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Understanding the Effects of Changes over Time to the OFDA 4000 Software

By

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SUMMARY

During the development of the OFDA 4000 there have been a number of iterations of the OFDA software. This is a logical process in being able to satisfy IWTO requirements for the OFDA 4000 to demonstrate 'equivalence' for Hauteur, Barbe, their CV values **and the respective distribution statistics.**

Baxter (2005) has shown that OFDA 4000 values generated for the average values Hauteur, CVH, Barbe and CVB are in statistical agreement with the Almeter. There is new evidence emerging concerning the range within these parameters (Balasingham et.al. this meeting). Couchman's (2005) findings generally concur with this but there remains a continued debate concerning what appear to be systematic differences **in the distribution parameters** (Baxter 2005, Couchman 2005 & Balasingham et.al 2005) and the methodology used to convert optical length and scan step diameter readings to Hauteur and Barbe.

The IWTO questionnaire that was sent to IWTO national committees after the Hobart meeting, seeking their feedback re the commercial importance of a range of MFL parameters, did not receive many replies. This low level and conflicting response makes it difficult for technicians to advise IWTO members of the importance of the technical differences being observed between the Almeter and the OFDA4000. Significant differences are occurring in the K (short fibre) and the L (long fibre) values so commercial members need to decide if the differences will cause trading problems.

This paper reports on observations of the effects of the software iterations over a 2 year period and on the current situation regarding attempts to match the cumulative distribution curves which generate all the 'fibre' length attributes reported by the Almeter.

The current OFDA 4000 software (Ver."5.18" "Calb date = 30 Nov 04") was used by Baxter (2005) in reporting the results of an international round trial and thus results for earlier versions are by and large, redundant except in the context of understanding the changes that have been made to the software and why they are important in trying to match the Almeter's cumulative capacitance also referred to as the cumulative distribution or frequency curves.

Reported OFDA Capacitance Modeling

Brims (2002) reports. ... *"the Almeter scans the beard with a capacitance sensor to measure the quantity of wool at each point along the beard. This measurement is proportional to the number of fibres multiplied by the cross sectional area of each fibre at that point. This cross section biased length is called Hauteur [11][12]. If the diameter of the fibres does not alter along the beard, then the Hauteur will be the same as fibre length."*

"The Almeter does not measure fibre length." This is, however, a moot point and has been well debated to the extent that there is now clear understanding that each length measurement system has its own set of biases.

Brims continues the explanation...*"A change in fibre diameter profile along the beard will cause the Hauteur to be different from the fibre length. Since this is based on the cross sectional area, the difference is proportional to the square of diameter.*

For example, if the diameter has a 5% increase from 20um to 21um along the beard, the increase in the cross sectional area will be (21/20)² or 10.2%."

“The OFDA4000 measures length by counting the number of fibres across the beard at 5mm steps. It is recognised that this length may be known as “OFDA4000 length”, (now defined by IWTO as Optical Length)..... “The hauteur (sic) is calculated from multiplying this length by the square of the diameter profile, and the barbe (sic) is calculated from the length distribution in a similar way to the Almeter, although the Almeter barbe will be different since it is based on hauteur and not length. The OFDA4000 provides the length based barbe and the hauteur based barbe to compare with Almeter barbe.”. This refers to software Ver.5, 23 Apr 99.

“Summarizing the length values from OFDA4000

“The drawn fibre beard is held in the microscope focal plane by the beard guide, which is set to a gap size of 0.2mm to prevent holding the fibres so tightly that they break, and to allow neps to pass through. The state of the fibres when their length is measured is semi stretched. At the point that the end of the fibre passes through the guide and stops being counted, the fibre will have shrunk slightly from the almost fully stretched state it was in as it left the beard.

The first scan across the beard is not at the start of the beard (0mm) since this is held in the gripper. The position of the first scan to the end of the beard is set by the width of the fibre guide, the distance from the guide to the tip of the gripper and the length of fibres inside the gripper. In theory, the end of the beard will never be perfectly aligned, but will at best be aligned in a range equal to the needle bed protrusion step size. This size can be varied to achieve the correct draw density, and is typically 1.5mm.

Hence at best the fibres are aligned to +/- 0.75mm of the “true” end of the beard, where the true end of the beard is defined as the mid point of the feed step. The computer automatically adds this length since it has determined the step size. With the current prototype, the first measurement takes place 6.8mm from the end of the beard. The next prototype is being constructed to reduce the position of this first measurement to less than 5mm from the beard end.

The number of fibres at each 5mm step along the beard is interpolated from the actual scan positions since the first scan is not 0mm, but at typically 6.8mm. The diameter profile at 0 mm and 5mm is set equal to the first diameter scan to simplify the analysis. The cumulative percentage of fibres at 0 and 5mm is set to 100% and the value at 10mm, 15mm etc is interpolated from the scan count above and below each point.

The hauteur distribution is calculated by multiplying the number of fibres remaining at each length by the square of the diameter at that length, which creates the cross section biased length.”

In 2004, Brims added to the public disclosure of methodology in a paper to the IWTO Sliver Group. A significant departure from the original methodology was an alteration to the diameter power function from um^2 to $um^{>1.5<2}$ and the addition of a 'stretching' routine.

Observation of this 'stretching' and some of the likely implications was first reported by Couchman (2004) on data obtained from Series 2 MES files (software Ver 5.16 04June04). This first attempt by the OFDA 4000 to overcome a 12mm L_{1H} deficiency in differences from the Almeter results failed to resolve the problem and additional changes were then made by adding extra CI's to the long tail of the Hauteur distribution in Ver 5.18 30Nov05 of the software.

