16. Recent Developments in Wool Metrology

Australian Wool Testing Authority

Learning objectives

By the end of this topic, you should have:

- an appreciation of the factors which drive developments in wool metrology; and
- a guide to possible future developments in wool metrology.

Key terms and concepts

Fleece testing, presale testing, top testing, testing for certification, spectroscopy.

Introduction to the topic

This topic briefly describes the framework in which future developments may occur in wool metrology and provides examples of possible developments.

16.1 Brief history

Two major developments in the middle of the twentieth century led to the development of wool metrology: the development of core sampling of wool bales by the US Department of Agriculture in the 1930's, and the development of Airflow testing of diameter in the 1940's and 1950's (Sommerville 2002). Core sampling provided a means of readily obtaining representative samples from greasy and clean wool bales, and the use of Airflow for the measurement of mean fibre diameter (MFD) enabled the development of a relatively cheap and simple alternative commercial test to microscopic examination of individual wool fibres.

These developments were followed in the 1960' and 1970's with commercial testing of regain, for both clean and greasy wool, and wool yield for greasy wool. The concept of presale testing of wool, rather than subjective appraisal, gradually gained acceptance in Australia during this period. There was also a fundamental change from assessing capped bales of wool to assessing Display Samples consisting of a series of grab samples extracted from each bale in a lot, i.e. Sample by Sample. Testing of Staple Length and Staple Strength was introduced in the 1980's and was beginning to gain acceptance by the end of the decade. The next introduction of a major new measurement technology occurred in 2000 with the introduction of Laserscan, which provided measurement of the standard deviation (SD) and coefficient of variation of diameter (CVD), comfort factor (CF) and mean fibre curvature (MFC).

Each of these developments was implemented to aid in the specification of wool lots for trading purposes, and so Standard procedures were developed to ensure that measurements were repeatable, and accurate and precise within acknowledged boundaries. The most commonly employed Standards for wool testing in Australia are the International Wool Textile Organisation (IWTO) Standards (IWTO-19-2012). Sampling regimes compatible with these Standards are set out in the IWTO Regulations. These Standards and Regulations developed in parallel with the development of the testing instruments. A full listing of current IWTO Standards concerned with raw wool testing is included in Table 16.1. IWTO Draft Standards are also available for many of the characteristics included in the full Standards, plus, for example, counting contaminant coloured fibres, mothproofing, wool fibre length, Chemical residues testing and the diameter of fibre ends.

Table 16.1 Listing of IWTO Test Methods concerned with Raw Wool Testing. Source: IWTO (2013).

Code Number	Full Title
IWTO-2-2007	Method for the Determination of the pH Value of a Water Extract of Wool
IWTO-3-86	Methos of Test for the Acid Content of Wool
IWTO-6-2013	Method of Test for the Determination of the Mean Diameter of Wool Fibres in Combed Sliver using the Airflow Apparatus
IWTO-7-2011	Sub-Sampling Staples from Grab Samples
IWTO-8-2011	Method of Determining Fibre Diameter Distribution Parameters and Percentage Medullated Fibres in Wool and Other Animal Fibres by Projection Microscope
IWTO-10-2003	Method of Determination of the Dichloromethane Soluble Matter in Combed Wool and Commercially Scoured Carbonised Wool
IWTO-12-2012	Measurement of the Mean and Distribution of Fibre Diameter Using the Sirolan-Laserscan Fibre Diameter Analyser
IWTO-17-2011	Determination of Fibre Length Distribution Parameters
IWTO-19-2012	Determination of Wool Base and Vegetable Matter Base of Core Samples of Raw Wool
IWTO-20-2004)	Method for the Determination of the Felting Properties of Loose Wool and Top
IWTO-28-2013	Determination by the Airflow Method of the Mean Fibre Diameter of Core Samples of Raw Wool
IWTO-30-2007	Determination of Staple Length and Staple Strength
IWTO-31-2002	Calculation of IWTO Combined Certificates for Deliveries of Raw Wool
IWTO-32-2005	Determination of Bundle Strength of Wool Fibres
IWTO-33-2003	Determination of Oven-Dry Mass and Calculated Invoice Mass of Scoured and Carbonised Wool
IWTO-34-1998	Determination of Oven-Dry Mass and Calculated Invoice Mass, and Calculated Merchantable Mass of Wool Tops
IWTO-35-2003	Method for the Measurement for the Colour of Sliver
IWTO-38-1999	Method for Grab Sampling Greasy Wool from Bales
IWTO-41-1992	Determination of the Invoice Mass of Scoured or Carbonised Wool or Tops or Noils by Capacitance Method
IWTO-47-2013	Measurement of the Mean and Distribution of Fibre Diameter of Wool using an Optical Fibre Diameter Analyser (OFDA)
IWTO-52-2006	Conditioning Procedures for Testing Textiles
IWTO-55-1999	Method of Automatic Counting and Classifying Cleanliness Faults in Tops using the Optalyser Instrument
IWTO-56-2013	Method for the Measurement of Colour of Raw Wool
IWTO-57-2000	Determination of Medullated Fibre Content of Wool and Mohair Samples by Opacity Measurements using an OFDA
IWTO-58-2000	Scanning Electron Microscopic Analysis of Specialty Fibres and Sheep's Wool and their Blends

