EFFECT OF RESIN TYPE ON PROPERTIES OF STEAM-PRESS-CURED FLAKEBOARDS

CHUNG-YUN HSE
ROBERT L. GEIMER
W. ERNEST HSU
R.C. TANG

ABSTRACT

Six potentially important wood adhesives for gluing southern pine and white oak flakeboards were evaluated for their performances in steam-injection pressing and conventional platen pressing. Of the six resins tested, polyisocyanate resin performed well in both steam injection and conventional platen pressings. Phenol-formaldehyde (PF) and melamine urea-formaldehyde (MUF) resins performed poorly in steam-injection pressing. However, adding a small amount of polyisocyanate improved performance considerably. Bending strengths were consistently higher with conventional platen pressing than with steam-injection pressing. The lower density face in steam-injection pressing would result in lower bending properties. In PF and MUF resin systems, steam-injection pressing resulted in low bond strength and high dimensional stability, whereas conventional platen pressing resulted in high bond strength and low dimensional stability. The pairing of low strength with high stability suggested that bonding strength could not be the cause of improvement in dimensional stability. Most probably, steam pressing reduced internal stresses and stabilized the flakes, which in turn resulted in an improvement in dimensional stability. The improvement in dimensional stability may also be related to less strength loss of the board in steam-injection pressing when exposed to high relative humidity treatment.

Steam-press curing is a method of hot-pressing-wood composite panels by injecting steam directly into the board during the pressing process. The injected steam raises the internal mat temperature, which in turn rapidly cures the resin binder in the composite panels. It was shown, for instance, 1-inch-thick, 45- pcf phenolic-bonded particleboard was fully cured in 1 minute at a steam pressure of 300 psi (430°F). This time was substantially shorter than the 15 minutes needed with a conventional platen pressing method (16).

The economic potential of this process has recently stimulated attention on steam-injection pressing by a number of researchers (1-7,9-11,13-22). Most earlier processes used superheated steam (1,11,18). More recently, saturated steam was used in the developments of self-sealed (9) and unsealed (3) steam-injection pressing processes. These new techniques provide better control of temperature and board moisture in the manufacturing process and were chosen for this study.

The objective of this study was to compare the properties of steam-injection pressed flakeboards made from either southern pine or white oak, using six different resin adhesives, with control boards pressed in a conventional fashion.

EXPERIMENTAL PROCEDURES

The six resin combinations chosen for the study were: phenol-formaldehyde (PF), melamine urea-formaldehyde (MUF), phenol-formaldehyde/melamine urea-formaldehyde (PF/MUF),polymeric isocyanate (PIC), polyisocyanate/phenol-formaldehyde (PIC/PF), and polyisocyanate/urea- formaldehyde (PIC/UF).

The resin contents, based on ovendry weight of wood furnish, were: PF = 4.5 percent; MUF = 4.5 percent; PIC = 2.5 percent; PF/MUF = blended as in a three-layer board with 1/3 PF-blended flakes at each face and 1/3 MUF-blended flakes at the core, the resin content was 4.5 percent (resin solids based on ovendried wood) in all three layers; PIC/PF =blend as in situpolymerization in which PIC (0.625%) was applied before PF (3.375%); and PIC/UF = blend as in situ polymerization in which PIC (0.833%) was applied before UF (3%).

The authors are, respectively, Principal Wood Scientist, USDA Forest Serv., Southern Forest Expt. Sta., Pineville, LA 71360; Research Wood Technologist, USDA Forest Serv., Forest Prod. Lab., Madison, WI 53705-2398; Composite Development Scientist, Forintek Canada Corp., Ottawa, ON Canada; and Professor, School of Forestry, Auburn Univ., Auburn, AL 36849-5418. This paper was received for publication in August 1993.

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TABLE 1. — Effect of resin type and pressing method on internal bond strength.