The new power function and changes to the length distribution statistics did help to improve agreement of the distribution statistics whilst still maintaining the H_a & CVH_a values but did alter the distributions and thus resulted in other effects. These were reported by Couchman (2005) who believed them to be commercially sensitive and significant.

Again, the following text is quoted for reasons of accurate description and this section refers to Versions 5.16 and 5.18 of the software i.e. from mid 2004.

“How OFDA Measures Hauteur Using Capacitance Prediction

Trial and error was used to simulate the low pass effect of the beard start and the stretching effect of the fibre ends not being aligned with the beard. An unexpected discovery was that the cross section area was best matched by raising the diameter to a power less than 2. The exact coefficients used are commercially confidential since they can be used to allow other length measurement systems to simulate Almeter hauteur.

The final procedure is as follows:

- 1. The percentage of fibres at each 5mm scan point is linear interpolated to 1mm*
- 2. The diameter profile measured at each 5mm scan point is linear interpolated to 1mm resolution, with the beard end placed at 20mm resolution,*
- 3. The percentage of fibres at each 1mm point is multiplied by the diameter at that point*
- 4. A Gaussian low pass filter ($1mm < SD < 4mm$) is convolved with the curve.*
- 5. The long end of the beard is stretched by a fixed percentage (in the range 1.05 to 1.3%), raised to the power n ($1.5 < n < 2$). This simulates the cross section biased area of a very well end aligned beard*
- 6. The final capacitance curve is aligned at the 50% rising edge point and this is used as the start of the beard.*
- 7. The curve is sampled at 5mm intervals to provide the hauteur percentages.*

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8. *Barbe is calculated from the predicted hauteur.*
 9. *Length is not adjusted."*

What exactly is meant by dot-point 4 (above) is unclear and the rationale for "stretching the long end of the beard" by a fixed percentage and altering the diameter power function is debatable from a metrology point of view.

A recent study by Couchman & Turk (2005) that attempted to develop an improved capacitance model for the OFDA 4000, confirmed earlier reported anomalies in the data sets (Couchman 2004 & 2005) and reported on them in respect to capacitance modeling effects. Couchman's earlier trials demonstrated that systematic biases existed in the distribution curves of tops and he considered them to have commercial significance.

The Couchman & Turk observed, varying numbers of repeat measurements, additional class intervals and other features in the MES files data sets consistent with the "stretching" routine Brims describes above. These software changes in the OFDA4000 made it difficult for the authors to be confident in the results of the new model which relied on the base diameter and optical length figures originating from those MES file data sets rather than measured values alone. The study does show a statistically significant improvement in the matching of the Almeter and this new OFDA model ($P > 0.01$) for the distribution curves. In addition, the critical L_{10H} , L_{5H} and L_{1H} values have since been shown to also be not significantly different to the AL100 values in a matched pairs t test but the K_{20H} , K_{25H} and K_{30H} values remained significantly different from the AL100 values in the same analysis. The new OFDA model distribution curve results still remained significantly different to the Almeter's distribution curves. To reiterate, it is the distribution curves that dictate the subsequent calculation and reporting of mean (Ha or Barbe), CV (Ha or Barbe) and the commercially sensitive K & L distribution features for either 'length' measurement system.

Couchman (2004 & 2005) has suggested that these data anomalies result in unstable effects across tops relating to the distribution statistics which are of commercial significance, particularly for the low K values (K_{15} - K_{30}) and the high L values (L_{10} to L_1) for both Hauteur and Barbe distributions. He also suggests that whilst these differences in distribution values are systematic over the distribution range for each top they are variable between tops; i.e. tops of differing greasy blends have different degrees of variation between the measurement systems.

There is little debate about the mean values of Hauteur and Barbe and their respective CV values from an averaged result perspective. Baxter (2005) has reported on these in a report describing an international round trial for the OFDA 4000. Further details will be provided in this meeting by Fish et.al. and Balasingham et.al., in papers comparing the Almeter and Laserscan results from the TEAM 3 trials with OFDA 4000 results from the same tops, which show the range of differences at any given mean value. This feature should be of interest to commercial users of these measurements as it could affect commercial decisions.

Couchman & Turk postulated on the effect of using 'paired' (or repeated) data in modelling capacitance but at that point the changing step distance was not known (see below). They believe that such changes will affect diameter, length and subsequently Hauteur and Barbe and their associated distribution statistics. There is currently some indication from a limited data set (see below), using the existing MES files, that the anomalies between the Laserscan and OFDA 4000 diameter results (tables 4 & 5) may in fact partly explain the diameter differences reported by Fish et.al. and Balasingham et.al. (this meeting).

Understanding the OFDA Scan Measurement Routine.

During September 2005, Couchman undertook a small trial that re-measured one of his previously reported reference tops (Couchman (2004) & (2005), Couchman & Turk, (2005)) a number of times and counted the number of step travel distances and movements of the fibre gripper along with the number of scanning operations and matched that with the data presented in the MES file (the OFDA's output file). A video camera was used to capture the visual results as confirmation of the counts made.

Until recently it was not clearly understood, by those other than the developers of the OFDA 4000, how this was being done. Consequently no study was carried out to measure what, if any, affects this might be having on other parameters, particularly those of commercial importance. They had been seen purely as anomalies in the data sets.

This new small study revealed that, what had previously been reported as 5mm steps was, in fact, a series of 12 x 5mm steps and then a lengthened step distance of 10mm to the end of the fibre draw scan, subsequently referred to as the 5:10 step routine. This has subsequently been confirmed by the developers. This routine results in a sequence of repeated data in pairs once the 12 x 5mm (60mm) scan is reached to infill the skipped 5mm class intervals until a critical number of fibres is reached at which point the routine combines diameter data from adjacent scans to improve diameter precision, it completes the data array with additional values after the last scan is completed.

