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A Comparison of Diameter Measurement Technologies from Interwoollabs International Round Trials for Wool Tops

By

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1. Summary

The differences in measuring Mean Fibre Diameter of wool tops by four different IWTO Test Methods were examined; namely:

- the Airflow Method (IWTO-6)
- the Projection Microscope Method (IWTO-8)
- the Laserscan Method (IWTO-12); and
- the OFDA Method (IWTO-47).

Differences in the measured Mean Fibre Diameter between methods were up to 0.3µm for tops measuring less than 26µm and up to 0.8µm for tops greater then 26µm. Some of the observed differences between the Airflow and the other methods were found to be related to the Coefficient of Variation of Fibre Diameter of the sample being measured. When this was taken into account, there were still differences that might be related to medullation content; however, further research is required to identify the factors that cause the differences.

The Laserscan and OFDA methods showed the least variation between methods when paired comparisons were made.

Three of the methods examined (Projection Microscope, Laserscan and OFDA) also provide a measurement of the fibre diameter variability. The Standard Deviation of Fibre Diameter (SD) was used to compare them.

For SD's less than 8.0µm, the differences in measured SD by the three methods were up to 0.3µm whereas for SD's greater than 8.0µm the differences could be as high as 0.6µm. Both Laserscan and OFDA show different trends when compared against the Projection Microscope measurements. Further research is required to identify the factors that cause the differences.

2. Introduction

The International Association of Wool Textile Laboratories, more commonly known as Interwoollabs, was established at the 38th IWTO Conference in June 1969. Currently, Interwoollabs runs four programmes that deal with the measurement of the fibre diameter of wool tops using the following:

- The Airflow Apparatus in accordance with IWTO-6 (operative since 1969)
- The Projection Microscope in accordance with IWTO-8 (operative since 1972)
- The Laserscan Instrument in accordance with IWTO-12 (operative since 1995); and
- The OFDA Instrument in accordance with IWTO-47 (operative since 1995)

This report presents a comparison of the measurements achieved by the different instruments.

3. Materials and Methods

The Interwoollabs Round Trials are conducted at 6 monthly intervals (i.e. two per year).

In the case of the Airflow Method, each participating laboratory measures six test specimens from eight different wool tops per trial. The eight tops are selected to cover a wide range of Mean Fibre Diameter (MFD). On completion of each trial, Interwoollabs provides a comprehensive report to the trial participants which includes the overall MFD for each top and the between-laboratories Standard Deviation (SD_{LABS}) for each top.

In the case of the Projection Microscope Method, each participating laboratory measures 600 fibres from each of three test specimens (i.e. a total of 1800 fibres) from four different wool tops per trial. The four tops are selected to cover a wide range of MFD but are not necessarily tops that have been included in the Airflow trial running at the same time. On completion of each trial, Interwoollabs provides a comprehensive report to the trial participants which includes the overall MFD for each top and the between-laboratories Standard Deviation (SD_{LABS}) for each top.

In the case of the Laserscan Method, each participating laboratory measures six test specimens from eight different wool tops per trial. The Laserscans would all have been calibrated with the original calibration model not the revised model proposed by Irvine and Barry[1]. The eight tops are the same tops that are used for the Airflow Round Trial. On completion of each trial, Interwoollabs provides a comprehensive report to the trial participants which includes the overall MFD for each top and the between-laboratories Standard Deviation (SD_{LABS}) for each top.

In the case of the OFDA Method, each participating laboratory measures six test specimens from eight different wool tops per trial. The eight tops are the same tops that are used for the Airflow Round Trial. On completion of each trial, Interwoollabs provides a comprehensive report to the trial participants which includes the overall MFD for each top and the between-laboratories Standard Deviation (SD_{LABS}) for each top.

For the purposes of this report the Trial Average for each wool top for each Method of test was used as the basis for comparisons. As stated above, there was direct correspondence between the measurements made for the wool tops for the Airflow, Laserscan and OFDA methods as the same top samples were measured in each trial. To determine the corresponding Projection Microscope measurements for the tops included in this study it was necessary to review data from earlier trials to find relevant data. As the data did not match in time, the Projection Microscope data for all trials where a particular top was measured were pooled to give a single value for the purposes of comparison.

An estimate of the repeatability of the Trial Average for each method was estimated from the between-laboratories Standard Deviation.

It has been demonstrated[2,3] that the Airflow measurement of MFD is influenced by the Coefficient of Variation of Fibre Diameter (CVD) of the sample being measured and the expected CVD of a calibration top with the same MFD as the sample (estimated by Projection Microscope). Hence, as well as comparing the Airflow directly with the Projection Microscope, Laserscan and OFDA the Airflow was compared with a calculated “Airflow Equivalent” for each of the Laserscan and OFDA methods to remove differences that would arise from the CVD of the sample being measured.

4. Results and Discussion

From the Interwoollabs data base it was possible to extract a subset of 40 trial samples where diameter had been measured by all four methods (i.e. the Airflow, Projection Microscope, Laserscan and OFDA methods).

