J&L Fiber Services
Pulp Challenge from the J & L Spring 2007 E-Newsletter “TakingStock”

Low Consistency Refining Optimization Opportunity

Grade: Linerboard

Refiner: 1-46” Beloit DD Refiner
Refiner Motor: 2000 HP, 450 RPM
Refiner Plate Pattern:
1. 46” diameter refiner plate (46” diameter refining zone)
2. J&L Reverse Flare “Anti-Plug” Design
3. Bar width = 2.0/16”
4. Groove Width = 2.8/16”
5. Groove Depth = 5.5/16”
6. KM/Rev = 60

Alloy: C90

Recommended Flow Range for a 46” Refiner w/ 46” Plates at 450 RPM: Low = 1025 GPM, Medium = 1675 GPM, High = 3275 GPM

Fiber: OCC
Flow: 790 GPM
Consistency: 4.8%
HP Applied: 781 HP
Refiner No Load: 325 HP
Refiner Issues:
1. 1 month plate life – Failure mode: bar wear due to serration (refiner plate clashing)
2. Poor OCC fiber strength development

What can be done with the refining process and with the refiner plate design / alloy to help increase plate life and improve OCC fiber strength?

Solution: Apply the J&L Low Consistency Refining Six Step Sub-System Analysis to come up with the optimization solution that will improve plate life and increase the OCC fiber development. (To learn more about this process, refer to “Refining System Optimization – A Simple Six-Step Process” at http://www.jlfiberservices.com/takingstock/TakingStockArchive.htm).

J&L REFINING SIX STEP “SUB-SYSTEM” ANALYSIS

Hydraulics - Flow
Consistency
Specific Energy (HPD/T)
Delta CSF / HPD/T
Refining Intensity (WS/M)
Plate Material

Process Optimization &/or Pattern Alloy Recommendation
Step I. **Hydraulics** – Evaluate Refiners Hydraulic Conditions and Compare to the Recommended Industry Standards

A. For optimal fiber development, the recommended hydraulic (flow) range for 46” refiner with refiner plates that have 46” of effective refining area and a 450 RPM motor is Low = 1025 GPM, Medium = 1675 GPM, High = 3275 GPM (see capacity chart below).

<table>
<thead>
<tr>
<th>DIA INCHES</th>
<th>MAX POWER HP</th>
<th>NORMAL RPM</th>
<th>NO LOAD HP</th>
<th>FLOW RATES - GPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>46</td>
<td>2000</td>
<td>450</td>
<td>325</td>
<td>LOW 1025</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MED 1675</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>HIGH 3275</td>
</tr>
</tbody>
</table>

B. The current flow thru this refiner is **790 GPM**. This is considered very low. When the refiner is operating in the correct hydraulic range …

- The rotor is stable & centered
- The probability of fiber mat formation between the plates increases
- Fiber strength development potential is maximized
- Plate life potential is maximized
- Variation is minimized.

B. The negatives to low flow conditions are:

- Little or No Fiber Mat Between Plates
- Fiber Channeling
- High Pressure Rise (25-50 psi)
- Plate Clashing
- Short Plate Life
- Inefficient Refining (power Vs fiber development)
- Poor Strength Development
- Increased Fines Generation

Note: Shorter Fiber is More Susceptible to Problems Under Low Flow Conditions Than Long Fiber SW.
C. To solve the low flow conditions, there are several possible solutions.

1. Install a recirculation loop around the refiner and recirculate 885 GPM around the refiner. With 790 GPM going forward and 885 GPM recirculating around the refiner, 1675 GPM flows thru the refiner. This refiner is now operating in the correct hydraulic range. Recirculation will hydraulically satisfy the refiner and increase the probability of fiber to fiber and fiber to bar contact.

2. Make a pattern change. The current pattern has a 2.8/16” groove width and a 5.5/16” groove depth. This is considered to be a medium to high capacity pattern. To reduce the amount of fiber channeling in these low flow conditions and increase the probability of getting fibers on the bar edge for energy transfer, one could install a narrower and shallower groove pattern with less volumetric capacity. Lower capacity patterns in low flow conditions will get more fibers on the bar edges for more efficient energy transfer.

3. Utilize a 42” cutback design (see cutback plate below) – the recommended hydraulic (flow) range for 46” refiner with 42” refiner plates and a 450 RPM motor is Low = 775 GPM, Medium = 1250 GPM, High = 2400 GPM (see capacity chart below).

By installing a 42” Cutback plate the 46” refiner, at 790 GPM, the refiner is now operating in the recommended hydraulic range.

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### DOUBLE DISK REFINER CAPACITY CHART

**RECOMMENDED FLOW RANGES FOR VARIOUS SIZE REFINERS**

**US UNITS - 60 HZ SPEEDS**

<table>
<thead>
<tr>
<th>DIA INCHES</th>
<th>MAX POWER HP</th>
<th>NORMAL RPM</th>
<th>NO LOAD HP</th>
<th>FLOW RATES - GPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>42</td>
<td>1500</td>
<td>450</td>
<td>220</td>
<td>775 Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1250 Med</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2400 High</td>
</tr>
<tr>
<td>46</td>
<td>2000</td>
<td>450</td>
<td>325</td>
<td>1025 Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1675 Med</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3275 High</td>
</tr>
</tbody>
</table>

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4. Operate the refiner in Holdback mode. Holdback mode can be implemented by reversing the motor leads or by installing the “Odd Pattern Numbered” Plate Patterns in the “Even Pattern Numbered” Plate positions and visa versa.

