Reel Wheels: an Application Of Material Science

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Abstract

Circular plates of reconstituted wood were fabricated and destructively tested to appraise the potential of such material for cable reel flanges. The reconstituted wood consisted of flakeboard from quality-cut flakes and also from factory residue. The highquality flakeboard used 0.020- by 1/2- by 2-inch southern pine flakes cut on a disk flaker, whereas the flakeboard from residues was of 2 degrees of refinement, and consisted of 50 percent lumber residue and 50 percent hogged plywood scrap. Flake alignment variations in the plates included all random, all radial, all concentric, radial face and concentric core, vice versa, and radial face with random core. Plates were subjected to both center loading and impact tests. The testing related processing variables to strength and stiffness. Best properties resulted from combinations of radial and concentric alignments for face and core. All random alignment resulted in better properties than either the all concentric or all radial alignment. Although none of the plates from plant residue had the strength of plates from the quality-cut material, proper techniques used in the refinement of the residue improved strength performance by approximately 60 percent. The study demonstrates the versatile combinations of strength and stiffness made possible by materials engineering of wood.

RECONSTITUTED wood particle panels were originally developed for nonstructural applications. However, commercialization of products such as mobile home decking and flakeboard roof, wall, and floor sheathing, as well as recent manufacturing techniques incorporating flake alignment, have prompted exploration for other structural applications of reconstituted wood.

The U.S. Forest Products Laboratory recently received an inquiry from a cable reel manufacturer about the possible use of woodwaste to produce reel flanges. This inquiry led to a small study exploring the use of reconstituted wood particles for such an application. The purpose of this research was to determine the effects of certain processing variables on a number of properties of circular flakeboard plates—properties addressed by material science which would likely be important in the performance of actual reel flanges. The flakeboard variables given attention included flake type, flake alignment, layering techniques, density, and thickness. The circular plates included no finishing details such as grooving, bolt holes, or hardware, which are required for actual reel flanges, and were known as "reel wheels."

During service, cable reel flanges are subjected to both static and impact loads normal to the disk surface. Cursory investigation showed that analysis of stress-strain relationships in a circular flat plate is rather complicated, depending in part on loading method, plate thickness, and material structure. Radial and tangential stresses[1] for the outer surfaces of a flat circular plate of isotropic material, supported on the edges and uniformly loaded on a concentric circular ring of radius r_o, are shown in Figure 1. Engineering design of this type product, made with reconstituted wood, is morecomplex than that encountered using isotropic materials. Consideration must be given to average density, density gradients, flake types, layer effects, and polarized flake alignment as well as the more conventional process factors of resin type, resin quantity, mat moisture content, and pressing techniques. While this study was restricted to flat plates, design could include such items as molded ribs or projections to further enhance performance.

Wheel Construction

To obtain some basic and comparative data a series of reel wheels were constructed using 0.020- by 1/2- by 2-

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[1] Formulas used to derive stresses are from Raymond J. Roark. 1954. Formulas for Stress and Strain. 3d edition, McGraw & Hill Book Co., New York, N.Y.

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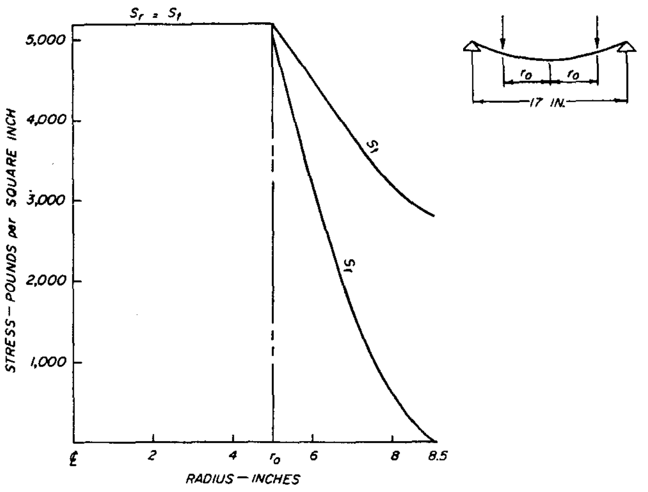

Figure 1. - Radial, S_r, and tangential, S_t ,compressive stress on the upper surface of a flat, circular plate supported on the edge and uniformly loaded on a concentric ring of radius r_o. The figure is based on 1/2-inch-thick isotropic material loaded with 3,000 pounds (V = 0.25).

