Shaping-Lathe Headrig Yields Solid and Molded-Flake Hardwood Products

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Abstract

A shaping-lathe headrig, operated one shift daily, can be used to manufacture hardwood cants to be resawn into pallet stock, one-piece and dowel-laminated crossties, posts and rails, and other solid wood products in lengths from 6 to 9 feet. Residual flakes machined by the headrig supply a three-shift operation in which molded pallets and 4- by 8-foot sheets of structural exterior flakeboard are manufactured. The proposed plant will process about 68 cords (5,100 ft.³) of mixed-species hardwood daily. On net annual sales of $2,947,536, profit before income taxes is estimated at $872,410 or 30.3 percent of the required $2,880,000 investment (100% equity) required for plant construction, startup, and operating capital. The complex is to employ 49 people in plant and office; supporting woods operations would provide additional jobs. The technology of molding pallets from flakes is developing rapidly; but as yet, no data on product performance in service are available.

In the southern and eastern regions of the United States hardwoods of lower than sawtimber grade are in excess supply; i.e., growth exceeds consumption. This paper explains a concept whereby tree-length mixed hardwoods of small diameter—yielding 6- to 9-foot-long bolts 6 to 13 inches in diameter inside bark (DIB) at the small end—can supply a plant manufacturing solid-wood products plus pallets and structural panels hot-pressed from residual flakes.

Concept

A shaping-lathe headrig (4) will be utilized to convert hardwood bolts to cants for a range of solid wood products such as nailed wood pallets (Fig. 1) and dowel-laminated crossties (3). Residues from the headrig are flakes which will be combined with urea resin to yield molded pallets (Fig. 2).

The technology of molding and pressing products from flake-resin mixtures has been the subject of intensive study in numerous laboratories for years (1, 2, 6, 7, 8, 9, 12). Many wood technologists are convinced that a molded-flake pallet can be useful and competitive in the materials handling industry. As yet, no data are published on service performance of pallets molded from flakes. This paper, however, is written on the assumption that molded-flake pallets will be successful. In one design, such pallets are pressed with dimpled decks (visualize a muffin tin with nine recesses) to form integral feet in such a configuration that the pallets nest for shipping. Pallet decks in this design will probably be about 5/8 inch thick with feet 1-1/2 to 3-1/2 inches high.

The flakes also can be blended with a phenolic resin to yield 1/2-inch-thick exterior structural flakeboard.

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panels intended to compete in price and function with sheathing grades of softwood plywood. The sheathing panels will be formed from a single-layer mat, have random flake orientation, and use flakes 3 inches long and about 0.020-inch thick cut from a controlled mix of species. Board density will be about 50 pounds per cubic foot on emergence from the hot press at 3 percent moisture content (MC). Based on data from Price and Lehmann (11), such panels should have about the following properties:

- Modulus of elasticity: 700,000 psi
- Modulus of rupture: 5,500 psi
- Internal bond strength: 80 psi
- Linear expansion (30% to 90% RH): 0.20%
- Drop height to failure under 30-pound impact test over 24-inch span; load applied 6 inches from an unsupported edge:
  - 1/2-inch thickness: 51 in.
  - 5/8-inch thickness: 58 in.

**Machine Selection**

A shaping-lathe headrig (Fig. 3) with capacity to machine mixed-species logs from 6 feet to 9 feet long, and 5 inches to 15 inches in diameter, can turn out a variety of rough green or air-dry products for a range of markets, as follows:

**Industrial market**
- Cants to be resawed into pallet shook
- Light timbers to 9 feet in length
- Industrial blocking of odd cross section; e.g., round, hexagonal, or octagonal
- Hexagonal cants to be crosscut into industrial block flooring

**Railroad and highway market**
- One-piece crossties to 9 feet in length
- Dowel-laminated crossties to 9 feet in length
- Highway posts (round or square) in lengths from 4-1/2 to 9 feet