5. Reduce the Consistency. By reducing the consistency from 4.8% to 3.5%, the flow increases to 1083 GPM. This flow is now within the recommended flow range for a 46”

6. Install a smaller refiner that is more appropriate for the flow conditions.

Step II. Consistency – Evaluate the % Consistency of the OCC flowing thru the Refiner and Compare to the Recommended Industry Standards

A. For optimal fiber development, the recommended % consistency range for OCC is 3.5-5%. (see chart below).

<table>
<thead>
<tr>
<th>FIBER TYPE</th>
<th>RECOMMENDED RANGE OF REFINING CONSISTENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCC</td>
<td>3.5 - 5%</td>
</tr>
</tbody>
</table>

B. The current % Consistency of the OCC flowing thru this refiner is 4.8%.

This is considered to be OK. Like Hydraulics, when the refiner is operating in the correct consistency range …

- The probability of fiber mat formation between the plates increases
- Fiber strength development potential is maximized
- Plate life potential is maximized
- Variation is minimized.

Step III. Specific Energy – Evaluate the amount of Specific Energy applied to the OCC flowing thru the Refiner and Compare to the Recommended Industry Standards

A. Specific Energy or HorsePower Days per Ton (HPD/T) is the amount of energy applied directly to the fiber. Available specific energy is calculated by subtracting the no-load HP (a function of refiner speed and disc diameter) from the connected HP, and dividing by the daily production rate. The result is a term defined as Net HP Days per Ton, or NHPD/T.

Listed below are the calculations for NO Load and Specific Energy.

\[
\text{No Load (HP)} = (3.083 \times 10^{-13}) \times (\text{Dia}^{4.249}) \times (\text{RPM}^3)
\]

\[
\text{Dia} = \text{Diameter if the Effective Refining Area in inches}
\]

\[
\text{RPM} = \text{Refiner Plate Speed}
\]

\[
\text{SPECIFIC ENERGY} = \text{NHPD/T} = \frac{\text{(Applied Motor Load HP} - \text{No Load HP})}{\text{TPD}}
\]
B. Currently, with an applied load of 781 HP and with 228 TPD of OCC flowing thru the 46" refiner, the refiner is applying 2.0 HPD/T to the OCC fiber (see calculations below).

No Load (HP) = (3.083 x 10^{-13}) x (46^{4.249}) x (450^{3}) = 325 HP

SPECIFIC ENERGY = NHPD/T = (Applied Motor Load HP - No Load HP) / (TPD)

SPECIFIC ENERGY = HPD/T = (781 - 325) / (228) = 2.0 HPD/T

For maximum strength development the recommended HPD/T requirements for OCC is 2.5-5.0 HPD/T (see chart below). In other words, when developing refiner curves on OCC, the tensile, ring crush, mullen, etc, values max out in the 2.5 – 5.0 HPD/T range.

<table>
<thead>
<tr>
<th>GRADE</th>
<th>HPD/UST</th>
<th>KWH/UST</th>
<th>KWH/MT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grades w/ OCC</td>
<td>OCC</td>
<td>2.5 - 5.0</td>
<td>81 - 117</td>
</tr>
</tbody>
</table>
Under current conditions, at 2.0 HPD/T, the OCC is just starting to reach its strength potential (see curve below).

C. To increase the specific energy into the OCC for increased fiber strength one could simply load up the refiner. Full load (2000 HP) Specific Energy = 7.3 HPD/T. This option will give you more specific energy & OCC strength development. However, with this option and with the current pattern, as the refiner load increases so will the refining intensity. More specific energy with the current plate design may not work due to the freeness reduction and machine drainage limitations that go along with added power and increased intensity.

A second option would be to install a lower intensity pattern and load up the refiner to 3 - 5 HPD/T. A lower intensity pattern will allow for more HPD/T for more strength development while maintaining the current CSF / machine drainage requirements. We will discuss this in Step V of the J&L Low Consistency Refining Six Step Sub-System Analysis.

Step IV. CSF Drop / HPD/T – Evaluate the Points if CSF Drop per HPD/T applied and Compare to the OCC Standards

A. CSF Drop / HPD/T: Freeness drop per HPD/T is calculated by the following equation:

\[
\text{CSF Drop} / \text{HPD/T} = (\text{CSF inlet} - \text{CSF outlet}) / (\text{HPD/T})
\]

Freeness drop per HPD/T is a great measure to determine a refiner’s or a refining system’s efficiency. Freeness drop per HPD/T can be used to determine when plates are worn out, if there is a mechanical problem with the refiner, if the plates have been installed incorrectly, or to determine if the correct pattern is being used.

No Freeness data was provided with this problem.

