



SAVING \$1 MILLION PER YEAR USING ZERO AND SHORT SPAN TENSILE TESTING TO OPTIMIZE PROCESS CONTROL STRATEGIES

ABSTRACT

Process control strategies are currently based upon controlling unit processes by controlling input variables. The unstated assumption underlying this strategy is that each unit process is receiving and sending a constant raw material in terms of papermaking quality. This incorrect assumption is costing papermachine systems millions per year. Measurements derived from Zero and Short Span Tensile Testing provide a common language, of the papermaking quality of the raw material, to optimize current process control strategies to save each papermachine system more than \$1 Million per year.

INTRODUCTION

A truly ideal papermachine system would allow an operator to dial in a grade and the process control systems would take over and smoothly generate, at 100% efficiency, the required tonnage. No broke, no breaks, no variation in furnish costs and at optimum machine speed....

Why is this picture so far from reality? Why is the softwood/ hardwood ratio frequently being increased? Why is energy input to the refiners adjusted? Why do machine speeds vary running the same grade on different days? Why is there constant “finger pointing” dialogue between the papermachine superintendent and pulp mill superintendent?

Process control strategies are currently based upon controlling unit processes by controlling input variables with, at best, subjective adjustments to accommodate changes in a process specific output data base; e.g. the digester input variables (time, temperature, chemicals) with adjustments based on Kappa number, the bleach plant, similarly, with adjustments based on brightness, refiner energy input with adjustments based on freeness, etc., while the papermachine responds to runnability and paper properties determined at the reel. The unstated assumption underlying this strategy is that any given process is receiving a constant raw material from the prior process and delivering a constant raw material to the next process. The heterogeneous, variable character of the primary raw material, the wood chips entering the process, denies the validity of this assumption. What is currently lacking is a common language that will highlight the manner by which each unit process is interacting with this variable raw material, and how this affects the profitability of the mill.

This paper will discuss:

1. the “common language” using zero and short span tensile testing (ZERO-SPAN 3000) to generate the fiber quality numbers,
2. a conceptual framework for optimizing process control strategies using ZERO-SPAN 3000,
3. the justification for implementing such a strategy,
4. the necessary conditions for implementing ZERO-SPAN 3000 control strategies,
5. the method of implementation.



FIBER QUALITY TESTING USING ZERO-SPAN 3000 – THE COMMON LANGUAGE

Zero and short span tensile testing (ZERO-SPAN 3000) generate fiber quality numbers that uniformly apply to all unit processes, from the brown stock washer to the reel of the papermachine, thus providing a universal common language. ZERO-SPAN 3000 procedures can be developed to allow a pulp sample taken from any process location in the papermachine system, to be rapidly and economically converted into electronic data describing the quality of the fibers in the pulp sample in terms of the average strength of individual fibers, their average length, and their average ability to bond.

In effect a ZERO-SPAN 3000 operator interacts with a ZERO-SPAN 3000 system to convert the pulp sample into test sheets, and to test these sheets in order to produce the electronic fiber quality numbers for export as papermill operating and control data. A test sheet, when wetted, loses all coherence and becomes a wet fiber aggregate. When two sets of jaws held in intimate contact at zero span are used to securely clamp the wet fibers contained by the width of the jaws, the load that can be transferred from one set of jaws to the other is supported by those fibers which are clamped by both jaws. If these fibers are strong they will be able to transfer a greater load than if they are weak. The failure load of this wet zero span test thus gives a measure of average fiber strength. The average value generated from replicating a number of tests is called the FS number.

This same test can also be conducted with the jaws separated by a short span of 0.4 mm. Under these conditions some of the fibers which are securely clamped at zero span will be so located that they will fail to span the gap. This means that fewer fibers will be available to transfer load between the jaws and so the failure load of the wet short span test will be lower than that of the wet zero span test. The number of fibers that will fail to span the short span gap will increase as fibers get shorter. This means that the wet short span test will fall relative to the wet zero span test. Thus the ratio of the wet short span test to the wet zero span test will decline as fiber length declines and this ratio provides a direct measure of average fiber length. This ratio is called the L number.