**Consumer market (via retail lumber yards)**
- Fence posts (4-1/2 to 9 ft. long)
- Fence rails (6 to 9 ft. long)
- Cants for resawing into 8-foot studs or 4 by 4's
- Cabin logs
- Architectural crossties for use in landscaping

**Furniture market**
- Cants in 6- to 9-foot lengths for conversion to furniture dimension stock
- Rounded-up veneer bolts, or cants for slicing crosstie side lumber

Four single-opening, 600-psig presses, each measuring 4-1/2 by 8-1/2 feet and equipped with mat-forming and resin-blending equipment that can use urea or phenolic resins can produce molded-flake pallets for the industrial market or 4- by 8-foot exterior structural flakeboard sheathing for the housing market. Four
single-opening presses are proposed, rather than one 4-opening press, to give floor-level access to manipulate pallet molds, to accommodate thick mats and molds, and to permit sequential placing on the assembled mats.

In this operation, raw material balance between headrig and press is crucial. The headrig should supply flakes in an amount adequate for the pressing operation, and the pressing operation should use all the flakes produced by the headrig.

The material balance between the headrig and the presses is complicated by their differing modes of operation. The headrig need operate only 8 hours to supply the pressing operation for 24 hours. Therefore, substantial storage capacity is needed between headrig
and pressing plant. Green-flake storage facilities must be comprised of two chambers or silos so that a constant blend of 40 percent soft hardwoods (e.g., sweetgum, yellow-poplar, or red maple) and 60 percent dense hardwoods (e.g., oaks and hickory) can be maintained in the furnish going to the hot presses.

Additionally, a mechanism must be provided for disposition of flakes manufactured in excess of the pressing plant's requirements; conversely, an alternative flake source is required in the event of an unscheduled shutdown of the headrig.

**Flake Requirements**

A logical starting place for plant design is determination of flake tonnage required by the pressing operation each 24 hours. This requirement will differ according to product. Molded-pallet manufacture with the short cycles typical of furnishes using urea resins (5-min. cycle sustained for 22.5 hr.) will use more flakes than sheathing manufacture, which calls for phenolic resins and cycle times of about 7 minutes.

**Molded Pallets**

The four single-opening presses will produce eight 42- by 48-inch pallets (trimmed dimension) at each closing. On a 5-minute cycle, production per 24 hours (22.5 effective) will be 2,160 pallets

\[ \text{OD flakes needed per 24 hours} = \frac{22.5 \times 60 \times 8}{5} \]

2,160 pallets, before trimming to final size, measure 44 by 50 inches by 5/8-inch thick, and are pressed to a density of 50 pounds per cubic foot at 7 percent MC, each untrimmed pallet will weigh 39.8 pounds

\[ \text{OD weight of each untrimmed pallet} = \frac{44 \times 50 \times 625 \times 60}{12} \]

Ovendry (OD) weight of each untrimmed pallet will therefore be 37.2 pounds (i.e., 39.8/1.07).

If furnish (flakes plus resin) is supplied at 11 percent MC gives each untrimmed panel a weight of 79.6 pounds (i.e., 73.0 \times 1.09). Components necessary for 100 pounds of furnish at 9 percent MC are:

- Dry components (100/1.09) = 91.7 pounds
- Wood flakes, dry = 86.5 pounds
- Resin solids, dry = 5.2 pounds
- Water (flakes at 2% MC; resin at 42% solids) = 1.7 pounds
- Water in resin = 5.2 \times 86.5/42 = 7.2 pounds

Thus, each 24 hours usable flakes (OD) ranging from 26.5 tons for 1/2-inch sheathing to 37.0 tons for 5/8-inch-thick pallets must be supplied by the shaping-lathe headrig and from cull wood entering the log deck. Assuming that 10 percent of the gross tonnage of flakes delivered to the pressing plant is screened out as fines and diverted to the fuel pile, gross 24-hour tonnage required will be 29.4 to 41.1 tons of unscreened flakes. At the outset, it is assumed that 10 percent of the bark-free wood reaching the log deck is unsuitable for the headrig because of small size, excessive crook, or rot. Thus, about 9.1 tons daily of bark-free wood will bypass the headrig and proceed directly to a small flaker supplying the pressing plant (Figs. 4 and 5). If the headrig is inoperative on a scheduled shift, this roundwood flaker could temporarily supply sufficient flakes to operate the pressing plant.