Step V. Intensity – Evaluate the current Refining Intensity (ws/m) and Compare to the Recommended Industry Standards for OCC

A. Refining Intensity is calculated by dividing the Net HP applied by the total length of bar edge crossings within the refining cavity at a given speed. The necessary constants are then used to arrive at units of Watt-Seconds per Meter (W-s/m). Refining Intensity can be calculated using the following diagram.
equation:

\[
\text{Refining Intensity} = \text{SEL} = \frac{\text{Gross Motor Load} - \text{No Load} \text{ kW} \times (60 \text{ sec/min})}{\text{(Bar Edge Crossings KM/REV) \times (RPM)}}
\]

Since the speed of the refiner motor is fixed, the only way to change the refining intensity (at a given motor load) is to alter the bar/groove configuration of the refiner plates. Putting more bars on a given plate increases the total length of bar edge crossings, and subsequently reduces the refining intensity. The converse is also true, fewer bars increase the refining intensity.

More bars on a plate increase the bar surface area in which the power is distributed across to the fiber. More surface area allows a more gentle application of the power, which in turn will increase the degree of fiber fibrillation and reduce the amount of fiber cutting and CSF reduction. Low Intensity refining leads to improved fiber development, less CSF reduction, less fines generation, and subsequently improved strength.

B. Current Refining Intensity: At the refiner loading of 781 HP (582 kW) and with the 46" pattern and its corresponding 60 KM of bar edge crossings / Rev the refining intensity for the OCC refiner is 0.76 Ws/m.

\[
\text{Refining Intensity} = \text{SEL} = \frac{781 \text{ HP} - 325 \text{ HP}}{(1.341 \text{ HP/KW}) \times (60 \text{ sec/min})} \times \frac{(60 \text{ KM/REV}) \times (450 \text{ RPM})}{(60 \text{ KM/REV}) \times (450 \text{ RPM})}
\]

Refining Intensity = SEL = 0.76 Ws/m

Your current refining intensity of 0.76 Ws/m at the current 2.0 HPD/T is considered to be OK for the OCC. For maximum OCC fiber fibrillation we recommend refining intensities in the 0.75 – 2.5 Ws/m (lower is generally better for OCC fiber) range where you will get more fibrillation, more strength development, and less CSF drop at 0.75 Ws/m and more fiber cutting at 2.5 Ws/m.

<table>
<thead>
<tr>
<th>FIBER TYPE</th>
<th>TYPICAL SEL RANGE WS/M</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCC</td>
<td>0.75 - 2.5 (As low as possible w/out Plugging)</td>
</tr>
</tbody>
</table>

C. To improve the OCC strength (move up the OCC strength development curve) while maintaining OCC freeness levels and the drainage requirements on the paper machine, J&L recommends applying more specific energy while utilizing J&L’s lower intensity, reverse flare, anti-plugging 46EJ.501/502 pattern. This pattern has 77 KM/Rev.

With the recommended pattern (77 KM/Rev) and the current pattern (60 KM/Rev), listed below in the table are the refining intensities at 2.0, 3.0, 4.0, and 5.0 HPD/T:

<table>
<thead>
<tr>
<th>Motor Load - HP</th>
<th>Current 2.0 HPD/T</th>
<th>3.0 HPD/T</th>
<th>4.0 HPD/T</th>
<th>5.0 HPD/T</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>781</td>
<td>1009</td>
<td>1237</td>
<td>1465</td>
</tr>
<tr>
<td>Intensity (WS/M) w/ Current 60 KM/Rev Pattern</td>
<td>0.75</td>
<td>1.13</td>
<td>1.51</td>
<td>1.89</td>
</tr>
<tr>
<td>Intensity (WS/M) w/ 77 KM/Rev Pattern</td>
<td>0.58</td>
<td>0.88</td>
<td>1.17</td>
<td>1.47</td>
</tr>
</tbody>
</table>
With the recommended lower intensity 46EJ,501/502 pattern up to 4.0 HPD/T can be applied to the OCC while maintaining a very low intensity for minimal freeness reduction.

The graphs below show the relationship (described above) between specific energy and intensity to strength development and freeness reduction.

**Increase Strength & Minimize CSF Reduction**

**Step VI. Plate Material** – Evaluate the current Plate Material and Failure Modes and Determine if an Upgrade is available.

A. The current alloy is C90. C90 is an excellent alloy. C90 is a surface hardened stainless steel alloy that has the unbreakable characteristics of conventional 17-4 pH (C40) and has the surface hardness (55 Rockwell "C") and the wear resistant properties of white irons.

B. To improve the wear resistance over C90, J&L recommends our recently developed exclusive C91 alloy. C91 is harder more wear resistant alloy then C90 with near equal breakage characteristics. See Alloy graphs below.
**Conclusion**

By applying the J&L Low Consistency Refining Six Step Sub-System Analysis to the OCC refining problem above, we were able to come up with the optimization solution that will improve plate life and increase the OCC fiber development.

To improve the hydraulic conditions, improve plate life and to increase the OCC fiber development, we recommended installing the lower capacity, lower intensity reverse flare anti-plugging 46EJ..501/502 pattern in C91 alloy.