16.2 Areas of current usage

The are five different areas in which raw wool measurements are used, viz. trading, prediction of expected performance, performance monitoring (quality control/assurance), product and/or process development, and marketing.

Trading

Most trading in wool occurs when farm lots are sold to be accumulated into processing consignments. This trade relies on IWTO Standard measurements for yield (including vegetable matter base), MFD, staple length and strength measurements. Other measurements which are sometimes requested in this trade include: CVD, CV(SL), clean colour and MFC.

Measurements are also used to value individual animals, especially rams, in which case MFD, SD, CVD, comfort factor, MFC, yield, staple strength are often used.

Commercially scoured wool and wool top are traded based on regain and residual grease, MFD and possibly, colour measurements based on IWTO Standards. Wool top is also measured for fibre length (hauteur) and variation in fibre length according to IWTO Standards.

Performance monitoring

Raw Wool measurements are used in performance monitoring (or Quality Control) during scouring (e.g. colour measurement) and combing (e.g., MFD, Hauteur, CV (Hauteur)).

Prediction

Raw Wool measurements are used to predict Top and Scoured Wool specifications, e.g. TEAM equations (TEAM-3 Steering Committee 2004), clean colour (Mahar, Osbourne and Burke 1996), Top and Noil Yields (IWTO Regulations), Length after Carding (Mahar, Osbourne and Burke 1996).

Product and process development

Examples of the use of Raw Wool measurement in Process and Product Development include, Glacial® wool from WRONZ (Ranford, Ellery and Wall 2002), fleece testing to improve clip preparation and sheep selection, process improvement in scouring, carding, combing, and spinning.

Marketing

Raw Wool measurements are used to provide market information about price trends and relationships between wool properties and price or wool supply. They can be used to discern niche markets for wool with particular properties (e.g. Elite type wool), as well as in supply chain partnerships in which wool producers, or groups of producers, link with an individual processor and spinner, fabric and/or garment manufacturer.

Relevant trends in wool production, trading and processing

There are several trends in the Wool Industry which may influence, or even guide, future developments in Wool Metrology. There is considerable interest in the use of on-farm testing as a means of improving clip preparation, sheep selection and, possibly, specification (certification) of sale lots (Baxter 2002).

There continues to be interest in establishing niche markets for specialised, or particular, 'types' wool based on geography, e.g. New Zealand Merino, or sheep stud/line, e.g. Egelabra, wool properties, e.g. Elite wool, or growing conditions, e.g. 'organically grown' wool. These are examples of wool producers trying to establish closer links with potential clients further along the wool processing chain.

