MANDREL BENDING TESTS FOR AIRCRAFT VENEER

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MANDREL BENDING TESTS FOR AIRCRAFT VENEER

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The bending of specimens of veneer around mandrels of particular sizes has been shown to cause breakage in pieces with steep slopes of grain from the plane of the sheet but not in ones with relatively straight grain. Slopes steeper than 1 in 10 are permitted only with strict limitations in veneer for aircraft plywood,[2] however, the magnitude of such slopes cannot be readily determined except by complicated measurements. In lieu of dependence on the judgment of inspectors, based only on the appearance of veneer, as to whether slopes from the plane of the sheet are acceptable, a mandrel bending test was developed at the Forest Products Laboratory for veneer to be used in aircraft plywood.

It is necessary to avoid steep slopes of grain from planes of sheets of veneer because of their serious effects on strength and shrinkage of aircraft plywood. As a consequence, maximum slopes that are permissible have been determined. From bending many thousands of veneer specimens at the Forest Products Laboratory, critical radii of curvature in relation to acceptability were determined for different thicknesses and species. These large amounts of data have been reflected in specifications for aircraft plywood.[2]

This report is prepared to describe the mandrel bending test by giving supplementary information on its details that, for practical reasons, cannot be included in specifications. Such information is intended to facilitate the use of this test in the production of satisfactory aircraft plywood.

The study made during World War II showed that the percentage of breakage of veneer was correlated with radius of curvature of mandrels when the specimens were bent to a U-shape. In addition, veneer with acceptable slopes of grain from the sheet broke only on much smaller radii of curvature than veneer with slopes steeper than 1 in 10, the maximum permissible slope of grain from the plane of the sheet. Critical radii of curvature also were found to be correlated with particular thicknesses, although the ratio of critical radius to

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[1]Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2]Army-Navy Specification Plywood and Veneer; Aircraft Flat Panel. AN - P - 69a. 7 Feb., 1946.

thickness was approximately the same for some thicknesses of veneer. Species that are permissible for aircraft plywood tended to be arranged in three groups, more or less in relation to the respective specific gravity of the wood and for hardwoods and softwoods. This arrangement permitted a minimizing of the number of radii of curvature necessary for testing veneer by mandrel bending.

Equipment for Mandrel Bending

Only relatively simple equipment is required for the mandrel bending test to determine the acceptability of veneer with respect to slope of grain from the plane of the sheet. Drying ovens can be obtained in most large cities from firms that handle laboratory equipment. The mandrels and frames to facilitate handling of specimens of veneer can be made in many woodworking shops at or near veneer and plywood plants.

Drying Ovens

It is known that the presence of considerable moisture in wood permits it to be bent to smaller radii of curvature than extremely dry wood. In order to avoid the effects of variations in moisture during mandrel bending tests, the veneer is oven-dried to 0.0 percent moisture content. Test specimens of veneer can be satisfactorily dried in 4 to 5 hours in a thermostatically controlled electric oven at about 105° C. when the specimens are loosely placed in a rack. A simple drying rack, which can be easily made, is shown in figure 1 along with an oven for drying the specimens.

Mandrels

The mandrels for this test are simple cylinders, the sizes of which conform to specifications as to radii of curvature for testing different species and thicknesses of veneer used in aircraft plywood. Several sizes of mandrels, each about 1-1/2 inches high, can be arranged together in any convenient order, such as is shown in figure 2. The different species and thicknesses of veneer being tested by any particular plant determine the number of mandrels that are needed. For example, a mill testing mahogany, khaya, and yellow-poplar veneer would need one mandrel with the required radius of curvature for each thickness of veneer, but another plant testing birch and sweetgum veneer in addition to the above species would need additional mandrels.

Mandrels can be made of sugar maple or of any other hardwood species of about the same density that can be smoothly turned. Thoroughly dry lumber should be used for solid or glued-up blocks from which mandrels are turned, so that subsequent changes in sizes of the mandrels will be minimized with changes of atmospheric humidity in the plants. Many woodworking shops available to veneer and plywood plants are equipped with lathes to turn mandrels within tolerances of 0.01 of an inch in diameter.