inch southern pine flakes cut on a disk flaker. Construction techniques were varied to obtain both homogeneous and three-layer wheels using various combinations of random and oriented flake arrangement. Lacking the detailed materials-engineering data necessary to make an indepth analysis, design was based on intuitive judgment. Variations included all random alignment, all radial alignment, all concentric alignment, radially aligned faces with concentrically aligned cores, vice versa, and radially aligned faces with randomly aligned cores. It was suspected that the poorest performance would be derived with full concentric and full radial alignment, improved with random, and best with the combinations of concentric and radial alignment.

Construction constants were as follows:

thickness–1/2 inch
trimmed diameter–24 inches
density–40 pounds per cubic foot (ovendry (OD) basis)
phenol resin solids–5 percent (OD wood basis)
wax solids–1 percent (OD wood basis)
mat moisture content–10 percent
press temperature–350°F
press closure–1 minute
press time–10 minutes
face:core weight ratio–1:1

In addition, one wheel was made at a thickness of 3/4 inch and another wheel with a density of 47 pounds per cubic foot, both having random flake orientation throughout. Randomly, radially, and concentrically aligned wheels are shown in Figure 2. A forming box consisting of a frame fitted with metal slats was used to align the flakes (Fig. 3). Wheels were formed on a circular caul plate pivoted in the center. Radial alignment was achieved by positioning the forming box with the fins in a radial direction. Concentric alignment was done with the box shifted so that the fins were tangentially oriented, using only a pie-shaped portion as illustrated in Figure 4. After a layer of flakes was deposited on the caul (during which the caul was turned

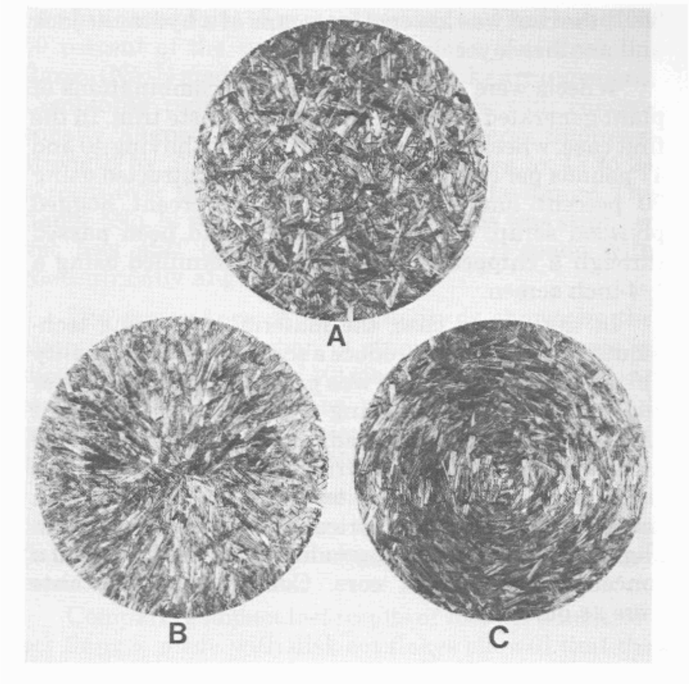

Figure 2. - Reel flanges made with A) random, B) radial, and C) concentric flake alignment.

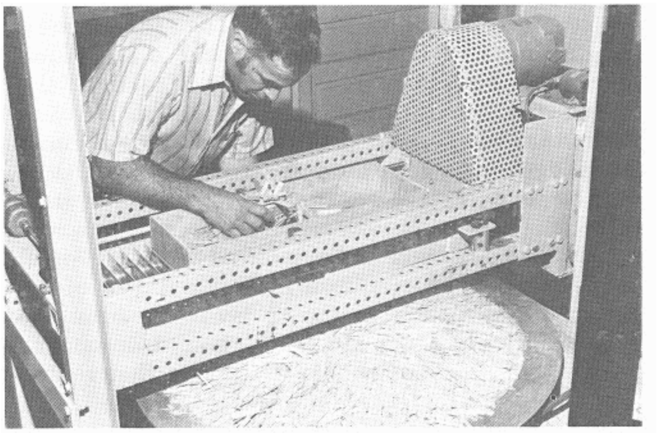

Figure 3. - Equipment for aligning flakes. Shown are the marking template, forming box with aligning fins, and rotatable caul.

