

High-Frequency and Hot-Platen Curing Of Medium-Density Fiberboards

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Abstract

The effects of two curing methods—high-frequency heating and hot-platen heating—on the properties of a urea-formaldehyde-bonded medium-density fiberboard prepared with a southern-hardwoods furnish (50% southern red oak, 25% mockernut hickory, and 25% sweetgum) were studied. Boards of three densities—38, 44, and 50 lb./ft.³—were cured by the two heating methods. IB strength of the high-frequency-cured boards was greater than that of the hot-platen-cured boards at all density levels. Bending properties of the high-frequency-cured boards exceeded those of the hot-platen-cured boards at the highest density level, only. There were no significant differences attributable to the two curing methods in tension parallel to the surface, linear expansion, and thickness swelling.

MEDIUM DENSITY FIBERBOARD (MDF) made of pressurized-refined fiber was first manufactured, on a commercial scale, in 1965 at Deposit, New York (2). The urea-formaldehyde resin in this board was cured in a hot-platen press in which a large portion of the energy required was supplied by high-frequency

dielectric heating. Some MDF plants built subsequent to the plant at Deposit rely on high-frequency dielectric heating to cure the resin, while others have been designed to produce board solely by hot-platen heating. Whether either resin-curing system has an inherent advantage, in terms of board properties, has not been established in the literature.

This research was designed to compare high-frequency- and hot-platen-cured MDF. Comparisons are based on strength properties, dimensional stability, and density profiles of the boards. Nominal 5/8-inch-thick boards, made at three densities (38, 44, and 50 lb./ft.³), were cured by each of the two heating methods. Three boards (replications) were made for each combination of density and resin-curing method; hence a total of 18 boards are represented in the study.

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Materials and Methods

Board Materials

The fiber furnish for the boards was produced by double-disk, pressurized-refining of a hardwood chip mixture. The chips, with bark included, were 50 percent southern red oak (*Quercus falcata* var. *falcata*), 25 percent mockernut hickory (*Carya tomentosa*) and 25 percent sweetgum (*Liquidambar styraciflua*). Percentages were based on oven-dry (OD) weights. Eight percent urea-formaldehyde resin, based on OD weight of the fibers, was used to bond the board. The adhesive was a 65 percent solids, pre-catalyzed commercial resin. The fiber-adhesive blend had a moisture content (MC) of approximately 10 percent.

Mat Formation

The 16- by 21-inch fiber mats were formed in a laboratory gravity-former. The former, an open-ended plywood box 30 inches high, has a means of breaking up fiber clumps when the furnish is hand-fed into its top. The dispersing mechanism, which can be manually positioned as required to cause uniform buildup of the mat, consists of a rotating shaft fitted with 2-inch spines. The mats were prepressed at a pressure of 300 psi for 2 minutes. Each prepressed mat was placed on a 1/2-inch plywood sheet, and the assembly was wrapped in polyethylene film and sealed with tape. The mats were formed, prepressed, and sealed at Pineville, Louisiana. As many as 3 days elapsed while the prepressed boards were in transit to Mississippi State, Mississippi, where they were pressed and cured.

Adhesive Curing

Adhesive curing was accomplished in a 26- by 26-inch steam-heated hot-press to which a high-frequency (6 MHz) generator is connected. The prepressed mats were placed in the press without cauls, and the press was closed to stops. Maximum pressure was 500 psi. Platen temperature for the hot-pressed panels was 270°F. When the stops were contacted, the pressure was gradually reduced to prevent excessive forces on the press stops. After removal from the press, the boards were cooled to room temperature.

The high-frequency-cured boards were pressed in a manner similar to that used for the hot-pressed boards (platen temperature of 270°F). When maximum pressure (500 psi) on the mat was reached, high-frequency energy was applied at a nominal rate of 5,000 watts. Total time of high-frequency energy application was directly related to the board density.

Pressing parameters for each board density are presented in Table 1 for both the hot-platen and high-frequency curing methods.