The diameters of mandrels are equal to specified thicknesses of veneer T times the required ratio of radius of curvature[2] (R); for example, for 1/24-inch mahogany veneer

T x R = Radius of curvature
0.040-inch x 50 = 2.00 inches

Hence 1/24-inch mahogany is tested on a mandrel 4 inches in diameter (2 times the radius of curvature). With this formula the size of mandrels can be determined for any specific thickness and for any species of veneer that are permissible for use in aircraft plywood.

Testing Procedures

Specifications for veneer to be tested by mandrel bending[2] require that tests be made on specimens about 1 inch wide. Their edges are cut parallel to the fiber direction so as to avoid slope of grain from edges of the specimens. It is recommended that specimens be cut from samples of veneer about 12 inches along the grain from which consecutive specimens across the grain are to be sawed or clipped. The minimum sampling of veneer also is specified for veneer to be used in aircraft plywood.[2]

Because each sheet of veneer has both a tight side and a loose side, it is necessary to determine which is the tight side and to mark that side, preferably when the samples are obtained from the sheet. This insures that inspectors will always be able to make the bending test with the tight side out and the loose side of the specimens against the mandrel. If the tight side is placed against the mandrel, even exceedingly small checks on the loose side may cause failure, and, thereby, cause unnecessary rejection of approximately straight-grain veneer.

Specimens about 1 inch wide and 12 inches along the grain are bent to a U-shape so that the fiber direction follows, or is normal to, the curvature of the mandrel. The specimens are held firmly against the mandrel by the thumbs of the inspector (fig. 3) but in such a way that specimens are not supported on the tension (outer) surface except where they are held in place. After being bent to a U-shape, unbroken specimens are released without increasing the radius of curvature as they are being removed from the mandrel.

The mandrel bending is done on oven-dry specimens taken directly from the oven. In this way the test is made under constant conditions of moisture content and temperature. During the development of mandrel bending tests, it was found convenient to leave the oven door open, but with the heating elements turned on to assure reasonably constant testing conditions. It is necessary, however, for the inspector always to protect his thumbs from the heat since they become extremely tender after testing even 10 or 20 hot specimens. Fingers cut from worn-out leather gloves have been found to give satisfactory protection when slipped over the thumbs while making a large number of mandrel bending tests. The leather provides a satisfactory surface with which to hold the specimen firmly in contact with the mandrel and also to protect the thumbs from uncomfortably high temperatures.

Breakage of more than 20 percent of the specimens from any flitch, crate or stack of veneer[2] shall be a sufficient reason for rejection of the material represented by those specimens. Any specimen with a fracture that extends 1/8-inch or more across the grain shall be considered broken. Tears along the grain, however, that begin at the edge and extend into the specimens shall not be considered breakage. Such tears indicate slopes of grain from the edge and not slopes from the plane of the sheet, since mandrel bending was designed only for testing whether the latter slopes were within permissible limits for aircraft plywood. Breakage is determined before removal from the mandrel. Figure 4 shows breakage in the bending test in the part of a specimen with excessively steep slope of grain from the plane of the sheet, but none in the other part with relatively straight grain.

Figure 1.--Veneer specimens in racks for oven drying before the mandrel bending tests are made.

(ZM 60539 F)