As diameter is an integral part of the capacitance model calculation, 'pairing' of data, changes to the step distance function and changes to the diameter calculation in this manner will affect the efficiency of the model and indeed will influence the cumulative 'capacitance' and hence residual values (difference between Almeter and any of the models results) obtained

The Couchman & Turk study provided an opportunity to better understand differences in raw data and distribution statistics observed in a earlier studies by Couchman (2004 & 2005) whilst attempting to develop a better fitting 'capacitance' model. With this knowledge as background understanding it is believed that this step measuring function may be having a significant effect on results from that and earlier studies using both the current and earlier versions of the OFDA software.

Changes to Mean Fibre Diameter over Time

During the historic measurement over time of Couchman's reference tops, there has been a noticeable change between trials in both the mean diameter and the CVd values. These are both very highly significant ($P > 0.001$ see Appendix 1) between tops and between trials. It is difficult to account for such differences from repeat testing of the same Interwoollab tops on 3 separate occasions. Table 1 provides the mean of 4 tests in each series.

Table 1.

Top Identity	Series 1	Series 2	Series 3	Total	Laserscan (S3)
Mean Fibre Diameter					
AD	20.63	20.18	20.35	20.39	20.5
ZZ	22.43	22.25	22.34	22.34	22.4
AP	20.88	20.55	20.66	20.70	20.8
AB	21.69	21.34	21.50	21.51	21.6
AZ	22.37	22.02	22.14	22.18	22.0
CVd (%)					
AD	21.81	22.27	21.98	22.02	
ZZ	23.45	24.18	23.89	23.84	
AP	21.04	21.39	20.84	21.09	
AB	22.47	23.08	22.16	22.57	
AZ	20.59	21.04	20.69	20.78	

Note 1: Top ZZ in Series 2 was only measured twice. The missing values were calculated as the mean of the existing measurements for that top in Series 2.

Note 2: The Laserscan values derived from a bulk sample of each top tested during the Series 3 trial are provided as a comparative value.

There are 2 possible explanations for this:-

- There are calibration differences or
- Differences are due to sampling and measurement routines.

The differences would appear to be more than one could expect purely as a consequence of between repeat test differences. If it is due to changes in the calibration routine then this raises additional questions, on the appropriateness of the diameter algorithms and points relating to software changes in the capacitance modelling for Hauteur and Barbe. Without further experiments it is difficult to shed further light on these differences, however there is reason for concern if it is the latter.

Doubling of the step distance travel part-way through the scanning routine at a set mandatory distance (60mm), which occurred after Series 1, is likely to introduce a sampling bias through a disproportion of fibres (< the true frequency) being selected at the long (coarse) end of the distribution. If this data is subsequently used in the mean diameter calculation then the mean will decrease. The details in Figure 1 below support this hypothesis.

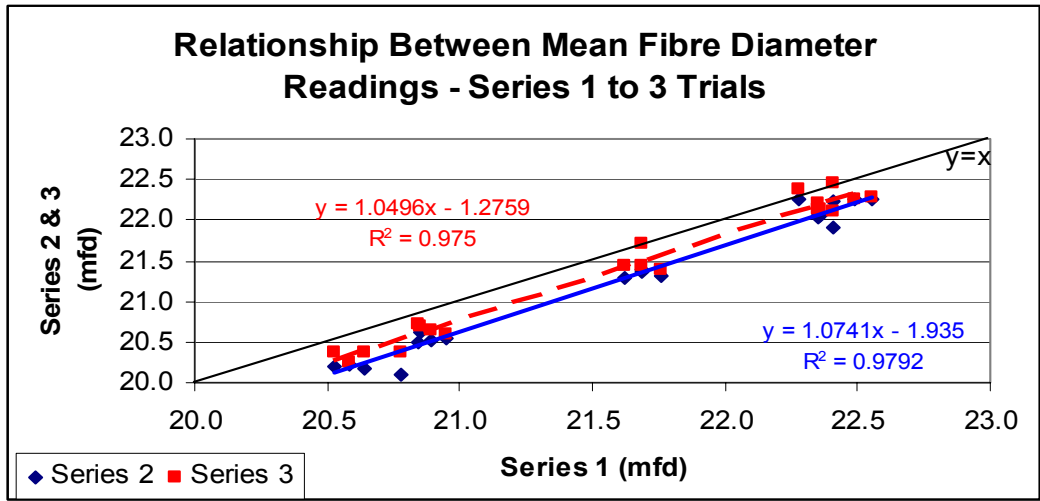


Figure 1.

The reduced differences observed between Series 1 & Series 3 data compared to the Series 1 & 2 comparisons may be due to the use of additional CI values being inserted into the data set but no attempt has been made to quantify this. There is therefore some indication that sample and measurement routines are having an effect as the scan step distance in the measurement routine has changed twice since Series 1 tests were undertaken.

Further work is required to test this hypothesis and confirm the current measurement and calculation routines used in the OFDA software.

Changes to Optical Length Measurements over Time.

As with the observed mean fibre diameter changes there has been an observed increase in the optical length of the maximum fibre length over the series of these trials. This is referred to here as CI_{Max} or the class interval in which the last optical length frequency value is recorded.

Brims has previously advised that the Length values have remained the same, (see point 9 page 3 above... 9. *Length is not adjusted.*) it is only the Hauteur distribution values that have been stretched ... (5. *The long end of the beard is stretched by a fixed percentage (in the range 1.05 to 1.3%),* to improve the long fibre distribution statistics. Once again, it is postulated that the change from a 5mm step distance to the 5:10 step routine is impacting on the observed change in the reporting of the maximum class interval for the physical length of the fibres in the sample as illustrated in Figure 2 below.

