16. Fibre Diameter Measurement of Slivers and Tops

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Learning objectives

- On completion of this topic you should be able to:
- outline the method of sampling slivers for fibre diameter measurement
- explain the operating principles of the Projection Microscope, OFDA100, OFDA4000 and Laserscan for measuring slivers and tops, and compare their advantages/disadvantages
- use projection microscope results to:
  - construct a suitable table for the data
  - draw a fibre diameter distribution as a histogram
  - calculate the mean fibre diameter, standard deviation and coefficient of variation
- compare the precision levels possible with the various instruments used for measuring mean fibre diamete

Key terms and concepts

Fibre diameter, mean fibre diameter, standard deviation, coefficient of variation of diameter, fibre diameter distribution, IWTO, Projection Microscope, Airflow, Laserscan, OFDA, snippet, micron, 95% confidence level, diameter profile

Introduction to the topic

Many wool properties remain almost unchanged from raw wool through to top. These include mean fibre diameter and fibre diameter distribution where the only real change occurs because of any differences between the characteristics of the top and the noil. Other properties such as base colour are highly correlated from raw wool to top (Cottle and Zhao 1998) but anomalies can occur due to processing variability.

Some raw wool properties influence the properties of the top, but do not survive themselves in the top. Examples are staple length and strength, which help to determine top fibre length, but because staple structure is lost in processing these properties are not relevant to top.

This topic covers the methods used to measure the fibre diameter characteristics of slivers and tops. Fibre diameter is arguably their most important property, because of the importance of fibre diameter in the efficient spinning of fine worsted yarns and in the manufacturing light, soft handling fabrics for apparel. The finer the fibres, and the fewer the number of fibres present in a cross section of a yarn produced from the fibres; the more flexible is the yarn. These factors are critical to the quality of wool fabrics.

A number of methods have been developed for measuring the fibre diameter of wool, notably the projection microscope, airflow, Laserscan and OFDA (Optical Fibre Diameter Analyser). The latter two methods utilising modern technologies have largely replaced the first two methods. However, the Projection Microscope provides the benchmark test by which the other methods are calibrated.

A document produced by AWTA Ltd, *Laserscan – a new technology for the new millennium* (see Reading – AWTA 1999.pdf) is a useful source of information on the general principles of fibre diameter measurement, as well as describing the Laserscan instrument (AWTA 1999).

16.1 International test methods

The International Wool Textile Organisation (IWTO) has developed three test methods, based on different instruments, which may be used to issue test certificates for the mean fibre diameter of combed sliver (top). These methods are:

- IWTO 6: Method of Test for the Determination of the Mean Diameter of Wool Fibres in Combed Sliver using the Airflow Apparatus
- IWTO 12: Measurement of the Mean and Distribution of Fibre Diameter using the Laserscan Fibre Diameter Analyser
- IWTO 47: Measurement of the Mean and Distribution of Fibre Diameter of Wool using an Optical Fibre Diameter Analyser (OFDA).

The Airflow method was first established as an IWTO test method in 1975 and until quite recently it has been the wool industry's principal method for determining the mean fibre diameter of wool. The Laserscan and OFDA test methods were both introduced in 1995 and the transition from Airflow to these new methods for commercial wool fibre diameter testing and certification is now complete.

The manual method which provides a means of calibrating the instruments used to carry out the above methods uses the Projection Microscope:

- IWTO 8: Method of Determining Fibre Diameter Distribution Parameters and Percentage of Medullated Fibres in Wool and Other Animal Fibres by the Projection Microscope.

In addition, IWTO have published regulations for the testing of wool slivers for mean fibre diameter and mean fibre length. This document states:

- the requirements with respect to weighing, identification and sampling of the lot
- the method to be used for the combination of results from a number of samples
- range check requirements
- format for certification
- procedures for check tests, retests and provision of guarantees.

The latest versions of these IWTO test methods and regulations are contained on the IWTO Specifications CD-ROM, which may be obtained from The Woolmark Company (http://www.wool.com/services_iwto.php).

16.2 Mean fibre diameter

Wool fibres are not uniform cylinders – the cross-section can range from roughly circular to highly elliptical or kidney-shaped (See reading – AWTA 2002a.pdf). Furthermore, the thickness can vary substantially along the fibres. And in a sample of wool the constituent fibres will vary widely in their thicknesses. While a number of options are available to define the fineness of wool fibres, the industry has chosen to define fibre diameter in terms of the average thickness of a two-dimensional projected image of a large number of short fibre sections (or snippets). These are measured using a Projection Microscope (or Lanameter). The unit used for measuring fibre diameter is the micron (or micrometer), where 1 micron (1µm) = 10^{-6} meter. The very finest wools have mean fibre diameters of around 13 µm while the coarsest wools can exceed 40 µm.

Fibre snippets are generally 0.8 – 2 mm long, cut from fibres at random positions along their length. Snippets are obtained from a wool sliver using a guillotine or microtome (Figure 16.4). These are spread on a glass slide in a mounting fluid under a glass cover slip. They are magnified using a projection microscope and the widths of the magnified images are measured using a graduated scale. Care is taken to ensure that the snippet being measured is in focus and that each snippet is measured only once.

Calculation of mean fibre diameter and associated statistics

The measurements made on the snippets are grouped into class intervals, usually 2 microns wide. They are recorded on a frequency distribution table, an example of which is shown in Table 16.1.

Table 16.1 Fibre diameter distribution data. Source: Canesis Network (2006).