The short span test can also be conducted on the dry test sheet. In this case, the fibers exist as a coherent network. It is unnecessary that the fiber itself be clamped by both jaws in order to transfer a load, because all fibers are interconnected. The consequence of drying is to bond all the fibers together so that all fibers can participate in load transfer. This bonding effect means that the dry short span value will be higher than the wet short span value. This difference will increase as the degree or extent of bonding increases. Thus the ratio of the dry to wet short span test will increase as the bonding in the dry sheet increases. This ratio is thus a measure of the bonding ability of the fibers in the test sheet. This ratio is called the B number.



OPTIMIZING PROCESS CONTROL STRATEGIES USING ZERO-SPAN 3000 - A MODEL

A conceptual framework for using ZERO-SPAN 3000 to optimize process control strategies for a papermachine system is schematically illustrated in Figure 1(end of paper). The wet zero span tensile or Fiber Strength (FS) category of the component pulps being delivered to the papermachine system (viz. pine, gum and broke) are routinely determined. Grade standard HPD/T (for Std FS category pulps) are reduced for Lo FS category pulps, increased for Hi FS category pulps. Blending of components is adjusted from grade standard percentages (when all components are in the Std category) depending upon status of each component relative to Std. Grade standard papermachine operational settings (viz. headbox consistency, jet to wire velocity ratio, wet box and flat box and couch vacuums, machine speed, etc.) are also adjusted as necessary to accommodate furnish category information.

JUSTIFICATION FOR USING ZERO-SPAN 3000

The current operating strategy employed on many papermachines is to “center-line” by grade, the processing conditions (refiner settings, blend percentages, papermachine settings) defined by a process of historical averaging. Variances from target properties at the reel of the papermachine are used to adjust process conditions in accordance with the dictates of the combined experience of the shift operators. The dry line, couch vacuum, etc., are then used as a between-reel guide to the operation of the tickler refiners.

Process upsets, no matter where they originate, are typically first noted at the papermachine, either as papermachine upsets, or QC warnings based on paper quality at the reel. The papermaking response is necessarily a process of experientially driven trial and error until a satisfactory resolution is effected. Since many sources are recognized as potentially contributing to papermaking upsets, each demanding different responses, the absence of definitive information guarantees that problems will arrive unheralded at the papermachine and that the trial and error consequences will be significantly wasteful in respect to both paper quality and papermachine productivity. ZERO-SPAN 3000 strategies are designed to ensure the elimination of unheralded upsets due to marginal or poor fiber quality of the furnish, and when unavoidable, to provide the specific means to minimize its impact. Since currently unmeasured changes in the fiber quality of the papermachine furnish are generally found to account for some 50-80% of papermachine upsets, ZERO-SPAN 3000 clearly commands a very significant cost saving potential.

The following is a historical record of one papermachine’s routine upsets and monthly losses, expressed in terms of tons of product.

1. Rolls rejected for low tear 33 tons per month
2. Rolls rejected for low mullen 38 tons per month
3. Rolls rejected for off color 237 tons per month
4. Lost paper at grade change-overs 254 tons per month
5. Lost paper due to breaks 416 tons per month
6. Lost paper due to wash-ups 196 tons per month



7. Per 1% reduction in avg bwt. 120 tons/month less furnish
8. Per 1% reduction in pine 72 tons/month reduced pine
9. Per 1% increase in m/s 120 tons/month more paper
10. Per 1% CaCO₃ subst'n 120 tons/month reduced fiber

Inadvertent changes in fiber quality can clearly be responsible for low tear or mullen of strength grades (1&2). Since dye retention is affected, among other things, by fiber quality, inadvertent changes can be expected to contribute to off color paper at the reel (3). Certainty about furnish make-up would be expected to reduce the elapsed time before grade quality was achieved at change-over events (4). Fiber quality is one parameter that can contribute to excessive papermachine breaks (5). The frequency of wash-ups due to build up on the press roll is quite variable during the production of filler grades, suggesting that fiber quality might be a contributing factor (6).

Other historical cost factors are (1) higher than necessary pine content, and (2) greater than target basis weight, both of which are used to provide a safety factor for grade strength or machine runnability. In addition, furnish uncertainties result in maintaining machine speeds which are “safe” but potentially below optimum when furnish quality is properly accounted for similarly for average filler content. The potential contribution of these factors is illustrated below in terms of tons per month of product for each 1% improvement in performance.