In order to provide a comparison between the different methods of measurement the results are presented as graphs of between-method differences against one of the methods. The repeatability of the plotted points can be estimated from the between-laboratories standard deviation (see section 4.1).

As the Airflow method is currently the basis of commercial trade, it is used as the basis for the first series of comparisons (see section 4.2).

It has been recognised for many years that the measurements from the Airflow method are influenced by both the CVD of the sample and the medullation content of the sample being measured. The magnitude of the differences that one could expect has not been a major issue in the past as the Airflow was the only method that found prominence in commercial trading. However, with the introduction of the newer technologies, Laserscan and OFDA, that are unaffected by CVD and possibly medullation content, these

differences take on a new significance. In this report an attempt is made to remove the influence of CVD from the comparisons by calculating an "Airflow Equivalent" value for Laserscan and OFDA (section 4.3).

Despite the imperfections of the Projection Microscope method many believe it to be the closest thing the Wool Industry has to a Primary Standard Method. Consequently the other methods of measuring MFD are compared to it in section 4.4.

As the Projection Microscope, Laserscan and OFDA methods all give estimates of fibre diameter distribution as well as MFD, a comparison of the measured Between-Fibre Standard Deviation (SD) has been examined (see section 4.5).

4.1 Repeatability of the Trial Average

The repeatability of the trial average can be estimated from the between-laboratories standard deviation (SD_{LABS}). Figure 1 shows the relationship between the SD_{LABS} and the measured MFD.

The SD_{LABS} increased with the measured MFD for the four methods of measurement. The highest variation was exhibited by the Projection Microscope. The variation exhibited by the Airflow and OFDA methods were found to be similar in magnitude with the variation exhibited by the Laserscan method the lowest of all the four methods.

The confidence limit for the trial average can be estimated as follows:

$$95\%\ \text{Confidence Limit} = \frac{196 \times SD_{LABS}}{\sqrt{n}}$$

Where n = the number of laboratories participating in a Round Trial
= 100 for Airflow
= 40 for Projection Microscope
= 17 for Laserscan; and
= 27 for OFDA

Table 1: Approximate 95% Confidence Limits for Trial Averages for MFD

MFD	Method	95% Confidence Limit
20µm	Airflow	±0.03µm
	Laserscan	±0.05µm
	OFDA	±0.06µm
	Projection Microscope	±0.09µm
35µm	Airflow	±0.08µm
	Laserscan	±0.14µm
	OFDA	±0.15µm
	Projection Microscope	±0.16µm

From the above table the expected uncertainty in the estimate of the differences between any two methods would be of the order of ±0.1µm to ±0.2µm (i.e. $\sqrt{2}$ x Confidence Limit).

Figure 2 shows the relationship between the SD_{LABS} for CVD and the measured Projection Microscope CVD. In this case there was no strong evidence for a confidence limit that varied with the measured CVD. The Laserscan and OFDA produced similar variation in CVD whereas the Projection Microscope was higher.

4.2 Mean Fibre Diameter Comparisons – Projection Microscope, Laserscan and OFDA with Airflow

Figures 3 and 4 show the differences between Laserscan and Airflow (LSN-AF) and OFDA and Airflow (OFDA-AF) graphed against the Airflow Measurement (AF) respectively. Any difference outside the ±0.2µm range would be considered to be a difference that has not arisen from normal random variation. Both Laserscan and OFDA show differences greater than this range with a greater incidence when the MFD is greater than 26µm. In the case where the MFD is greater than 26µm, the differences from the Airflow could be as high as 0.8µm compared to 0.3µm in the MFD range less than 26µm.

Figure 5 shows the differences between OFDA and Laserscan (OFDA-LSN) on the same basis as figures 3 and 4. One would conclude there is better agreement in MFD estimates for Laserscan and OFDA than between either one of them and Airflow.

Figure 6 shows the differences (AF-PM) between Airflow(AF) and Projection Microscope (PM) on the same basis as figures 3, 4 and 5. The differences are not as large as those seen for Laserscan and OFDA but can still be between 0.4 and 0.5μm. It must be emphasised at this point that the results presented in Figure 6 are for Interwoollabs Round Trial samples not calibration tops. Trial tops that consistently show large differences between Projection Microscope and Airflow are excluded form becoming calibration standards.

4.3 Mean Fibre Diameter Comparisons – "Airflow Equivalents" with Airflow

The "Laserscan - Airflow" equivalent diameter (LSNAF) is calculated as follows:

$$LSNAF = \frac{LSN_{MFD} \times (1 + C^2_{LSN})}{(1 + C^2_{STD})}$$

where LSN_{MFD} = the Mean Fibre Diameter of the sample determined by Laserscan.

C^2_{LSN} = the square of the fractional coefficient of variation as determined by Laserscan.

$$C^2_{STD} = \left(\frac{0.2992 \times LSN_{MFD} - 17880}{LSN_{MFD}} \right)^2$$

The "OFDA - Airflow" equivalent (OFDAF) is calculated in the same manner as above by replacing the LSN values with OFDA values.

