A systems approach to pressure screen control in the pulp mill

Dan P. Dumdie
Process control supervisor
Daishowa America Co. Ltd.
P.O. Box 271
Port Angeles, WA 98362
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A process control strategy for operating pulp mill pressure screens improved paper machine efficiency and press room performance, significantly reduced refiner power requirements, decreased chemical pulp usage, increased refiner pulp production rates, and produced a more consistent and higher freeness pulp with substantially less debris.

The Daishowa America Port Angeles mill makes lightweight directory paper from refiner groundwood and purchased kraft. Because of the lightweight sheet, paper machine runnability and press room performance are very sensitive to pulp mill shives and other furnish debris. In an attempt to improve the relative competitive position of the Port Angeles mill and to improve paper machine efficiencies, we installed Hooper pressure screens on both the thermomechanical pulp (TMP) and refiner mechanical pulp (RMP) lines. The new slotted screens replaced antiquated gravity Cowans, which provided poor shive removal efficiencies. The project exceeded all expectations for improved quality, lower costs, and higher efficiencies. Much of this can be attributed to the unique control system that was developed for the project.

Process background

The purpose of a pulp mill pressure screen is to fractionate the feed stream fiber into an accept stream containing quality pulp and a reject stream containing shives and other debris.

The feed enters at the top of the screen, where it is rotated inside a cylindrical screening basket by a motor-driven rotor. The basket may contain holes or slots for the accept fibers to pass through. The rejects cannot penetrate the screen. Instead, they travel to the bottom of the basket where they are forced out the reject line. The rotor contains tips which rotate past the holes or slots to produce strong negative-pressure pulses. This helps keep the screen from blinding. As the fibers fractionate down the screen basket, they quickly dewater. Consequently, two dilution lines are required to help maintain uniform consistency near the bottom of the basket.

Screen performance can be defined in terms of shive removal efficiency (SRE). This is the weight percentage of shives and other debris that is removed from the pulp by the screen:

\[ SRE = \left( \frac{F_r C_r}{F_f C_f} \right) \times 100\% \]  \hspace{1cm} (1)

where

- \( SRE \) = shive removal efficiency, %
- \( F_r, F_f \) = reject and feed flows, L/min
- \( C_r, C_f \) = reject and feed consistencies, %

Dumdie is process control supervisor at Daishowa America Co. Ltd., P.O. Box 271, Port Angeles, WA 98362.

The SRE is a function of screen reject rate (RR), which is the weight percentage of total dry fiber that is rejected by the pressure screen:

\[ RR = \frac{[F_r C_s]}{[F_c C_r]} \times 100\% \]  

(2)

Nelson and Bolton (1) have developed an empirical equation relating shive removal efficiency to screen reject rate:

\[ SRE = \frac{RR}{1.0 - Q(1 - RR)} \]  

(3)

A single coefficient, called the screening quotient (Q), determines the shape of the efficiency curve (Fig. 1). The quotient can be determined for any screen from a few experimental data points and a least squares curve-fitting program. The screening quotient varies from 0.0 to 1.0. A value of 0.0 represents a screen with no efficiency for shive removal (45° line), and a quotient of 1.0 represents a perfect screen (100% efficient).

The Port Angeles mill has implemented on-line reject rate control to help operations manage screening efficiencies for various paper machine grades. This puts controller setpoints in terms of actual reject rates and shive removal efficiencies (engineering units) rather than in terms of flows and consistencies that are used in conventional regulatory control systems. This has had a very positive effect on the training of operating personnel.

### Process control

There are a number of important control objectives for operating a pulp mill pressure screening system. First, it is essential to achieve a high SRE to produce quality accepts while keeping the amount of rejected material to a minimum. The rejects should be concentrated with shives, chop, and other debris. This keeps the amount of rework (reject refining) to a minimum and helps reduce operating costs. In addition to maintaining a consistent and high level of accept cleanliness, screen controls should also produce a pulp with uniform fiber fractions and a constant freeness. Screening process quality is strictly a function of accept cleanliness and freeness. Finally, the control system must be able to balance screen throughput with process runnability. The controls must be capable of handling maximum pulp production while keeping screen blinding, reject line plugging, and other operating problems to a minimum.

All of these quality and operating considerations can be addressed using the control strategy presented in Fig. 2.
The system consists of one supervisory and seven regulatory loops for each screen. These loops can be placed into one of three logical categories for discussion: reject control, inventory control, and feed control.

