DETECTION OF COMPRESSION FAILURES IN WOOD

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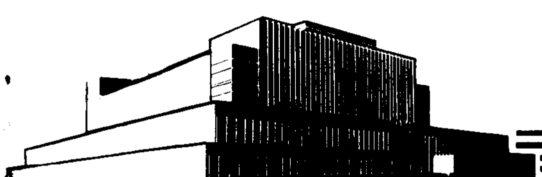

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

In Cooperation with the University of Wisconsin

DETECTION OF COMPRESSION FAILURES IN WOOD[1]

By

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Compression failures are sometimes also known by a variety of other names. Some of these are thunder-shake, lightning-shake, heartbreak, crossbreak, and upset.

Compression failures are deformations of the fibers due to excessive end compression, or to compression resulting from bending. The deformations range from well-defined buckling of the fibers visible with the unaided eye as wrinkles across the face of the piece, as shown in figure 1, to slight failures of the fiber walls (fig. 2) visible only with a microscope.[3]

Occurrence of Compression Failures

They may develop when standing trees are bent severely by the wind, sleet, or snow, or when timber is felled over irregularities of the ground. They may also be due to rough handling of wood at any stage in processing, to excessive stresses in service, or possibly to longitudinal stresses induced by the growth of the tree. They have been observed in many species, including some native to the tropics as well as some native to the temperate zone, in softwoods and hardwoods, and in woods of high, low, and intermediate density.

Illustrative of compression failures formed in the living tree, apparently as the result of a storm many years prior to felling, is the piece of a Sitka spruce board shown in figure 1. Formation of the compression failure shown in the figure, evidently injured the growing cells under the bark, and as a result wide distorted rings developed during subsequent growth. There is also a discolored area about the terminus of the failure. There are other causes

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[1]This is one of a series of progress reports prepared by the Forest Products Laboratory relating to the use of wood in aircraft issued in cooperation with the Army-Navy-Civil Committee on Aircraft Design Criteria. Original report published in June 1944.

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

[3]Beinfait, J. L., Relation of the Manner of Failure to the Structure of Wood Under Compression Parallel to the Grain. Jour. Agricultural Research 33:2, July 15, 1926.

for distorted rings of this kind, since they may be brought about by other injuries to the growing cells, which for some years thereafter form wound tissue. Whenever such distorted rings occur in a board, however, the portion of the board that was nearer the center of the tree should be examined carefully for compression failures.

Effect of Compression Failures

Because of the behavior of wood in compression, compression failures do not greatly affect the compressive strength, The buckling of the fibers, which characterizes compression failures, however, may seriously affect the tensile strength, and hence the bending strength of wood, The shock resisting ability or toughness, which is affected by the degree of deformation of a piece in bending, is among the properties most seriously affected. The extent and degree of severity of a compression failure are factors influencing the effect on strength, but there is no satisfactory way of evaluating their effect as can be done with other types of defects, such as knots.

The effect of compression failures on toughness is illustrated by the results of tests on specimens taken from the piece illustrated in figure 3 B. Specimens from the lower left-hand portion of the piece contained compression failures and had an average toughness of 53 inch-pounds per specimen, as compared to an average of 170 inch-pounds for specimens from the upper right-hand portion. The density of the two sets of samples was very similar.

Wood containing compression failures in any degree should not be used in aircraft structural members, or for other purposes where high strength is essential. Specifications for aircraft lumber accordingly require that "all lumber shall be free from compression failures."

Methods of Detecting Compression Failures in Wood or Wood Parts

Compression failures are easier to detect on smoothly sawn or planed surfaces or in finished lumber, than in rough-sawn stock. A good hand lens is of assistance when the failures are small or when only a small area is to be examined.

Inspection for compression failures may be made by the following methods:

1. Side grain inspection.--Look along the smooth surface of a piece, with the light striking along the grain at an angle of about 20° with the surface. The point of view should be varied between 45° and vertical, on the same side of vertical as the light source, as shown in figure 4. Other angles of light and vision should be tried.

2. End grain inspection for end breakage of fibers.--The appearance of the end grain of a piece often gives an effective indication of compression failures, if they are present at that section. In figures 3 and 5, A and B, are shown sawed crosscut surfaces of Sitka spruce where fibers have broken off close to the saw cut, giving definite evidence of compression failures.

3. Veneer inspection by transmitted light.--Transmitted light is helpful in the detection of compression failures in veneer. By holding the sheet of veneer to the light, so that the side observed is in shadow, a compression failure appears as a dark irregular line across the grain (fig. 6).

