any influence associated with the "tip to 1st scan" value its relationship to the L^{95} value i.e. the length of 95% of fibres, i.e. those closest to the beard start (short fibre end), was examined.

Figures 6 and 7 provide those analyses for both models.

Fig. 6. Diameter² Model (1) "Tip to 1st Scan" Distance and L^{95} Value.

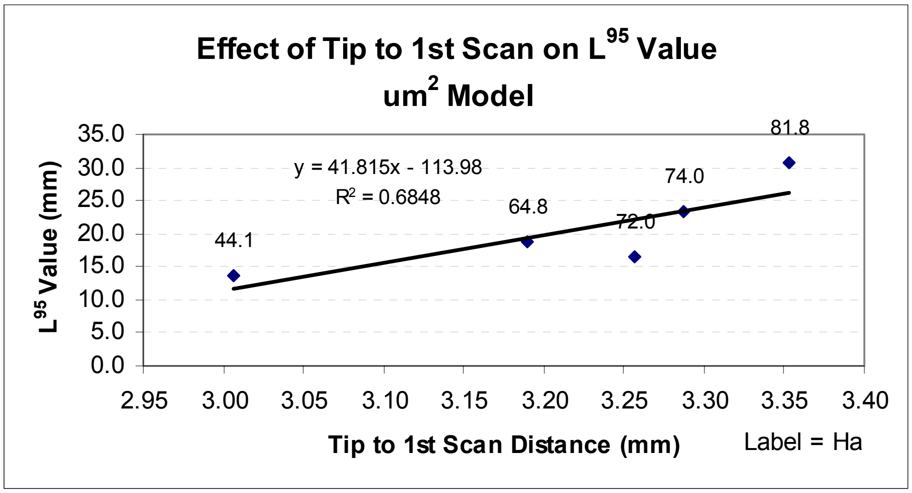
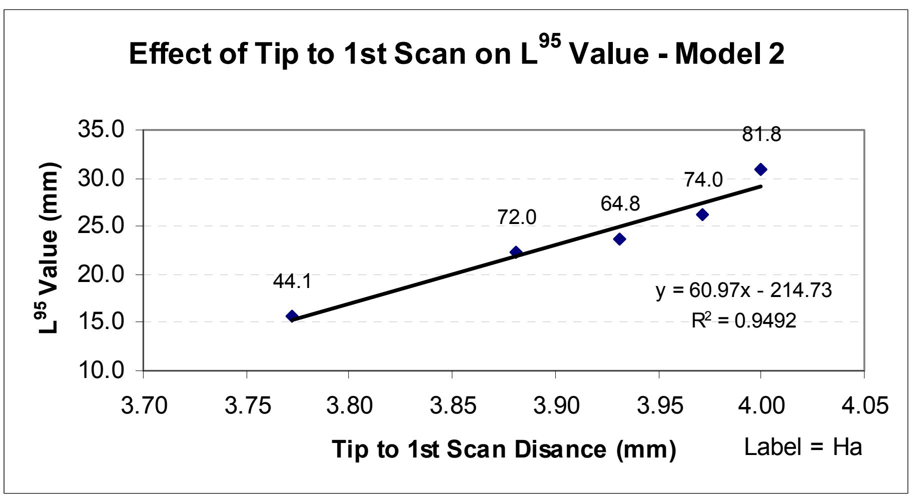


Fig 7. Diameter <1.5>2.0 Model (2) "Tip to 1st Scan" Distance and L^{95} Value.



Both these figures demonstrate a strong relationship and once again there is a clear improvement in the relationship resulting from Model 2. There is a relationship between the two attributes and this also translates to a relationship with Hauteur per se. as is demonstrated in Figures 8 & 9.