It has been shown that these calculations remove the influence of CVD from any comparison with the Airflow Method[2].

Figures 7 and 8 show the comparisons of the calculated "Airflow Equivalent" values for Laserscan (LSNAF) and OFDA (OFDAF). These figures can be directly compared to figures 3 and 4. The variation around the zero line is reduced for MFD less than 26μm. Differences greater than 0.6μm can still occur above 26μm. The medullation content is recognised as a factor that can affect the measurement of MFD by the Airflow Method. Interwoollabs does not require laboratories, who participate in the Projection Microscope Programme, to provide medullation content and as such it was not possible to isolate the reasons for the observed differences.

4.4 Mean Fibre Diameter Comparisons – Laserscan and OFDA with Projection Microscope

Figures 9 and 10 show the differences between Laserscan and Projection Microscope (LSN-PM) and OFDA and Projection Microscope (OFDA-PM) compared to the MFD measured by Projection Microscope (PM). In these comparisons, CVD and medullation content should not be factors that explain the observed differences.

The variation around the zero line is less than that observed for the Airflow comparisons (compare figures 3 and 4) and slightly less than the variation observed for the "Airflow Equivalent" comparisons (compare figures 7 and 8). Differences of up to 0.6μm can still occur. No explanation can be provided as to the reasons for the observed differences.

On the basis of comparing all the figures from 3 to 10, the best agreement in the measurement of MFD was observed for the Laserscan and OFDA instruments. The Projection Microscope Method was closer to the Laserscan and OFDA than was the Airflow. The reasons for the observed differences needs to be researched and explained in a technical sense.

4.5 Standard Deviation of Fibre Diameter Comparisons – Laserscan and OFDA with Projection Microscope

Figures 11 and 12 show the differences in Laserscan and Projection Microscope Standard Deviation ((LSN-PM)SD) and the OFDA and Projection Microscope Standard Deviation ((OFDA-PM)SD) graphed against the Projection Microscope Standard Deviation.

Both Laserscan and OFDA show different trends compared to Projection Microscope. For wools with Standard Deviations less than 8.0μm difference between the two new technologies and Projection Microscope could be up to 0.2μm. For wools with Standard Deviations greater than 8.0μm the differences between the newer technologies and Projection Microscope could be as high as 0.6 to 0.7μm.

Figure 13 shows the differences in measured SD for OFDA and Laserscan ((OFDA-LSN)SD) compared to Projection Microscope SD. This comparison shows the same curvilinear trend reported in earlier Round Trials[4]. The agreement at values of SD greater than 8.0μm is better between the newer technologies than that observed for either Laserscan or OFDA compared to the Projection Microscope.

The observed differences need to be researched to provide technical explanations as to the factors that underpin the observed differences.

5. Conclusions

The four different technologies for measuring Mean Fibre Diameter can give different measures by up to 0.3μm for wool tops with Mean Fibre Diameter less than 26μm and up to 0.6μm for wool tops with Mean Fibre Diameters greater than 26μm.

In comparing any two measurement technologies of the Airflow, Projection Microscope , Laserscan and OFDA, the greatest consistency was obtained between Laserscan and OFDA with some differences still approaching 0.4μm for two of the 40 wools. The majority show differences of less than approximately 0.2μm.

The reason for the observed differences needs to be further researched.

The measurement differences for Standard Deviation indicate differences between Projection Microscope, Laserscan and OFDA of up to 0.3μm for Standard Deviations less than 8.0μm and differences up to 0.6μm for Standard Deviations greater than 8.0μm. Both Laserscan and OFDA exhibit differences to the values obtained by Projection Microscope that need to be further researched.

The major unexplained differences observed between the methods occur for wools with Mean Fibre Diameters greater than 26μm.

6. Bibliography

1. P.A. Irvine and R.G. Barry, “Improved Calibration Model for the Sirolan-Laserscan”, IWTO Tech. Cttee., Report 1, Nice Meeting, December, 1997.

2. A.R. Lindsay and J.W. Marler, “The Effect of the Coefficient of Variation of Fibre Diameter of Blends of Wool Tops when Measured by Airflow, Laserscan and OFDA.”, IWTO Tech. Cttee., Report 13, Boston Meeting, May, 1997.

3. P.J. Sommerville, “The Effect of Between Fibre Coefficient of Variation on the Fibre Fineness Measured by the Airflow.”, IWTO Tech. Cttee., Report 14, Boston Meeting, May, 1997.

4. H. Harig, “Report of the 1995 IWTO Round Trial. Part II : Wool Tops.”, IWTO Tech. Cttee., Report 16, Harrogate Meeting, June, 1995.