4. Toughness tests.--The Forest Products Laboratory toughness test is very helpful in detecting compression failures in lumber. The presence of compression failures in the test specimens is indicated by low and erratic toughness values. Limitation of this method is that the test specimens do not necessarily represent an entire plank or piece.

Detailed Discussion of Methods of Detection

Side Grain Inspection

Compression failures in wood can best be seen on smoothly planed surfaces so placed that light strikes along the grain at an angle of about 20" with the surface. When no magnification is used, the point of view should be varied between 45° and vertical, on the same side of vertical as the light source, as shown in figure 4. Other angles of light and vision, however, should be tried. A concentrated light source, such as a spotlight, is best. Light from a window, because it comes from one general direction, is better than the more or less diffused light common to most workrooms or outdoors. When viewed in the manner described, a failure appears as an irregular line extending across the grain, as shown in figure 1. When a hand lens or a microscope is used, as will be described later, the same arrangement with respect to light source is recommended, except that it is best to keep the point of view at vertical due to distortion of the field when any other position is used.

End Grain Inspection for End Breakage of Fibers

The presence of numerous, minute compression failures in Sitka spruce is often indicated by the appearance of the sawed crosscut surface, as shown in figures 3 and 5. Below and to the left of the black line in figure 3 B, radially aligned groups of springwood and summerwood fibers were broken off along minute compression failures close to the saw cut, rather than being cut off by the saw. Above and to the right of the black line, where there are no compression failures, the saw cut appears normal. Although the springwood of this portion of the cross section was broken off in places, the summerwood was cut off by the saw. While presence of this characteristic end breakage of fiber on the crosscut surface indicates pressence of compression failures, its ab-.

sence is not proof of the absence of compression failures, because to develop end breakage of fiber, the saw cut must, obviously, come close to those failures which are present.

Compression failures may be scattered over most of the cross section of a piece, as is indicated by the presence of end breakage of fiber in the crosscuts shown in figures 3 A, 5 A, and 5 B.

The appearance of end breakage of fiber due to compression failures varies slightly, depending on the type of saw used. The radial alignment of the groups of fibers broken out is not changed, however, as may be seen in figures 3 and 5, which show crosscuts made by a rough cut-off saw and a novelty cut-off saw. There is no difficulty in detecting end breakage of fiber due to compression failures, no matter what type of cut-off saw is used.

Veneer Inspection by Transmitted Light

The use of transmitted light is an aid to detection of compression failures in veneer; When the sheet is held up to a bright light, 'so that the side observed is in shadow, a compression failure appears as a dark, irregular line across the grain. Figure 6 shows a compression failure as it appears by transmitted light. This method is usually more effective with light-colored woods, such as Sitka spruce, than with dark-colored species, such as mahogany. A light box, similar to that used in detecting compression wood in veneer, is also useful for detecting compression failures.[4]

Toughness Tests

The Forest Products Laboratory toughness testing machine[5] is helpful in detecting the presence of compression failures. This machine measures the work done in breaking small specimens (5/8" by 5/8" by 10"). Since compression failures greatly affect the tensile strength and shock resistance of wood, their presence in specimens is indicated by low and erratic toughness values in the Forest Products Laboratory toughness test. The possibility is always present, however, that the test specimens selected from readily accessible portions in a given piece of wood may not be representative of the entire piece with respect to the presence of compression failures. For this reason, careful visual inspection is always essential.

Use of Hand Lens

A good hand lens is of assistance when the failures are minute or when only a small area is to be examined. Figure 7 A shows a series of compression

[4]Compression Wood: Importance and Detection in Aircraft Veneer and Plywood. Forest Products Laboratory Rept. No. 1586, Sept. 1943, Reviewed and reaffirmed 1959.

[5]Forest Products Laboratory's Toughness Testing Machine. Forest Products Laboratory Rept. No. 1308, Nov. 1941, Reviewed and reaffirmed 1961.

failures at a magnification of 5 diameters. These failures were just barely visible to the unaided eye in the original piece. In the laboratory, magnification up to 60 diameters by means of a low-power microscope is very helpful, Figure 7 B shows a view of compression failures on a tangential surface at a magnification of 60 diameters. When examining a piece of wood with a hand lens, care must be taken not to mistake for compression failures those minute breaks in the surface fibers that are sometimes caused by planing. These surface breaks can be removed with a sharp pocket knife, whereas a compression failure is usually still visible after a thin shaving has been taken off. The knife must be sharp (a safety razor blade is better)so that a very thin shaving can be removed without crushing the remaining fibers and thereby obscuring a compression failure if it is present.

