Paper Machine Supervisory Speed Control

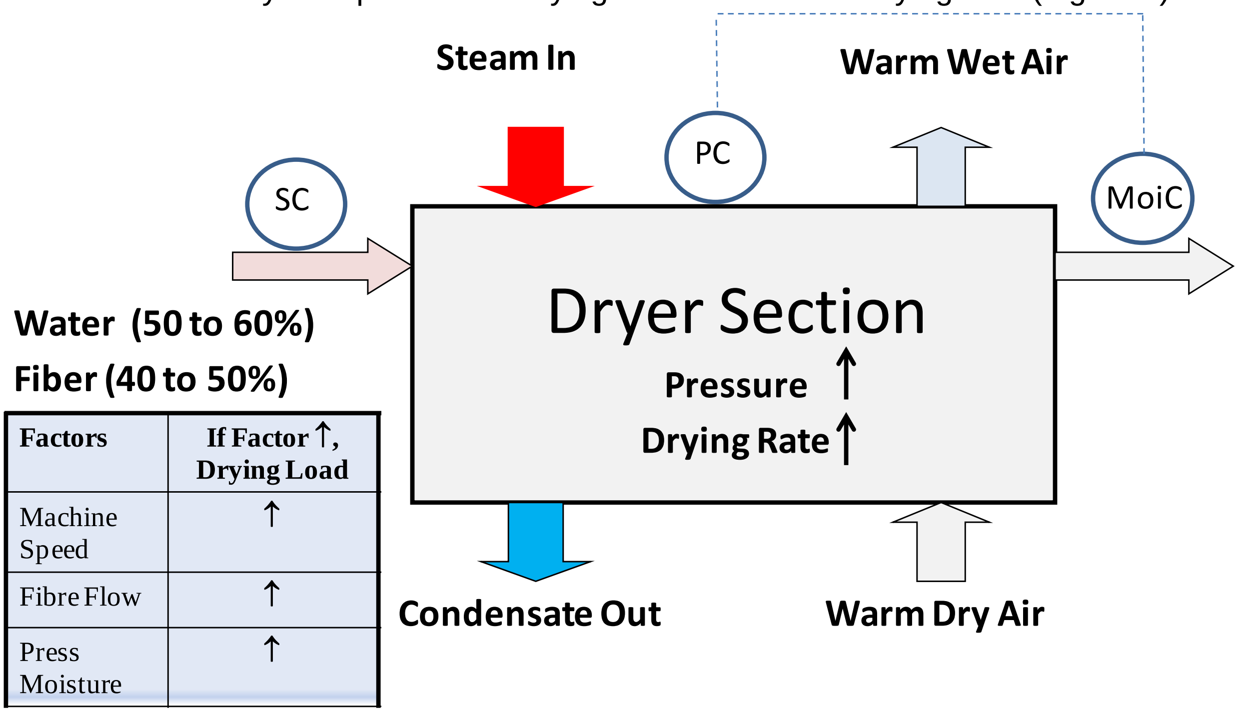
A/ Introduction

Dryer Limit control is often employed on paper machines where drying capacity is the primary production rate bottleneck. In a conventional dryer limit strategy the Dryer Section pressure targets are base-loaded at/close to maximum and the Moisture controller adjusts Machine speed. While this strategy offers the potential for maximizing production rate in the face of furnish and process variations, there are significant pitfalls. On many paper machines drying capacity is not the only bottleneck and adjusting speed will degrade product quality and operating efficiency. Moreover, the conventional dryer limit strategy is difficult to optimize because of the strong interaction between the Basis Weight and Moisture controllers and the more complex Moisture dynamics.
ProNamics Control in collaboration with Lambda Controls has developed an alternate strategy that we call 'Supervisory Speed Logic Control'. The objective of this multi-variable controller is to maximize production performance - not just the machine speed.

