Ratio Control for Pulp & Paper Consistency Control

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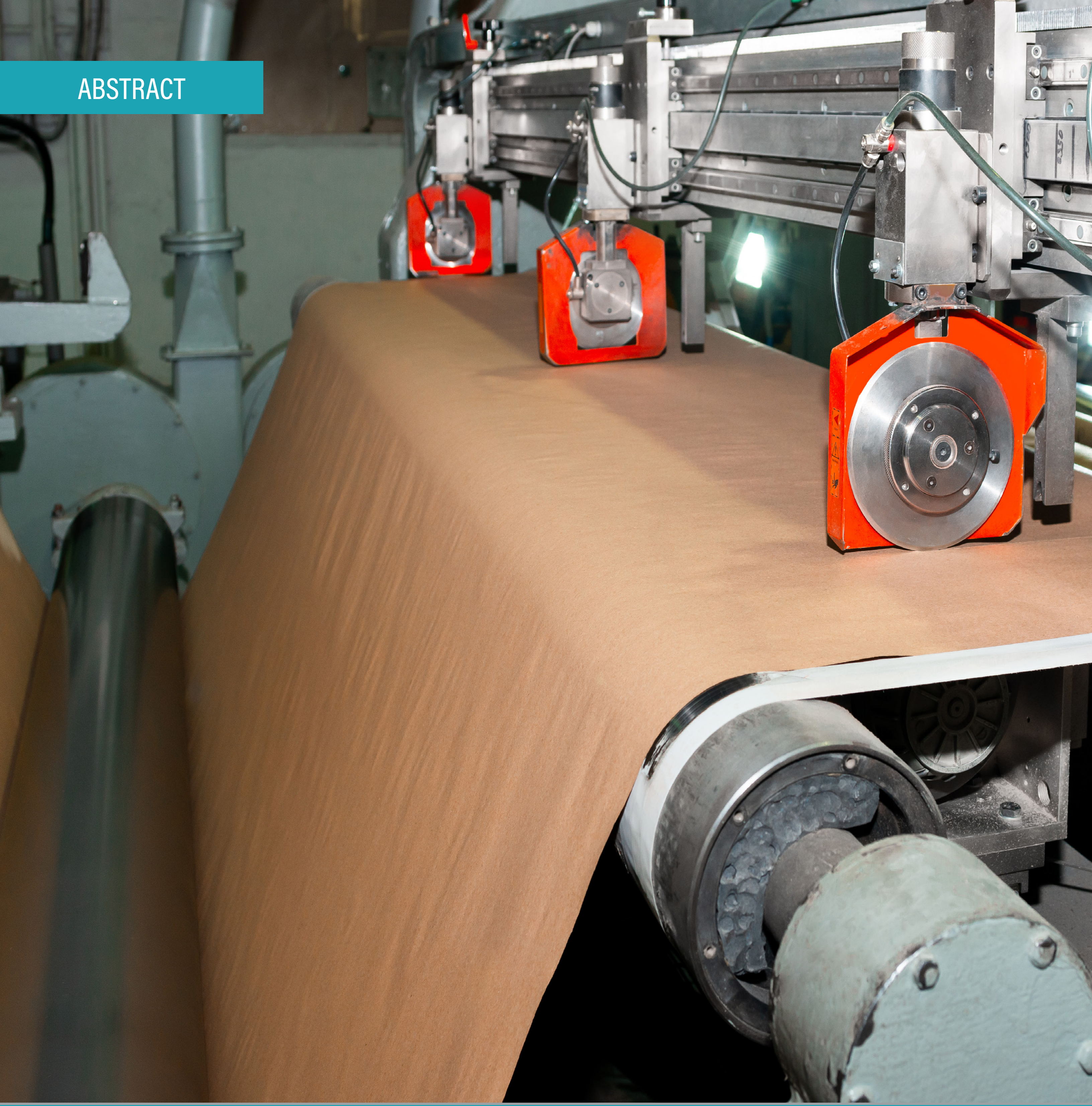
CONTENT

ABSTRACT



Consistency in papermaking is one of the fundamentals of the papermaking process. So, controlling consistency throughout the process is very important to the final product. This tech tip will focus on the papermaking consistency control, however ratio control can be applied across various industries.