Reject control

A typical screen SRE curve is shown in Fig. 3. Optimum pressure screen operation occurs at a constant RR on the knee of this curve. At the optimum, pulp debris is removed while long-fiber fractions are retained. This results in a uniform freeness and cleanliness of screened accepts. At higher than optimum RR, quality long fiber is lost, and reject refining costs can become extreme. Some installations typically run at excessive RR because this provides good screen runnability at higher pulp production rates. Excessive reject rates are typical in applications where the screens are undersized. The problem, however, can also occur if dry chips, worn refiner plates, or other abnormal conditions cause high shive levels in the screen feed. At lower than optimum RR, debris is not adequately removed, and freeness variability can be quite large even with small variations in RR.

We have implemented three modes of supervisory control. The first is reject flow control, which must be used during startup with white water while consistencies are outside their respective transmitter ranges. The second and third modes are described below and provide a means of directly regulating RR and SRE.

With adequate instrumentation, supervisory control can maintain a constant RR on the screens. The supervisory equation comes from the material balance (Eq. 2) and is used to compute the desired reject flow rate:

\[ F_R = \frac{RR(F_R C_R)}{100 C_B} \]

(4)

The reject flow is simply a function of on-line instrument data and the RR which is supplied by the operator as a setpoint. Once computed, \( F_R \) is used as a supervisory setpoint for the reject flow controller, as shown in Fig. 2.

Taking this system one step further, the SRE curve (screening quotient) can be put directly into the control computer. This allows operations to enter its setpoint as an efficiency. In this case, the RR used in Eq. 4 is read directly from the screen's efficiency curve. It is often desirable to have operators enter setpoints in terms of engineering units. This helps promote a better understanding of the process as well as the controls.

Pressure screen RR control (Eq. 4) obviously requires an accurate and reliable measurement of both process flow and consistency. A magnetic flow tube is adequate for the flow measurement, and the optical Cerlic ACM/CT20/50 has proven satisfactory for consistency measurement.

Before selecting a consistency sensor, we ran an extensive two-month trial on both optical and mechanical transmitters over a consistency range of 1.0% to 2.0%. During this period, the Cerlic unit outperformed all other sensors in terms of linearity, signal-to-noise ratio and calibration drift. By combining all 35 ACM data points collected over the two-month trial and running a regression analysis, a correlation coefficient of 0.95 and a standard error of 0.07% consistency were obtained. Standard errors for the mechanical sensors were nearly three times that of the optical unit. The mechanicals also showed a very poor signal-to-noise ratio in this 1.0% to 2.0% consistency range.

Inventory control

The main objective for inventory control is to prevent the screen feed tank from running empty or from overflowing during normal operation. There are a number of ways to achieve this control. However, the method selected must be compatible with other objectives such as maintaining screen throughput and accept quality.

Port Angeles uses a simple accepts flow loop cascaded to the surge tank level controller, as shown in Fig. 2. This optimizes throughput and keeps the overall freeness drop across the screening system at a minimum.

It is quite common for a screen basket to slowly blind during a period of several hours. Regardless of this partial blinding, the accepts flow loop (Fig. 2) will maintain a constant process throughput. In contrast, a more conventional approach to inventory control is to manipulate the screen differential pressure (DP). This can successfully regulate feed tank level; however, it also significantly reduces throughput when the screen partially blinds (i.e., as the screen slowly blinds, the accept valve closes to maintain DP). On the other hand, flow control opens the accepts valve during a partial blind to maintain throughput. The
only lost time with accepts flow control is the 20 s necessary to flush the basket each time it completely blinks.

Still another method of inventory control is to recycle a portion of the screen accepts to the feed tank. Because of the recycling, this method can result in a significant reduction in accepted long fiber and freeness. Moreover, as the recycle flow needed to control the level varies, so will the freeness and pulp quality vary. Finally, recycling accepts will decrease screen throughput. All of these problems can be eliminated by manipulating accepts flow to control the feed-tank level.

**Feed control**

Feed stream pressure and consistency play an important role in the overall operation of a pressure screen system. They are the only process variables that require control in the screen feed.