**Exterior Structural Flakeboard Sheathing**

The four single-opening presses also will produce eight 42- by 8-foot panels at each closing. On a 7-minute cycle (5 min. press time, 1 min. closing, 10-sec. charging, 10-sec. form ing, production per 24 hours (22.5 effective) will therefore be 771 panels

\[ \text{Resin solids consumption per 24 hours} = \frac{22.5 \times 60 \times 4}{7} \]

If panels, before being trimmed to final size, measure 52 by 100 inches by 1/2-inch thick, and are pressed to 50 pounds per cubic foot at 3 percent MC, then each untrimmed panel will weigh 75.2 pounds

\[ \text{OD weight of each untrimmed panel} = \frac{52 \times 100 \times 5}{12} \]

The OD weight of each untrimmed panel will be 73.0 pounds

\[ \frac{5.2}{86.5 \times 5.2} \times 100 \]

On an OD basis, resin solids amount to 5.7 percent of furnish weight.

**Materials Balance**

Thus, each 24 hours usable flakes (OD) ranging from 26.5 tons for 1/2-inch sheathing to 37.0 tons for 5/8-inch-thick pallets must be supplied by the shaping-lathe headrig and from cull wood entering the log deck. Assuming that 10 percent of the gross tonnage of flakes delivered to the pressing plant is screened out as fines and diverted to the fuel pile, gross 24-hour tonnage required will be 29.4 to 41.1 tons of unscreened flakes. At the outset, it is assumed that 10 percent of the bark-free wood reaching the log deck is unsuitable for the headrig because of small size, excessive crook, or rot. Thus, about 9.1 tons daily of bark-free wood will bypass the headrig and proceed directly to a small flaker supplying the pressing plant (Figs. 4 and 5). If the headrig is inoperative on a scheduled shift, this roundwood flaker could temporarily supply sufficient flakes to operate the pressing plant.

**Materials Balance**

From 20.3 (i.e., 29.4-9.1) to 32 (41.1-9.1) OD tons of flakes are due from the headrig daily. Because the
The number of bolts run through the headrig each day is fairly constant at 1,440 pieces (i.e., 4 bolts per min. × 360 min.), the range in flake output must be accomplished by varying the flake to solid wood ratio of the headrig output.

If the average cant produced on the headrig has an untrimmed length of 92 inches and its cross section is octagonal so that it contains a 4-by-6-inch rectangular central cant with two 1-inch beveled-edge sideboards (Fig. 6), then it will contain about 1.81 cubic feet (i.e., $\frac{4 \times 6 + 2 \times 6 \times 92}{144} = \frac{144}{12}$).

With average specific gravity (SG) of 0.57 (green volume and OD weight), such a cant has an OD weight of 35.6 pounds per cubic foot or 64.4 pounds (OD).

A cant of these dimensions can be cut from a cylinder 7.2 inches in diameter or from a normally tapered bolt having a midpoint diameter close to 8 inches. A 92-inch bolt with midpoint diameter of 8 inches contains 2.68 cubic feet (i.e., $\frac{4 \times 8 \times 92}{144} = \frac{144}{12}$).

Such a bolt would, if cut to the pattern of Figure 6, yield 0.48 pound of dry flakes for each pound of dry cant, or 30.9 pounds of flakes.

A 6-by-6-inch cant squared from a 92-inch log with midpoint diameter of 9.5 inches would yield 65.9 pounds of dry flakes.

