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ULTRA-LOW INTENSITY REFINING OF SHORT FIBERED PULPS

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ABSTRACT

The benefits of refining at very low intensity on short, or fragile, paper making fibers have been investigated over the years. Industry practice has been constrained, however, by limitations in manufacturing technology required to produce fine patterns that have acceptable capacity and plate life.

An innovative technology has now been developed and commercialized that allows for significant reductions in refining intensities without compromising operating costs. The plate manufacturing method utilizes laser technology to produce component parts from wrought stainless steel plate. The parts are then bonded together, resulting in a high degree of mechanical integrity. Unique plate geometries can be produced that achieve extremely high bar edge lengths, while maintaining or exceeding flow capacity and operating life of conventional refiner plates. Results from these ultra low intensity refining plates have demonstrated significant benefits for hardwood and mechanical pulps. Typical results have shown 5-10% gains in strength properties and energy savings in the order of 10-15% with hardwood pulps. Mechanical pulps can benefit from the ability to apply greater amounts of specific energy resulting in lower shive content and higher strength levels without sacrificing drainage. As an added benefit, improvements of up to double conventional plate life have also been achieved.

Two mill case studies are presented which demonstrate the performance and reliability of this technology.

Introduction

The refining of pulp prior to making paper is one of the most important steps in the papermaking process. With optimized refining, high quality products can be produced using less expensive fiber while reducing both chemical and energy usage. The importance of proper refining is now greater than ever due to the increased use of recycled fibers, faster paper machine speeds, increased demands from customers, and a focus at all mills to reduce their manufacturing costs.

For short fibered pulps such as hardwood kraft and sulfite, recycled fiber and mechanical pulps, many studies conducted over the years have confirmed the beneficial effects of refining at very low intensity [1,2,3,4]. These benefits include better strength and porosity development, improved refining efficiency, and greater shive reduction. To achieve low intensity refining in an efficient manner requires refiner plates with narrow bar-groove patterns. However, until recently, industry practice had been constrained by limitations in manufacturing technology to produce plates with fine patterns that have acceptable capacity and plate life. Casting techniques had reached the limit of the finest bar width that could be produced at a reasonable groove depth without becoming too flow restrictive.

Using their combined experience in aerospace manufacturing and papermaking, the makers of AFT Finebar® plates have developed an innovative technology that allows for significant reductions in refining intensities without compromising operating costs.

Refining theory

Refining involves imparting mechanical action to pulp fibers in order to alter their cell wall structure. Although different methods are used to quantify this action, it is generally accepted that the refining effect in any given refiner is determined by the amount of refining taking place and the intensity of the refining action.

The basic refining mechanism is based on the principle of Specific Edge Load (SEL). This theory is the most widely used method to characterize low consistency refiners. SEL theory assumes that the majority of the refining action takes place at the leading edge of the refiner plate bars. It characterizes the amount of refining taking place as specific energy and the type of refining as Specific Edge Load or intensity.

Specific energy is calculated based on the net applied power (motor load minus no-load power) divided by the throughput. This variable is typically controlled via a power or specific energy set point, which in turn controls the plate gap and the total power applied to the fiber.

$$Energy(kWh/t) = \frac{MotorLoad - NoLoadPower}{TonsPerDay}$$

(1)

The Specific Edge Load (or refining intensity) is a measure of the severity of impact when two bars cross and forces are imparted to the fibers and fiber flocs. Too severe an impact can damage the fibers and result in fiber cutting, fines generation, lack of fibrillation, and poor strength development. Specific edge load is determined by the net power applied divided by the bar edge length of the refiner plate pattern times the motor speed.

$$SEL(Ws/m) = k \cdot \frac{MotorLoad - NoLoadPower}{BarEgdeLength \cdot refinerSpeed}$$

(2)

The table below shows general refining intensity and applied energy guidelines for various types of pulp:

Pulp	Intensity	Energy per pass
Type	(Ws/m)	(net kWh/t)
HWK	0.2-0.6	20-100
Recycle	0.2-0.8	20-60
GWD	0.2-0.5	20-100
TMP	0.2-0.5	40-100

Since the applied power is set by the amount of refining required and motor speed is typically fixed, the only economic way to achieve low refining intensity is to increase the available bar edge length.

