Using Online Tools to Predict Finished Products Physicals in Pulp Slurries

by David Zerr

VP, R&D at Pulmac Systems International

Abstract – Pulp mill and paper machine personnel are challenged to keep an eye on variations of incoming pulp and whitewater returns. In most instances, paper machine breaks are often the first and sometimes only indication that the pulp slurry hitting their paper machine has changed. While there can be several likely causes for these variations, there are few online systems that can provide an early warning system to operators or management of upcoming issues, let alone control the process to prevent these upsets.

Keywords: Edge technology, advanced APCs, predictive analytics

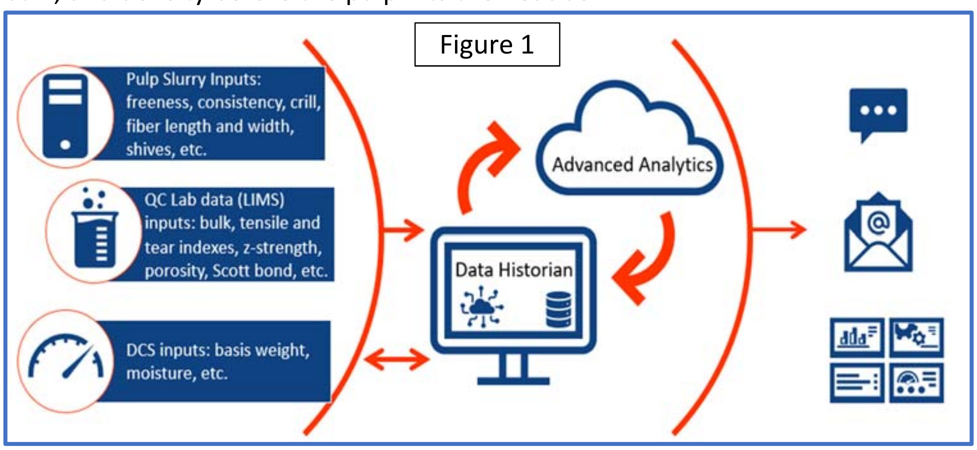
Challenge: This paper will provide details on an online, edge, and cloud solution that can warn of upcoming issues and take corrective action to prevent them. While many of the properties are thought to be only available from a QC lab after the parent reel has turned up, these are now available online with a 15-minute frequency. Once calibrated to the mill's QC lab data, these online tests include, depending on the grade being run, fiber length and width distribution, development of crill before and after refining, freeness, fiber wall thickness, burst, tensile, STFI, stretch, TEA, brightness, opacity, water retention and stiffness. Over 300 process variables can be measured and controlled.

This technology also allows recent developments of online crill, fiber wall thickness, coarseness, and predictive analytics to pinpoint issues long before upsets occur.

Key Discussion Points: Today's paper will focus on edge technology and cloud advanced analytics solutions that predict key process variables before the pulp slurry is sent to the paper machine. Highlights of this newly developed instrument in the pulp slurry, which are subsequently mapped through QC lab measurements, including tags on additives such as cationic starches for linerboard, to predict properties critical to the runnability of the paper machine.

Further, this technology can be tied to refiner automation controls to maintain properties such as freeness, strength properties, etc. Without this monitoring and controlling, most mills see on average three PM breaks per day. The measurements focus on properties such as freeness, tensile, crill, tear, burst, Scott Bond, z-strength, bulk, and density before the pulp hits the headbox.

Figure 1



Technology behind this measurement system[1]: Pulp samples are collected, hand samples run, then are compared to corresponding PM lab data during corresponding times. Variations in pulp quality data are modeled from fiber variations and other properties. This pulp slurry modeling to QC lab data can then be used in real-time to calculate end-product physicals long before the laboratory results are available. This allows production managers, quality managers, and process operators to see current quality levels and their variations in real-time. Figure 1 shows this process in action using cloud based advanced analytics.

Graphs show the correlation between QC lab and calculated values: Figures 2a, 2b, 2c and 2d show the correlation between samples measured in the QC lab and calculated values from the edge technology system. Note: Data are simulated.

Figure 2a – Predicted **freeness** values plotted against QC lab's values.