To supply 20.3 to 32.0 tons of unscreened dry flakes from 1,440 bolts daily requires an average flake yield per bolt of 28.2 to 44.4 pounds (OD). Thus, the average log.
processed must be from 8 to 9.5 inches in diameter; cants should have average cross sections of 32 to 36 square inches, and untrimmed lengths of about 92 inches. Because some cants will have wavy edges, edging equipment must be used after cant ripsaws to yield wane-free pallet stock.

Lumber yield per day on one 8-hour shift should range from 28,800 board feet
\[
\left(\frac{4 \times 6 + 2 \times 4 \times 92 - 2 \times 1440}{12}\right)
\]
to 32,400 board feet
\[
\left(\frac{6 + 6 \times 92 - 2 \times 1440}{12}\right)
\]
Assuming an average midpoint bolt diameter of 8.75 inches inside bark, and an untrimmed length of 92 inches, average inside-bark volume of each bolt will be about 3.20 cubic feet; 1,440 of such bolts will contain about 4,608 cubic feet, or 61.4 cords at 75 cubic feet of bark-free wood per cord.

Because about 10 percent of wood received on the merchandising deck will be routed directly to a flaker and bypass the headrig (because of excessive crook, rot, or small diameter), total wood crossing the merchandising deck should total about 68.2 cords, i.e., 61.4/0.9 (Fig. 5).

Sawdust and hog fuel produced in bucking the bolts and in processing 1,440 cants per day through ripsaws, edgers, and end trimmers, will amount to about 11.7 tons (OD).

Bark yield from 68.2 cords of mixed species (containing 5,115 ft.\(^2\) of bark-free wood having an OD weight of 91.0 tons) will amount to about 13.6 tons (OD) (Fig. 5).

Cull pallet shook, crossties, posts, and other solid-wood products will total about 10 percent of total solid product volume (5). Thus, of the 44.0 tons (dry) of solid-wood products, 4.4 tons will end as fuel (Fig. 5).

**Economic Analysis**

The total operation has three centers: the log deck and sawmill, the pressing plant, and the nailed-pallet fabrication plant. In this discussion, these three operations are combined to simplify analysis.

The plant will run 5 days per week 48 weeks of the year; that is, 10 days will be for paid holidays and another 10 days for annual vacations, during which time the plant will be shut down for maintenance. The yard, log deck, sawmill, and nailed-pallet plant will operate one 8-hour shift 5 days per week; the pressing plant will operate 24 hours 5 days per week.

**Sales**

Net sales prices (after all discounts and commissions) of the plant's products are estimated to range from $106 to $205 per ton of OD commodity (Table 1). Tonnage output of the pressing plant is assumed equally divided between molded pallets made with urea resins and 1/2-inch structural flakeboard made with phenolic resins. Fifty percent of the solid-wood output from the sawmill will go to the nailed pallet plant as usable, square-edged, cut-to-length shook; the remaining 50 percent of the solid wood will be sold as rough green untreated crossties, posts, rails, and light timbers.

**Net sales**

Net annual sales should total $2,947,536 (Table 2). Three percent of the nailed pallets, molded pallets, and flakeboard panels are assumed to be rejects that are converted to fuel.

**Raw Material Cost**

Of a total raw material cost of $746,126, cordwood amounts to $343,797 or 58 percent; resin costs of $227,520 are 30 percent. Nails for solid-wood pallets, steel dowels for dowel-laminated crossties (3), and fungicide account for the remaining 12 percent (Table 3).
Stainless dowels @ (Assumes half of solid-wood product t hrough resin, 95% of 228 $0.00)

Steel dowels @ $3.00/pallet (146,395 pallets of 25 fbm each)

Fungicide (for selected solid-wood products)

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### Table 4. Capital requirement for plant

