Power Cost Reduction Through Advanced Quality Control and Refiner Segment Change at Tembec Pine Falls

Co-Authors:
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ABSTRACT

In late 2004 the Tembec Pine Falls mill, teamed up with Metso’s Paper and Automation divisions to achieve optimal refining performance by consistently producing high quality pulp with minimal power costs. These objectives required the implementation of advanced controls and real time optimization technologies combined with refiner segment configuration changes on the mainline refiners to prove the concept and measure the savings contribution of the segments and controls independently. As significant energy savings and a large reduction in pulp quality variability were accomplished and sustained, the mill decided to proceed with a permanent installation of the main line system and extended the controls and optimization to incorporate screening and reject refining. A mill peak power control and optimization module was also implemented to optimize operations by managing total mill power and peak load.

Four key mechanisms for energy cost reduction were utilized during the project:

- Specific energy reduction through:
  - freeness target shift (possible due to variability reduction),
  - optimization of refiner operation (accomplished through advanced control),
  - refiner segment changes,
- Power cost reduction by lowering mill peak power.

The advanced quality control component was configured to minimize pulp quality variability while achieving the energy reduction objectives.

The results from the project were very positive. Initially, there was a reduction in specific energy in main line refining in excess of 4% attributable to refiner segment changes. This was increased to a 7% reduction in specific energy when the advanced control was implemented on the mainline refiners.

After final optimization of the mainline control system and implementation of advanced control on the screens and reject refiner the energy reduction was increased to more than 10%.

Monthly peak power load at the mill was reduced from 80 MW to less than 75MW. This also resulted in a significant reduction in power costs.

In addition to energy cost reduction, the project achieved the desired reduction in pulp quality variability. The freeness variance on mainline refiners was reduced by 31%. After reject and screen implementation, variance of reject refiner freeness was reduced 10% compared to the level it reached with only mainline control. The quality improvement was not limited to the TMP mill. A measurable increase in MD Tensile and CD Tear occurred on both paper machines during the same time period.

Since completion of the project in November of 2005 the system has sustained energy cost savings for the Pine Falls mill.

INTRODUCTION

The pulp and paper industry is faced with major challenges. For mills operating the thermo mechanical pulping (TMP) process the difficulty has increased significantly with rising power prices, reducing wood supply/wood quality and a reduction in newsprint demand and prices. To offset these challenges, TMP mills need to implement
energy / quality optimization strategies with specific objectives to decrease energy costs while improving product quality.

In late 2004 Tembec Pine Falls (Pine Falls, Manitoba) and Metso’s Paper and Automation Divisions began an effort to address these challenges. The objective was to reduce power costs through advanced quality control and refiner segment pattern changes while improving pulp quality variability.

Tembec Pine Falls is a modern TMP mill with a production capacity of 600 tons per day. Mainline refining includes two RGP 82 CD refiners followed by one stage of low consistency refining. Mainline stock passes through two stages of screening. The accept stock from the mainline screens is sent to the TMP disc thickener. The reject stock is refined again in a single RGP 82 CD refiner. A simplified process flow diagram is shown in Figure 1.

Figure 1. Simplified Process Flow Diagram.

To minimize risk and prove potential savings, the initial work was done on a trial basis. The trial consisted of advanced quality control on the mainline refiners and primary refiner segment pattern changes. Due to the significant energy reduction, the advanced control system was expanded to cover the entire TMP mill.

ADVANCED CONTROL CONFIGURATION

Prior to the implementation of advanced control at Pine Falls, a well established regulatory control system was in place. The regulatory control system provided stable control of refiner gaps, dilutions, and preheater pressure. A simple advanced regulatory control loop was in place for primary refiner blowline consistency. This loop manipulated the primary refiner infeed dilution to keep the near-IR based consistency measurement on target. Pressure screens were controlled to a volumetric reject rate target.

These controls were replaced with an advanced quality control system which included process and pulp quality software sensors (properties estimators), multivariable model predictive control (MPC) with real time economic optimizers. In order to improve quality control and optimize operations, continuous measurement of key process variables is needed. As with most mills, Pine falls relied on analyzers that measured pulp properties using in a limited number of locations in the process. The analyzers process samples sequentially and result in long delays between measurements. To overcome this problem, the key measurements from analyzers are complemented with software sensors to generate continuous predictions of key process and pulp quality properties such as consistencies, freeness, and fiber length, throughout the process. In this configuration, the analyzers are used to automatically tune the software sensors.
The software sensors combine both statistical modeling techniques as well as mechanistic models of the TMP process. These models were developed using historical process data and are tuned on-line to both pulp quality sensors and lab test measurements. The key software sensor outputs for the system are listed in Table 1.

