The Shaping Lathe Headrig

KEY TO UTILIZATION OF HARDWOODS GROWING ON SOUTHERN PINE SITES

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ABSTRACT—For every cubic foot of pine on southern pine sites, there is about 0.8 cubic foot of hardwood. The shaping-lathe headrig, now in the final stages of commercialization, is a key to utilizing these small mixed hardwoods for pallets and industrial lumber. Lathe residues in the form of flakes can be the raw material for a new major industry manufacturing exterior structural flakeboard competitive in price and function with sheathing grades of plywood. Other likely uses for lathe residues include manufacture of pulp, medium-density particleboard, and molded composites of foamed resin and match-size wood particles.

Off-site hardwoods, growing on land better suited for southern pines, have posed a problem to foresters for decades. Such trees have generally been uneconomic to harvest. If left undisturbed, they occupy space better used by pines, but to destroy them during site preparation for pine plantations is an expensive operation, whether attempted by bulldozing, chaining, or chemical applications. This paper describes a utilization system that has promise of converting these hardwoods from liability to asset, and at the same time easing site preparation for succeeding plantations.

The Resource

The economic importance of the southern pine resource is well recognized. By the end of the century these pines—which grow on 138 million acres in the twelve southern states—will yield over half the softwood cut in the United States.

Less well recognized is the magnitude of hardwood volume on the very same acres. Forest Survey data show that, for every foot of southern pine growing, there exists about 0.8 cubic foot of hardwoods on the same sites. Total volume of pine-site hardwoods is about 54 billion cubic feet (*8*). This volume is increasing (12 percent over the last decade), with annual growth exceeding removals by 71 percent (*9*).

Forest Survey data for Alabama, Louisiana, Oklahoma, and Texas indicate that the volume is in 22 species, of which half are oaks (table 1). Probably much the same situation prevails southwide. On average, the trees are small and slow-growing, with stems 6 to 8 inches in d.b.h. predominating. Figure 1 illustrates a stand on easy terrain in central Louisiana. Mountain sites and more scattered stands present harder tasks to the converter.

Over the years, countless attempts to use pine-site hardwoods have been thwarted by the diversity of species, scattered occurrence of trees, smallness and shortness of boles, branchiness of crowns, and prevalence of knots. Further, most species have a wood specific gravity about 15 percent greater than that of southern pine, and hence it is difficult to make reconstituted panel products whose weight does not exceed that presently acceptable to the trade.

Recent demand for paper, however, has given great impetus to whole-tree chipping of mixed hardwoods to yield barky chips for southern pulpmills. This development will substantially increase drain on the hardwood resource.

Simultaneously demand has increased for hardwood pallets and for roof sheathing panels to be used under shingles on houses. On a weight basis, lumber and structural panel products are worth several times more than pulp chips. It therefore seems logical that tree portions that can be converted to lumber and panel products should be so converted, with the remainder chipped for pulping. This has been the course of development in the southern pine industry (*2, 4, 5*) and will likely be the course for hardwoods if a newly developed shaping-lathe headrig (*6, 7*) proves as workable as it appears.

Shaping Lathe Headrig

Chipping headrigs used in the conversion of southern pine cut in the 90-0 and 90-90 modes (fig. 2), are best applied to logs 8 feet or more in length without butt swell, crook, or sweep. Products are cants to be resawn into structural lumber, and the peripheral wood is removed as pulp chips. The cants characteristically display some torn grain around knots.

A prototype headrig cutting in the 0-90 mode was first demonstrated more than 10 years ago (*1, 3*) and now nears commercial application (*6*). Operating on the principle of a shaping lathe, it is particularly adapted to short logs of irregular contour, since it relies for workpiece position on end chucks rather than on through-feed chains or rolls. Smoothness of the machined surfaces approaches that of millwork. In contrast to other headrigs, this version can readily produce rounds, hexagons, octagons, and trapezoids as well as square or rectangular cants. Thus it lends itself to the manufacture of pallet parts and other industrial lumber, together with posts and rails for fencing. Moreover, its residue is veneer-like particles well adapted for use in structural flakeboard. Such flakes are commonly 2 to 3 inches long, 0.015 to 0.045 thick, and perhaps 3/8-inch wide. Structural exterior flakeboard is being test-marketed and appears likely to compete effectively with sheathing grades of plywood. It is currently manufactured from softwoods and aspen (*Populus* spp.), but research indicates it can be made from mixed southern hardwoods.