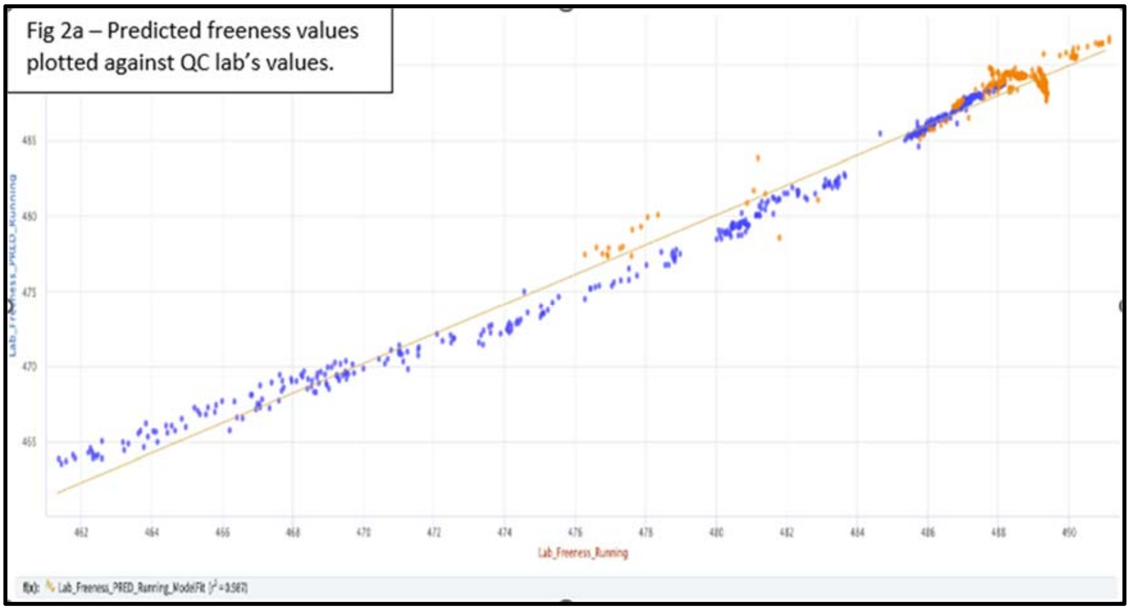


Figure 2b – Predicted **tensile** values plotted against QC lab's values.

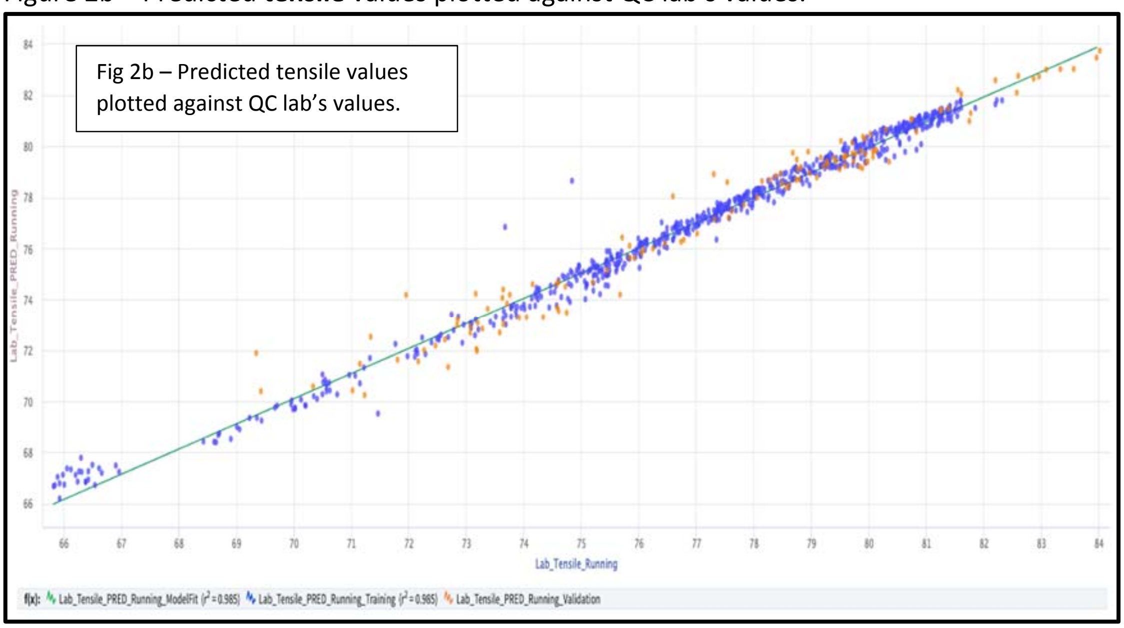


Figure 2c – Predicted **tear** values plotted against QC lab's values.