The gains in computing and communications, e.g. through the internet, also offer potential to change aspects of wool trading. There are now technologies to accommodate the huge information load which metrology can generate to specify wool properties. Could we see trading in wool which is 100% specified, rather than being available for viewing and handling?

Predictions, like the TEAM equations, appear to be improving as they are refined, offering a climate of greater certainty for production planning in early stage processing.
There is a trend towards greater use of raw wool measurement in breeding strategies and in ram judging.

And there has been a definite shift in early stage processing from Europe, Japan and Australia to China and India, over the last 10 years.

16. 3 New measurement technologies

Spectroscopic measurements

In recent years Near Infrared Reflectance (NIR) has been introduced to both performance monitoring (especially in scouring companies in New Zealand – Ranford, Ellery and Wall (2002) and certified Testing (IWTO-19). NIR is now used for moisture and residual grease content measurement, colour and even for approximate measurements of MFD by wool scours, and for residual grease and ash content of scoured core samples in presale certificate testing.

In principle, NIR spectroscopy relies on calibration to existing measurement technologies and relates the quantity of a given non-wool contaminant (e.g. grease) to absorption patterns over a range of wavelengths. They offer a faster, simpler measurement than traditional method. It may be possible to extend this technology to on-farm yield testing (i.e., determining the proportion of wool in a sample of greasy wool) and so provide a means of specifying sale lots based on on-farm testing. X-ray scanning, as used in security checks at airports, has also shown potential in this regard.

In short, the use of spectroscopy has provided a means of replacing traditional methods of measurement of residual grease and dirt in core scoured wool for certification. It is conceivable that spectroscopy in some form, e.g. NIR, X-ray, gamma radiation, or in combination, may provide a simple direct estimate of wool base and vegetable matter base, thus negating the need for much of the current testing regime for these two properties.

Image analysis

The biggest development in this area over the past 30 years has been FibreGen, an image analysis instrument designed to detect dark and medullated fibre (DMF) in top.
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In brief, the FibreGen system consists of three principal procedures (IWTO DTM-64-2012): sample preparation, sample scanning, followed by contamination analysis and reporting. Sample webs are produced from wool top using either a Toeniessen Drafting Machine (Figure 16.1), or a Drum Card (Figure 16.2) (Quiniou & Wang, 2012).

Figure 16.1: A Modified Toeniessen Drafting Machine

Figure 16.2: An Ashford Drum Card

Both instruments parallelise fibres and produce a web of uniform thickness. Webs are then placed into bags and dosed with a liquid of similar refractive index than white wool (nwool = 1.553), so that contaminants are highly visible.

The liquid is then spread uniformly across the sample web using rollers and the bag is sealed. Five sub-samples of 10g of wool top are to be prepared for a FibreGen test.

The measurement equipment consists in two major units (Figure 3):

- A high resolution scanner (1200 dpi), and
- A computer

Figure 3: FibreGen Instrumentation

After preparation, samples are scanned. Scan images are transferred to the computer for analysis and quantification of contamination.

The FibreGen image analysis software (AWTA FibreGen Team, 2010) is used to analyse, quantify and grade contaminants based on the image of the sample. Using colour and geometric parameters, FibreGen is able to firstly detect isolated objects, then identify wether the object is a Dark / Coloured Fibre or VM contaminant. Using colour and geometric parameters, Dark and Coloured Fibres are graded into three sub-categories, while VM are classified into four sub-categories. A final report showing the quantity of contaminants for each sub-category is then issued. An example of each sub-category used for classification of contaminants is provided in Table 16.3.

Table 16.3: Dark Fibre, Coloured Fibre and Vegetable Matter Classification for FibreGen.

Definition	Dark Fibres		Coloured Fibres	Vegetable Matter			
				Straw and seeds		Burrs	
	Dark	Very Dark		3 – 10mm	>10mm	3 – 10mm	>10mm
Name	DF1	DF2	CF	VF1	VF2	VNF1	VNF2

This technology has the potential to develop into a method for measuring contamination in Raw Wool.

