EFFECT OF MOISTURE CONTENT AND SPEED OF CUT ON QUALITY OF ROTARY-CUT VENEER
Abstract

Within the limits of the study, high moisture content in the wood and high cutting speed resulted in higher loads on the roller bar than when cutting wood having moderate moisture content at slow cutting speed. In general, veneer cut with high loads on the roller bar was thinner and weaker in tension perpendicular to the grain than veneer cut with moderate loads on the roller bar.
EFFECT OF MOISTURE CONTENT AND SPEED OF CUT ON QUALITY OF ROTARY-CUT VENEER

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Introduction

High moisture content in green wood is sometimes thought to affect veneer cutting. For example, sapwood of Douglas-fir and sinker heartwood of redwood may shatter or shell\(^2\) during rotary cutting. In a recent study (6)\(^3\) with southern pine, we sometimes encountered shattering of sapwood veneer, particularly when the wood was subject to high pressure by the roller bar. Pine sapwood made permeable by bacteria (5) was less inclined to shatter during cutting.

Speed of cut may also affect veneer cutting. Some researchers say fast cutting is beneficial; others say slow cutting helps. The majority say cutting speed has no significant effect on veneer quality.

It seemed that these two factors, moisture content in the wood and speed of cut, might be interrelated. If so, this may explain the different opinions about the relationship of veneer quality to speed of cut. High moisture content in the wood, combined with high cutting speeds, should cause higher forces on the pressure bar than would occur when cutting wood into veneer at low moisture content and at a low speed.

Water is relatively noncompressible. When wood saturated with water is cut at high velocity, the water does not have time to escape, resulting in higher resistance of the wood to penetration of a knife or pressure bar. This, in turn, may cause differences in the quality of the veneer produced. A better understanding of this relationship should help veneer manufacturers to improve the quality of veneer they produce.

1Maintained at Madison, Wis., in cooperation with the University of Wisconsin.
2Shelling is a separation of the wood at a springwood-summerwood boundary. Shattering is breaking of the wood, on the tight side of the veneer, into many small-to-large, loosely connected fiber bundles.
3Underlined numbers in parentheses refer to Literature Cited at end of report.
Consequently, this study was to determine if different moisture contents in matched southern pine disks would affect the properties of veneer cut at low speed in comparison to that cut at moderately high speed. In a second part of the study, we examined how a wider range of cutting speeds affect the quality of veneer cut from southern pine and yellow-poplar disks, all with high moisture content.

Measurements were made of the loads on the roller bar during cutting and of the quality of the veneer produced. Measurements of the knife edge were made before and after cutting.

**Review of Literature**

Prokes (8) described the effect of cutting speed and sharpness of the knife on the surface quality of alder veneer sliced about 1/4 inch thick. The wood had been heated prior to slicing. Roughness was primarily due to a fuzzy surface on the alder veneer and Prokes’ graphs show that roughness decreased as the cutting speed increased. This effect was accentuated when cutting with a dull knife. Increasing the cutting speed from 80 to 160 feet a minute markedly improved the quality of the surface cut with a dull knife. The effect of speed was less at higher velocities. Prokes stated that at cutting speeds above 295 feet per minute, one cannot expect any further improvement of the surface.

Hoadley (2) cut 1- by 1-inch veneer slips 0.060 inch thick from basswood slightly above fiber saturation and from matched samples that had been pressure-treated with water. He found that saturated wood required more force to cut, and the veneer produced was thinner and weaker in tension perpendicular to the grain than veneer cut from blocks slightly above fiber saturation.

Fiehl and associates reported (1) that their short study showed little difference in quality between veneer produced at high speeds and that produced at low speeds.

Knospe (3) states that velocity of cut within the range ordinarily used in veneer cutting does not affect veneer quality.