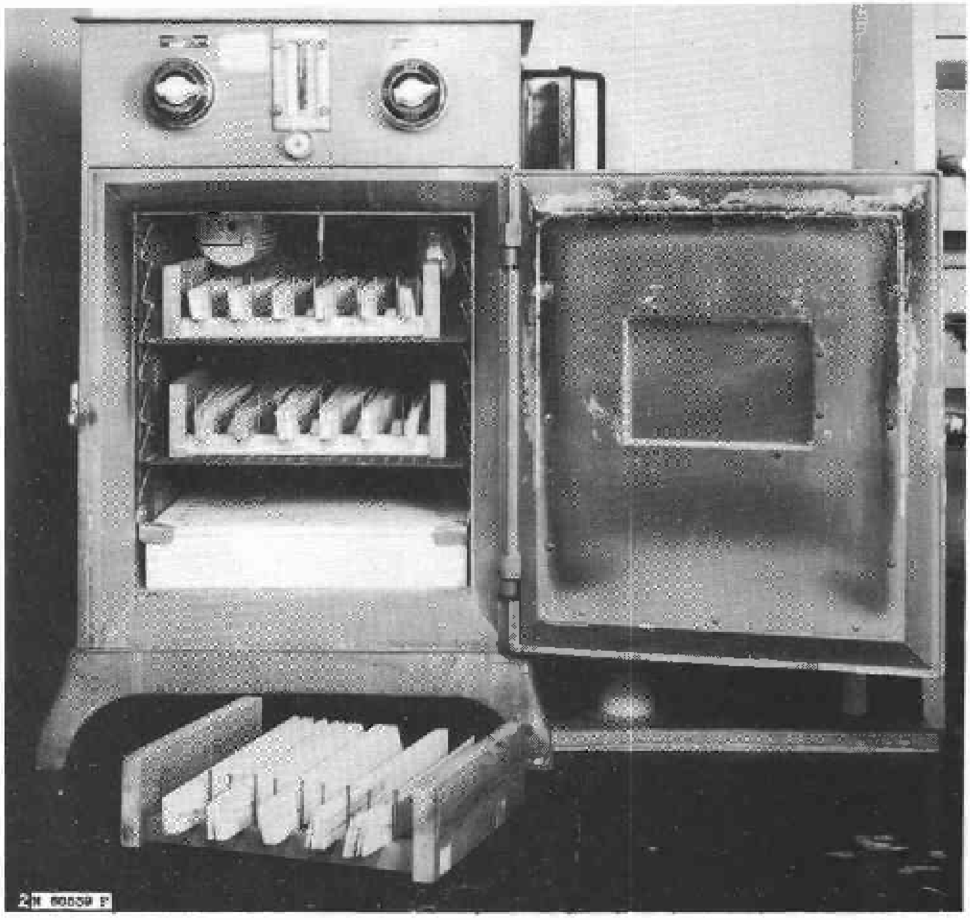
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Figure 2.--Mandrels used in making bending tests on veneer to determine whether its slopes of grain from the plane of the sheet are permissible for aircraft plywood. These included most of the sizes needed for testing hardwood species of veneer.

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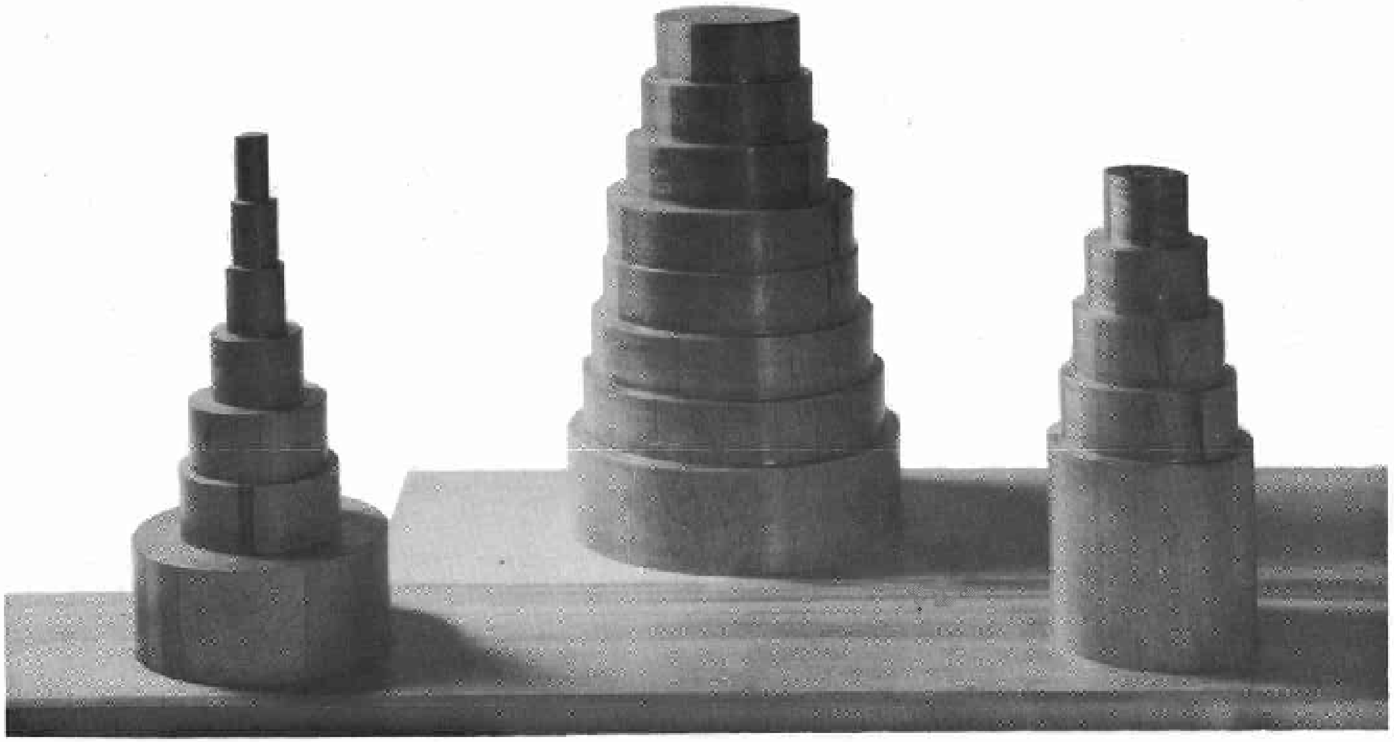

