

ELECTRON MICROSCOPY STUDY OF HARDBOARDS¹

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ABSTRACT

Wet-formed and dry-formed aspen fiber hardboards are examined by transmission electron microscopy to obtain information on the hardboard internal structure and fiber-resin interactions. These factors, when related to strength and dimensional properties of hardboards, may be helpful in determining hardboard quality and suitability for structural use.

During hardboard manufacturing, the wood cells break apart at the middle lamella and come in contact again when subjected to pressure during hot-pressing. Occasionally fibers remain attached in bundles. Various stages of middle lamella degradation can be observed. When totally disintegrated, middle lamella appears as dark granular material. Voids of variable size exist in medium- and high-density wet- and dry-formed hardboards. In wet-formed boards the resin (which has high electron opaqueness and appears black) shows even distribution. In dry-formed boards the resin shows uneven distribution; it is present as large accumulations in some areas but absent in others.

Keywords: Hardboards, wet-formed, dry-formed, structure, resin distribution, electron microscopy.

INTRODUCTION

In producing hardboard we aim to achieve acceptable mechanical properties by economical means. By determining physical properties, we know which boards will and which will not meet specific end-use performance requirements. Often however, we do not know why boards fail. To find out, we examined the structure

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² Maintained at Madison, WI, in cooperation with the University of Wisconsin.

Wet-formed hardboards:

FIG. 1. High density, 0.5% phenol-formaldehyde (PF). Different cell types, vessels (V), parenchyma (P), and fibers (F) present. Dark granular material scattered between cells. $\times 3,040$.

FIG. 2. High density, 0.5% PF. Large voids between the fibers. $\times 3,110$.

FIG. 3. High density, 0.5% PF. Fibers attached in a bundle; middle lamella (ML) not changed. PF between the vessel (V) and parenchyma cell (P) and in some fiber lumina (arrows). $\times 4,760$.

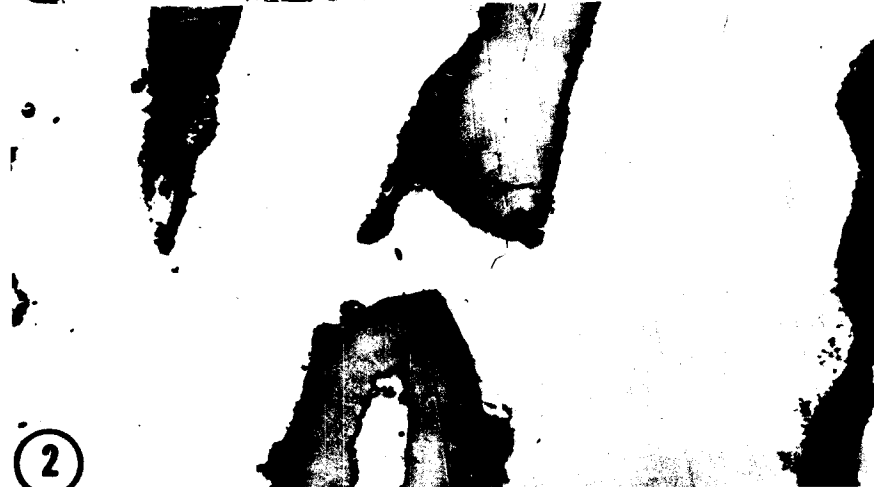
Wet-formed hardboards:

FIG. 4. High density, 0.5% PF. Fibers attached in a bundle; middle lamella (ML) has undergone softening (arrow). $\times 4,760$.