<table>
<thead>
<tr>
<th>Item</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>YARD, LOG DECK, AND SAWMILL</td>
<td></td>
</tr>
<tr>
<td>40 acres of land on railroad siding</td>
<td>400,000</td>
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<tr>
<td>Yard improvement</td>
<td>10,000</td>
</tr>
<tr>
<td>Weight scale for tree-length logs</td>
<td>20,000</td>
</tr>
<tr>
<td>Yard forklift</td>
<td>50,000</td>
</tr>
<tr>
<td>Log deck and debarker</td>
<td>75,000</td>
</tr>
<tr>
<td>Bucking station and multi-pocket log sorter for length, diameter, and species class</td>
<td>75,000</td>
</tr>
<tr>
<td>Drum flaker for unacceptable wood of small diameter or with excessive rot or crook</td>
<td>25,000</td>
</tr>
<tr>
<td>Fuel bin for outside sales with conveyors to it</td>
<td>30,000</td>
</tr>
<tr>
<td>Fork to bring bolts to sawmill and to remove solid-wood products</td>
<td>15,000</td>
</tr>
<tr>
<td>6-foot shaping lathe with infeed and outfeed decks</td>
<td>150,000</td>
</tr>
<tr>
<td>Flake conveyor to pressing plant</td>
<td>10,000</td>
</tr>
<tr>
<td>Fuel conveyor to pressing plant</td>
<td>10,000</td>
</tr>
<tr>
<td>Remanufacturing line with resaw, cut-to-length saws, edge, and stacks</td>
<td>40,000</td>
</tr>
<tr>
<td>Doweling machine for crossies</td>
<td>15,000</td>
</tr>
<tr>
<td>Building (60 by 200 ft. at $15/ft.)</td>
<td>180,000</td>
</tr>
<tr>
<td>Utilities</td>
<td>15,000</td>
</tr>
<tr>
<td>Wiring</td>
<td>20,000</td>
</tr>
<tr>
<td>Filing room for entire complex (incl. spare heads and saws)</td>
<td>75,000</td>
</tr>
<tr>
<td>Contingency</td>
<td>25,000</td>
</tr>
<tr>
<td>Total</td>
<td>880,000</td>
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<table>
<thead>
<tr>
<th>PRESSING PLANT FOR MOLDED PALLETS AND STRUCTURAL FLAKEBOARD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land (20 acres at $1,000/acre)</td>
</tr>
<tr>
<td>Building (60 by 200 ft. complete with power and lights @ $15/ft.)</td>
</tr>
<tr>
<td>Two flake aisles for green flakes</td>
</tr>
<tr>
<td>Sawmill or denser green flake by species group</td>
</tr>
<tr>
<td>Dryer for flakes</td>
</tr>
<tr>
<td>Dry surge bin and screen to eliminate fines</td>
</tr>
<tr>
<td>Blender for resin and flake</td>
</tr>
<tr>
<td>Former</td>
</tr>
<tr>
<td>Four presses 4-1/2 by 8-1/2 feet with 600 psi specific pressure, single opening for operation in sequence, complete with hydraulic pumping equipment</td>
</tr>
<tr>
<td>Pallet and panel trimmer, incl. conveyor to fuel storage</td>
</tr>
<tr>
<td>Fork lift</td>
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<tr>
<td>Fuel storage</td>
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<tr>
<td>Boiler house</td>
</tr>
<tr>
<td>Resin mixer, storage, wax facility, etc</td>
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<tr>
<td>Quality control equipment</td>
</tr>
<tr>
<td>Contingency</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NAILED-PALLET ASSEMBLY PLANT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land (20 acres @ $1,000/acre)</td>
</tr>
<tr>
<td>Building with electrical service and utilities ($10,000 ft. @ $15/ft.)</td>
</tr>
<tr>
<td>Fork lift</td>
</tr>
<tr>
<td>Block-cutting machine</td>
</tr>
<tr>
<td>Chamfering machine</td>
</tr>
<tr>
<td>Notching machine</td>
</tr>
<tr>
<td>Cyclone and piping to fuel house at sawmill</td>
</tr>
<tr>
<td>Saws, knives, and cutters</td>
</tr>
<tr>
<td>Pallet assembly line for layup and nailing</td>
</tr>
<tr>
<td>Contingency</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>Grand Total</td>
</tr>
</tbody>
</table>

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### Capital and Personnel Required

Capital required is as follows:
- Facilities (Table 4) $2,180,000
- Startup contingency fund 200,000
- Working capital 500,000

Total $2,880,000

The complex would employ 49 people and have a peak, including S. K. and S. K. C., of $388,000 (Table 6).