Staining Solutions of Limited Value

It has frequently been suggested that a staining solution of some sort might help to emphasize compression failures and aid in their detection by visual means. Accordingly, a number of stains and combinations of stains were applied to compression failures varying from those barely visible with the unaided eye to those which were quite pronounced. No useful results were obtained since only those failures which were easily visible to the eye were emphasized by the stain. Those failures which were difficult to detect, and which it was most desirable to emphasize, were not emphasized at all but, instead, were usually obscured by the stain.

Summary

Compression failures are more easily seen if the light, the piece, and the point of view are in proper relation to each other. A hand lens is of assistance under some circumstances. The presence of characteristic breakage of fiber on sawed end surfaces is particularly effective with some species. Transmitted light is an aid in examining veneer. The Forest Products Laboratory toughness test is also helpful in detecting compression failures. Microscopic examination is too time-consuming for inspection work, but is valuable in laboratory analysis of material suspected of containing compression failures.

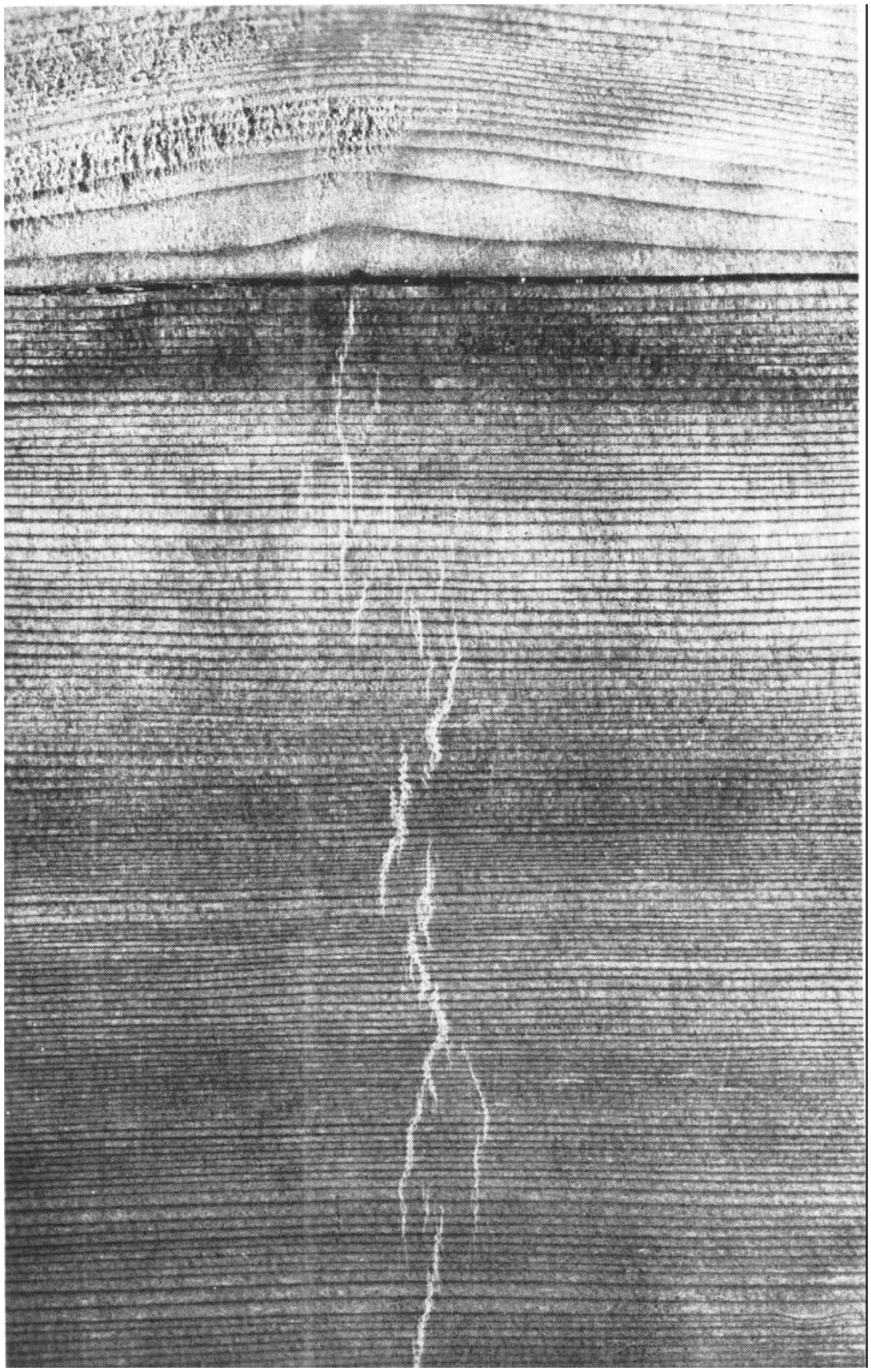

Figure 1.--Compression failures in edge-grained Sitka spruce. The failures developed in the tree many years before felling. They end in an annual ring in which the growing cells were injured causing distortion of subsequent growth rings.