	Pine flakeboard			White oak flakeboard		
	Steam-injection pressing		Conventional	Steam-injection pressing		Conventional
Resin	Self-sealed	Unsealed	pressing	Self-sealed	Unsealed	pressing
	(psi)					
PF	14.1[a] (14.0)[c]	26.8 (15.4)	79.9 (7.4)	11.1 (14.8)	30.4 (14.7)	40.9 (13.9)
	12.5[b] (12.8)	23.6 (8.1)	66.7 (6.3)	16.2 (7.1)	26.8 (5.9)	12.3 (9.3)
MUF	13.1 (8.2)	10.4 (12.1)	66.0 (8.7)	13.5 (19.5)	39.3 (15.2)	66.2 (14.0)
	11.3 (15.2)	10.4 (18.3)	41.3 (12.5)	12.0 (18.2)	31.2 (15.5)	38.8 (3.1)
PF/MUF	10.7 (18.6)	14.3 (17.9)	50.6 (2.1)	25.4 (18.7)	32.0 (15.2)	36.6 (16.9)
	9.8 (18.7)	17.0 (13.2)	44.6 (16.0)	17.1 (18.3)	27.4 (13.7)	22.7 (15.0)
PIC	101.2 (6.6)	107.0 (12.7)	116.5 (5.2)	92.2 (9.6)	106.1 (8.4)	117.5 (12.8)
	93.6 (9.1)	106.9 (5.0)	91.9 (9.3)	89.1 (9.5)	94.6 (3.1)	77.5 (11.4)
PIC/PF	76.4 (13.8)	93.9 (11.1)	72.8 (18.1)	99.8 (8.2)	101.6 (8.6)	45.1 (7.6)
	68.7 (10.4)	73.0 (11.9)	59.6 (13.1)	69.7 (7.6)	85.2 (7.7)	45.4 (10.5)
PIC/UF	69.4 (3.4)	74.7 (9.9)	88.3 (7.9)	46.2 (13.9)	55.8 (16.7)	88.5 (12.2)
	69.7 (10.7)	45.2 (14.1)	82.8 (4.8)	42.1 (13.5)	48.6 (5.0)	64.3 (12.9)

[a] Upper numbers refer to specimens before conditioning to high RH treatment.
[b] Lower numbers refer to specimens after conditioning to high RH treatment.
[c] Numbers in parentheses are coefficients of variation (in percent) for each test.

A total of 36 flakeboards (two species x six resins x three replications) were made in the laboratory of the USDA Forest Service Southern Forest Experiment Station, Pineville, La. The flakes were 3inches long, 0.015 inch thick, and had variable widths. The3/4- by 42-by 42-inch panels were pressed in a conventional manner. Press temperature was 425°F and press time was 10 minutes for the pine boards and 12 minutes for the oak boards. These same 36 board types were pressed using a self-sealed steam injection process at Forintek Canada Corp. in Ottawa, Ontario, and with an unsealed steam injection process at the USDA Forest Service Forest Products Laboratory, Madison, Wis. Descriptions of variations in board size and press schedules follow.

SELF SEALED STEAM-INJECTION PRESSING

The general pressing conditions were: board size = 3/4 by 24 by 24 inches; press temperature = 420°F; steam injection pressure = 150 psi; and compression frame = 1/4 by 1-1/2 inches. The 5-minute press cycle was: 1 minute of pressing time before steam injection; 1 minute of steam injection into top mat; 30 seconds of steam exhaust from top of mat; 1-1/2 minutes of steam injection into top of mat; and 1 minute of steam exhaust and press open.

UNSEALED STEAM-INJECTION PRESSING

The general pressing conditions for pine boards were: board size =3/4 by 26 by 30 inches. The press cycle was: 33 seconds of closed press to a 1.6-inch press opening; hold press at 1.6 inch, injecting steam into top of mat at rate of 600 lb./hr. for 2 seconds; close press to 0.75 inch at 0.09 in./sec., injecting steam at rate of 500 lb./hr. for 9 seconds; hold at 0.75 inch for 10 seconds; shut off steam valve, hold the press, and let steam in the manifold dissipate for 90 seconds; hold at 0.75 inch for 90 seconds and vent to exhaust steam; decompress at a rate of 5 psi/sec. and exhaust steam for 4 seconds; hold at a pressure of 20 psi for 10 seconds; and open to 10 inches at 0.25 in./sec. for 39 seconds.