7. Acknowledgments

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Figure 1: Between Labs SD for MFD

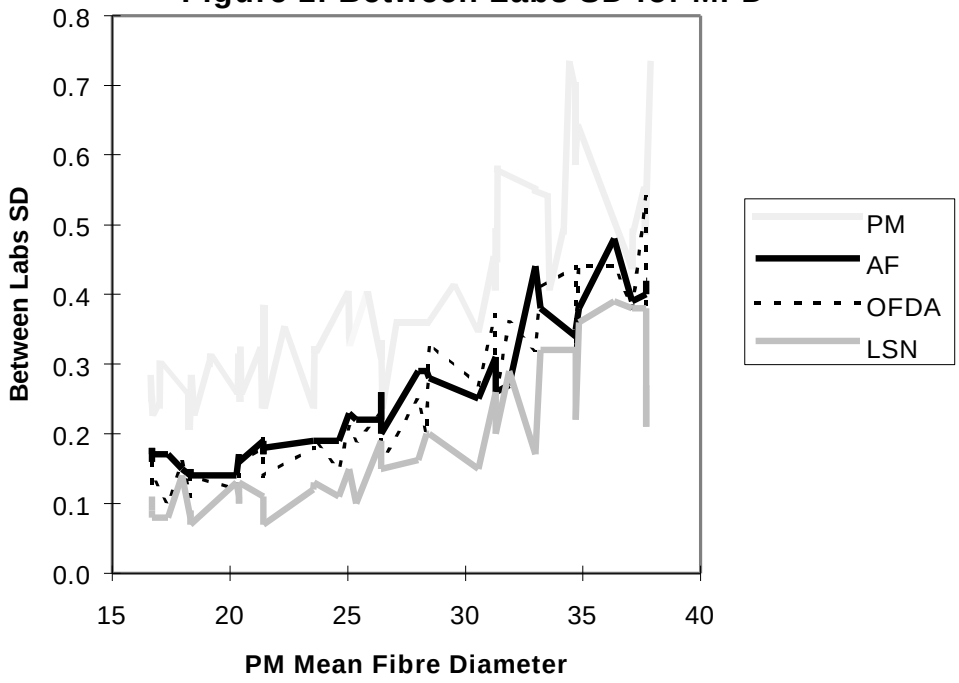

Figure 2: Between Labs SD for CVD

