Flakeboard Properties as Affected By Flake Cutting Techniques

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Abstract

Flakeboards were prepared from flakes obtained from disk, drum, and ring flakers, and a shaping-lathe headrig. Species used were lodgepole pine, loblolly pine, sweetgum, southern red oak, and mockernut hickory at 1.25 compression ratio and two resin contents (5% and 8%). The three-layer panels had 25 percent of the largest flakes on each surface; all other material retained on screens 1/16 inch or larger was in the core. Flakes were cut 2.25 inches long and 0.02 inch thick. The target flake length was obtained or exceeded for all but red oak and hickory flakes made in the ring flaker. Except for disk-cut flakes, the flakes were less than 0.02 inch thick. Screen analysis varied significantly among flakes and species. The ring flaker produced the most fines. Effects of species and resin content on the strength, stability, and durability of flakeboard depend on the flaker. For panels from each flaker an increase in resin content slightly increased strength and improved panel stability. Although panels were fabricated at equivalent compression ratios, the higher density species yielded panels with greater strength but these panels deteriorated most after accelerated aging. One flaker was not clearly superior to the others. Generally, the strengths and MOEs of lathe- and disk-cut flake panels were similar and higher than those of the ring- and drum-cut flake panels. The ring-cut flake panels had the highest IB, but the high IB did not result in lower dimensional stability measurements based on the 24-hour water-soak test. By limiting flaker evaluation to one species and certain test properties, a flaker could be chosen that would yield a panel superior to panels fabricated with flakes produced on other flakers.

Logging residue from many regions is being evaluated by the Forest Service to provide technical data on the feasibility of using such residue in structural sheathing products. Western residues are mostly from softwoods; small, cull, low-grade hardwoods comprise the residue from the southern United States. Development of a structural panel utilizing the western residue has been the concern of the Forest Products Laboratory (FPL) in Madison, Wisconsin. The Southern Forest Experiment Station (SO) in Pineville, Louisiana, has concentrated on the southern residue. Both laboratories have recommended three-layer panels, but differences in flakes and particles have dictated different layering and particle geometries.

This study describes the influence of various flake generation techniques on particle geometry and flakeboard properties. Relationships associated with particle bonding were also studied. Factors not considered were flake thickness, combinations of furnish (i.e., flakes in combination with fibers, sawdust, hammermill material, etc.), flakes from different machines combined to make one panel, and panel construction.

Material and Methods

Small-diameter bolts (about 7 in.) of sweetgum (*Liquidambar styraciflua* L.), red oak (*Quercus falcata* Michx.), mockernut hickory (*Carya tomentosa* Nutt.), and loblolly pine (*Pinus taeda* L.) were obtained in central Louisiana. Small-diameter lodgepole pine (*Pinus contorta* Dougl.) logs were obtained in Colorado and shipped to Louisiana. Material of each species was randomly divided for flaking with disk and ring flakers at FPL, shaping-lathe headrig at SO, or drum flaker at Washington State University. Before flaking, all material was debarked by hand. The flakers were calibrated to produce flakes 2.25 inches long, 0.020 inch thick, and random width. Ring-flakes were produced by chipping bolts in a drum chipper that produced chips 2.50 inches long and then flaking. The shaping-lathe headrig employed circular cams for maximum flake production and flaked the bolts at the rate of 1 inch per revolution down to a 4-inch diameter. The drum flaker feeding mechanism pivoted through a small angle

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instead of flaking the bolts horizontally. Discussions of the flaking principles of the machines are in Maloney (4) and Koch (3).

Lathe flakes were dried to less than 10 percent moisture content (MC) and shipped to FPL. Drum flakes were shipped green to FPL with a small amount of formaldehyde added to inhibit mildew and fungus growth. Before panel fabrication, all flakes were dried to about 3 percent MC and screened through 2-, 1-, 1/2-, 1/4-, 1/8-, and 1/16-inch screens. The material that passed through the 1/16-inch screen was discarded after the percentage of the total weight that it composed was calculated.