The original prototype established the principle of the shaping-lathe headrig. A second prototype was constructed in 1973, under contract with Stetson-Ross of Seattle, Washington, to provide detailed information necessary to the design and construction of a commercial machine (*6*). This model is capable of chucking a bolt 12 inches in diameter and 6.5 inches long (fig. 3). Bolts are clamped in the chucks of the workpiece spindle, which turns at about 15 r.p.m. Attached to the spindle is a replaceable cam having the shape and dimensions of the desired cant. The cam rotates and moves with the workpiece until it strikes a follower aligned with the cutterhead. As the workpiece makes a single revolution, the center distance between cutterhead and workpiece changes in response to the cam, and the workpiece (log) is machined to the shape and dimensions of the cam. Since the log makes only a single revolution while being sized, machining time is brief—about 4 seconds.

The cutterhead is 18 inches in diameter and is turned at 1,800 r.p.m. by a 30-hp motor. To minimize power requirement and enhance flake quality, rake angle is large—43°. Clearance angle, at 5°, is considered the minimum necessary to avoid undue interference with the workpiece. The resulting sharpness angle of 42° yields a cutting edge moderately resistant to nicking.

The cutterhead is in two segments, each 3-1/2 inches long and slotted for 10 knives. The two segments are indexed 18° from each other, to cause flake severance at their junction.

Figure 1. Small, slow-growing hardwoods occupy millions of southern acres that would be more profitable if converted to pine. The new shaping headrig will facilitate such conversion by creating markets for the hardwoods.

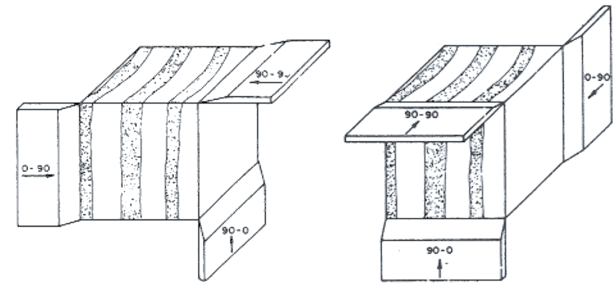

Figure 2. Designation of the three major machining directions. The first number is the angle the cutting edge makes with the grain, the second is the angle between cutter movement and grain.

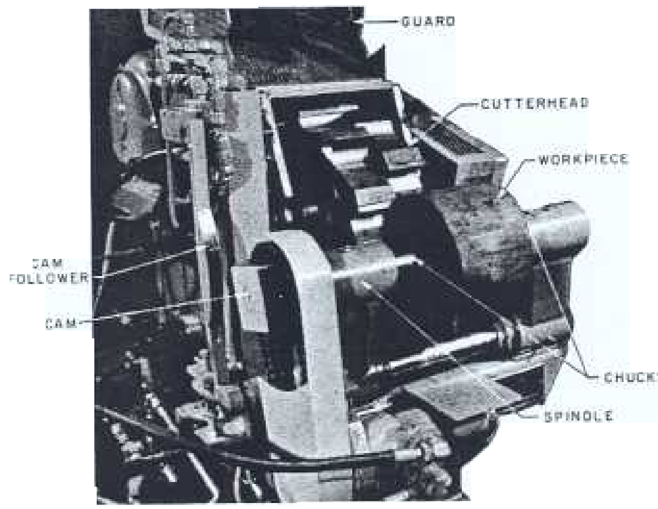

Figure 3. Second prototype of Koch shaping-lathe headrig with 10-knife flaking cutter in place. Cam is 4 inches square. The bolt, when machined, will also measure 4 inches square.

Results from Prototype Trials

Testing of the 1973 prototype showed that flaking heads yield cants with excellent surface quality and dimensional accuracy. Up-milling is more practical than down-milling. Water-soaked wood cut at 160°F required 5.5 percent less net cutterhead power than green wood cut at 72°F. Net specific cutting energy showed positive linear correlation with wood specific gravity and negative correlation with flake thickness; for up-milling of hot and cold loblolly pine, sweetgum, hickory, and southern red oak, it averaged 9.92 hp minutes per cubic foot of wood removed as flakes (pooled data for flake thicknesses of 0.015, 0.025, and 0.035 inch).