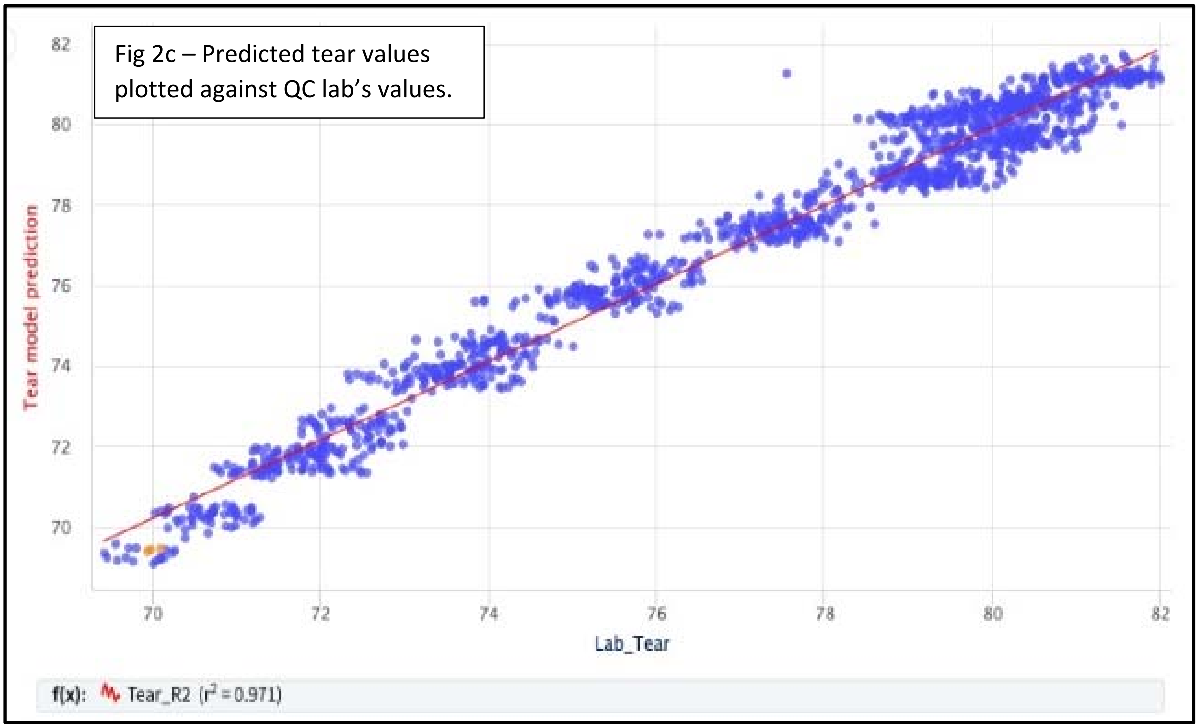
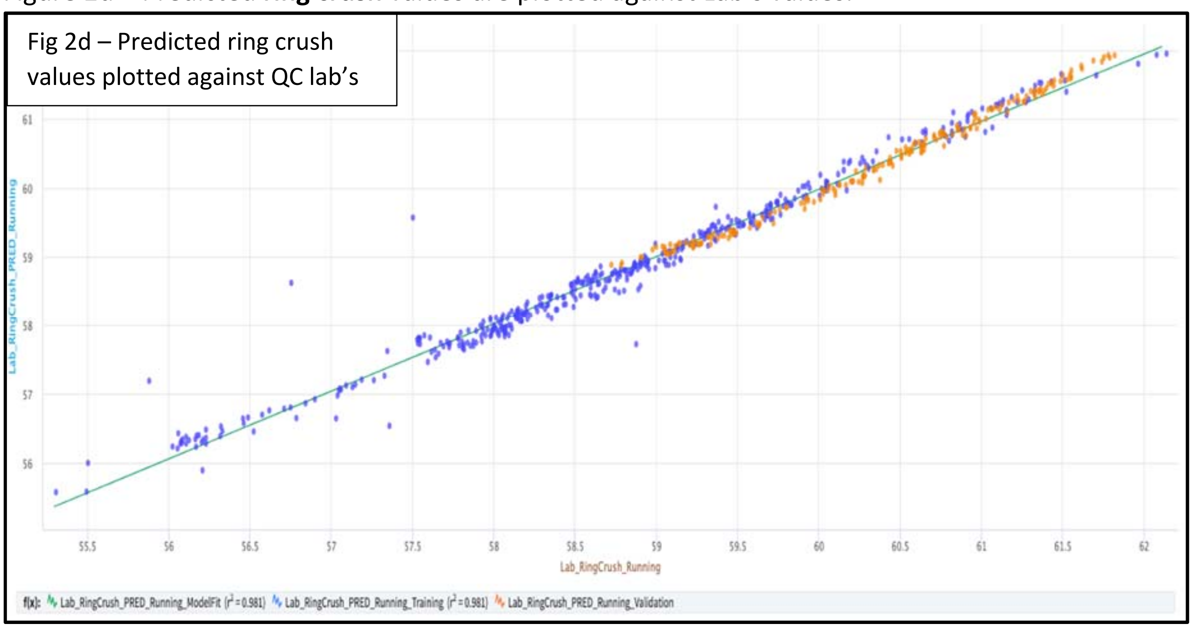