For each species and flaker combination, two panels were fabricated for each combination of two resin contents (5% and 8% based on ovendry (OD) weight of flakes) and two densities. We are concerned here only with panel densities established at a compression ratio (ratio of panel density to species density) of 1.25. (We report these matters in more detail in another paper (5).)

Panel manufacturing conditions were:

- Panel size: 1/2 inch by 24 inches by 28 inches
- Binder: Phenol-formaldehyde liquid resin
- Additive: 1 percent wax emulsion (based on OD weight of flakes)
- Mat MC: 9 to 10 percent
- Mat construction: Three-layer, with 25 percent of largest flakes per surface layer
- Press temperature: 340°F
- Press cycle: 1 minute to thickness stops, then pressure necessary to maintain position
- Total press time: 8 minutes
- Post-cure: Immediately after pressing, panels were hotstacked overnight in an insulated box.

After manufacture, the unsanded panels were cut into test specimens, conditioned at 50 percent relative humidity (RH), and tested according to ASTM Standard D-1037-72a (1). Four specimens were tested in bending according to the ASTM standard at 50 percent RH and two more after aging. Bending strength (MOR) and stiffness (MOE) of aged specimens were calculated based on specimens' dimensions before aging.

Two internal bond (IB) strength test specimens were cut from each tested bending specimen. Dimensional stability tests were performed on specimens subjected to an OD vacuum-pressure soak (OD-VPS) (2), RH exposure between 30 and 90 percent at 80°F, and 24-hour water-soak.

Results and Discussion

All panel properties were influenced by interactions of the main factors — flaker, species, and resin content. An analysis of these complex interactions has been presented (5). This paper presents major trends and effects, based on observed means, to allow an assessment of the flakers.

Screen Analysis and Resin Coverage

Screen analysis varied significantly among flakers (Table 1). The ring flaker produced from 21.4 to 25.6 percent fines depending on the species (Table 1). Drum, lathe, and disk flakers yielded 7.7, 3.5, and 2.2 percent fines. The most fines the lathe and drum flakers produced was in cutting oak (6.9% and 12.4%). The disk flaker made most fines when cutting lodgepole pine and hickory (3.2% and 3.5%).

TABLE 1. — *Percent of material retained on each screen size.*

Species and flaker	Hole in screen size (in.) 2	1	1/2	1/4	1/8	1/16	Fines[a]
	-------	-------	-------	%	-------	-------	-------
Lodgepole pine							
Disk	4.1	48.7	25.9	11.6	3.2	3.3	3.2
Drum	1.7	45.2	20.8	13.1	6.3	5.7	7.2
Ring	0.0	0.4	5.6	31.8	20.6	20.1	21.4
Lathe	0.3	56.8	27.3	10.2	1.5	1.4	2.8
Loblolly pine							
Disk	5.8	61.2	23.8	5.7	1.1	1.1	1.3
Drum	0.0	24.6	33.5	19.6	8.3	6.9	7.1
Ring	0.0	0.2	2.4	25.4	24.0	22.4	25.6
Lathe	0.0	17.8	44.5	25.9	4.5	3.2	4.1
Sweetgum							
Disk	4.3	60.3	23.8	7.6	1.4	1.1	1.5
Drum	0.0	39.4	31.4	13.8	5.9	4.8	4.7
Drum, 1[b]	0.0	1.8	32.2	34.9	14.1	9.3	7.7
Ring	0.0	0.1	3.8	31.9	19.4	20.1	24.7
Lathe	0.0	64.3	27.2	5.5	1.0	0.7	1.3
Red oak							
Disk	1.2	39.0	35.5	19.0	2.4	1.2	1.7
Drum	0.0	4.5	19.5	36.7	14.7	12.2	12.4
Ring	0.0	0.0	0.5	22.0	25.8	26.2	25.5
Lathe	0.0	4.6	28.0	44.1	9.9	6.5	6.9
Hickory							
Disk	0.9	46.9	27.2	13.5	4.8	3.3	3.5
Disk, 1[b]	0.0	4.2	42.1	33.1	11.0	4.8	4.8
Drum	0.0	25.9	32.3	20.7	7.9	6.3	6.9
Drum, 1/2[c]	0.0	0.7	10.3	49.6	17.7	11.9	9.8
Ring	0.0	0.0	1.7	25.7	27.8	23.7	21.1
Lathe	1.0	33.8	34.1	21.1	5.3	2.4	2.3

[a]Material that passed through the 1/16-inch screen.
[b]Flakes on the 1-inch and larger screens were passed through the drum chipper, added to the other screens, and rescreened to yield the tabulated percentages for panel fabrication.
[c]Flakes on the 1/2-inch and larger screens were passed through the drum chipper, added to the other screens, and rescreened to yield the tabulated percentages for panel fabrication.