To manufacture 0.015-inch-thick flakes with a 6-knife head rotating at 3,600 r.p.m., average cutterhead demand will be about 267 hp when machining green, unheated hardwoods of 0.75 density, 12-inch diameter, and 53-inch length into 8- by 8-inch cants. Peak demand, assuming a maximum depth of cut of 3 inches, will be 510 hp.

If flakes 0.030 inch thick are cut with a 3-knife head, average cutterhead demand will be about 206 hp when machining 8-inch squares from green, dense 12-inch bolts 53 inches long. Peak demand during 3-inch-deep cuts will be 356 hp.

One-and-one-half horsepower net delivered to the workpiece spindle should be sufficient to turn the bolt against peak forces exerted by the cutterhead. Bolt deflections in bending and torsion should not be serious when cants have diameters above 6 inches. If bolts are highly eccentric (for example, if 3-inch-deep cuts are needed to make 4-inch-round posts), however, bending deflections may be as much as 1/16- to 1/8-inch, and torsional deflection may be 2 degrees.

The Commercial Version

The first commercial version of the shaping-lathe headrig (Figure 4) will manufacture southern hardwood flakes and pallet cants by summer of 1975. It carries a 54-inch-long, 6-knife cutterhead, with 12-inch cutting circle. The cutterhead is turned at 3,600 r.p.m. by a 300-hp motor designed to momentarily carry a 200-percent overload without pullout from synchronous speed. The workpiece is driven from one end with a 5-hp, variable-speed motor that provides rotational speeds in the range from 9 to 27 r.p.m. The headrig will accept bolts 3.5 to 12 inches in diameter in lengths from 40 to 53 inches. Since the log need make only a single revolution to be sized, machining time is a brief 4 seconds. With semi-automatic log centering and charging, the lathe should consume six logs per minute. Per-shift production of 4 by 4's from 6-inch logs 4 feet long should therefore be about 12,500 board feet of cants plus 30 tons of green flakes or chips. If logs are larger, for example of sufficient diameter to yield 8 by 8's, then per-shift production will approach 50,000 board feet with proportionately greater yield of flakes or chips.

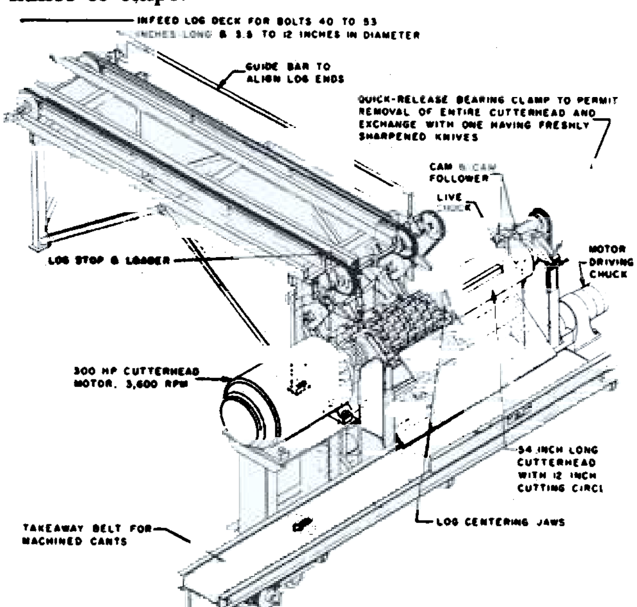

Figure 4. Sketch of commercial version of the shaping-lathe headrig, including log deck, centering device, charger, and takeaway conveyor for machined cants. Flakes are blown from the cutterhead hood (removed for purposes of this illustration) for conveying to flakeboard plant. Design feed rate is six logs per minute. Smoothly machined cants will have the shape and dimensions of replaceable cams mounted on the workpiece spindle. (Drawing from Stetson-Ross, Seattle.)

Products

Under the assumption that merchantable logs or bolts can be separated from entire trees prior to chipping of the remainder, the shaping-lathe headrig can be central to manufacture of several products.