Class interval (μm)	Mid-point (d) (μm)	No. of snippets (n)	% of snippets (F)	d x n	d^2 x n
0-2	1	0	0	0	0
2-4	3	0	0	0	0
4-6	5	0	0	0	0
6-8	7	0	0	0	0
8-10	9	0	0	0	0
10-12	11	2	0.05	22	242
12-14	13	23	0.575	299	3887
14-16	15	144	3.6	2160	32400
16-18	17	719	17.975	12223	207791
18-20	19	1365	34.125	25935	492765
20-22	21	997	24.925	20937	439677
22-24	23	380	9.5	8740	201020
24-26	25	197	4.925	4925	123125
26-28	27	92	2.3	2484	67068
28-30	29	53	1.325	1537	44573
30-32	31	19	0.475	589	18259
32-34	33	8	0.2	264	8712
34-36	35	1	0.025	35	1225
36-38	37	0	0	0	0
38-40	39	0	0	0	0
	Totals	4000	100	80150	1640744

This table provides the data required to construct a fibre diameter distribution histogram (http://www.awta.com.au/Publications/Fact_Sheets/Fact_sheet_002 .htm), as shown in Figure 16.1. Note that the histogram uses the percentage of fibre snippets, which makes it easier to compare different histograms.

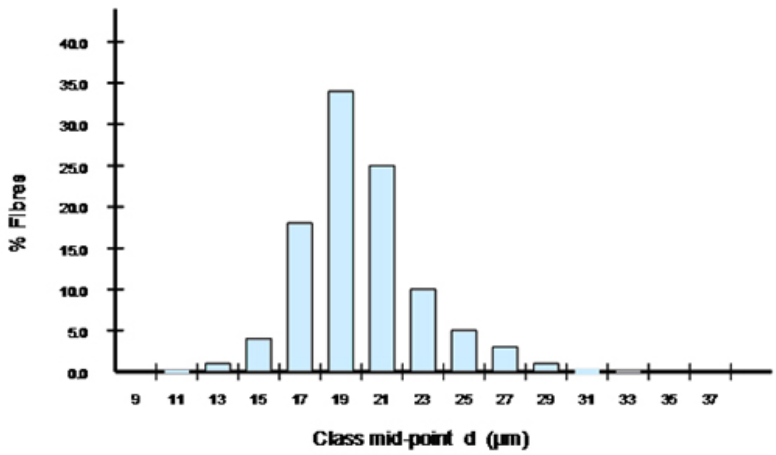

Figure 16.1 Fibre diameter distribution. Source: Canesis Network (2006).

Calculating the mean fibre diameter (MFD) from distribution data is quite simple. For each class interval select the middle of the range d and multiply this by the total number of fibre snippets n. Add the products then divide by the total number of fibre snippets. For these data:

$$\text{MFD} = \frac{\Sigma \text{ d x n}}{\text{n}} = \frac{80150}{4000} = \mathbf{20.03\ \mu m}$$

Calculation of the standard deviation and the coefficient of variation

The standard deviation of fibre diameter (SD) measures the dispersion (or spread) in the fibre diameter distribution. Calculation of the standard deviation from the distribution data is a little more complicated because it involves a further calculation – multiplying the square of the diameter by the number of fibre snippets in each class interval.

$$SD = \sqrt{\frac{\sum n \times d^2 - \frac{(\sum n \times d)^2}{\sum n}}{\sum n - 1}}$$

$$= \sqrt{\frac{1640744 - \frac{(80150)^2}{4000}}{4000 - 1}}$$

$$= \mathbf{2.95\ \mu m}$$

If we assume that the fibre diameter distribution is bell-shaped, i.e. normal (which is usually approximately true), 68% of the fibres fall within one SD of the MFD and 95% of all fibres fall within two SDs of the MFD. For example, for a sliver with MFD = 20 µm and SD = 4 µm, 68% of all fibres are in the range 16-24 µm and 95% of all fibres are in the range 12-28 µm.

While the standard deviation is useful in describing the dispersion of a fibre diameter distribution, it is less useful in comparing different lots of wool unless the fibre diameters are very close or equal. As the MFD increases so does the SD.

For commercial purposes, a measure of dispersion that is comparable for different mean fibre diameters is preferable. This is the coefficient of variation (CVD).

$$CVD = \frac{SD}{MFD} \times 100 = \frac{2.95}{20.03} \times 100 = \mathbf{14.7\%}$$

Because the Standard Deviation is linearly related to the mean fibre diameter, the coefficient of variation is generally independent of the mean fibre diameter.

Although the mean fibre diameter is the major price determinant for wool, the degree of fibre diameter variation is also important. Wools with higher MFDs and lower CVDs have been found to produce yarns with properties similar to wools with lower MFDs and higher CVDs. The so called “5% rule” says that a 5% change in CVD is equivalent to a 1 micron change in MFD. For example, a wool with a MFD of 21 µm and a CVD of 20% will produce yarns with properties similar to 20 µm wool with a CVD of 25%.

16.3 Sampling requirements

Where test results for a consignment of sliver or top are to be issued on an IWTO test certificate, the IWTO regulations require that:

1. Samples are to be taken from bales of sliver distributed equally throughout processing of the consignment
2. Only one sample is to be taken per bale, with a minimum of 5 samples per consignment
3. At least one sample must be tested per 5,000kg of conditioned sliver
4. Samples drawn for testing must weigh at least 10g.

16.4 Instrument calibration

Instruments used for measuring the fibre diameter of wool are usually calibrated using Interwoollabs IH Standard Tops. These comprise 8 specially prepared combed slivers which have been measured by many laboratories by Airflow and Projection Microscope in repeated round trials. Interwoollabs, based in the UK, supply the tops together with their standard mean fibre diameter values. Where a test result is to be issued on an IWTO test certificate, instrument calibration using the Interwoollabs tops is mandatory. The calibration procedures and calculations for each instrument are outlined in its relevant IWTO test method.