There are several means to achieve this goal. The MultiDisk refiner was developed in the late 1970's specifically for this purpose, when refiner plate machining and casting techniques had reached the limit of the finest patterns that could be produced with a reasonable groove depth. Bar edge length was increased by increasing the number of disc pairs in the refiner from two in conventional double disc to six pair in the MultiDisk. Although significant quality improvements were achieved, the key disadvantage of these refiners is their high annual plate cost.

Another means to increase edge length is to increase the plate diameter to obtain a greater surface area of bar lengths. These are often referred to as 'overhung' plates. The downside to this technique is the increase in no load power consumption required as plate diameter increases. No load power is a function of plate diameter to the power of 4.3 according to the following equation:

$$NoLoadPower = k \cdot (PlateDiameter)^{4.3} \cdot (MotorSpeed)^{3}$$

(3)

In addition to increasing no load power consumption, larger diameter plates may also compromise the refiner hydraulics if the refiner becomes oversized for the stock flow. As refiners are essentially inefficient pumps, it is important that flow be commensurate with the refiner capacity, a function of its diameter and speed. Hydraulic imbalance could affect the quality of the refining result and impact plate life.

Recent Developments

An innovative technology was introduced in the late 1990's that addressed these limitations, using technology adapted from the aerospace industry where high performance and durability are critical.

The patented manufacturing process consists of precision laser cutting component parts of the refiner plates from sheets of wrought stainless steel. The parts are assembled and then subjected to a high temperature diffusion bonding process in a vacuum furnace that fuses the parts together. Unlike castings, there is no tooling required for this manufacturing process as it is software based. This allows for a high degree of flexibility in producing products to meet specific customer needs.

This process enables plates to be produced with very fine bar patterns and high volumetric capacity. Bars and grooves of any reasonable dimension can be produced as fine as to a 1.3,1.3 mm bar-groove pattern. The combination of narrow high strength bars and rectangular grooves results in a greater hydraulic capacity for these fabricated plates compared to cast plates with U-shaped grooves.

These unique design characteristics create a number of process advantages that, when properly applied, can dramatically impact the overall quality and cost of the paper and paperboard products.

Low Intensity Refining Benefits

All short fibered pulps benefit from very low intensity refining, for both improved quality and energy efficiency. Our experience has shown that optimum refining takes place at refining intensities below 0.6 Ws/m.

Some of the most significant benefits achieved through low intensity refining have been:

- Improved tensile strength and porosity at a given bulk or drainage
- Increase bulk at smoothness or drainage

- Improved pick resistance of hardwood vessel segments
- Reduced energy requirements to achieve target specifications for hardwood pulps
- Greater shive reduction at a given drainage for mechanical pulps.

Subsequent manufacturing cost reductions can result from improved filler retention, increased filler usage, increased machine speed and reduced basis weight, as well as reduced off-spec product and fewer customer complaints.

The ability to achieve these benefits with fine bar-groove patterns can be explained by the following mechanism. With a greater number of bar edge crossing points, there is a greater chance of capturing short fiber material on the bar edges and treating it in the refining zone. This results in a thicker fiber mat between the plates (more fiber-to-fiber interaction) and a greater number of fibers being treated. Each impact on the fibers is more gentle as the applied power is distributed over a high number of bar edges. The gentle refining action increases the specific surface area of the fibers by fibrillating their outer surface, leading to greater strength development. In the case of hardwood chemical pulps, this also leads to a faster change in drainage (freeness, SR) for a given amount of applied energy. Fiber length is preserved, and fiber collapse is minimized so as to lessen the amount of bulk loss with refining.

Low intensity refining also contributes to longer plate life as each bar is subjected to lower refining forces, thereby reducing its wear rate. There is also a better fiber mat formation in the refining zone, a wider gap between the rotor and stator refiner plates, and less plate-to-plate contact.

Case Studies

The following case studies demonstrate the benefits that low intensity refining have provided for hardwood kraft and mechanical pulp applications.

Mill Application #1

The subject mill has three 38" (965 mm) hardwood refiners operating in parallel. Cast plates with a bar-groove-depth of 2.4,2.4,6.4 mm were being used to refine the hardwood furnish. This was one of the finest available 38" cast patterns, with a bar edge length of approx. 88 km/rev.

The mill trialed a set of 38" 1.6,2.0,8.7 mm fabricated plates (FB) with a bar edge length of 132 km/rev. With 50% more edge length than the cast pattern, the operating intensity range was reduced from 0.8-1.0 Ws/m to 0.5-0.6 Ws/m. The trial objective was to compare pulp quality and plate life in a side-by-side plate comparison. Pulp quality results are shown in Figures 1 – 4 and summarized below.