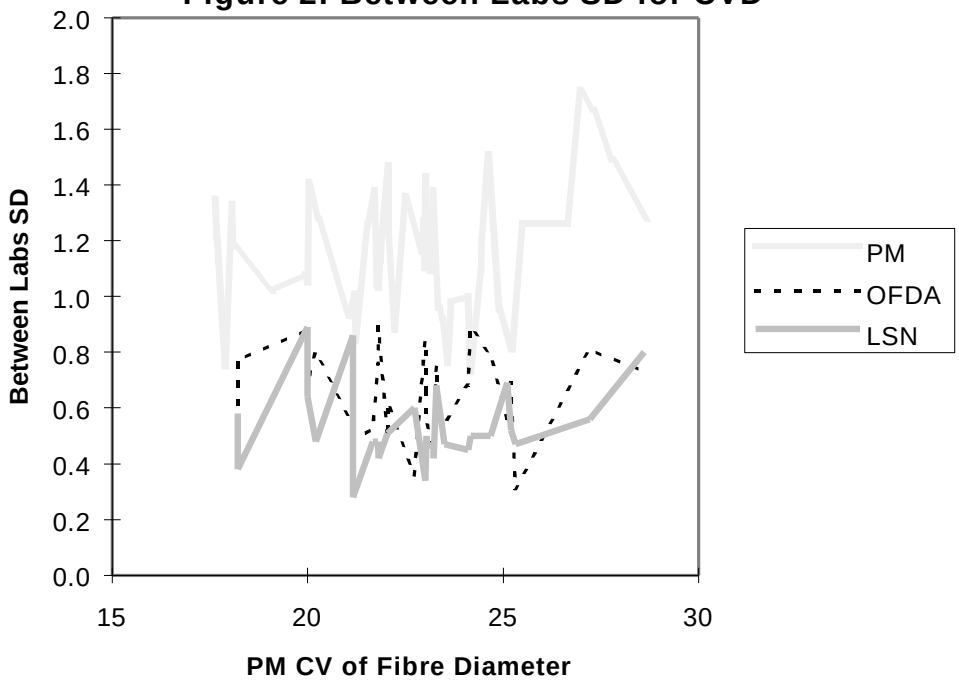

Figure 3: (LSN-AF) vs AF

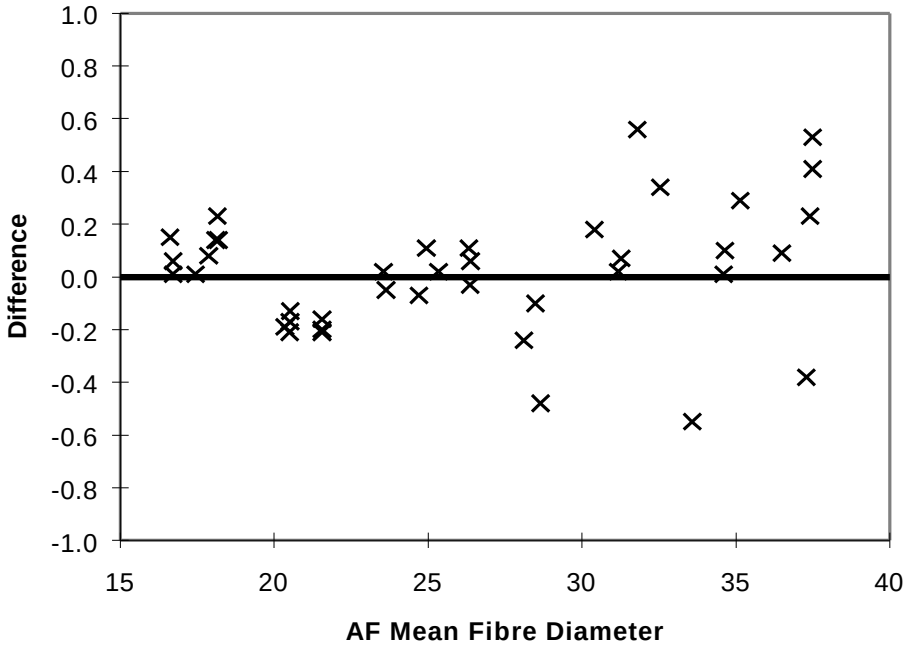

Figure 4: (OFDA-AF) vs AF

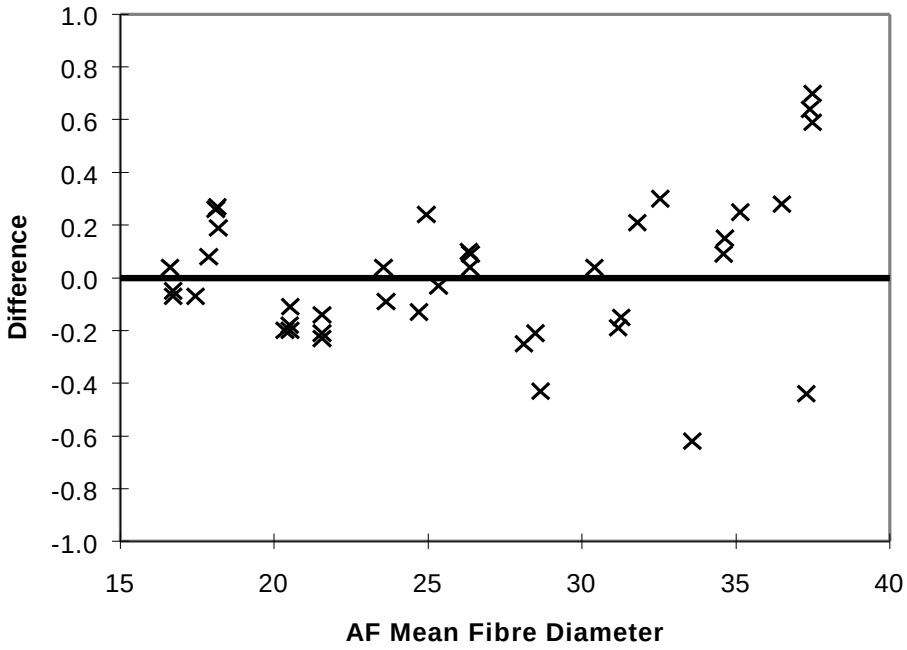

Figure 5: (OFDA-LSN) vs AF