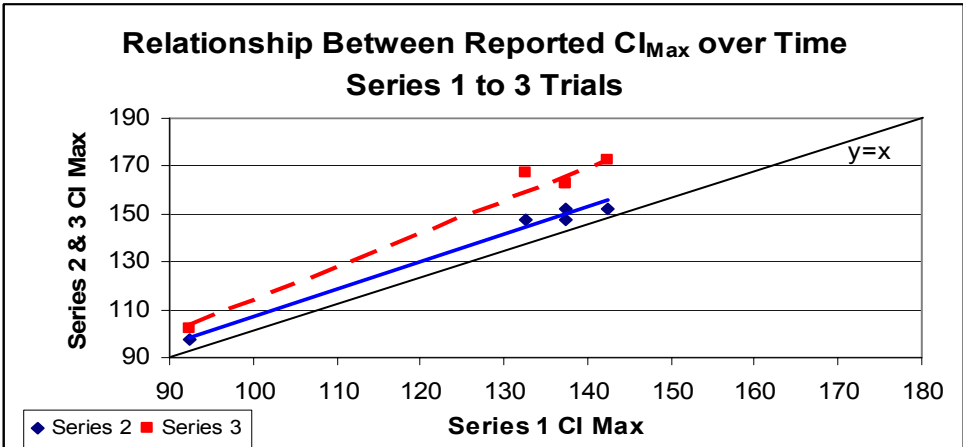


Figure 2.

This also has implications in the calculation of the cumulative frequency distribution for the optical (measured) length of the top. An example for Top AD, the shortest top least affected by the stretching routine, is provided below in Figure 3. The effect of “stretching” the long end, whilst increasing the values in the L₁₀ to L₁ regions for Optical Length, Hauteur and Barbe actually depresses the cumulative distribution curve in the main body of the curve.

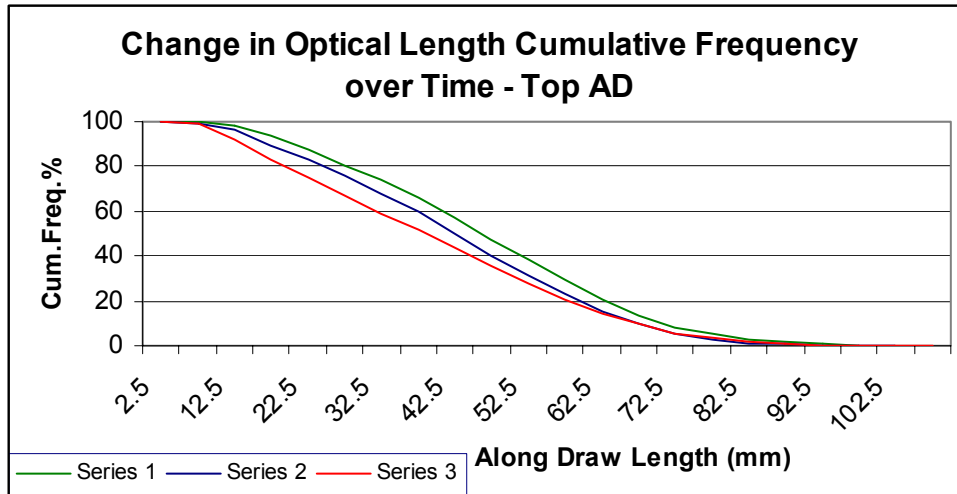


Figure 3.

The change in the K_{20L} value for this top is also visibly obvious, around 8.9% difference between Series 1 and Series 3, on an initial K_{20L} value in Series 1 of 9.8%.

Observation on the scale of the plot above tends to hide the effect at the long fibre end, that which is of interest to spinners. These effects are demonstrated below in Figure 4 for the long end i.e. approx L_{1L} . Again, this is for top AD (the shortest top) which is little influenced by the 'stretching' routine. It does however serve to demonstrate the change in the maximum fibre length observed in these trials and even for very short tops (Top AD = 44mm Ha). The change for this short top is something of the order of 7.5mm from Series 1 (no stretching) to Series 3 (current stretching). In other tops studied, this change is as high as 35mm.

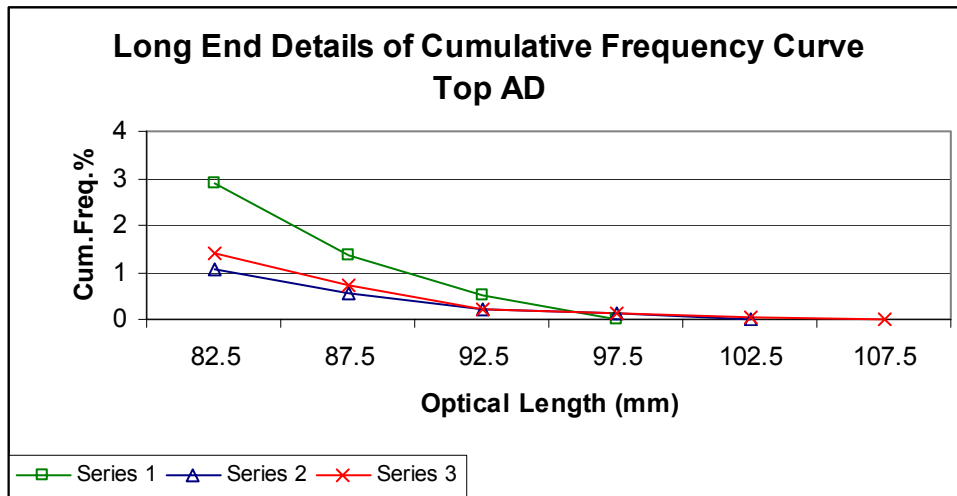


Figure 4.