Pallet cants, posts, and rails—As previously noted, the headrig can readily make rounds, hexagons, or trapezoids as well as square or rectangular cants, according to the shape of cam used on the setworks (fig. 5). Such solid-wood products, when machined with a flaking head, have surfaces approaching millwork in quality (fig. 6) and can be distinguished by faint circumferential traces across the grain at regular intervals. These traces define the length of cutterhead knife segments, which in turn determine flake length.

The headrig should find its primary application in the manufacture of industrial wood parts—principally cants for pallet deckboards and stringers. Figure 7 illustrates opportunities for very high lumber recovery by ripping pallet deckboards from octagonal cants. Other possibilities for high-yield products such as round or octagonal fence rails, highway posts, blocking, and industrial end-grain flooring will doubtless occur to the reader.

Extension of the machine to handle 8-foot-6-inch crossties would not be difficult, but few firms can log the 2,000 daily tie cuts required to keep the machine occupied. Should crossties steel-dowelled from pairs of 4.5- by 7-inch cants be proved feasible, a shaping-lathe headrig could economically produce such cants from logs 8.4 inches in diameter.

Structural exterior flakeboard—A major potential for the lathe lies in its ability to cheaply produce, as a residue, large tonnages of veneer-like flakes measuring perhaps 3 inches long and 0.015 inch thick (fig. 8). These flakes—with the addition of about 5 percent of phenol-formaldehyde resin—can be manufactured into a structural exterior flakeboard that should compete in function with sheathing grades of plywood. Price competitiveness of flakeboard sheathing will depend on future supplies and pricing of the required resin.

The structural exterior flakeboard shown in figure 9 is 50 percent southern red oak, 25 percent hickory, and 25 percent sweetgum. With random flake orientation throughout, it has modulus of elasticity of 809,000 p.s.i., and modulus of rupture in excess of 4,500 p.s.i. Board density, based on weight and volume at 7.5 percent moisture content, is 49 pounds per cubic foot. If boards are formed with flakes on face and back aligned and oriented parallel to panel length, their density can be reduced significantly without loss in modulus of elasticity. Research on such boards is not yet complete, but early results are promising.

Medium-density particleboard—Flakes cut on the headrig also yield superior disk-refined mechanical fiber for medium-density particleboard (fig. 10). Fibers of all 22 species listed in table 1 can be mixed with small amounts of resin to yield hot-pressed boards with near-uniform density throughout panel thickness, with good edge integrity and internal bond strength, and with reasonably high moduli of rupture and elasticity. Such boards are finding an increasing market in the furniture industry, primarily because their sound edges and smooth faces permit direct printing of surface patterns. The direct deposition of photographic facsimiles of wood grain, in place of overlaid veneers required for poorer core surfaces, results in substantial manufacturing economies.

Processes to align fibers—such as that developed by Talbot[1]—hold promise of significantly increasing stiffness and bending strength of reconstituted boards.

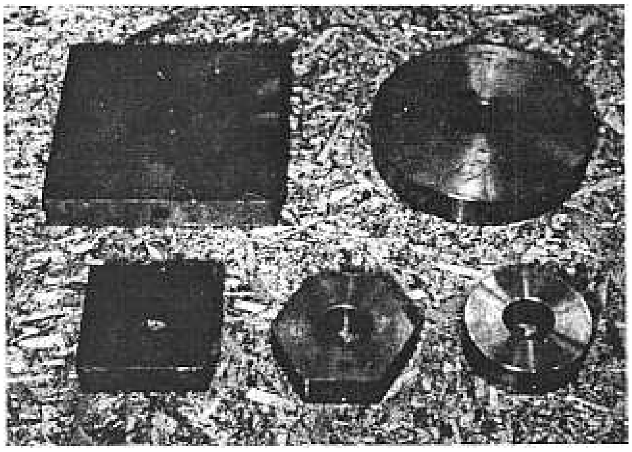

Figure 5. Typical cams for shaping-lathe headrig. The largest is 8 inches in diameter, and the hexagon measures 4 inches across the flats.

