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Fundamental Principles of Fibre Fineness Measurement

Part 9

Harmonics

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HARMONICS

Principle

Fourier (1768-1830) showed that any periodic motion could be built by adding sinusoidal harmonic components of waves in proper proportions. This process applies to all oscillating systems, such as electromagnetic waves and sound waves.

The musical notes produced by stringed instruments, are the result of standing waves being established along the strings, either by plucking or bowing the strings. The frequency and the amplitude of these waves, and hence the sound they produce, is determined by the thickness and density of each string, the tension applied and its length.

Likewise, standing waves can be generated in a string by placing the string in the path of an oscillating sound source. If the string is maintained at a constant tension and length, and the frequency of the sound source is varied the string will be observed to vibrate, with a standing waveform observed along the fibre at specific frequencies, depending upon the diameter, density, tension and the length.

$$D_v^2 = \frac{K}{\nu^2} \qquad 1$$

where $D_v =$ the diameter of the string

$K =$ a constant depending on density, tension and length

$\nu =$ the harmonic frequency

Development

Gonsalves (1947) described a method for measuring a diameter of a fibre by using an instrument he called a vibrascope. Dart and Peterson (1949) using a similar instrument showed that by varying the frequency, tension, or length, the diameter of a fibre can be measured providing two of these variables are maintained constant.

Buchanan & Bolin (1952) described a simple vibrascope they had developed for the measurement of fibre diameter of single fibres from individual sheep. They found that the diameter of a vibrating wool fibre could be determined from the following equation.

$$D_v^2 = \frac{T \times 980 \times 10^8}{L^2 \nu^2 \rho \times 3.1416} \qquad 2$$

where $T =$ the applied tension in grams

$L =$ the length of the fibre in cm

$\rho =$ the density of wool

$\nu =$ the frequency of the oscillation.

The authors reported that the method correlated with measurements obtained from cross-sections examined under the microscope and was considerably faster, with forty to fifty fibres being measured in one hour.

This system measures root mean square diameter because the fibre is assumed to be circular. However the system also assumes uniform fibre thickness along the length of the fibre and it is well documented that this is not the case in almost all instances.

Technical Issues

The major limitation of this technology is that it is limited to single fibre measurements, which means that establishing a mean fibre fineness estimate for a commercial consignment would be slow and consequently expensive. The precision of the method has never been documented, which probably is an indication that it is less than the precision of alternative methods, simply because of the sampling difficulties.

Commercial Issues

The Vibrascope has never found a commercial application in wool testing and its use has generally been confined to applications where precision has not been as critical as that normally expected in commercial transactions. Within Australia the technology has been re-examined for possible applications by woolgrowers in assisting them to select animals and class the fleeces during shearing, but the cost and inherent sampling problems very quickly ruled the technology out for this application.

The Vibrascope is still used for the estimation of fineness of synthetic fibres, where variation along and between fibres (cut from the same production batch) is considerably less, and the sampling variation is much reduced.

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