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NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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RAKE ANGLE FOR PLANING HARD MAPLE DETERMINED BEST BY DEPTH OF CHIPPED GRAIN

ABSTRACT. — Indicates that rake angle for hard maple and perhaps other hardwoods should be determined by depth rather than frequency of machining defects.

OXFORD: 823.1:176.1. KEY WORDS: knife planing, machining (wood), rake angle, surface quality.

Although abrasive planing and cross-grain knife planing can reduce or eliminate many severe defects in hardwoods, large volumes of hard maple and other hardwoods are still knife planed parallel to the grain. Hence, machining technology to improve knife planing parallel to the grain is still needed.

The rake angle for knife planing has previously been selected by frequency of occurrence of machining defects, usually chipped grain. The frequency of chipped grain generally increases as rake angle increases. This trend has been shown by Davis[1] and has also been shown in a planing study[2] with sycamore. However, the study with sycamore and another study[3] with clear hard maple indicated that the depth of the defect below the surface and not the frequency of occurrence determines the required amount of subsequent processing to remove chipped grain. Thus, development of machining technology to produce the shallowest possible defect will reduce waste substantially.

The study with clear hard maple compared surface roughness from planing hard maple across the grain and parallel to the grain. Results from various combinations of depth of cut (1/32, 1/16, and 1/8 inch), feed rate (10, 20, and 30 knife marks per inch), and rake angle (10, 20, 30, and 45 degrees) indicated that rake angles of 20 or 30 degrees produced the minimum depth of defect when planing hard maple parallel to the grain. This conflicted with previous guidelines recommended for planing hardwoods, including hard maple. Hence, an attempt was made to determine the rake angle or angles that produced the shallowest depth of chipped grain. The results indicate that combinations of moderate rake angles and feed rates are best.

METHOD OF STUDY

Hard maple lumber including all sound growth characteristics (knots, etc.) was planed with the top front head of a molding machine. All growth characteristics were included because the severest machining defects generally occur in the areas of sloped grain associated with the growth characteristics. The lumber was conditioned at 8 percent moisture content.

1 *Davis, E. M. Machining and related characteristics of United States hardwoods. USDA Tech. Bull. 1267, 68 p. 1962.*

2 *Stewart, Harold A. Effect of cutting angle and depth of cut on the occurrence of chipped grain on sycamore. USDA Forest Serv. Res. Note NC-92, 4 p. N. Cent. Forest Exp. Sta., St. Paul, Minn. 1970.*

3 *Stewart, Harold A. Cross-grain knife planing hard maple produces high-quality surfaces and flakes. Forest Prod. J. 20(10): 39-42. 1970.*

Machine parameters except for feed rate and rake angle were not varied. The cutterhead diameter and r.p.m. were 6 inches and 4,700, respectively. The rake angle was varied from 10 to 45 degrees in increments of 5 degrees. The 40-degree rake angle was omitted. The feed rate was varied to nominally give 10, 20, and 30 knife marks per inch.[4]

The depth of cut was constant at 1/16 inch, a common setting for finish knife planing. The depth of cut does not affect the average or maximum chip thickness per knife as much as feed rate; hence, the feed rate and rake angle interaction was studied. The constant depth of cut (1/16 inch) also served as a basis for comparing depth of defect results with frequency of defect results from previous work.[1]

Sufficient material was planed at each combination of test variables to give many examples of chipped grain representing the severest conditions likely to occur in most practical situations. Surface profiles of the most severe machining defects (chipped and torn grain) were then traced with a stylus-type profilometer, and the peak-to-valley depth of defect was measured from the surface profile. Measuring the maximum depth of chipped grain from a dynamic situation such as knife planing precludes normal statistical methods; further, the results from similar machining trials may be inconsistent. Nevertheless, the defect depth determines how much further processing is necessary; therefore, the defect depth should be measured and be the criterion for selecting the rake angle.

RESULTS AND DISCUSSION

The following results were observed:

1. Moderate rake angles of 20 and 25 degrees produced the shallowest chipped grain at 30 knife marks per inch (fig. 1).

2. At rake angles equal to or less than 25 degrees, the depth of defect increased as the number of knife marks per inch decreased.

3. At rake angles equal to or greater than 30 degrees, the depth of defect was approximately the same at all numbers of knife marks per inch (fig. 1).

4. At 10 knife marks per inch the depth of chipped grain was approximately the same for all rake angles (fig. 1).

5. The most severe chipped grain defect occurred when planing against approximately a 10-degree slope of grain; this substantiates previous results[5] from planing white ash.

6. After planing with a rake angle of 25 degrees (fig. 2), the depth of defect increased more rapidly as the number of knife marks per inch decreased at a slope of grain of approximately 10 degrees than at slopes of grain less than 5 degrees.

7. Chipped grain depth at "pockets" of short grain (fig. 3) appeared to be independent of machining combinations of rake angle and knife marks per inch. Further, it was generally as severe or more severe than conventional chipped grain (fig. 3).