**Table 1.** Key Software Sensor Outputs.

<table>
<thead>
<tr>
<th>Software Sensor Output</th>
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<td>mm</td>
</tr>
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</table>

The control and optimization portion of the system is designed not only to regulate and improve process stability but to steer the process to a more economical operating point. For this purpose, a multivariable model predictive control (MPC) technology was used. Unlike the approach of controlling the process with a series of single regulatory control loops, multivariable model predictive control draws an envelope around the whole process and exploits the fact that multiple variables (screw speed, dilutions, gaps, etc) can be used simultaneously to achieve multiple control objectives (production, freeness, fiber length, motor loads, consistencies, etc.). MPC uses models of the relationships between process inputs (manipulated variables) and the process outputs (controlled variables) to decouple the complex process interactions.

Since the process is controlled as a whole, the different response times in the modeled relationships must be considered. This is addressed using dynamic (time based) models to define the relationships imbedded in MPC.

The manipulated variables used for MPC are listed in Table 2. The controlled variables are listed in Table 3.

**Table 2.** MPC Manipulated Variables.

<table>
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<td>Screen Volumetric Reject Rates</td>
<td>%</td>
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</tbody>
</table>
Table 3. MPC Controlled Variables.

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<th>MPC Controlled Variables</th>
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<td>Total Mill Power Load</td>
<td>MW</td>
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Strand and Fralic have provided a more detailed specification for the advanced control technology used in previous publications\(^1,2\).

**ENERGY COST REDUCTION**

The primary objective of this project was reducing power costs while maintaining the same pulp quality. To achieve the maximum savings possible, four independent cost reduction techniques were employed. Three of the techniques were focused on reducing specific energy (the amount of energy required to produce a quantity of pulp). They were refiner segment pattern changes, freeness target shift, and refiner control optimizations. The specific energy reduction techniques were implemented sequentially to help identify the individual impacts of the changes. The effects are shown in Figure 2. The specific energy values in this figure have been normalized to preserve mill confidentiality.

**Figure 2.** Specific Energy Reduction.

The fourth technique aimed to reduce electrical power costs directly through mill peak load control. Each cost reduction technique is described in more detail in the following subsections.

**Segment Pattern Changes**
The first phase of the project included a significant change in primary refiner segment patterns. Prior to this step, the primary refiner was running standard, unidirectional, low-energy segments. These were replaced with segments designed to aggressively reduce specific energy. The geometry of the segments was configured to produce optimal pumping of stock through the refiner while still achieving fiber development. The selected design was used with great success at the Joutesnsco BCTMP mill.

The new segments were put in place on January 18, 2005 and specific energy reduction occurred right away (as seen in Figure 2). The calculated reduction in specific energy was in excess of 4%. Due to several issues, the segments’ pattern in the flat/cd zones of the primary refiner was replaced with the original ones on May 12, 2005. The new center plate design was kept in place however. This maintained some of the increased stock pumping force and specific energy reduction.

**Freeness Target Shift**

After implementation of advanced quality control, pulp quality variability decreased significantly (as described in the Pulp Quality Variability Reduction section). With lower variability, there was less risk of producing under refined/high freeness pulp. Consequently, pulp freeness targets could be shifted upwards without adversely affecting paper quality.

In the TMP process, freeness is used as an indication of fiber development. As more energy is applied in a refiner, more fiber development occurs and freeness decreases. Consequently, lower freeness correlates with higher specific energy. To take advantage of this relationship, the mainline freeness target was increased by 15 ml. As expected, a significant specific energy shift occurred. Figure 3 expands the data set shown in Figure 2 to make the freeness effect more visible.

**Figure 3.** Specific Energy Reduction Following Freeness Target Shift.

**Refiner Optimizations**

Several optimizations were implemented as part of the advanced control system. The optimizations were configured to push the process into a lower energy operating range, but not to the point where quality targets were violated. They were selected based on successful results in previous energy reduction efforts and an analysis of Pine Falls process data. The key optimizations included production maximization, flat gap maximization, and consistency minimization.
In most TMP processes there is a negative correlation between production and specific energy. This is clearly evident in the Pine Falls’ data as shown in Figure 4.

**Figure 4.** Mainline Production and Specific Energy Relationship.

Due to this relationship, production rate was maximized - when possible- without producing off target pulp. Production optimization was also constrained by the peak load control (see Peak Load Control section).