Top testing

The OFDA4000 instrument (Brims and Baxter 2004) is currently available and undergoing comparison trials with Almeter and Laserscan instruments. The OFDA4000 provides estimates of length and length distribution parameters (including hauteur and barbe), estimates of diameter parameters including MFD, SD, CVD, CF, and the diameter of fibre ends, curvature parameters, and an estimate of the diameter profile of fibres in top. The instrument offers potential for measurements of fibre length and length/diameter relationships which have not previously been available. It is unclear how this new information will be applied in either the trading or product/process development areas. There is the potential that the additional information may improve processing prediction from greasy wool to top, and from top to yarn, and may even enable selection of fibres with particular fdp's in top to spin yarns with specialised characteristics, e.g. different combinations of surface softness and stiffness.

The detection and elimination of faults, e.g. neps, vegetable specks, dark and medullated fibres, in top is currently an expensive operation which is usually performed manually. There is currently a technical solution to this problem, the Optalyser, an image analysis instrument for fault detection, but it is prohibitively expensive and not widely used. With advances in image analysis, it seems likely that a cheaper system may be developed for fault detection in top.

Fabric Testing

Recently, development emphasis has been placed on predicting the dextral and comfort attributes of wool fabrics. Two major developments in this area are the Wool HandleMeter, and the Wool ComfortMeter. Both were initiatives developed by the Sheep CRC in response to consumer feedback.

The Wool HandleMeter (Figure 16.4) was developed by the Sheep Co-operative Research Centre (Sheep CRC) and its partners for measuring the handle attributes of single jersey next to skin fabrics. Fabrics are conditioned in a temperature and humidity controlled room for at least eight hours prior to testing. Three subsamples are then cut using a round 100cm^2 cutter. Each subsample is placed on the sample plate, the mass plate lowers on top of the sample and the force transducer rod measures the force required to push the fabric through the orifice.