Pressing conditions for oak boards were the same as pine boards with slight modifications in the press cycle: steam was injected into the top mat for 4 seconds; held at 0.75 inch for 20 seconds before shutting off steam valve; and steam in the manifold was dissipated for 70 seconds.

For each panel, flakes were weighed and placed in a rotating drum blender. The required amount of resin was then weighed and applied to the flakes with air-atomization nozzles. The blended flakes were felted into the final mat with a forming box. The mat was transferred immediately to a single-opening hot-press and pressed with the specified conditions. The targeted densities were 42 and 46 pcf for the pine and white oak boards, respectively.

After hot-pressing, the panels were returned to the Pineville laboratory, trimmed, and cut into 3- by 20.5-inch (Canada) and 3- by 22-inch (Madison and Pineville) test specimens. The specimens were randomly divided into 2 groups with 72 specimens in each group (6 specimens each per resin and species) for mechanical strength and dimensional stability tests.

The specimens for the mechanical strength test were divided into 2 subgroups with 36 specimens in each subgroup (3 specimens per resin and species) for conditioning at low relative humidity (RH) (80°F and 65% RH) and high RH (80°F and 95% RH). After conditioning, mechanical strength tests (bending strength and tensile strength perpendicular to the face) were performed in accordance with ASTM standards for evaluating properties of wood-based fiber and particle panel materials (ASTM D 1037-72). The specimens were first tested for bending and then cut into 2-by 2-inch specimens for the internal bond (IB) test.

The specimens for the dimensional stability test were also divided into 2 subgroups with 36 specimens in each subgroup (3 specimens each per resin and species) for a 24-hour water-soak test and ovendry vacuum-pressure soak test (ODVPS). The 24-hour water-soak test consisted of soaking specimens in tap water for 24 hours. Weights, thicknesses, and lengths were measured before and after soaking. The ODVPS specimens were evaluated under the following conditions: 1) specimens were dried at 102°C for 24 hours; 2) specimens were placed *in* a pressure cylinder and flooded with tap water; and 3) the system was subjected to a vacuum 27±2 inches of mercury for 1 hour and pressure > 90±10 psi for 2 hours. This procedure was developed by the American Plywood Association (APA) and is designated as A PA Test Method P-1. Linear expansion (LE) and thickness swell (TS) values were based on the change from the ovendry condition to the end of the ODVPS cycle.

RESULTS AND DISCUSSION

MECHANICAL STRENGTH

Internal bond. — **Table 1** summarizes average IB for each combination of resins, species, and pressing method. Average IB varied widely, ranging from 10.4 psi to slightly over 117 psi. The most significant result among the various resin systems was the high strength of the PIC resins with both conventional and steam-injection pressings. The PIC resin yielded the highest IB for both pine and white oak boards with the exception of white oak flakeboards made with self-sealed steam-injection pressing.

On average, the PF, MUF, and PF/MUF resin systems performed poorly in bond strength with steam-injection pressing **(Fig. 1).** Of the two methods of steam pressing used, IB was slightly higher with the unsealed system than the self-sealed system. The poor performance of PF resins with both self-sealed and unsealed pressing systems is attributed mainly to over penetration of the liquid phenolic resin. Similar results were also reported in previous studies (4,14). It should be noted, however, that the powdered PF resins, with their commonly higher molecular weight and dryness, appear to tolerate the higher moisture conditions of steam injection without experiencing over penetration. The pressing cycles for self-sealed steam-injection pressing used in this study, for instance, have been used successfully in waferboards with powdered phenolic resins (10).

In the two combined resin systems containing PIC, the lB increased substantially with steam-injection pressing for both PIC/PF and PIC/UF resin systems, respectively, as compared to PF and MUF resins **(Fig. 2).** Furthermore, it is noted that the PIC/PF resin system, with 15 percent of PIC in the blend (i.e., 0.625% PIC based on ovendry weight of wood), attained the same level of IB strength with the PIC resin system (i.e., 2.5% based on ovendry weight of wood) in bonding oak boards. These results suggest that the PIC/PF resin system would be considered an excellent alternative resin system for flakeboard in steam- injection pressing with either PF resin with substantially improved performance at small cost increases or to PIC resins with substantial economic gains.