The depth of defect in a prescribed machining situation depends primarily on the slope of grain. Further, these results and previous work[5] with a 25-degree rake angle indicate that the most severe chipped grain occurs at approximately 10-degree slope of grain, which is found frequently near knots and cross grain.

When planing with rake angles of 20 and 25 degrees at 30 knife marks per inch, about 1/64 inch would have to be sanded away to remove the chipped grain if the slope of grain were maintained at less than 5 degrees. At greater slopes of grain and 30 knife marks per inch, approximately 1/32 inch would have to be sanded away. If the knife marks were decreased to 10 or less by increasing feed rate, 1/16 inch or more would have to be sanded to remove the chipped grain from boards planed with all of the rake angles studied.

At fast feed rates (10 knife marks per inch) the depth of defect is not reduced greatly when using 20- to 25-degree rake angles, as it was at slower feed rates. As feed rate was increased to 10 knife marks per inch or less, the depth of defect became approximately the same for all rake angles tested. Hence, hard maple should be knife planed with a 20- or 25-degree rake angle at slower feed rates.

Rake angles of 20 and 25 degrees agree favorably with past recommendations for knife planing hard maple and other hardwoods.[1] Although smaller rake angles were previously recommended for knife planing some hardwoods, they were not widely used

[4] *Number of knife marks per inch* $= \dfrac{(rpm)\ \text{No. of knives}}{(\text{Feed rate} - \text{feed/min.})\ 12\ \text{inches/ft.}}$

[5] *Stewart, Harold A. Abrasive vs. knife planing. Forest Prod. J. 20(7): 43-47. 1970.*

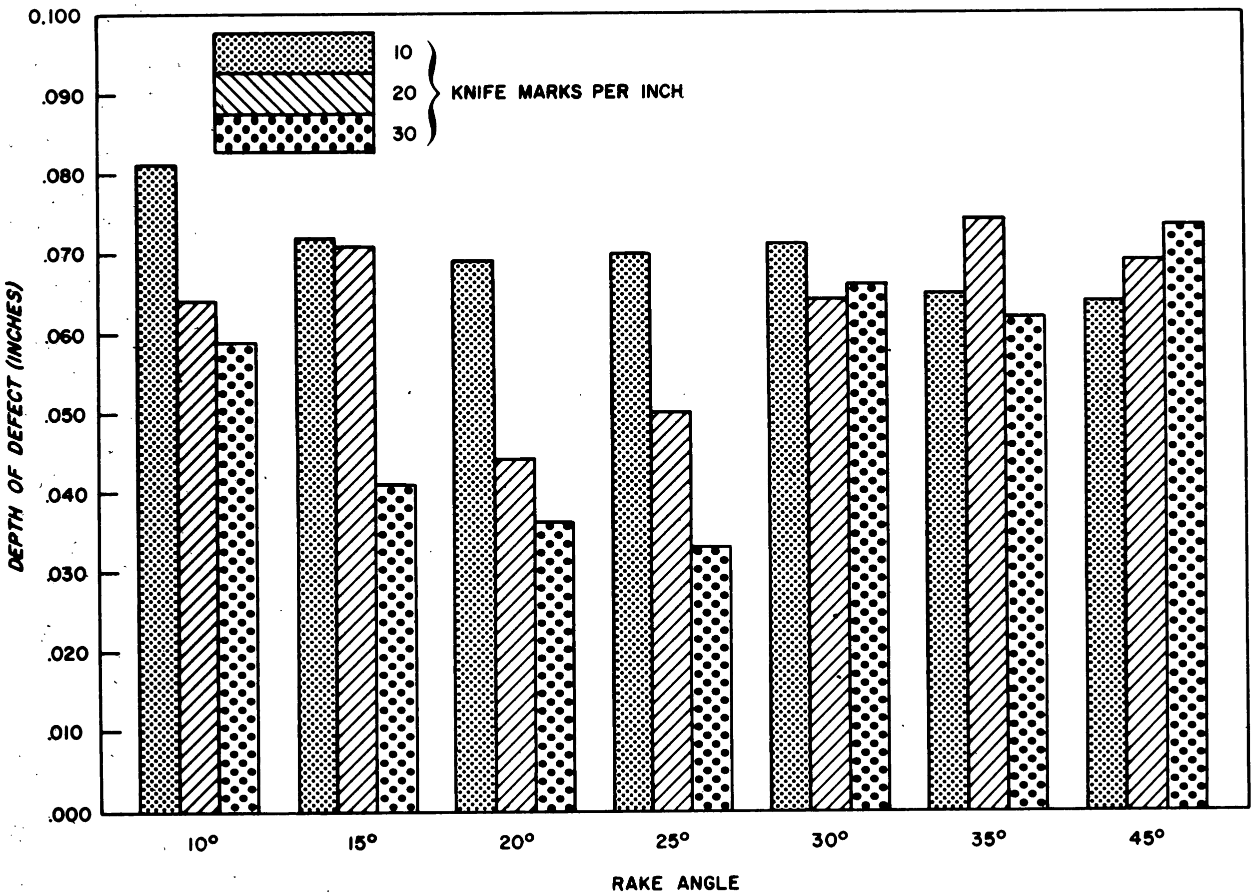

Figure 1. — *Maximum depth of defect measured after knife planing at 10, 20, and 30 knife marks per inch with each rake angle. Maximum depth of chipped grain at approximately 10-degree slope of grain.*

because they required more power and frequent sharpening. Also, the effect of smaller rake angles upon the severity or depth of defect was essentially unknown.