Consistency Measurements

Below we will define what consistency and how it is measured. The explaining is not set to be a full definition/explanation. It will allow us to start seeing why ratio control is the best strategies in controlling consistency. Consistency is defined as percent of fiber, plus percent of any additive(s).

$$\%\ Consistency = \%\ Fiber + \%\ Additive \qquad \textbf{(Eq. 1)}$$

The additive is basically anything else making up the slurry of pulp. This could range from clay, chemicals, or fillers. The percent fiber can be broken down to the following:

$$\%\ Fiber = \frac{Dry\ Weight\ of\ (Solids\ -\ Additive)}{Total\ Weight\ of\ the\ Sample} \times 100\% \qquad \textbf{(Eq. 2)}$$

To determine the weight of the additives an ash test must be performed. A dried sample is burned to remove all fiber content. What remains is the ash. Typically, ash is important to the papermaker, but real no concern to consistency control. Consistency could be defined as:

$$\%\ Consistency = \frac{Dry\ Weight\ of\ Solids}{Weight\ of\ Mixture} \times 100\% \qquad \textbf{(Eq. 3)}$$

CONTROL STRATEGIES

The control strategy for consistency is reducing the variation in the consistency. Sounds pretty obvious but the real questions are: By how much do we reduced the variations? What is or can fix what is causing the variations? How much variation can we accept?

There are three types of control strategies that will be covered. All these strategies can be found in one form or the other throughout a mill or in other industrial applications. Consistency control can be talked about in many other applications in a paper mill, for example high density chest or thickeners, this section will focus on controlling consistency from a stock chest.

In the papermaking process the stock is diluted and thicken many times to prepare it for use on the paper machine. Different types of cleaning and fiber preparation equipment (e.g., screens, refiners) require the stock slurry to be at certain consistency for optimal performance. The stock chest is the last place where consistency can be changed and is the most important, because after this we are making paper. The material balance equations for a typical chest consistency control:

Scripts F = Flow, C = Consistency
Sub-Scripts c = chest, d = dilution, f = furnish supplied from chest

$$F_c C_c = F_d C_d = F_f C_f \qquad \textbf{(Eq. 4)}$$

$$F_c + F_d = F_f \qquad \textbf{(Eq. 5)}$$

Solving for F_c in equation 5 and then substituting into equation 4 yields:

$$C_f = \frac{F_d}{F_f} (C_d - C_c) + C_c \qquad \textbf{(Eq. 6)}$$

$$\text{Let } R = \frac{F_d}{F_f} \ \textbf{(Eq. 7)}\text{, and } \Delta C = Cd - Cc \quad \textbf{(Eq. 8)}$$

Substituting equation 7 and 8 into equation 6 yields:

$$Cf = R \cdot \Delta C + Cc \qquad \textbf{(Eq. 9)}$$

Equation 9 shows that any changes in flows or consistency will cause the control loop to response. This is what we would except but looking carefully at the relationship between the two different flows highlight that the ratio will only be the same when one increases the other must also to obtain the desired consistency. This point is important if the selected control strategy will be able to handle variations in respects to flow/pressure, consistency, and dead time.

A typical feedback control loop for controlling consistency consists of a consistency transmitter installed on the discharge of the pump piping and a control valve on the dilution piping. The PID controller receives consistency values from the consistency transmitter, compares it to the set point and then responds by changing the valve position. This type of control can not control disturbances in the dilution header and furnish demand.