Specimen Preparation and Testing

Two static bending, linear expansion, tension parallel to the plane of the board, and density specimens, and six internal bond (IB) specimens were cut from each test panel (1.75-in. edge trim allowed). All test specimens were conditioned at 50 percent relative humidity (RH) and 70°F for 3 weeks prior to testing.

Table 1 — PRESSING PARAMETERS AND ROUGH-BOARD DATA FOR THE HIGH-FREQUENCY- AND HOT-PRESS-CURED PANELS.

	Nominal density (lb./ft. ³)					
	38		44		50	
	Hot press	High frequency	Hot press	High frequency	Hot press	High frequency
MC out of press(%)	7.0	3.9				3.5
MC at 50% RH(%)	7.5	6.7				6.6
Density ¹ (lb./ft. ³)	37.3	38.0				46.7
Time to stops(sec.)	11	13				44
Total press time(sec.)	480	96				132

¹Density based on weight and volume at equilibrium with 50 percent RH.

Testing was done in accordance with ASTM Standard D-1037-72a (1), with the exception that static bending specimens were 2 inches wide rather than the 3 inches specified in the standard, and thickness swelling was measured on the linear expansion specimen. IB samples were sanded to remove the pre-cure layer and insure failure in the core.

Variation of density through the board thickness—the density profile—was determined by an x-ray radiography method. Two specimens (7/16-in. thick in the plane of the board) from each board were placed on edge on a single sheet of Kodak Industrial Type AA Ready Pack film and exposed for 1.9 minutes at 30 kV and 3 mA by a Faxitron Model 805 x-ray unit. The opaqueness of the developed film was inversely proportional to the mass of the substance (fiberboard) through which the x-rays passed; hence, it was related to the density of the board. At the same time that samples from the study boards were being exposed to x-rays, control samples (covering a density range of 31 to 62 lb./ft.³) of uniform density were also exposed. Relative opaqueness — determined by light transmission — of the film where “shielded” by the study samples was compared to that where “shielded” by the control samples to give quantitative density profiles. The method used has been described in detail by Nearn and Bassett (4).

Data Analysis

The effects of board density and curing methods on board properties were scrutinized by analysis of variance and multiple regression analyses.

Results

Pressing Parameters

The maximum press closing rate (time to stops) in Table 1 attainable with the available equipment was used for both the high-frequency- and hot-press-cured boards. Time to stops was not affected by curing method at the low board density, but was significantly lower for high-frequency-cured boards at the medium and high board densities (Table 1). At the high board density, time to stops of the hot-press-cured boards was about three times that of the high-frequency-cured boards.