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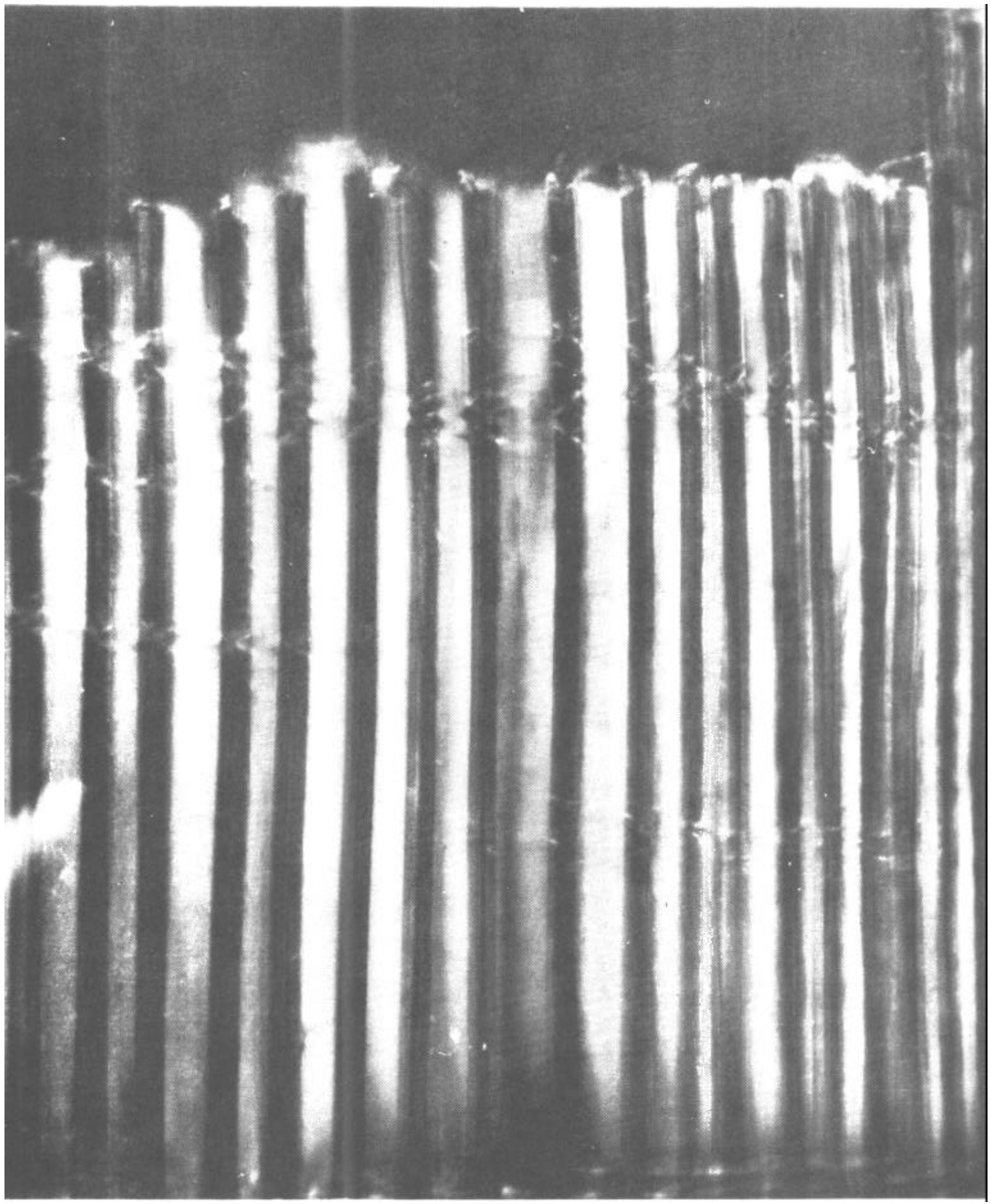

Figure 2.--Thin radial section through tension failure of Sitka spruce showing compression failure near the fracture and evidence that fracture followed a compression failure across the grain. Section magnified 290 diameters.