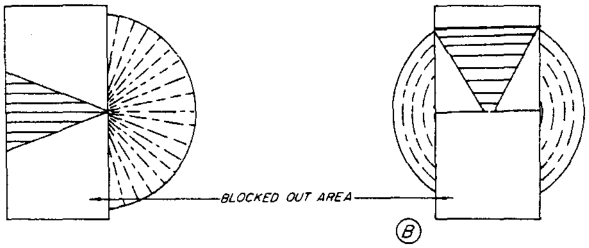

Figure 4. - Polarized flake alignment technique: A) is the arrangement for radial alignment, B) for concentric alignment.

360°) the caul was lowered by means of a hydraulic jack and another layer deposited.

Wheels were also made using two combinations of plant-generated plywood and lumber waste trim. In the first case, wheels with random alignment having 40 and 47 pounds per cubic foot density were constructed using 50 percent lumber residue and 50 percent hogged plywood scrap. The lumber residue had been passed through a chipper and further hammermilled using a 1/4-inch screen.

In the second case, the material processing techniques were vaned to produce a somewhat better quality flake. The lumber residue was passed through a chipper and further refined in a ring-type flaker (knives set at 0.030 in.) and screened to eliminate the 1/32-inch fine fraction, while the plywood trim was chipped, flaked in a ring flaker, and screened to eliminate the 1/16-inch fines. Two wheels were fabricated, one with all random alignment, and one having radially aligned faces and a concentrically aligned core. Construction constants were as outlined.

Testing

Tests were designed to indicate the effect of construction variables on certain properties that govern performance of cable reel flanges rather than to measure end use performance directly.

Testing was done in two modes. To simulate flange stresses induced by spooling wire on the reel, the wheels were center-loaded with a 10-inch disk and supported by a ring having an inside diameter of 17 inches. Deflection was measured at a point directly beneath the edge of the loading disk. Another test was designed to simulate impact that would occur if the reel were dropped on a flange edge or dragged sideways across the floor. In this test a 50-pound weight was dropped on the center of an 8-1/2-inch-wide by 24-inch-long specimen, which was supported on its ends and reinforced with 1-1/2-inch Douglas-fir lumber as shown in Figure 5. Use of the Douglas-fir stiffeners promoted breakage near the supported ends of the specimens as intended. Specimens tested without the reinforcement failed near their center. Drop height was increased by 1-inch increments from a distance of 6 inches until the specimen broke.

Complete evaluation of reel wheels for use as cable reel flanges would necessarily include simulated forklift handling, edge drops, moisture cycling, and other tests.

Results and Discussion

The 17-inch span, center load test was a measurement of both shear and bending strength. What appears to be both punch-through shear and bending failures in a flange (No. 9) made from factory residues is illustrated in Figure 6. Load-deflection curves show a slight degree of nonlinearity (Fig. 7).

Test results are given in Table 1. It is evident that good material strength properties are required in both the radial and the tangential directions. For panels of equal thickness and density the following comparisons can be made. Those flanges having either complete radial or complete tangential flake alignment (Nos. 4

