The future of fibre measurement

A better understanding of fibre morphology, both in the lab and online, will offer the industry tremendous operational benefits and financial rewards provided that newly-available measurements are adopted, says Bill Dannelly*

The paper industry is going through a multi-faceted transformation, about digitalisation, workforce trends and switching to a more innovative or sustainable culture, and about building on global networks.

To remain both competitive and profitable, mills must harness their supply chains to optimise their products, processes, organisational set-ups and business models. For many paper producers, these big themes can be addressed by looking more closely at some of the smallest components – the fibres their products are made of.

But, with generally low margins and limited capital budgets, the priority for spending in paper mills is typically on required maintenance, followed by projects that remove bottlenecks to increase productivity and ensure a good return. For innovative projects to attract investment, it is necessary to find opportunities that offer low risk and high potential returns.

It has long been time for the pulp and paper sector to get beyond its traditional mindset by recognising the huge potential that small, but significant, optimisation projects can make. One such example is the adoption of advanced fibre measurements which, when combined with artificial intelligence (AI) techniques, can provide far greater control of end-product quality, generating high value with the minimum of, if any, risk. It is often the low-hanging fruit – the everyday tools such as fibre measurement – we take for granted that can yield the greatest returns. The sooner the industry starts recognising the potential value that can be mined from their processes with easily accessible tools, the better.

Fibre lines will be operationally more efficient with the adoption of more precise analysis at a nano scale

Employing new advancements in fibre measurements can benefit operations – from new product development to better quality products – and help in the drive for better efficiency and higher profitability.

Emergence of micro-cellulose and nano-cellulose products to drive sustainability

A recent trend in cellulosic pulps is the development and use of micro-cellulose and nano-cellulose formats to produce new, improved and more sustainable paper products. These include; micro-fibrillated cellulose (MFC) produced by manufacturers such as Borregaard, Norske Skog and FibreLean, cellulose nanofibre (CNF) produced by Nippon Paper and others, and cellulose fibrils (CF) produced by Kruger.

All of these nanofibre products are very small with a high specific surface area, and are often used as strengthening agents because they increase the amount of hydrogen bonding in a sheet to improve its tensile strength. Because the nanofibres are cellulose-based, they can be used to replace other bonding agents such as polymers derived from petroleum products, and thus offer a more sustainable alternative.

One challenge with nanofibres, however, is that conventional fibre analysers are not designed for detecting and characterising such small fibres, although an analytical method that can detect and characterise small particles in a pulp suspension was developed and patented in the 1980s. Since 2016, a commercial laboratory instrument using this concept has been available as an add-on module for ABB's L&W Fibre Tester, the L&W Crill.

Crill particles are typically 100 times smaller than a pulp fibre, but are important indicators of fibre bonding and strength properties. Unlike the detection of conventional pulp fibres, which depends on image analysis with visible light, this technique compares the intensity of two wavelengths of light transmitted through a pulp suspension: ultraviolet light (365 nm) and infrared light (850 nm). The crill content is presented as the crill quota, or the ratio of the UV/IR transmission losses.

The crill measurement technique was originally developed to monitor the process of refining, where crill particles are removed from the fibre wall. A linear relationship was discovered between the crill quota and the refining energy, both in high-consistency mechanical pulp refining and in low-consistency chemical pulp refining. As more facilities for the manufacture of nano-cellulose products are built in the future, crill measurement will become an invaluable tool for quality control and for controlling the refining energy, given that the manufacture of these products can be energy intensive.