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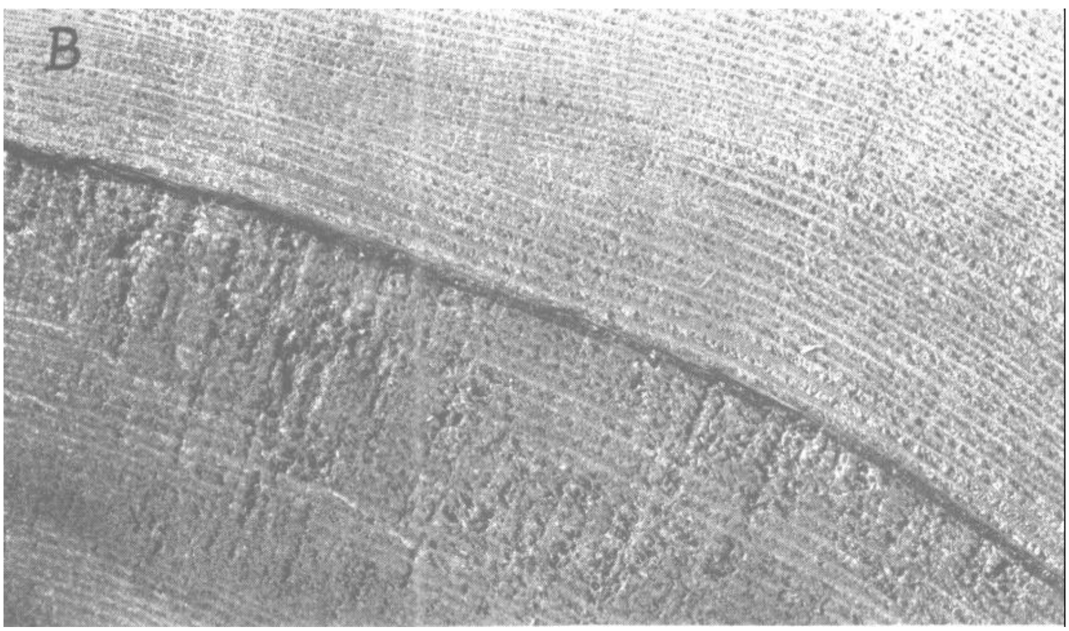

Figure 3.--Sawed crosscuts through Sitka spruce wood made by a rough cut-off saw, showing end breakage of fiber due to presence of numerous, minute compression failures: A, compression failures distributed across most of the cross section of the piece; B, compression failures confined to that portion of the cross section on the lower left side of the black line.

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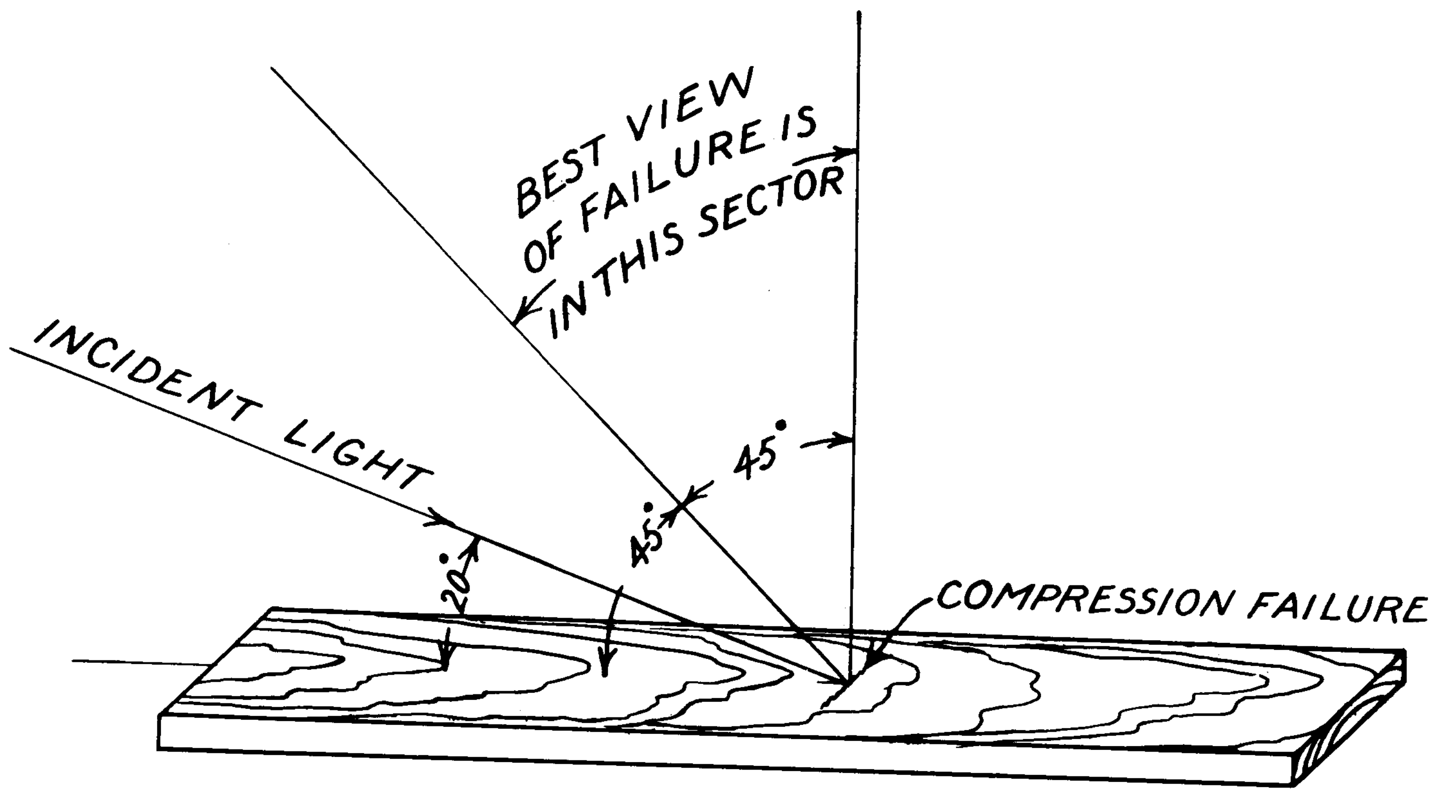

