Rule based PI control of a TMP refiner's motor load

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ABSTRACT: The load variation of TMP refining greatly influences TMP pulp quality. Combining a rule based system with a PI controller provides an innovative approach to control refiner load. Results show significant reduction in load and freeness standard deviations and the near elimination of refiner trip outs due to process upsets.

KEYWORDS: Control systems, distributed control, load control, loads, quality, refiners, refining, thermomechanical pulps.

The quality of TMP is extremely important in the production of lightweight coated paper. Obviously, refining has the greatest impact on TMP pulp quality. Changes in chip properties, chip delivery, refining zone consistency, refining plates, and refining load cause quality variations in the refining operation.

The TMP refiners at the author's facility consist of two rotating discs with grooved plates as **Fig. 1** shows. A 4000-hp or 2000-hp motor drives each one. A hydraulic cylinder that exerts pressure on one of the discs changes the plate gap. Chips and dilution water enter near the axis and form a few thousandths of an inch pad between the plates. Some of the refiners have a top-winder feeder that ensures a consistent feed. Centrifugal action forces the pulp outward along the plates with discharge at the bottom boundary. Laboratory tests monitor the refining zone consistency for control through adjustment of dilution water flow.

Two linear voltage differential transmitters (LVDT) measure the plate gap. Plate position is another term for plate gap. One LVDT is on the controlled disc's shaft to measure plate movement. The other is on the refiner base to measure physical stretch. Signals from both provide a calculation of a "true" plate position. A "gain only" controller manipulates a hydraulic servo valve to try to sustain a constant plate gap. Machine operators manually adjust the plate position setpoint to maintain refiner motor load. A metering screw conveyer controls the refiner's production rate and specific energy.

In the spring of 1991, the TMP refiner control hardware underwent improvement with installation of a programmable logic controller (PLC) to do refiner plate protection interlocks. This PLC also acted as an interface to the refiner plate position controls for a DCS. **Figure 2** graphically represents the control system. With this upgrade in control hardware, it became feasible to examine the possibilities of closed loop refiner load control.

Analysis

There are many papers on controlling TMP refiners. They primarily mention two large obstacles in controlling load. One is the process gain change that exists in the refining process due to plate wear. Plate wear normally occurs gradually over several hundred hours of plate life. Predicting process gain as a function of plate life is not feasible. This is due to the ever present possibility of plate clashing that reduces plate life or causes plate destruction.

The other obstacle to overcome is the process dynamics resulting from plate gap change. **Figure 3** shows motor load as a function of plate gap. As the plate gap decreases, the motor load increases until a "pinch-off" point occurs. At this point, the refiner's pulp pad collapses and the refiner's load drops significantly.[1] This point changes with plate wear, production rate, and refining consistency. It is obvious from the figure that results could be disastrous us-

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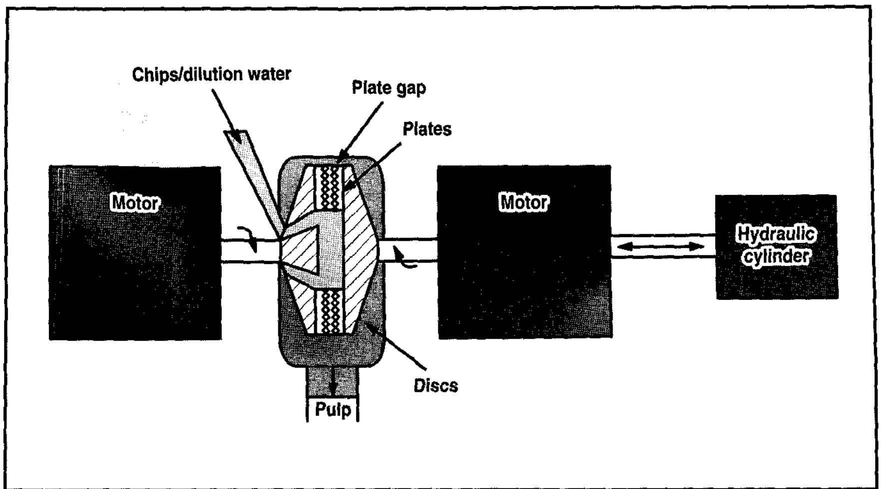
[1]Dumont, G. A. and Astrom, K. J., *PAPRICAN Miscellaneous Reports, MR 98*, PAPRICAN, Pointe Claire (1986).

ing a regular proportional-integral (PI) controller to control refiner load.

