The Effect of Hot Storage on High Yield Pulp

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THE EFFECT OF HOT STORAGE ON HIGH YIELD PULP

Jeffrey D. Hampton
April 2001

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THE EFFECT OF HOT STORAGE ON HIGH YIELD PULP

Jeffrey D. Hampton

Western Michigan University, 2001

In order to comply with new environmental regulations, the Menasha Corporation’s Paperboard Division installed a 150 ton capacity blow tank and non-condensable gas collection system at the Otsego, MI mill. Concerns over the potential changes in pulp quality resulting from the hot storage time created a need for this study.

The objectives of the study were to determine the effects of hot storage under alkaline conditions on the refinability, fiber characteristics, and brightness of a semichemical mixed hardwood pulp. An experiment was designed to duplicate in the laboratory the internal conditions of the blow tank. Pulp was then stored at varying time periods from 2 to 8 hours and refined in a PFI Mill Laboratory refiner at three freeness levels (630, 400, 200 mL CSF). The pulp brightness was tested and compared against a control. Finally, the samples were tested for fiber characteristics by a Pulmac Z-span 3000 and given a pulp strength index value.

The results proved to be beneficial at the industrial level. The refinability of the pulp samples after hot storage was increased by 2.5% after two hours and 7.1% after eight hours. The potential annual energy saving in the beater room is $106,500. The pulp strength index after hot storage increased. There is no correlation between
storage time and change in PSI although the average strength increase across all storage times and refining levels was 8.3%. Pulp brightness was unaffected at the 2 and 4 hour storage times however, after 6 and 8 hours the pulp darkened by 10.3% to 18% as a result of alkali darkening.
The Effect of Hot Storage on High Yield Pulp

By

Jeffrey D. Hampton

A Thesis
Submitted to the
Faculty of The School of Engineering and Applied Sciences
in partial fulfillment of the
requirements for the
Degree of Bachelors of Science
Department of Paper and Printing Science and Engineering

Western Michigan University
Kalamazoo, Michigan
April 20
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PROBLEM STATEMENT

The problem to be studied in this project is the effect of hot storage on high yield pulp. Semichemical mixed hardwood pulp stored at approximately 200°F for up to 12 hours will be the specific pulp studied. In order to understand the effect of hot storage, the fiber characteristics, refinability, and brightness must be tested over the course of the storage time.

The idea for this project arose in April of 2000 while working as a co-op for the Menasha Corporation's Paperboard Division in Otsego, Mi. The mill produces 800 tons per day of corrugating medium on two machines. The furnish consists of 70% OCC and 30% virgin mixed hardwood semichemical pulp processed on site. In an effort to meet Cluster Rule environmental standards, the pulp mill was to bring a 150 ton capacity blow tank on-line in January 2001. The new vessel replaces a much smaller dilution tank, which can not be upgraded to meet the new environmental standards for the collection of non-condensable gases. The blow tank will also give the pulp mill added flexibility, in terms of storage when problems arise. Because of the large blow tank capacity, the digester may continue to run in the event that the equipment downstream must shut down. However, few data are available on how the pulp quality may change due to the storage in the vessel. This lack of information created a need for this research.
LITERATURE REVIEW

Significant research has been done on the effect of storage on high yield pulps. This research is mainly focused on storing mechanical or thermo-mechanical pulps at high consistencies and temperature after hot stock refining. Analogies can be drawn from the nine sited works to predict the effect of hot storage on semichemical pulps stored before brown stock washing. Two major concerns, brightness reversion and the effect on strength properties are addressed.

Storing the pulp at a high temp was shown to decrease pulp brightness. Brightness values of TMP stored at 100°C decreased by 10% over 24 hours according to Lunan et al. (1). They also found significant losses in brightness at storage temperatures above 65°C. Harris and Karnis (2) studied the effect of time and temperature on brightness reversion of TMP and found a significant loss of brightness. They attributed it to an acceleration of aging due to elevated temperatures.

Pulp consistency is a factor in brightness reversion of stored high yield pulps. Pulp stored at low temperatures over a wide range of consistencies (4-50%) displayed no significant changes in brightness. However, at consistencies between 4-15%, brightness decreases were proportional to temperature. TMP stored at 80°C at a consistency of 4-15% lost 4% ISO brightness. At consistencies above 15 percent, no further losses occurred (1). Harris and Karnis (2) also found
that a darkening occurred most dramatically below 15% consistency; though the losses continued to occur up to 40% consistency.