The feedstock pressure has no effect on screening quality, efficiency, or throughput; however, feed pressure can have an impact on process runnability. The feed pressure is controlled using a simple feedback loop, as shown in Fig. 2. It is tuned much the same as a flow loop. The setpoint of this controller establishes the internal pressure of the screen, which in turn determines the pressure drops across all screen system valves (feed, accepts, rejects, and dilution). Depending on process stock temperature and screen throughput, the feed pressure setpoint must be adjusted to prevent valve cavitation and the runnability problems associated with it. In this respect, proper valve sizing for all anticipated production rates is a critical step in the overall process design of the screening system. We commonly raise feed temperature to improve screen runnability and increase throughput. Under these conditions, the valves are even more prone to cavitation if improperly sized.

The feedstock consistency requires very tight control because it does influence screen throughput and runnability, and it can also affect accept quality. A change as small as 0.1% consistency can have a large impact on pulp throughput and the frequency of screen blinding. Typically, an increase in feed consistency will increase screen throughput; however, runnability (blinding) will become a problem if the consistency gets too high. Consequently, there is an optimum feed consistency, and it changes as chip furnish and refiner plate conditions change. Finally, a large variability in feed consistency can upset the screen runnability and increase throughput. Under these conditions, the valves are even more prone to cavitation if improperly sized.

To adequately control feed consistency, trim dilution is required at the suction of the pump. Port Angeles uses an advanced control strategy with adaptive tuning (2), as shown in Fig. 2. The strategy regulates consistency by manipulating the ratio of dilution flow to total feed flow. This not only provides uniform consistency but also ensures that the dilution water is turned off during an automated flush cycle when the screen blinds (i.e., dilution flow is ratioed to feed flow, which is turned off during the flush cycle). Good consistency regulation is also important immediately after a screen blind to aid in process recovery and to avoid subsequent blinding. The adaptive controls satisfy this need quite well.

Not all of the pulp dilution needs be done at the pump suction. Typically, some dilution water is added at the surge tank with the incoming stock. However, the amount of dilution at the pump should be enough to lower feed consistency by at least a 0.4% to 0.5% range. A valve position controller (VPC) can then be used, as shown in Fig. 2, to keep the pump suction dilution valve at mid range. The VPC is a proportional integral (PI) controller which manipulates dilution flow into the screen surge tank.

**Application results**

The pulp mill pressure screen project at Port Angeles exceeded all expectations for improved quality, efficiency, cost savings, and ease of process startup. The mill attributes this success to the control system and to the improved technology associated with pressure screen operation.

**Quality and efficiency**

Paper machine and press room efficiencies improved significantly after startup. Fiber cutter (shive) problems were reduced from the No. 1 cause of breaks on the paper machines to the No. 3 cause. Press room performance experienced a similar improvement. Shive related problems on the presses were decreased from the No. 1 cause of web breaks to No. 4 (0.2% of web breaks due to shives). Ray cells in the screen accepts also were reduced by 33%.

In addition to these benefits, the shive content in the paper machine furnish was cut in half while the CSF was increased by 10 points on the RMP refiner line and by 20 points on the TMP line. The additional long fiber improved paper machine drainage and significantly enhanced the physical strength properties of the sheet.

**Cost savings**

The improvements in long-fiber fractions and paper machine drainage resulted in a reduction of kraft usage by at least 3% of virgin furnish (saving US$ 1 million annually). The refiner production rates were also increased by 25% on both lines. This accommodated the increased paper machine efficiencies very well and paved the way for several machine speed-up projects. The increased production also reduced refiner power consumption by 12%, which currently saves us US$ 1.2 million annually.

It was impossible to precisely determine the total dollar savings associated with the pressure screen project. However, there is no doubt that the project payback was less than two years.

**Screen startup**

The new screening system was brought on-line without a major pulp mill down. The extensive instrumentation was very revealing of the process and provided information that allowed operations to complete the startup within 12 h. A process simulator developed in the Bailey Network-90 Distributed Control System (DCS) was used to train operators several months before startup. This also contributed to a successful project, making the transition from simulation to on-line operation very smooth. The simulator also proved invaluable for check out of the DCS configuration.

One of the most important steps during startup was to get the feed consistency calibrated. Port Angeles converts
the 4-20-mA transmitter signal to a percent consistency using a linear regression equation in the DCS. Laboratory data for the regression is collected by averaging the results of triplicate samples taken at each of three different consistencies.