16.5 Testing instruments and methods

Projection microscope

The projection microscope, as the name implies, projects a magnified image of the fibres onto a measuring screen which has a calibrated scale used to measure the diameter of the fibres (See reading – AWTA 2002b.pdf). It is a manual operation (Figure 16.2).

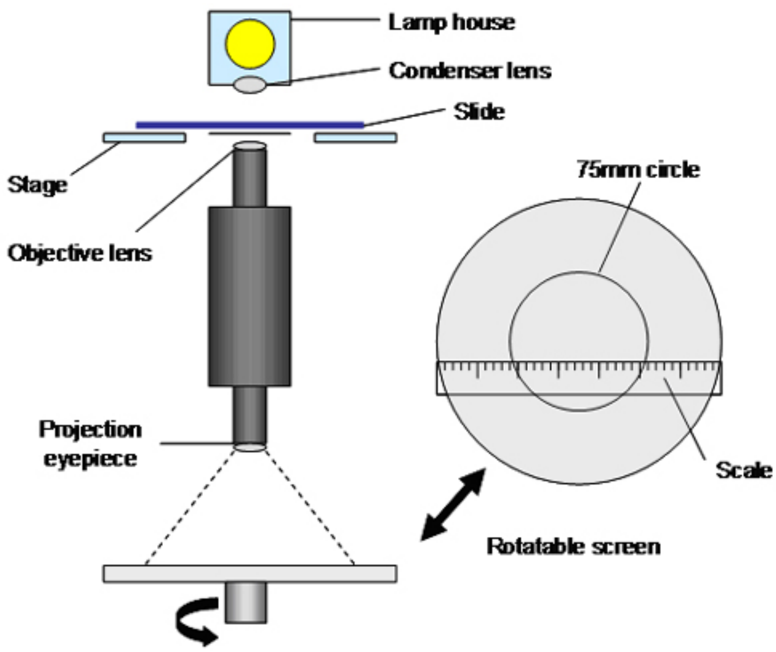

Figure 16.2 Projection Microscope. Source: Canesis Network (2006).

Any microscope that can project the image onto a screen may be used, but the two most widely used are the WIRA microscope and Reichart Lanameter. The magnification required is 500X and the instruments are calibrated by a graticule.
Snippets are cut from the conditioned sample of sliver, at random positions along the sliver. They are mounted on a standard microscope slide in a suitable medium and a cover slip is applied.

The slide is placed under the microscope lens and the slide moved across and down (in 0.5mm steps) during measurement so that its area is covered uniformly, but no fibre is measured twice. After each movement the fibre images are focussed and their widths measured and placed into 2mm classes. Fibres are not measured if:

- more than half their width is outside the 75mm measurement circle
- their end(s) lie within the measurement circle
- fibres that cross each other in the measurement circle.

The frequency distribution formed from this operation is used to calculate mean fibre diameter and fibre diameter distribution.

Three important factors affect results obtained using this method:

- It is very slow and labour intensive (a rate of approximately 600 snippets in two hours is achievable for a good operator)
- It is operator dependent. Standard wool tops are provided to calibrate operators. This means that this method is not directly traceable to the International Standards Organisation (ISO) standard metre
- It is dependent on sample preparation. If the snippets are cut too short the result will be biased toward a larger diameter. This is because the more elliptical fibres lie on their major axis on the microscope slide. Coarser fibres are considered to be more elliptical in their cross-sectional shape, therefore these fibres will measure as being thicker.

Airflow

The Airflow instrument operates on the principle that the resistance to the flow of air through a plug of wool fibres of a given mass will increase as the mean fibre diameter decreases (and the surface area increases), for a given pressure drop (See reading – AWTA 2004.pdf).

Since the method is indirect, the instrument must be calibrated by international standard tops which have been measured by both projection microscope and Airflow devices.

In practice a conditioned and carded test specimen is placed in a fixed volume chamber and measurements are recorded in millimeters (the scale reading for the change in pressure). The mean value is converted to micrometers using the second order regression line of the calibration curve constructed from measurements on the Standard tops. A standard atmosphere is required as the method depends on the weight of the test specimen (2.5g ± 0.004g).

This method only measures mean fibre diameter and provides no information on the distribution of fibre diameter in the sample.

The major factors that affect results obtained from this method are:

- It is dependent on sample preparation. The calibration material and unknown samples must be prepared by the same method. Shirley Analysing is the most widely used method of carding
- It is affected by changes in fibre density. While changes in fibre density are difficult to quantify, they are a source of error. For example, medullation has a marked effect
- Being an indirect method it requires a supply of standard calibration tops.

The Airflow method is now obsolete and is no longer used for the commercial testing of wool.

OFDA 100 (Optical fibre diameter analyser)

An instrument based on image analysis methods, called FIDAM was developed by AWTA in the 1980s, but was eventually not commercialised. This decision led to another company further developing FIDAM and eventually a new instrument called OFDA was available from 1991. Today OFDA is manufactured and sold by BSC Electronics (Western Australia).

The OFDA 100 system is essentially an automatic image analysis system (Figure 16.3).