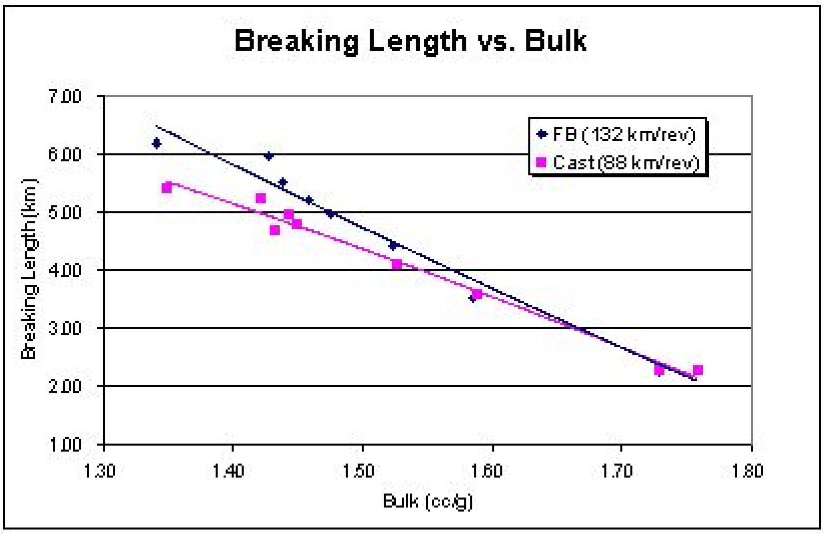

Figure 1

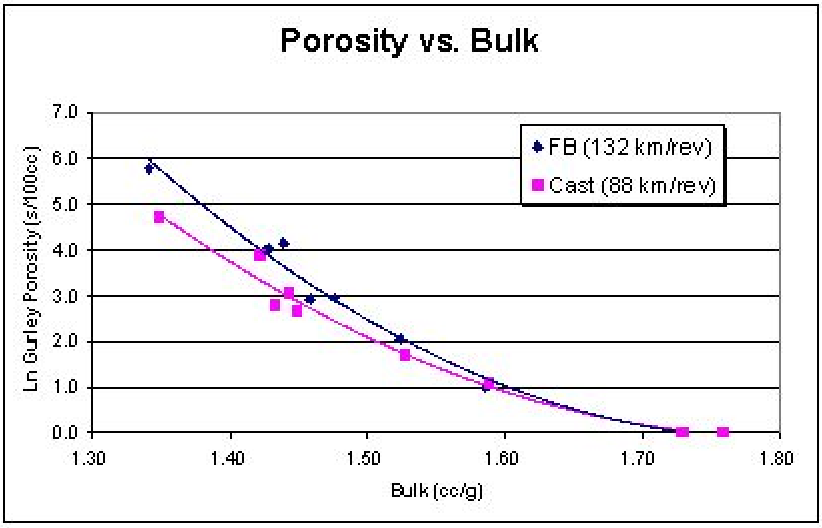

Figure 2

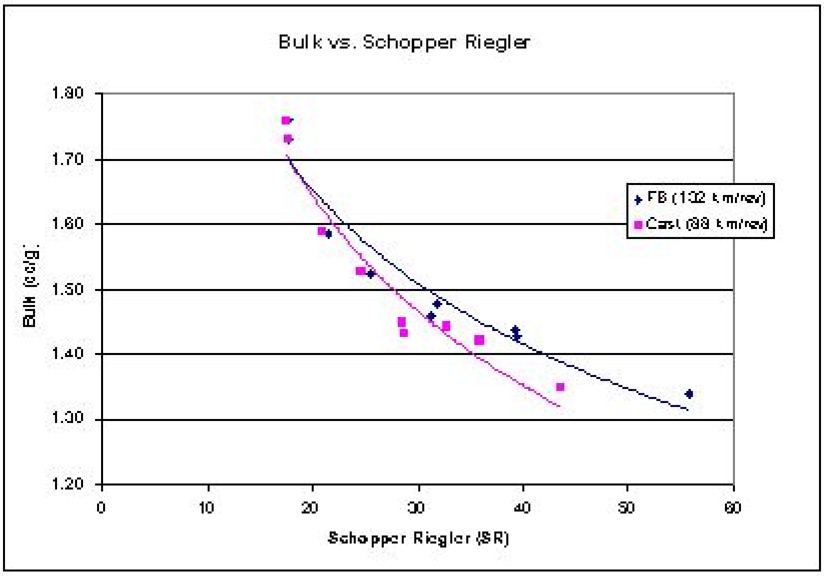

Figure 3

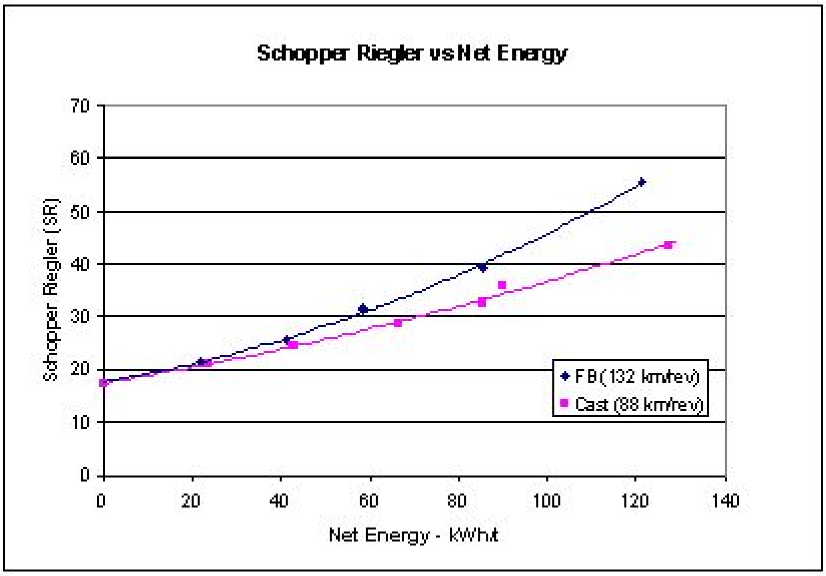

Figure 4

Compared at the mill's target freeness of 300 CSF (40 SR), the lower intensity plates resulted in 2% more bulk, a 5% increase in tear strength and a 9% greater tensile strength. In addition to gains in pulp properties, the mill realized a 13% reduction in applied energy and found that their plate life had doubled with lower intensity refining. All of these factors contributed to improved operations and cost savings for the mill.

Mill Application #2

The subject mill has a low consistency groundwood post-refining system consisting of three 34"(864 mm) refiners. They were using a cast plate design with a bar-groove-depth of 2.5,3.5,4.8 mm and a bar edge