B/ Background

Conventional Weight and Moisture control

On paper machines where drying capacity is *not* the primary production bottleneck the Moisture controller adjusts the steam pressure as shown in Figure 1. The Moisture controller essentially manipulates the drying rate to match the drying load (Figure 2)



Factors	If Factor ↑, Drying Load
Machine Speed	↑
Fibre Flow	↑
Press Moisture	↑

Figure 1 Typical Moisture Control strategy on Machines that are not dryer limited

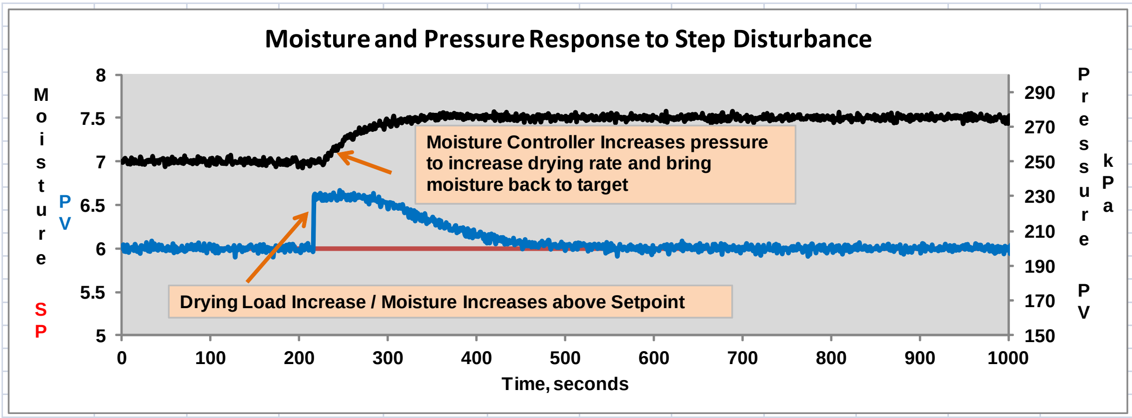


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Figure 2 Moisture Control response to a drying load increase

The sheet Weight controller adjusts the thick stock flowrate (TSF) to maintain weight at target. An increase in the TSF will increase the sheet weight but will also increase the drying load and the reel moisture (Figure 3). Dry Weight control is preferred to Basis Weight control since it is not affected by Dryer pressure changes, thereby decoupling the Dry Weight and Moisture controllers. A Feedforward controller is often employed to compensate immediately for the effect of a Fibre flowrate change, minimizing the impact on Moisture.

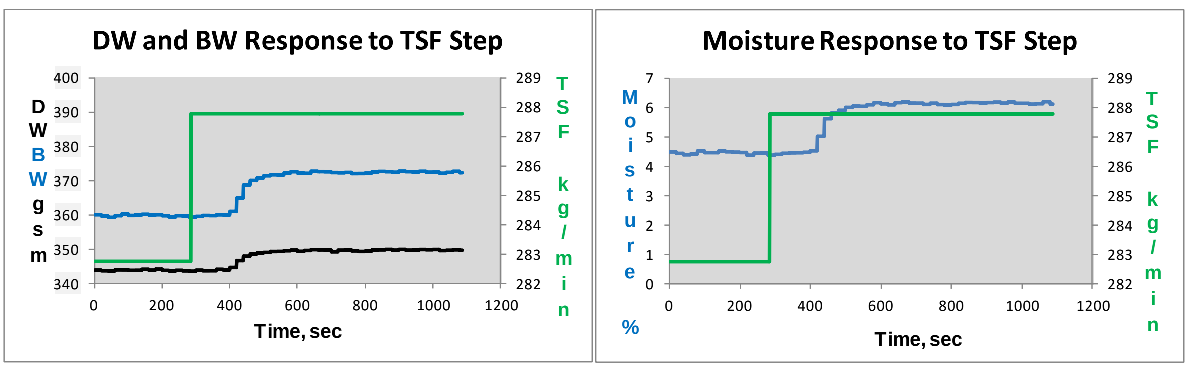


Figure 3 Weight and Moisture response to a TSF step. Loops in Manual mode

Even though the Moisture and Dry Weight controllers are not interactive, conventional Dry Weight and Moisture control has some challenges. The dynamics of these loops are *highly non-linear* (Figure 4). The Dry Weight process gain decreases with machine speed. Process deadtime decreases with machine speed. The Moisture process gain decreases with steam pressure and with production rate.