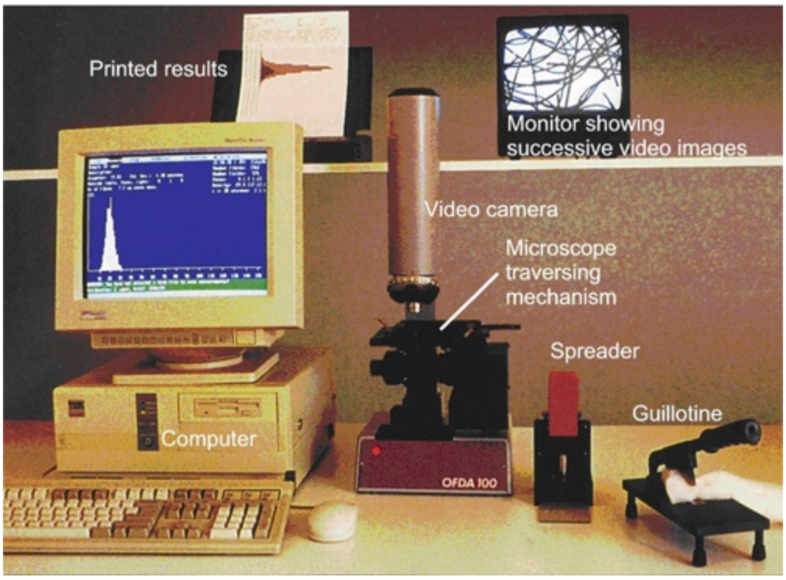

Figure 16.3 OFDA system. Source: BSC Electronics with permission.

It comprises:

- A personal computer which controls the operation of the microscope and processes the signal from the video camera into fibre diameter data
- An optical microscope with (1) an 13-Y traversing stage driven by stepper motors and (2) a light-emitting diode (LED) light source which operates in a stroboscopic mode
- A solid state (CCD) video camera that converts the light image to a video signal
- A frame grabber board mounted inside the PC captures and stores the video image
- Monitor for displaying the fibre images
- Software for synchronising the camera, strobing the LED and positioning the microscope slide as well as performing the measurement tasks. It reads the stored image data and performs pattern recognition processes to locate the fibre snippet images and measure their diameter. Brief details of the algorithm are given by Baxter (Baxter, Brims and Taylor 1992)
- Guillotine and snippet spreader device for distributing them on the glass slides.

The guillotine is used to cut snippets of a standard length of 2mm (Figure 16.4).

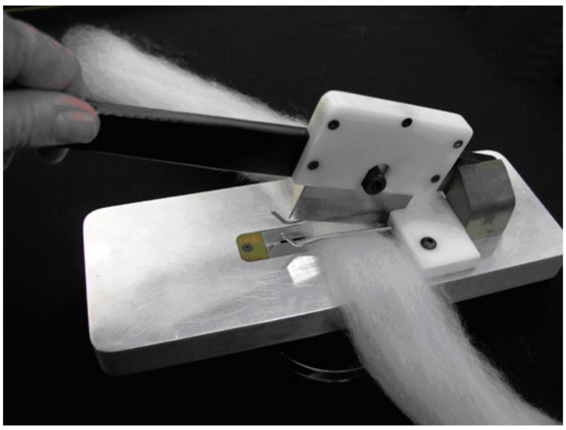

Figure 16.4 Guillotining of sliver. Source: Canesis Network (2006).

The IWTO test method requires that snippets not be cut within 100mm of either end of the sliver or make sequential cuts within the lengths of the longest fibres. Using a guillotine the population of snippets obtained will be biased towards the longer fibres, i.e. more snippets will be obtained from longer fibres. Hence the mean fibre diameter of wool is a length-weighted mean.
The snippets are deposited evenly on a 70mm x 70mm hinged glass slide using the spreader (Figure 16.5) in a symmetrical pattern (Figure 16.6). The desirable obscuration ratio (snippet area to total slide area) is about 15-25%.

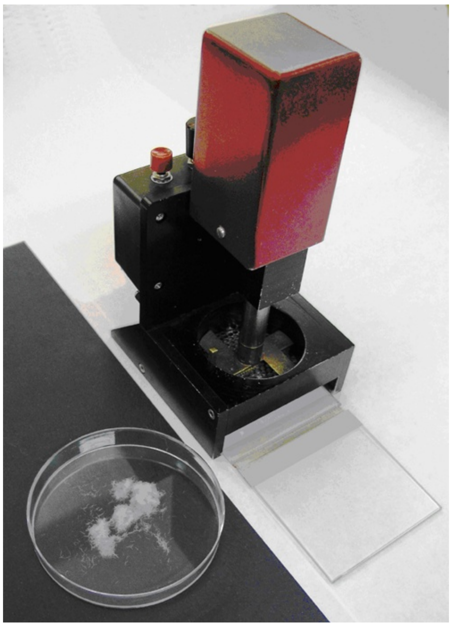

Figure 16.5 Snippet spreader device. Source: Canesis Network (2006).

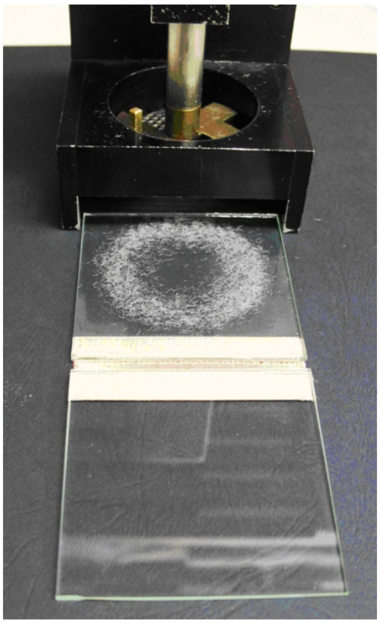

Figure 16.6 Snippets spread on a slide before closing. Source: Canesis Network (2006).