In Table I, these nine sources of increased output or decreased cost have been converted to an annual impact on the profitability of this papermachine using the following hypothetical financial relationships: average selling price per ton is \$800, furnish cost at \$375 per ton, differential cost of pine over gum at \$20 per ton, price discount for rejected tonnage at \$200 per ton, differential cost of fiber or CaCO₃ is \$300. The marginal savings of increased output is taken to be average selling price less average furnish cost.

TABLE 1

Annual Savings* Accessible to Implementing Zero-Span 3000

Cost Items	Annual Cost	Annual savings
Rejects-Low Tear	\$ 80,000	50%- \$ 40,000
Rejects-Low Mullen	90,000	50%- 45,000
Change-overs	1,290,000	10%- 129,000
Breaks	2,120,000	10%- 212,000
Wash-ups	1,000,000	10%- 100,000
Productivity Items		
per 1% avg bwt reduction	\$ 540,000	25%- \$135,000
per 1% avg pine reduction	20,000	2%- 40,000
per 1% avg speed increase	610,000	5%- 306,000
Total	Total \$6,750,000	\$1.2 Million

*Based on hypothetical financial relationships



Based on this scenario, ZERO-SPAN 3000 information would have to contribute on a papermachine in each of these areas in order to achieve a one million dollar a year increase in machine savings.

CONDITIONS FOR IMPLEMENTING ZERO-SPAN 3000

To realize \$1 million in annual savings, or any comparable profit enhancement scenario requires:

1. a proper understanding and mill-wide commitment to an installation program,
2. an effective implementation plan,
3. production floor leadership to drive implementation where it counts - on the papermachine,
4. system capability to optimize process control strategies using ZERO-SPAN 3000 fiber quality numbers.

1. **Understanding and Commitment:** The goal of fiber quality testing using ZERO-SPAN 3000 is unequivocally to add measurably and significantly to papermachine profitability. To accomplish this means installing ZERO-SPAN 3000 capability and staffing it to achieve a reliable and productive data output capability; it means assuring the technical support and dedication to execute an efficient implementation plan; it means the production and management support to ensure that validated strategies are implemented.
2. **An Efficient Implementation Plan:** An efficient implementation plan is one which establishes concrete project goals leading logically and with reasonable dispatch to new control strategies for a papermachine that provides an unambiguous measure of associated profit enhancement. Such a plan is not conceivable without the initial commitment of a full time process technician to operate and fulfill the output requirements of the ZERO-SPAN 3000 testing equipment, and a full time, experienced process engineer to ensure that output data is converted as quickly as possible into validated control strategies. The implementation of such strategies will require the additional technician and management support to provide round-the-clock data output from ZERO-SPAN 3000 testing equipment. Full implementation should be currently assessed as a one year project; that is, it is an expectation that one year from installation, new control strategies will be in place yielding profit enhancements which satisfy management's investment calculations.
3. **On Floor Production Leadership:** From day one there is a need for production involvement in the assessment of output data from the ZERO-SPAN 3000 testing equipment . These data must ultimately change operator behavior in the wet end and on the machine if they are to generate profits, and on-going input from the floor level is a vital component to a successful installation.
4. **System Capability:** A targeted papermachine system needs to have a minimum capability for effective implementation. Sampling arrangements at critical system locations must be in place for routine testing. Refiners must have remote control and load sensors. Instrumentation



at the wet end of the papermachine (flat box vacuums, wet box vacuum, jet to wire velocity ratio) must have objective indicators. Furnish blend control (consistency and flow) and papermachine instrumentation in respect to basis weight, caliper, moisture and filler content must be remotely measured and controlled to easily integrate into objective control strategies.

IMPLEMENTATION

Implementation means

- (1) Installation: installing ZERO-SPAN 3000 capability and providing necessary operational manpower,
- (2) Data Base Production: generating the necessary data bases,
- (3) Experimentation: conducting the ZERO-SPAN 3000 experimentation needed to validate proposed fiber process control (FPC) strategies,
and
- (4) Integration: integrating validated FPC strategies into the routine operation of the papermachine.

Installation:

Prior to installation the following resources must be committed:

1. The package cost of ZERO-SPAN 3000 testing equipment, training, desired technical support, etc.
2. A suitable home for the ZERO-SPAN 3000 testing equipment, plus installation support.
3. Installation of sampling stations as needed, at critical process locations.
4. A full time process engineer to “run” the project.
5. A full time technician to operate the ZERO-SPAN 3000 testing equipment to generate initial data base, followed by full shift testing support.
6. ZERO-SPAN 3000 equipment maintenance support.
7. The involvement and support of production and technical personnel for a year project.
8. Senior level commitment and active oversight involvement in the project.