Figure 4 shows the short-term motor load variation on a TMP refiner. This particular refiner does not have a top-winder feeder that causes a large part of the short-term variability. **Figure 5** shows the long-term variability of a TMP refining line containing three refiners in series. The values are hourly averages and show as many as five line trip outs over a seven-day period. These hip outs usually occur when the refiner loses load due to refiner base expansion, plate wear, pinch-offs, or improper operator attention. The operator is constantly monitoring refiner load to prevent this. Otherwise trip outs would occur even more frequently. Trip outs cause quality problems and production loss. Figure 5 also shows that there is a large degree of long-term variation in refiner line power and specific energy. Since specific energy correlates directly to such pulp properties as freeness and burst, any reduction in load variability should improve TMP quality.

1. Diagram of TMP refiner



Control strategy

The goals of the power control strategy were threefold:

- Ensure that the power control strategy would be a safer mode of refiner plate movement. The objective would be to decrease or eliminate plate clashing.
- Significantly minimize power and freeness variation in the long term. This improvement would give a higher quality TMP pulp for the paper machine.
- Control the short-term power variation to reduce refiner trip outs. This would not only aid in process performance but also bring quick operator acceptance.

Several different strategies are available to control TMP refiner load. One early reference discussed the implementation of a logic based power control. This controller moved the plate position to minimize long-term variability. It also had some protection against plate clashing.[2] In the past decade, there has been more work dealing with developing faster-acting control schemes. One such scheme involves using an adaptive gain Dahlin controller that would change the sign of its gain based on a pinch-off condition.[1,3] There has also been some instrumentation development in the area of plate positioning and plate clashing detection. Improvements in these areas would aid in refiner plate and load control operation.

The one common theme in all the control designs is to avoid the pinch-off area of refiner operation. After observing operators in pinch-off situations, it became obvious that their success rate in overcoming pinch-offs was extremely high. This led to the decision to try to implement a PI controller that used rule-based logic to recover from pinch-off situations. Development of this type of control scheme would take advantage of the current control system's PLC capabilities, and it would not require additional instrumentation.

Figure 6 shows an example of the two areas of control operation. The function of the rule based logic is simple—determine when the process is in a pinch-off situation and rescue the PI controller from its desire to drive the plates together. Software containing operator mechanisms for determining and recovering from pinch-off situations allowed development of an efficient rule-based system. Operators are able to monitor refiner operation from the DCS, and the system alarms and recovers appropriately when the plates move into the rule-based area of control.

Simplicity was a factor in the development of the PI controller to keep most of the control focus on the rule-base part of the system. To deal with the refiner's process gain change, there was a deadband around the PI controller's power input. Future efforts will involve removal of the deadband and will make the PI controller a self-tuning regulator or a variation of the deadband based on some statistical method to keep the gain constant.