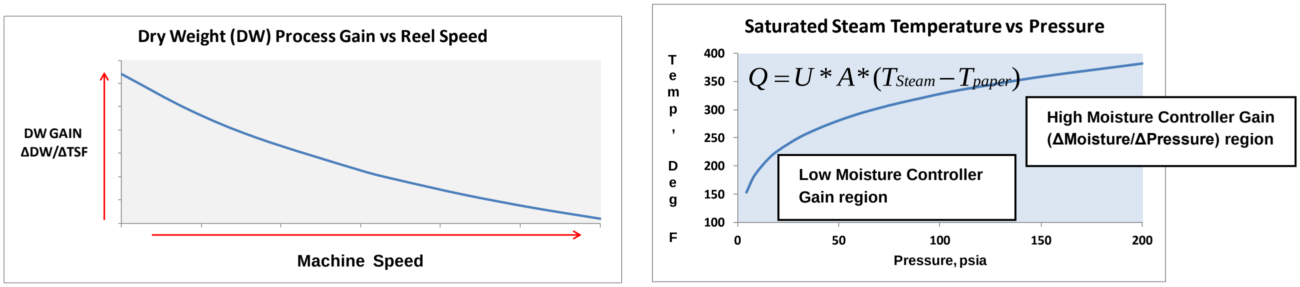


Figure 4 - the process gain of the Weight controller decreases with machine speed. The **Moisture controller process gain decreases with pressure due to the non-linear saturated steam pressure – temperature relationship.**

Grade dependent controller tuning is the most popular method of mitigating the impact of the non-linear dynamics. The controller tuning constants are adjusted in order to compensate for the change in the process dynamics, hopefully maintaining the desired closed loop performance over all production conditions.

The Dry Weight and Moisture control strategies shown in Figure 5 are a more elegant solution to the non-linear problem. The Dry Weight controller adjusts the fibre flow to machine speed ***ratio*** rather than the fibre flow. The Moisture controller adjusts the drying energy input per ton rather than the dryer pressure. With these controlled variables the dynamics of the Weight and Moisture controllers are linearized, largely eliminating the need for grade dependent tuning. Moreover, there is built-in feedforward action to compensate for production rate changes.