From the material that was to be used in panel fabrication, 50 flakes per screen size were measured for length, width, and thickness[1]. Disk-cut flakes had the smallest surface area per pound of flakes followed by the lathe-cut flakes. Ring-cut flakes had the largest surface area per pound except for loblolly pine for which drum flakes had the largest. Since constant amounts of resin were applied (5% or 8%), resin solids applied per thousand square feet of flake surface area were inversely correlated with surface area per pound of flakes.

A flake length-to-thickness ratio of 112.5 was anticipated; i.e., 2.25-inch target flake length/0.020-inch target flake thickness. Although very few flakes remained on the 2-inch screen (Table 1), average length exceeded 2 inches for flakes remaining on screens as small as 1/2 inch. In general, flake thickness did not change with screen sizes above 1/2 inch, and the thinnest flakes were on the 1/16-inch screen. Except with the disk flaker, the anticipated length-to-thickness ratio of flakes retained on 1/2-inch and larger screens

[1]Tables containing these data are available from the authors.

was achieved (Fig. 1). The low disk-flaker ratio occurred because flake thickness exceeded target thickness; the other flakers yielded slightly less than target thickness. Dimension ratio varied more for core flakes than face flakes.

Bending Strength

Panels of lathe-cut flakes had the highest average strength followed by disk-, ring-, and drum-cut flake panels for initial (50% RH) and accelerated aging test conditions (Table 2). Accelerated aging lowered bending strength of panels from all of the flakers. Lathe-cut flake panels were strongest for the species with the lowest specific gravity (SG) (lodgepole pine) and the two species with the highest SGs (Table 3). Loblolly pine and sweetgum panels made from disk-cut flakes were strongest. Although the lathe- and disk-cut flake panels were strongest overall, each also had a panel of one species that was weakest; i.e., hickory for the disk and loblolly pine for the lathe.

At the initial test conditions increasing resin content from 5 to 8 percent raised MOR an average of 16 percent; after accelerated aging, MOR was 24 percent higher for the 8 percent resin content than for the 5 percent. By increasing resin content, bending strength for lathe- and disk-cut flake panels increased 14.3 percent and 10.8 percent, while the ring- and drum-cut flake panels had a 19.0 percent increase. Except with lathe-cut flake panels, the greatest strength increase caused by increasing resin content occurred with hickory; lodgepole pine had the largest strength increase for the lathe-cut flake panels.

Modulus of Elasticity

The MOE trends were similar to those of bending strength. An increase in resin content increased MOE of all except lathe-cut flake panels. At the higher resin content, both the ring- and drum-cut flake panels yielded 10.4 percent increase in MOE, but the disk-cut flake