The slide is closed and placed on the stage of microscope, and the measurement process is commenced. During scanning up to 2000 or more images may be acquired and analysed. Each image, which covers an area of about 1mm by 1.5mm, is analysed in real time and between three and 50 fibres may be measured. Sixteen images are analysed each second.

Each measurement on a prepared slide takes less than two minutes to locate and measure over 4000 fibre snippets, and analyse the results. Each fibre diameter measurement is assigned by the software to a diameter bin 1 μm wide. After a pre-set number of fibres have been measured the contents of the bins are analysed to calculate the mean fibre diameter, the fibre diameter distribution and other statistics.

The results are presented on the computer screen and they may also be printed.

Laserscan

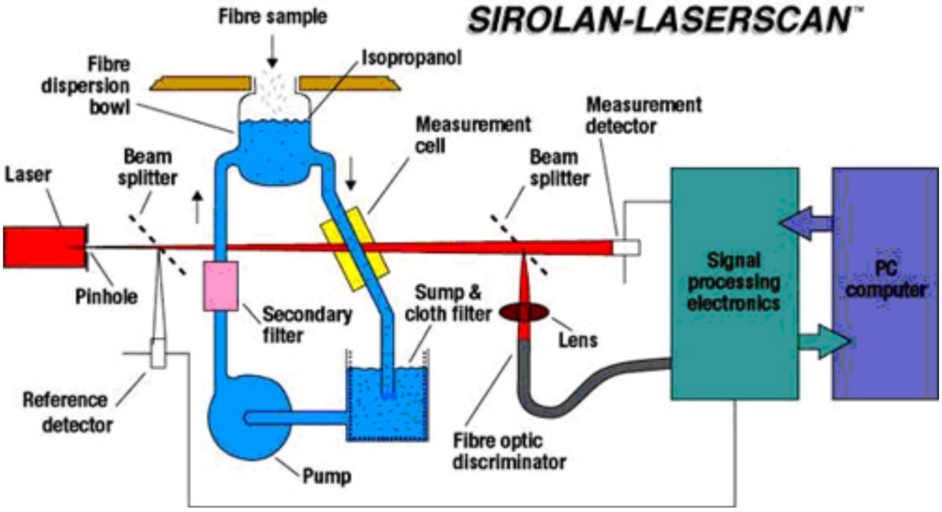

Figure 16.7 Laserscan system. Source: AWTA Ltd. (available from website - http://www.awta.com.au/).

Development of Laserscan by CSIRO commenced in 1971, and in the early 1980s its predecessor, the FDA (Fibre Diameter Analyser) was launched. The modern Laserscan evolved from FDA, and an IWTO test method for this instrument was approved in 1995. The instrument is now marketed and supplied by AWTA Ltd.

The process of acquiring the snippets by guillotining a sliver at random positions along its length, is the same as for the projection microscope and OFDA, but there is no need to mount the snippets on a glass slide for presentation to the instrument. It is required for 2 test specimens to be measured from each sliver subsample.

Figure 16.7 shows how LASERSCAN operates. Fibres snippets are dispersed into an isopropanol-water mixture, or alternatively a water/detergent mixture (Crowe et al. 2000). The suspension of snippets in the transport fluid passes through a measurement cell. While passing through the cell the fibre snippets intersect a fine beam of light from a laser which is directed at a measurement detector. The optical response in this instrument is not simply a shadowing of the fibre on the cell but a more complex diffraction pattern. An electrical signal is produced by the detector that is proportional to the amount of light falling on it. Hence, when a fibre snippet passes through the beam this electrical signal is reduced by an amount that is directly proportional to the projected area, and therefore thickness or diameter of the fibre. The relationship between the magnitude of the change in detector signal and the mean fibre diameter is determined by calibrating the instrument using standard wool tops.

It is important that only snippets that fully intersect the beam are measured. Also, only one snippet can be measured at any instant or else the signal from the detector will indicate the snippet is either finer or coarser than it really is. To ensure that (1) only single snippets are measured and (2) the snippets fully intersect the beam, the instrument uses a special fibre optic discriminator as the detector. The principle of this device is shown in Figure 16.8. It consists of a ring of fibre optic detectors surrounding a central fibre optic detector. The signal from each of these is continuously monitored. The Laserscan computer detects when decreases in signal from the central detector and two of the surrounding detectors occur simultaneously and it matches this event with the signal from the main detector. Events that do not match this selection criterion are rejected and the measurements are not recorded.

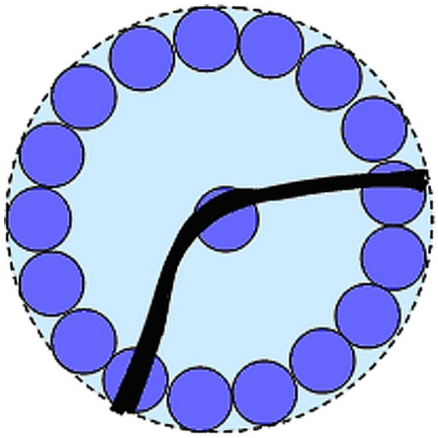

Figure 16.8 Laserscan fibre optic discriminator. Source: Canesis Network (2006).

By operating in this way Laserscan resembles the projection microscope, in that only measurements on individual snippets are used to produce the fibre diameter distribution. This requirement is particularly important in eliminating the bias resulting from selective sampling from the total population of snippets presented to the instrument.