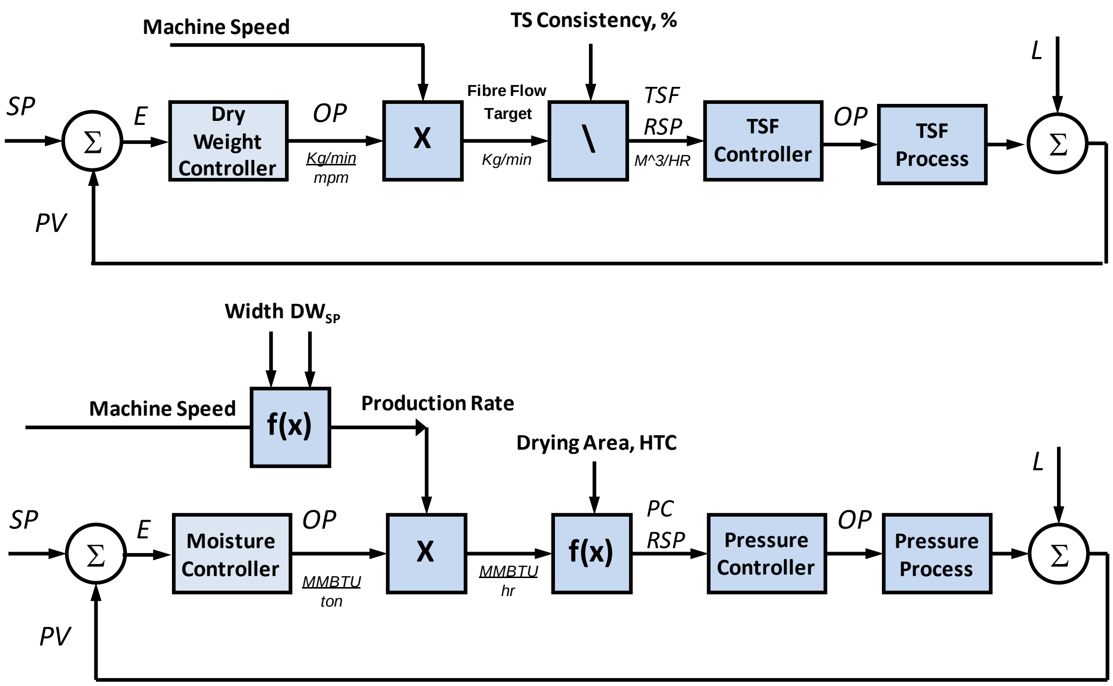


Figure 5 – the cascade ratio strategies linearize the dynamics of the Weight and Moisture controllers and compensate immediately for speed changes

Conventional Dryer Limit Control

On paper machines where drying capacity *is* the primary production bottleneck the Moisture controller is often configured to adjust the *Machine speed* rather than the Dryer Pressure. This strategy (Figure 6) is commonly referred to as *dryer limit control*.

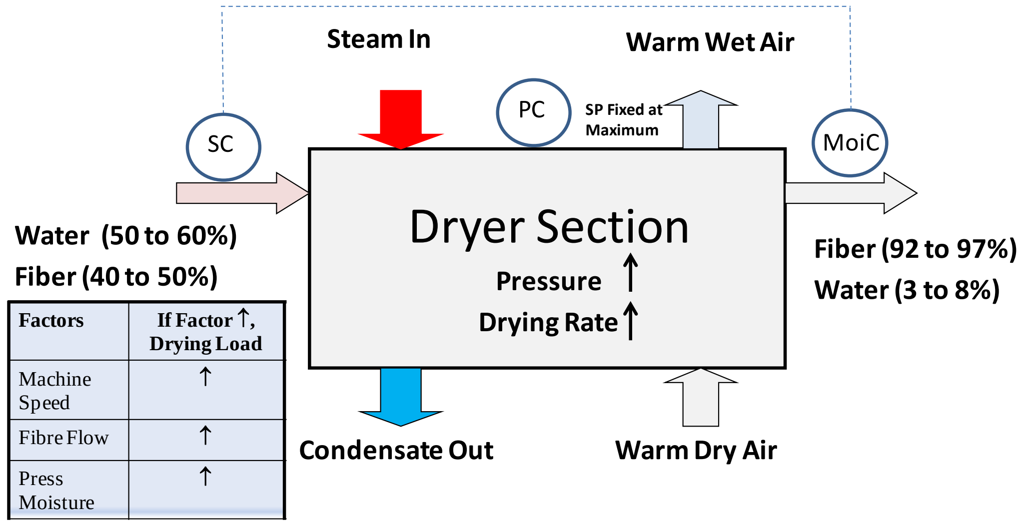


Figure 6 – Conventional Dryer Limit Control Overview

The dryer pressures are fixed at/near maximum value – thereby maximizing the *drying rate*. The Moisture controller adjusts the machine speed, effectively manipulating the *drying load.* If variation in furnish characteristics increases the drying load (by increasing the sheet moisture content at the dryer inlet) the Moisture controller will decrease the machine speed to rebalance the drying load with the drying rate.

Continuously adjusting the machine speed to maintain sheet moisture on target maximizes the *potential* production rate but has more inherent risks. Speed variation can / does degrade operating efficiency through increased sheet break frequency. It also tends to degrade product quality - increasing cull losses. Dryer limit control is very frequently 'turned off' because the risks are greater than the benefits.   From a control perspective, the dryer limit strategy is much more difficult to implement successfully because of the strong interaction between the Dry Weight and Moisture Controller as shown in Figure 8. The dynamics of the Moisture feedback controller are usually more complex (and variable) since a machine speed change will result in Headbox flow rate and consistency changes. A Dry Weight / Moisture decoupling strategy needs to be implemented and properly tuned.

