RESIN DISTRIBUTION IN HARDBOARD: EVALUATED BY INTERNAL BOND STRENGTH AND FLUORESCENCE MICROSCOPY

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ABSTRACT

Product performance, to a large extent, depends upon the uniformity of resin deposition on or through the hardboard product. Presently, destructive testing of the hardboard, by measuring its internal bond (IB) strength, is the only method that will provide information about adhesive bond performance.

The objective of our research was to compare IB test results with resin distribution patterns observed by microscopy of wet- and dry-formed medium- and high-density hardboards formed under varying conditions of pre- and post-blending variables.

Using fluorescence microscopical techniques, we found that differences in resin distribution can be clearly detected. We observed that decreasing the resin solids content, mechanically increasing the fiber rubbing action with the resin, and changing the rate of resin application were effective ways for improving resin distribution in hardboard furnish. Our microscopic technique also showed that uniform distribution of the resin throughout the hardboard produced boards with the highest IB strengths.

This research provides guidelines for estimating levels of IB strength based on the use of a developed fluorescence microscopical technique.

Keywords: Resin, distribution, hardboard, internal bond, microscopy.

INTRODUCTION

The uniformity of resin distribution, as measured by internal bond (IB) testing, has been shown to affect the bond quality of dry-process composition boards made from either wood flakes, fibers, or particles. Today, most plants producing composition boards apply a liquid resin-wax emulsion mixture onto the furnish as it passes through blending equipment. Blenders are designed to agitate the wood furnish while the resin and/or additives are either sprayed or applied by centrifugal atomization onto the furnish, with the objective of achieving uniform resin droplet dispersion.

Composition board strength and physical properties can be greatly influenced by parameters such as resin distribution, resin droplet size, wood species, and furnish size and geometry. Destructive testing of bonded wood, usually an IB test, provides information on how well the wood pieces have been bonded together.

TABLE 1. *Internal bond values for wet- and dry-formed high- and medium-density hardboards with varying resin contents.*[1]

Hardboard density	Forming procedure	Resin content	Number of boards	Number of internal bond samples	Internal bond	
					Maximum stress	Standard deviation
		%			*lb/in.*[2]	
High (0.8–1.2 specific gravity)	Wet[2]	0.5	3	12	192	53
		1.0	3	12	282	65
	Dry[3]	2.0	4	10	44	18
		4.0	3	9	91	27
Medium (0.5–0.8 specific gravity)	Wet[2]	2.0	3	9	76	41
		4.0	3	9	98	50
	Dry[3]	6.0	6	12	4	3
		8.0	6	12	10	4

[1] Fiber used for all boardmaking was pressure-refined aspen stemwood.
[2] Resin applied in water slurry for wet-formed hardboard. Wet-formed boards measured 20 × 20 in.
[3] Resin applied at 32 ml/min at a 36% solids content. Dry-formed boards measured 14 × 14 in.

It would be desirable if a non-destructive test method were available for determining resin distribution patterns in composition boards.

Literature describing techniques for detecting the distribution of adhesives on the surfaces of wood particles and flakes is limited. Fluorescence microscopy with ultraviolet radiation for detecting the presence of various adhesives on fracture surfaces has been reported (Quirk 1968). Furuno et al. (1983) used fluorescence microscopy to study the effect of resin application variables (e.g., drum speed, flake quantity, resin content, species mix, flake moisture content, and flake type) on cured and uncured resin distribution on hardwood flakes before board formation.

There is a considerable amount of information on using embedding media, soluble in water or organic solvents, for semithin sectioning of animal tissues for microscopic study (e.g., Bennett et al. 1976; Semba 1979). For studying resin distribution in flakeboards, Lehmann (1968) used rather thick, plastic-embedded sections and viewed them in transmitted ultraviolet light. These thick sections and the low magnifications used were excellent for studying resin distribution parameters, but were not adequate for studying board structural features or resin-wood interactions. For 10- to 20-micron sections (necessary to follow continuous resin distribution in hardboards), embedding techniques were developed (Murmanis et al. 1986a). Upon examination, we found that resin distribution was very uniform in wet-formed hardboards, and very uneven in dry-formed boards.