Figure 2d – Predicted **ring crush** values are plotted against Lab's values.



What's the typical R^2 value using this technology? Typical R^2 values are in the 90% to 95% confidence range. To achieve this level of confidence though, multiple passes and regression analysis are required to achieve.

Benefits of this technology - If you think of this as an advanced process control loop, it helps underscore the technology and purpose. Once the initial mapping by grade occurs, the system automatically reads the data from the sensors, called modules, and then sends that to the data historian where it communicates with the cloud based analytics tools to predict finished product physicals. Depending on the type of sample being analyzed, this takes anywhere from 5 to 15 minutes to determine physicals and provide results back to the DCS, HMI or mobile devices. This also performs a validation check to ensure that the data is within the preset control limits and ensure that the pulp properties are within target. Variables measured are grade dependent. Assuming this is for a linerboard grade, typical variables include freeness, STFI, Mullen, porosity (Gurley), bulk, fiber dimensions and

Scott bond. Basis weight and moisture would come from the PM's online scanner. Non-traditional variables that are now being used include crill, coarseness and fiber wall thickness, allowing a greater understanding of variables in both incoming wood supplies as well as monitoring of the refiners. Process can be run closer to targeted specifications and when they deviate from preset limits, it can be configured to either auto-correct, alarm or both. This early predictive analysis can warn of variations in freeness, which leads to PM breaks, to providing a minimum of 30-minutes before one would typically receive QC data from the parent reel.

Explanation of Crill – Crill is not well known, so a brief explanation is in order. Crill is a by-product of refining and contributes greatly to overall sheet strength. As noted on Figure 3, crill can be identified as the hairy little fibers within the pulp slurry. They are either bound or free of fiber. Crill fibrils are roughly a hundred times smaller than the fibers themselves yet play an oversized role in providing fiber-to-fiber bonding. Crill fibrils act like Velcro to bond fibers together. This is true for both 'macro' and 'micro' fibers as found in micro fibrillated fibers (MFC).

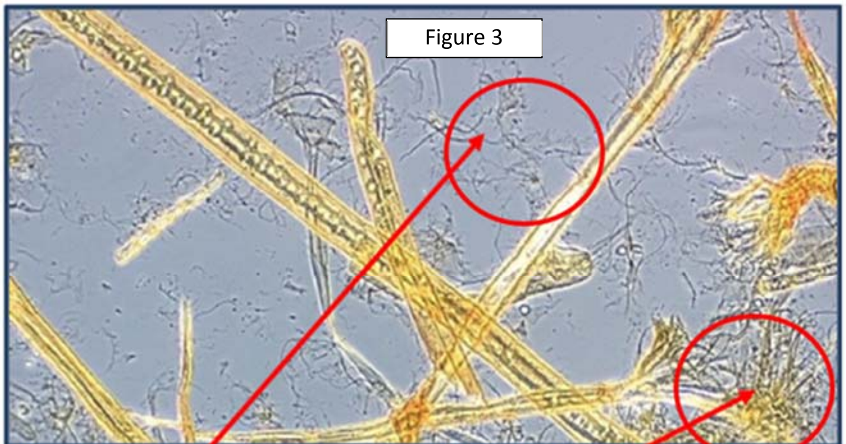
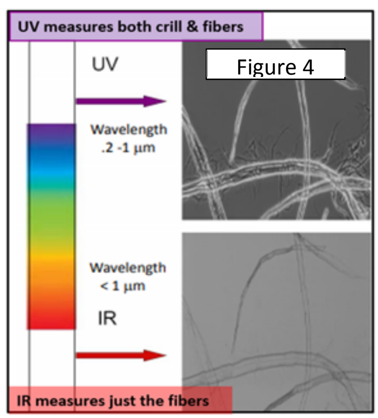