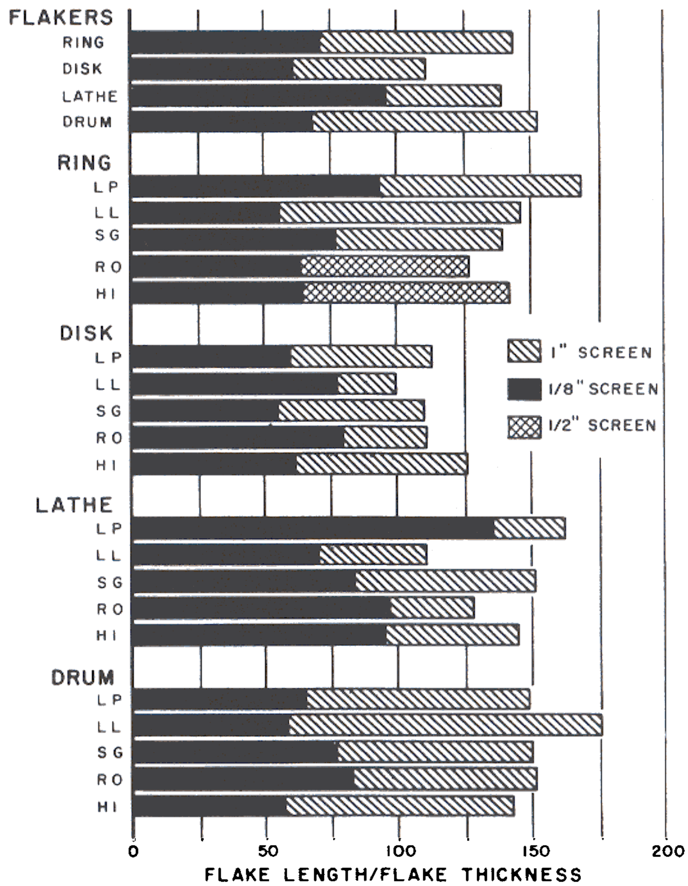

Figure 1. — Ratio of flake length to flake thickness for lodgepole pine (LP), loblolly pine (LL), sweetgum (SG), red oak (RO), and hickory (HI) flakes cut on four flakers.

TABLE 2. — *Strength and dimensional stability properties of panels made from flakes of five species. Flakes were produced on four flakers and panels were pressed to a 1.25 compression ratio.*

	Density at 50% RH	MOR (psi)		MOE (1,000 psi)		IB (psi)		LE (%)			TS (%)		
	(pcf)	INIT[a]	AA[a]	INIT	AA	INIT	AA	30-90% RH	24-hr. WS[a]	OD-VPS[a]	30-90% RH	24-hr. WS	OD-VPS
Overall	42.6	5,016	3,825	647	499	105	27	0.17	0.07	0.27	13.9	15.8	27.4
Flaker													
Ring	41.1	4,803	3,684	610	480	132	34	.16	.09	.31	14.4	19.0	29.5
Disk	42.9	4,988	3,934	665	530	96	33	.20	.05	.28	13.0	13.6	26.3
Lathe	43.1	5,565	4,083	685	514	104	21	.15	.04	.22	12.1	13.2	23.5
Drum	43.3	4,706	3,600	629	473	87	20	.16	.09	.27	15.9	17.2	30.2
Species[b]													
LP	30.9	3,717	3,252	525	458	58	23	.12	.08	.21	14.3	19.4	24.2
LL	39.4	4,226	3,475	579	477	70	31	.12	.09	.22	13.9	21.0	24.8
SG	39.8	4,136	3,438	567	455	72	22	.17	.08	.27	14.2	15.9	28.3
RO	48.2	5,711	3,962	752	523	135	27	.18	.06	.28	13.4	11.1	27.8
HI	55.7	7,290	4,999	812	585	189	33	.24	.03	.35	13.5	11.4	31.9
Resin (%)													
5	42.2	4,643	3,415	623	463	86	16	.16	.06	.26	15.4	18.0	31.6
8	43.0	5,389	4,235	671	536	123	39	.17	.08	.28	12.3	13.5	23.2

[a]INIT=50% RH test condition.
AA=after accelerated aging.
24-hr. WS=24-hour water-soak.
OD-VPS=ovendry vacuum-pressure soak.
[b]LP=lodgepole pine, LL=loblolly pine,
SG=sweetgum, RO=red oak, HI=hickory.

