Forest Thinnings

for Integrated Lumber and Paper Production

Integrated lumber and paper production using forest thinning materials from U.S. National Forests can significantly reduce the cost of prescriptive thinning operations. Many of the trees removed during forest thinnings are in small-diameter classes (diameter at breast height ≤6 in) with suppressed growth. These trees produce low lumber yield but can produce quality thermomechanical pulps (TMPs) due to uniformity of wood density and tracheid wall structure and a high mature wood fraction. This was demonstrated in commercial trials conducted at a lumber mill and a newsprint mill in the U.S. Pacific Northwest. Whole log and residual chips from forest thinnings produced at the lumber mill were combined with chips from normal pulping operations to produce newsprint. In all TMP trials, no significant change was found in correlations between the pulp long fraction and the pulp Canadian Standard Freeness.

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The Problem

Following decades of forest fire suppression, many National Forests in the United States are overcrowded with older small-diameter trees. Tree stand overpopulation has created fuel overloading in these forests, a major contributor to the incidence and extent of catastrophic wildfires that have destroyed property and caused loss of lives. Although controlled burning is not an option for forestlands near communities, selective forest thinning can reduce fuel loading and the risks associated with these devastating fires and benefit local communities (Mason et al. 2006). High-value and large-volume uses for forest thinnings are critical to generate economic returns that could offset the cost of expensive thinning operations. Efficient utilization of thinning material can make healthy forest management economical and sustainable. Ideally, the production of solid wood products, such as dimension lumber or poles and posts, could generate economic returns that would substantially offset thinning costs. However, many trees from forest thinning operations are in small-diameter classes (≤6 in. diameter at breast height, DBH), resulting in low lumber yields. Using these materials for biofuel is still at infancy and not ready for commercial production. An alternative use of these thinning materials that could produce high values and could also utilize large volumes is paper production. Ironically, quality wood chips for papermaking are currently in short supply in the Western United States. Therefore, a significant volume of small-diameter thinning materials could be diverted to paper mills, with large-diameter trees going to lumber mills. This would provide a unique opportunity to integrate the production of lumber and paper, satisfying the management needs of the Forest Service and the raw material needs of the forest products industry.

Forest thinning materials from U.S. National Forests are different from traditional thinning materials in plantation forestry. High juvenile wood content is the major characteristic of thinning materials from plantation forestry, a concern for wood fiber production by the pulp and paper industry due to low mechanical strength of fibers from juvenile wood (Zobel and van Buijtenen 1989). Forest thinning materials from U.S. National Forests include many older trees that have small diameters as a result of many years of suppressed growth; for example, the DBH of a 100-year-old tree can be 5 in. or less. Although juvenile wood content is low, the industry perception has been that forest thinning materials are inferior for fiber production. As a result, these thinning materials have not been well accepted by the pulp and paper industry as a viable fiber source, which in effect reduces the value of the thinning materials and negatively impacts the economics of thinning operations.

The objectives of our research are to (1) dispel the notion that thinning residuals are "inferior" to conventional wood sources through rigorous laboratory testing, commercial

Logs from forest thinning operations can be used for lumber and newsprint. (Bottom photo courtesy of Ponderay Newsprint Co., Usk, Washington.)