Fig.8 Model 1

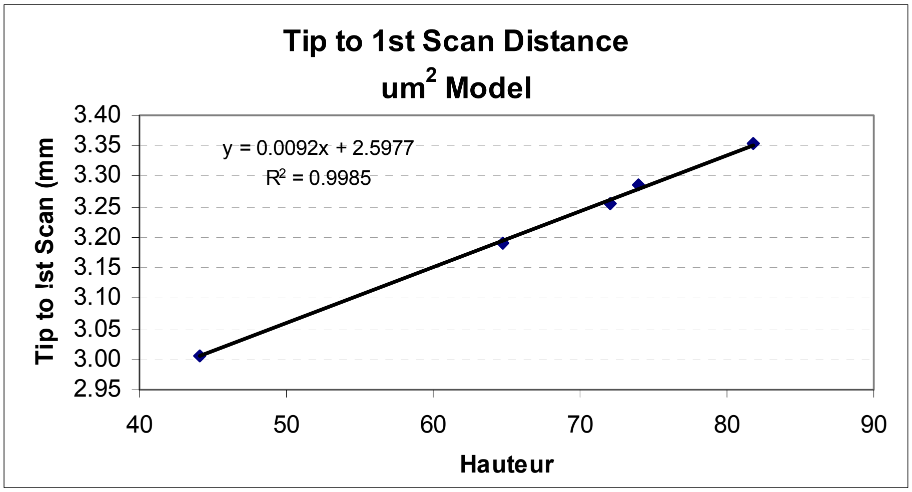
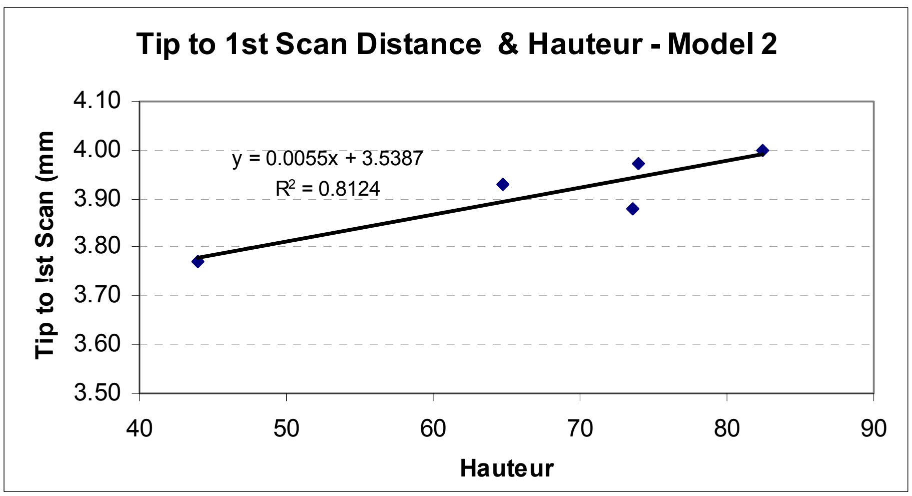


Fig 9. Model 2

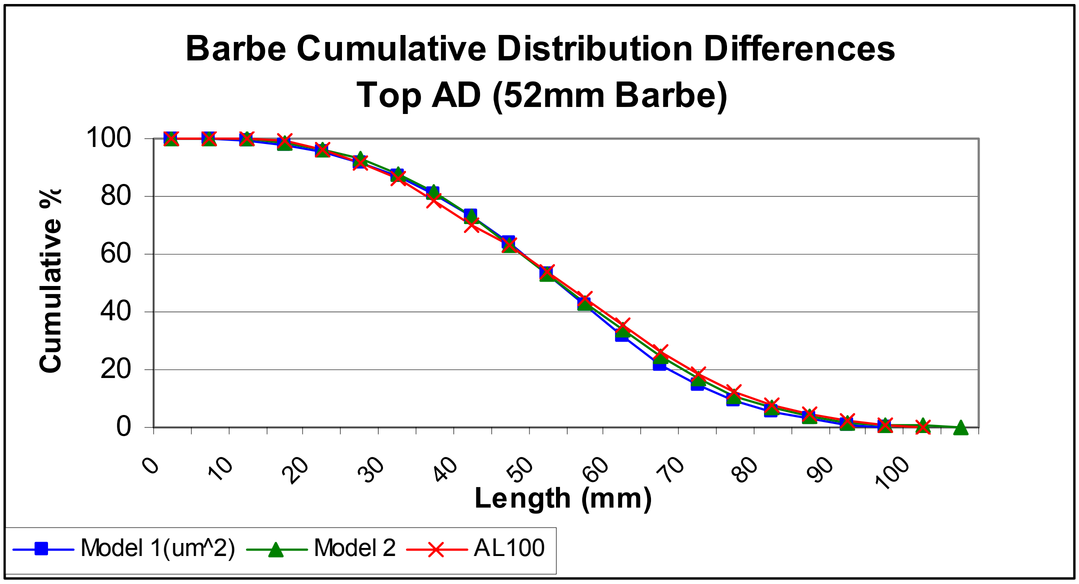


Brim's paper (6) suggests that all the capacitance curves in that paper have a resolution of 1mm, and are aligned so that the 50% threshold at the rising edge is at 20mm, i.e. at a set distance.