Figure 4.--Most effective angle of view and angle between wood surface and incident light when searching for compression failures.

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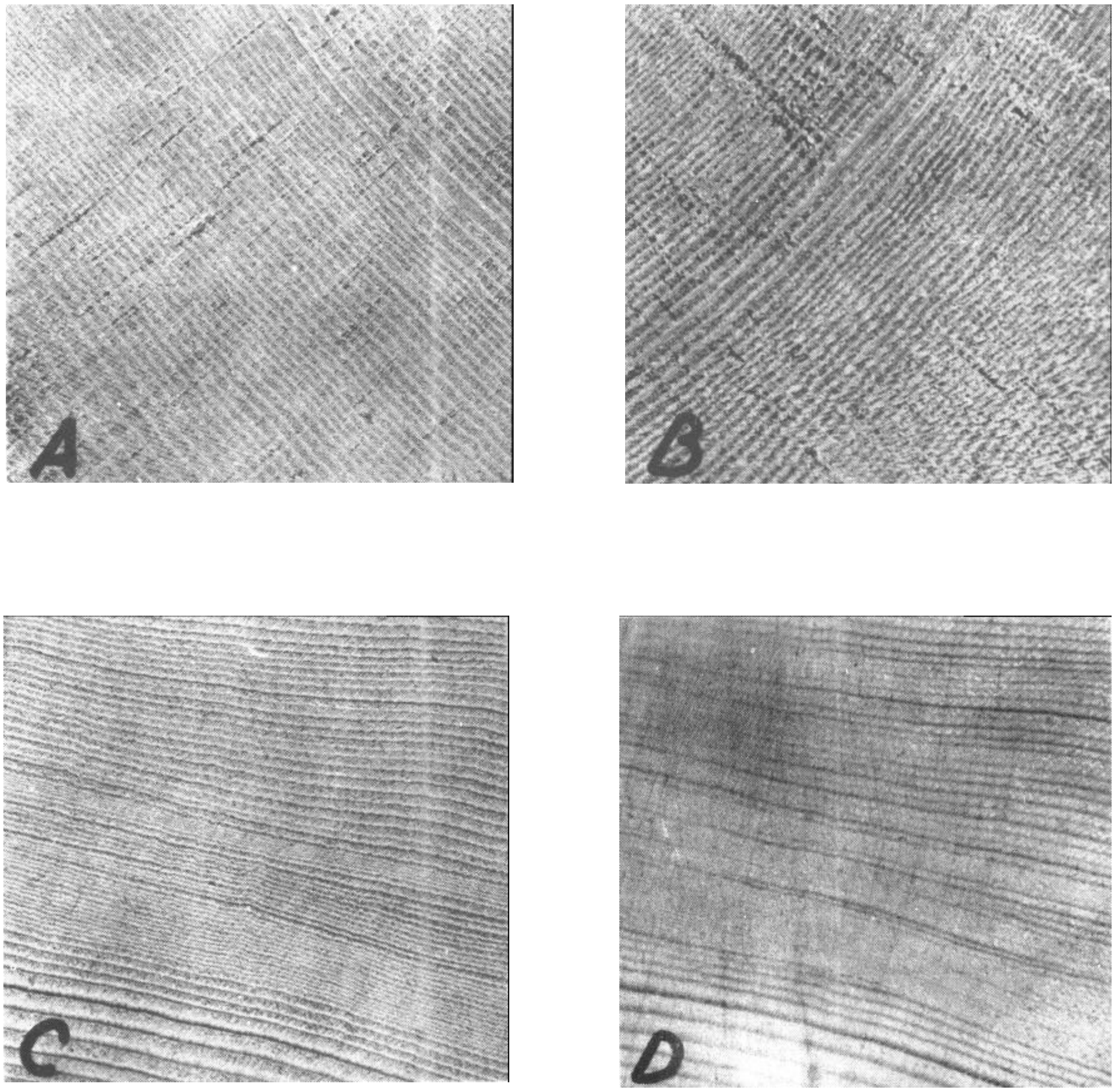