Flat gaps on all refiners were maximized. Previous work\(^3\) has shown that doing more energy application in the CD zone of a refiner results in lower energy requirements. In this case, the primary flat gap maximization was given slight priority over the secondary flat gap maximization.

Since lower consistency correlates with reduced refining intensity and specific energy, the blowline consistency on the primary refiner was minimized.

All three of these optimizations were implemented when the control system was put online. This accounts for the specific energy reduction shown in Figure 2. Later in the project (June and July 2005), the optimizations were gradually tuned to be more aggressive. The effect of that change can also be seen in Figure 2.

**Peak Load Control**

The power contract at the Pine Falls mill contains and incentive to reduce peak power usage each month. Peak power usage is defined as the highest hourly power load during a month. A portion of the power price paid is determined by the peak load in the previous month. This means any reduction in peak load translates to power cost savings.

The advanced control system was configured to achieve a reduction in peak load. The mill load was configured to be a controlled variable. An optimization was set to maximize production and utilize as much load below the peak as possible. The peak load reduction effort was also aided by the specific energy reduction. As energy requirements were reduced there was a natural reduction in peak load.

With this control strategy, there was a very large reduction in peak load. The reduction can be seen in Figure 5.
After implementation of the three specific energy reduction techniques described above, both Metso and Tembec calculations verified a specific energy reduction in excess of 10%. The mill peak load was reduced by more than 5 MW. These results have actually improved over time. Figure 6 shows the specific energy since completion of the project.

The sustained energy cost savings were possible due to the commitment of both Metso and Tembec Pine Falls to maintain the installed components.

**PULP QUALITY VARIABILITY REDUCTION**
Key pulp quality values were configured as controlled variables in the advanced control system. This allowed for a reduction in pulp quality variability even while energy cost was being minimized. The main pulp quality variable tracked at Pine Falls is freeness. Consequently, freeness was the focus for variability reduction.

The TMP operators set the limits for freeness and the advanced control system moved the manipulated variables to keep the predicted freeness in range. The mainline freeness variance as measured by an inline PQM was reduced by 31%. The variance reduction is apparent from the histogram plotted in Figure 6.

**Figure 6.** Mainline PQM Freeness Histogram.

As mainline freeness variability decreased, the refined reject freeness variability was reduced as well. After the reject refiner advanced control was implemented, rejects freeness variances was reduced by an additional 10%.

**PAPER QUALITY SHIFT**

Occasionally, with a large reduction in TMP specific energy, a drop in paper strength occurs. This is caused by the reduction in energy used to develop the pulp fibers. With this project no reduction in paper strength was observed. During the timeframe of project implementation paper strength actually improved. The strength improvement may be partially caused by the reduction in pulp quality variability.

Figure 7 shows the upward shift in CD tear strength that occurred on the paper machines after advanced control was implemented. The data in this chart was normalized to preserve mill confidentiality. A similar shift is apparent in the MD tensile data.
CONCLUSIONS

The effort to reduce energy costs while improving pulp quality variability was successful. Through advanced control implementation and segment pattern changes a specific energy reduction of more than 10% was achieved. Further energy cost savings were achieved by reducing the peak power load of the mill.

The quality control portion of the system reduced mainline freeness variance by 31% and rejects freeness variance by 10%. In spite of the significant energy reduction, an increase in paper strength was observed.

Through proactive maintenance of the installed components, the benefits continue to be realized at the Tembec Pine Falls’ mill.

REFERENCES


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International Mechanical Pulping Conference 2007
Presentation Overview

- Introduction/Background
- Advanced Control Configuration
- Energy Cost Reduction
  - Segment Pattern Changes
  - Freeness Target Shift
  - Refiner Optimizations
  - Peak Load Control
  - Long Term Energy Cost Reduction
- Pulp Quality Variability Reduction
- Paper Quality Shift
- Summary/Conclusions
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- **Paper Quality Shift**
- Summary/Conclusions
The Pulp and Paper Industry is Faced with major challenges.

For Thermo-Mechanical Pulping (TMP) mills these include:

- Rising Power Prices
- Reducing in Wood Supply Quality
- Reduction in Newsprint Demand/Price

To remain competitive, TMP mills must optimize their process to both decrease energy cost and improve pulp quality.
In Late 2004 Tembec Pine Falls and Metso’s Paper and Automation Divisions began an effort to address these challenges.

Project Objective –
Reduce Power Costs and Maximize Product Quality.