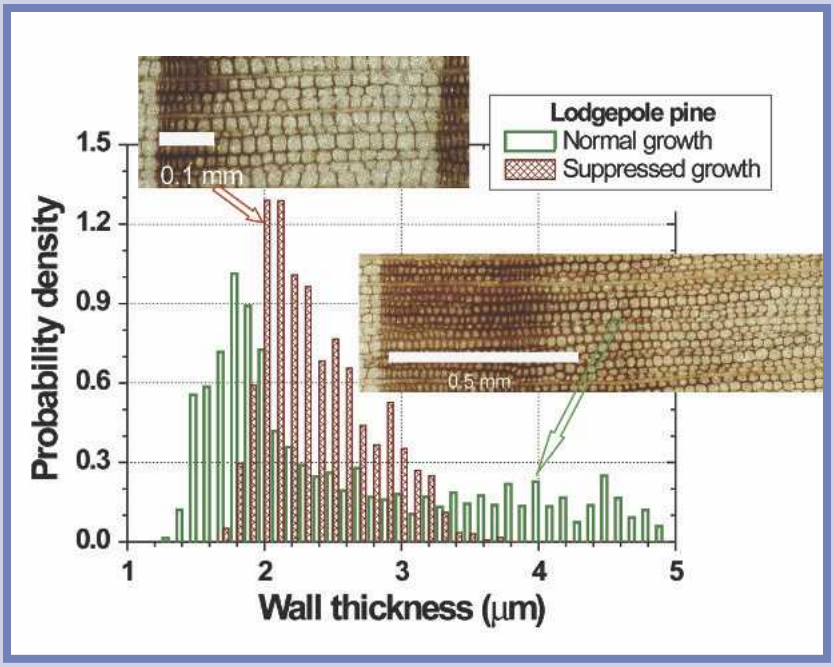

Figure 1. — Effect of tree growth conditions on wood tracheid geometry. Normal growth produced a bimodal distribution with clear distinction between earlywood (thin wall) and latewood (thick wall), whereas suppressed growth produced a uniform (narrow) distribution with no distinction between earlywood and latewood. Photographs were taken from wood core samples from which data shown were obtained by SilviScan measurements.

demonstration, and educational outreach to promote the utilization of forest thinnings, and (2) encourage collaboration between industry and the Forest Service to solve a problem of significant national interest.

Laboratory Discovery

Several studies have been conducted at the USDA Forest Products Laboratory (FPL) on thermomechanical pulping (TMP) of small-diameter trees (Myers et al. 1999, Myers 2004). The results indicated that small-diameter trees are suitable for TMP production, with less refining energy required, but may produce slightly inferior pulp. For example, mechanical properties (tensile, tear, burst) of handsheets made of thinning materials are consistently lower (10 to 30%) than those of paper made from sawmill residual chips through laboratory refining. Although these results provided a useful but preliminary evaluation of the potential of forest thinning materials as a wood fiber source, we believe that the results have limited scientific value. Because the studies did not investigate the unique anatomical properties of small-diameter suppressed-growth trees that were pertinent to mechanical refining, they did not provide fundamental answers to whether or not these trees are a viable source of thermomechanical pulps. Furthermore, the laboratory refining protocol employed in these studies involved multi-pass refining (up to five passes) to achieve a target freeness of 100 Canadian Standard Freeness (CSF). This caused significant fiber damage (about half the length-weighted-averaged fiber length of commercial TMP). Consequently, the quality of pulp produced under this protocol cannot be compared with the quality of commercially produced pulp with high confidence. However, it can be used to distinguish the relative refining energy requirements for controlled laboratory experiments.

This study included an effort to understand fundamental wood density and anatomical properties. Both SilviScan (by the Commonwealth Scientific and Industrial Research Organization, Tasmania, Australia) and in-house image analyses (Vahey et al. 2007) of wood core samples were conducted to elucidate the anatomical differences between suppressed-growth and normal-growth trees (Klungness et al. 2006, Zhu et al. 2007). In these analyses, we were particularly interested in the effects of tree growth conditions on variations of wood density, tracheid wall thickness, and diameters between earlywood and latewood. We found that suppressed growth resulted in less distinction between earlywood and latewood in terms of wood density and tracheid geometry. As a result, small-diameter suppressed-growth trees have a more uniform tracheid density and wall structure within the rings (**Fig. 1**), an important factor that could improve pulp properties in the production of TMPs. For example, loblolly pine is an excellent fiber source for chemical pulps, but it produces inferior TMP primarily because of the distinct difference in wood tracheid geometry between earlywood and latewood (Rudie et al. 1994). The distinct difference between earlywood and latewood tracheid wall thickness (bimodal distribution) creates a conundrum in mechanical refining optimization. Either the earlywood tracheids are severely damaged and shortened when refining is optimized for latewood or the latewood is not well refined when refining is optimized for earlywood.

The uniformity in wood density and tracheid structure, along with a higher volume fraction of mature wood, leads us to believe that older small-diameter suppressed-growth trees can produce consistent, good quality TMP.

Building a Partnership

To make the case for these laboratory discoveries and to assess potential risks and benefits of using forest thinning materials for pulp production, collaboration between FPL and the University of Idaho (UI) was first established. The TMP process unit operations were analyzed, and a process simulation for mass and energy balance was developed. Initial simulations confirmed the favorable results obtained in laboratory studies at FPL. These encouraging results led us to consider the possible scale-up of pulping trials.