Inhibition of brightness reversion has been extensively studied. Pan and Ragauskas (3) investigated the arrest of induced reversion by various sulfur compounds. Thiols were found to be effective in short term storage and disulfides were found to be effective during longer storage times. Hindered nitroxide is among the newest of yellowing inhibitors. BTMP treated with such an inhibitor had brightness reversions after 600 days similar to bleached kraft pulp over the same time period (4).

Storage at high temperature affects the freeness of TMP. Lunan et al. (1) found an increase in freeness of TMP when stored at 100°F. In fact, after 24 hours, the freeness increased from 100 mL CSF to nearly 300 mL CSF. They also reported an increase in CSF with increase of consistency for temperatures above 65°C.

Strength properties are adversely affected by hot storage. Lunan et al. (1) reported a 50% decrease in burst index after 24 hours of hot storage, with the steepest decline between zero and eight hours. Breaking length and wet web tensile were also significantly reduced. However during the same time period, the wet-web stretch increased by nearly 100%. The loss of strength and increase of stretch in the wet web may adversely affect the machine runnability (5). Latency caused by curl setting of the fibers induced by high temperature during storage is the cause of the loss of strength (1). Harris and Karnis (2) reported similar conclusions. They state that curl setting creates residual latency, which can not be removed.
Barbe et al. (6) developed the OPCO process in which fibers are permanently curled by heat and chemicals. This process allows high yield pulp to have characteristics of lower yield sulfite pulp thus improving the runnability on the paper machine. The OPCO process could be used to reduce the loss of strength resulting from hot storage and thereby reducing the negative effects.

Dawson et al. (7) proposes recirculation of the pulp slurry at elevated temperatures in order to rapidly remove latency in the laboratory. Their research shows a decrease in latency removal time of 86% over the traditional method of hot agitation. This method could be useful if the experimental pulp is stored under near freezing conditions between testing phases.

By collectively studying the above body of research, we can assume that brightness and strength properties will decrease with storage time and temperature. We can also conclude freeness values will increase with time and temperature of storage. Some brightness reversion may be avoided by the addition of thiol or hindered nitroxide to the pulp slurry.
EXPERIMENTAL

Materials

The hardwood pulp was obtained from the Menasha Corporation's Otsego Board Mill. The Otsego mill utilizes a semichemical cooking process using sodium carbonate as its cooking chemical applied at 300 lb./Ton. The wood is fed into a continuous digester and cooked at 350 °F for 30 minutes. After cooking is complete, the pulp travels through a Defibrator and out the blow line where the samples are to be taken. Four samples will be required to conduct the four retention trials. No chemicals were added with the exception of weak black liquor used to dilute the pulp to 4% consistency. Standard pulp and paper industry testing equipment was used in addition to the Pulmac Z-span 3000.

Treatments

Each treatment required 500 oven dry grams of pulp. Each sample was divided into equal halves and randomly assigned treatment A or B. Treatment A is the control treatment and includes no storage. Each trial must have a control as reference because the samples will be collected at different times. Treatment B included hot storage for varying times and is the experimental treatment. The following table presents each treatment in detail and order of experimentation.
Table 1

Experimental Conditions

<table>
<thead>
<tr>
<th>Treatment A</th>
<th>Treatment B</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 gram sample</td>
<td>250 gram sample</td>
</tr>
<tr>
<td>No hot storage</td>
<td>Hot storage</td>
</tr>
<tr>
<td>Washing</td>
<td>Washing</td>
</tr>
<tr>
<td>Cold Storage</td>
<td>Cold Storage</td>
</tr>
<tr>
<td>Refining (3 levels)</td>
<td>Refining (3 levels)</td>
</tr>
<tr>
<td>Pulp testing</td>
<td>Pulp testing</td>
</tr>
</tbody>
</table>

**Hot Storage:**

Hot storage was carried out in a hot water bath. Approximately 250 o.d. grams of pulp will be diluted to 4% consistency by using black liquor from the pulp mill brown stock washer in a metal 2.5 gallon pail. The sample will then be placed inside a 5 gallon steaming vessel for the desired storage time. The water inside the steaming vessel was maintained at boiling temperatures for the entire trial period. Four storage times (2, 4, 6, and 8 hours) constitute the four trials.

**Washing/Screening:**

After storage, the pulp was then washed at 95°C to prevent the curl-setting of fibers caused by latency. Washing was carried out by dilution and extraction of the hot water in a Noble and Wood handsheet mold. The pulp had conductivity less than 700 µmho after washing and was prepared for refining in accordance with TAPPI T 205 cm-85.
Cold Storage:

The washed pulp samples were stored in a cooler at 4°C to prevent cellulose degradation between testing phases. Hot storage trials and pulp testing were conducted with minimal cold storage time variance as to reduce experimental differences.