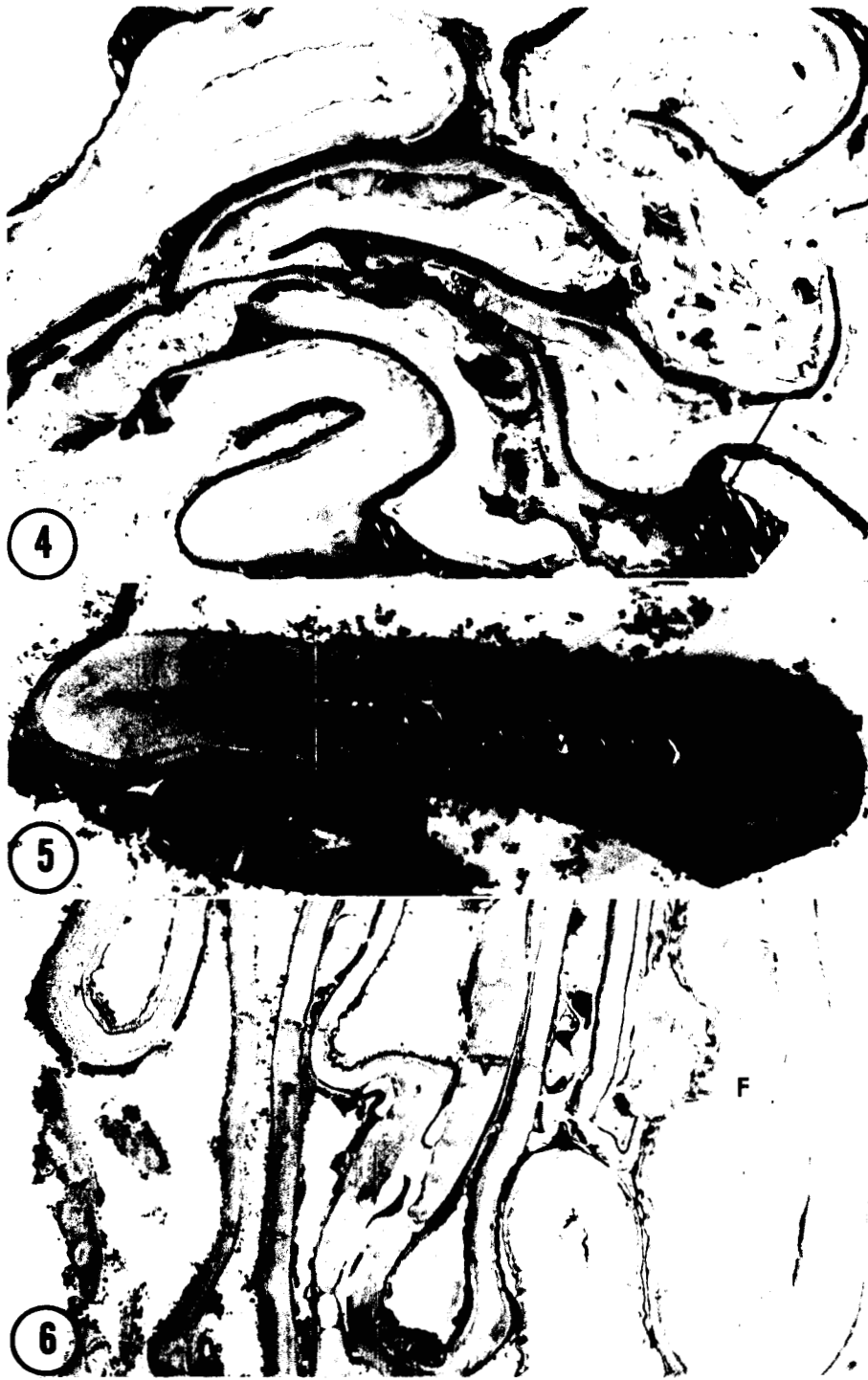
FIG. 5. High density, 0.5% PF. Softened middle lamella (ML) in the fiber lumen. $\times 5,300$.

Dry-formed hardboards:

FIG. 6. High density, 2% PF. Different cell types, vessels (V), parenchyma (P), and fibers (F) present. Dark granular material between cells. $\times 3,040$.



ML85 9104



MC85 9101



MC85 9102

Dry-formed hardboards:

FIG. 7. Medium density, 6% PF. Fibers attached in a bundle. Middle lamella softened at cell corners (arrow). $\times 3,040$.

FIG. 8. Medium density, 8% PF. Finely granular substance between the fibers. Softened middle lamella attached to some fibers (arrow). $\times 7,380$.

and the fiber-resin interactions of hardboards in detail using the electron microscope.

Presently only a few reports on electron microscopy of hardboards are available (e.g., Kruse and Parameswaran 1978; Parameswaran and Himmelreich 1979). More information on detailed board structure will help us correlate the structure

of boards with their mechanical properties and optimize processing procedures to provide boards with acceptable mechanical properties.

