Wool Metrology – Past and Current Trends and Future Requirements

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Summary

Historically, the processors and other users of wool, not the producers, have driven the development of objective measurement systems for various wool characteristics. Producers were initially very reluctant to adopt objective measurements, preferring to remain with subjective assessment techniques. Measurement and specification of raw material characteristics is a fundamental assumption of modern manufacturing processes. It is central to maintaining product quality. The adoption of objective measurement of raw wool by wool processors has been driven by the same need. Defining the technical performance of these measurement systems is the role of wool metrologists. In recent years there has been increasing interest by wool producers in objective measurements, particularly in technologies that will better assist them in their on-farm management systems. This interest is likely to have a major influence on future requirements.

Introduction

Put quite simply, metrology is the science of measurement. In broad terms metrologists are generally focussed upon developing (evaluating) technologies and systems for objectively measuring the quality attributes of raw materials and manufactured products. In the wool industry the work of metrologists has been pivotal in the development of modern marketing systems and will be even more so in future systems.

Wool Metrology - Defining Quality Attributes of Greasy Wool and Wool Products

It is essential that raw materials and products meet the requirements of those who use them (Sommerville 1998). This **fitness for use** defines their quality. There are two general aspects of quality: **quality of design** and **quality of conformance**.

Raw materials and products are generally available in various grades or levels of quality. These variations are often intentional, and consequently the appropriate technical term in such instances is quality of design. For example, all wool suits serve the same basic function, but they are available in a range of designs, fabrics and prices, aimed at specific market segments.

On the other hand, quality of conformance is how well the product conforms to the specifications and tolerances required by the design. Quality of conformance is influenced by a number of factors. In the case of wool suits these may include the following:

- Variability of the greasy wool,
- Choice of the manufacturing processes,
- Operation of these processes,
- Training and supervision of the work force,
- Type of quality-assurance system (process controls, tests, inspection activities etc),
- Extent to which these quality assurance systems are followed, and
- Motivation of the workforce to achieve quality.

Every product, including wool, possesses a number of elements that jointly describe its fitness for use. These elements are often called **quality characteristics**. Quality characteristics may be of several types, for example:

1. **Physical:** length, weight, fineness, yarn evenness.
2. **Sensory:** handle, feel, appearance, colour.
3. **Time Orientation:** reliability, durability, serviceability.

Generally it is difficult (and expensive) to provide customers with raw materials and products that have flawless quality characteristics. A major reason for this difficulty is **variability**. There is a certain amount of variability inherent in any raw material or product and consequently no two products can never be identical. Wool is an extremely variable material. It varies along the fibre, between fibres, between staples, between animals, between mobs, between bloodlines and between regions. If the wool industry wishes to improve quality and reduce overall cost it must find ways of restricting or controlling the impact of this inherent variability of the fibre on the quality of finished textile products. Wool metrologists have provided us with some of the means to do this.

Quality characteristics can be estimated subjectively, or they can be assigned a numerical value using objective measurements. Traditionally, the hand and the eye were the major tools used to determine the value and processing attributes of wool. Today however, at all levels of the industry, technology providing objective measurements is increasingly replacing the senses of vision and touch.

Wool Metrology – Historical Overview

The use of objective measurements in wool processing goes back more than a century. The first recorded attempt to objectively measure wool's most important characteristic, fibre fineness, was in 1777, when Daubenton measured the width of some wool fibres under a microscope by comparison with lines drawn on a piece of quartz (Sommerville, 1999). During the 19th century and the first half of the 20th century, the microscope became the favoured instrument for directly determining the fineness of wool tops. However, it was the development of coretesting in the USA after 1937, by the US Department of Agriculture (USDA), US Customs and the Boston Wool Trade Association that made the representative sampling of bales of greasy or scoured wool possible, and led to the development of test methods, which were able to provide more accurate and precise estimates of the important value-determining characteristics of greasy wool in mill consignments.

A major breakthrough in wool metrology occurred in the period 1945 to 1955 with the development of the Airflow instrument, thereby providing a relatively inexpensive but indirect method for measuring the fineness of tops. In the UK, Wool Industry Research Association (WIRA) and the British Wool Federation (BWF) developed yield and fineness test methods, and both the USA and Europe established different processing and moisture tolerances to estimate commercial yields of fibre obtained from greasy wool. Following upon earlier developments in the USA (1937-1945) and New Zealand (1951) Commonwealth Scientific & Industrial Research Organisation (CSIRO) in Australia developed manual pressure core equipment in co-operation with with the Australian Wool Testing Authority (now AWTA Ltd) and the New Zealand Wool Testing Authority (now NZWTA Ltd) and it designed machine coretesting equipment suitable for large volume testing (NSW Department of Technical & Further Education, 1976).