Whilst this paper is devoted to the L distributions for Hauteur similar issues occur with Barbe. A detailed analysis of the L category values for Barbe has not been undertaken but the figure below is presented to purely illustrate that there are similar effects to those observed for the Hauteur L category distributions.

Figure 10 below shows the cumulative Barbe distribution curves for Models 1 & 2 compared to the AL100 curve. Once again this illustrates that Model 2 data is closer to the Almeter. Differences still occur in the same regions of the distribution curve as occur in the Hauteur data. This is important to the carding wool trade and the example provided here is typical of carding wool lengths measured in LAC tests.

Fig.10. Example of Barbe Distribution Differences



Conclusions.

This report highlights differences in the L categories and thus their K distribution corollary values derived from different "capacitance" models used by the OFDA 4000 to calculate Hauteur and Barbe distributions and statistics. These differences occur in the short and long fibre ends of the distribution and counter-balance each other to provide what appear to be reasonable estimates for the main parameters of Hauteur, Barbe and their respective CV values. The differences however indicate a systematic bias in the values derived by both capacitance models used to date. Whilst data presented above reports on preliminary work there is a strong suggestion that the tip to 1st scan value may hold the key to further improvement in the OFDA 4000 capacitance model rather than the adjustment of the cross-sectional area factor. Because of the preliminary nature of this study it is also unclear, at this stage, if other known biases associated with capacitances are influencing the differences being observed in the new Model 2 capacitance model used by the OFDA 4000.

If we go back to basic physics and assume that a fibre is perfectly cylindrical, as the Almeter does, then the linear density of that cylinder is described by $\pi r^2 L$ * specific gravity. If we assume that the specific gravity of fibres is equal and π is constant then the formula can be reduced to $r^2 L$. This is after all what we are trying to model when we translate the length and diameter information derived by the OFDA 4000 into an equivalent cumulative capacitance distribution for further calculation of actual Hauteur, Hauteur distribution, Barbe and Barbe distribution statistics.

The use of the power term diameter $^{>1.5 < 2.0}$ (Model 2) therefore needs to be questioned and perhaps we should be focussing on the area of the "beard correction" instead as well as investigating some of the other known capacitance bias influences.

It is recommended further that the definition of Hauteur and Hauteur distributions be amended in IWTO17-04 and IWTO 26-98 to the following to assist in defining more precisely what Hauteur and its distributions are affected by. The following changes to the definition to include the words "*and capacitance*" is therefore recommended for inclusion in IWTO17-04 and IWTO 26-98:-

"Hauteur = cross-section <u>and capacitance</u> biased length".

This is the subject of a separate Submission; SG-01 (this meeting).

Acknowledgements:

The author wishes to thank BSC Electronics and Mr Mark Brims for the offer to provide access to one of their OFDA 4000 instruments for investigations. In addition, the early provision of the draft of Report 01 (this meeting) provided the opportunity to undertake further testing and to report on this work. Without this co-operation this would not have been possible.

Acknowledgement is also made to staff and management of the two laboratories involved in these trials.

REFERENCES

1) Brims, M. (2002) *Introducing OFDA4000: Improving Agreement on Hauteur Measurement between OFDA4000 and Almeter.* IWTO Sliver Group, Barcelona, Report SG02

2) Brims, M. (2003) *Improving Agreement on Hauteur Measurement between OFDA4000 and* Almeter*.* IWTO Sliver Group, Buenos Aries, Report SG02

3) Brims, M., Baxter P.,(2004) *Improving Agreement on Hauteur Measurement between OFDA4000 and Almeter.* IWTO Sliver Group, Evian, Report SG01

4) IWTO-17-04 Determination of Fibre Length Distribution Parameters

5) Couchman R.C. & Holmes P.J., (2003) *Report on Equivalence Round Trials for the Almeter AL2ooo*. IWTO Sliver Group, Debrovnik, Report SG03,

6) Brims, M., (2004) *Improving Agreement on Hauteur Measurement between OFDA4000 and Almeter.* IWTO Sliver Group, Shanghai, Report SG01

7.) IWTO-26-98 Glossary of Terms.