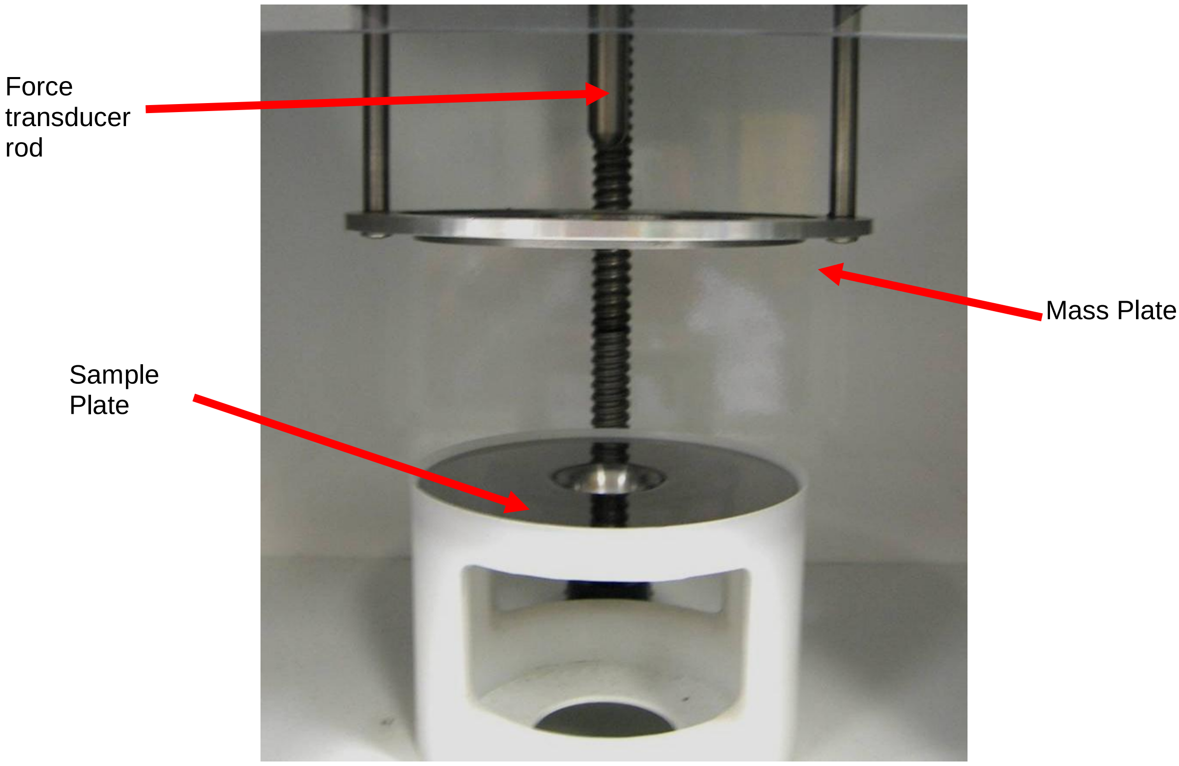

Figure 17.4: Key components of the Wool HandleMeter.

The software then converts the force into a force displacement curve from which it can calculate the handle attributes of the sample. An average result is derived from the three subsamples and each handle attribute is rated on a scale of 0-10, with an overall summary result (Figure 16.5).

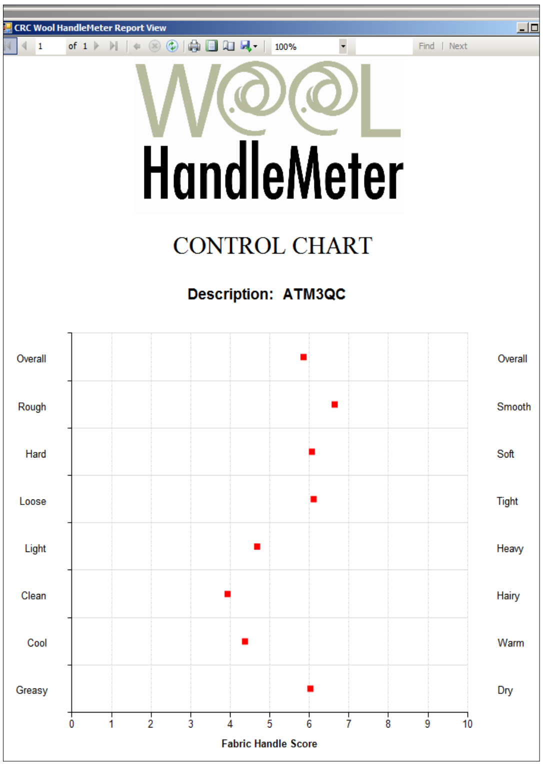

Figure 16.5: Example of the handle results.

The Wool HandleMeter is revolutionary because it provides a cheap, fast and objective way of measuring the handle attributes of wool. Traditionally, handles attributes had to be ascertained by panels of judges who would rate the fabrics based on their tactile sensations. This is a very expensive and laborious process and judge's opinions tended to vary widely. The Wool HandleMeter removes the element of subjectivity means that unlike in the past, the same fabric will achieve the same handle results regardless of when, where or by whom the testing is done.

This technology is useful to knitting mills because it allows them to ensure the fabric they produce is of consistent within and between batches. It can also help determine if the fabric is suitable for next to skin wear. This technology has the potential to be extended to other fabric types as it develops.

The Wool ComfortMeter (Figure 16.6) was also developed by the Sheep CRC and its partners. The Wool ComfortMeter measures the fibres protruding from knitwear fabrics or garments which can cause an itchy sensation. The fabric to be tested is placed face up on the measurement bed and the measurement head scans over the fabric, detecting the protruding fibres. The Wool ComfortMeter then correlates this data with data gathered in a wearer trial to determine the Comfort Factor (the Comfort Factor is the percentage of fibres less than 30µm) of the fabric.