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Figure 3.--Procedure used in bending a specimen during the mandrel bending test, showing (left) specimen held in position by the thumbs at the start and (right) at the finish of a test in which the specimen did not break.

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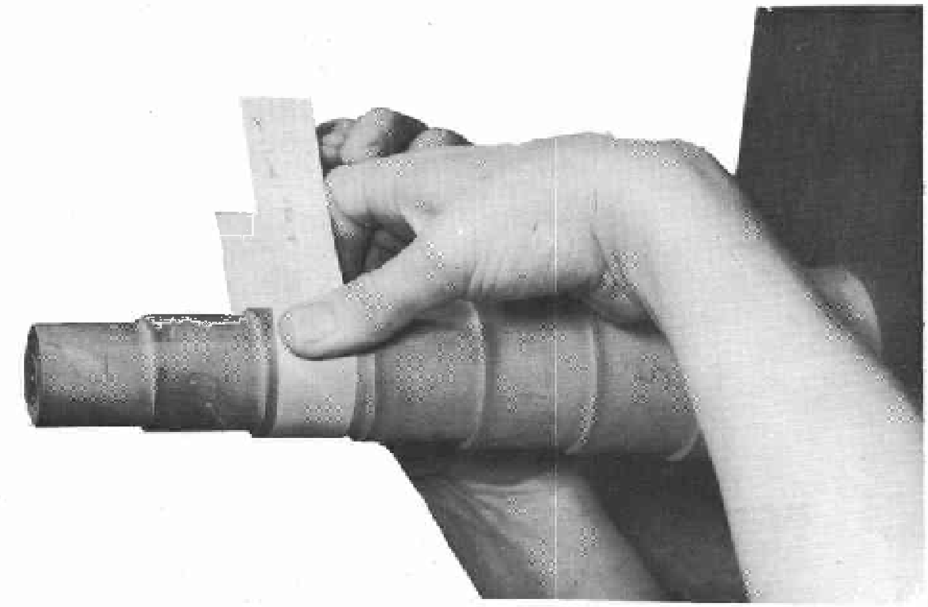