Figure 3 Crill in Pulp Solution. Crill is defined as "bound" or attached to a fiber or "free" of a fiber. The key benefit of analyzing crill is to monitor and control the amount of refining and dewatering in pulp.

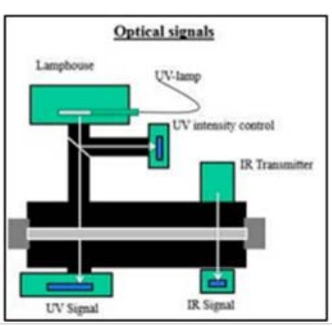
Historically, freeness and fiber length were the primary control targets for refining. With *Crill, it is the single variable having the strongest connection to pulp strength properties.* The more crill present on and around the fibers, the stronger the paper or board will be. Once crill is understood, pulps can then be refined to a crill level vs. freeness or fiber length. This in turn allows lowering energy consumption on the refiners.[2] Of course, freeness levels must be actively controlled due to the challenge of crill impeding drainage on a paper machine.

How Is crill measured? Crill measurements are made on refined pulps before and after washing. The more crill is developed, the better binding ability they have, which in turn results in a stronger paper and board. Attached (or bound) crill, unattached (or free) crill and fiber areas can be quickly sampled using ultraviolet (UV) wavelengths. As noted in Figure 4, to measure fibers only, infrared (IR) is used to calculate the fiber area. An average of 150 measurements are taken online. Crill is about 0.25 µm wide, making it very difficult to measure based on image analysis, especially in the visible range.[2] From these measurements, a critically important value is calculated: the crill to fiber ratio (CFR). The higher this ratio, the greater strength properties are developed. *Research studies at Innventia, part of RISE Research Institutes of Sweden, have shown that crill is the single variable having the strongest connection to paper or board strength. The more crill there are on and around the fibres, the stronger the paper or board will be. By measuring the amount of crill it is possible to pre-calculate the strength of paper and board and hence define the refining needed to optimise the amount of crill. The crill module can measure total, free and attached crill on the fibre online. The technology is also used on MFC/nano applications.*[2]



Crill measurements are based on comparing two optically measured surface areas (light absorption).

- ❖ The total area of fibers and crill is measured with UV.
- ❖ The total area of the fibers only, is measured with IR.



Improving control of refining is an essential outcome: In Figure 5, we see the blueprint on how data is collected from the sensors (e.g., separate modules for each variable) to be measured and controlled. In this illustration,

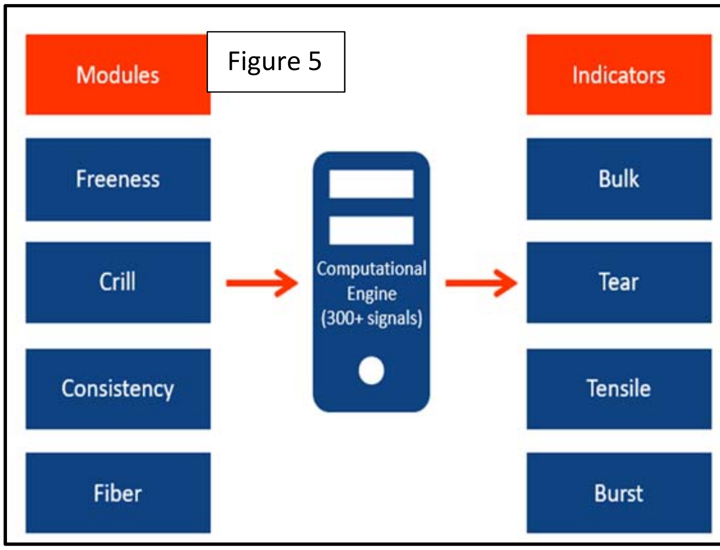


Figure 5

Benefits of this system include:

