Effective Management of Pulp Strength : The Zero-Span Approach

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Introduction:

In the last decade, a technical language has evolved[1][2][3] which can reliably interconnect all production stages in the manufacture of pulp and paper. Performance and process efficiencies can be directly monitored and effectively controlled from pulping, to bleaching, to stock preparation, on up to the performance of paper at the reel and in converting and printing plants. The same language applies to research activities as well, forging a more direct link between the pure science of papermaking and its more practical applications.[4] This language is based on the Zero-Span measurement of average fiber strength (FS), supported by measurements of average fiber length (L) and average bonding propensity (B). By incorporating Zero-Span measurement, mills are starting to apply this technical language to control process performance and to determine pulp lot quality. By tracing the FS number through all stages of production a statistically significant map of standard quality together with normal variation can be plotted for the entire operation. This flexible mapping capability can be exploited to optimize process efficiencies, to accurately and precisely define pulp lot quality, and to optimize pulp blends in the furnish. In the start-up of a new fiberline, a Zero-Span testing program can be especially valuable to work through all the noise in generating the reliable data correlations necessary for implementing on-line process control systems.

The Limitations of Viscosity and Beater Curves:

Conventional laboratory testing has served the pulp and paper industry well over the years. However the limitations that are associated with viscosity measurements and beater curves can now be redressed through Zero-Span testing.[5] First, let's look at the shortcomings of the traditional methods.

a) Viscosity Test

The papermaking quality of a pulp in the pulp mill has been associated with the numbers produced by the viscosity test. Viscosity has indeed proved useful because it does

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[1] Annergren, G. "Fundamentals of Pulp Quality and Paper Properties," Pulping Conference Proceedings, 1999

[2] Balint, L., "At What Cost Quality? Case Studies of Measurements that Facilitate Optimization of Cost and Quality, Pulping/Process & Product Conference Proceedings," TAPPI Press, 2000

[3] Cowan, W.F., "Testing Pulp Quality -an alternative to conventional laboratory evaluation," TAPPI Journal, Vol 77, No 10, 1994

[4] See, for example, Gibson, A., and Wajer, M.," Magnesium Hydroxide: The Use of Magnesium Hydroxide as An Alkali and Cellulose Protector in Chemical Pulp Bleaching" Pulp & Paper Scientific, November 2003

[5] Cowan, W.F. "Understanding Handsheet Tensile and Tear in Terms of Pulmac Fiber Quality Numbers," Pulmac Study, 1994

measure one aspect of fiber strength – the aspect associated with average cellulose molecular chain length. However, it is an extremely restrictive association. A pulp fiber is a complex arrangement of cellulose molecules. Its strength will be determined by not only by cellulose molecular chain length but also by the manner in which these molecules are integrated. While the viscosity test is a sensitive measure of the average length of the cellulose molecules present in the fiber, it is insensitive to the important changes in fiber structure which distinguish different wood species, and the fiber degradation which unavoidably accompanies the pulping, bleaching and refining processes.

The FS number will be affected by everything that affects the load bearing capability of the fiber. It will thus be sensitive to the combined effect of changes both in molecular length ***and*** structural arrangement. The important contribution of the polymer chain length of the cellulose molecule to the strength of the fiber may indeed be indicated by viscosity measurement. But overall fiber strength will be much more completely determined by the FS number.

b) Beater Curves:

The handsheet tensile/burst/tear response to standard laboratory beating is a common label used to characterize the quality of pulp. Maintaining these numbers within a certain envelope used to be generally interpreted as an adequate characterization of pulp uniformity. While these results are certainly a necessary attribute of pulp uniformity, they are not nearly sufficient for the purpose. [6] Due to the time delay in preparing beater curves, this insufficiency becomes increasingly apparent as rate of production increases. The FS number can effectively close the circle on this important quality goal. The fiber degradation that necessarily accompanies commercial pulping and bleaching processes will be reflected in a significant drop in an FS number. On a three shift basis, a single Zero-Span installation can determine the FS number of over 100 pulp samples drawn per 24 hour period. This capability can characterize pulp produced every quarter hour which is as close to a real time basis as is practically possible with any off-line procedure.