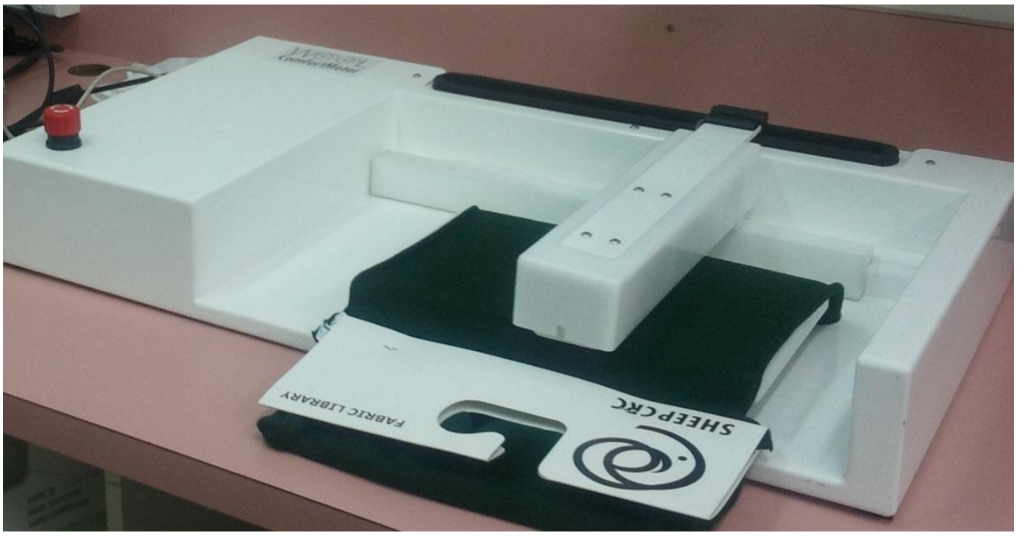

Figure 16.6: The Wool ComfortMeter with a fabric on the test bed.

Testing fabric or garments on the Wool ComfortMeter can determine their suitability for next to skin wear. This is useful to determine if the fabric or garment is fit for purpose.

Readings

The following readings are available on web learning management systems

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TEAM-3 Steering Committee, 2004, TEAM-3 Processing Trial – Final Report,.

Glossary of terms

Check Test	A Check Test is verification of documentation and calculations forming the basis of the Certificate on which a doubt has been raised and, if possible, a set of additional measurements made, in accordance with the same standard IWTO Test Method as was adopted for the original test, on that portion of the sample material remaining after that original test. Where no sample material remains, a Recore Check Test may be carried out as part of the check testing procedures. Check testing is restricted to tests carried out by the Test House, which conducted the original test
Recore Check Test	This is a set of measurements made, in accordance with the relevant IWTO Test Methods and Regulations, on a further sample of raw wool drawn from the delivery as part of the check testing procedures. A Recore check test may only be conducted where a Certificate has not been delivered in relation to a contract. Where staple measurements are involved this definition applies to a fresh grab sample taken from the lot rather than a core sample
Retest	This is a set of measurements made, in accordance with the relevant IWTO Test Methods, on a further sample of raw wool drawn from a delivery for which the original Certificate is in doubt. This differs from a Recore Check Test in that duplicate core (grab) samples are drawn for possible testing by two separate Test Houses to resolve a disputed result. Such sample material must be obtained by recoring (regrabbing) and reweighing all bales, in accordance with the current IWTO Core (Staple) Test Regulations
Testing Error	A Testing Error is deemed to have occurred if the Maximum Retest Range is exceeded
Maximum Retest Range	The Maximum Retest Range (i.e. the difference between the values of a retest and the original Test Certificate or an earlier retest) is a statistically (and scientifically) determined upper and lower limit which, provided the test procedure has been rigorously adhered to, will very rarely be exceeded purely by chance The Maximum Retest Range defines the maximum allowable difference between two test results

In addition to the above glossary, a comprehensive Glossary of Terms can be found as a reading for this topic (AWTA 2002.pdf).