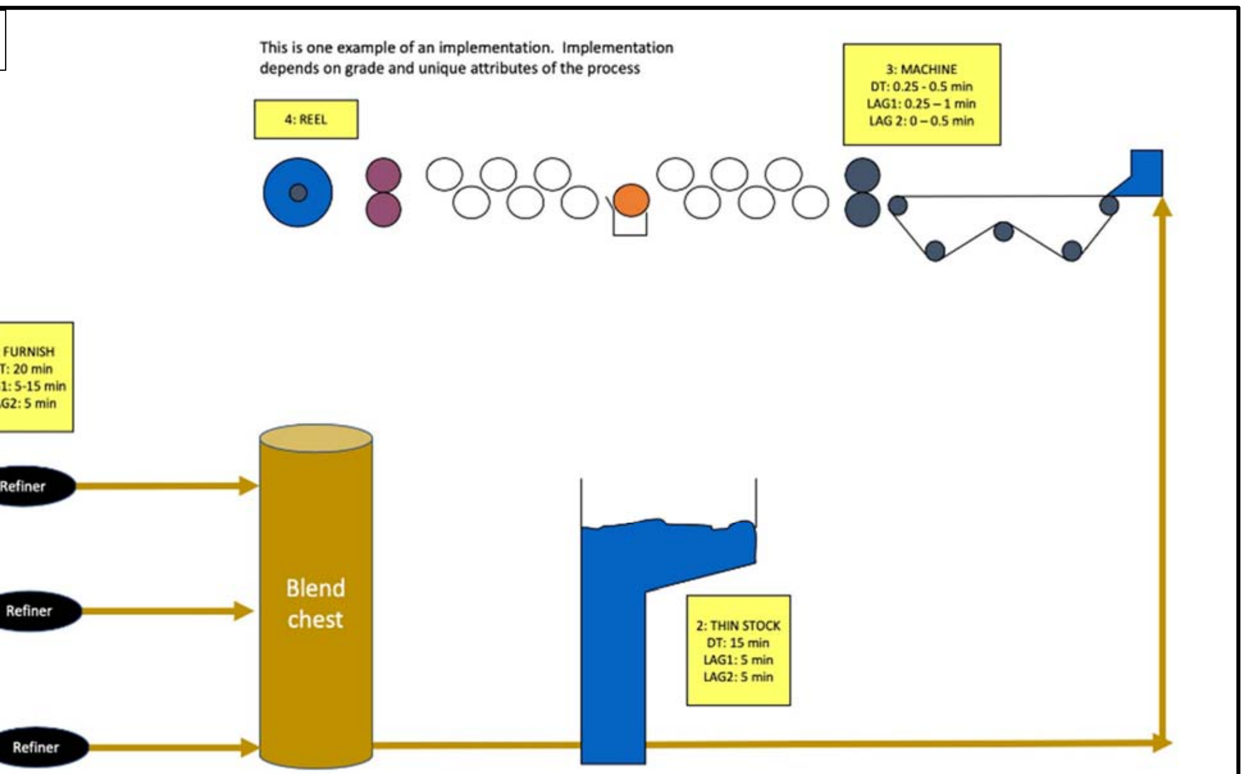
- Monitors all analyzer modules
- Real-time performance check of modules
- Early indication of service needs
- Easy to generate summary reports
- Analysis available every 5 – 15 minutes

Predicted Data

- As crill and fiber data are measured from the UV and IR scans, this data is then fed into software.
- This software predicts finished product physicals.
- Output such as bulk, tear, tensile, crill, burst, Scott Bond plus many other variables can be displayed such as fiber length, width, curl, fines, freeness+.
- Output can be sent to the DCS, HMI Screens and even to an iPhone or Android phone.

sensor data is collected on freeness, crill, consistency and fibers. This is then sent to the cloud. With past data mapped to the QC data, this allows calculated value for each variable to be determined. This data is then forwarded for each variable to the DCS, HMI screens and to iPhones / Android phones. Updates occur roughly every 15 minutes. Figure 6 depicts how this would be implemented. Desired sampler modules (e.g., freeness, crill, etc.) would be added before and after each refiner, after the blend chest, and thin stock, which are sent to the data historian and then to the cloud for advanced analytics to compute the predicted finished product physicals as shown in Figure 5.