The most interesting results in gluing white oak flakeboard with conventional pressing were the higher IBs achieved with the MUF resin as compared to the PF resin and the superior performance of PIC/UF as compared to the PIC/PF resin systems (Fig. 3). Both MUF and UF are amino-based adhesives and are known to work well with various hardwoods with wide ranges of wood densities, as indicated in previous studies (8,12).

As shown in **Table 1,** the high RH treatment resulted in decreases in IB for most of the specimens. It is noted that the conventionally pressed flakeboard had a higher percentage loss of IB than that found in steam-injection pressing with the exception of PIC/PF-bonded pine and oak boards and PIC/UF-bonded pine boards. The higher percentage loss

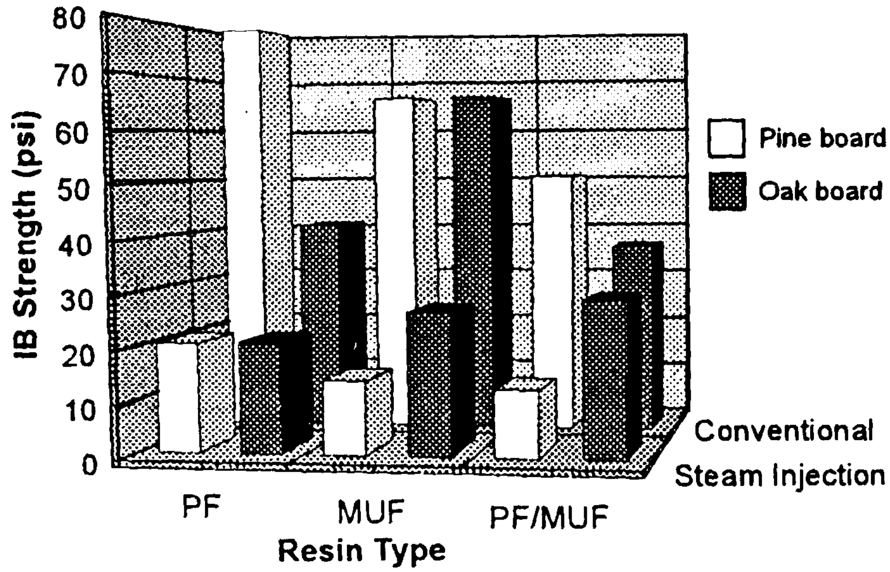

Figure 1. — Effect of steam-injection pressing on internal bond strength of flakeboards bonded with PF, MUF, and PF/MUF resin adhesives.