Reading from the x axis for the vertical axis value of 1 provides an indication in the change in the L_{1L} value. It is clear from this observation that there is a substantial change in these L_{1L} values for the 3 separate trials. Respective changes in the diameter values observed in these trials when translated along with these L_{1L} values are likely to be magnified in respect to L_{1H} values.

Effects of Changes to Scan Distances - Diameter

To test the likely effects of changes to scan distances, the limited data used by Couchman & Turk, with the current OFDA software, discussed above, was used. This related to the 5 reference tops from earlier studies and one additional top (one with a bi-modal distribution). The other 2 tops used in that study were sourced independently and not measured in the manner described below.

Sample Preparation.

- Fibroliner samples from these tops were guillotined at 5mm steps in a CSIRO FEFI guillotine in such a manner as to mimic the OFDA 4000 scan points at 5mm intervals.

- The resultant snippets were then measured by Laserscan to provide a similar along draw diameter profile to that obtained by the OFDA 4000. In this study a minimum of 2000 snippets were measured in the Laserscan as opposed to the declining number of fibres remaining in a fibre draw due to the nature of a draw sample of an OFDA scan. There was a small departure from this sampling in so far as the last 4-5 CI Laserscan samples were pooled to ensure sufficient material was present to obtain this test number and precision. The resultant pooled value was applied to each of the affected class interval length frequency data when calculating the mean weighted diameter values.
- These data were then assigned the OFDA 'length' distribution frequencies, reported in the MES files, at each 5mm point.
- Two data sets were constructed from:-
 - a 5mm step travel
 - a 12 X 5mm step thence a 10mm step to the end of the fibre draw length (5:10 routine).

The data from the all 5mm steps array were compared to one where the data did not represent a scan distance (every 2nd 5mm step data past 12 CI's (60mm)) was removed from the data set. These 2 scenarios were tested to indicate if there was any likely effect arising from such a change. Table 4 also includes details of the number of 10mm scans, the % fibres >60mm and the slope of the diameter:length interaction observed by Couchman & Turk for these tops. The latter provides some insight to differences observed between tops in the slope of the diameter profile over the length of the fibre draw. A multiple regression analysis using these 3 parameters with the change in diameter from the different scanning routines provides a multiple R² value of 0.929, indicating that such a relationship exists. This data is included to enable the reader to observe some of the complicating factors that come into play with a mixed step scanning routine.

Results for Data from the Series 3 trials are presented below:-

Table 4.

Top	LS 5	LS 5:10	ΔLS 5 - LS 5:10	No. of 10mm CI's	% fibres > 60mm	Diameter : Length Interaction Slope
AD	20.55	20.52	0.03	5	14.23	0.457
ZZ	22.64	22.47	0.17	11	43.62	0.498
PRL#	18.72	18.74	-0.02	12	54.86	0.117
AP	20.74	20.65	0.09	11	64.78	0.265
AB	21.53	21.40	0.13	12	58.32	0.246
AZ	21.91	21.82	0.09	11	66.60	0.186
mean	21.02	20.93	0.08*			

Notes :1. These tops are in Hauteur order over the range 44mm to 82mm

2# Top PRL is believed to be a top constructed by blending 2 different length tops after finishing to produce a top with specific characteristics. This may explain the increase in diameter for the 5:10 routine.

These two data sets are significantly different (P>0.03) using a matched pairs t test indicating that, in this limited study, there is an effect of changing from a 5mm to a 10mm step travel at a fixed point in the OFDA measuring routine for these particular tops. This study needs to be undertaken on a larger data set using the two measurement routines to confirm these findings as a change of 0.08um (when rounded to 0.1um for reporting) is understood to be commercially significant.

This change in diameter from the use of different step routines (- 0.1um i.e. the current routine underestimates diameter by 0.1um), is a consequence of a proportionally smaller number of coarse fibres being measured at the long (coarse) end (>60mm) of the length distribution.

This limited study does however indicate that there is a sampling bias introduced with the changed step routine. It is noticeable that the difference for each top (Table 4) is not consistent with a simple Hauteur or physical length bias which can be gauged by the number of 10mm class intervals.

There are 3 complicating factors

- each top behaves differently and it is not as simple as looking at the number of 10mm steps in each test.
- each top has a different diameter:length interaction i.e. there is a different relationship between the diameter and length relationship for fibres in each length category for each top.
- the % of fibres >60mm (the point at which the 5mm steps cease and where subsequent measuring steps are 10mm) comes into play.

This latter point is illustrated in Figure 5 below. In short tops like Top AD (Ha = 44.2mm), only 5 x 10mm steps are used and only 14.2% of fibres are >60mm. On the other hand, Top AZ (Ha = 81.2mm) has 11 x 10mm steps and 66.6% of fibres >60mm.