A study plan was developed to broaden the partnership to conduct both industrial pilot-scale and commercial mill-scale pulping trials. With direct access to Forest Service personnel and resources, FPL researchers attempted to secure

forest thinning materials from qualifying federal lands and to locate expertise in forestry silviculture to better understand and quantify thinning materials. Two industrial partners, a sawmill and a paper mill, would also need to be recruited to participate in the trials. After a considerable search and several mill visits, both a suitable site and the industrial partners were found.

A Forest Service Collaboration

Forest Service personnel on the Colville National Forest (CNF) in northeastern Washington identified a 70-acre site near the East LeClerc Creek as a possible candidate for the study. To assess the viability of the site, personnel from the Forest Service's Pacific Northwest Research Station (PNW) determined species distribution, stem densities, and available log sizes. Representatives from FPL, PNW, Sullivan Lake Ranger District, and Newport Ranger District of CNF then met at the site and confirmed its appropriateness for the study and began logistical planning. Sample trees were then harvested and sent to FPL for analysis.

The Industrial Partners

Ponderay Valley Fibre, Inc. (PVF) (Usk, Washington), is a privately owned sawmill with about 70 employees. The mill has a fully integrated sawing and chipping operation that incorporates a modern Hewsaw™ (Mäntyharju, Finland) system. Lumber production and quality are optimized by scanning the diameter of each log independently to preset an optimal cutting profile. PVF has also developed a novel log-sorting system that optimizes Hewsaw™ performance. The Hewsaw™ used by PVF is capable of processing logs as small as 4.1 inch in diameter and is particularly suited to a study of small-diameter trees. Residual chips produced in the sawing operation are captured separately and shipped to the pulp mill. An off-line debarking/chipping operation is capable of processing trees of very small diameters (down to 2 in) and can be used to process nonsaw (out-of-spec) logs.

Ponderay Newsprint Company (PNC) (Usk, Washington) is a modern paper mill built in the late 1980s, one of the most recently built mills in the United States. The company employs about 200 people and has a daily production capacity of 800 tons of newsprint, consuming about 1,600 green (wet) tons of wood. The mill has parallel, two-stage TMP production lines with screening and rejects refining capacity. The motor of each refiner is rated at 25,000 horsepower. The paper machine runs at over 4,500 lineal feet per minute. The mill also operates a newsprint and magazine recycling operation that provides about 15 percent of the final pulp.

The geographic proximity of the mills, their familiarity with each other, and their willingness to take risks made them excellent participants for this partnership. The importance of the role of the industrial cooperators in this endeavor cannot be overstated. Both PVF and PNC were asked to accommodate specific project requirements that were well beyond their comfort zones. Furthermore, they were willing to assume all risks associated with complications that could have arisen throughout the trials. For PNC in particular, significant issues such as web breaks and sheet defects could seriously compromise productivity and product quality.

The first step in building this broad partnership was to ascertain the interests and concerns of the mills. PVF was primarily interested in the economic value of timber extracted from a selective thinning operation and would need to determine whether that value justified the expense of harvesting, hauling, and processing logs, in addition to costs associated with site remediation (USDA Forest Service, 1996). PNC was primarily interested in assessing the quality of chips made from PVF residuals and nonsaw logs as a potential reliable source of fiber for future production. However, to accommodate the research aspects of the project, PVF and PNC needed to provide additional resources (primarily staff time) and access to their mills and process data by FPL, PNW, and UI personnel. In exchange for these additional responsibilities, all harvested materials were provided to PVF and PNC at no cost. Mills of this scale are typically risk averse. Therefore, offering logs to PVF at no cost and requiring in turn that the chips produced by PVF be provided to PNC at no cost were to compensate the companies for their costs and risks associated with the project. Finally, to define the scope of the project and protect any confidential information provided by the mills, a Cooperative Research and Development Agreement (CRADA) was signed by all parties. A more detailed study plan was subsequently developed to define the responsibilities of all project participants and to document project expectations, strategies, and logistics.