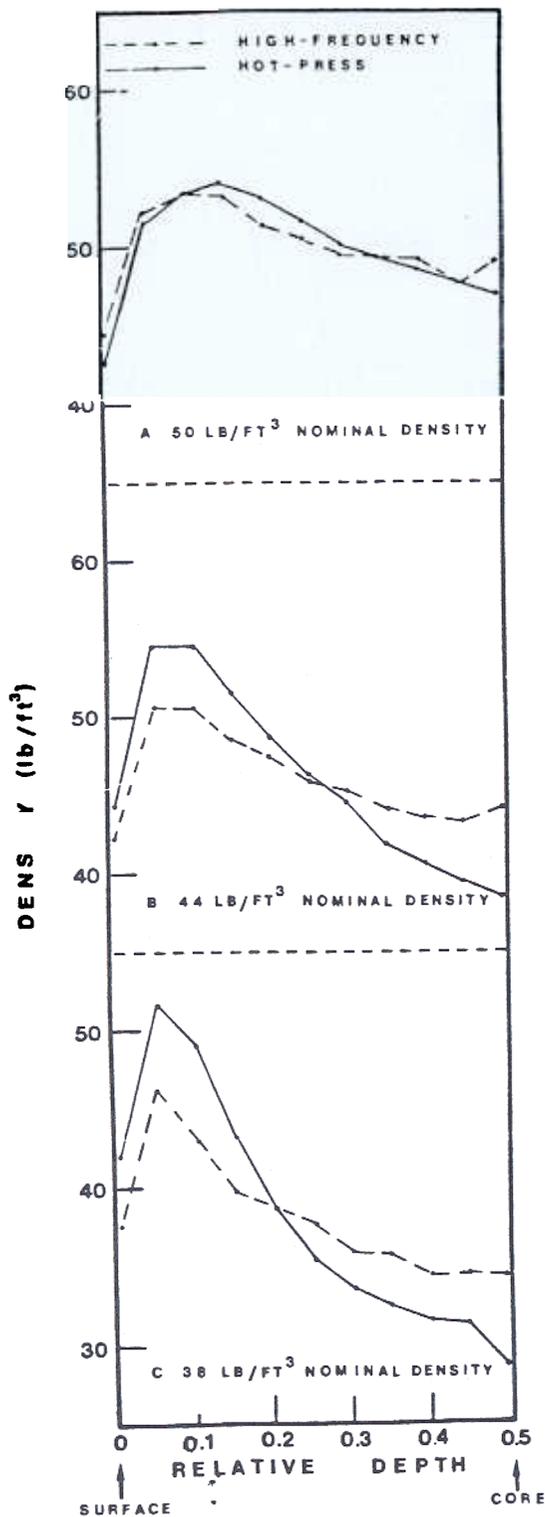


Figure 1. — Density profiles for high-frequency- and hot-press-cured panels of three nominal densities.

Density Profiles

Variation of density from the surface to the center of the board is shown in Figure 1. Variation patterns for each curing method are shown by individual lines. The points shown are averages of six samples (two samples from each of three replications).

The profiles are characterized by density peaks near the surfaces and decreasing density toward the board centers. The relatively low densities at the board surfaces are probably the results of precure, a condition which might have been eliminated, or minimized, had cauls been used. At the medium and low board densities (Fig. 1B and C), the density variation from surface to center of the high-frequency-cured boards was less than that for hot-press-cured boards. At the high board density, there was practically no difference between the density profiles produced by the two resin-curing methods.

Bending Results

Modulus of rupture (MOR) as a function of board density is shown in Figure 2 for both the hot-press and high-frequency-cured panels. The data are represented by a single regression since the effect of curing method was not significant (95% level of probability). MOR was, as would be expected, strongly influenced by board density.

Modulus of elasticity (MOE) is presented in Figure 3 as a function of board density. In this case, there was a significant (95% level) interaction between curing method and board density, hence, the MOE data for the two curing methods are represented by separate regression curves. The relationship between MOR and MOE for the 18 test panels is shown in Figure 4. This relationship is independent of curing method.

Internal Bond

IB strength is shown in Figure 5 as a function of board density. The effect of curing method as well as

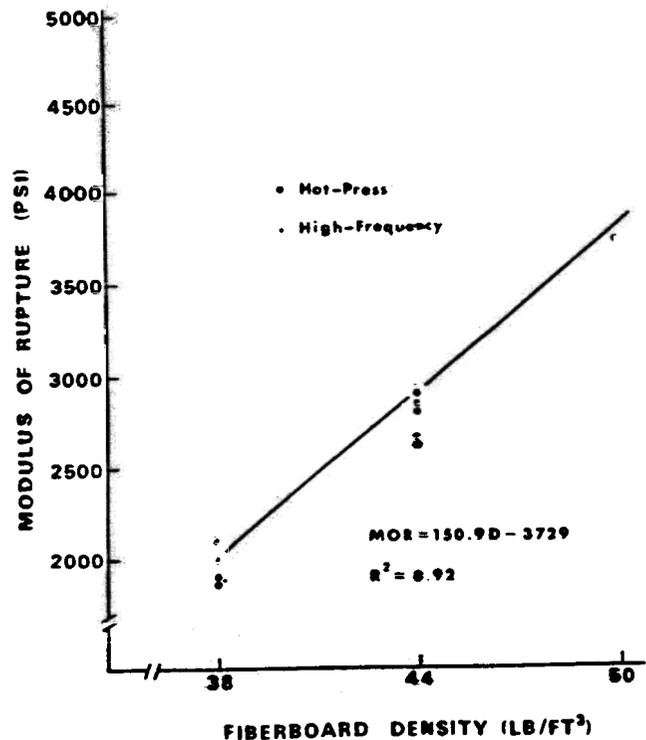


Figure 2. — MOR versus board density for hot-press- and high-frequency-cured MDF.