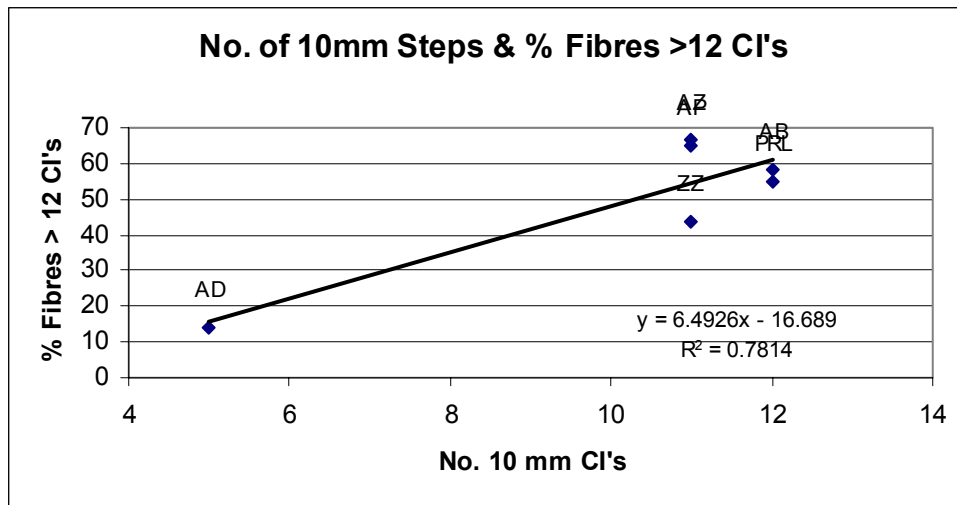


Figure 5.

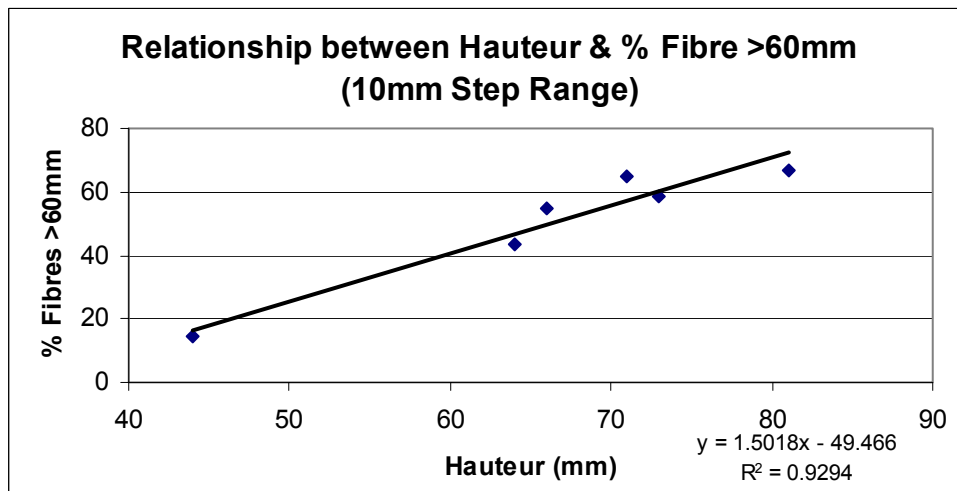


Figure 6.

It is unclear whether the data differences in Table 4 are real differences or slight differences due to Laserscan calibration effects for the single instrument used, which can occur and thus this should be repeated with more Laserscans to be confident of the outcome.

This possible bias will impinge on the diameter values reported for each top as shown above in Table 4, the fibre draw diameter profile plot along with the cumulative frequency curves, for Ha and Barbe, calculated from the base data of optical length and step diameter values. Modelling these effects is difficult.

A similar data set using the OFDA 4000 generated values (Table 5) shows similar results. Brims (unpubl.) has explained that the diameter data for the long end of the distribution is generated by pooling data from adjacent steps to increase the number of fibres reported and thus improve the precision of the mean value reported for each reported step in the distribution. In such situations it is normal to increase the sample size for the test to overcome such precision effects. Sample size for the OFDA 4000 is approx. 4,000 fibres as compared to the Almeter of approximately 30,000 fibres. Relying solely on the combined diameter data without full knowledge of the combination routine used could inject further anomalies into the data sets used to generate the diameter and cumulative frequency curves and perhaps may compromise the statistical significance values.

What is obvious from a comparison of the OFDA 4000 data is that the MES file mean diameter, that is reported as the test result, is exactly the same as that reported in the ** staple** array section of the MES file and both are different from a weighted mean diameter calculated from the use of the 5mm CI 'diameter' values and the optical length frequencies.

It could be argued that the optical length frequencies represent the true sample frequency within the top and thus this calculation should represent the mean diameter of the total sample. The OFDA differences (-0.1um) in the **staple** data array shows a similar but slightly lower difference (at 2 decimals) for the 5:10mm scan routine weighted mean diameter as that observed with the Laserscan data. Whilst this again is not significant the coincidence of a trend of similar magnitude and effect suggests further clarification could be beneficial as it can affect the modelling of capacitance, as discussed above.

The difference between the OFDA Test Report mean fibre diameter and the 5:10 step distance weighted mean diameter (-0.12) is highly significant ($P < 0.001$) using a matched pairs t test). This would suggest that the difference in diameter due to the method of calculation may have commercial significance.

Table 5. Reported & Calculated OFDA Based Diameter Values

Top	MES File mean um (A)	Weighted Mean Diameter	
		5mm mean um (B)	5:10 mm mean um (C)
AD	20.38	20.24	20.20
ZZ	22.45	22.37	22.28
AP	20.71	20.69	20.62
AB	21.45	21.41	21.36
AZ	22.13	22.02	22.01
PRL	18.61	18.63	18.56
MAB A	21.6	21.50	21.47
MAB B	19.76	19.67	19.66
mean	20.96	20.89	20.84
	Diff. A-B		0.06 #
	Diff. A-C		0.12**

** $P < 0.001$ Matched pairs t test for means..

differences to mean value subtractions due to rounding.

Until these questions are satisfactorily resolved with measurements generated from the 2 different step routines on a larger data set, it will be difficult to provide commercial interests within IWTO, guidance in respect to the commercial implications from these current observations.