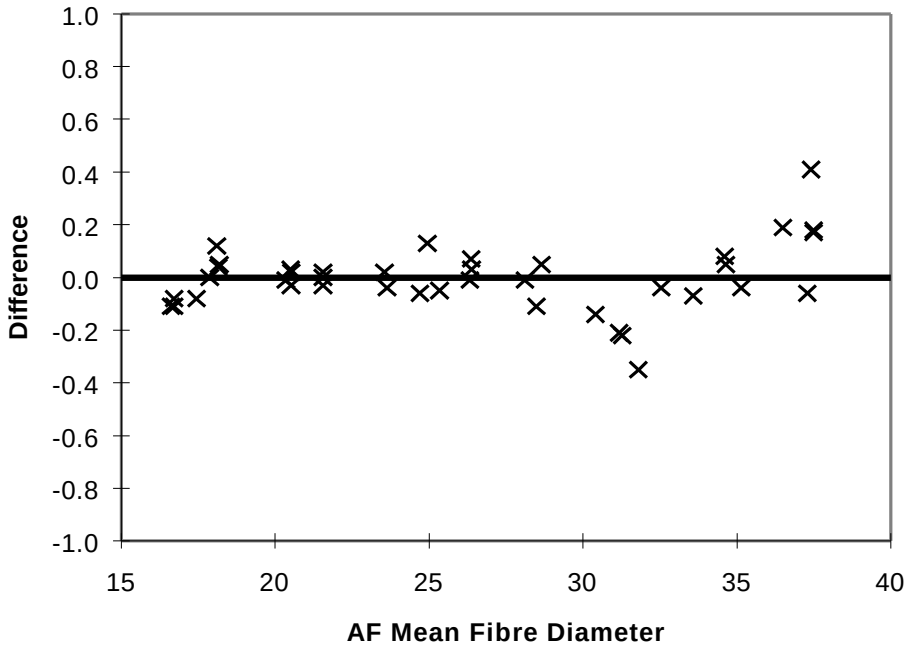

Figure 6: (AF-PM) vs AF

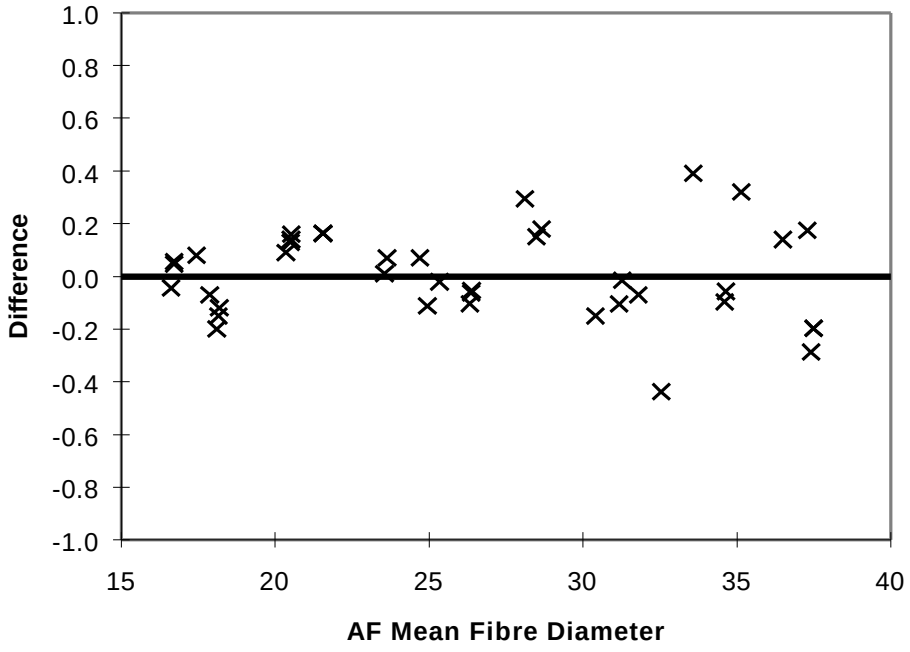

Figure 7: (LSNAF-AF) vs AF

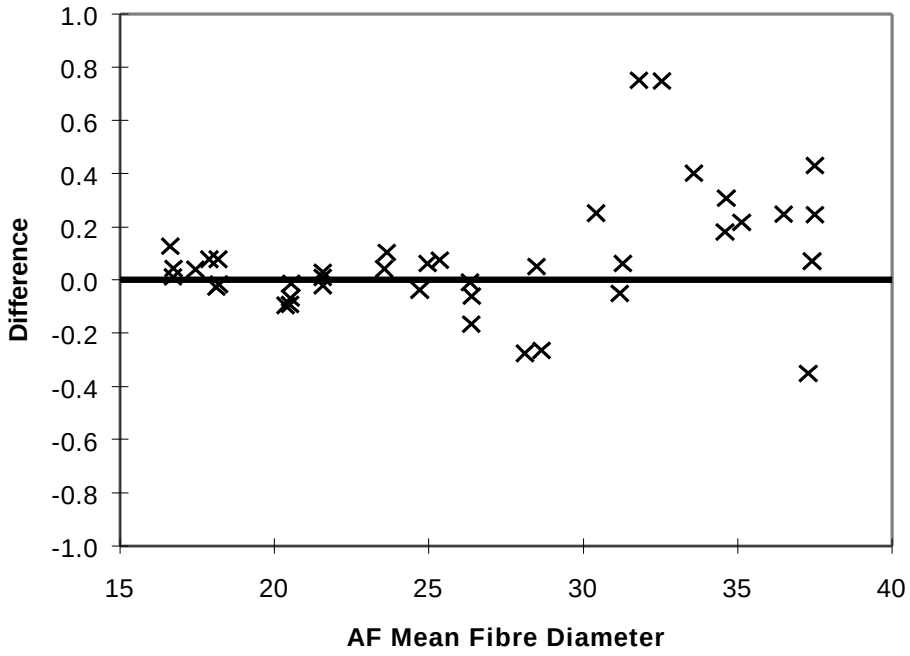