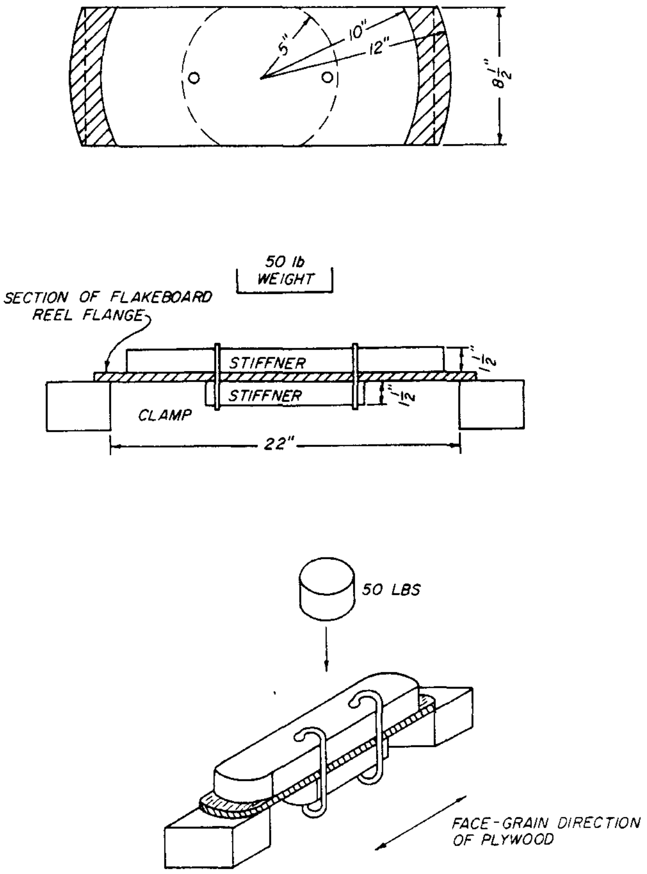

Figure 5. - Impact test jig. Shown are the disk section to be tested (top), the design of the jig (center), and the approximate placement of the dropped weight (bottom).

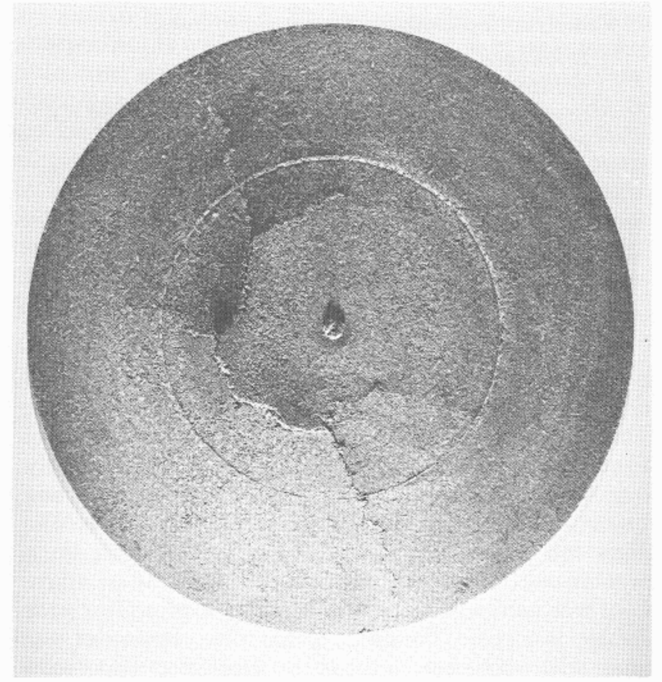

Figure 6. - Failure pattern in center load test for flange No. 9. (The 13-1/2-inch-diameter ridge showing in the photo is due to an imperfection in the caul plate and is of no significance.)

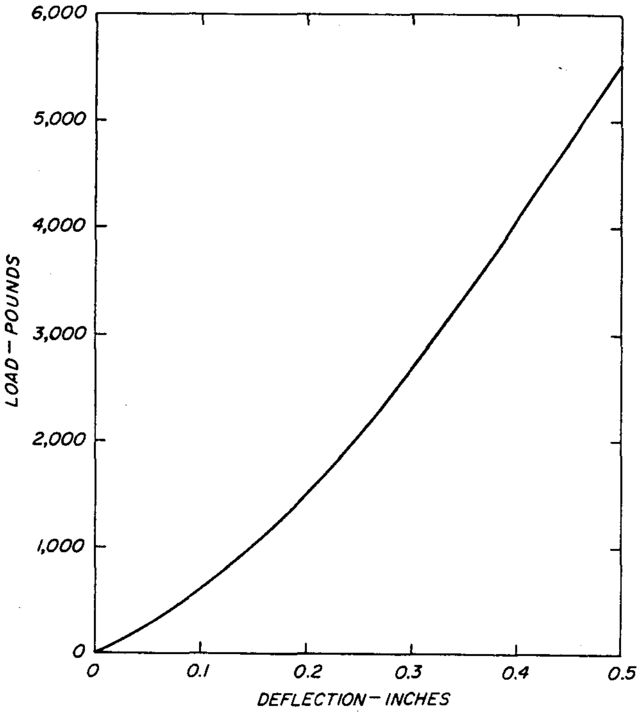

Figure 7. - Typical stress-strain curve for center loaded flanges. (Curve is for flange No. 6.)

and 5) were at least 18 percent weaker and had less than 50 percent of the stiffness (center load test) than the flange (No. 1) made with the random flake arrangement. Combining radially aligned flake faces with concentically aligned flake cores and vice versa improved strength by 32 to 27 percent and stiffness by 13 to 24 percent over that of the nonoriented flake flange. The flange (No. 6) with radially aligned faces was stronger but less stiff than that flange (No. 7) made with concentically aligned faces.