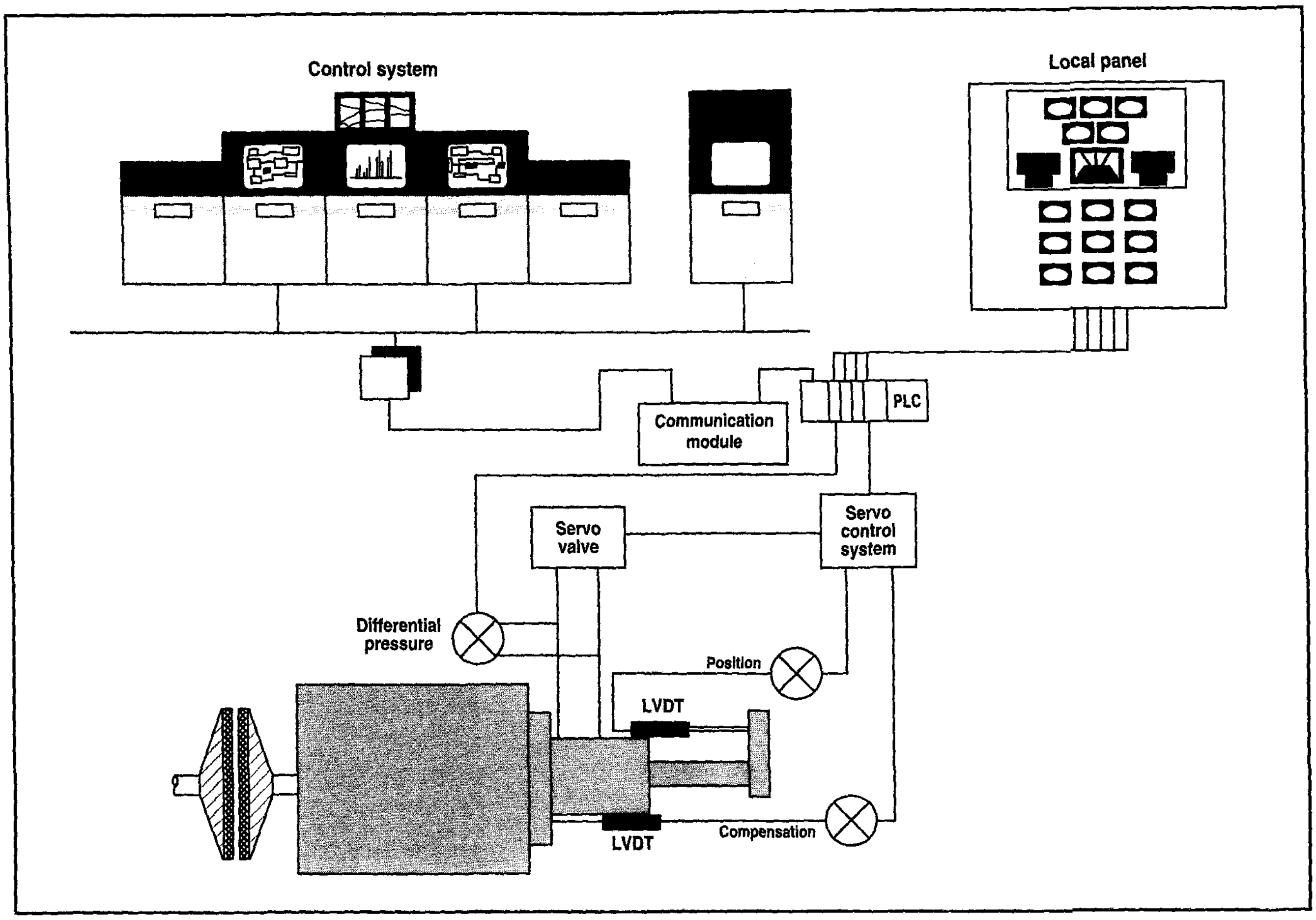
Results

Development and testing of the control scheme was accomplished on a TMP rejects refiner. After a successful trial period, the control strategy was implemented on the mainline refiners in the fall of 1991. Operator

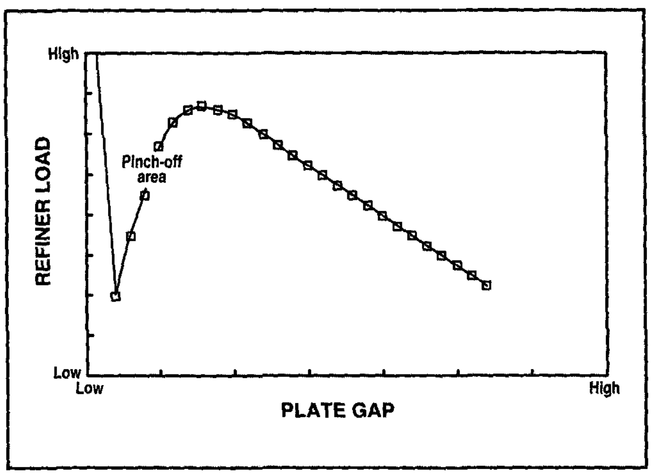
[2]Alsip, W. P., *Digital Control of a TMP Operation*, MacMillan Bloedel Ltd., Vancouver, 1979.

