FLAKEBOARD THICKNESS SWELLING. PART II. FUNDAMENTAL RESPONSE OF BOARD PROPERTIES TO STEAM INJECTION PRESSING

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ABSTRACT

The results of this study showed that the same relative reductions in thickness swelling (TS) previously obtained with steam-injection-pressed (SIP) resinless mats are also obtained in boards bonded with 3% isocyanate resin. Reductions in thickness swelling were proportional to steam time and pressure. Thickness swelling of 40% measured in conventionally pressed boards following a vacuum-pressure-soak treatment was reduced to 25% in a board exposed to 20 sec of steam at 600 kPa and to 6% in a board exposed to 40 sec of steam at 1,900 kPa. We believe that the reductions in thickness swelling result from a combination of flake plasticization, "lignin flow," and chemical modification. Bending properties of the SIP boards were substantially lower than that of conventionally pressed boards, which we attribute in part to the very short press times and the relatively fast decompression used to manufacture the SIP boards. Bending properties of SIP boards also suffered from a reduction of the vertical density gradient. However, this characteristic is favorable to shear properties.

Keywords: Flakeboard, steam injection, bending, shear, thickness swelling.

INTRODUCTION

Flakeboard, also known as oriented strandboard (OSB), will soon surpass plywood as the dominant panel in the huge North American sheathing market. A major difference in the performance of these two products is the greater thickness swelling (TS) of flakeboard under severe moisture conditions. This characteristic is a result of the higher pressures needed to consolidate the flakeboard mat. Previous research showed that injection of steam into a resinless flakeboard mat during pressing can substantially reduce the TS that occurs when the mat is submerged in water (Geimer et al. 1998). Thickness swelling of 350% in conventionally pressed resinless mats can be reduced to 200% with 20 sec of steam at 600 kPa pressure. A tenfold reduction in TS compared to that of conventionally pressed mats can be attained by increasing the steam time to 40 sec and steam pressure to 1,950 kPa. This research showed that a number of factors, including wood plasticization, "lignin flow," and chemical changes, may be responsible for

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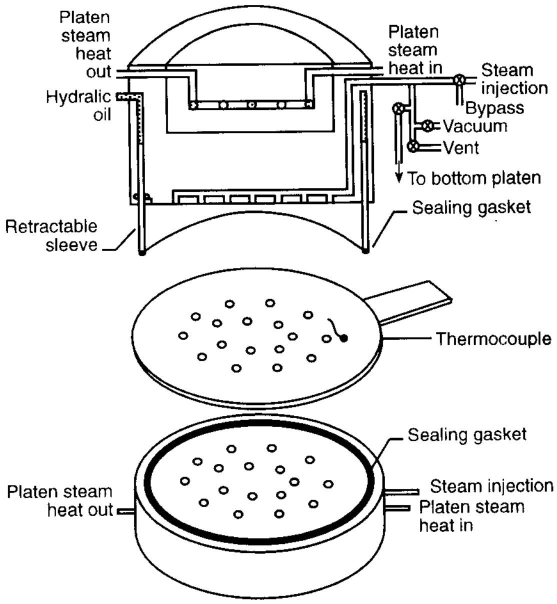

FIG. 1. Schematic for shielded steam injection platens.

FIG. 2. Flakeboard mats, 152-mm-diameter on circular perforated caul, are inserted between shielded steam injection platens.

the improvement in dimensional stability. As a logical sequel, in the research reported here we studied whether the same mechanisms function in a resin-bonded board and whether they can be related to both mechanical and physical properties.

OBJECTIVE

The objective of this study was to determine the influence of steam injection on thickness swelling, bending properties, and shear properties of isocyanate-bonded flakeboard. Steam time and steam pressure treatments were examined.

This report is the second in a series on thickness swelling in flakeboard. Part I covered the steam injection pressing variables that affect thickness swelling in a flakeboard mat. In the future, we intend to document the chemical analysis of steam-treated wood and explore the relationship with TS.

PROCEDURE

Board fabrication

Aspen (*Populus tremuloides*) ring-cut flakes averaging 0.762 mm in thickness were dried to a moisture content (MC) of approximately 4% and screened on a 0.08-cm-mesh screen; 23% of the total material passed through the screen and was eliminated. At any one time, enough flake furnish was blended with 3% isocyanate resin to produce 24 152-mm-diameter boards. All boards were fabricated to a target oven-dry (OD) specific gravity of 0.640, without accounting for the resin, and pressed to a target thickness of 13 mm. Mat MC was 5% when the mats were placed in the press.