Finally, smart transmitters were used where possible and also contributed to the speedy startup. In particular, smart pressure transmitters could be reanged quickly and on-line without the need for taking the process down or removing in-line instruments. The higher cost for these transmitters was more than paid for during startup, and the smart field devices continue to pay dividends in preventive maintenance.

Implementing the control system in Fig. 2 obviously requires a DCS and extensive field instrumentation. However, the benefits associated with advanced DCS projects typically justify the capital expense. This was clearly the case for our screening project.

**Literature cited**


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**Appendix**

**Automatic blind detection and flush**

Automatic blind detection for a pressure screen can be done in the DCS by monitoring the differential pressure (DP) across the screen basket. In a Hooper system, the rotor provides a pumping action or pressure boost across the basket. The DP in this case is defined as accept pressure minus feed pressure. As this differential drops from a positive to a negative value, blinding occurs, and it becomes necessary to flush or clean the screen.

Other screen manufacturers use foils, which do not boost pressure. The DP for these screens is defined as feed pressure minus accept pressure. In this case, the DP increases as the screen blinds. It is much easier to detect blind conditions on a Hooper screen since the DP change is so large (from +70 kPa to -55 kPa).

Once a screen blind has been detected, an automated flush cycle can be completed as follows:

1. Close the feed and accept valves and turn off the feed pump.
2. Open the reject and dilution valves 100%.
3. Continue running the screen motor and flushing the basket for about 20 s.
4. Put all controllers back on automatic and start the feed pump.

Some pressure screens do not use dilution water and may require more than a 20-s cleaning cycle.

**Automatic startup and shutdown**

The Port Angeles screening system on both refiner lines uses primary (P1) and secondary (S1) screens configured in a cascade arrangement. A small surge tank is used between the P1 and S1 screens. The automated startup sequence for this configuration is as follows:

1. Ensure the cleaner system is running on white water (permissive).
2. Open the dilution valves to the secondary screen 100%.
3. Open the seal water valves and satisfy any other utility requirements for the secondary screen.
4. Start the secondary screen motor and wait 20 s to monitor the motor load and alarm any problems.
5. Start the secondary screen feed pump.
6. Put all secondary screen regulatory controls on automatic and run on white water.
7. Put the secondary screen supervisory control loop in flow mode to maintain a constant reject flow rate.
8. Repeat steps 2-7 for the primary screen.
9. Start up the refiner mill and begin screening thick stock.
10. When both the feed and reject consistencies for P1 and S1 increase and enter the range of their respective consistency transmitters, switch the supervisory control loops to reject rate mode or shive removal efficiency mode.

The automated shutdown sequence is simply a logical reversal of the startup sequence. This ordering of steps was designed for Hooper screens and may require modifications when applied to other manufacturers' screens.
Miscellaneous project notes

There were several miscellaneous points of interest regarding the Port Angeles screening project that are worthy of mention. They relate to screen throughput and runnability, quality, operations, process design, and the controls:

1. Primary screen throughput and runnability were initially a problem at higher production rates on both the TMP and RMP lines. These problems were solved by raising the screen motor horsepower to increase rotor speed. This significantly improved screen throughput without increasing slot size or compromising quality.

2. The original system piping was designed so that secondary screen accepts could be combined with primary screen accepts and sent forward to the cleaners. This configuration helped ease initial throughput problems without significantly affecting quality.

3. Consistency control at the feed pump suction requires a large dilution line to ensure the in-pipe velocity does not exceed 1.2 m/s (3). In addition, the consistency transmitter should be placed 10-15 s downstream from the dilution line. This works well with the adaptive consistency controls and ensures adequate mixing while keeping the control loop deadtime to a minimum.

4. The automated startup sequence made it possible to use a very small surge tank between the P1 and S1 screens. However, the control strategy in Fig. 2 can be easily adapted to accommodate a directly connected P1-S1 as suggested by Hawkes (4).

5. As is the case with most advanced supervisory control systems, ongoing DCS attention is necessary to maintain peak system performance and quality.

6. Properly designed stand pipes with vacuum breakers were used on all accept and reject lines to ensure a constant backpressure on the valves and to guard against cavitation.

7. Although upper and lower dilution water is necessary for proper Hooper screen operation, tight control and flow instruments are not required. We found no correlation between dilution flow and accept quality.

8. As expected, the screening system was found very effective in removing shives from the pulp while the cleaners efficiently removed chop.