Steam-assisted hot-pressing of construction plywood

Ronald W. Jokerst
Robert L. Geimer

Abstract

This study was designed to determine if steam injection pressing used for fiberboard, particleboard, and flakeboard could be adapted to the pressing of plywood. Plywood panels were fabricated with and without adhesive and then pressed to determine the effects of steam injection Lime, steam injection pressure, and press pressure on heat transfer rate, moisture distribution, thickness loss, and adhesive-bond integrity. The time to reach 220°F (104°C) in the center glueline of five-ply, 0.5-inch- (12.7-mm-) thick Douglas-fir plywood was reduced 15 percent using certain combinations of steam injection pressing variables. Heat transfer rates increased with high steam pressures, lengthened steam times, and low panel pressures. However, the combination of variables that produce rapid heat transfer rates is also prone to induce excessive panel moisture with subsequent delamination.

Steam injection pressing[1] is a technique that has proven to be useful in reducing the press time of fiberboard, particleboard, and flakeboard by increasing the rate of heat transfer into the core of the boards. This study was designed to investigate steam press and board fabrication variables that affect the rate of heat transfer into five-ply plywood. Panels fabricated with and without adhesive were subjected to three levels of platen pressure, two levels of steam pressure, and three levels of steam time. Measurements were taken to determine the heat transfer rate, moisture distribution, thickness loss, and shear strength and wood failure when applicable.

Procedure

Five-ply, 0.5-inch- (12.7-mm-) thick cross-laminated Douglas-fir plywood panels were fabricated with and without adhesive. The 0.1-inch- (2.54-mm-) thick veneer had an initial moisture content (MC) of 4 percent. Lathe checks were oriented toward the panel center. The 28- by 26-inch (71- by 66-cm) panels extended 1 inch beyond the perforations in the steam platen used to press the panels. For panels containing adhesive, a commercially available phenolic resin (Borden's 7500D). formulated for high-level panel moisture applications (approximately 10%). was applied at 35 lb./ 1,000 ft.^{2} (171 g/m^2) of single glueline. A 10-minute closed assembly was followed by 5 minutes of prepressing at 150 psi (1.03 MPa).

The computer-controlled steam press, heated to 300°F (148°C). was programmed to obtain panel pressures of 75, 100, or 175 psi (517, 690, or 1206 kPa). Steam was then introduced into upper and lower platens at either 28 or 75 psi (193 or 517 kPa), corresponding to manifold temperatures of either 270°F or 320°F (132°C or 160°C) for 10, 35, or 60 seconds. The press was then closed within 10 seconds to obtain a panel pressure of 175 psi (1.2 1 MPa) and maintained at this pressure for the duration of the 6-minute press cycle. The combinations of press and steaming variables are shown in Table 1. These variable levels, as well as the specific combinations, were chosen following preliminary investigations to provide a range of meaningful results.

In this paper, condition combinations, such as 100/75/35, indicate platen pressure (psi), steam pressure (psi), and steam time (sec.), respectively.

1 Geimer, R.L. 1982. Steam injection pressing. In: Proc. 16th Inter. Particleboard Symp. Washington State Univ.. Pullman, Wash. pp. 1 15-134.

The authors are Research Wood Scientists, USDA Forest Serv., Forest Prod. Lab., One Gifford Pinchot Dr., Madison, WI 53705- 2398. This study was partially funded by a grant from the Plywood Research Foundation. The use of trade or firm names in this publication is for reader information and does not imply endorsement by the USDA of any product or service. This paper was received for publication in April 1992.

Forest Prod. J. 44(11/12):34-36.

TABLE 1. — *Response of plywood test panels to steam injection pressing conditions.*[a]

Process variable		Time to 220°F in second glueline[b]			Moisture content[c]				No. of good panels[d]	Shear strength	Wood failure	Thickness loss
					No adhesive		Adhesive					
Platen pressure	Steam pressure	Steam time	No adhesive	Adhesive	Center	Edge	Center	Edge				
---- (psi) ----		------- (sec.) -------			------------ (%) ------------					(psi)	---- (%) ----	
175	0	0	243	271	2.4	2.4	5.5	8.0	6/0	246	80	7.8
75	28	35	157	229	4.6	3.9	8.6	8.0	5/0	240	74	9.4
75	75	10	- -	209	- -	- -	9.6	8.8	2/3	192	65	12.9
75	75	35	72	172	15.0	6.3	9.2	5.2	0/3	- -	- -	- -
100	75	10	102	225	8.5	8.0	7.4	6.8	4/1	262	87	9.5
100	75	35	79	177	11.7	7.1	8.2	7.0	0/3	- -	- -	13.2
175	28	10	231	274	4.7	4.0	6.9	6.5	5/0	251	85	8.8
175	28	60	212	264	4.2	3.5	8.5	8.6	5/0	233	81	10.1
175	75	60	147	203	10.1	5.1	8.7	8.9	3/2	229	84	9.0

[a] Values are averaged from the total of sound panels; 1 psi = 6.8×10^3 Pa; - - indicates no data.
[b] Average temperature of three thermocouples in second glueline.
[c] Average of all plies.
[d] Number of sound panels/number of delaminated panels.

Five panels without adhesive and between three and five panels with adhesive were pressed at each condition. In addition, six control panels without adhesive and six with adhesive were pressed without steam at a panel pressure of 175 psi.