**General Experimental Procedure**

The main part of the study was made with short disks taken from two bolts of loblolly pine, each 4 feet long and approximately 14 inches in diameter. The bolts were stored under water about 1 year at the Laboratory. Examination of the wood indicated that there was some bacterial attack of the wood rays in the sapwood of the pine bolts. A bolt of yellow-poplar was used together with some of the southern pine in a second part of the study. All of the yellow-poplar veneer was heartwood and all of the loblolly pine veneer was sapwood.

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4 As a means of determining knife sharpness, Prokes measured the width of the light band reflected from the rounding of the knife edge. If the band did not exceed 9 microns, he considered the knife sharp; his dull knife had an edge band of 26.7 microns.
Each of the three 4-foot-longbolts, two of pine and one of yellow-poplar, were rounded to a diameter of about 12 inches on a lathe. The rounded bolts were crosscut into disks, each 6 inches in length, making a total of seven disks per bolt. Four randomly selected clear disks from each southern pine bolt were given a full-cell pressure treatment with water. The other three disks from a bolt were subjected to vacuum to remove some water.

All disks were then dipped for 10 seconds in a 1 percent solution of sodium pentachlorophenate and stored at 35°C and 80 percent relative humidity. The disks that had been pressure-treated with water were kept in closed polyethylene bags. The end sections of the other pine disks were exposed to permit drying. These latter disks were weighed periodically and drying was stopped when the calculated average moisture content was about 60 percent. Four months were required to dry the disks to about 60 percent moisture content.

Thus, there were matched sets of pine disks from each bolt, some having a moisture content of about 110 percent, and the others having about 60 percent moisture content when cut. The yellow-poplar disks did not have moisture added or removed as the pine, but were cut with the moisture naturally present in the bolt. The yellow-poplar varied from 93 to 117 percent moisture content when cut into veneer.

All cutting was done with the same lathe setup:

- **Knife feed**: 0.094 inch
- **Knife bevel**: 21°
- **Knife angle**: 90°
- **Roller bar**: 5/8 inch in diameter
- **Lead of the roller bar (height)**: 0.074 inch
- **Gap of the roller bar (opening)**: 0.074 inch

The gap of the roller bar was purposely set small to accentuate the effects of wood moisture content and speed of cut on the quality of veneer produced.

The apparatus used for this study was a metal-cutting lathe arranged with a fixture bolted to the cross slide (fig. 1). This fixture was designed to carry the knife and the roller pressure bar in the same orientation as on the typical commercial veneer-cutting lathe. Both vertical and angular knife adjustments were provided as well as lead and gap adjustment of the pressure bar.

The instrumentation was designed to record knife-edge deflection with respect to the fixture during the cutting operation, and also the fixture deflection at the roller bar height, with respect to the lathe cross slide. Timing marks were recorded once per revolution to facilitate comparison of data on the basis of individual revolutions of veneer.
Figure 1.--Experimental apparatus used to measure forces on the roller bar during cutting.
The knife-deflection sensor was a direct-current differential transformer with output fed through an amplifying and calibrating network into a direct-recording oscillograph. The calibration was adjusted to a recorded sensitivity of 1000:1 (0.1 inch on recorded chart equals 0.0001 inch deflection of knife edge).

The fixture-deflection sensor was a direct-current proximity transducer with output also suitably amplified, calibrated, and fed into the oscillograph. The calibration was adjusted to a recorded sensitivity of 400:1 (0.1 inch on recorded chart equals 0.00025 inch of fixture deflection).

One of the desired relationships to be provided by this study was the effect of wood moisture content and speed of cut on the force on the roller bar. Therefore, it was necessary to provide a means of converting the deflections obtained to equivalent force. For this purpose, deflection-force curves were plotted for both the knife and fixture by the incremental loading of each, using a standard proving ring.