Method –
TMP Process Optimization through segment change and advanced quality control.
Introduction/Background

➢ Tembec Pine Falls, Pine Falls, Manitoba
  – Modern Thermo Mechanical Pulping/Newsprint Mill
  – 1 Thermo-Mechanical Pulping Line (RGP 82 CD Refiners)
  – 2 Newsprint Machines
  – ??? metric tons/day average Newsprint Production
Introduction/Background

☉ Simplified Process Flow Diagram:

PINE FALLS PAPER CO., PINE FALLS
THERMOPULP® PLANT NEWSPRINT

- Freeness/Fiber Length (every 30 minutes)
- Consistency (continuous)
Initial work done on trial basis (mainline refiners only) to:
- Prove energy cost savings.
- Minimize risk.

Trial showed significant energy cost reduction.

Trial system was made permanent and advanced control extended to cover all of TMP.
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- **Pulp Quality Variability Reduction**
- **Paper Quality Shift**
- **Summary/Conclusions**
Prior to advanced control implementation, a good regulatory control system was in place.

This included stable control of:
- Production Rate
- Refiner Dilutions
- Plate Gaps
- Pressure Screen Volumetric Reject Rates
- Primary Blowline Consistency (using near-infrared consistency sensor and infeed dilution flow)
Advanced Control Configuration

➢ The advanced control system used has two major components:

– Software Sensors (property estimators)

– Model Predictive Control (MPC) with real-time economic optimization
Continuous process control works best with continuous process measurements.

In most TMP mills this is a challenge because many key optimization values are:

- unmeasured (cyclone consistencies, etc)
- measured infrequently (pqm samples, lab samples, etc)
- not measured accurately (lab consistencies, production rates, etc)

Software Sensors help overcome these challenges.
Advanced Control Configuration – Software Sensors

- **Software Sensors**: On-line, mathematical models that generate continuous property predictions.

- They can be a substitute physical sensors or lab measurements.

- They can also be used to supplement physical sensors and lab measurements.
  - In this case, the measurements are used to tune the software sensor on-line.
For this system, the software sensors used were:

– Specifically designed for the TMP process.
– Built from a combinations of statistical and mechanistic modeling techniques.
– Developed from historical process data.
– Tuned on-line to available pulp quality sensors and lab measurements.
## Advanced Control Configuration

### Key Software Sensor Outputs:

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</tbody>
</table>
The control/optimization part of the system was designed to:

- Improve process stability/reduce quality variability.
- Steer the process to a more economical operating point.

This was done using a Model Predictive Control Technology (dynamic matrix based).
**Model predictive control vs. typical advanced regulatory control:**

<table>
<thead>
<tr>
<th>Typical Advanced Regulatory Control</th>
<th>Model Predictive Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combination of individual PID control loops.</td>
<td>Singe controller with multiple inputs/outputs.</td>
</tr>
<tr>
<td>Loop interactions can’t be avoided, but can be minimized with proper tuning.</td>
<td>Controls process as a whole so interactions are eliminated.</td>
</tr>
<tr>
<td></td>
<td>Allows process to be both controlled and optimized.</td>
</tr>
</tbody>
</table>
Advanced Control Configuration – MPC

To decouple variable interactions and achieve multiple control objectives simultaneously, dynamic models are developed between each manipulated and controlled variable:
**Model Predictive Control (cont)**

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## Model Predictive Control (cont)

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<td>Total Mill Power Load</td>
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More information on the control technology used can be found in previous publications:


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- Advanced Control Configuration
- **Energy Cost Reduction**
  - Segment Pattern Changes
  - Freeness Target Shift
  - Refiner Optimizations
  - Peak Load Control
  - Long Term Energy Cost Reduction
- Pulp Quality Variability Reduction
- Paper Quality Shift
- Summary/Conclusions
Energy Cost Reduction

- Energy cost reduction provided the financial justification for the project.

- To maximize savings four independent cost reduction techniques were employed:
  - Refiner segment pattern changes (reduced specific energy).
  - Freeness target shift (reduced specific energy).
  - Refiner optimization (reduced specific energy).
  - Mill peak load reduction (reduced power price).
Energy Cost Reduction

Specific energy reduction techniques were implemented sequentially to help quantify the impacts:
Energy Cost Reduction – Segment Pattern Changes

- Prior to the project, the refiners were running standard, unidirectional, low energy segments.

- Primary segments pattern was replaced with a version designed to aggressively reduce energy.

- The new segment geometry was configured to aggressively pump stock through the refiners while preserving fiber development*.