[3]Dumont, G. A., *PAPRICAN Pulp and Paper Reports, PPR 228*, PAPRICAN, Pointe Claire (1980).

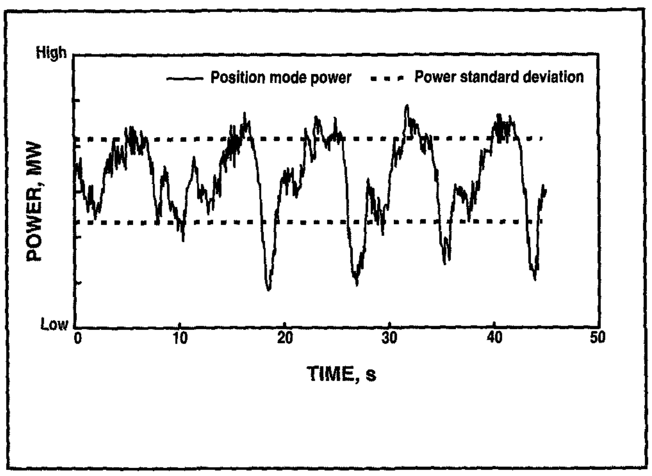
2. Control system



3. Variation in motor load as a function of plate gap



4. Short-term refiner load variation



acceptance was immediate. One line ran 13 consecutive days upon power control implementation without a single minute of downtime due to a refiner trip out. With the system at its maturity, line trip outs have decreased from an average of approximately one per day to approximately one per month.

Figure 7 shows the improvement of refiner line operation during a seven-day period. The long-term power and specific energy variability decreased significantly. The only downtime came from planned outages on the refiner line. **Figure 8** shows graphically the improvement of power control vs. position control over two separate 8-hour periods. The data came from the same refiner line at a one-week interval. **Figure 9** shows the reduction of short-term variability.

There was a trial to determine the actual amount of quality improvement. On the first day of the trial, a refiner line used position control only. The operator adjusted refiner plate positions to maintain a constant average load. Line production rate remained constant. Pulp samples taken every 20 min measured long-term freeness variability. **Figure 10** shows the results. One refiner tried to pinch-off during the middle part of the trial, but the operator stabilized it. It did take time for the operator to return the line to the correct load, however. Two days later, a trial used the same line in power control. **Figure 11** shows the improvement of variability in specific energy and freeness with the line operating in power control. **Figure 12** shows the trial comparisons of load and freeness standard deviations. The trial showed standard deviation reductions of 86% for long-term power, 33% for short-term power, and 41% for freeness. **Figure 13** represents these numbers graphically. Data collected for plate life and energy savings show potential benefits but require more operational time for observation.

Summary

The control strategy presented here provides an effective improvement in refining stability. Refiner trip outs are almost nonexistent. There is a significant reduction in load variation and a concomitant improvement in TMP pulp quality. By closing the control loop on refining load, there is also a capability for a higher level of control implementation in the TMP process. ■