Figure 6



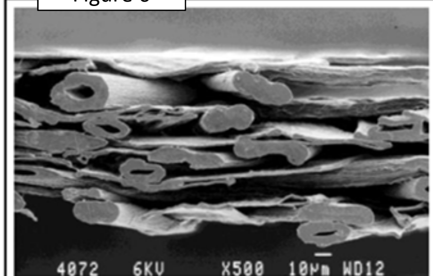
Review of Fiber Properties That Can Be Measured Online – Once mapped, freeness, bulk, tensile, STFI, burst, Mullen, fiber length, width, curl (with full distribution of all fiber size categories), brightness, dirt and shives, fiber wall thickness, fiber coarseness, crill and Kappa number can be measured, displayed, and stored in the historian.

Fiber Wall Thickness Module

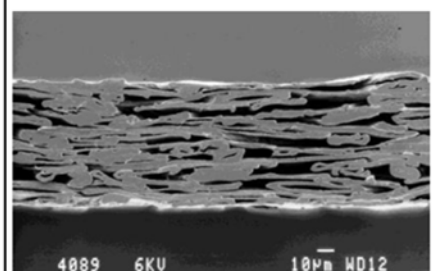
Review of Fiber Wall Thickness and Coarseness Properties – While some of these new additions may seem academic, *fiber wall thickness and coarseness* both add value. Data from fiber wall thickness module, shown to the right, when combined with fiber length data enable mills to show effects on end-use properties. These include refined pulp tensile strength properties that are typically costly and time-consuming to measure and are key elements of pulp quality for paper and board mills.

Another is *fiber coarseness*[4], which can now be measured online. In Figures 6 & 7, high and low coarseness fibers are illustrated as a side view (Figure 6) and an aerial view (Figure 7.). Key attributes on fiber coarseness provide a highly indicative measure of fiber flexibility and is the inverse of density. *High coarseness (HW pulps) pulps* are related to fiber with thicker fiber walls and have improved bulk, porosity, absorbency, drainage but low fiber bonding strength and potentially increased picking and linting. *Low coarseness fibers (SW pulps)* will have improved fiber-bonding, increased wet web strength, improved opacity, and improved formation, better coating holdout, higher overall strength, and increased water retention value.

Figure 6

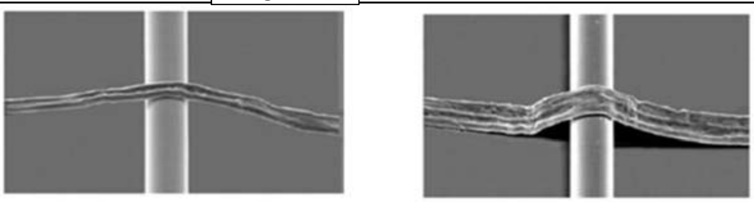


An example of High Coarseness (HW) Pulp



An example of Low Coarseness (SW) Pulp

Figure 7



High Coarseness Fiber Low Coarseness Fiber

Photos from Eucalyptus Online Book and Newsletter, ABTCP

Importance of Fiber Coarseness[5] Based on FP Innovation's Dr. H.F. Jang's groundbreaking work on measuring fiber wall thickness, he also made discoveries related to fiber length, fiber coarseness as well as fiber wall thickness.

Traditionally, fiber length has always been thought of as the leading indicator of strength. Surprisingly, it isn't. When several softwood market pulps were tested, conclusions drawn are:

- Fiber length only shows a 20% correlation.
- Fiber wall thickness shows 40% correlation.
- Fiber coarseness shows a 58% correlation.

Restated, fiber coarseness has the strongest correlation to strength with almost three times a better predictor of strength than fiber length.

Figure 8

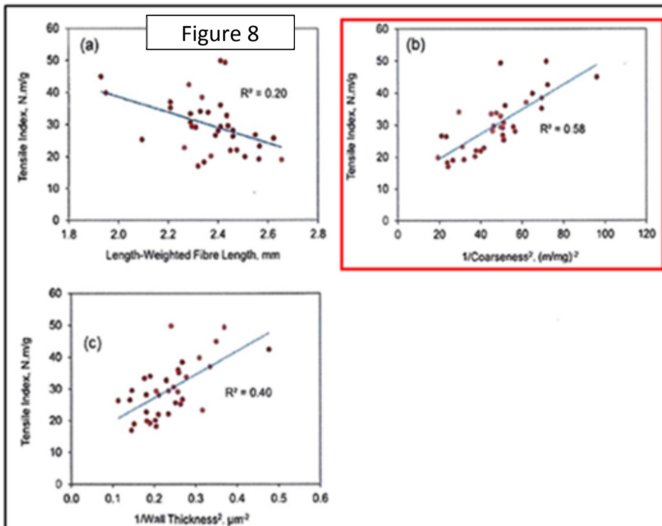


Fig. 8 (a) Tensile Index versus fibre length, (b) Tensile index versus 1/coarseness², and Tensile index versus 1/wall thickness².