Previous work has also shown that surface quality (when planing relatively straight-grained material) increases (frequency of defect decreases) as feed rate decreases to give 20 knife marks per inch.[1] This study showed that for widely varied slope of grain, surface quality (depth of defect) substantially improves as feed rate decreases to 30 knife marks per inch (fig. 2). Further, the surface quality, based on depth of chipped grain, would probably continue to improve if feed rates were decreased further. However, production rate may become impractically slow at feed rates resulting in more than 30 knife marks per inch. Burnishing, glazing, and surface damage may result from reducing feed rates below the 30 knife marks per inch. Also, planer knives tend to wear faster on the clearance side of the cutting edge at slow feed rates. Hence, machine operators or production managers must select their own optimum feed rate.

The severest defects occurred at pockets of short grain[6] where pieces of wood were chipped from the workpiece (fig. 3). The depth of the defect associated with these areas appeared to be independent of the rake angles and feed rates studied. These chip-outs

[6] *Monnett, C. G., Jr. Knife grinding and woodworking manual. Dependable Machine Co., Greensboro, N. C. 167 p.*

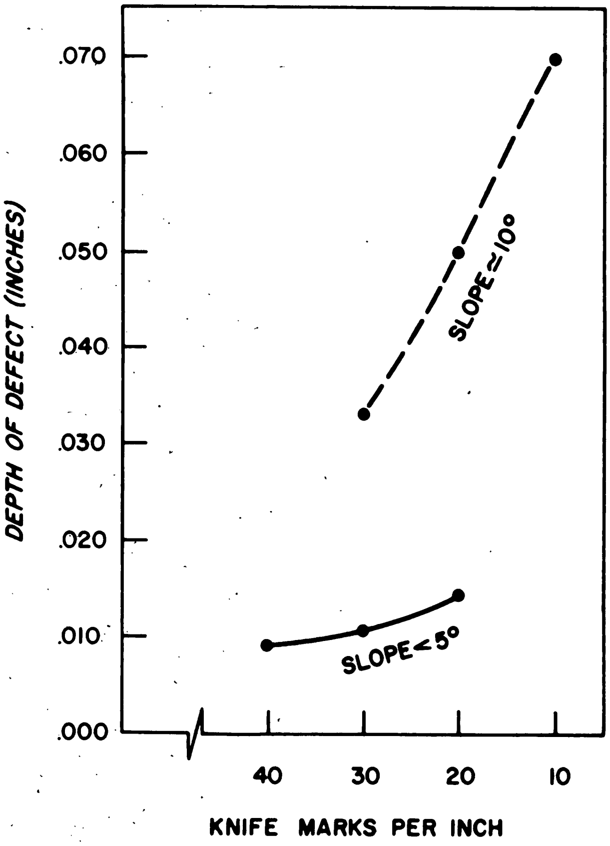

Figure 2. — *A comparison of maximum depth of defect at varying numbers of knife marks per inch for slopes of grain less than 5 degrees and approximately 10 degrees.*

occur most frequently on the heart side of a board and often near an overgrown knot; they are also associated with wavy grain. Thus, to reduce defect occurrence, such areas are often removed during

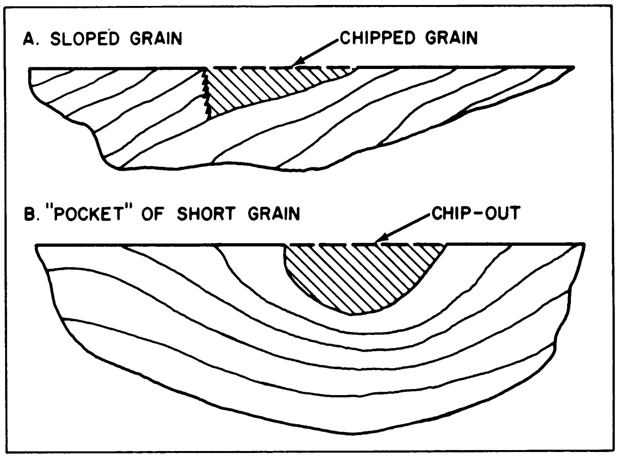

Figure 3. — *(A) Sloped grain associated with conventional chipped grain, and (B) a "pocket" of grain associated with chip-out.*

crosscutting and ripping operations. When only one side of a board will show, the sap side should be used.

Although moderate rake angles of 20 and 25 degrees and slower feed rates reduce the depth of chipped grain, it follows that proper machine maintenance, adjustment, and knife sharpening must also be carried out to minimize waste from knife planing parallel to the grain.

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