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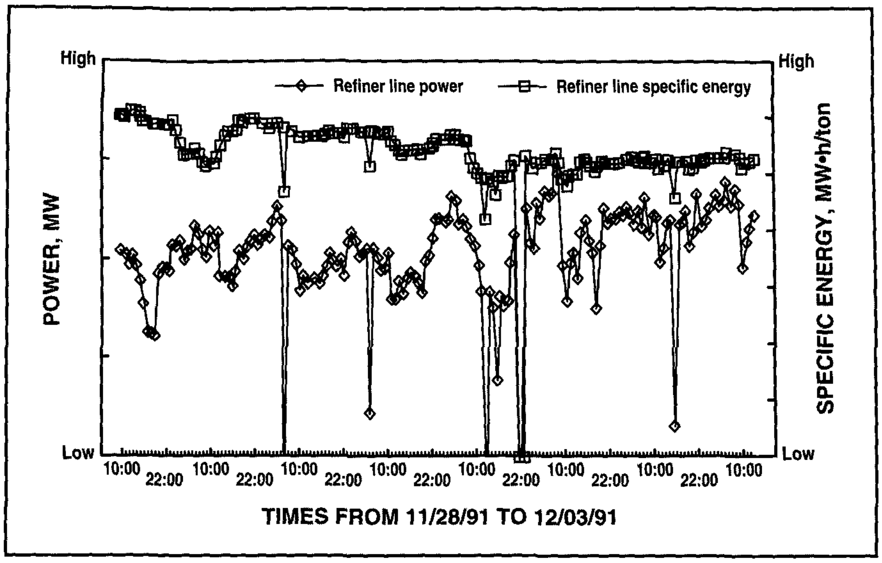
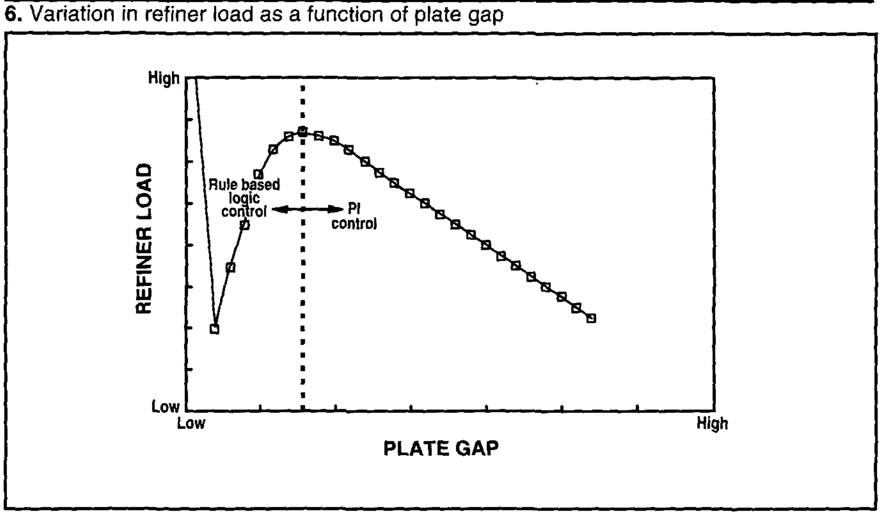
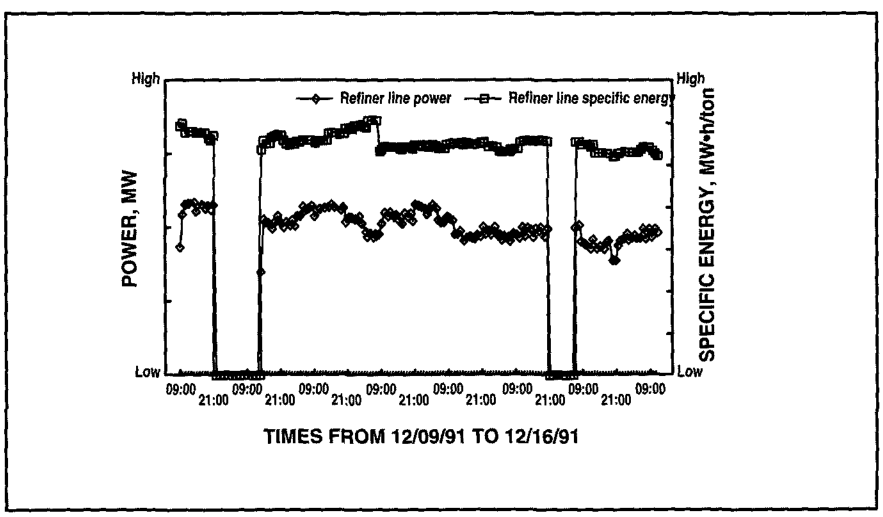
5. Refiner line operation before change over