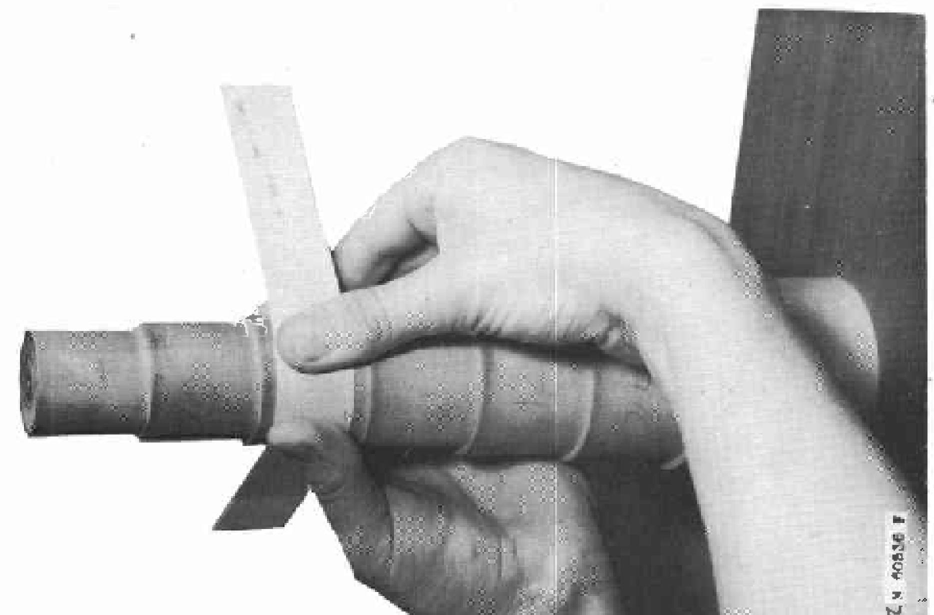

Figure 4.--A mandrel bending test showing a specimen that broke in the part with excessively steep slope of grain near the top edge, but not in the part with relatively straight grain.

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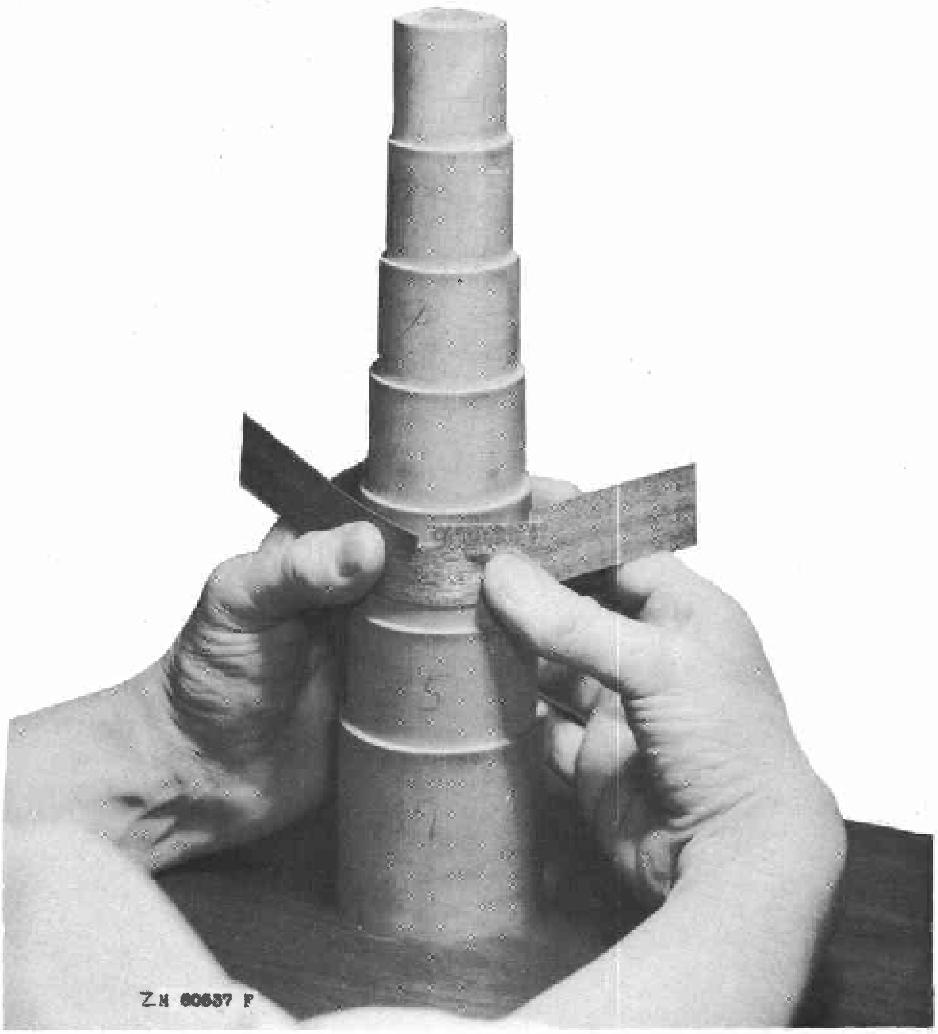
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