The objective of the present study was threefold: (1) to experiment with various resin application techniques to improve resin distribution in the dry-formed hardboards; (2) to study resin distribution microscopically; and (3) to compare resin distribution patterns with the IB strength of the dry-formed and wet-formed hardboards.

MATERIALS AND METHODS

The test materials for the present report were dry-formed high- and medium-density hardboards made from pressure-refined aspen stemwood fibers bonded with phenol-formaldehyde (PF) resin using variable resin solid contents and resin

TABLE 2. *Internal bond values for medium-density dry-formed hardboard made using varying resin preblending and postblending factors.*[1]

Resin solids content at application	Rate of resin application	Fiber treatment during and/or after resin application	Internal bond[2]	
			Maximum stress	Standard deviation
%	ml/min		lb/in.[2]	
48.2	32	None	4	1
48.2	32	Through refiner after blending	4	2
36.0	32	None	6	4
36.0	32	Through refiner after blending	17	9
24.0	32	None	15	8
24.0	32	Through refiner after blending	24	10
12.0	32	None	13	8
12.0	32	Through refiner after blending	17	10
24.0	425	None	20	6
24.0	425	Through refiner after blending	29	15
24.0	425	None	33	15
24.0	425	Combs added to blender Through refiner after blending	69	14
24.0	32	None	33	11
24.0	32	Combs added to blender Through refiner after blending	42	18

[1] Fiber used for all boardmaking was pressure-refined aspen stemwood. Boards measured 14 × 14 in. All boards made at a 6% resin level.

[2] There was 1 board per treatment and 13 IB samples per treatment.

application techniques. We also used wet-formed high- and medium-density PF bonded boards from a previous study (Murmanis et al. 1986a) for comparison of IB strengths in relation to different resin distribution patterns. Resin solid contents and IB strengths were compared in high- and medium-density wet- and dry-formed boards (Table 1). Medium-density dry-formed boards were chosen to study different resin application techniques at different resin solid contents. These specimens were used for comparing resin distribution patterns and IB strengths (Table 2).

Our laboratory resin applicator for treating dry fiber consists of a rotating drum with an internal spray gun. Phenol-formaldehyde resin is sprayed onto the dry fiber as it tumbles. Several approaches were tried to improve resin distribution on the fiber: (1) reducing resin solids content with distilled water (see Table 2, column 1, for concentrations) before spraying the fiber; (2) increasing the rate (ml/min) for resin application (see Table 2, column 2, for rates) to the fiber; (3) adding wooden combs (see Table 2, column 3) inside the treating drum to increase turbulence and fiber rubbing; and (4) passing resin-treated dry fiber through an 8-inch single disk atmospheric refiner (see Table 2, column 3) equipped with knobby plates, to create more fiber-to-fiber rubbing and resin spread.

Internal bond tests were conducted on all experimental hardboards by following test procedures specified in ASTM D 1037-78. Sections of hardboards were examined microscopically by the procedure described previously (Murmanis et al. 1986b).

RESULTS AND DISCUSSION

In previous research (Murmanis et al. 1986a), we compared resin distribution patterns in wet- and dry-formed high- and medium-density hardboards. We found that the resin was very evenly distributed in wet-formed boards, but very poorly distributed in dry-formed boards. The results of this study consist of comparing IB strength to resin distribution patterns from various wet- and dry-formed medium- and high-density hardboards made from fiber that had been treated in various ways after resin application.

Internal bond values, for high- and medium-density wet- and dry-formed hardboards, made using varying resin contents, are given in Table 1. Although higher resin concentrations were used for the dry-formed boards, the wet-formed high- and medium-density boards have IB values higher than the corresponding dry-formed high- and medium-density boards. The magnitude of fiber interfelting and bonding that occurs in manufacturing wet-formed hardboards does not occur in dry-formed hardboard. To achieve these same strength properties, dry-formed hardboards must depend upon a higher synthetic binder content, uniformly distributed over the fiber surfaces. The data in Table 1 are consistent with findings of previous research (Murmanis et al. 1986a), and support our assumption that uneven resin distribution is the cause of poor IB strengths found in the dry-formed hardboards. Furthermore, the values of 76 and 98 pounds per square inch for medium-density wet-formed hardboards made at resin concentrations of 2 and 4%, respectively, provide a convenient IB baseline performance level for gauging the success of experiments designed to improve IBs of dry-formed medium-density hardboard.