TABLE 3. — *Strength properties of panels made from flakes of five species. Flakes were cut on four types of flakers and panels pressed to a 1.25 compression ratio.*

Flaker	Species[a]	Bending strength (psi)		MOE (1,000 psi)		IB (psi)	
		Initial[b]	AA[b]	Initial	AA	Initial	AA
Ring	LP	3,141	2,837	432.8	390.7	68.6	35.3
	LL	4,200	3,569	555.0	483.8	96.6	44.8
	SG	3,936	3,151	543.1	449.9	82.7	15.4
	RO	5,393	3,758	697.7	485.9	168.0	37.3
	HI	7,347	5,103	821.1	589.0	244.2	39.2
Disk	LP	3,358	3,013	514.4	462.0	70.6	33.3
	LL	4,609	3,825	603.2	527.7	82.3	33.3
	SG	4,803	4,133	649.2	568.2	92.2	33.7
	RO	5,416	3,876	764.6	493.9	75.2	27.8
	HI	6,756	4,821	792.6	600.3	159.4	36.2
Lathe	LP	4,738	4,189	615.2	555.0	47.8	10.9
	LL	4,026	2,973	568.5	417.7	59.7	24.9
	SG	4,231	3,419	575.6	416.1	60.0	17.6
	RO	6,625	4,307	800.9	572.9	174.1	22.8
	HI	8,206	5,526	863.4	609.2	176.9	30.1
Drum	LP	3,631	2,967	537.2	425.0	43.2	11.9
	LL	4,068	3,532	591.1	478.2	42.3	21.3
	SG	3,573	3,048	498.1	385.9	52.3	21.4
	RO	5,409	3,906	744.6	538.0	122.1	20.4
	HI	6,849	4,548	772.4	539.5	176.6	26.8

[a]LP=lodgepole pine, LL=loblolly pine, SG=sweetgum, RO=red oak, HI=hickory.
[b]Initial=50% RH; AA=after accelerated aging.

panels had only an 8.0 percent increase. The average MOE increase of the lathe-flake panels was smallest (2.3%), but lodgepole pine panels fabricated with lathe-cut flakes had the greatest (18.2%) increase with increased resin content.

Panels of different species fabricated at the target compression ratio (CR) of 1.25 did not produce the same MOE. Hickory, then red oak, had the highest average MOEs and the highest MOE for each flaker (Table 3). Panels fabricated with lathe-cut flakes produced the stiffest panel for high and low SG species and the disk-cut flake panels for the two intermediate species (sweetgum and loblolly pine). The data indicated that as species SG increases the CR can decrease, but the boards will maintain equivalent properties. For instance, hickory fabricated at the lowest CR (1.21) was stiffest. Hickory and red oak could have been fabricated at even lower CRs and still maintained stiffness equal to that of the other species.

Internal Bond

The ring-cut flake panels had the highest IB for 50 percent RH and after accelerated aging (Table 2). At 50 percent RH, the ring-cut flake panels' IB was 28 pounds per square inch higher than the lathe-cut flake panels' IB, which was next highest. The IBs of the ring- and disk-cut flake panels after aging differed by only 1 pound per square inch and were greater than the IBs of the lathe-cut and drum-cut flake panels.

As species density increased, initial IB increased from 58 to 189 pounds per square inch (Table 2), indicating that an individual IB-CR relationship may exist for each species. After accelerated aging, however, high-density species had a much greater drop in IB. The decrease resulted in only an 11-psi IB range among species. These relationships generally held for panels of all species made from different flakers.

Linear Expansion (LE)

Except for drum-cut flake panels of lodgepole pine, the 24-hour water-soak produced less LE than 30 to 90 percent RH. The OD-VPS caused more LE than either of the other test conditions for all experimental factors (Table 2). Increasing resin content increased LE only 0.01 percent for the 30 to 90 percent RH condition and 0.02 percent for the water-soak and OD-VPS conditions. The effect of resin content on LE also depended on flaker type.

In general, as species density increased, LE based on OD-VPS and 30 to 90 percent RH increased, but LE based on the water-soak decreased (Tables 2 and 4). If all species are averaged, the lathe-cut flake panels had the lowest LE values for all three test conditions (Table 2). The lathe-cut flake panels of all species expanded less under OD-VPS than panels made from flakes produced by other flakers (Table 4). Except for red oak panels, lathe-cut flake panel boards expanded less under the water-soak (Table 4). However, for 30 to 90 percent RH, lathe-cut flake panels had the lowest LE for only one species — loblolly pine. Thus, to select the flaker that would yield the least LE, species and test condition should be considered. But, generally, the lathe was best (less than 0.25% regardless of test conditions).