The importance of flake quality is shown by the almost fourfold reduction in strength and stiffness in those flanges (Nos. 9 and 10) made from the poorer plant residue. Proper techniques used in initial material processing definitely improved the performance (note results of tests on flanges Nos. 11 and 12).

Increasing average density from 40 to 47 pounds per cubic foot greatly increases strength and stiffness in flanges manufactured from large flakes as well as those made from plant residue.

Comparing impact test results of those 1/2-inch, 40-pcf flanges made with disk-cut flakes showed that the flanges made with all random flake alignment (No. 1), and with radially aligned faces and concentrically aligned core (No. 6), gave superior performance. The

TABLE 1. - *Physical properties of cable reel flanges.*

Specimen No.	Material type	Flake alignment		Thickness (in.)	Density ([a]lb./ft.^{3})	Center load test		Impact
		Face	Core			Load at failure (lb.)	Deflection at failure (in./M lb.)	Maximum drop (in.)
1	0.020- by 0.5- by 2.0-in. southern pine flake	Random	Random	1/2	40	4,220	0.104	28
2	0.020- by 0.5- by 2.0-in. southern pine flake	Random	Random	1/2	47	6,050	.078	14
3	0.020- by 0.5- by 2.0-in. southern pine flake	Random	Random	3/4	40	7,720	.051	50
4	0.020- by 0.5- by 2.0-in. southern pine flake	Radial	Radial	1/2	40	3,300	.158	18
5	0.020- by 0.5- by 2.0-in. southern pine flake	Concentric	Concentric	1/2	40	3,460	.225	14
6	0.020- by 0.5- by 2.0-in. southern pine flake	Radial	Concentric	1/2	40	5,590	.091	28
7	0.020- by 0.5- by 2.0-in. southern pine flake	Concentric	Radial	1/2	40	5,350	.079	18
8	0.020- by 0.5- by 2.0-in. southern pine flake	Radial	Random	1/2	40	4,150	.123	23
9	Residue–hammermilled lumber, hogged plywood	Random	Random	1/2	40	1,080	.370	–
10	Residue–hammermilled lumber, hogged plywood	Random	Random	1/2	47	1,760	.233	6
11	Residue—flaked lumber and plywood	Random	Random	1/2	40	1.740	.230	6
12	Residue—flaked lumber and plywood	Radial	Concentric	1/2	40	1,900	.242	10
13	Three-ply Douglas-fir A-C plywood	–	–	3/8		2,150	.233	13
14	Five-ply Douglas-fir A-C plywood	–	–	1/2		4,400	.153	20

[a] Nominal density based on ovendry weight.

flange having a concentrically aligned face and radially aligned core (No. 7) ranked at the low end of the spectrum along with those having either all concentric or all radial flakealignment configurations. Modification of the test procedures to insure a rigid fastening of the stiffeners and to hold the ends of the boards firmly in place may be needed to reduce statistical variability.

For comparison, tests were conducted on circular plates cut from three-ply 3/8-inch-thick and fiveply 1/2-inch-thick Douglas-fir AC plywood, Table 1. The flange (No. 1) made with randomly oriented large flakes was 4 percent weaker (center load test) but 32 percent stiffer than the 1/2-inch plywood. The same flakeboard also performed better in the impact test than the plywood.

Summary

Circular 1/2-inch, 40-pcf “reel wheels” of randomly aligned flakeboard performed in a manner similar to that of five-ply 1/2-inch, AC plywood in a center load. test. Use of certain polarized alignment techniques further increased the strength and stiffness of the flakeboard flanges. Flake geometry is important in achieving maximum mechanical properties. Proper techniques used in initial processing of plant residues improved the material’s performance. The described research, while incorporating only broad product design parameters, does vividly illustrate the vast array of possibilities to create truly engineered products from a remarkable resource—wood.