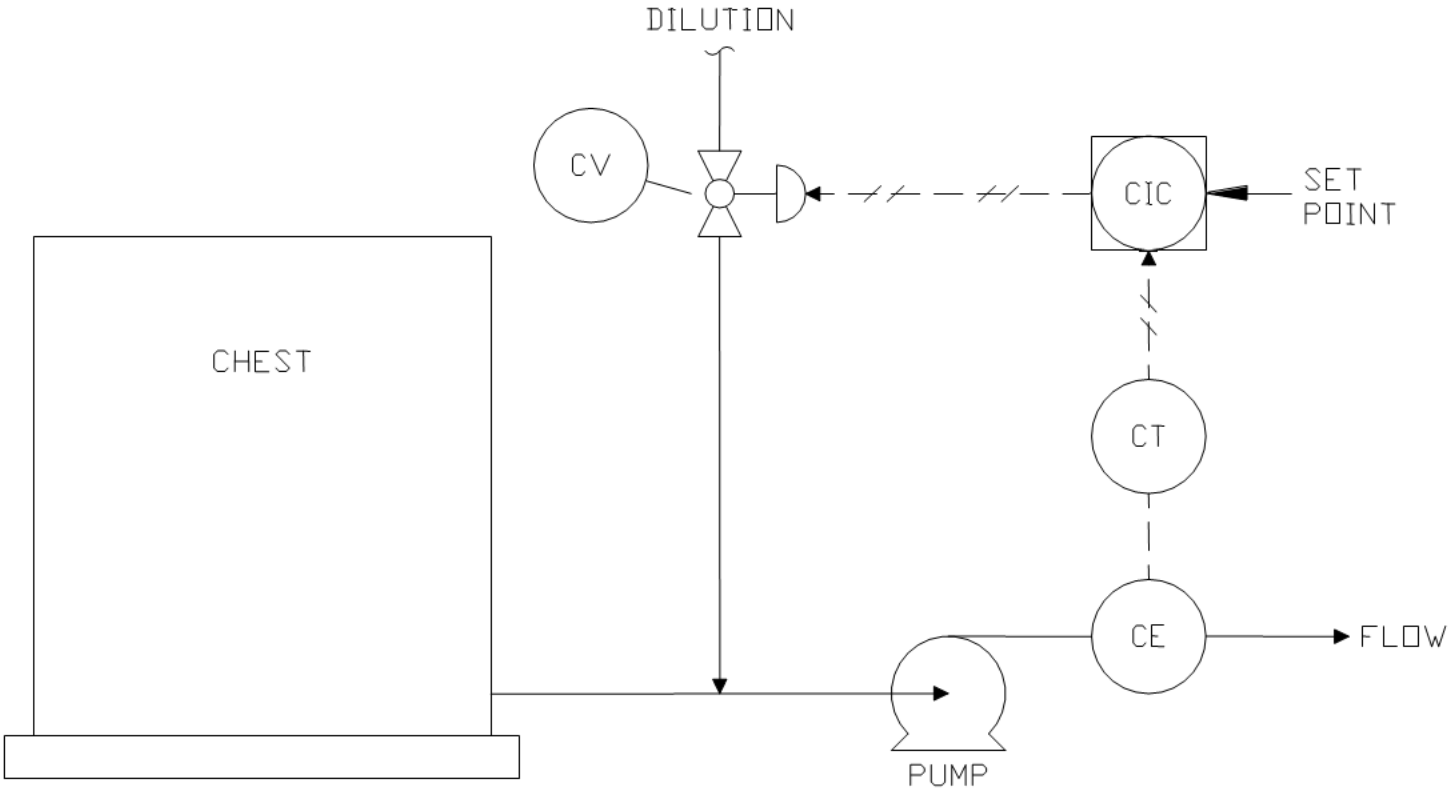


Figure 1.0 – Feedback Control

For a typical feedback control the process gain cannot be obtained by partial differentiation. This relates to the pressures and flows variables that will affect the overall performance of the control loop. This can be seen in equation 10 below.

$$C_f = \frac{F_d}{F_f}(C_d - C_c) + C_c \qquad \textbf{(Eq. 10)}$$

A cascade control loop for controlling consistency consists of a consistency transmitter installed on the discharge of the pump piping and a flow control loop on the dilution piping. The PID controller for the consistency receives consistency values from the consistency transmitter, compares it to the set point and then responds by changing the set point of the flow loop controller. This type of control strategies reduces the pressure variation in the dilution header by control the flow of the dilution water. This is good control if the furnish flow is consistent.

$$\frac{\Delta C}{F_f} \qquad \textbf{(Eq. 11)}$$

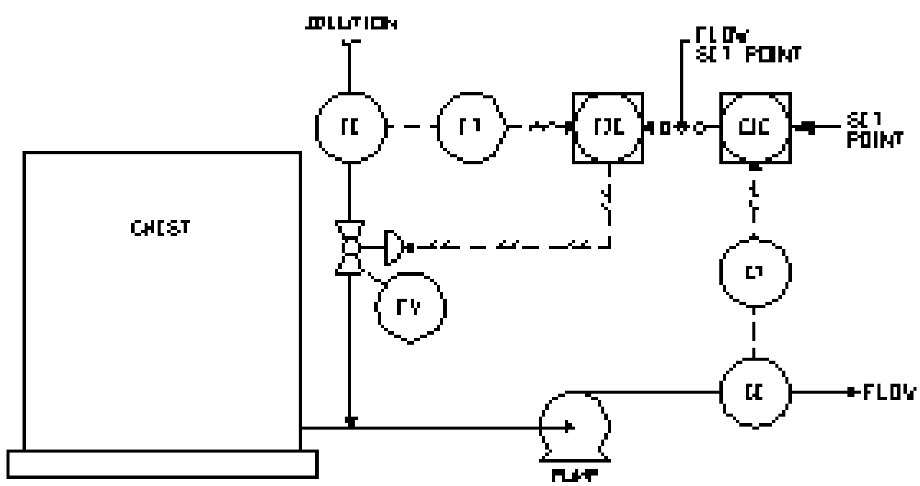


Figure 2.0 – Dilution Flow Rate

For Cascade Control the Process Gain is, where the furnish flow is inverse proportional to the consistency change. The dilution header pressure swings will not affect the dilution control loop in this control strategy. The furnish flow needs to be constant for the control loop to perform well. This can be seen in equation 12.