Effect of Step Distance on L_{Max}

The software routine changing the step distance has an obvious effect on the relationship between L_{MaxL} (the length of the longest fibre) and the number of 10mm measured points in the data array. The longer the longest fibre in the draw sample, the greater the number of 10mm steps > 60 mm.

It is now clear why there appears to be a series of repeat or paired values followed by what might be believed to be a reversion to true measured values in the MES files.

(Brims unpubl.), has only recently described the rationale for combining adjacent diameter data; to improve class interval diameter precision in low frequency counts. This routine is triggered by a minimum number of fibres counted ($n_{critical}$) and is then maintained until the end of the scan. What isn't clear is why it is necessary to add a number of class interval values to the data array, after L_{MaxL} (the length of the longest fibre) is reached. Couchman & Turk demonstrated that this has a part to play in affecting the cumulative capacitance curve in the mid regions of each distribution thus affecting the L & K values when trying to match the Almeter distributions.

Because the pairing routine is over-ridden by a critical minimum fibre count in the diameter measurement, the higher the frequency of long fibres that extend towards the L_{MaxL} value the larger any effect is likely to be on any specific top once the $n_{critical}$ is reached. The values presented for the pairing are in fact repeated for a number of steps to in-fill the 5mm class intervals that the 10mm step travel overpasses.

It is noteworthy that with 10mm steps, the OFDA always records a 10mm increment even if a fibre finishes at 1mm into the step. This will impact on any capacitance model and its distribution statistics. This is not the case with the Almeter which has 0.25mm steps and perhaps helps to explain some of the observed differences in distribution statistics.

This OFDA routine was introduced to increase the L_{1H} and L_{5H} values for the cumulative distribution to better match those distribution parameters from the Almeter. The OFDA routine however records L_{MaxH} fibres being longer than they actually are. This may become an issue for spinners interpreting the OFDA Reports when setting spinning frame ratch distances to avoid getting long fibres caught between the front and back rollers and thus producing "crackers" and uneven yarns. If a spinner opens the ratch in the belief that the longest fibres may be caught between the rollers when in fact such fibres do not exist, this will introduce drafting inefficiency also resulting in uneven yarns. In this respect, the observed differences in L_{MaxH} values were up to 35mm longer than expected for the OFDA distributions.

These parameters do indeed have commercial consequences one way or another. How important this is needs to be understood from a commercial stand point and spinners in particular should be aware of these possible differences which at present are not fully understood. Stretching the calculated distribution past the actual longest fibre length will in addition also affect the short fibre content calculation and this also will need to be assessed for commercial implications.

Physical Length in the OFDA & Almeter

The obvious question is whether the OFDA and the Almeter detect the same physical length when they scan a particular top.

Whilst a significant amount of work on this question remains to be done one example is provided. If a simple calculation of the number of scans by the OFDA scan distance is made for the top used in Couchman's latest trial, then the L_{MaxL} for the OFDA averaged 170mm (160mm, 180mm & 170mm respectively).

With the assistance of diagnostic software developed for the AL100 it is possible to determine the number of 0.25mm class intervals that the Almeter scan detects. In this particular top it was $639 \times 0.25\text{mm CI's} = 159.75\text{mm}$ i.e. the maximum length of fibre detected by the Almeter (including the beard squaring) L_{MaxL} is 159.75mm only 0.25mm different from the value* obtained in the OFDA. * Note: This L_{MaxL} could be different from the Ha_{Max} (or L_{MaxH}) for this top which the OFDA print-out reveals to be <160.0mm. The print-out provides data in 2.5mm steps.

It would appear therefore that the L_{MaxL} from the Almeter and OFDA 4000, when calculating the full scan length from the number of steps multiplied by the different step lengths, are both detecting the L_{MaxL} at approximately the same physical length.

As a consequence of applying a mandatory set distance change in step function distance (60mm) irrespective of sample draw length, the variable draw diameter profile along with differing fibre number frequency profiles, each top measured is likely to show differing effects in response to the application of a 'capacitance' model. This helps to explain the observations of variable distribution curves and statistics resulting from the OFDA 4000 demonstrated in earlier studies. A step distance of 10mm, at the long end of the distribution, is considered, by the author, to be too long to be able to accurately detect the subtle changes in fibre frequency, diameter and length necessary to accurately match the Almeter's cumulative distribution curve which undertakes its detection at 0.25mm scans for just these reasons. The same can be said for a 5mm scan distance at the short end of the distribution in respect to adjusting for the uneven fibre beard.

Future Directions

This review of software developments and reporting of recent work adds further to the requirement to better understand the methodology used to convert the OFDA's optical length to Hauteur and Barbe distribution frequencies and thus report Hauteur, Barbe, and their respective CV's in addition to the K & L distribution statistics.

Some of the points discussed above in relation to the length debate may, on the surface, appear to some observers to be minor, however when it is recognised that they form the basis for the subsequent calculation of 'capacitance' many of them are magnified to the extent that they are likely to have commercial significance. They are not simple concepts and therefore difficult to explain simply or to comprehend even amongst the technical community. The points relating to diameter however are of direct commercial interest.

There are opposing views on the significance of these effects. Brims (unpubl), believes that these changes have little effect on results whereas the author believes otherwise. Whether the points raised are sufficient in magnitude to create commercial difficulties is yet to be determined and the extent of these need to be gauged. Additional work is required to clarify exactly what the technical effects are likely to be. This is required before any commercial evaluation can be complete.