Pressing

Special shielded platens were designed and built to expose mats to high pressure (maximum of 2,000 kPa) steam before, during, or after closure of the press to target thickness (Fig. 1). Circular mats, 152 mm in diameter, are formed on a circular aluminum caul that has perforations matching those in the lower steam injection platen. Screens are usually placed below and on top of the mat. A deep 10-mm-wide circular slot is milled into the top head (surrounding the steam injection ports). This slot contains a piston in the form of a circular sleeve. In practice, the caul, mat, and screens are loaded onto the bottom circular platen with the sleeve in the retracted position (Fig. 2). The sleeve, sometimes referred to as a shield, is then forced to the down position by hydraulic oil pressurized in a nitrogen-loaded accumulator. The mat chamber is sealed when the o-ring gasket in the end of the sleeve contacts the top surface of the caul plate. A hole, drilled in the edge and exiting out the top surface of the caul, provides the means for inserting a thermocouple into the mat without interfering with the seal. When the press is closed, the sleeve retracts against the pressure of the oil and compressible nitrogen. Release of pressure in the accumulator system, after the chamber has been vented and while the press is closed, permits the sleeve to remain retracted when the press is opened.

Steam can be injected through the top platen or simultaneously through the top and bottom platens at any time during the press cycle. Steam pressure can be released instantly by opening the manifold to atmosphere. The advantage of this closed system is that mats can be exposed to controlled steam pressure for precise times, independent of the press position. The entire pressing operation is computer controlled, including press position and pressure, sleeve operation, steam flow or steam manifold pressure, vacuum application, and steam entry and release.

A general press schedule was used to delineate the effect of specific press variables on TS (Table 1). The range of steam duration was intentionally narrowed with increasing pressures to provide overlapping results between pressure treatments. Press variables recorded for a mat pressed at 1,500 kPa steam pressure for 20 sec are displayed in Fig. 3. Following an initial adjustment period of 2 sec, the press closed at a linear rate of 5 mm/sec. When a position corresponding to a mat height of 50 mm was reached, the press was scheduled to continue closing to 13 mm following a parabolic rate curve at the average rate of 2 mm/sec. When the mat had been compressed to 28 mm, a 1-sec burst of steam was used to purge the manifold. Steam was directed to the top platen and exhausted from the bottom platen for 2 sec to purge the mat of air. Steam was then directed into both the top and bottom platens. Manifold pressure was maintained at 1,500 kPa for 20 sec (Table 1), resulting in an internal board temperature of 188°C. The manifold was immediately vented to atmosphere following the specified steam period, allowing the board temperature to rapidly decrease to approximately 110°C. It took 9 sec for the press to close to target thickness after the steam purge was initiated. The press was held at this position for 20 sec (Table 1), which allowed 6 sec for exhausting the steam before decompression began. Following decompression at 2 mm/sec to 30 mm, the press opened at a rate of 6 mm/sec.

Six boards were pressed at each combination of steam manifold pressure, and steam time as noted in Table 1. In addition, six "control" boards were made without steam at the platen temperatures used for each steam pressure setting. The control mats were held at target thickness for 4 min to permit core temperature to approach platen temperature.

Board exposure and testing

Boards were immediately weighed and measured for thickness after removal from the press. For each treatment, two resin-bonded boards were conditioned to equilibrium at 27°C, 65% relative humidity (RH). One 50.8- by 57.1-mm Minnesota shear specimen and one 25.4- by 139.7-mm bending specimen were cut from each board. The shear specimen was tested in accordance with ASTM D1037 (ASTM 1992) procedures. Bending tests using a single-point center load were also performed according to ASTM D1037 procedures, with the exception that the span was 114.4 mm because of sample size limitations.

One board from each treatment was trimmed to 127-mm diameter and measured for TS after progressive equilibrium exposures to the following conditions: (1) initial oven-dry (OD1), (2) 27°C–50% RH, (3) 27°C–90% RH, (4) vacuum pressure soak (VPS), and (5) final oven-dry (OD2). The VPS treatment consisted of submerging boards in a sealed tank of water at ambient temperature while a vacuum of approximately 0.9 bars was applied for 30 min. Approximately 400 kPa water pres-

TABLE 1. *Press and steam injection schedules and variables.*

Press schedule	Cumulative time[b] (sec)	Steam schedule
Press and steam injection schedules[a]		
Hold at 137 mm for 2 sec		
	2	
Linear closure rate of 5 mm/sec to 50 mm		
	19	
Parabolic closure rate of 2 mm/sec to 13 mm		
	(26)	
		Steam flow of 350 kg/h; on at 28 mm for 3 sec[c]
	(29)	
		Steam at pressure (a) for (b) seconds
	37	
Hold at 13 mm for (c) seconds		
	(29 + b)	
		Vent
	37 + c	
Decompress at 2 mm/sec to 30 mm		
	45 + c	
Open at 6 mm/sec to 137 mm		
	63 + c	

Steam injection variables[a]

Steam manifold pressure (a) (kPa)	Steam time (b, c) (sec)	Steam temperature (°C)	Platen temperature (°C)
600	20	165	175
	40		
	80		
	160		
1,050	10	186	190
	20		
	40		
	80		
1,500	5	201	205
	10		
	20		
	40		
1,950	5	213	220
	10		
	20		
	40		

[a] Letters (a), (b), and (c) refer to steam injection variables (steam pressure, steam time, and press hold time, respectively) at target position. See Fig. 3.
[b] Cumulative times (in parentheses) apply to changes in steam injection schedule only.
[c] Steam purges manifold for 1 sec and mat (top to bottom) for 2 sec.

sure was applied for 30 min, and boards were then extracted, drained, weighed, and measured for TS. Thickness was averaged from measurements taken at four predetermined locations 25.4 mm from the edge of the board.

