Commercialization of Biopulping: An Energy-Saving and Environmentally-Friendly Technology for the Paper Industry

Ross Swaney, University of Wisconsin, Madison, WI
Masood Akhtar, Eric Horn and Michael Lentz, BioPulping International, Madison, WI
Carl Houtman and John Klungness, USDA Forest Service Forest Products Laboratory, Madison, WI

ABSTRACT
The biopulping process for treating wood chips prior to mechanical pulping has been scaled up through an extensive development program and has been demonstrated at 50 ton semicommercial scale. Detailed engineering analyses and design studies have been performed for full production-scale mill implementation, and the technology is ready for commercial use.
This paper will summarize the 50 ton pilot scale equipment constructed to allow in-mill evaluation tests, and design studies for commercial scale implementation of biomechanical pulping. Economic evaluation of the process will be presented, including production economics and operating costs.
The economic advantages of biomechanical pulping derive from several effects, led by significantly improved strength properties and significantly reduced refiner energy requirements. Production cost savings can be substantial. For example, at least $5 million/year net savings before license fees can be realized in an operation producing 242 ton/d of biomechanical pulp for 800 ton/d of blended LWC furnish.
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INTRODUCTION
Biopulping is the process of treating wood chips with a selective lignin-degrading fungus prior to pulping. The microscopic fungal action modifies the internal bonding in the wood fiber composite structure, producing "softened" chips that are far superior for mechanical pulping. This new process has progressed through an extensive development program ranging from laboratory studies to large scale demonstrations. Full-scale process implementation work is now underway.
The current process originated with research conducted at the University of Wisconsin Biotechnology Center and the USDA Forest Service Forest Products Laboratory (FPL), Madison, WI. Patents on the technology are held by the Wisconsin Alumni Research Foundation (WARF). Recently, BioPulping International, Inc. (BPI) was formed to commercialize the technology under exclusive license from WARF. Collaboration and support from state and federal agencies and institutions continues. Active projects with industrial partners are underway.
This paper describes the process economics of biopulping for application to mechanical pulping. Equipment constructed to allow in-mill evaluation of the process is described, along with an engineering design study of a full-scale implementation. Process development work is described in [1].

BASIC PROCESS DEVELOPMENT RESULTS
The biopulping process is the product of an extensive R&D program. Details of the original development work are presented in [2-7].
The following outcomes were achieved:
An extensive search and screening effort identified a fungus (*Ceriporiopsis subvermispora*) with outstanding selective biopulping efficacy and consistency of performance.
A successful surface steaming method of decontamination was developed to suppress competitor organisms economically.
An inexpensive inoculum nutrient was identified that permits very minute quantities of fungal inoculum to be effective on the large scale.
The process conditions required for optimal biopulping effect were determined.
The process was demonstrated at the 50 ton scale in proving trials.
The results established conclusively that the process provides the following benefits for mechanical pulping: fiber strength improvement, refiner electrical power savings, improved uniformity of quality in the chips produced, and pitch reduction. These are achieved with very low yield loss and no observed environmental liabilities. Some brightness loss occurs, but this can be restored using additional bleach chemicals.
Economic Analysis

The primary economic advantage of biopulping results from the greatly improved strength of the biomechanical pulp fibers. Substitution for expensive chemical pulp produces large savings. For instance, in the case of LWC, data confirm a replacement of kraft with biomechanical pulp amounting to 5% of the furnish.

In addition to strength improvement, refiner electrical power savings are substantial. For LWC, at least 33% less refiner energy is required.

These two major savings sources are readily quantified. Potentially supplementing these are several ancillary benefits worthy of note, although they will not be quantified and credited here. First, biopulping reduces the pitch content of the chips. Further, other spore–forming organisms are eliminated. Additionally, biopulping tends to reduce variations present in feed chips, resulting in improved uniformity in refiner feed. Also, the reduction in refiner energy requirement can provide a possible refiner throughput increase in situations where this would be advantageous.

Expenses associated with biopulping include:

Inoculum and nutrient supply cost.

Steam for decontamination and ventilation conditioning.

Power for ventilation and other equipment.

Wood yield loss (< 2%).

Bleaching chemical consumption increment.

Labor, maintenance, and overhead for the biopulping unit.