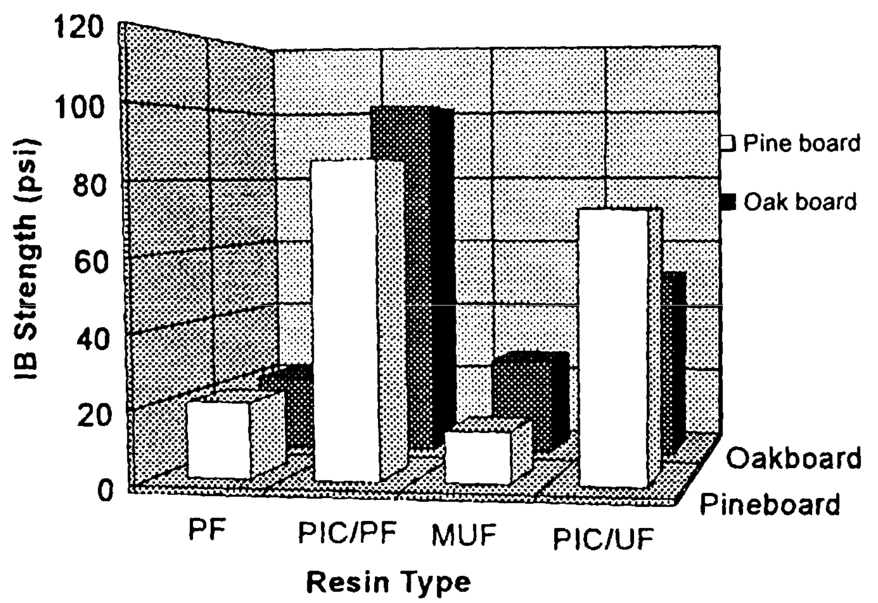

Figure 2. — Effect of combined resin systems containing polyisocyanate with steam-injection pressing on internal bond strength of pine and white oak flakeboards.

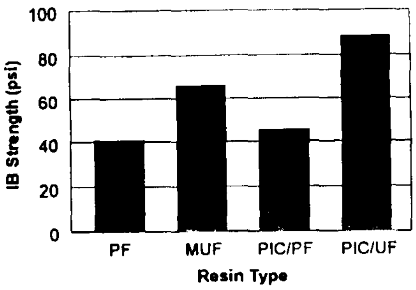

Figure 3. — Comparison of internal bond strength of white oak flakeboards bonded with amino-based adhesives and PF resins with conventional pressing.

TABLE 2. — Effect of resin type and pressing method on modulus of rupture.

	Pine flakeboard			White oak flakeboard		
	Steam-injection pressing		Conventional	Steam-injection pressing		Conventional
Resin	Self-sealed	Unsealed	pressing	Self-sealed	Unsealed	pressing
	(psi)					
PF	2,695[a] (6.6)[c]	2,498 (11.5)	4,094 (13.6)	2,706 (16.2)	2,739 (9.0)	2,787 (8.9)
	2,468[b] (1.6)	2,398 (7.0)	4,078 (6.9)	2,297 (10.7)	2,308 (13.8)	2,292 (13.3)
MUF	2,698 (7.5)	2,450 (12.2)	4,216 (14.3)	1,995 (18.6)	3,545 (14.8)	4,252 (8.6)
	2,372 (12.3)	2,126 (17.3)	2,920 (9.1)	1,935 (7.0)	2,238 (13.8)	3,581 (7.9)
PF/MUF	2,348 (18.7)	2,310 (12.1)	4,655 (15.2)	2,647 (19.3)	2,843 (5.7)	3,095 (11.4)
	2,148 (6.5)	2,260 (17.5)	3,487 (10.7)	1,926 (6.8)	2,587 (11.7)	2,251 (6.1)
PIC	4,439 (13.5)	4,227 (14.0)	5,098 (12.9)	4,105 (12.9)	4,599 (6.3)	4,639 (12.7)
	3,512 (7.5)	3,524 (9.7)	3,814 (13.2)	3,489 (3.6)	3,892 (9.2)	3,258 (6.4)
PIC/PF	3,778 (3.8)	3,929 (6.1)	4,438 (4.5)	3,764 (19.1)	3,434 (7.7)	4,277 (10.96)
	3,447 (6.5)	3,665 (6.9)	3,104 (6.0)	3,467 (6.8)	3,309 (11.4)	2,759 (11.2)
PIC/UF	3,830 (18.1)	3,044 (8.3)	4,081 (2.0)	2,180 (16.6)	2,813 (8.5)	5,854 (17.0)
	3,451 (5.0)	2,456 (2.1)	3,290 (10.6)	2,134 (11.2)	2,446 (15.1)	2,694 (14.2)

[a] Upper numbers are the results of a 24-hour water-soak test.
[b] Lower numbers are the results of an ovendry vacuum-pressure soak test.
[c] Numbers in parentheses are coefficients of variation (in percent) for each test.

TABLE 3. — Effect of resin type and pressing method on modulus of elasticity.