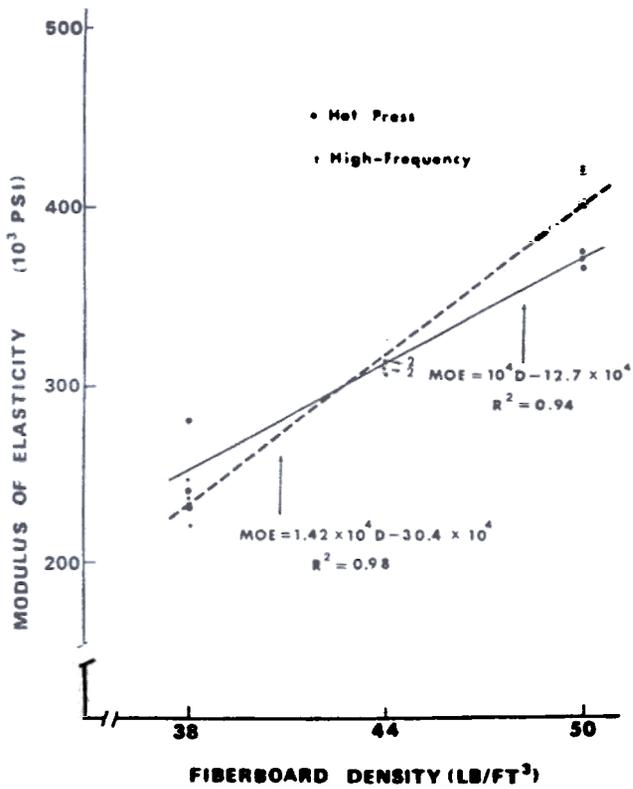


Figure 3. — MOE versus board density for hot-press- and high-frequency-cured MDF.

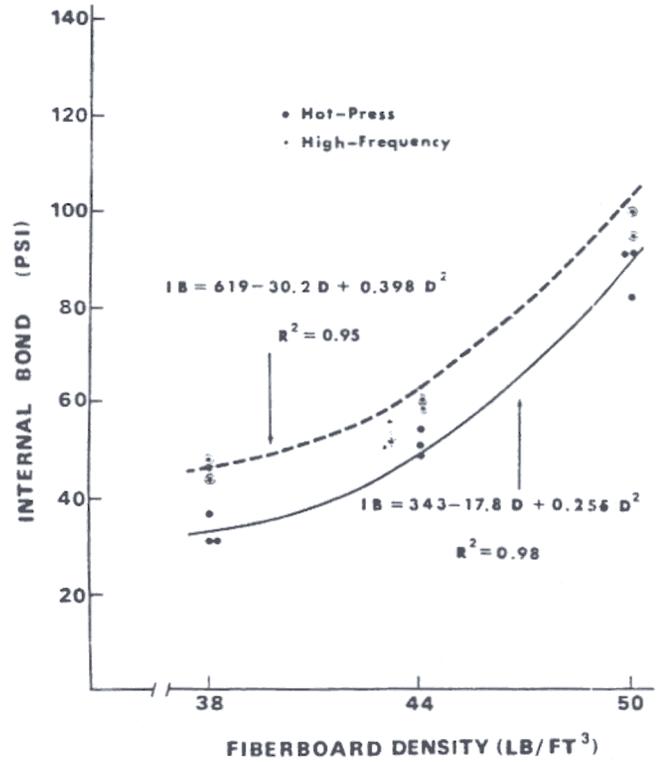


Figure 5. — IB strength versus density for hot-press- and high-frequency-cured MDF.