Refining:

Pulp was refined in the PFI laboratory refiner. The operation of the PFI mill is described in detail in TAPPI T 248 cm-85. Both treatments of pulp for a specific storage time were refined in the same manner. Three refining levels were attained: 630 mL, 450 mL, and 200 mL CSF respectively. Thirty oven dry grams of pulp at each level were needed. After refining was completed, the stock was tested in the Pulmac fiber analyzer and made into brightness pads according to TAPPI T 452 om-92.

Pulp Testing:

The pulp was tested using a Pulmac Z-Span 3000 (Figure 1). The Z-Span 3000 is an automated pulp testing machine. The tester has two stations, an automated handsheet former and an automated testing station. A diluted sample of pulp is added to the forming station of the machine and it produces six small handsheets. An operator removes the handsheets, three are saturated with water and all placed into the testing station. This unit tests both the wet and dry zero span and short span tensile.
Fast Strength Testing

Using the Z-Span 3000, operators can determine the strength of over 100 pulp samples in a 24 hour period. Once a slurry of measured consistency has been prepared a shift tester can process subsequent samples every 10 minutes.

**Description**

Pulmac’s Z-Span 3000 offers a complete Z-Span technology package in one compact and highly automated system. Any pulp or stock sample is first prepared at the Z-Span 3000 work station. The resulting slurry is then poured into the sheet former reservoir and 5 minutes after activation, 6 sample sheets are automatically delivered, ready to be weighed and loaded onto the tester feed tray. Upon initiating the hands-off test cycle, the custom-configured Z-Span database will be automatically updated within 5 minutes with numbers sensitive to changes in fiber strength, bonding, length and/or alignment.

**Benefits**

The Z-Span 3000 brings new certainty to pulp strength. Based on systematic testing, the numbers generated by the Z-Span 3000, will alert you before creeping process changes deteriorate pulp strength to beyond tolerance limits. Pulmac Z-Span strength testing can tell you what you need to know about the fiber strength your customer, the papermaker, wants. Direct benefits to your productivity can include, reducing downgraded pulp, penalty payments, and warehousing costs, all the while improving communication links with pulp users. Bottom-line: increased profitability.
From these tests, the bonding ability (B), fiber length (L) and fiber strength (FS) are calculated, as indicated below.

\[
\begin{align*}
FS &= \text{wet zero span value} \times \text{actual basis wt/target basis wt} \\
L &= \text{wet short span value/wet zero span value} \\
B &= \text{dry short span/wet short span}
\end{align*}
\]

Note that the fiber length is a unit less value representing a characteristic of the fiber.

Next, the pulp strength index (PSI) is generated. The PSI is a function of the bonding ability, strength and length of the fibers.

\[
PQI = FS \times L \times B^2
\]

The PSI was calculated for each refining level and plotted against storage time to determine the affect of storage on pulp quality.

Brightness Testing

Brightness pads were formed as per TAPPI T 452 om-92 to monitor brightness loss over the storage periods.
RESULTS

Refinability

The 630 mL freeness level is most significant in this study because it represents the level of refining done by the primary refiners in the pulp mill. At this level, the refinability of the pulp increased with storage time resulting in an increase of seven percent after 8 hours.

Table 2 contains the complete results of the refinability study. It is clear that the refining properties of the pulp are affected by storage time at all refining levels. The data does not support an increase in refinability with storage time on pulps refined to 400 and 200 ml CFS. It is also clear that the six hour sample refined differently from the other trials, showing a higher degree in refinability in both the experimental and control. This may in part be a result of the cooking recipe or experimental errors.

Table 2

<table>
<thead>
<tr>
<th>CSF (mL)</th>
<th>PFI Mill Revolutions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 hr</td>
</tr>
<tr>
<td>Exp'l</td>
<td>Control</td>
</tr>
<tr>
<td>630</td>
<td>1950</td>
</tr>
<tr>
<td>400</td>
<td>4400</td>
</tr>
<tr>
<td>200</td>
<td>5900</td>
</tr>
</tbody>
</table>
The increase in refinability at the 630 mL level will result in energy savings in the mill setting. Based on an average cost of 1.5 million dollars per year in energy costs, the pulp mill may save up to $106,500. Table 3 below provides the approximate annual cost saving per storage time.