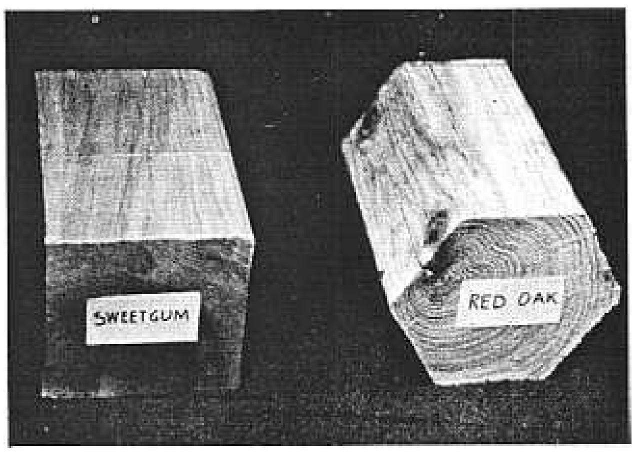

Figure 6. Cants produced on the lathe may be rectangular, round, trapezoidal, or triangular, as well as square or hexagonal. Because knives cut in the veneer direction and take shallow cuts, cant surfaces are smoothly machined with no tearout around knots.

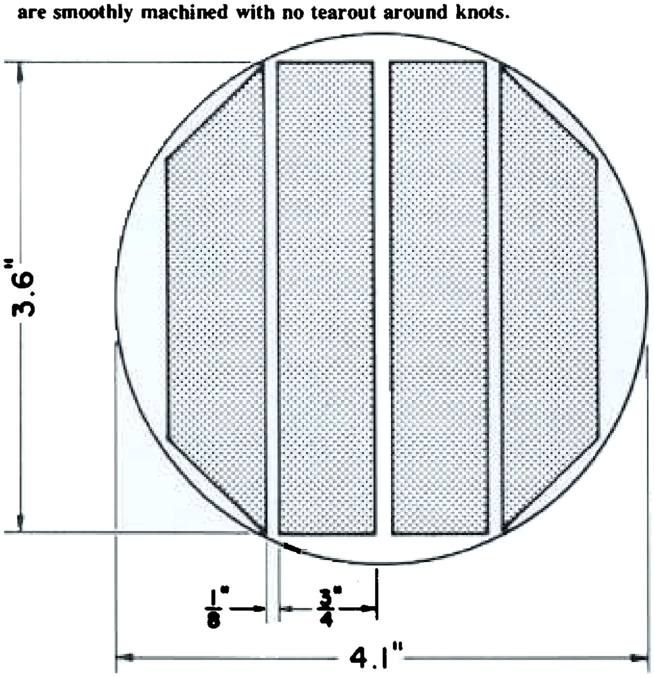

Figure 7. Sawing pattern whereby square-edged pallet deckboards can be ripped from the central portion of octagonal cants, and bevel-edged deckboards cut from outer portions. By this pattern, lumber recovery is about 14 board feet per cubic foot of log.

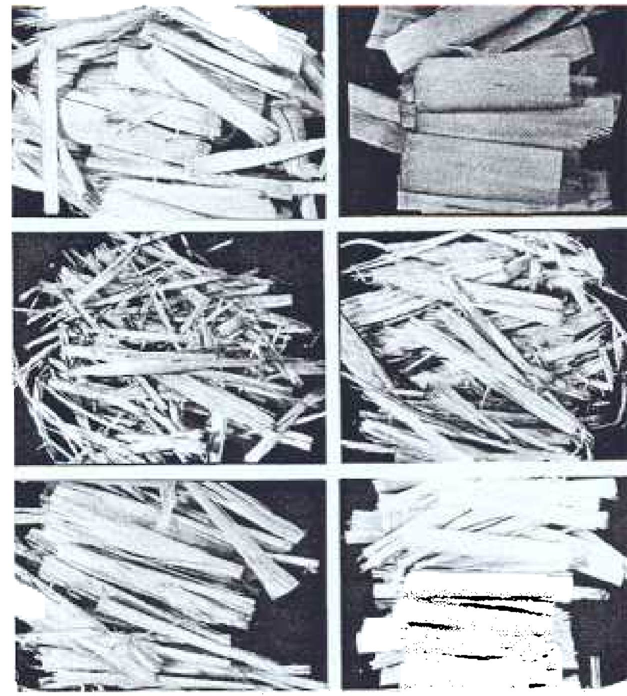

Figure 8. Upmilled flakes 0.015 inch thick and 3 inches long cut from sweetgum (top), southern red oak (center), and hickory (bottom) soaked in water at 72°F (left) and 160°F (right). The flakes have near optimum dimension for manufacture of structural exterior flakeboard.