The More Complete Zero-Span Picture

The case of a particular pulp mill we studied provides an excellent illustration of the normal trends found in all pulp mills. A decline in viscosity coincided with the decline in the FS number at the brown stock washer and through the bleach plant. However, the viscosity - FS number relationship was not found to hold between the unbleached and bleached pulps. A significant decline in viscosity between unbleached and bleached pulps was not reflected by a similar decline in the FS number. Important structural changes must have offset the decline in polymer chain length in order to account for the substantial displacement noted. A later drop in the FS number which followed drying was not matched at all by any corresponding change in viscosity. So, in this instance, the change in the FS Number must have indicated structural changes brought about by drying.

It is also useful to trace the L number. Typically, it tends to decline from brown stock washer through bleaching. The L number is sensitive to both geometric length and fiber curl. It is actually curl, not geometric length, which changes across the bleach plant. As lignin is dissolved fiber becomes increasingly curled and kinked. This tendency is further reinforced by the fiber collapse in the pulp dryer that allows internal hydrogen bonding to increase the propensity towards kinking and curling.

Kajaani - L number plots were derived in the same manner as were the FS-viscosity data points. The Kajaani measurement is also sensitive to structural changes. However, since

[6] Cowan, W.F. "Comparing Wet Zero Span Tensile Testing with Conventional Laboratory Pulp Evaluation," Process& & Product Quality Conference Proceedings, 1994

the nature of the test tends to straighten out fibers in order to present them optically, the declining optical length must have been due to a greater frequency of fibers being forced into a stapled configuration by the constraints of the flow through the capillary tube. In this sense the changes in the Kajaani number reflect a change in fiber flexibility rather than any meaningful change in length. Users of on-line optical systems for measuring fiber length should take note.

Changes in the bonding potential of fiber through the bleach plant were also observed in our case study. There is a noticeable tendency in the pulp mill for bonding potential (B) to be improved by conditions which also produce a decline in the FS number. Lower FS fibers tend to be more flexible (softer) and thus have a higher bonding potential. However, the structural change introduced by drying caused a decline in both the FS number and the bonding potential.

So with the Pulmac Zero-Span Solution a much more complete and timely picture of what is happening in and across all the pulping stages is possible. A more complete picture combines increased sensitivity to process variability with the understanding that is necessary for a more effective modulation of feedback control systems and for a more accurate identification of root causes of process upsets together with their opportune corrections. Pulp quality indicators can also be plotted with greater frequency, allowing much greater precision in characterizing pulp lot uniformity.

A General approach for introducing the Zero-Span Solution[7]:

Focus - FS Number:

A pulp mill has (or should have) three overriding production requirements. One, it must reduce pulp quality variability to a minimum. This is quite a challenge when producing hundreds of tonnes of pulp per day. Two, it must optimize its production so that its pulp will be as economical as it is uniform in quality. This also presents a significant challenge, given the infinite sources of variability in pulp production. Three, since perfect uniformity of quality is impractical, not to say impossible, a pulp mill must have the means to differentiate pulp lots with sufficient precision in order to optimize furnish blends for the paper side or to match lots of different quality characteristics with customers or usages requiring corresponding quality specifications.

The fiber parameter which best characterizes the papermaking quality of pulp leaving the pulping/bleaching process is the FS number. Pulps with FS numbers more than 4% below normal will begin to cause problems on the papermachine and by the time the FS number falls to 10% below normal, papermaking problems of one kind or another will crop up 70%-90% of the time. A Zero-Span program will characterize all pulp production on a routine basis in terms of its FS number. These numbers may then be used not only to provide feedback information as a means to reduce variability and to optimize pulp production, but also to ensure that all clients will receive pulp compliant with stipulated quality standards. Zeroing in on the FS number during start-up of a new fibreline can also help normalize operations in a speedy timeframe while building, from day one, the baseline fiber quality numbers that will likely prove helpful in detecting, isolating, and correcting process upsets.

Define Normal and Problem Variability:

Once a Zero-Span testing capability is installed and operational, routine shift testing should begin immediately. The resulting data base will enable quick determination of the average FS number and the extent of its normal variation across key production stages. This data base is organized into pulp strength histograms of pulp production versus FS number. The variability in the FS number picked up by the pulp strength histogram will be caused by the interaction of process variables such as chemical concentrations, temperature, reaction time, and refiner

[7] For example, refer to the "Trial Mill Strength Profile Study" conducted by Pulmac in 2003.

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condition, with variations in wood quality such as chip size and uniformity, moisture content, and species mix.