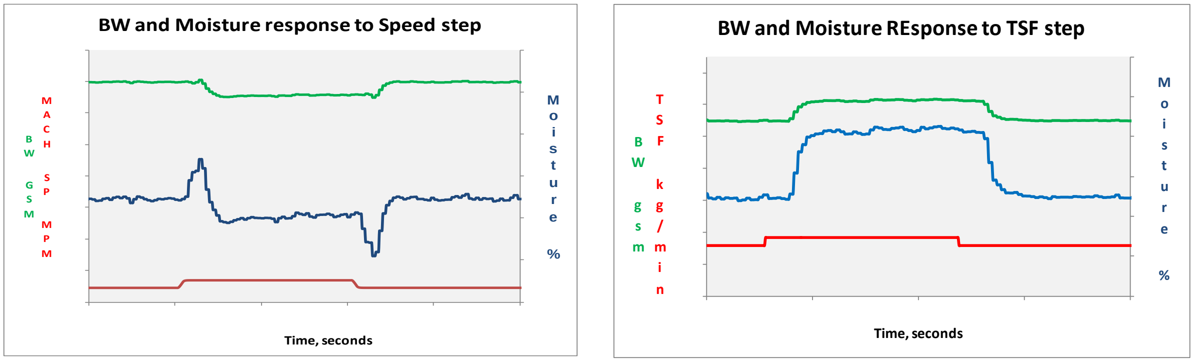


Figure 8 - shows the strong interaction and complex Moisture response dynamics of the conventional dryer limit strategy