The snippets are filtered from the liquid after passing the beam and the liquid re-circulated. The fibres have been shown to pass the laser beam in a random orientation in rotation about the fibre axis. The device can measure 2000 fibre snippets in approximately two minutes.

The individual measurements are collected in 1 mm classes. The mean fibre diameter and fibre diameter distribution are calculated from the frequency distribution obtained from this operation. The measurement of mean fibre curvature is also possible with this instrument.

Laserscan results are less reliant on laboratory conditioning than other methods for measuring fibre diameter because the snippets are immersed in a mixture containing water at a known concentration which ensures even, rapid conditioning.

OFDA 4000

In an ideal situation no correlation is expected between the length of a fibre and its mean fibre diameter. However, in practice tops can have a diameter profile where there is a relationship between the mean diameter of a fibre and its length. This can arise in wool tops if:

a) wools of different length and strength characteristics are blended for topmaking
b) fibres are selectively broken in topmaking, e.g. if finer fibres break more readily than coarser fibres so that the longest fibres in the top are the coarsest
c) blending wool from different sources, e.g. short fine wool blended with coarser, longer wool.

OFDA 4000 is a new instrument from BSC Electronics Pty Ltd that has been developed for simultaneously measuring fibre length, fibre diameter, diameter profile and fibre curvature in slivers and tops using a digital video microscope. Details of its operation are provided by Brims (2002).

OFDA 4000 has evolved from OFDA100 and from OFDA2000, which is a portable instrument for measuring greasy wool fibre diameter and having the additional capability of measuring the diameter profile along a wool staple. It has been developed primarily for quality control in topmaking and research use.

A fibre aligner device has been developed for preparing a beard of fibres from a top and presenting it to the microscope:

- Beards of density from 100 fibres to the full number of fibres across the top can be extracted
- The beard is lightly clamped to hold the fibres in the focal plane of the microscope while video images are captured every 1.2mm across the beard, and every 5mm along the beard
- The process continues until the number of fibres viewed falls below a threshold, indicating that the end of the beard has been reached
- If the number of fibres counted in the first scan has not reached a preset minimum value another beard is presented and measured, with all results being summed for analysis.

The diameter measurement software is identical to that used in OFDA 100, except that the maximum fibre count is extended to 300,000.

The diameter-related statistics provided by OFDA 4000 are:

- Mean, standard deviation and histogram of diameter
- Comfort factor
- Diameter profile along beard (graph of fibre diameter along, standard deviation along)
- Fibre end comfort factor (measured at aligned end of beard) to provide a measure of the risk of prickle in a fabric.

In addition measures of fibre length and curvature are also provided.

Brims (2002) provides a series of examples of fibre diameter profiles (i.e. micron versus length along a beard).

The manufacturers of OFDA 4000 claim that it can replace:

- Almeter Fibroliner and Measurement Unit (the well-established system for measuring the fibre length characteristics of slivers and tops)
- OFDA100 and Laserscan (the established instruments for fibre diameter measurement).

It is also claimed that the results on a sliver or top can be produced using one minute of operator time.

Figure 16.9 has been derived from data on a top provided by Brims (2002).

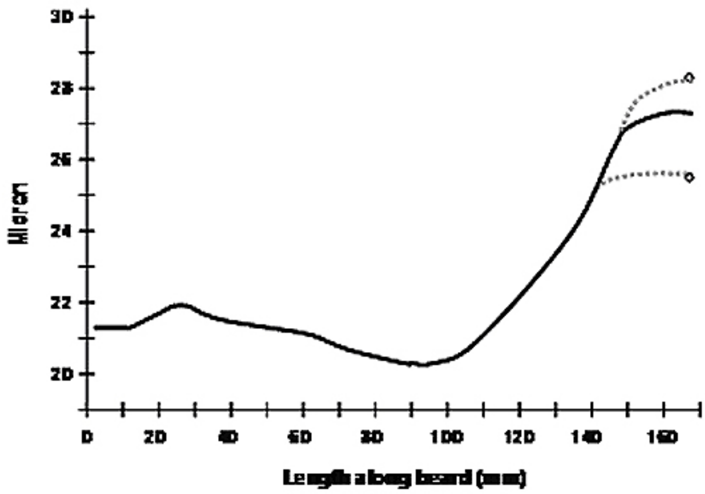

Figure 16.9 Diameter profile for a top. Source: Canesis Network (2006).

The profile curve is actually the average of 10 repeats measurements on the same top, with a minimum of 4000 fibres per measurement. It shows a significant increase in mean fibre diameter as the fibre length increases above about 120mm. The profile is less repeatable near the end of the beard due to the inevitable reduction in the number of fibres. The variation in this region is indicated by the dotted curves.

Based on the results provided by Brims there is considerable variation in the shape of the profiles of tops obtained from different sources. Some profiles show a steady increase in micron with length, while others show a distinct peak or dip in micron in the mid-length range.

16.6 Precision of fibre diameter testing

In the testing of wool, repeated testing of a sample will not provide exactly the same result. Variation is associated with every measurement, arising from limitations of the instrument, the sample preparation and the sampling itself. Variation due to human intervention is also present, but modern automated measurement systems significantly reduce this contribution.

The precision of a measurement is an indicator of the magnitude of the expected variation in a result. It is usually defined as a range within which 95% of all repeated measurements should lie. Extensive testing trials with the four instruments used for measuring fibre diameter have been conducted, enabling the levels of precision achievable with them when testing wool sliver to be compared. The 95% confidence levels are shown in Table 16.2 (AWTA 1999).

Table 16.2 Precision levels for fibre diameter testing of slivers (MFD). Source: AWTA (1999).