Pilot-Scale Evaluation

Pulping of sample trees was first conducted (Klungness et al. 2006) at an industry pilot-scale refining facility (Andritz, Inc., Springfield, Ohio). Data from a reputable industrial pilot scale refining facility provide confidence for commercial demonstration. Both control and testing refining runs were conducted. The control run used wood chips supplied by the pulp mill (PNC) for normal operations with about 50 percent lodgepole pine (*Pinus contorta*) and 50 percent hemlock/grand fir (*Tsuga heterophylla/Abies*

Ponderay Newsprint Company's Usk, Washington, mill, built in the late 1980s, is one of the nation's newest papermills. (Photo courtesy of Ponderay Newsprint Co., Usk, Washington.)

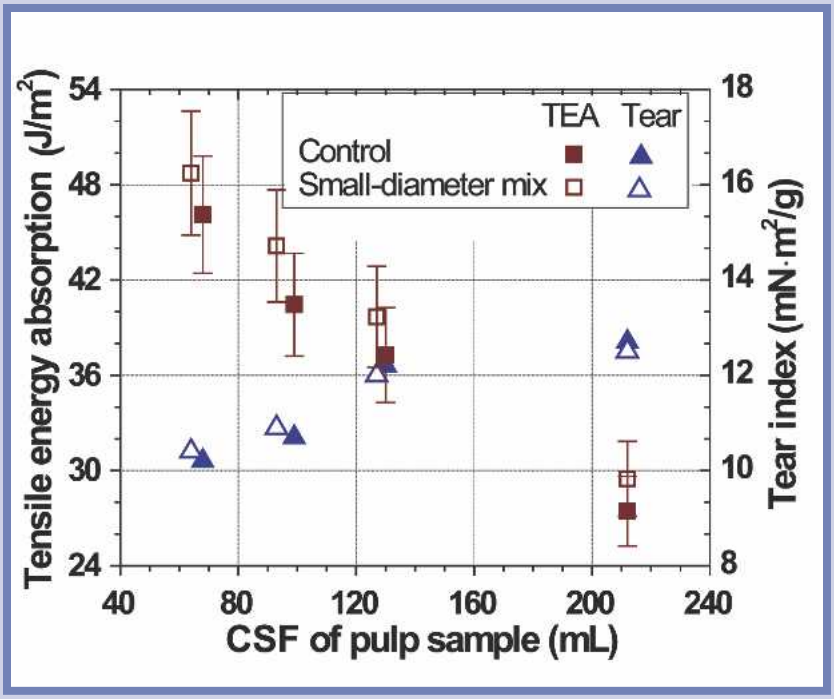

Figure 2. — Comparisons of paper tear resistance and tensile energy absorption of handsheets made from normal mill chips and chips blended with 25 percent chips made of suppressed-growth small-diameter logs. Error bars for TEA were shown to indicate that the differences between the control and small-diameter mix are real.

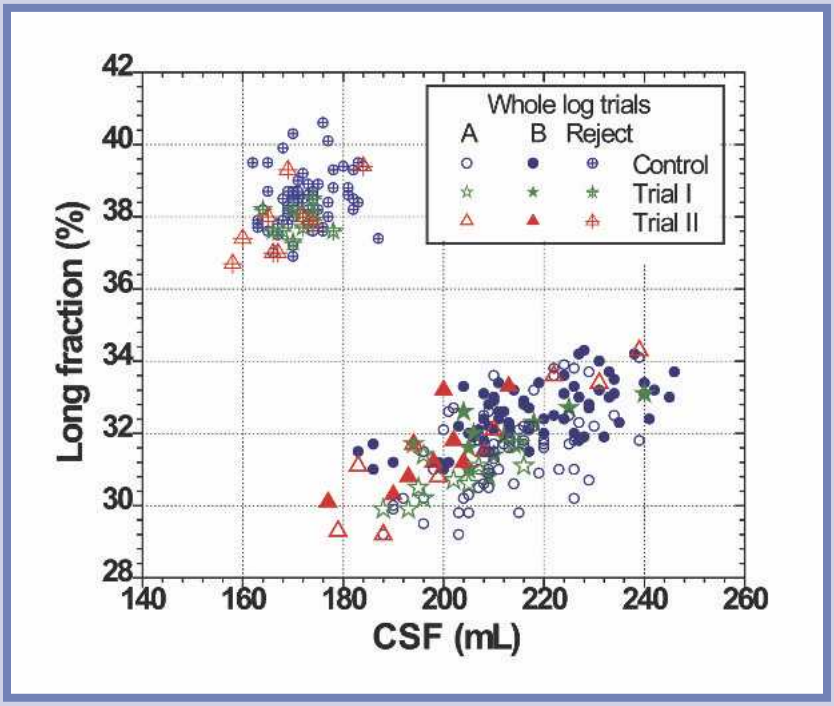

Figure 3. — Pulp mill process data show the relationship between pulp long fraction and pulp freeness during mill trials and normal operation for key sampling points at refiner A, B, and the reject refiner.