Appendix A

Fig.A1 AD = 44.1mm Ha

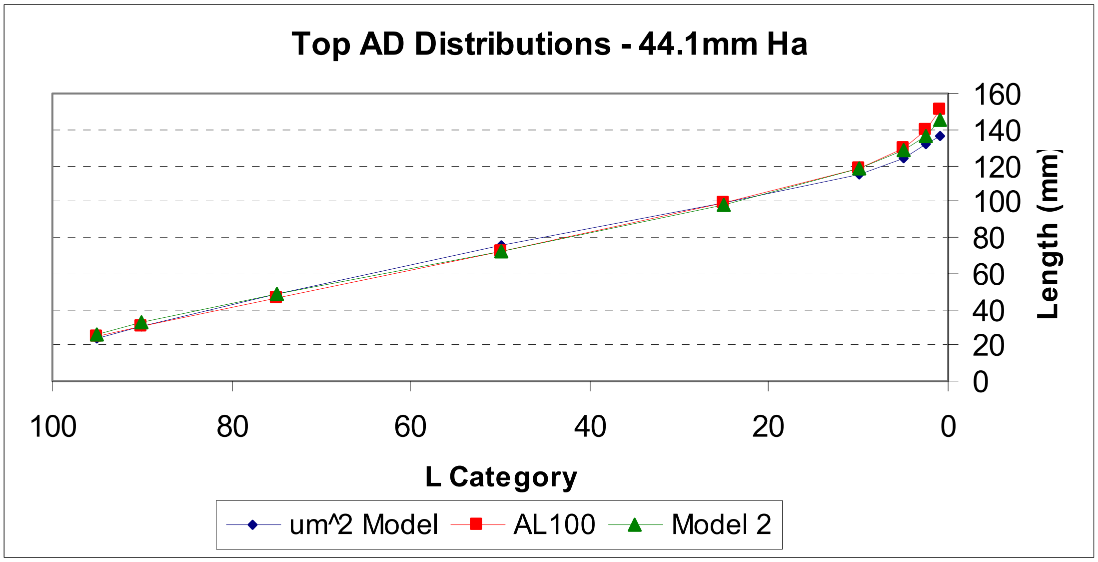


Fig A2. ZZ 64.8mm Ha.