Energy Cost Reduction – Segment Pattern Changes

- New segment pattern installed on January 18, 2005.
- Specific energy reduction occurred immediately.
- Calculated reduction from segments was more than 4%.
- New pattern removed from flat and conical zones on May 12, 2005, but new center plate design was maintained.
Energy Cost Reduction – Segment Pattern Changes

- Advanced Control Begins
- Optimizations Re-Tuned
- New Segment Pattern Partially Removed
- Baseline Energy

% of Baseline Specific Energy

- Segement Trial Begins
- Freeness Target Increased

Dates:
- 11/19/04
- 1/8/05
- 2/27/05
- 4/18/05
- 6/7/05
- 7/27/05
- 9/15/05
After implementation of advanced control, pulp quality variability decreased significantly.

This allowed mainline freeness to be increased 15ml without hurting paper quality.

Higher freeness corresponds to lower specific energy.

The higher freeness resulted in significantly lower specific energy.
Specific energy following freeness target shift:

- Baseline Energy
- Freeness Target Increased
Refiner optimizations were configured to push the process to the most efficient operating range without hurting controlled variables.

Specific optimizations were selected based on previous control efforts and multivariate analysis of operating data.

These included:

- Production Rate Maximization
- Flat Gap Maximization
- Bowline Consistency Minimization
Energy Cost Reduction – Refiner Optimizations

➢ Production Rate shows a strong negative correlation with specific energy:
This lead to an optimization that maximizes production rate to minimize energy.

This optimization is constrained by total mill load to prevent setting a load peak.
Previous work by Strand et al* has shown that running wide flat gaps can result in lower specific energy.

This lead to an optimization that maximized refiner flat gaps.

Energy Cost Reduction – Refiner Optimizations

- Low bowline consistency correlated with lower refining intensity in the process data.

- The relationship was the strongest in the primary refiner data.

- This lead to an optimization that minimized consistency (with the most emphasis on primary blowline consistency).
Once all these optimizations were on-line and tuned correctly energy dropped significantly.

![Graph showing energy cost reduction over time with specific milestones marked such as Segment Trial Begins, Advanced Control Begins, Freeness Target Increased, Optimizations Re-Tuned, and New Segment Pattern Partially Removed. The graph plots % of Baseline Specific Energy against dates from 11/19/04 to 9/15/05.]
The Pine Falls power contract contains an incentive to reduce monthly peak power usage. A portion of the power price paid is determined based on the highest hourly load from the previous month. Any reduction in peak load translates to power cost savings.
Energy Cost Reduction – Peak Load Control

- Mill Peak load set as a controlled variable.

- All manipulated variables (emphasis on production rate) are manipulated to prevent exceeding mill determined peak.

- As specific energy decreased, a natural reduction in peak load also occurred.
Energy Cost Reduction – Peak Load Control

Peek Load Reduction:

- Baseline Average Peak
- Control Implementation

Month


Mill Peak Load (MW)
Energy Cost Reduction — Long Term Reduction

- Both Metso and Tembec calculations confirmed a specific energy reduction greater than 10%.

- Mill peak power load was reduced more than 5 MW.

- These savings have improved over time.
Energy Cost Reduction – Long Term Reduction

Baseline Energy

% of Baseline Specific Energy

12/1/05 1/20/06 3/11/06 4/30/06 6/19/06 8/8/06 9/27/06 11/16/06 1/5/07
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Pulp Quality Variability Reduction

- The main pulp quality variable tracked at Pine Falls is Freeness.

- Freeness was configured as a controlled variable.
  - Operators set freeness limits.
  - Control system minimized energy while keeping freeness in range.

- With control latency freeness variance was reduced by 31%.
Pulp Quality Variability Reduction

- Both the variability reduction and freeness target shift are apparent.
Pulp Quality Variability Reduction

- With mainline control implementation, refined reject freeness variance decreased.

- After control was implemented on screens and rejects, refined reject freeness variance decreased an additional 10%.
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- **Paper Quality Shift**
- Summary/Conclusions
A reduction in TMP specific energy can sometimes result in a reduction in paper quality.

This did not occur at Pine Falls.

Paper strength actually improved during the timeframe of the project.
Paper Quality Shift

Normalized Paper Machine CD Tear:

- A similar shift in MD tensile was observed.
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Summary/Conclusions

- The effort to reduce energy costs and improve pulp quality was successful.

- Through advanced control and segment pattern change specific energy was reduced more than 10%.

- Mill peak power load was reduced by more than 5MW.

- Mainline freeness variance was decreased by 31% and paper strength improved.

- Through proactive maintenance the benefits continue to be realized by the Pine Falls mill.
Thank You