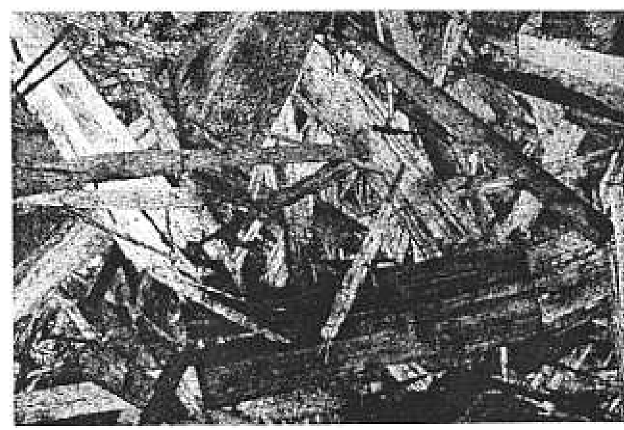

Figure 9. Flakes are randomly oriented in this homogeneous single-layer structural exterior flakeboard intended to compete in price and function with sheathing grades of plywood. The board is 50 percent southern red oak, 25 percent hickory, and 25 percent sweetgum.

In short, the market outlook for medium-density boards made from mixed southern hardwoods appears good, and substantial expansion of production capacity is anticipated.

Foamed urethane products—Over the years wood has always suffered in competition with plastics because of its inability to flow under pressure into molded forms. In contrast, plastics can be heated and injected into cavities to assume complex molded shapes. But now, A. A. Marra[2] has developed a process whereby fibrillated wood particles of matchstick size can be carried in a foaming urethane resin to fill curved cavities with a structural matrix of wood bonded at interstices by resin. Fibrillated wood particles (*Figure 11*) are placed in the mold cavity, only partially filling it. Then resin totalling a quarter of the wood weight (in some cases an amount equal to the wood weight) is added, the mold top is locked in place,