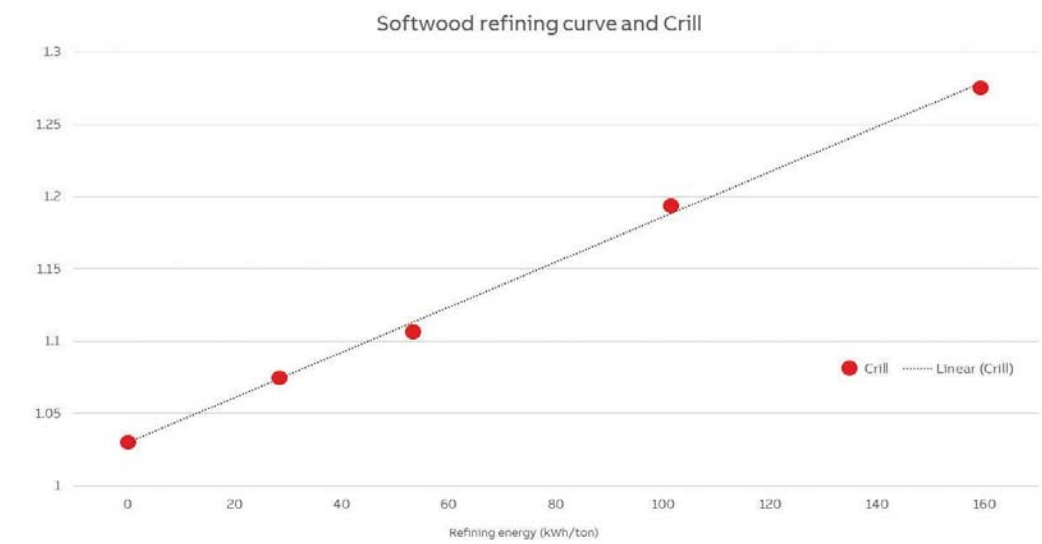

Figure 1: The relationship between crill quota and refining energy

Figure 2: Online measurement, such as that provided by ABB's L&W Freeness Online, provides frequent, automated and accurate measurement to better optimise refining

Pulp and paper producers looking at more sustainable production would be well-advised to evaluate if their fibre morphology measurements are sufficiently advanced and well suited for the detection and characterisation of nano-cellulose fibres.

Online testing for better quality control

Paper, board and tissue manufacturers use pulp from a variety of sources, including long-fibred softwood pulps for strength, short-fibred pulps such as eucalyptus for opacity, bulk and softness, and recovered fibres from a variety of species and geographic areas. Those that control their own forestry operations and have integrated pulping operations can rely on a fairly consistent raw material, but need to measure the effect of pulping parameters on fibre quality. In the case of non-integrated operations, understanding the characteristics of the incoming fibres and having the ability to adjust the recipe is imperative to be able to meet customer product specifications. ▸

Figure 3: Kraft fibres treated to induce curl (source, FPInnovations)

For many decades, manufacturers have relied on lab tests such as freeness, shive content, size classification and various strength tests performed on handsheets to provide information on the properties of the fibres they are using. While informative, the data from these lab tests are neither timely enough to make process adjustments nor frequent enough to characterise the variability of fibre properties.

Now, with the advancement of online testing, automated sampling equipment and lab testing -- combined with data historians, sophisticated control systems and emerging AI techniques – mill operators can benefit from far more detailed, timely information on fibre quality. These powerful online tools allow quality improvement and variability reduction while lowering manufacturing costs.

Big data and artificial intelligence

Over the last 20 years, fibre measurement in pulping and paper making has benefitted from huge advances in computer power, low-cost data storage and new analytical techniques. Most mills now have data historians that can store thousands of measurements from across the facility at time intervals of seconds to hours, for up to several years, and this data can be used to build powerful predictive models.

Modern fibre morphology analysers can directly analyse thousands of fibre suspensions, reporting on the deviation of properties such as length, width, wall thickness, shape factor, kink index, fines content, shive content and coarseness. While such measurements help develop better insights into the characteristics of the pulp furnish, and cost little to perform, their real value only emerges when combined with other online and offline mill data to develop tools for better quality control.

Adoption of soft sensor and advanced control strategies

In the future, the adoption of soft sensor and advanced control strategies will become more important for producers to enable tighter process control, reduce variability, avoid rejection of off-spec product and achieve a greater return on investment.

Soft sensors, or calculated online measurements, offer huge potential value in their use to control the refining process. A soft sensor specific to a mill's process can be built using a combination of lab experiments and machine learning. New advanced process control techniques can then be applied, incorporating a predicted paper strength variable to optimise the refining process.