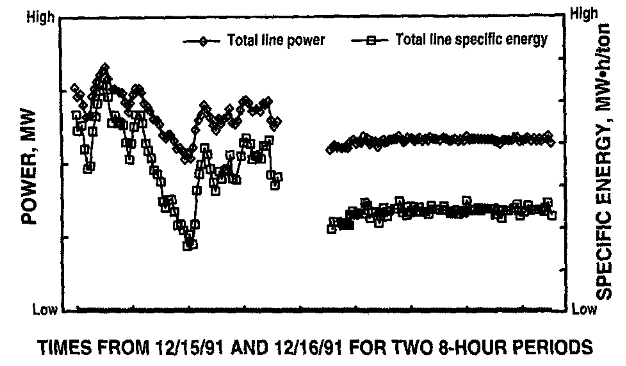
6. Variation in refiner load as a function of plate gap



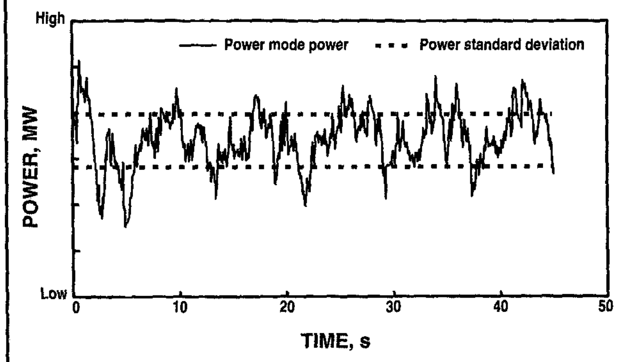
7. Improvement of refiner line operation



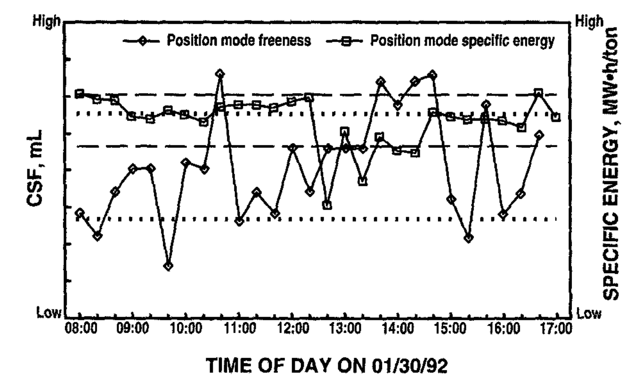
8. Improvement of load variation



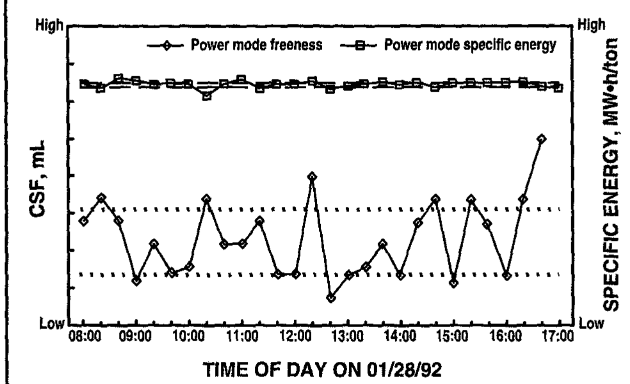
9. Short-term refiner load variation improvement



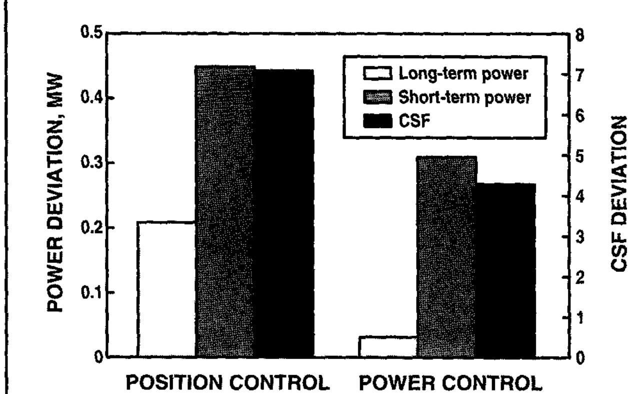
10. Position mode trial



11. Power mode trial



12. Comparisons of load and CSF standard deviations



13. Reductions in standard deviation for long-term power, short-term power, and CSF