length of 41 km/rev. The mill's objectives were to improve strength development and reduce the shive content of their groundwood pulp.

The mill first trialed a set of fabricated plates with a 1.6,1.6,4.8 mm bar-groove-depth configuration and a bar edge length of 120 km/rev. Over an applied energy range of up to 90 kWh/t, the refining intensity was reduced from a maximum of 0.8 Ws/m to 0.3 Ws/m.

In a subsequent optimization step, the mill ran a finer pattern with a 1.3,1.6 mm bar-groove width and a bar edge length of 163 km/rev. This further reduced the refining intensity to 0.2 Ws/m. The refining intensity ranges for all three patterns are compared in Figure 5.

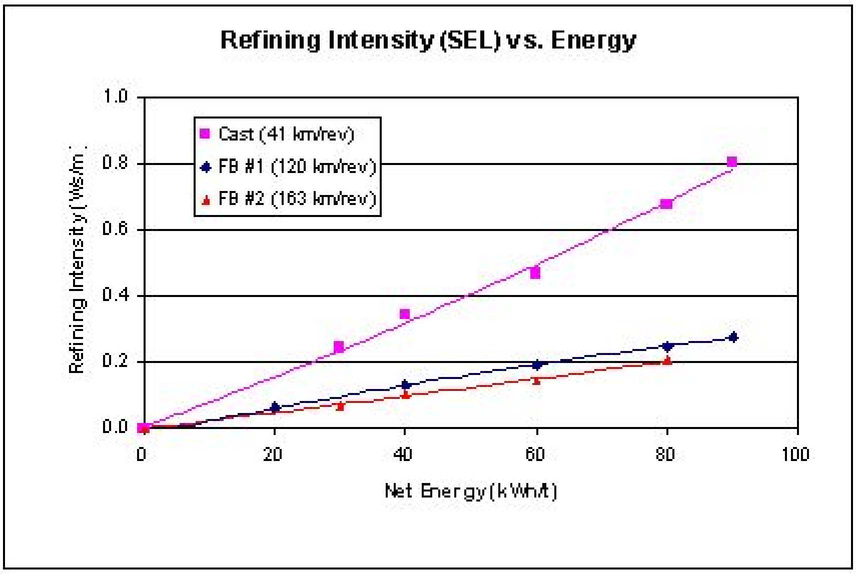

Figure 5

Figures 6 & 7 illustrate the percent improvements in tensile strength and shive reduction achieved across the post-refiner with each plate pattern.

