Measuring wool: from Mikronmeter to FiberLux

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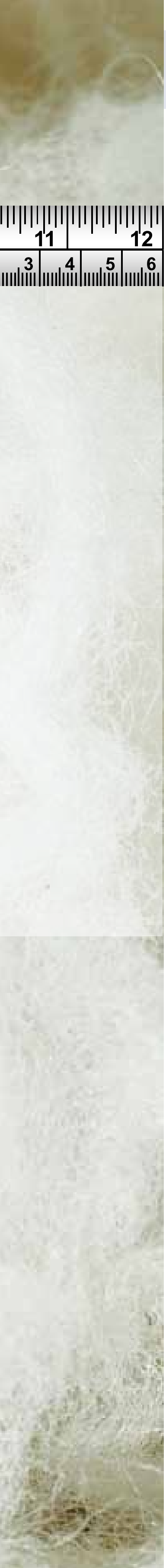

We have long known that the mean fibre diameter (fineness) is the main quality and price-determining factor for apparel-type wool, making it paramount for wool farmers in terms of breeding, classing, economical returns and other farm management objectives.

Traditionally, farmers, wool handlers, brokers and buyers estimated the quality or fineness of the wool using the subjective eye-and-hand (touch) method, which relied largely on the relationship between the wool fineness or diameter and the staple crimp frequency, the latter generally increasing as the wool becomes finer (ie as the diameter decreases).

Duerden quantified this relationship in the late 1920s for South African Merino wool, while Lang did the same for Australian Merino wool in the late 1940s. Nevertheless, from the studies of Duerden and Lang, it became clear that for the same diameter, the staple crimp frequency could vary widely. It then follows that staple crimp frequency per se is not a reliable measure of the fineness of wool.

This, therefore, placed a big question mark on the subjective hand-and-eye assessment of wool quality, fineness in particular.

Although certain appraisers were highly specialised and accurate in estimating the fibre diameter, the above considerations led investigation into an instrument to determine wool fineness or wool fibre diameter.

By the mid-1900s, such instrument measurement techniques were developed based upon the microscope and airflow principles, followed in the late 1900s by highly sophisticated and expensive laser and image-analysis-based automatic systems. All these proved to be accurate and reliable but generally only suitable for laboratories and testing houses.

The problem of the accurate on-farm measurement of mean fibre diameter of wool remained, which led to the development of a suitable cost-effective instrument-based technique for this purpose.

Opto-mechanical Mikronmeter

Since the time of Thomas Young (1773–1892), several attempts have been made to apply the principle of light diffraction for fibre diameter measurement. The use of the light diffraction from a bundle of fibres to determine fibre diameter was

Dr Anton Botha (CSIR) demonstrating the original Opto-mechanical Mikronmeter.

proposed as far back as 1824, and again about a century later.

In the 1920s and 1930s, some successes were in fact achieved with light-diffraction-based devices for determining animal fibre diameter, particularly wool. Nevertheless, in spite of some promising results, no such device reached the market until the mid-1960s when the first opto-mechanical Mikronmeter was developed. The device could determine the mean fibre diameter of wool based upon the diffraction of white light. It was developed and commercialised by the National Physical Research Laboratory (NPRL) in collaboration with the South African Wool Textile Research Institute (SAWTRI).

The Mikronmeter was simple to handle, robust, battery operated and quick. It simply required inserting a small, randomised clean tuft (bundle) of fibres, preferably from a mid-rib sample, in a sample holder, which was then inserted into the Mikronmeter. The operator then looked into the instrument, very much like a telescope, and adjusted it until he/she could see a clear circular diffraction pattern, the size of which was determined by the diameter of the fibre, and reference ring that coincided with the first dark diffraction minimum. At this point, the fibre diameter in micron was read off directly on a calibrated scale on the side of the instrument.

In 1969, the instrument was demonstrated in Port Elizabeth, Bloemfontein and Pretoria.

Marketing the Mikronmeter commenced around the middle of 1969, and could be ordered directly from SAWTRI in Port Elizabeth at a cost of R49,50, with an additional 14 cents for packaging and handling and 59 cents for postage and insurance. A number of Mikronmeters were sold in South Africa and Australia.

Nevertheless, although the instrument was inexpensive, robust and user friendly, certain operators found it difficult to use, thereby obtaining inaccurate results.

This also emerged from trials conducted by researchers in South Africa and Australia, which led to the discontinuation of the Mikronmeter. Nevertheless, the principle of measurement appeared sound and accurate.

Opto-electronic Mikronmeter

Prof Lawrance Hunter initiated the first attempts at developing an affordable, robust, portable, accurate and reliable electronic version of the Mikronmeter in 1991. At the time, he was a textile scientist at the South African Wool Textile Research Institute (SAWTRI), and head of the Department of Textile Science at the University of Port Elizabeth (UPE). He discussed his ideas with Dr Franz Hengstberger, an opto-electronic expert of the Productiontek Institute of the Council for Scientific and Industrial Research (CSIR), who expressed great interest in such a tool. The development started in 1992 and continued even after Dr Hengstberger was transferred.