Today, many mills are adopting freeness control given that it is now possible to have frequent, automated and accurate measurement of freeness from automated measurement systems coupled with these online soft sensors. Freeness, however, is a blunt instrument. It is often used as an indicator of the bonding potential of the pulp, but it is actually a measurement of the drainability of the pulp, which can be important if it limits the speed of the paper or board machine. A lower freeness, however, can be produced in several ways: as a result of refining, from a higher concentration of undesirable low-surface-area ray cells with poor bonding potential, or from shorter fibres. A more practical characterisation of pulp uses other measurements of fibre morphology properties, such as the surface area of the pulp calculated from the cumulative length and width of the fibres, which is more directly correlated with the strength of the final product.

As a result, closed-loop control is possible by using the predicted strength properties and fibre morphology parameters to manipulate and accurately control pulp refining and furnish blending operations. Stabilisation and continuous control of strength properties can lead to reduced strength variation and improved machine runnability, quality and throughput.

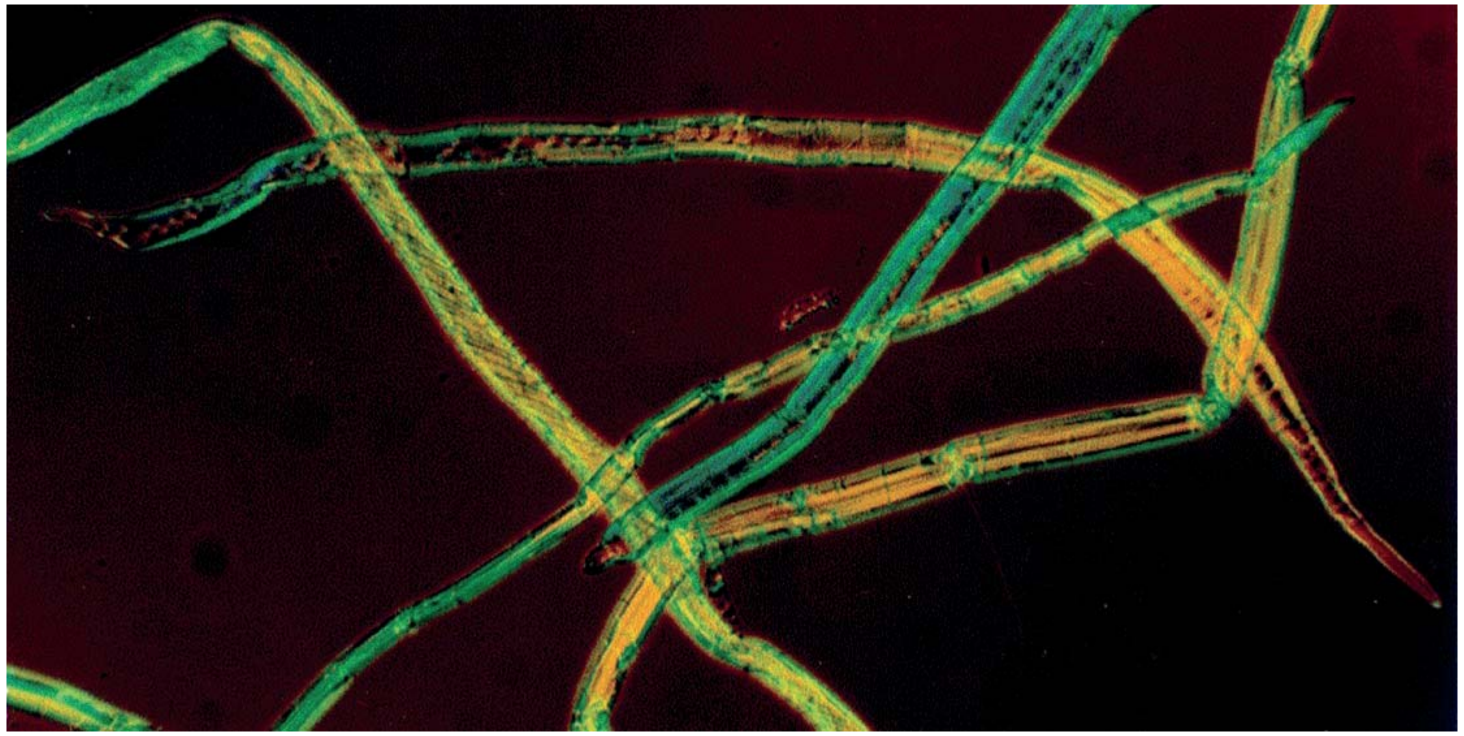

Figure 4: Bleached softwood fibres at different magnifications. At 100 times magnification, the deformations such as local kinks and softer bends can be seen