grandis). All chips were made from sawmill residuals of normal-growth trees. The testing run blended 25 percent chips from small-diameter logs supplied by the saw mill (PVF). These chips were 50 percent Douglas-fir (*Pseudotsuga menziesii*) residual chips and 50 percent small-diameter lodgepole pine whole-log chips. Comparisons of pulp properties were based on properties of handsheets made of refined pulp samples at various pulp freeness (the measure of the degree of pulp refining) levels. The key mechanical properties of TMP for newsprint are tear resistance and tensile properties. Equivalent tear resistances were obtained between the papers made from control and small-diameter mixed runs (**Fig. 2**). The small-diameter mixed sample produced paper with slightly higher total tensile energy absorption than that from control chips (**Fig. 2**).

Commercial Demonstration

Data from the pilot-scale runs warranted commercial demonstration. The East LeClerc site was selectively harvested by PVF according to Forest Service specifications. The logs were collected and sorted at a landing site and were later hauled to PVF for processing.

For the sawmill trial, all logs with severe defects (heart rot, checks, and distortion) and minimum diameters less than 4.1 in (typically tops) were segregated from the saw logs and chipped as "whole logs." The larger saw logs were then processed through the automated Hewsaw™ system at PVF. The Hewsaw™ system was designed to maximize recovery of lumber while converting all residues into chips. Both whole-log chips and residual chips were shipped to PNC for separate pulping trials. Preliminary results based on visual grading inspections by PVF indicated that lumber produced from the thinned trees met their product specification (visually acceptable). Chip samples were collected for subsequent analysis at FPL.

Two separate pulping trials were conducted at PNC. The first trial was an evaluation of the pulping characteristics of whole log chips when added to the mill's conventional chip blend. This portion of the study was of particular interest to PNC and the paper industry because a large quantity of this material is available and its quality for papermaking was unknown. But only a small fraction (~ 20%) is typically used due to chip inconsistency (such as species, color, moisture, degradation). For our trials, a 44 percent whole-log blend (30% from this thinning study) was used. For the

residual chip trial, up to 50 percent of the chips from this study were used to substitute the mill's normal residual chips. The correlation between pulp long fractions (long fibers that help to produce strong paper) with pulp freeness is often used by TMP pulp mills for qualitative evaluation of pulp quality. Equivalent pulp quality was obtained in both trials (**Fig. 3**) with similar and less refining energy requirements in residuals and whole log trials, respectively. These results indicate that chips generated from forest thinnings as either "whole log" or sawmill "residuals" produced acceptable, commercial-quality TMP for newsprint production. The paper produced met PNC product specifications.

Summary and Lessons Learned

In summary, we demonstrated that forest thinning material is a viable source for wood fiber through pilot-scale experiments and commercial pulp mill demonstration. Integrated production of lumber and wood fiber can help improve thinning economics for sustainable healthy forest management. Thinning also improves the health of the forest (**Fig. 4**). Long-term benefits from this study include the following: (1) The utilization of forest thinnings was promoted by dispelling the notion that thinning residuals are "inferior" to conventional wood sources through rigorous laboratory testing and educational outreach. (2) Collaboration was encouraged between industry and Forest Service to solve a problem of significant national interest. (3) Timber harvested from forest thinning operations was shown to have value for production of both lumber and paper.

Figure 4. — A part of the forest before and after thinning. Before thinning (top), the site was characterized by heavy ground fuels, ladder fuels that can carry fire from the ground into the forest canopy, and a closed canopy that would permit fire to move through the canopy during windy conditions. After thinning (bottom), much of the ladder fuels have been removed and the canopy has been opened to reduce the chance of crown fire.

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Cooperative efforts from the Colville National Forest, Ponderay Valley Fibre (Vaagen Brothers Lumber), Inc., and Ponderay Newsprint Company are greatly appreciated.