The work culminated in 1994 in a laser-based laboratory bench-top instrument system, consisting of a PC, a digital voltmeter, a laser diode source, with focusing lens, pin hole, collimating and imaging lenses, a silicone photodiode array (including a PC board with its required electronic circuits) and power supply.

Although the laboratory instrument produced promising results, lack of funding precluded additional work required to develop and optimise the system and produce a working prototype. Sadly, work ceased at the end of 1994.

The first prototype Opto-electronic Mikronmeter developed and built by Walter Frazer.

During this time, Walter Frazer, an opto-electronic specialist at SAWTRI, also became involved in further research to develop an electronic Mikronmeter with a target price set at between R3 000 and R5 000.

The CSIR and Cape Wools SA jointly provided the funding. After several laser-based concepts, one employing parallel rays from a laser diode, diffracted by a randomly orientated bundle fibres and sensing the irradiance of the diffracted rays at two coplanar points, provided a measure of the mean fibre diameter. The output was a digital LCD display in microns.

Initial results looked promising and the first prototype was produced around 1998. The CSIR then lodged a provisional patent, based upon the concept, in September 2000 with Frazer as the inventor.

Further prototypes were produced around 2000. Nevertheless, more intensive trials indicated that results were not consistent to the required accuracy.

This was ascribed to the use of a linear two-diode array, rather than a circular multiple diode array which affected the accuracy of the instrument. This necessitated further research and development for which additional funding was required.

Various efforts in 2000/2001 to secure the funding proved unsuccessful and the project was discontinued. Around this time, a group of wool farmers approached the National Metrology Laboratory (NML) in Pretoria to develop a Mikronmeter, but because of a lack of funds, nothing transpired.

Opto-electronic FibreLux

Not prepared to give up, in 2003, Prof Hunter founded a consortium of organisations with the high-level expertise required to develop such an instrument. In 2004, the consortium prepared a project proposal for funding and submitted it to the Innovation Fund. The necessary funding for a three-year project was approved in 2006. This enabled further research and development. The consortium consisted of the following members:

- the CSIR National Metrology Laboratory (NML) located in Pretoria
- the CSIR National Fibre, Textile and Clothing Centre (NFTCC), ex-Textek and ex-SAWTRI, located in Summerstrand, Port Elizabeth
- Nelson Mandela Metropolitan University (NMMU), previously the University of Port Elizabeth
- the National Wool Growers' Association (NWGA) of South Africa, located in Port Elizabeth
- Mashihe Dynamics (Pty) Ltd, located in Pretoria
- Mlungiseleli Rural Development Consultancy (MRDC), located in Bhisho
- Measuring Instruments Technology (MIT) (Pty) Ltd, located in Pretoria.

After some research, it was found that a laser-light source was not the best option; a light emitting diode (LED) as a light source proving to be a better option.

After three years of intensive research, a battery-operated, opto-electronic instrument was developed for on-farm use. The system was based upon the diffraction of light, from a parallel fibre bundle easily mounted in a sample holder, the diffraction pattern being detected and measured by an array of sensors and then analysed using sophisticated algorithms and artificial intelligence.

The sensory arrangement was configured to sense the diffraction pattern at at least two wavelength bands. The processor was configured to evaluate interference patterns at the respective wavelength bands and calculate the mean fibre diameter of the bundle of fibres.

Walter Frazer (left) and Prof Lawrance Hunter admiring the recently commercialised FibreLux. The picture was taken shortly before Frazer passed away.

A parallel or random array of fibres are easily mounted on a sample holder which is inserted in a slot in the instrument. The mean fibre diameter is then read and displayed within 20 seconds. The accuracy of the reading is about 0,5 μ for wool ranging in diameter from about 16 to 26 μ. The instrument was given the name FibreLux, which was registered as a trademark in 2010.

After initial trials, involving six prototype FibreLuxes were built and tested. Demonstrations took place during 2010 at the National Maize Producers' Organisation, the NWGO and South African Mohair Growers' Association congresses to determine interest and specific requirements. Without exception, the responses proved very positive.

In 2012, Nekan Trading signed an agreement with consortium members and the TIA to commercialise the FibreLux. The instrument was produced and marketed commercially in 2014 in collaboration with the NWGA as distributor. This, therefore, successfully concluded the journey of 50 years from the Opto-mechanical Mikronmeter to the Opto-electronic FibreLux for on-farm use.

Work is currently carried out to include measure variation (CV) in fibre diameter of a sample, and the diameter of coarser animal fibres, such as mohair.

*** This article was written as a tribute to Walter Frazer who passed away on 3 October 2014 at the age of 84 years.**