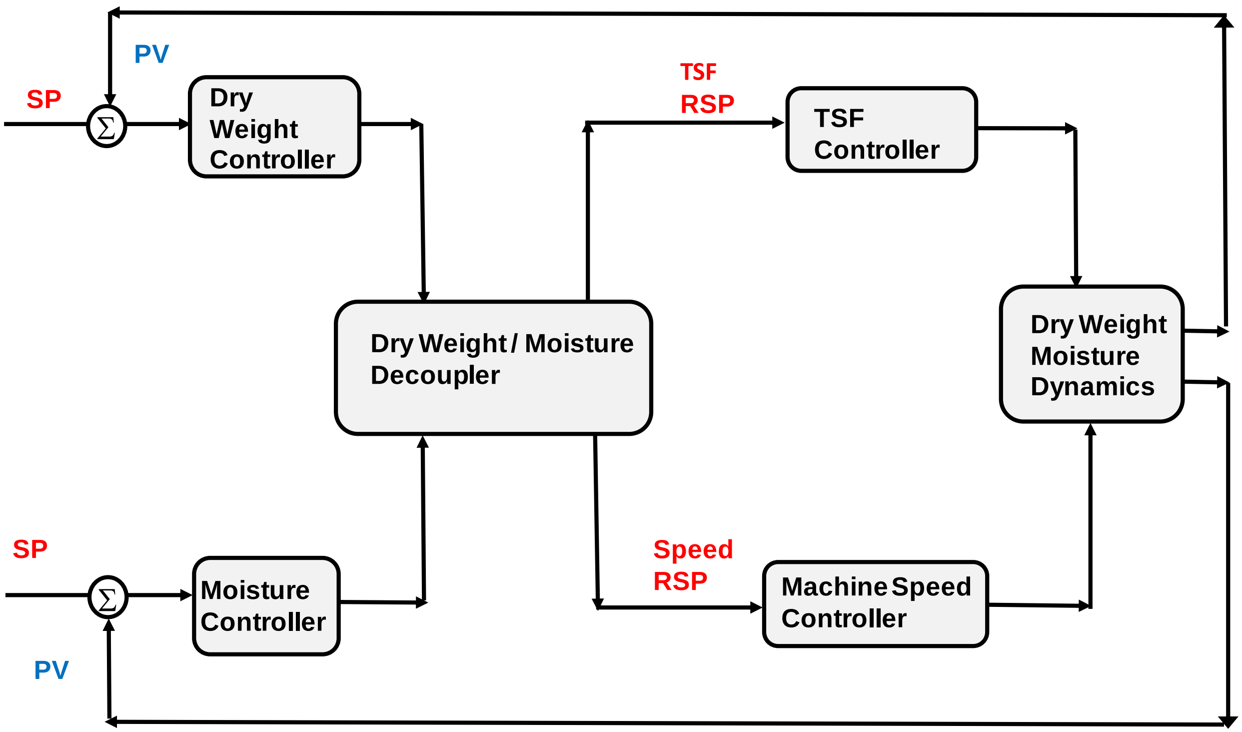
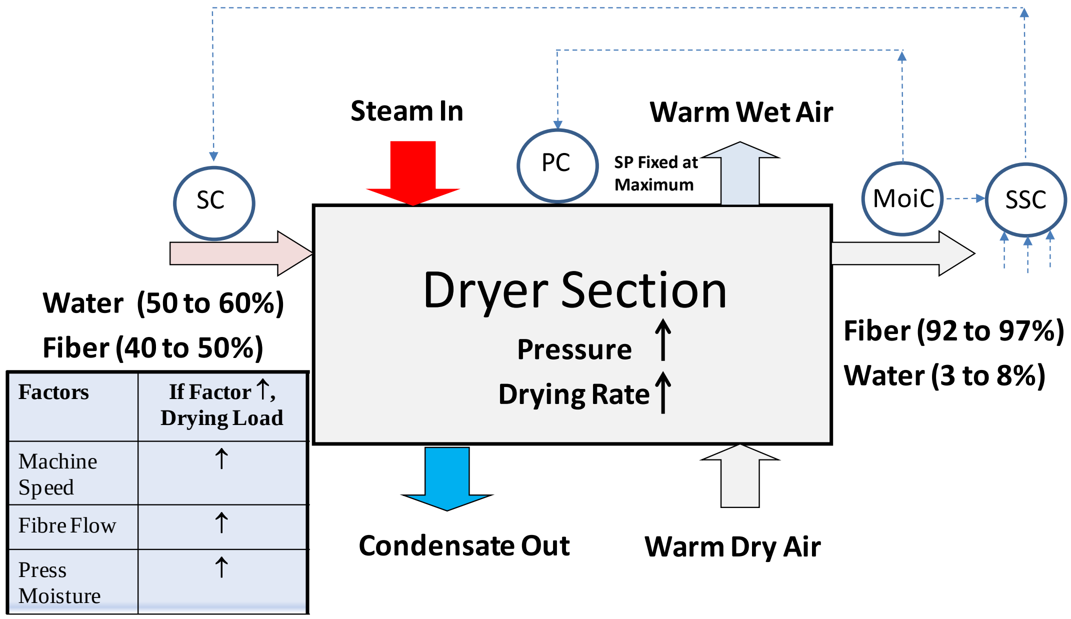


Figure 9 - Dryer limit control strategy with decoupler

C/ An alternate approach - Supervisory Speed Control

If the conventional Dryer Limit strategy is degrading the overall production rate and product quality, a logic *based Supervisory Speed Controller* (Figure 10) is worth considering. The overall objective of this multivariable controller is to maximize production rate while *maintaining product quality within specifications*.



Factors	If Factor ↑, Drying Load
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Figure 10 – Supervisory Speed Control - Overview

The Supervisory speed logic controller block diagram is shown in Figure 11a.