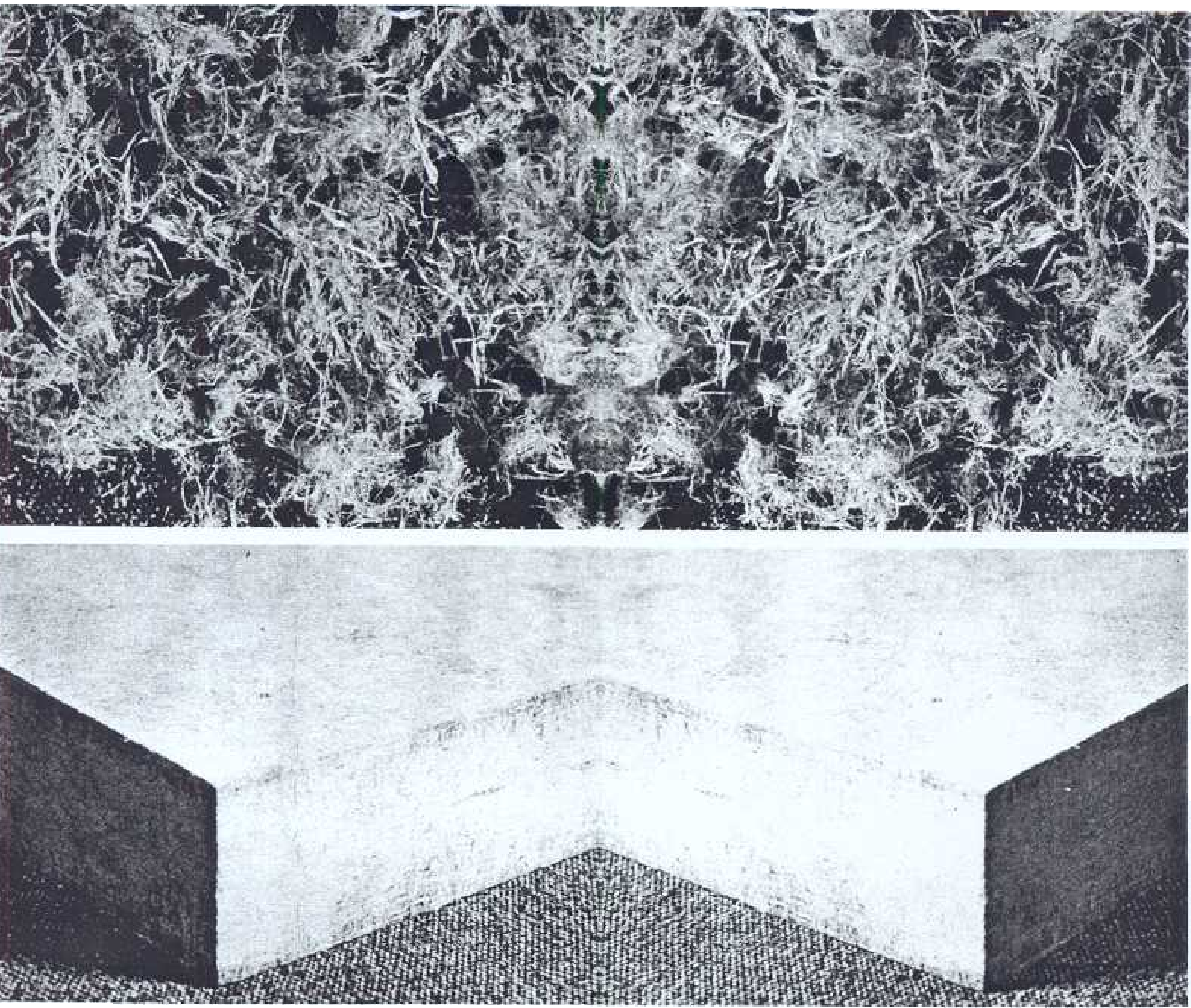

Figure 10. (Top) Fiber disk-refined from southern red oak wood. Individual fibers are about 1.3 mm long; bundles illustrated are somewhat larger. (Bottom) Southern red oak fiberboard pressed to have near-uniform density throughout thickness. The board is 3/4-inch thick and weighs 42 pounds per cubic foot when at 7 percent moisture content. Modulus of elasticity is 367,000 p.s.i., and modulus of rupture is 3,190 p.s.i.

and in a few moments the cavity is completely filled with a structural matrix of desired density (*Figure 12*).

Because molds can be inexpensive and the system is tolerant of species and tree grade, the process appears to have substantial commercial potential for manufacture of a wide range of products including such diverse items as caskets, speaker cabinets, pallets, containers, and structural panels.

Conclusions

I believe that application of the shaping-lathe headrig will not only alleviate shortages of industrial hardwood lumber but will also give impetus to two specialty industries—the manufacture of medium-density particleboard and of wood-resin composites. Further, it is likely to create a third major industry manufacturing structural exterior flakeboard competitive in price and function with sheathing grades of plywood. My reasons are several:

- The hardwood resource is close to population centers where sheathing finds its major market.
- The hardwood resource is also conveniently near manufacturing centers where industrial lumber and pallets are used in greatest volume.
- The hardwood pallet market is growing vigorously, and cants for manufacture of deckboards and stringers are in short supply. Hardwood stumpage

[1]Talbot, J. W. 1974. Electrically aligned particleboard. Presentation at *Particleboard Series Symposium No. 8*, Pullman, Wash., March 26-28.

[2]Marra, A. A. 1974. Analysis of the utility of southern hardwoods as a furnish for low-density composite products. Final Report FS-SO-3201-2.42, March 15, 1974. South. For. Exp. Stn., USDA For. Serv., Pineville, La.

(of the type required by the process described) is plentiful and in many areas is readily available at reasonable cost.

- Flakes residual from the lathe headrig can be produced at a fraction of the cost of pine veneer and can be manufactured into structural exterior panels by a less labor-intensive process than that of manufacturing plywood.

The flakeboard contemplated will be slightly heavier than sheathing plywood, and will use more scarce phenol-formaldehyde resin (5 percent by weight compared to about 2.5 percent for plywood). It seems to me, however, that the compelling economic advantages outweigh the presently discernible disadvantages.

I predict that in the next 10 years this new board —and its close relatives, the fiberboards—are going to change wood procurement patterns in the South to the same degree the chipping headrig changed patterns during the past 10 years.