Instrument	**Precision (95% Confidence Level)**	
	20 microns	**35 microns**
Projection Microscope	± 0.60	± 1.40
Airflow	± 0.41	± 0.55
OFDA	± 0.30	± 0.66
Laserscan	± 0.25	± 0.64

Where test results are to be included on an IWTO test certificate because they form part of a commercial transaction, procedures are in place to ensure that the inherent variability in wool testing does not compromise the quality of the data provided. Each instrument will require a certain number of subsamples and test specimens to be used, and where necessary additional tests may be required.

Critical range values

The critical range values enable decisions concerning how many additional test specimens or subsamples may need to be tested, depending on the range of the first set of results.

Requirements for OFDA

According to IWTO 47, for sliver testing using OFDA, determine the range in MFD between two slides from the same subsample. If the difference exceeds the value shown in Table 16.3 for the appropriate MFD, prepare and measure another slide. The test method outlines the subsequent steps to be taken, depending on whether new results are within the range. For example, if the range between 2 of the 3 results falls within the allowable range then discard the third result.

When all subsamples of sliver have been measured, and the mean fibre diameters calculated, calculate the range between subsamples. If this exceeds the allowable range in Table 16.3, test two further subsamples. If the appropriate range is still exceeded discard any result that may be regarded as an outlier, and calculate the range again. In the event of the range still not complying, combine the results from all subsamples.

Table 16.3 Critical ranges for OFDA. Source: IWTO-47.

Mean fibre diameter Between two slides		<26 μm	>26 μm
		0.4	0.7
	Number of subsamples		
Range between subsamples (μm)	2	0.3	0.5
	3	0.3	0.6
	4	0.3	0.6
	5	0.4	0.6
	6	0.4	0.7
	7	0.4	0.7
	8	0.4	0.7

Requirements for Laserscan

The corresponding test method for using Laserscan (IWTO-12) also includes a set of critical range values (Table 16.4).

Table 16.4 Critical ranges for Laserscan (99% level of confidence). Source: IWTO-12.

MFD (μm)	SD (μm)	Number of test specimens				
		4	7	8	11	12
Up to 15.0	0.1064	0.5	0.5	0.5	0.6	0.6
15-1 – 20.0	0.1736	0.8	0.8	0.9	0.9	0.9
20.1 – 25.0	0.2409	1.1	1.2	1.2	1.3	1.3
25.1 – 30.0	0.3081	1.4	1.5	1.5	1.6	1.6
30.1 – 35.0	0.3754	1.7	1.8	1.9	2.0	2.0
Greater than 25.1	0.4426	1.9	2.2	2.2	2.3	2.3

Four test specimens are measured and the range of the results calculated. If the range of the four readings is less than or equal to the critical range for 4 readings the testing process is complete.

However, if the range is exceeded, four additional test specimens are measured and the range re-calculated. Consult the test method for the subsequent steps required, depending on whether or not the range of the 8 readings exceeds the appropriate critical or not.

Retesting

According to the IWTO regulations, to allow for unusually high variability within a lot of sliver or top, the range of the results for MFD should not exceed 0.6 μm. If this limit is exceeded, the lot should re-sampled and re-tested. The regulations deal with the possibilities of the new results being either within or outside the required range.

16.7 Comparison of the instruments

The three instruments for measuring fibre diameter, projection microscope, OFDA and Laserscan, operate on very different principles and use different geometrical definitions of fibre fineness. Therefore it might be expected that they will not always agree in the results they produce, even when measuring identical slivers. In practice, the established IWTO calibration procedures, which use standard Interwoollabs tops, are able to achieve very acceptable levels of agreement between instruments, especially for MFD, SD and CVD in the middle of the micron range (Marler, Shepherd and Barry 1999).

However when the diameter histograms are closely compared, small deviations are observed at the extremes of the micron range. These are not surprising because the Interwoollabs tops range from 15 – 38 microns and outside this range extrapolation techniques are required. However, these differences are unlikely to have any impact on processing or product performance.

See also round trial data comparing the different instruments (http://www.iwgofda.com/pdf (http://www.iwgofda.com/pdf/Performance of the OFDA 100 compared to other methods.PDF).

Readings [3]

The readings indicated with * are available on web learning management systems

1. *AWTA, 1999, Sirolan Laserscan™ - A new technology for the millennium, Australian Wool Testing Authority Ltd., Technical brochure, September 1999.
2. *AWTA, 2002a, Understanding fibre diameter measurement – Fundamental concepts, Australian Wool Testing Authority Ltd. Newsletter, January 2002, pp.10.
3. *AWTA, 2002b, Fundamentals of fibre fineness measurement – The projection microscope, Australian Wool Testing Authority Ltd. Newsletter, May 2002, pp.18.
4. *AWTA, 2002c, Fundamentals of fibre fineness measurement – Gravimetry, Australian Wool Testing Authority Ltd. Newsletter, October 2002, pp.18.
5. AWTA, 2003a, Using optical diffraction to measure fibre fineness, Australian Wool Testing Authority Ltd. Newsletter, February 2003, pp.24.
6. AWTA, 2003b, Direct measurement of fibre fineness, Australian Wool Testing Authority Ltd. Newsletter, July 2003, p.24.
7. AWTA, 2003d, Using conductivity to measure fibre fineness, Australian Wool Testing Authority Ltd. Newsletter, December 2003, p.18.
8. *AWTA, 2004, The Airflow instrument – Using porosity to measure mean fibre diameter, Australian Wool Testing Authority Ltd. Newsletter, March 2004, pp.18-21
9. *AWTA, 2005, Using photometry to measure mean fibre diameter (1950 – 1970), Australian Wool Testing Authority Ltd. Newsletter, April 2005, pp.23-24.