Thickness Swell (TS)

The largest amount of TS occurred under OD-VPS conditions (Table 2). An increase in resin content decreased TS by 3, 5, and 8 percent for the 30 to 90 percent RH, water-soak, and OD-VPS conditions. The TS for the ring-cut flake panels after the water-soak exceeded the TS of drum-cut flake panels. Otherwise, the order of increasing TS for all three conditions was the lathe-, disk-, ring-, and drum-cut flake panels.

As species SG increased, a trend toward increased TS for OD-VPS was evident. In the water-soak. TS

TABLE 4. — *Dimensional stability properties of panels made from flakes of five species. Flakes were cut on four types of flakers and panels pressed to 1.25 compression ratio.*

		LE (%)			TS (%)		
Flaker	Species[a]	30-90% RH	24-hr. WS[b]	OD-VPS[b]	30-90% RH	24-hr. WS	OD-VPS
Ring	LP	0.15	0.11	0.26	14.1	18.6	23.6
	LL	.12	.11	.27	14.4	18.9	25.9
	SG	.15	.10	.28	16.1	22.4	31.2
	RO	.16	.07	.30	14.3	15.7	32.0
	HI	.22	.06	.42	12.8	19.3	34.9
Disk	LP	.15	.07	.23	15.1	18.6	24.4
	LL	.13	.07	.23	13.4	17.6	22.2
	SG	.20	.06	.22	13.2	13.9	27.4
	RO	.21	.02	.28	12.1	10.2	27.4
	HI	.31	.02	.39	11.4	7.8	30.1
Lathe	LP	.11	.07	.18	11.9	17.9	20.6
	LL	.11	.07	.17	12.2	20.8	23.3
	SG	.15	.01	.21	12.6	9.9	25.6
	RO	.17	.04	.24	11.7	9.1	23.7
	HI	.23	.00	.30	12.2	8.2	24.7
Drum	LP	.07	.08	.19	15.8	22.5	28.1
	LL	.14	.11	.23	15.6	26.7	27.6
	SG	.18	.14	.33	14.9	17.1	29.1
	RO	.19	.09	.29	15.5	9.6	28.1
	HI	.20	.04	.31	17.7	10.2	37.9

[a]LP=lodgepole pine, LL=loblolly pine, SG=sweetgum, RO=red oak, HI=hickory.
[b]24-hr. WS=24-hour water soak.
OD-VPS=ovendry vacuum-pressure soak.

varied inversely with SG. Under the 30 to 90 percent RH test, the species displayed a fairly uniform TS, with averages ranging from 13.4 percent for red oak to 14.3 percent for lodgepole pine. Red oak and hickory TS in the 30 to 90 percent RH test was higher than in the water-soak, but the reverse occurred for the other species. Generally, these trends were evident for each flaker (Table 4). Other than the fact that the lathe-cut flake panels had the least TS for the three hardwoods based on OD-VPS, the best flaker for a particular species to yield a low TS depended on the test conditions.

Summary Comparisons

Species densities ranged from 23.7 pounds per cubic foot for lodgepole pine to 45.8 pounds per cubic foot for hickory. A CR of 1.25 was attempted, but CRs generally decreased as species density increased. In general, panels of species with high densities had better MOR, MOE, and IB properties than less dense species. However, the high density species generally had a greater loss in these properties after aging. This loss may indicate bonding difficulties for high density species or may be caused by anatomical characteristics. Because of weight limitations for intended end uses, the density of panels from species such as hickory may need to be reduced. However, the reduction must be accomplished without the after-aging properties declining below those of the low-density species.

In attempting to select the best flaker, one must remember the four machines were made to cut particles of about the same geometry and only a small amount of material was flaked. No flaker consistently yielded panels with the best properties. One possible ranking could involve averaging the species data for each flaker. But in doing so, one must be aware that species-flaker interactions can alter the ranking. Thus, one should consider the species to be flaked and then compare the performance of the flakers. If one species and several properties were selected for analysis, a flaker could be chosen that would yield a panel superior to panels fabricated with flakes produced on other flakers. If minimum acceptable property values are met by each flaker, selection could be decided by one property.

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