Figure 5.--Effect of different saws on end breakage of fiber due to compression failures in Sitka spruce. A and C were cut with a hollow ground cut-off saw; B and D with a novelty cut-off saw. A and B are from the same piece and contained compression failures. C and B are from a different piece and contained no compression failures.

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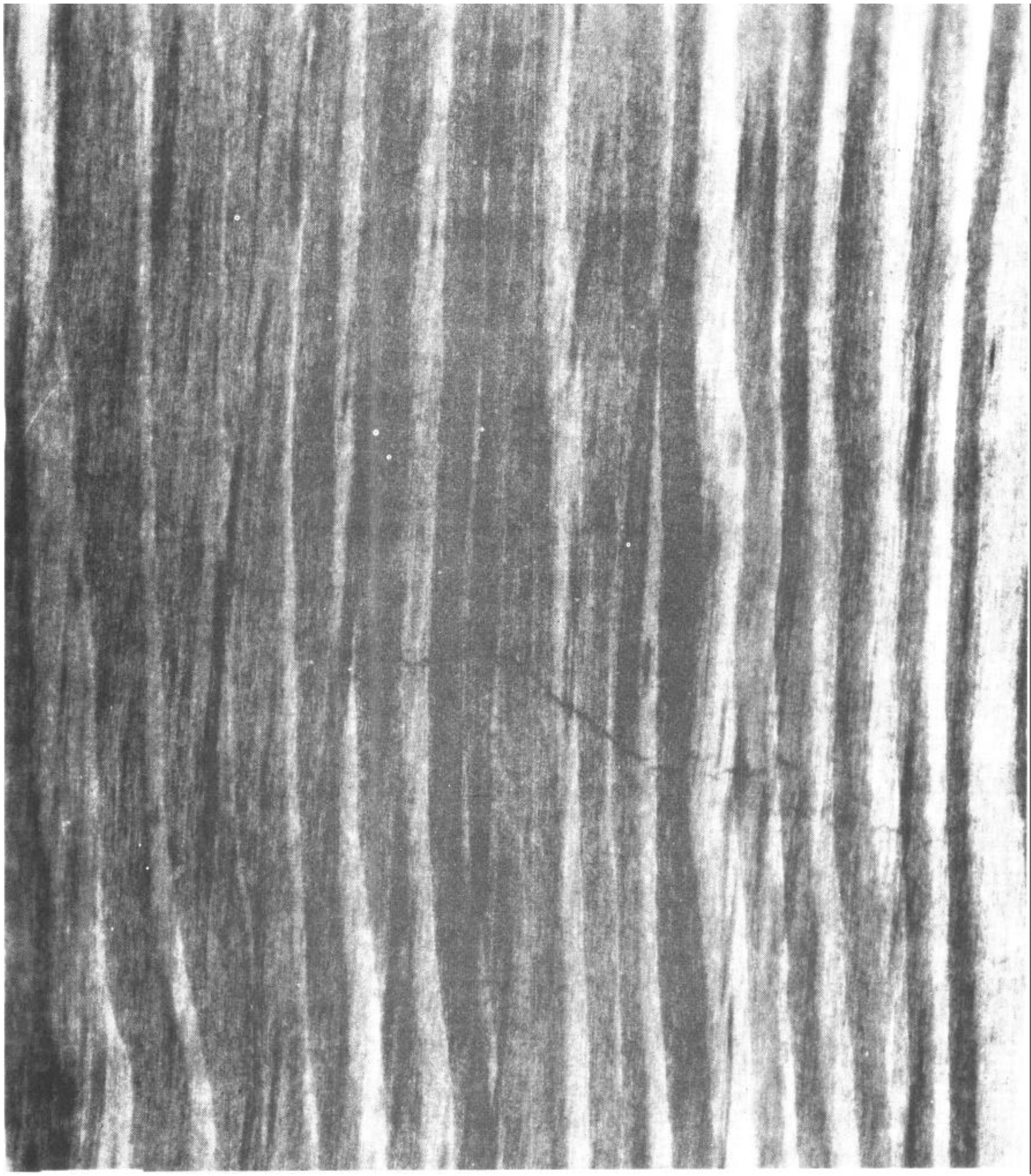

Figure 6.--Compression failure in rotary-cut yellowpoplar veneer as photographed by transmitted light.