From an IWTO test method point of view, this may have implications for the IWTO Length Working Group draft Test Method for the OFDA 4000 with particular reference to length calibrations and verification of the step distance of the gripper mechanism and the effect this has on both the diameter and length parameters and precision statistics reported by the OFDA 4000. It also highlights the desirability of including the software version number in the Draft Test Method to ensure that the only legitimate comparison of results is obtained when using the same version of the software that was used to demonstrate equivalence.

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Appendix 1.

Table A1 Anova: Two-Factor With Replication
Mean Fibre Diameter

	<i>Series 1</i>	<i>Series 2</i>	<i>Series 3</i>	<i>Total</i>	<i>Laserscan (S3)</i>	
AD						
Count	4	4	4	12		
Sum	82.53	80.7	81.39	244.62		
Average	20.63	20.18	20.35	20.39	20.5	
Variance	0.011692	0.002967	0.004225	0.043973		
Differences between Series Trial Results						
		S1 - S2	S1 - S3	S2 - S3		
		0.46	0.29	-0.17		
ZZ						
Count	4	4	4	12		
Sum	89.73	89	89.36	268.09		
Average	22.43	22.25	22.34	22.34	22.4	
Variance	0.013625	6.67E-05	0.007667	0.011881		
		S1 - S2	S1 - S3	S2 - S3		
		0.18	0.09	-0.09		
AP						
Count	4	4	4	12		
Sum	83.53	82.2	82.64	248.37		
Average	20.88	20.55	20.66	20.70	20.8	
Variance	0.002492	0.0026	0.002467	0.02293		
		S1 - S2	S1 - S3	S2 - S3		
		0.33	0.22	-0.11		
AB						
Count	4	4	4	12		
Sum	86.76	85.34	86	258.1		
Average	21.69	21.34	21.50	21.51	21.6	
Variance	0.003267	0.001967	0.0204	0.029942		
		S1 - S2	S1 - S3	S2 - S3		
		0.36	0.19	-0.16		
AZ						
Count	4	4	4	12		
Sum	89.47	88.09	88.56	266.12		
Average	22.37	22.02	22.14	22.18	22.0	
Variance	0.000825	0.004825	0.002333	0.024552		
		S1 - S2	S1 - S3	S2 - S3		
		0.34	0.23	-0.12		
Total						
Count	20	20	20			
Sum	432.02	425.33	427.95			
Average	21.60	21.27	21.40			
Variance	0.582104	0.685803	0.657757			
		S1 - S2	S1 - S3	S2 - S3		
		0.33	0.20	-0.13		
ANOVA						
<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Sample	36.25798	4	9.064496	1670.02	2.7E-48	2.578737
Columns	1.136423	2	0.568212	104.6859	1.18E-17	3.20432
Interaction	0.085377	8	0.010672	1.966198	0.073	2.152134
Within	0.24425	45	0.005428			
Total	37.72403	59				

Table A 2 Anova: Two-Factor With Replication

CVd

	Series 1	Series 2	Series 3	Total
AD				
Count	4	4	4	12
Sum	0.8724	0.8907	0.8792	2.6423
Average	0.2181	0.2227	0.2198	0.2202
Variance	1.54E-05	6.53E-06	7.3E-06	1.19E-05
		S1 - S2	S1 - S3	S2 - S3
		-0.46%	-0.17%	0.29%

ZZ				
Count	4	4	4	12
Sum	0.9379	0.9672	0.9557	2.8607
Average	0.2345	0.2418	0.2389	0.2384
Variance	3.37E-06	1.42E-06	4.75E-06	1.25E-05
		S1 - S2	S1 - S3	S2 - S3
		-0.73%	-0.44%	0.29%

AP				
Count	4	4	4	12
Sum	0.8418	0.8559	0.8339	2.5317
Average	0.2104	0.2139	0.2084	0.2109
Variance	8.04E-06	2.2E-06	9.17E-06	1.09E-05
		S1 - S2	S1 - S3	S2 - S3
		-0.35%	0.20%	0.55%

AB				
Count	4	4	4	12
Sum	0.8990	0.9234	0.8865	2.7090
Average	0.2247	0.2308	0.2216	0.2257
Variance	8.11E-06	5.59E-05	1.46E-06	3.39E-05
		S1 - S2	S1 - S3	S2 - S3
		-0.61%	0.31%	0.92%

AZ				
Count	4	4	4	12
Sum	0.8239	0.8418	0.8279	2.4937
Average	0.2059	0.2104	0.2069	0.2078

t-Test: Paired Two Sample for Means – Table 4 Data

	LS 5	LS 5:10
Mean	21.02	20.93
Variance	1.85315	1.685427
Observations	6	6
Pearson Correlation	0.999808	
Hypothesized Mean Difference	0	
df	5	
t Stat	2.931453	
P(T<=t) one-tail	0.016289	
t Critical one-tail	2.015049	
P(T<=t) two-tail	0.032578	
t Critical two-tail	2.570578	

Multiple Regression Statistics for Table 4 Data

<i>Regression Statistics</i>								
Multiple R	0.929078							
R Square	0.863186							
Adjusted R Square	0.657964							
Standard Error	0.039909							
Observations	6							
ANOVA	df	SS	MS	F	<i>Significance F</i>			
Regression	3	0.020098	0.006699	4.206119	0.198033			
Residual	2	0.003185	0.001593					
Total	5	0.023283						
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	-0.30921	0.120176	-2.57298	0.123651	-0.82628	0.207866	-0.82628	0.207866
No. CIs	0.004752	0.014464	0.328509	0.773734	-0.05748	0.066986	-0.05748	0.066986
%>60mm	0.003405	0.002274	1.497578	0.272947	-0.00638	0.013188	-0.00638	0.013188
D:L Slope	0.577128	0.171082	3.373396	0.077763	-0.15898	1.313236	-0.15898	1.313236