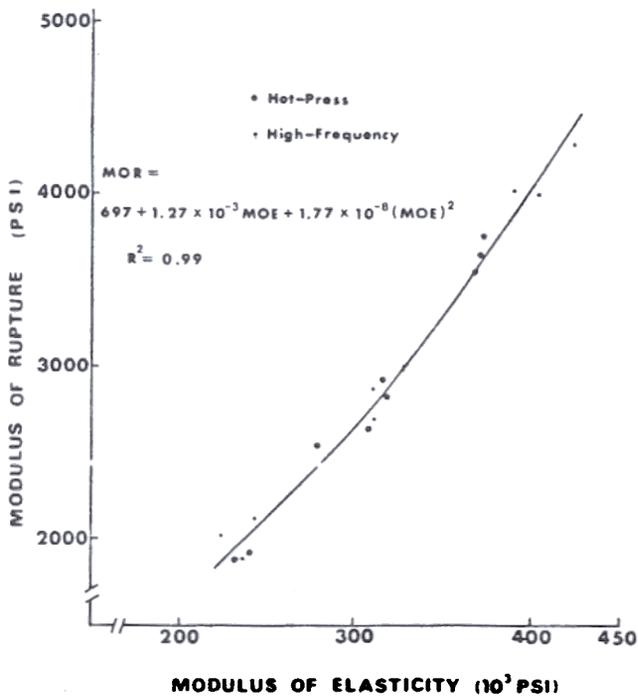


Figure 4. — MOR as a function of MOE for both hot-press- and high-frequency-cured MDF.

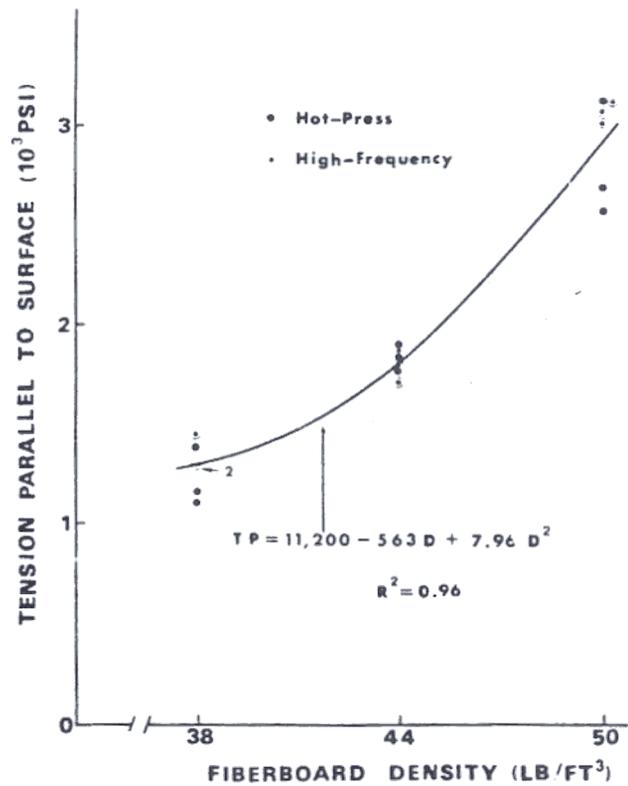


Figure 6. — Tensile strength parallel to the surface versus density for MDF cured by high-frequency and hot-pressing.

Table 2. — RESULTS OF LINEAR EXPANSION AND THICKNESS SWELLING MEASUREMENTS OF HIGH-FREQUENCY (H-F) AND HOT-PRESS (H-P) CURED MDF.