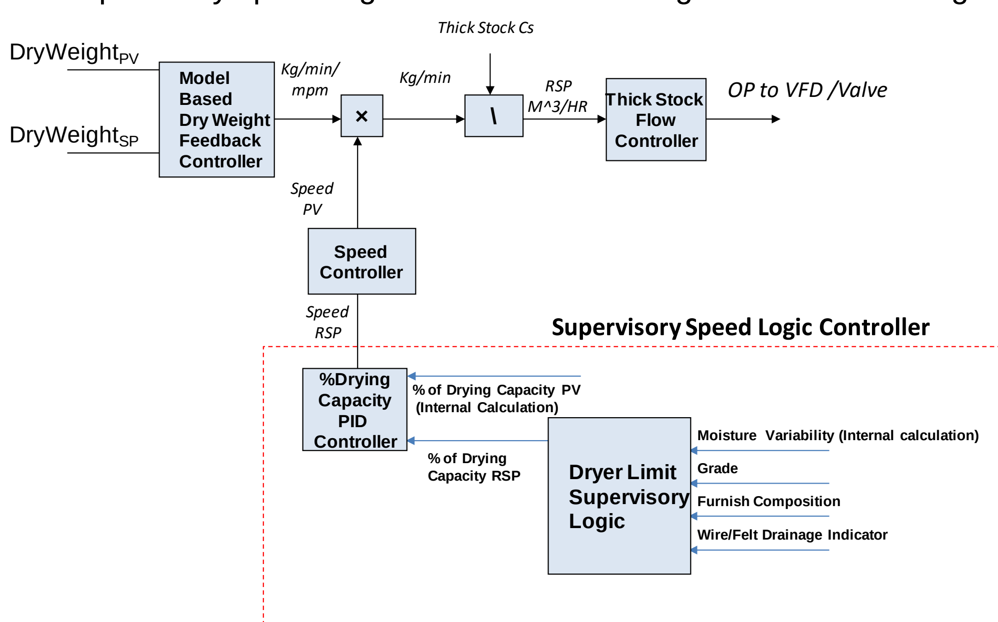

Figure 11a – Supervisory Speed Control – Dry Weight Control block diagram

The inputs include the product grade, moisture variability (calculated internally), furnish ratio and a wire section drainage performance indicator. A %Drying Capacity setpoint is calculated and controlled to target by slowly adjusting the machine speed.   This ensures a reasonable Moisture control range (via dryer pressure adjustment) and a production rate that is near maximum. Feedforward logic compensates for the speed disturbance to both the Dry Weight and Moisture controller (Figure 11b).

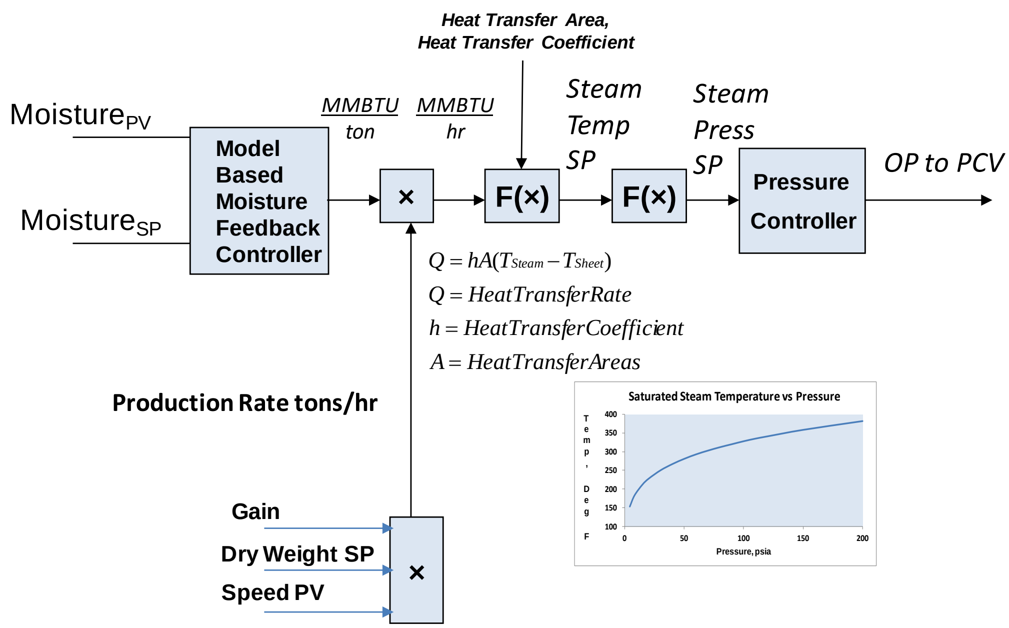

Figure 11b – Supervisory Speed Control - Moisture Control block diagram

This strategy has some significant benefits versus conventional dryer limit control.