By the late 1960's methods for preparing and measuring the fineness of greasy wool by Airflow had also been developed, and this instrument, despite its known limitations, became the primary technology for measuring the fineness of wool (Sommerville, 1998).

The international adoption of common sampling and testing procedures became possible through the International Wool Textile Organisation (IWTO). Although the organisation was established in 1930, it was not until 1965 that technical and commercial delegates at IWTO were able to agree on coretesting processes, which are the basis of the methods used universally today. Following the development of grab sampling during the 1970's, under the auspices of the Australian Objective Measurement Program (AOMP) (Australian Wool Corporation, 1973), and staple measurement tests in the early 1980's, it was the IWTO that enabled a common sampling and measurement process to be adopted for all wool growing countries.

Once wool metrologists had developed the sampling and testing technologies and Standard Test Methods became available, the impetus for the growth in objective measurement of mill consignments and then presale farm lots was driven by the users of wool, to assist them in ensuring the quality of conformance of the yarns, fabrics and garments they produced. Wool producers were initially reluctant to adopt objective measurement and sale by sample of auction lots, but adoption accelerated throughout the 1970's as price differentials between untested and tested lots became evident.

The development of the Airflow also provided sheep breeders with a rapid and relatively inexpensive means to obtain objective information about the fineness of the wool produced by individual sheep. The value of this information, when used in conjunction with the traditional techniques associated with the senses of vision and touch, had already been demonstrated (Newton-Turner *et al* 1953).

Since 1990, new technologies for determining fineness of greasy wool (Sirolan™ Laserscan, OFDA100 OFDA2000) have become available. The advantage of these technologies over the Airflow primarily lies in their facility to be used for on-farm testing services, rather than laboratory based testing services. While much remains to be done to improve these technologies they offer a means to conveniently and efficiently integrate objective measurement of wool fibre fineness into wool harvesting and classing systems, as well as simultaneously providing information for breeding decisions.

Technical and Commercial Requirements of Wool Testing Systems

Objective determination of defined characteristics of materials usually involves measurements based on a small proportion of the material of interest. Where materials are **homogeneous**, obtaining a representative sub-sample of the whole is a relatively simple problem. Where there is **heterogeneity** obtaining a sub-sample that is representative of the whole is a much more difficult task.

There are a several factors that bear on the technical and commercial application of objective measurement systems (Sommerville 1998; Douglas 2000). We will consider only the four most important of these here.

Sampling

Wool is a **heterogeneous material**, both in the bulk or when still on the sheep's back. The sampling procedures for sale lots or consignments of wool have been carefully developed to ensure that the sample represents the bulk with a predictable degree of error. The requirements for sampling the bulk also extend to further sub-sampling of the sample itself, in order to measure a specific characteristic. The theory and practice of these sampling regimes will not be considered here. Suffice to say the same theory and practice also applies to sampling from individual animals. **Sampling is the first and most important step in any wool testing system**.

Precision

Precision describes the reproducibility of results – that is the agreement between numerical values of two or more measurements determined using the same measurement systems. Common components of all measurement systems are:

- sampling (both from the bulk and further sampling of samples obtained from the bulk),
- instruments or machines,
- laboratories, and
- people.

Each of these components introduces errors and the errors are additive. The precision of a measurement of any particular characteristic is therefore determined by the sum of the errors in each of these components of the measurement system.

Bias

Wool metrologists are concerned with two types of errors:

- random or indeterminate errors; and
- systematic or determinate errors.

The error in the mean of a number of replicate measurements is equal to the sum of these two errors.

Random or indeterminate errors impact upon precision. Bias may have little or no effect on precision, but it has a significant effect upon accuracy i.e. how close the measurement is to the "true" result.

Bias is a result of systematic or determinate errors. Systematic errors always act in one direction, resulting in a consistently larger or a consistently smaller result than that provided by the reference measurement. Bias can result from several causes, and generally, these can be classified into one of six groups:

- sampling;
- differences in fundamental assumptions;
- personal errors;
- instrumental errors;
- method errors; or
- interferences.

Bias may be constant over the range of variation of the characteristic being measured, or it may vary over this range. One of the objectives of standardising wool testing systems is the elimination or at least the minimisation of bias. Where bias cannot be eliminated, provided it is not level dependent, a measurement technology may still be useful.

Cost

The adoption of objective measurements is almost wholly influenced by the costs versus the benefits. Therefore, in establishing an objective measurement system, factors such as sampling, precision and bias must be balanced against the costs and the potential benefits. As a general rule, metrologists try to balance the demands of sampling, precision and bias to provide a measurement at an acceptable cost. This inevitably means that (technical) compromises must be made.