This system provides tighter control of the process. Once the process is understood, tightening of process limits is possible. Further, this provides confidence that grade data and specs are met, permitting dropping basis weights by grade.

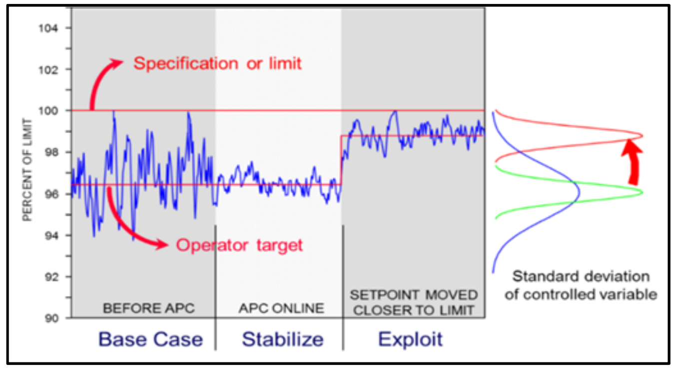
Example of these dynamics at play at the first mill in Sweden to implement this[6]:

• Monitoring of all modules added to the system.
• Real-time performance check on the modules

• Early indication of service needs.
• Check-up after service.
• Easy to generate summary reports.

Valuable product physicals[6] can now be accurately predicted using crill, coarseness and freeness data after refining in the pulp slurry state. If a customer wants a certain combination of bulk and strength, this can be dealt with within this process. Recognizing that most producing pulp mills do not have refiners in their mills, studies can be developed to optimize refiner settings, plate designs, and furnish to optimize the process. This contributes to stable pulp quality, quicker grade changes and reduces lab testing.

In Summary - Utilization of this relatively new edge technology can detect key variables within 5-to-15-minute intervals. These avenues include tightening of targets is high on the list. With less process variation, fewer chemicals are needed; switching to less expensive fibers is possible; or lowering basis weights and achieving faster grade changes.



Appendix

References:

1. Advanced Analytics for Process Manufacturing Data utilizing Seeq - Describes product details on predictive modeling using Seeq advanced analytics. https://www.seeq.com/; https://www.seeq.com/product/seeq-data-lab
2. Sundvall, Öjvind - Crill Measurement – Data from cut sheet of PulpEye's crill module https://www.pulpeye.com/products/pulpeye/crilleye/.
3. Yokoyama, Katsuhiko *Fiber Wall Thickness* Jan 2017 **Technology of Pulp Analyzer System with Fiber Wall Thickness Measurements** - *Efficient method for raw material control to make sure that the mix of e.g., sawmill chips, roundwood from thinnings, different species etc. is done so that a consistent pulp quality is maintained.*
4. Sharp, Stuart **Fiber Coarseness** –*Fisher International A Technical Look at Pulp & Paper Fiber Aug 25, 2020.*
5. Jang, HF Journal of Science & Technology for Forest Products and Processes, Vol. 6, No. 6, *Circularly polarized light method and device for determining wall thickness and orientations of fibrils of cellulosic fibres*, *https://patentimages.storage.googleapis.com/51/fc/c6/ba4e6864aae23f/EP1706725B1.pdf*
6. Williamson, Mark - Pulp & Paper International July 2014 First Installation of crill at Waggeryd Cell in Sweden - https://www.pulpeye.com/wp-content/uploads/2014/08/CrillEye_PPI_July-2014_copy.pdf; http://www.ipwonline.de/Home/News/5361 and http://www.p3-news.com/SubscriptionEn/Article/eaa281bf6c7f55740456ea5668724ede1a1893fa
7. Teucke, Sabine and Meltzer, Frank - Constant Pulp Quality and Refining Know-How -Using Online Fibre Measurement and the Mercer Fibre Centre - Presented at PACWEST 2018 by Sabine Teucke and Frank Meltzer, Mercer Pulp, Germany