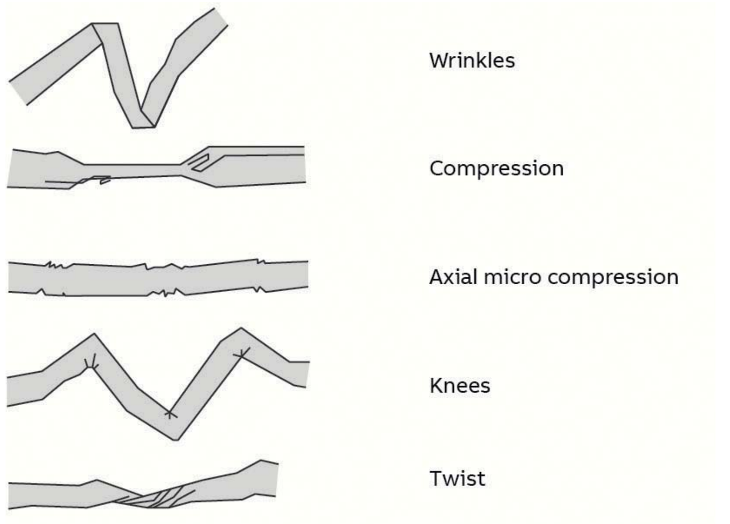

Figure 5: Various types of fiber deformation

Greater focus on understanding impact of deformed fibres as stretchable paper set to replace plastic

The stretchability of paper is already important for certain speciality paper products, including sack paper used for cement, chemicals and flour, where flexibility of the paper without tearing is required. Due to increased demand for sustainable products that are bio-sourced, recyclable and compostable, many new paper-based products are being developed to substitute for plastic packaging, with the challenge often being how to maintain the equivalent stretchability of plastic.

One way to overcome this is to produce a network of deformed or curled fibres, which can be achieved through either chemical or mechanical processes. Deformed fibres create a more elastic paper when the paper is freely dried. To ensure the pulp has the appropriate properties to produce the desired stretch, fibre morphology analysers can be used to measure a number of properties, including the shape factor and kink index.

Shape factor is an important pulp quality measurement used to determine the straightness of fibres. While a high shape factor correlates well with tensile strength and stiffness, a lower shape factor indicates there are deformations present that enable the fibres to stretch.

The kink index is used to identify local deformations or 'knees' in the fibres. To calculate the kink index, changes in the direction of the main axis of the fibres within a limited distance of the fibre are counted when the angle is 20 degrees or more. Kink measurement correlates well with shape factor in most cases, since local deformations are included in the shape factor.

By using one or both of these measurements and correlating them with the measured stretch of handsheets or the final product, manufacturers can optimise their chemical or mechanical curl-setting treatments to achieve the desired stretchability, as shown in Figure 3. This will undoubtedly lead to new extensible paper products that will become important as sustainable replacements for plastic packaging.

Conclusion

Techniques for fibre measurement in the lab have existed as long as pulping technologies, but now the industry is at an exciting point where more advanced technology is ready to help make product, process and quality optimisation not just possible but easily attainable.

The emergence of more rapid and precise measurements, as well as new ways to characterise fibre morphology, both in the lab and online, offers the industry tremendous benefits. Used together with big-data-backed techniques and advanced control strategies, paper manufacturers will be able to improve quality and reduce variability while lowering manufacturing costs. Adopting these technologies to develop the paper products of the future is a great opportunity for investment considering the unique low risk/high reward scenario they offer.

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Bill Dannelly, global product line manager for pulp and paper at technology group ABB: "the industry is at an exciting point"