A one week period will be necessary to install the equipment, train instrument maintenance personnel, and establish initial sampling, testing and data flow and evaluation procedures.

Data Base Production:

New control strategies using ZERO-SPAN 3000 can only be applied from a data base which, for any current papermachine system, simply does not exist. Acquisition of this knowledge base is the initial task for implementation. This means defining current operational reality (in the absence of ZERO-SPAN 3000) from original component pulps, through all processes of refining and blending, to the reel of the papermachine.

Component Pulps: Fiber quality is known to interact strongly with refiner action; i.e. a constant refining input will exaggerate the differences in fiber quality leaving the refiner over those arriving. Fundamental to any proactive control strategy is therefore a data base which describes the extent of



fiber quality variation currently associated with the production of all component pulps (pine, gum, and broke).

Refining: Fiber quality after refining is determined by fiber quality prior to refining, and the manner in which such fibers respond to the refining environment defined by tackle, consistency and energy input. A data base describing the relation between input and output fiber quality for different entering fiber qualities and for different refiner processing conditions covering the normal spectrum of options, is an essential prelude to creating effective refiner control strategies.

Blending: The fiber quality of the furnish delivered to the papermachine is primarily dependent upon the fiber quality of each component pulp delivered to the blend chest and the percentage blend that is employed. A secondary effect is that induced by the post-blend, tickler refiners. A data base designed to demonstrate the extent to which the fiber quality of the mixed furnish interacts with papermachine operation and paper quality at the reel, is an essential prelude to creating effective blend control strategies.

Papermachine: The art of papermaking is reflected in the manner by which the papermaker adjusts his machine to accommodate the impact of changes in the quality of the fibers being delivered to the headbox. The amount of water he brings onto the wire, the use of wet box and flat box vacuums to achieve optimum drainage and papermaking quality, adjusting drag/rush condition of the stock jet from the slice, these are all examples from the papermakers tool kit. Reversing the logic means that papermachine operation is technically linked to furnish quality. Defining this relationship can only flow from the data base which links the fiber quality of the blend to the operating conditions employed by the papermaker.

Experimentation & Integration:

The various data bases discussed above (component pulp data bases, primary refining data bases, and blending-papermach-ine data base) will provide a fully integrated picture of fiber quality as it is delivered by the component pulps (pine, gum, broke), how that quality interacts with refining and how the blended furnish consequently interacts with the papermaking operation. This means that when the blend-papermachine data base has empirically identified safe, marginal and poor fiber quality furnishes, the other data bases will identify the process conditions which produce safe, marginal, and poor fiber quality furnishes. This information will necessarily suggest proactive process alterations (refining and blending) which will act to move what would otherwise be marginal or poor fiber quality furnishes in the direction of safe fiber quality furnishes. Such hypothetical alterations can be fully tested to ensure their reliability as well as defining their limits. Once any such control strategy has been validated, a plan can be put in place to integrate the strategy into the routine production operation in the most effective manner possible.



CONCLUSION

Current process control strategies are predicated on unit process data basis, with the tacit assumption that constant raw material is the norm. These strategies clearly need updating as evidenced by the tremendous operator judgement required to maintain production.

Fiber quality testing, using ZERO-SPAN 3000 technology, will provide the common language for the papermaking quality of the raw material throughout the mill. Now process control strategies can be optimized even though the original raw material, the wood chips, are highly variable.

This optimization process can ultimately be justified by \$1 million of annual savings per papermachine by reducing broke levels, decreasing furnish costs, reducing machine breaks, and increasing machine speeds.

Implementation means installing ZERO-SPAN 3000 capability, generating the necessary data bases, conducting the experimentation needed to validate proposed strategies, and integrating validated strategies into the routine operation of the papermachine. "There ain't no free lunch" - Changing operator behavior with better information will only happen if the mill is committed. This is a year project starting with a full time process engineer, a full time ZERO-SPAN 3000 system operator, enthusiastic technical and management support and above all production involvement and support.

However, the rewards are savings of more than \$1 million per year!

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