Table 2 summarizes IB data for medium-density dry-formed hardboards made with different resin concentrations, resin application rates, or with various mechanical operations done to improve resin distribution on the aspen fibers or fiber bundles. In all dry-formed boards made with 6% PF resin, which was applied at a constant rate of 32 ml/min and with resin solids content ranging from 48.2 to 12%, fluorescence photomicrographs confirm that the resin was distributed very unevenly (Figs. 1–5). The wood, because of its fluorescence in UV, is light in color; the PF is dark. Resin was present in large clumps in some areas, leaving other areas devoid of resin (Figs. 1 and 2). Passing resin-coated fibers through the refiner before mat formation did not have any appreciable influence on either the hardboard structure or the resin distribution. Figure 1A and 1B, with resin applied at a 48.2% resin solids content level, provides visual evidence of this observation. The pairs of samples at 36 and 24% resin solids content looked alike and were similar to samples at 48.2% resin solids content, as shown in Fig. 2A and 2B, respectively. The IB values for the three sample pairs (Table 2) were also very low. In a pair of samples with resin diluted to a 12% solids content before spraying on the fibers, the resin was also distributed in clumps, but because of lesser amounts available, the clumps were less dense than in the samples with higher resin solids content. Internal bond strengths for these hardboards were very low. It can be generally stated that there was some improvement in IB strength whenever the resin solids content was reduced prior to application and whenever the fiber was passed through the refiner after resin application (Table 2).

Medium-density dry-formed hardboards (resin solids at application = 24%, resin level in finished hardboard = 6%) were used to study resin distribution

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Fig. 1.   Liquid phenolic resin at 48% solids content sprayed on dry fibers and fiber bundles. (A) Fibers not passed through refiner before mat formation (160×), and (B) fibers passed through refiner before mat formation (200×).
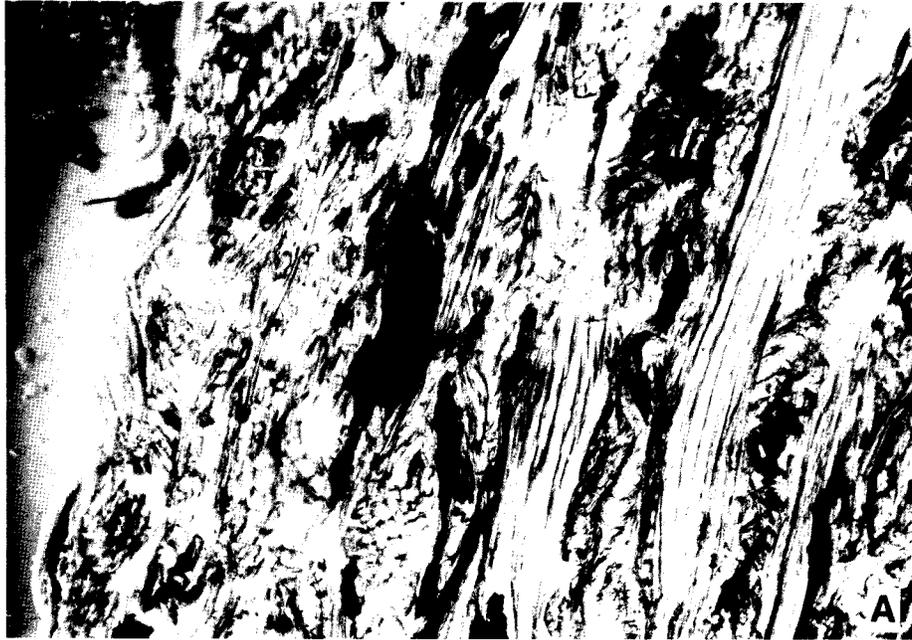
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Fig. 2. Liquid phenolic resin applied to dry fiber at (A) 36% solids content level (160×), and (B) 24% solids content level (160×).

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Fig. 3. Dry-formed hardboard showing resin distribution at a resin application rate of 425 ml/min and a resin solids content of 24% (160×).

patterns by evaluating the effect of: (1) resin application rates of 32 and 425 ml/min, (2) the addition of wooden combs or mixing bars inside the resin blender, and (3) passing the resin-blended fiber through the atmospheric refiner prior to mat formation. Evaluations were made microscopically (Figs. 3–5) and by IB testing (Table 2).