One board from each press condition was trimmed to a diameter of 127 mm and measured for thickness following equilibration at 27°C–65% RH. Boards were then placed in a horizontal position under water. After 24 h, boards were extracted, drained, weighed, and measured for TS. Thickness swelling was av-

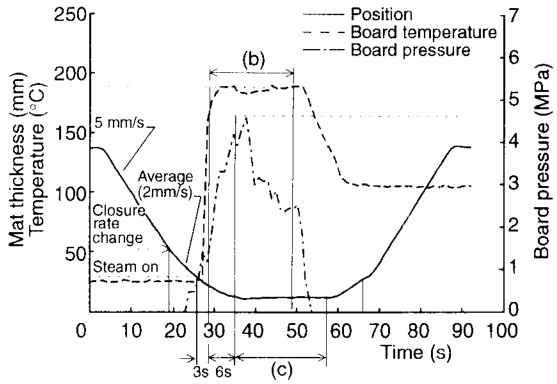

FIG. 3. Press schedule for mats exposed to 1,500 kPa steam (a) for 20 sec (b). Press dwell time was 20 sec (c).

eraged from measurements taken at four predetermined locations 25.4 mm from the edge of the board. The same sample was again measured for thickness after submersion for 48, 168, 336, and 504 h.

Specimens measuring 50.8 by 57.1 mm were cut from each remaining board for each press condition and used to obtain vertical density profiles after conditioning to 27°C–65% RH. These specimens will be used along with the remaining boards to obtain measurements of TS and mechanical properties after 1 year.

RESULTS AND DISCUSSION

Previous exploratory studies

A lengthy set of exploratory studies indicated that 24-h watersoak TS of a resinless mat decreased with steam treatment during pressing. This reduction was accentuated if the steam was introduced during press closure and continued without interruption until the press had reached target thickness. Applying this sequential SIP pattern, the press schedule and treatment levels given in Table 1 were developed and used to determine the effect of steam pressure and steam duration on out-of-press and 24-h TS of resinless mats (Table 2) (Geimer et al. 1998). At low treatment levels, out-of-press TS (initial springback) of resinless mats was affected by out-of-press MC. As the treatment levels increased, the favorable effects of SIP masked any detrimental effects of increased MC, and both out-of-press and 24-h TS decreased with increasing steam time and pressure. We attribute improvement in out-of-press TS to both plasticization of the wood and "lignin flow." We attribute improvement in 24-h TS to "lignin flow" and chemical changes in the wood.

The term "lignin flow" is qualified because (1) lignin, as used in this report, includes hemicelluloses, free sugars, and extractives, and (2) the flow of these substances can affect TS in a number of ways. What we envision is a softening of the noncrystalline cellular material and its movement to surround, conform to, and perhaps invade the deformed cellular structure. We also extend this in a macroscopic manner to the formation of a coating or partial coating on the exterior surface of the wood particles that comprise the composite furnish.

TABLE 2. *Resinless mat thickness swelling.*

Press and steam conditions					Mat conditions		
						TS (10.75-mm basis)	
Steam pressure (kPa)	Steam time (sec)	Platen temp (°C)	Total time (sec)	Max temp (°C)	Out-of-press MC (%)	Out of press (%)	24 h (%)
600	20	175	54	155	19.7	82	205
	40	175	74	163	17.5	60	191
	80	175	114	163	20.4	52	173
	160	175	194	163	23.4	55	158
1,050	10	190	50	173	13.6	30	164
	20	190	57	177	15.4	29	147
	40	190	77	180	17.1	28	129
	80	190	120	181	21.7	20	101
1,500	5	205	44	207	10.4	13	148
	10	205	49	202	13.1	13	118
	20	205	59	190	15.7	13	87
	40	205	79	192	18.4	9	63
1,950	5	220	44	233	13.1	19	114
	10	220	49	234	12.0	5	90
	20	220	59	194	14.7	5	61
	40	220	77	201	15.9	1	32
—	—	175	278	123	3.2	31	351
—	—	190	279	129	2.1	20	352
—	—	205	279	136	1.6	18	361
—	—	220	277	141	1.3	17	338