Figure 8: (OFDAF-AF) vs AF

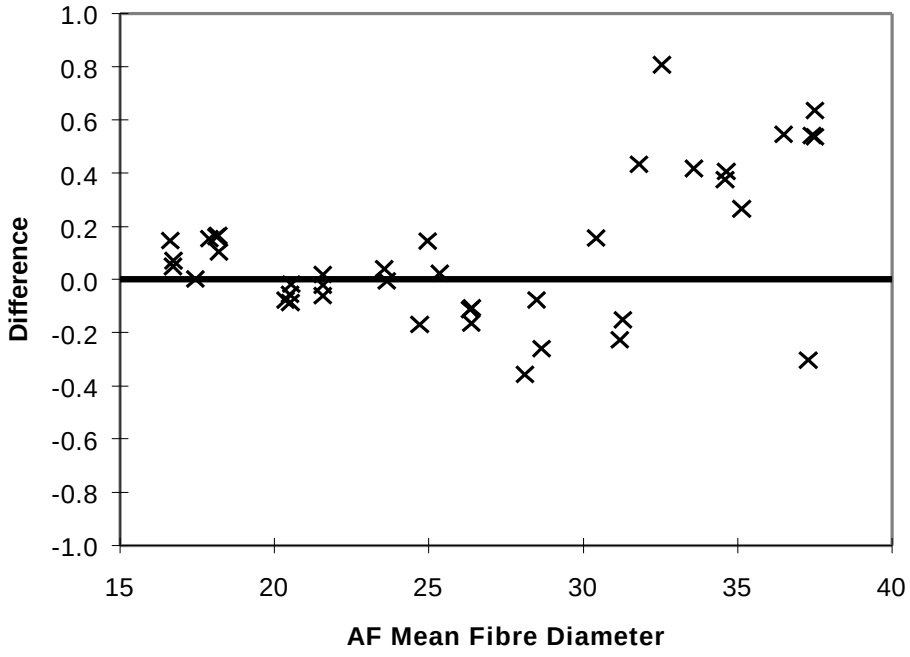

Figure 9: (LSN-PM) vs PM

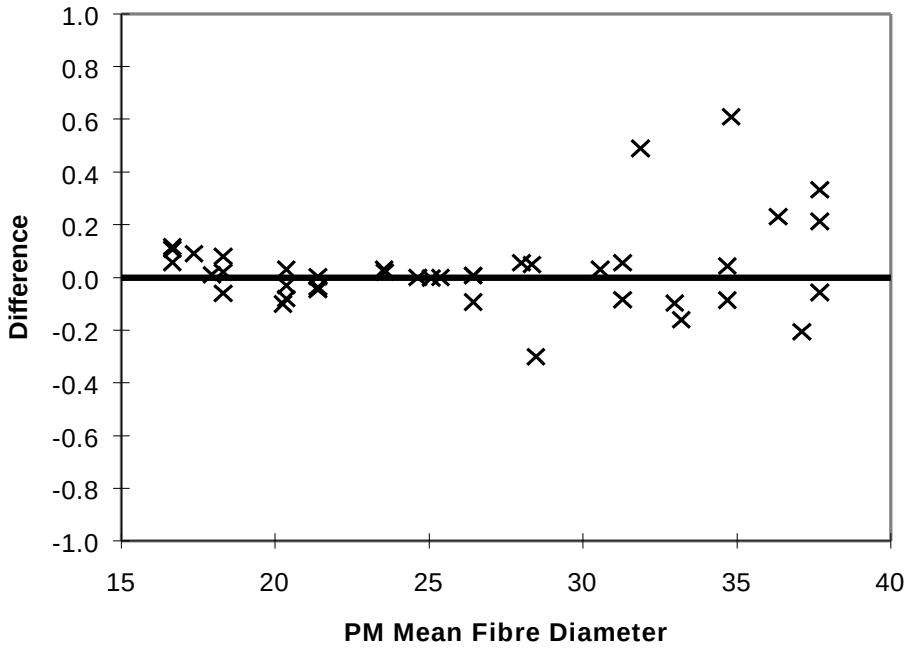

Figure 10: (OFDA-PM) vs PM

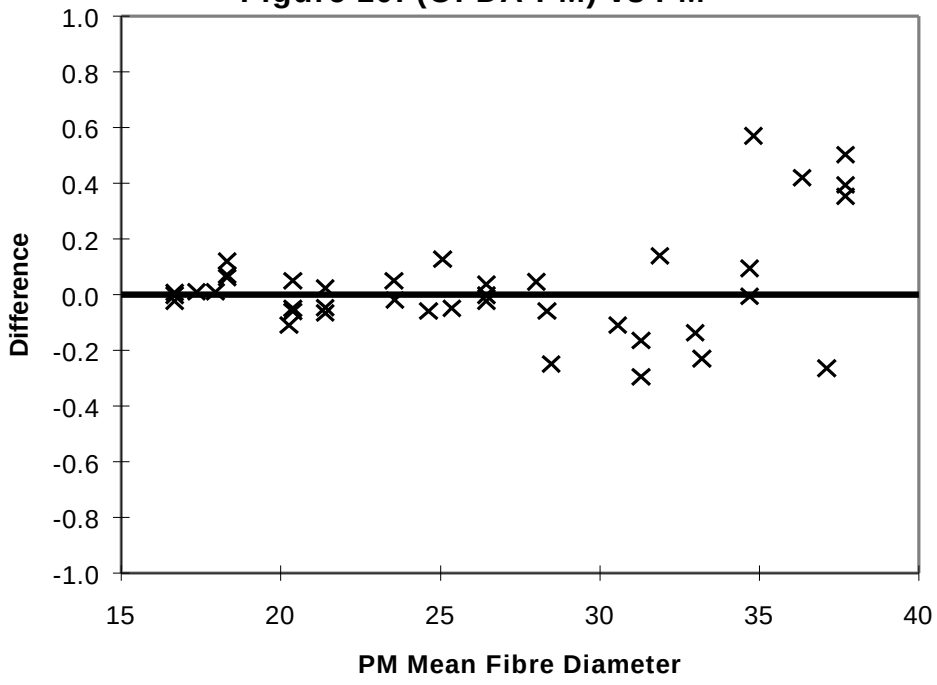