	Pine flakeboard			White oak flakeboard		
	Steam-injection pressing		Conventional	Steam-injection pressing		Conventional
Resin	Self-sealed	Unsealed	pressing	Self-sealed	Unsealed	pressing
	(× 1,000 psi)					
PF	499[a] (6.2)[c]	382 (8.2)	535 (7.6)	347 (10.8)	416 (5.6)	380 (6.4)
	299[b] (6.1)	332 (6.9)	392 (8.1)	307 (7.0)	333 (1.7)	287 (9.3)
MUF	504 (3.3)	348 (10.4)	564 (10.5)	361 (9.1)	406 (13.6)	502 (8.5)
	356 (4.2)	300 (7.3)	390 (5.6)	221 (5.1)	301 (1.3)	371 (7.9)
PF/MUF	466 (8.1)	464 (6.7)	533 (10.8)	410 (5.5)	393 (14.6)	453 (6.7)
	389 (4.7)	312 (11.9)	441 (4.3)	283 (1.6)	359 (10.3)	272 (4.8)
PIC	480 (2.6)	489 (10.4)	562 (5.6)	470 (8.2)	468 (10.2)	495 (7.8)
	438 (7.9)	381 (10.4)	460 (7.3)	358 (10.2)	404 (6.2)	333 (10.7)
PIC/PF	421 (13.1)	489 (4.5)	548 (8.2)	442 (12.0)	416 (8.8)	442 (9.9)
	382 (8.1)	412 (5.2)	386 (6.3)	355 (5.9)	366 (6.9)	282 (16.7)
PIC/UF	555 (0.4)	475 (9.3)	510 (13.0)	375 (12.5)	391 (4.9)	499 (12.5)
	405 (6.6)	347 (1.4)	345 (9.1)	242 (5.2)	352 (5.9)	301 (9.3)

[a] Upper numbers are the results of a 24-hour water-soak test.
[b] Lower numbers are the results of an ovendry vacuum-pressure soak test.
[c] Numbers in parentheses are coefficients of variation (in percent) for each test.

of IB is interesting, particularly if one considers that higher IB was also obtained for the same boards. The higher IB suggests the cured resins could not be the cause of higher strength loss. It has generally been assumed that steam-injection pressing would lead to compression stress relief and produce boards with exceptionally good dimensional stability. Thus, it is likely that less swelling stresses and the improved panel dimensional stability resulted in less IB strength loss with high RH treatment.

Bending strength. — Average modulus of rupture (MOR) values are summarized in **Table 2.** MOR values were consistently higher with conventional platen pressing than with steam-injection pressing. For conventional platen pressing, all resins exceeded 4,000 psi MOR with the exception of PF- and PF/MUF-bonded white oak boards. In contrast, only the PIC-bonded flakeboards with steam-injection pressing exceeded the same level of MOR value. These lower MORvalues with steam-injection pressing may be, to a large extent, related to the panel density gradient. It has been shown that the density profile in a steam-injection-pressed board tends to be very flat (2). It was expected that the lower density face would have resulted in lower bending properties.

The PF and PF/MUF resins with steam-injection pressing also resulted in lower bending strength. However, adding PIC into the resin system improved performance substantially. For example, the PIC/PF resin system with about 15 percent PIC increased MOR values by more than 30 percent over PF resin. Improvements in bending strength were also evident in southern pine flakeboards with the PIC/UF resin system as compared with MUF resin. However, little increase in MOR was shown with white oak boards.

As expected, long-term exposure to high RHs consistently weakened the bending strength for all specimens **(Table 2).** Based on the average of six resins, the flakeboard made with conventional platen pressing had a higher percentage reduction in bending strength (30% for white oak boards and 21% for southern pine boards) than those made with unsealed steam-injection pressing (16% for white oak boards and 10% for southern pine boards) and self-sealed steam-injection pressing (12% for white oak boards and 11% for southern pine boards).

Stiffness. — Average modulus of elasticity (MOE) values are summarized in **Table 3.** Average MOE values were highest for the PIC resins (493,889 psi), followed in decreasing order by PIC/UF resin (467,333 psi), PIC/PF resin (459,667 psi), PF/MUF resin (453,167 psi), MUF resin (447,611 psi), and PF resin (426,278 psi).