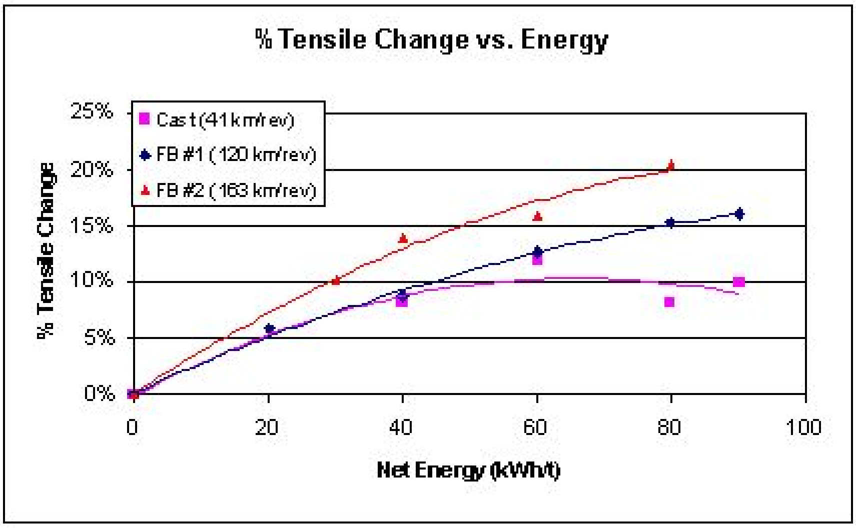

Figure 6

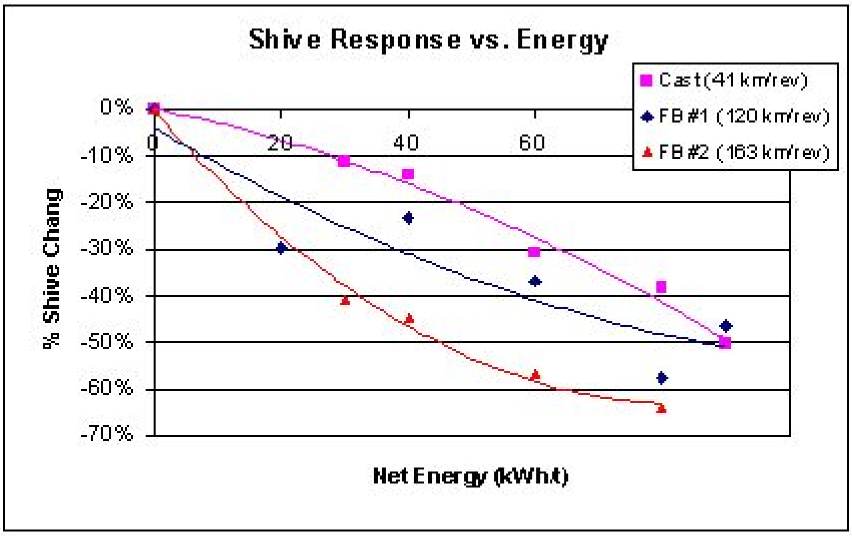

Figure 7

Tensile strength with the cast plates started dropping off as applied energy was increased beyond 50 kWh/t, whereas there continued to be improvements in strength with the finer plate patterns. At that energy level, the refining intensity was 0.4 Ws/m for the cast plates and below 0.2 Ws/m for the fabricated plates.

With the finest plate pattern (163 km/rev), the groundwood tensile strength increased 20% across the post-refiner while shive content dropped by over 60%, thus meeting the refining objectives set out by the mill.

Summary

The benefits of ultra-low intensity refining on short fiber pulp have been well documented. Until recently, however, the challenge has been to achieve these low intensity levels in a cost-effective manner. A novel plate manufacturing process using laser technology has now been developed and commercialized to achieve this objective. Results from these ultra low intensity refiner plates have demonstrated significant benefits for hardwood and mechanical pulps. Depending on the particular refining conditions (i.e. furnish and process variables), opportunities exist for quality improvements, energy optimization, and/or plate wear reduction through application of this technology.

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