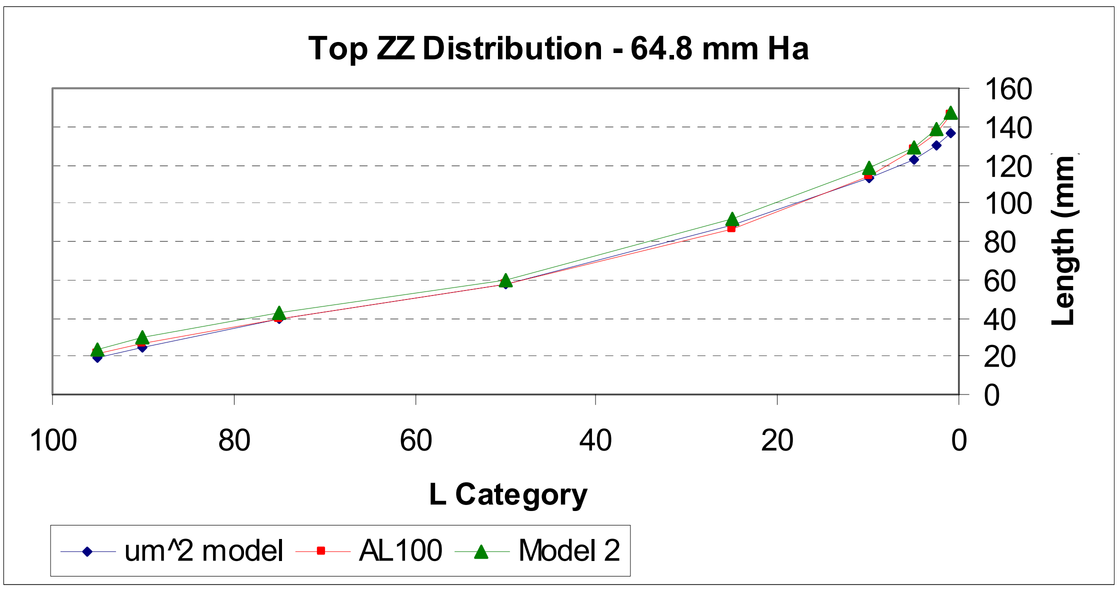


Fig.A3 AP 72.0mm Ha

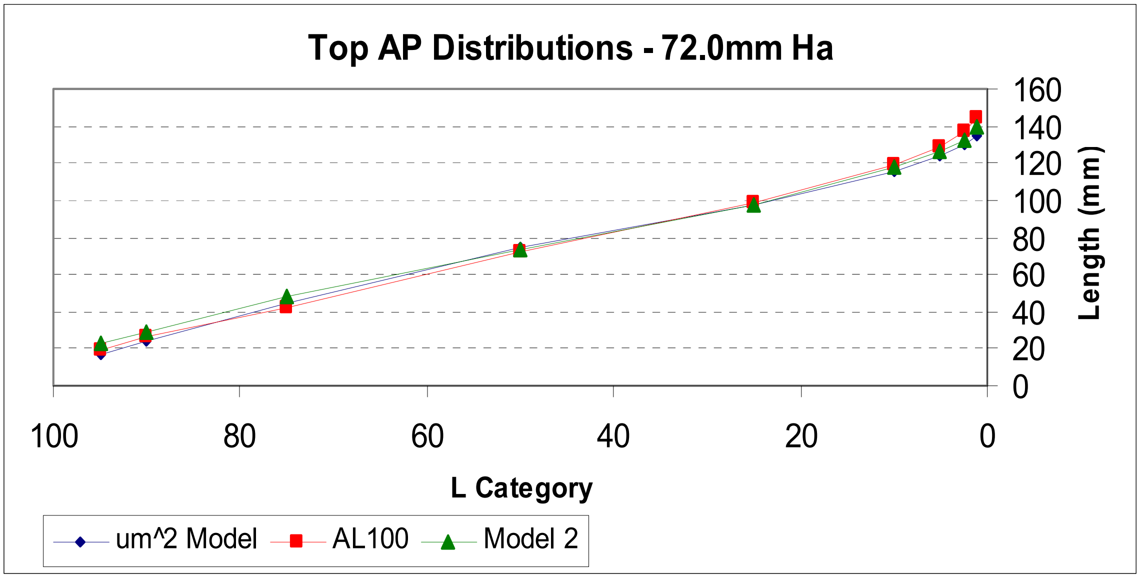


Fig A4. AB 74.0mm Ha

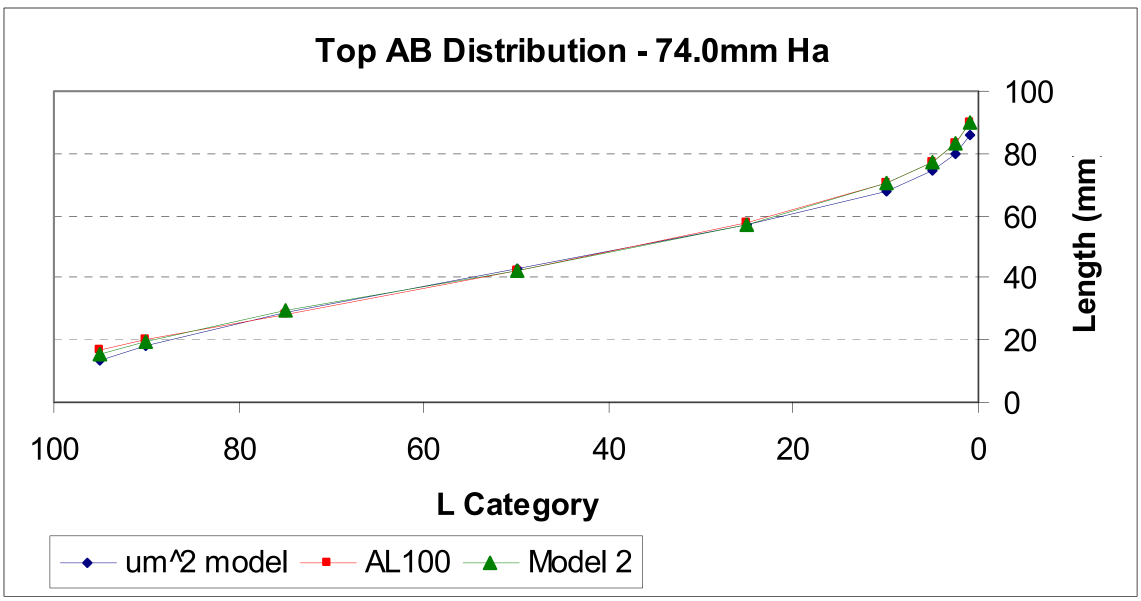


Fig.A5. AZ 81.8mm Ha