Temperatures, measured with thermocouples in the top two gluelines at the center, quarter-point, and edge of the panel were monitored every 0.5 second for the first minute and every 10 seconds thereafter. MC values were obtained from 2-inch- (5-cm-) diameter disks cut adjacent to the thermocouples. The MC level of the individual veneers was measured in panels without adhesive. The MC values obtained for the adhesively bonded boards are an average of all plies. Adhesive bond strength and percentage of wood failure were evaluated using standard 1 by 3- 1/4-inch (2.54- by 8.26-cm) tensile shear specimens[2]. Ten specimens were given a 1 -hour vacuum-pressure soak and tested wet. The wood failure estimates were made after the specimens had dried. To estimate thickness loss, the panel center was measured immediately after prepressing and compared with the panel center measured immediately after hot-pressing.

Results and discussion

The rapid, almost instantaneous, increase in core temperature, typical of steam-injected particleboard, does not occur in steam-injected plywood. Temperature change is relatively gradual, as shown by time-temperature curves for two steamed condilions (100/75/35 and 175/75/60) and the control (175/0/0) in Figure 1. There appeared to be a trend for the temperature to increase faster in the center compared with the quarter -point or edge-monitored positions. However, no consistent differences in heat times at these positions could be discerned, and

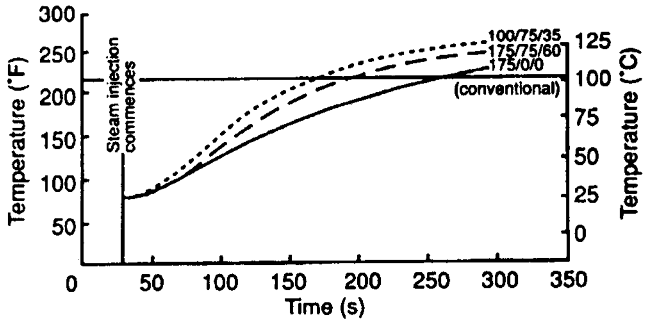

Figure 1.– Development of temperature in the second glueline of adhesively bonded five-ply plywood during hot-pressing. Two panels (100/75/35 and 175/75/60) are compared to the control panel (175/0/0). (Descriptors refer to platen pressure (psi), steam pressure (psi), and steam time (sec.), respectively.)

values in Table 1 are the average of the three positions for the second glueline. The increase in response time of the second glueline compared to the first glueline (data not shown) varied from 33 to 160 percent, depending on the pressing variables. Heat transfer rate, indicated by the average time required to increase the second glueline to 220°F (104°C). is affected by all process variables (press platen pressure, steam injection pressure, and steam injection time) (Table 1). In all cases, increasing the length of steam duration decreased the time for the second glueline to reach 220°F. The most rapid heat transfer occurs when steam can pass through cracks and voids in the veneer. High press platen pressures restrict these passages. Increasing the steam injection pressure from 28 to 75 psi (193 to 5 17 kPa) increases the driving force of the steam and also decreases the effective pressure on the panel, allowing the cracks to remain open. However, the tradeoff for rapid heat transfer is increased energy loss, resulting from steam escaping. The adhesive appears to act as a physical barrier to

[2] U.S. Department of Commerce. 1983. Softwood plywood construction and industrial voluntary product standard PS 1-83. National Bureau of Standards, Washington, D.C.

steam convection as well as an additional heat sink. Consider the relative rate of heat transfer in panels pressed with and without adhesive using the 100/75/10 condition. The time to reach 220°F increased from 102 seconds for those panels pressed without adhesive to 225 seconds for those panels with adhesive (Table 1).

The increase in MC of the steamed panels made without adhesive compared to the control panels made without adhesive gives an indication of the amount of steam penetration (Table 1). In many cases, the higher MC of the center samples was accompanied by a faster increase in temperature. However, as mentioned previously, this relationship was not consistent. The large difference between the MC at the center and edge of those panels receiving large amounts of steam (75/75/35, 100/75/35, and 175/75/60) indicates water migration during the final stages of pressing. The center veneer layer was found to be 1 to 2 percent greater in MC than the surface veneers (data not shown). Large MC differences, attributed to pressing conditions. were not detected in the panels with adhesive. In most cases, moisture was distributed evenly across the width of these panels.

Out-of-press delamination occurred under conditions that substantially increased the MC of the panel center (see column under no adhesive, center, Table 1). Conditions that did not result in out-of-press delamination had no adverse effects on shear strength or percentage of wood failure. Condition 100/75/10 was unusual in that it produced one delaminated panel, but this condition also produced other panels having the highest average strength and percentage of wood failure.

All steam-injection-pressed panels suffered greater thickness loss than did the control panels. Thickness loss will become even greater as the panels lose moisture. However, reduction in press time, with accompanying reduction in sustained pressure and greater springback, will reduce thickness loss.

No attempt was made to decrease total press time. The 75/28/35 panel provided a 15 percent reduction in time to reach 220°F in the second glueline without any panel delamination. press time reduction is dependent on increasing heat transfer without incurring excessive moisture. Optimization of steam injection duration, steam pressure, press pressure, andvarious sequential combinations of these variables or the addition of a vacuum drying stage could prove beneficial to actual reduction in press time.

Conclusions

Increases in the heat transfer rate to the center gluelines of a five-ply plywood panel were obtained by steam injection pressing. The rate of heat transfer depended on steam passing through cracks and voids in the veneer and was highly influenced by steam pressure, steam time, and platen pressure, in that order. Fast heat transfer in panels made without adhesives was usually accompanied by an increase in the MC of the central portion of the panel when compared to the edges. This differential in moisture was not apparent in panels fabricated with adhesives. The adhesive acts not only to retard the heat transfer but distributes the added moisture throughout the length and width of the panel. When moisture was excessive, the panels were prone to delaminate. A 15 percent reduction in the time for the temperature in the second glueline to reach 220°F was obtained without an appreciable reduction in strength when steam was introduced for 35 seconds at a steam pressure of 28 psi and a platen pressure of 75 psi. All steam-injected panels experienced greater thickness loss than did the conventionally pressed control panel.