As with MOR, the average MOE value decreased with steam-injection pressing as compared to conventional platen pressing. The average MOE values were:

TABLE 4. — Effect of resin type and pressing method on thickness swelling.

Resin	Pine flakeboard: Steam-injection pressing, Self-sealed	Pine flakeboard: Steam-injection pressing, Unsealed	Pine flakeboard: Conventional pressing	White oak flakeboard: Steam-injection pressing, Self-sealed	White oak flakeboard: Steam-injection pressing, Unsealed	White oak flakeboard: Conventional pressing
	----	----	---- (%) ----	----	----	----
PF	15.5[a] (4.3)[b]	23.0 (4.2)	24.9 (10.5)	14.5 (4.8)	45.2 (7.6)	64.0 (6.0)
	18.8[b] (4.6)	25.3 (9.2)	26.3 (8.7)	20.2 (14.1)	29.1 (3.1)	49.9 (5.7)
MUF	14.9 (3.6)	26.6 (9.1)	30.2 (2.0)	29.9 (2.2)	23.4 (10.0)	22.0 (7.6)
	18.5 (6.5)	27.9 (11.9)	23.1 (6.1)	25.6 (7.8)	22.7 (8.3)	24.3 (8.2)
PF/MUF	15.8 (8.2)	24.6 (11.7)	26.9 (4.2)	20.2 (6.3)	23.4 (8.1)	50.0 (18.3)
	20.2 (4.7)	26.3 (7.4)	25.9 (8.1)	21.5 (7.4)	28.2 (10.5)	38.4 (5.5)
PIC	12.1 (9.7)	19.9 (5.2)	27.2 (5.4)	11.1 (3.2)	9.6 (13.5)	13.8 (14.6)
	14.5 (5.6)	22.3 (13.2)	24.7 (3.7)	16.1 (2.8)	31.3 (1.6)	39.9 (1.8)
PIC/PF	13.0 (9.1)	16.7 (14.6)	27.0 (8.3)	15.2 (1.7)	23.5 (5.3)	30.6 (5.2)
	17.7 (1.7)	22.7 (3.0)	24.9 (8.4)	18.4 (0.5)	30.8 (10.3)	31.4 (7.6)
PIC/UF	14.7 (13.2)	26.1 (8.2)	33.2 (5.2)	21.0 (3.3)	29.9 (9.4)	24.3 (13.8)
	17.4 (10.0)	26.5 (3.6)	25.2 (4.9)	24.2 (1.1)	31.8 (6.9)	33.1 (8.6)

[a] Upper numbers are the results of a 24-hour water-soak test.
[b] Lower numbers are the results of an ovendry vacuum-pressure soak test.
[c] Numbers in parentheses are coefficients of variation (in percent) for each test.

TABLE 5. — Average thickness swelling for three pressing methods.

Specie and test	Self-sealed steam-injection pressing	Unsealed steam-injection pressing	Conventional pressing
	----	---- (%) ----	----
Southern pine			
ODVPS[a]	17.9	25.1	25.4
24-hr. soak	14.3	22.8	28.2
White oak			
ODVPS	21.0	29.0	36.2
24-hr. soak	18.7	25.8	39.1

[a] ODVPS = ovendry vacuum-pressure soak.

TABLE 6. — Effect of resin type and pressing method on linear expansion by ovendry vacuum-pressure soak test.