To see the net effect of the above savings and expense factors, consider the example case of LWC production described in Table I. The base case blends conventional mechanical pulp, kraft pulp, and groundwood at rates of 220, 400, and 180 ton/d respectively. With biopulping, these rates become 242, 360, and 198 ton/d respectively. Table II summarizes the relative production costs for conventional mechanical and biomechanical pulps, including 33% refiner electricity savings and biopulping operating costs (northern U.S. climate). Table III shows the total furnish production costs. The net savings amount to about 18 $/ton of furnish pulp, or $5 million/y for the example mill before payment of license fees.

Table I. Basis for 800 ton/d LWC Example.

TMP:	220 ton/d	Wood:	$ 80 /ton
Kraft:	400 ton/d	Kraft:	$ 500 /ton
GW:	180 ton/d	GW:	$ 233 /ton

Production:	350 d/year
Refiner power:	3,033 kW·h/ton
Electricity cost:	0.04 $/kW·h
TMP yield:	95 %
TMP / Kraft / GW:	27.5 / 50.0 / 22.5 %

Table II. TMP Pulp Manufacturing Costs ($/ton)

Cost	Conventional	Biopulping TMP
Energy:	121	81
Wood:	84	86
Bleach:	10	16
Other Costs:	60	60
Biotreatment:	-	15
Total	275	258

Table III. Total Furnish Manufacturing Costs

Conventional			
Pulp	Ton/d	$/ton	10^6 $/year
TMP	220	275	21.2
Kraft	400	500	70.0
GW	180	233	14.7
Total	800		105.9

Biopulping			
Pulp	Ton/d	$/ton	10^6 $/year
TMP	242	258	21.9
Kraft	360	500	63.0
GW	198	233	16.1
Total	800		101.0

CURRENT ACTIVITIES

Mobile Pilot Plant

Since biopulping has been demonstrated at the 50 ton batch scale, the remaining tests needed for commercial adoption involve demonstration of commercial paper machine operation and resulting sheet properties. To allow these tests, and anticipating that various producers with different products will desire individual in-mill confirmation, a mobile pilot plant facility has been designed and constructed. This facility is designed to produce 50 ton batches of biopulped chips at the mill site.

The processing equipment is mounted on two trailers. The first one contains the decontamination and inoculation equipment (see Figures 1-3). In a 12 h operation it will lay out a 50 ton batch of inoculated chips in a semicircular arc pile. Underneath the pile is a distribution tunnel system for the ventilation air (Figure 4). The second trailer (Figure 5) contains the ventilation/conditioning equipment and transport space for the portable under-pile ventilation tunnel. This system allows mill-site tests to be conducted in a modest space requirement and with only minor site provisions. After the 14 day bioreaction time, the biotreated chips are reclaimed from the pile and fed to the mill as a 50 ton batch.

Figure 1 show the steam injection manifold feeding the decontamination steaming conveyor. The conveyor lies parallel to the integral steam boiler mounted on the trailer. Figure 2 shows the chip cooling system during assembly. Figure 3 show the pivoting inoculation/pile-building conveyor cantilevered off the rear end of the trailer. This conveyor swings through a semicircular arc, depositing the inoculated chips on top of the ventilation tunnel to form the arc-shaped incubation pile. The conveyor rotates forward and stows for highway transport. Nominal throughput for the inoculation/pile-building system is 4 ton/h.

Figure 4 shows a portable section of the ventilation tunnel, which is positioned on the ground to run along the centerline of the incubation pile. Figure 5 shows the second trailer with the ventilation /conditioning equipment that feeds the air tunnel. This system maintains careful control of the temperature and humidity of the air fed to the pile. It adjusts to remove the metabolic heat release over the 14 day incubation period while accurately maintaining the chip pile temperature profile and moisture content.

Figure 1. Mobile pilot plant inoculation and pile-building trailer: Decontamination steaming conveyor alongside of boiler.


Figure 2. Chip cooling belt and blower system (partially assembled).


Figure 3. Decontamination and inoculation trailer end view. Rotating inoculation/pile-building conveyor raised in operating position.

Figure 4. Section of portable under-pile ventilation tunnel.

Figure 5. Ventilation/conditioning equipment trailer.

Engineering Study for Production Plant

Harris Group, Inc. was commissioned to prepare a preliminary plant design and capital cost estimate for a full-scale production facility for a potential first site of commercial implementation. Results of this study will be described in the conference presentation.

CONCLUSIONS

Detailed engineering analyses and design studies have been performed for full production-scale mill implementation of biopulping as a pretreatment for mechanical pulping operations. The technology is ready for commercial deployment. A mobile pilot plant has been constructed to permit direct in-mill testing of 50 ton batches by prospective paper mill adopters.

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