Past and Current Trends in Wool Metrology

Wool metrologists have and are continuing to focus upon developing objective measurement systems to replace the subjective systems previously used, and consequently measure, where possible, exactly the same quality criteria. The systems for determining the key bulk parameters required by the users of greasy wool (Yield, Vegetable Matter Base, Mean Fibre Diameter, Diameter Distribution, Colour, Staple Length & Staple Strength) are now well established and in everyday use in mill specifications, performance monitoring and commercial transactions.

The most significant trend that has occurred is the simplification of sampling and testing requirements in response to the testing of smaller and smaller lots (Morgan, 1994, 1995, 1996) . The average farm lot now tested in Australia is 6 bales – almost half of what it was 20 years ago. The compromises between precision and cost that were negotiated in developing the first Standard Test Methods were initially predicated upon mill consignments of 50-200 bales. Over the years, sampling and testing requirements have been appropriately modified to reflect this trend to testing of smaller lots.

The advent of new technologies for determining fineness distribution characteristics, such as Sirolan Laserscan and OFDA 100, has provided new measurements such as Coefficient of Variation of Diameter (CVD), Mean Fibre Curvature (MFC), Medullation, and Comfort Factor (CF). Of these only CVD and Medullation have been associated with existing or new Standard Test Methods.

Both the Sirolan Laserscan and OFDA 100 technologies have been adapted to provide systems for on-farm measurement of fibre characteristics (Sirolan Fleecescan and OFDA 2000), with the OFDA 2000 instrument also providing information about along-fibre variations within staples (staple profiles).

As yet there is little demand from wool users for the new measurements of MFC, CF or Staple Profile. In most part this is due to the fact that as yet there is little or no demonstrated economic benefit to the users. In the main, wool producers have demonstrated far more interest in these parameters than their customers.

It is not always essential that measurements developed by wool metrologists and applied by wool producers are also required by wool users. For example wool producers can use Staple Profile measurements as a tool to assist them to manage the staple strength of their flocks (Peterson *et al* 2000). Until there is clear evidence that this measurement can provide direct benefits to the users of wool they are unlikely to demand it.

The trend on the part of wool growers to use these new parameters so that they are better able to control the quality characteristics of their wool is to be applauded. However, challenge for wool metrologists is to ensure that there is adequate technical performance information so that producers can make the best commercial decisions when using these measurements.

Future Requirements

The most important contribution of wool metrologists has been to develop technologies and systems to provide information that better predicts processing performance and hence quality of conformance to the user's requirements. Key to this has been defining the limitations and capabilities of these systems by establishing Standard Test Methods with a specified precision.

Historically, new wool measurement technologies have emerged at a relatively leisurely pace, and wool metrologists have had ample time to complete the fundamental studies required to evaluate and specify the performance of these technologies. However, in recent years, the deployment of new technologies, particularly for on-farm applications, has occurred with little substantive metrology information being available. In the case of Certification, IWTO provides a mechanism (albeit somewhat bureaucratic) that ensures that new measurements can be used with confidence. While the requirements for on-farm technologies may not be as stringent, an adequate definition of the precision of these technologies is still commercially important (Marler 2001). But wool metrologists need to be able to respond to these new and emerging technologies more quickly than has occurred to date. Principally this is an issue of funding that must be taken on board by wool producers, and the organisations and companies that provide new wool measurement technologies and metrology services.

The value of any new measurements to wool users can only be determined by appropriately designed trials. In general these are very expensive. Currently AWTA Ltd is funding two such trials. The first, the TEAM 3 trial, is updating the TEAM 2 prediction formulae to reflect the improvements made in scouring, carding and combing over the last 10 years, and to also evaluate the importance of new information such as CVD and MFC on processing prediction. The second, the Non-fleece Wool Processing Trial, is also examining the importance of these parameters as well as the influence of staple extensibility and staple profile. Both trials are aiming to further improve the prediction of quality of conformance of mill consignments, but mechanisms for funding the evaluation of processing benefits of new future measurements will be required.

On-farm certification is also seen by some as an important future requirement. In 2001/2002 the total cost of Presale Certification, including brokers and warehousing charges, was $137M (AWEX 2001). If on-farm certification is to become a reality this is one, among many, benchmarks that must be met. Using existing individual fleece measurement systems, determining only fibre fineness characteristics would currently cost between $135M and $170M, with a totally inadequate precision (Marler *et al* 2002a, 2002b). Significant technological challenges remain to make on-farm certification competitive with the existing Presale Certification system. However, there is still considerable scope for further development of on-farm fibre measurement systems, which can deliver economic benefits to wool producers via more efficient sheep selection, production management and wool classing.

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