### Other Expenses

In addition to raw materials and manpower, other expense items include:

- Depreciation of investment (land excluded) $210,000
- Over 10 years on a straight-line basis, i.e., $2,100,000/10

### Other

- Supplies and maintenance (includes molds for pallet pressing operation) $110,000
- Operation of three automobiles 10,000
- Other travel expense 6,000
- Telephone, taxes, insurance, and other overhead 74,000
- Power and other utilities 50,000

Total $250,000

**Projected Annual Operating Statement**

On annual sales of $2,947,536 profit before income taxes is projected at $872,410 or 29.6 percent. Profit, as a proportion of invested capital, is projected to be 30.3 percent (Table 6).

### Discussion

Some of the assumptions underlying this analysis may be open to question. An effort to anticipate and answer the questions seems useful.

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Molded products will weigh more per cubic foot (51 or 52 lb.); increased product weight should not inhibit sales of molded pallets but is a disadvantage in flakeboard sheathing panels. Carpenters routinely handle 1/2-inch-thick gypsum boards which weigh about 50 pounds per cubic foot, so perhaps sheathing panels of comparable weight will be acceptable. Machine nailing of sheathing panels may be too conservative; a 1 or 2 percent reject rate might be more realistic.

Lumber Quality and Product Reject Rate

We have assumed that cants cut from sound bolts will yield 90 percent usable pallet shock, ties, and posts, an estimate supported by Large and Frost (5). Our assumed 3 percent reject rate, with no salvage except for fuel, in nailed pallets, molded pallets, and flakeboard sheathing panels may be too conservative; a 1 or 2 percent reject rate might be more realistic.

Product Sales Prices

Accurate assessment of achievable net sales prices is critical to this analysis. We believe that the prices listed (Table 1) are attainable, but recognize that prevailing sales prices for the planned commodities can fluctuate, and may periodically drop below tabulated values.

Equipment Costs and Maintenance

An assumption that many equipment buyers may challenge is our estimate that four single-opening 4-1/2-by 8-1/2-foot, 600-psi presses can be built (with necessary pumping equipment) and installed for $500,000 annually. Our conviction is based on the fact that one of the authors is currently (1977) building similar presses at a comparable price and is prepared to build additional presses and auxiliary equipment.

Other equipment in the yard and mill, the nailing plant, and the molding plant is also modestly priced according to our belief that the investment in depreciable plant and equipment need total no more than $2,100,000.

Molded Pallets

Since the molded-flake pallet is a product not yet tested in service, industrialists considering this utilization concept might prefer to divert the tonnage of flakes dedicated to pallets (Table 2) to 5/8-inch sheathing instead. Both products should sell for $200 to $205 per ton (OD basis), but press cycle time for 5/8-inch phenolic...
The output of pallets made with urea-formaldehyde resin is nearly double that of pallets made with urea-formaldehyde resin. This halving of output, i.e., 3,672 tons of molded pallets annually compared to 1,836 tons of 5/8-inch structural panels, would alter material balances and reduce pre-tax income even though both products sell for about the same price per ton.

Despite these reservations and uncertainties, it is believed that the manufacturing concept has merit, and deserves further economic analyses specific to site and regional market. For sustained operations, sites appropriate for the proposed enterprise should encompass within reasonable transport distance about 32,000 acres of hardwood woodlands continuously available to loggers supplying the plant.

Literature Cited