- The Supervisory speed controller will make less aggressive speed adjustments, thereby reducing impact on product quality and operating efficiency. The Moisture and Weight variability are maintained within limits by adjusting the % Drying Capacity setpoint. Furnish composition and Wire drainage conditions. are used to trim the % Drying Capacity setpoint.
- The Dry Weight controller process dynamics will be relatively linear, simplifying controller tuning and resulting in more uniform control performance over the entire grade range.
- The Moisture controller dynamics will be relatively linear simplifying controller tuning and resulting in more uniform control performance over the entire grade range. .
- The operator 'window' on dryer performance will be upgraded. Key dryer performance variables such as steam flowrate to each dryer section, drying rate and energy efficiency will be calculated and trended.

D/ How to Improve Process performance on Dryer limited machines

Our experiences with dry end control improvement over the past 2 decades have taught us that a multi-phase approach is required for success.

Phase 1 – Ensure Good Regulatory Control

The first priority is to survey the regulatory loops in the wet end and dryer sections of the machine. This is 'low hanging fruit' in a program to reduce Weight and Moisture variability. The key loops include thick stock flow and consistency, cleaner/screen flows and pressures, Headbox pressure, dryer pressures and differentials. The survey will reveal loops that require retuning, control valves that need repair or replacement, sensors that need repair /replacement or repositioning and wet end control strategies that need upgrading.

Phase 2 – Evaluate Weight and Moisture Controls

After Phase 1 is complete, the performance of the Weight and Moisture controllers need to be evaluated. Data is gathered to characterize the magnitude and spectral content of the Weight and Moisture variability in Auto and Manual modes. Open loop bump tests are conducted to measure process dynamics and determine whether the controllers (and decouplers) require retuning. As noted above, the complexities of dryer limit control often mean that a significant part of the product variability is controller induced. Optimizing the tuning of the Weight and Moisture controllers may provide significant benefits. However, control strategy modifications (such as supervisory speed control) may be necessary to make the desired process improvements.

The expected benefits to process performance of tuning or control strategy modifications are best evaluated using a *dynamic process simulation.* Process simulations, which can be customized at a relatively low cost, provide a solid basis for developing a path forward. The relative ability of alternative control strategies to respond to process disturbances can be quantified. The expected improvement from retuning can be estimated. The need for potentially disruptive (and expensive) on-line step testing is minimized.

Phase 3 – Implement and Test Tuning and Control Strategy modifications

Implementing the proposed modifications to the Weight and Moisture controllers is the next step. Immediately after implementation, setpoint and load response tests are conducted to ensure that the control performance meets expectations. Finally, the economic impact of the modifications need to be assessed by comparing product variability and operating efficiency over a 3 to 6 month period.

E/ How Can We Help

ProNamics Control Inc is a process optimization company based in Vancouver, BC. Our mandate is to maximize the value of process control to improve profitability. To that end, the company conducts process and control optimization surveys, prepares process simulations to establish best practices and provides a range of training courses related to process control optimization.

Lambda Controls is an independent process control optimization consulting company specializing in the Pulp and Paper industry. The focus of Lambda Controls is to help customers reduce process variability and obtain the best possible performance from process equipment, instrumentation, and regulatory control loops.

Over the past decade we have conducted over 50 paper machine optimization surveys, identifying and correcting process control and variability problems in all paper machine process areas. We are experts in Weight and Moisture control strategies and use dynamic simulation tools to customize control strategies to match the needs of our clients. Please give us a call to discuss how we can help.