Resin	Pine flakeboard: Steam-injection pressing, Self-sealed	Pine flakeboard: Steam-injection pressing, Unsealed	Pine flakeboard: Conventional pressing	White oak flakeboard: Steam-injection pressing, Self-sealed	White oak flakeboard: Steam-injection pressing, Unsealed	White oak flakeboard: Conventional pressing
	----	----	---- (%) ----	----	----	----
PF	0.231 (10.4)[a]	0.413 (14.7)	0.290 (14.8)	0.227 (21.1)	0.333 (13.5)	0.558 (8.3)
MUF	0.298 (21.0)	0.516 (8.9)	0.230 (2.1)	0.226 (20.7)	0.394 (17.7)	0.299 (8.1)
PF/MUF	0.312 (13.1)	0.506 (10.2)	0.314 (7.4)	0.242 (10.3)	0.343 (9.3)	0.305 (10.4)
PIC	0.247 (21.4)	0.367 (1.9)	0.315 (10.7)	0.270 (13.2)	0.342 (7.1)	0.370 (3.7)
PIC/PF	0.278 (6.1)	0.351 (16.2)	0.368 (10.6)	0.227 (15.4)	0.242 (14.0)	0.351 (2.3)
PIC/UF	0.187 (18.1)	0.507 (13.0)	0.318 (2.3)	0.211 (17.1)	0.301 (9.7)	0.274 (13.7)

[a] Numbers in parentheses are coefficents of variation.

Species	Self-sealed steam-injection pressing	Unsealed steam-injection pressing	Conventional platen pressing
	----	---- (psi) ----	----
Southern pine	487,500	441,222	542,111
White oak	400,833	414,667	461,833

Long-term exposure to high RH also resulted in decreasing MOE values for all test combinations **(Table 3).** Based on an average of six resins, the flakeboards made with conventional platen pressing had a higher percentage reduction of MOE (33% for white oak and 26% for southern pine) than those made with unsealed steam-injection pressing (15% for white oak and 21% for southern pine) and self-sealed steam-injection pressing (23% for white oak and southern pine).

DIMENSIONAL STABILITY

Thickness swelling. — **Table 4** summarizes average TS for each combination of resin, specie, and pressing method. Average TS in samples soaked for 24 hours ranged from 12 to 33 percent for the southern pine boards and from 10 to 64 percent for the white oak boards. Average TS for the samples subjected to ODVPS ranged from 14 to 28 percent for the pine flakeboards and from 16 to 50 percent for the oak boards.

The amount of TS varied from test to test and was affected strongly by pressing method. As shown in **Table 5,** the conventionally pressed panels swelled consistently more than steam-injection pressed panels. For the two methods of steam-injection pressing, the panels made with self-sealed steam-injection pressing were slightly more stable than unsealed steam-injection-pressed panels.

The improvements in dimensional stability properties with steam-injection pressing are interesting, particularly if one considers that extremely low bond strengths were also obtained for the same boards. For instance, average TS values for the 24-hour soak for PF and MUF resins in self-sealed steam injection and conventional platen pressing were 18.7 and 35.3 percent, respectively, and IB values were 12.9 and 63.2 psi, respectively. These would result in pairing lower lB with higher stability (lower thickness swelling), indicating that the IB strength could not be the cause of improvement in dimensional stability. Apparently, steam pressing produces less internal stress and stabilizes the flakes, which in turn results in improvements in dimensional stability.

Linear expansion. — **Table 6** summarizes average LE for each combination of resin type, pressing method, and specie.

As with TS, self-sealed steam-injection pressing resulted in the most stable panels with the exception of MUF-bonded southern pine boards. It should be noted that in several cases conventional pressing produced more stable boards than those made using unsealed steam pressing. On average, pine boards were slightly more stable than white oak boards.

CONCLUSIONS

Of the six resins evaluated, polyisocyanate resin performed well in both steam injection and conventional platen pressings. PF and MUF resins performed poorly in steam-injection pressing. This may have been a function of the press cycle used. However, the addition of a small amount of polyisoeyanate improved performance considerably.

Bending strengths were consistently higher with conventional platen pressing than with steam-injection pressing. The lower density face in steam-injection pressing would result in lower bending properties.

In PF and MUF resin systems, the steam-injection pressing cycles used resulted in low bond strength and high dimensional stability, whereas conventional platen pressing resulted in high bond strength and low dimensional stability. The pairing of low strength with high stability suggested that bonding strength could not be the cause of improvement in dimensional stability. Most probably, steam pressing produced less internal stress and stabilized the flakes, which in turn resulted in improvements in dimensional stability. This improvement may also be related to less strength loss of the board in steam-injection pressing when exposed to high RH treatment.

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