Figure 3 shows the resin distribution in a medium-density dry-formed hardboard when the resin was applied at an application rate of 425 ml/min. Resin distribution at this application rate does not appear to be any different from the resin distribution observed on boards made at a rate of 32 ml/min. There was a slight improvement in IB values (Table 2) when resin was applied at the faster rate. This apparently was caused by better atomization of the resin.

Addition of wooden combs to the treating drum appeared to create a more even distribution of resin at the application rates of 425 ml/min (Fig. 4A) and 32 ml/min (Fig. 4B). This improved resin distribution resulted in an increase of IB, as noted in Table 2, by apparently increasing fiber-to-fiber rubbing action, and thus giving a better resin distribution. When this fiber was subsequently passed through the single-disk refiner after resin application, the increase in IB strength was dramatic (Table 2). Figure 5 is a photomicrograph of a medium-density dry-formed hardboard, which shows the resin distribution on dry fibers and fiber bundles after this combination of treatments. These findings tend to substantiate the observation that fiber interlocking, good resin distribution, and the corre-

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Fig. 4.   Dry-formed hardboard showing resin distribution when wooden combs were added to the resin application drum. Resin solids content was 24%. (A) Resin applied at 425 ml/min (200×), and (B) resin applied at 32 ml/min (200×).
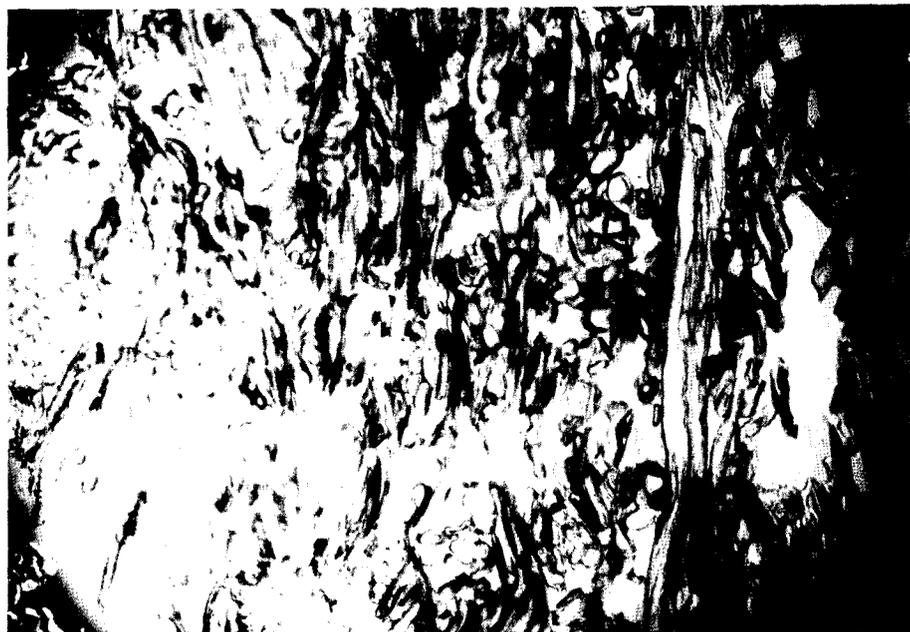
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FIG. 5. Dry-formed hardboard showing resin distribution at resin application rate of 425 ml/min resin solids content of 24%, with wooden combs added to the resin blender, and after the blended fiber was passed through an atmospheric refiner (200×).

sponding improvement in resin spot welds are critical to producing dry-formed medium-density hardboards with acceptable values for IB strength.

CONCLUSIONS

1. Differences in the uniformity of phenolic resin, deposited on fibers and fiber bundles, can be clearly detected by examining hardboard (wet- and dry-formed) sections in a fluorescence microscope.

2. Fiber samples that appear microscopically to have a more uniformly deposited resin pattern also produce dry-formed hardboards that have higher IB strength values.

3. Reducing the solids content of the adhesive solution from 48 to 24%, using a much higher resin application rate, adding combs or mixing bars to the resin blender, and passing the blended fibers through a refiner to increase fiber-rubbing action, improved IB values of medium-density dry-formed hardboards substantially.

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