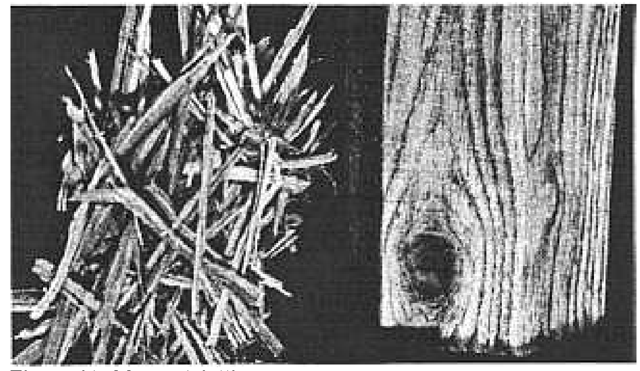

Figure 11. Matchstick-like particles about 0.05 inch thick up-milled from southern red oak at 72°F to leave a hexagonal cant.

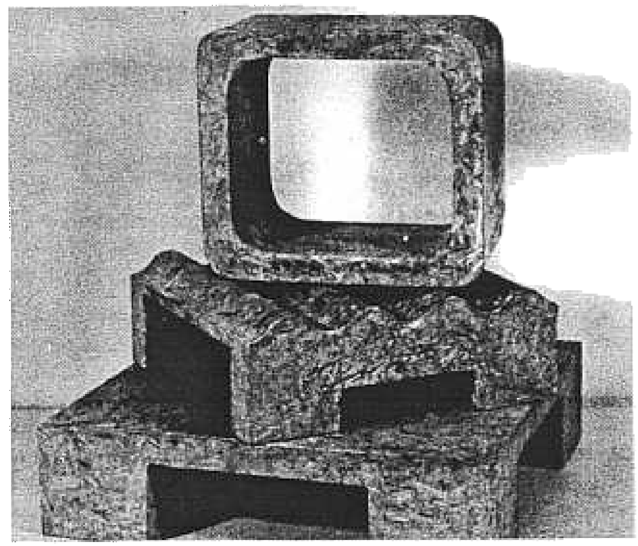

Figure 12. Products illustrative of shape obtainable with composites of matchstick-like particles and foamed resin.

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Table 1. Hardwood species predominating on southern pine sites, and their volume; Alabama, Louisiana, Texas, Oklahoma, 1963-1965.[1]

Species	Million cu. ft.	Percent	Cummulative percent
Sweetgum (*Liquidambar styraciflua* L.)	2,329.1	21	21
Hickory, true (*Carya* spp.)	1,155.8	10	31
Black tupelo (*Nyssa sylvatica* Marsh.)	1,049.0	9	40
Post oak (*Quercus stellata* Wangenh.)	984.8	9	49
Southern red oak (*Q. falcata* Michx.)	969.1	9	58
Water oak (*Q. nigra* L.)	942.0	8	66
White oak (*Q. alba* L.)	912.1	8	74
Yellow-poplar (*Liriodendron tulipifera* L.)	422.1	4	78
Sweetbay (*Magnolia virginiana* L.)	325.0	3	81
Black oak (*Q. velutina* Lam.)	292.9	3	84
Cherrybark oak (*Q. falcata* var. *pagodaefolia* Ell.)	276.1	2	86
White ash (*Fraxinus americana* L.)	241.1	2	88
Green ash (*F. pennsylvanica* Marsh.)	186.1	2	90
Red maple (*Acer rubrum* L.)	167.4		91
American elm (*Ulmus americana* L.)	167.2		92
Winged elm (*U. alata* Michx.)	159.2		93
Hackberry (*Celtis occidentalis* L.)	135.3		94
Northern red oak (*Q. rubra* L.)	122.8		95
Scarlet oak (*Q. coccinea* Muenchh.)	92.5	1	96
Shumard oak (*Q. shumardii* Buckl.)	82.1	1	97
Laurel oak (*Q. laurifolia* Michx.)	75.9	1	98
Blackjack oak (*Q. marilandica* Muenchh.)	?	1	99

[1]Data compiled by Forest Resources Research Work Unit, Southern Forest Experiment Station, USDA Forest Service, New Orleans, La.