$$\frac{\partial c_f}{\partial F_d} = \frac{\Delta C}{F_f} \qquad \text{(Eq. 12)}$$

A ratio control loop for controlling consistency consists of a consistency transmitter and flow transmitter installed on the discharge of the pump piping and a flow control loop on the dilution pipe. The PID controller for the consistency receives consistency values from the consistency transmitter, compares it to the set point and then responds by changing the ratio set point in the ratio controller. The ratio control loop uses the material balance equations to define the relationship of each of the process variables, leaving only the consistency in the chest and dilution water to consider. By applying control strategies from the material balance yield a control loop with less variations and good control over a range of conditions.

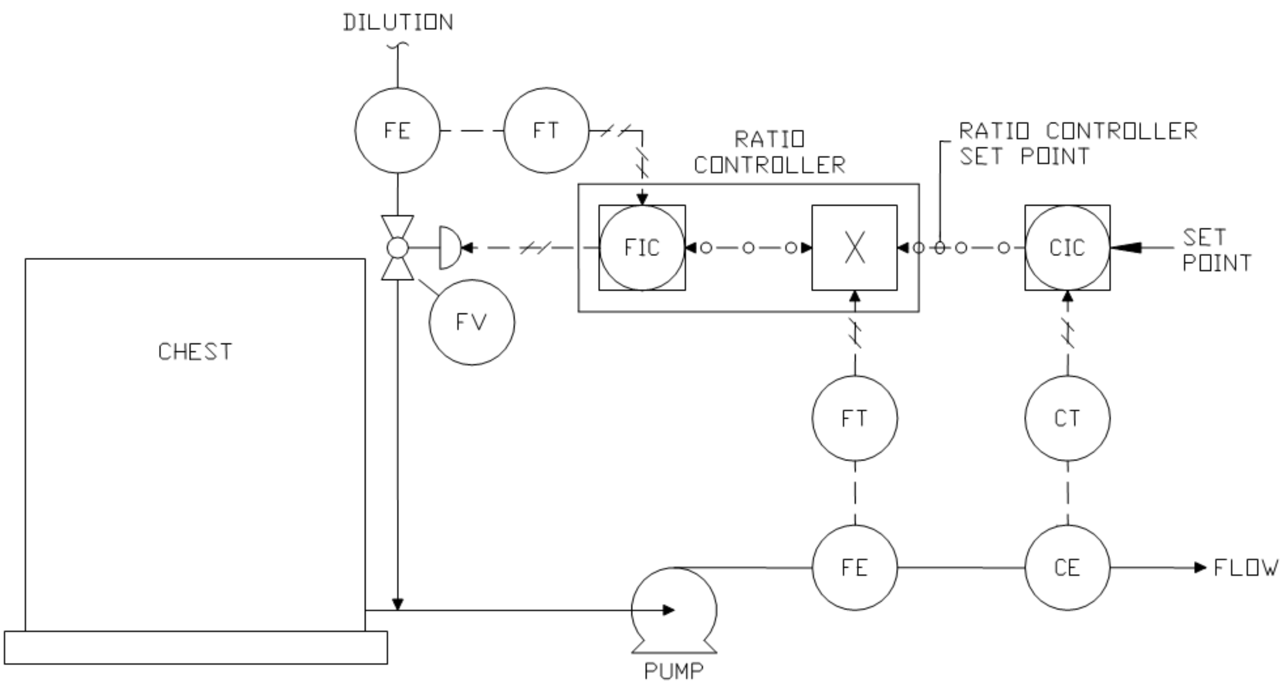


Figure 3.0 – Ratio Control

For Ratio Control the Process Gain is, where only the consistency of the chest and dilution water is of any concern. The dilution header pressure swings and furnish demand will not affect the control loop. We have been able to partial differentiation the process gains from the flows and pressure allowing the control to focus on consistency. This can be seen in equation 13.

$$\frac{\partial c_f}{\partial R} = \Delta C \qquad \text{(Eq. 13)}$$

CONCLUSION

In conclusion, where greater control is required using a mass/energy balance can be used to aid in the design of the control strategies allowing the engineer to select the best strategy.

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