Board density (lb./ft. ³)	Linear expansion Thickness swell					
	Δ MC ¹		Δ MC		Δ MC	
	H-F (%)	H-P (%)	H-F (%/%)	H-P (%/%)	H-F (%/%)	H-P (%/%)
36	3.4	3.3	0.030	0.04	0.63	0.62
44	3.3	3.1	0.036	0.035	0.63	0.64
50	3.2	2.9	0.041	0.042	0.66	0.66

¹Change in MC between equilibrium at 50 percent RH and 70°F and equilibrium at 90 percent RH and 70°F. Expressed in percentage points of change.

board density was significant for this important board property. IB strength of the high-frequency-cured boards was higher than that of the hot-press-cured boards at all density levels.

Tension Parallel-to-Surface

Tensile strength parallel to the board surface was not affected significantly by curing method; hence, all data can be represented by a single regression curve (Fig. 6). As would be expected, board density strongly affected tensile values.

Dimensional Stability

Results of linear expansion and thickness swelling (50 to 90% RH) measurements are presented in Table 2. The thickness swelling measurements presented here were made on the linear expansion samples since there was not sufficient material for separate samples. The results are presented relative to MC change since equilibrium with 90 percent RH may not have been reached. Linear expansion, expressed relative to MC change, was significantly (95% level) affected (positive relationship) by board density but was not affected by curing method. Thickness swelling, also expressed relative to MC change, was not affected significantly by either curing method or board density. The linear expansion results are similar to those presented by Suchsland (5) for a commercial hardwood-furnish MDF, and by Lehmann (3) for several commercial medium density hardboards and insulation boards.

Discussion and Conclusions

High-frequency curing contributed to rapid press closing by the rapid increase in mat temperature it provided, and to more nearly uniform temperature distribution within a mat by virtue of simultaneous heat adsorption throughout its thickness. The former condition works to produce more pronounced density profiles, and the latter less pronounced (or more uniform) density profiles. The density profiles in Figure 1 are manifestations of both press closing rate and heating method. Since, at the low board density, time to stops was unaffected by curing method, the less pronounced density profile was produced by high-frequency curing since it produced more uniform heating of the mat. At the high board density, the rapid closing rate achieved in the high-frequency-cured mats was offset, in regard to density profile, by uniform heating, so density profiles of these boards

were similar to those of the hot-press-cured mats in which press closing was relatively slow.

Differences in board properties between high-frequency- and hot-press-cured boards might be attributed to differences in the density profiles and/or quality of inter-fiber bonds produced by the two methods of transferring heat to the consolidated mat. In view of the density profiles for the low and medium density boards (Fig. 1B and C), it might be reasoned that the hot-press-cured boards (high surface density) would be stronger in bending than the high-frequency-cured boards at the two density levels. However, at the two lower board-density levels, the bending properties of the two curing methods are approximately equal. At the higher density level, one would expect equal properties based on similar density profiles (Fig. 1A); however, at the higher density level, the high-frequency-cured boards are apparently stronger and stiffer in bending (Figs. 2 and 3) than the hot-press cured boards.

Ordinarily, in a homogenous board, IB specimens fail in the plane of lowest density (the center) when density decreases from surface to board center. The higher IB strengths of the high-frequency-cured boards (compared to hot-press cured) (Fig. 5) are compatible with the higher core densities of the boards cured by this method (Fig. 1C and B) at the low and medium density levels. However, the greater IB strength of the high-frequency-cured boards at the higher density level (Fig. 5) is not explained by the density gradients produced by the two curing methods (Fig. 1A).

Consideration of the bending properties, IB strength, and density profiles suggests that high-frequency curing produced more tenacious interfiber bonding than did hot-press curing of the urea-formaldehyde resin. However, this position is refuted by the indifference to curing method of tension parallel to the surface (Fig. 6), linear expansion, and thickness swelling (Table 2).

The high-frequency-cured MDF in this study was, on the whole, superior to that cured by conventional hot-pressing. This conclusion is based on the equal or better strength properties of the former and its more uniform density distribution, which is an advantage in many applications. It should not be concluded, however, that hot-pressed boards cannot be produced with properties equal to those of high-frequency-cured boards by manipulation of the press cycle and variables such as furnish MC and resin formulation.

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