Table 3

Cost Savings as a Result of Hot Storage

<table>
<thead>
<tr>
<th>PFI Mill Revolutions to Achieve 630 mL CSF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage Time</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>2 hr</td>
</tr>
<tr>
<td>4 hr</td>
</tr>
<tr>
<td>6 hr</td>
</tr>
<tr>
<td>8 hr</td>
</tr>
</tbody>
</table>

Pulp Strength Testing

The pulp strength was tested by Pulmac Industries on the Pulmac Z-span 3000. The results show an increase in pulp strength index at all refining levels and storage times with the exception of the 630 and 400 mL freeness levels of the two hour storage time and the 400 mL freeness level of the six hour storage time. There seems to be no correlation between PSI and storage time; however, PSI and refining level are strongly correlated. An increase in refining level produces an increase in PSI over all storage trials. Table 3 below contains the PSI data for each storage time.
### Table 4

Effect of Storage Time and Refining on PSI values

<table>
<thead>
<tr>
<th>Storage Time</th>
<th>Freeness level mL</th>
<th>Control</th>
<th>Exp'l</th>
<th>%Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 hr 630</td>
<td>84.8</td>
<td>81.3</td>
<td>-4.1</td>
<td></td>
</tr>
<tr>
<td>2 hr 400</td>
<td>128.9</td>
<td>116.5</td>
<td>-9.6</td>
<td></td>
</tr>
<tr>
<td>2 hr 200</td>
<td>160.8</td>
<td>164.4</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>4 hr 630</td>
<td>84.8</td>
<td>92.6</td>
<td>9.2</td>
<td></td>
</tr>
<tr>
<td>4 hr 400</td>
<td>128.9</td>
<td>130</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>4 hr 200</td>
<td>160</td>
<td>178.8</td>
<td>11.8</td>
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<tr>
<td>6 hr 630</td>
<td>77.5</td>
<td>93.9</td>
<td>21.2</td>
<td></td>
</tr>
<tr>
<td>6 hr 400</td>
<td>120</td>
<td>106.9</td>
<td>-10.9</td>
<td></td>
</tr>
<tr>
<td>6 hr 200</td>
<td>161.3</td>
<td>173.4</td>
<td>7.5</td>
<td></td>
</tr>
<tr>
<td>8 hr 630</td>
<td>78.7</td>
<td>81.7</td>
<td>3.8</td>
<td></td>
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<tr>
<td>8 hr 400</td>
<td>129.1</td>
<td>133.8</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>8 hr 200</td>
<td>178.9</td>
<td>201.3</td>
<td>12.5</td>
<td></td>
</tr>
</tbody>
</table>

Anomalies are in bold

### Brightness Testing

The effect of hot storage times of two and four hours on pulp brightness is statistically insignificant using the six sigma method of data analysis. However, storage times of six and eight hours are significantly affected. Because the brightness of the unbleached pulp is low, any slight increase or decrease may be undetectable to the eye. Visual comparisons of the pulp brightness pads were ambiguous. Figure 1 below shows the effects of hot storage on pulp brightness. A complete table of all the brightness data can be found in appendix 2.
Chart 2. Effect of Hot Storage on Brightness
CONCLUSIONS

The refinability of high yield pulp increases with retention time under alkaline conditions. The 630 mL refining level showed an increase in refinability of 2.5% after 2 hours of storage to 7.1% after eight hours of hot storage. The other refining levels also produced a reduction of energy input however, in a random manner. The 630 mL freeness level is representative of the target freeness of the pulp mill's primary refiners. The average annual energy cost to power the refiners is $1,500,000. Storing the pulp in the blow tank for eight hours could result in cost savings of $106,500 per year.

The PSI value of the pulp increases with storage time in the blow tank and with refining energy. There is no correlation between storage time and extent of change in strength. The average strength increase across all refining levels and times is 8.3%. For the 630 mL freeness level an unusually high increase of 21.2% occurred after six hours of storage. If this value is ignored the average strength increase at the 630 mL level is 8.8%.

Pulp brightness is unaffected after storage times of two and four hours. Storage of pulp for six and eight hours results in alkali darkening by 10.3% to 18.0. Since the pulp investigated in this experiment is used to make corrugating medium a darkening of the pulp is not currently a concern of the mill. Adding hydrogen peroxide, thiols,
or hindered nitroxide in the high density storage chests could counteract the alkali darkening if new products sensitive to brightness changes are developed.

It is apparent in the mill setting that storing high yield pulp under alkaline conditions for eight hours in a blow tank will result in alkaline darkening, an increase of refinability, and an increase in pulp strength. Annual savings of $105,000 in power costs may result from the increase in refinability.
REFERENCES


8. TAPPI Test Methods. 1997. TAPPI Press, Atlanta, GA.

Appendix-A

Experimental Data
<table>
<thead>
<tr>
<th>target</th>
<th>2c</th>
<th>2e</th>
<th>2-var</th>
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<th>4-var</th>
<th>6c</th>
<th>6e</th>
<th>6-var</th>
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