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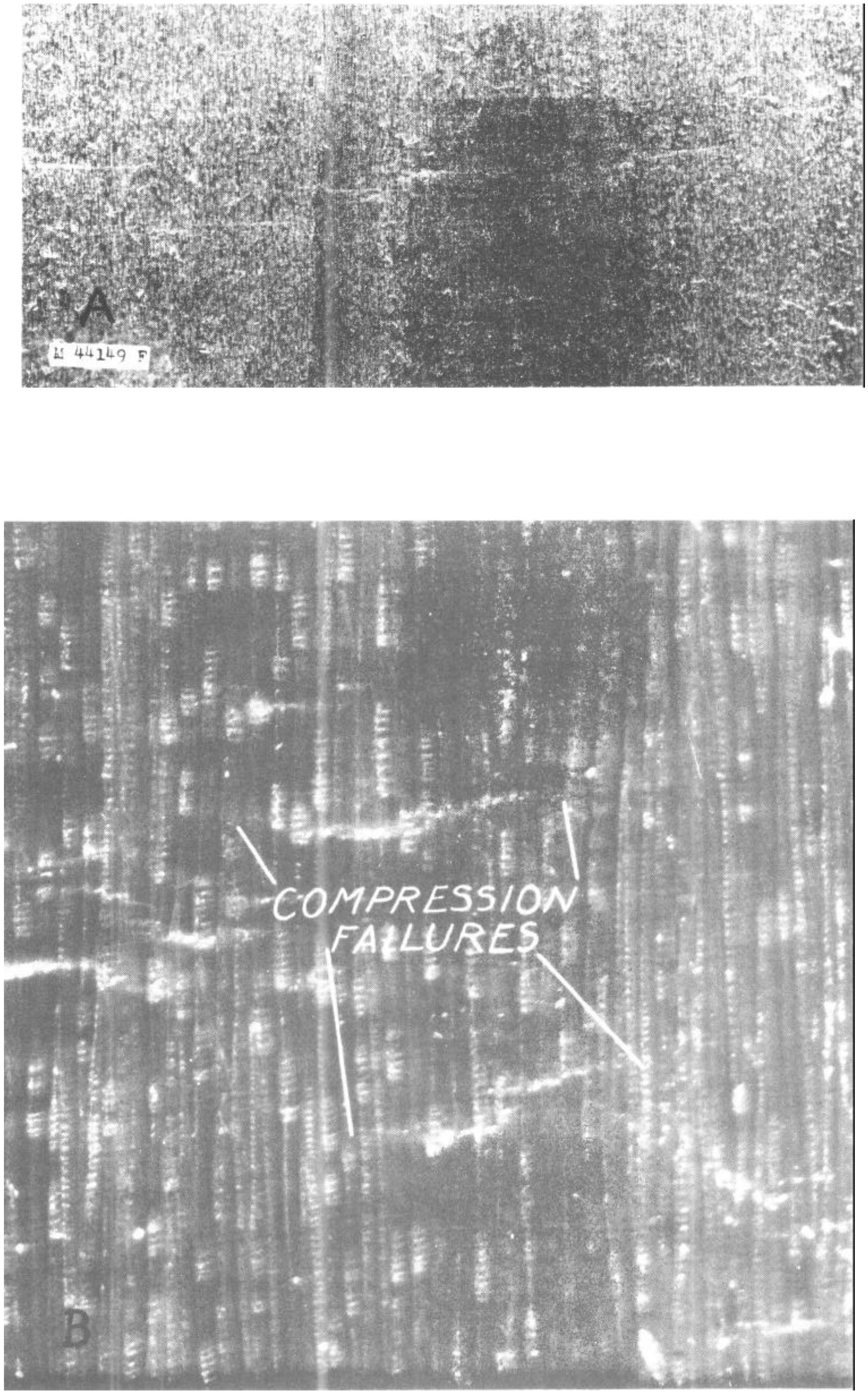

Figure 7.--Minute compression failures in Sitka spruce as seen on the tangential surface: A, failures barely visible to the unaided eye in the original piece are shown at a magnification of 5 diameters; B, failures almost invisible to the unaided eye in the original piece are shown at a magnification of 60 diameters.

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