MATERIALS AND METHODS

The test material was wet- or dry-formed, high- or medium-density hardboard from pressure refined aspen stemwood cells bonded with phenol-formaldehyde (PF), at diverse resin contents based on oven-dry fiber weight. In wet-formed, high-density boards, the resin content used was 0.5% or 1%, in medium-density boards, 2% or 4%. In dry-formed, high-density boards, the resin content was 2% or 4%, in medium-density boards, 6% or 8%. The procedure used to produce the laboratory-scale boards is described in a separate report (Myers and Crist, in preparation).

For electron microscopy, small (about 1 mm³) pieces of hardboard were fixed in 2.5% aqueous KMnO₄ for 2 hours at room temperature and dehydrated in acetone series, followed by propylene oxide. Embedded in a mixture of araldite, epon, and dodecyl succinic anhydride in proportions 1:1:3 (Mollenhauer 1964), the samples were polymerized in oven at 80 C and sectioned with a diamond knife. Micrographs were taken with RCA EMU 3G microscope.

RESULTS

Wet-formed hardboards

During hardboard manufacturing, the aspen stemwood cells break apart at the middle lamella and then come in contact again when subjected to pressure during hot-pressing. The middle lamella disintegrates and what remains is probably the dark, granular material scattered between the cells (Fig. 1). We observed that some cells did not come in contact again and that voids existed both in high- and medium-density boards. Occasionally the voids reached a considerable size, even in high-density boards (Fig. 2).

Some cells, particularly fibers, remained attached in bundles (Fig. 3). In some bundles, especially in exposed areas, the middle lamella was swollen and softened, and it showed rippling during sectioning (Fig. 4, arrows). The softened middle lamella, when loosened, might land within the cell lumina (Fig. 5). When a bundle consisted of many cells of similar type (which were then packed tightly), the middle lamella remained unchanged (Fig. 3). In Fig. 3, phenol-formaldehyde resin (which has high electron opaqueness and appears black) is visible between the vessel and the parenchyma cell and in some fiber lumina (arrows). Collapsed lumina in the fibers may have resulted from hot-pressing. In wet-formed, high- and medium-density hardboards, the phenol-formaldehyde resin was never found in highly visible accumulations, even in boards bonded with 4% resin.

Dry-formed hardboards

Dry-formed, high- and medium-density boards showed variable structure. Some areas within them appeared similar to the wet-formed boards (Fig. 6). Again, some fibers remained attached in bundles with unchanged (arrow) or softened middle lamella (arrow) between them (Fig. 7). Sometimes a very fine precipitate (not observed in wet-formed boards) was scattered between the cells and in the cell lumina (Fig. 8). This precipitate could be freely pulverized cellular material.



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Dry-formed hardboards:

FIG. 9. High density, 4% PF. PF (arrow) fills spaces between the cells. Middle lamella (ML) visible. $\times 6,160$.

FIG. 10. High density, 4% PF. PF fills spaces between the cells and is in the cell lumina. $\times 8,500$.

FIG. 11. Medium density, 6% PF. PF between the cells; air bubbles (arrow) trapped in PF. $\times 7,380$.

The majority of dry-formed boards differed strikingly from the wet-formed boards in showing large accumulations of resin in localized areas. Resin filled spaces between the cells (arrow) and filled the cell lumina (Figs. 9 and 10). Sometimes small air bubbles were trapped within the resin (Fig. 11, arrows).

DISCUSSION

Internal bond strength tests (ASTM 1978) are routinely used to provide a measure of bonding between the fibers within the hardboards. Our tests showed that the wet-formed boards possess acceptable internal bond strength, whereas the dry-formed boards do not. Microscopical observations show that the wet- and dry-formed boards differ mainly in resin distribution. In the electron micrographs of wet-formed boards, the resin is barely visible because of the low resin content of the boards (0.5% or 1%) and its even distribution. The major disadvantage of the wet-formed hardboard is water pollution.

Industrial practice has shown that high concentrations of resin (6% and 8%) are required to manufacture acceptable dry-formed hardboards. Our electron microscopy study reveals that the distribution of resin on dry fiber is very uneven. Some areas have large accumulations, while others have none.

In this laboratory we are experimenting with other techniques for resin application that should provide a more even distribution.

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