Pulp mills typically have reasonable control over process input variables, and generally know when process upsets occur. On the other hand, variations in wood quality are largely invisible to the production operation. This means that the changes in FS number that are driven by changes in wood quality are largely unpredictable and therefore beyond the scope of normal process control strategies. Variations in the FS number driven by changing wood quality are referred to in our program as ***normal variability***. Normal variability could well account for a ± 6% spread in the FS number about the mean value. The larger swings in process variables are generally triggered by production upsets or are an unintended consequence of necessary process adjustments done to accommodate changes in user-defined pulp quality requirements. These larger swings are referred to as ***problem variability***.

While production remains in the range of normal variability, the Zero-Span program serves to apply the FS label to the pulp strength quality indicator in frequent intervals and to generate more and more data that can be later correlated with concurrent process changes that are also recorded. These correlations build the knowledge base that can provide greater insights regarding the myriad of complex cause and effect relationships that uniquely characterize any pulping operation. When production ranges into the problem variability area, Zero-Span testing and analysis can be put to immediate work isolating and correcting the root cause. With the accumulated knowledge base already established, this correcting process will itself become more and more routine. And, as an added benefit, optimization strategies will become more and more apparent and their implementation increasingly certain and controlled. Still, while timely feedback will greatly assist efforts to quickly identify and reverse negative quality trends, production upsets will occur from time to time and will produce some quantities of reject quality pulp. Two possible strategies can be visualized for dealing with such pulps. First they can be segregated and sold as off-quality. But an alternative that will fetch a higher per tonne price is to recover such pulps prior to drying and to bleed them back into normal production at a low fixed rate. The resulting blended pulp lot will exhibit acceptable FS numbers and uniformity.

In Conclusion - Value Added Pulping:

With few exceptions, the overall productivity of any papermaking operation depends far more on the ***uniformity*** of the furnish quality than it does on its ***absolute*** quality. This is because papermachine operation is adjusted to run reliably with a given furnish. Change the furnish and those adjustments become out of tune. A furnish is materially unchanged if its FS value is held within a range of ±4% from a defining normal value. Should the FS number drift outside this range problems will be experienced on the papermachine. So maintaining the FS number within 4% of the mean value will define a target quality for pulp that will be satisfactorily runnable on any client papermachine.

The Zero-Span approach will allow a mill to introduce a value added marketing strategy based not only on its ability to ensure repetitive uniform quality, but also on its ability to match pulp quality with real papermaking need. Zero Span testing will permit quality labeling of all production in terms of a small number of categories each of which will consist of pulp with a specified uniformity. Approximately 90% of pulp production will fall into one or other of these categories. Very few papermachine operations really gain any useful advantage by seeking to maximize the strength of the pulps they use. In fact for many grades of paper a lower FS pulp may well have characteristics (e.g. more flexible, easier to beat fibers) which actually enhance its performance over a higher FS pulp. By focusing the sales effort on ***matching*** the right pulp to the customer's actual needs, and then guaranteeing on-going uniformity of quality, all categories of pulp can be sold at market, and possibly even at premium price.

A pulp mill has three overriding production goals. It must minimize pulp quality variability to ensure continued smooth and efficient operation of the papermachine, it must optimize production in order to maintain its competitiveness, and it must be able to differentiate pulp lot quality with sufficient precision in order to optimize furnish blends and the recycling of reject quality pulp and to match lots of different quality characteristics with clients requiring corresponding quality specifications. Pulmac Inc's Zero Span suite of equipment provides the pulp producer with the means to achieve all three of these important objectives.

Pulmac Inc. of Montreal, Canada manufactures and supports a suite of equipment that can establish a complete Zero-Span capability in the pulp or paper mill. This company, which traces its lineage back some 50 years, refers to this suite of equipment as the Pulmac Canadian Zero-Span Solution. The three major pieces of equipment that serve as the heart to this solution are the Automated Sheet Former (ASF), the Zero-Span Tester, and the Pulmac Laboratory Beater. The ASF automatically produces six dry test sheets from a pulp slurry first prepared by a 5 minute run in the Pulmac Laboratory Beater. The Zero-Span Tester automatically tests the prepared sheets three at a time for FS, L and B numbers. Ancillary equipment needed to support the preparation of the pulp slurry for the ASF includes the Pulmac Dewatering Device, a fluffer, and a digital scale. Together with its team of sales and service agents around the globe, Pulmac Inc is willing, ready, and able to bring the Zero-Span Solution into your mill.

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