Summary

Summary Slides are available on web learning management systems

Many wool properties remain almost unchanged from raw wool through to top. These include mean fibre diameter and fibre diameter distribution where the only real change occurs because of any differences between the characteristics of the top and the noil. Other properties, such as base colour, are highly correlated from raw wool to top but anomalies can occur due to processing variability.

This topic covers the methods used to measure the fibre diameter characteristics of slivers and tops – sampling, specimen preparation, instrument operation and the analysis of the results. Fibre diameter is arguably their most important property, because of the importance of fibre diameter in the efficient spinning of fine worsted yarns and in the manufacturing light, soft handling fabrics for apparel.

A number of IWTO test methods have been developed for measuring the fibre diameter of wool, notably using the Projection Microscope, Airflow, Laserscan and OFDA (Optical Fibre Diameter Analyser). The latter two methods utilising modern technologies have largely replaced the first two methods for routine commercial testing. However, the Projection Microscope provides the benchmark test by which the other methods are calibrated.

References

Australian Wool Testing Authority Ltd. (AWTA), 1999, Sirolan Laserscan™ - A new technology for the millennium, Australian Wool Testing Authority Ltd., Technical brochure, September 1999.

Baxter, B P, Brims, M A and Taylor, T B, 1992, 'Description and Performance of the Optical Fibre Diameter Analyser (OFDA),' *Journal of the Textile Institute,* vol. 83(4), pp. 507.

Brims, M A, 2002, 'Introducing OFDA4000 – A new instrument for simultaneous measurement of fibre length and diameter in tops,' *Proceedings. of IWTO,* Report No. SG 2, Barcelona.

BSC Electronics, OFDA System, BSC Electronics, OFDA100 Product Information Brochure.

Cottle, D.J. and Zhao, W. 1998, 'Changes in wool colour. Part III: Processing,' *Journal of the Textile Institute,* vol. 89(1), pp. 26.

Crowe, D W and Marler, J W, 2000, Calibrating Laserscan for raw wool measurement and an evaluation of an alternative transport fluid, *Proceedings. of IWTO,* Technology and Standards Committee, Report No. RWG 03, Nice.

IWTO 6, Method of Test for the Determination of the Mean Diameter of Wool Fibres in Combed Sliver using the Airflow Apparatus, International Wool Textile Organisation test method.

IWTO 8, Method of Determining Fibre Diameter Distribution Parameters and Percentage of Medullated Fibres in Wool and Other Animal Fibres by the Projection Microscope, International Wool Textile Organisation test method.

IWTO 12, Measurement of the Mean and Distribution of Fibre Diameter using the Laserscan Fibre Diameter Analyser, International Wool Textile Organisation test method.

IWTO 47, Measurement of the Mean and Distribution of Fibre Diameter of Wool using an Optical Fibre Diameter Analyser (OFDA), International Wool Textile Organisation test method.

Marler, J W, Shepherd, G R and Barry, R G, 1999, 'A comparison of histograms from OFDA, Projection Microscope and Laserscan for wool tops,' *Proceedings. of IWTO,* Report No. SG 01, Florence.

Glossary of terms

Airflow	An indirect method of measuring the mean fibre diameter of wool using the rate of air flow, or the pressure drop when air is forced through a compressed sample of wool ain a standard chamber
Comfort factor	The percentage of fibres in a fibre diameter distribution which are less than or equal to 30 μm
Confidence limits	An expression of the precision of the mean of a set of values, usually associated with a stated probability such as 95%. It is the interval around the mean within which, with the stated probability, the true value is expected to lie
Diameter profile	A graph depicting how the mean fibre diameter varies with distance along a 'beard' of aligned fibres, as formed by the Almeter Fibroliner or OFDA4000
Fineness	Mean fibre diameter
Graticule	A glass plate with a series of accurate and closely-spaced lines ruled into its surface, for the calibration of microscopes
IWTO	International Wool Textile Organisation, the body responsible for developing and maintaining the test methods, regulations and other procedures involved with the measurement and marketing of wool
Laserscan	An instrument for obtaining the wool fibre diameter distribution and its associated statistics by the detection of shadows of fibre snippets in a laser beam
Mean fibre diameter	The average thickness of a sample of wool fibres, measured in microns (μm)
Micron	A unit of measurement of fibre diameter, correctly termed a micron (μm). 1 micron equals one-millionth of a metre
Microtome	A guillotine consisting of two parallel blades separated by 0.8 – 2.0mm, used to cut through a sample of top or sliver to obtain a sample of fibre snippets
OFDA	Optical Fibre Diameter Analyser – an instrument for obtaining the wool fibre diameter distribution and its associated statistics using an automated microscope and digital image analysis techniques
Projection Microscope	A manually-operated instrument for obtaining the wool fibre diameter distribution and its associated statistics. Magnified images of the profiles of fibre snippets are projected on a screen and their widths measured by using a graduated scale
Sample	The sliver drawn from, and representative of a lot
Sliver subsample	A randomly drawn portion representative of a sliver or top, from which guillotined snippets are cut
Snippet	Very short section of fibre, typically 0.8 – 2.0mm long which is cut to measure fibre diameter
Strobing	A light source switching on and off at a moderate to high frequency
Test specimen	The snippets taken from a sliver subsample, which are fed into the testing instrument
Top	A substantially parallel assembly of fibres, essentially free of short fibres, vegetable matter and neps