Figure 11: (LSN-PM)SD vs PM(SD)

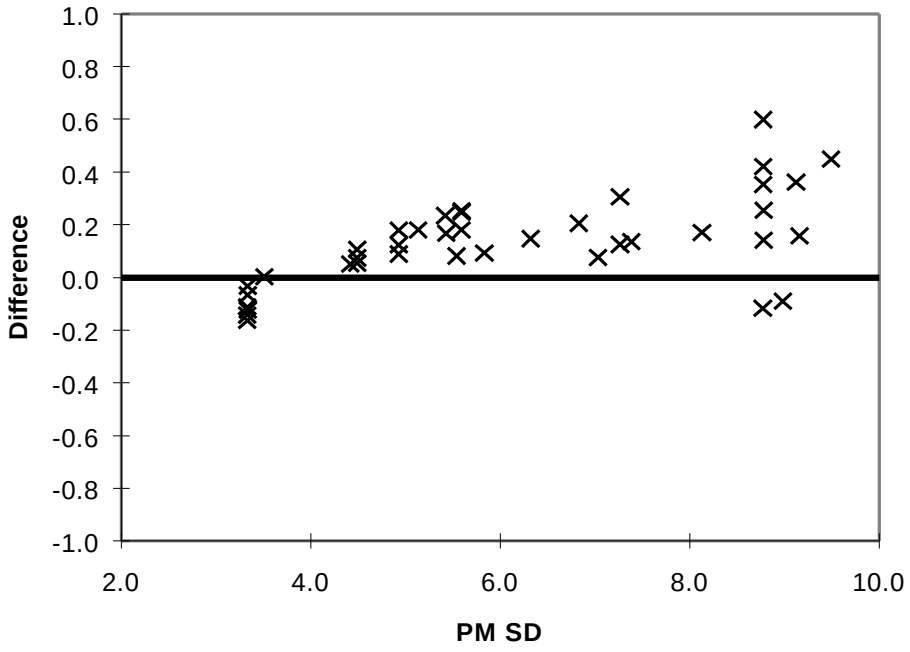

Figure 12: (OFDA-PM)SD vs PM(SD)

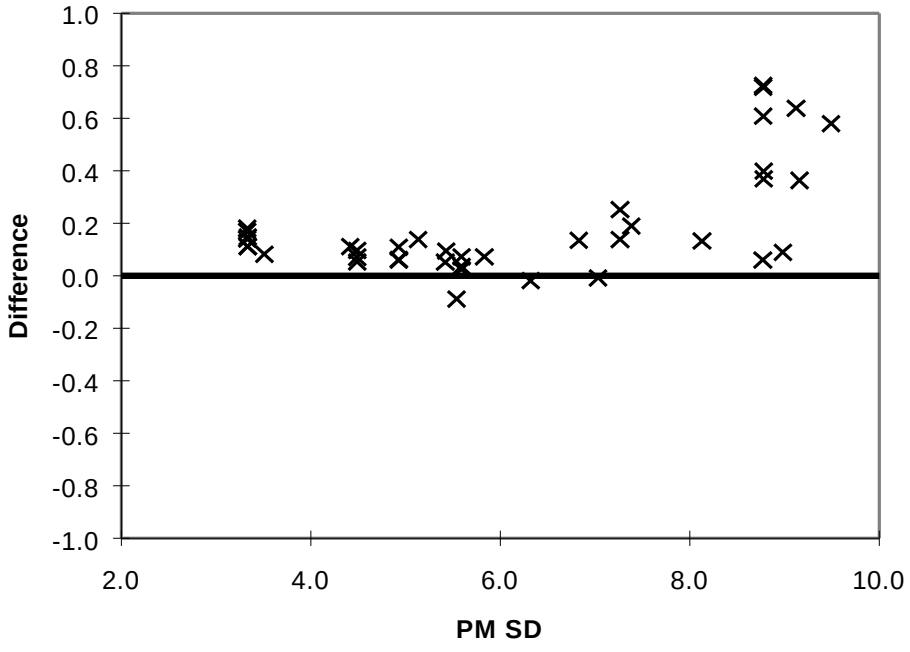

Figure 13: (OFDA-LSN)SD vs PM(SD)