A radial line was marked on each disk prior to cutting into veneer. At least 21 revolutions of veneer were cut from each disk. As the veneer came from the lathe, it was reeled in a continuous ribbon. The ribbon of veneer was then unreeled and cut into sheets, each sheet representing one revolution of the disk. These sheets were numbered consecutively and evaluated as representative of the particular wood moisture content and speed of cut being used. Four properties were determined: load on the roller bar during cutting, green and dry veneer thicknesses, depth of roughness depressions on the tight side of the green veneer, and strength of the green veneer in tension perpendicular to the grain.

Five thickness measurements were made for each revolution of veneer, three across one end of the sheet and one on each side approximately 1 foot from the ends of the sheet.

The tight side of the veneer from each revolution was examined under low-incidence light. Two or more of the larger roughness depressions visible under these conditions were marked with a pencil. These depressions were then measured by shadow sectioning (4), and the deepest depression was recorded as the surface roughness of the sheet.

Three specimens for evaluation of tension perpendicular to the grain were taken from odd-numbered veneer revolutions 5, 7, 9, etc. Each specimen was 5 inches across the grain and 1 inch along the grain. All samples were loaded in an Instron machine with a head travel of 0.1 inch per minute. The distance between the jaws which held the tension sample was 2 inches. The maximum load for each sample was recorded in pounds.

Even-numbered veneer sheets 4 to 20 were used to determine the moisture content of the veneer after cutting. These sheets were remeasured for thickness after being dried to a moisture content of about 10 percent. The samples were then rewet and boiled to determine if veneer thickness would return to the original green thickness or if some compression could be recovered.
An estimate of knife sharpness was obtained by taking three molds with silicone rubber before and after cutting. Cross sections of the molds were examined with a microscope and the width of the edge, similar to the edge band as measured by Prokes,\(^4\) was recorded in microns.

**Interaction of Moisture Content and Speed of Cut**

Four disks from each of two loblolly pine bolts were used in this first part of the study. Of these, two from each bolt had been pressure-treated with water to a moisture content of about 110 percent and two had been air dried to a moisture content of about 60 percent. One disk at about 110 percent moisture content and one disk at about 60 percent moisture content from each log were cut at 7 revolutions per minute (about 20 feet per minute). The matched set of disks was cut at 100 revolutions per minute (about 300 feet per minute). The results are summarized in table 1.

The loads on the roller bar shown in table 1 support the theory that wood moisture and veneer cutting speed are related. As predicted, the highest loads came when cutting wood at about 110 percent moisture content and 300 feet per minute. These loads were about one-third greater than when cutting pine wood at 60 percent moisture content and 20 feet per minute. Intermediate loads were developed when cutting wood at a high moisture content and low speed or cutting wood at a low moisture content and high speed. The different loads on the roller bar were reflected in veneer quality, particularly veneer thickness and strength in tension perpendicular to the grain.

The green veneer thickness was the same as the feed, 0.094 inch, for the disks that had been dried to 60 percent moisture content. These disks developed the least load on the roller bar during cutting. The veneer from the disks having about 110 percent moisture content and cut at 20 feet per minute was just under the nominal knife feed, averaging 0.093 inch. The big effect on veneer thickness came at the high cutting speed, 300 feet per minute, with disks having about 110 percent moisture content. Veneer from these disks averaged 0.085 inch in thickness or 0.009 inch less than the feed of the knife. These disks had the highest load on the roller bar.

The strength of the veneer in tension perpendicular to the grain was inversely proportional to the loads on the roller bar. The veneer cut at 20 feet per minute from the disks at 60 percent moisture content was approximately twice as strong in tension perpendicular to the grain as veneer cut at 300 feet per minute from disks at 110 percent moisture content.

Surface roughness was similar for veneer cut at both moisture contents and cutting speeds. The shattering of the veneer that we rather expected did not develop except in a few scattered spots. The fact that the pine had been made somewhat permeable by bacteria attack during 1 year of storage may have contributed to the good performance.
Table 1.--Veneer quality of southern pine disks cut at two speeds and two moisture contents\(^1\)

<table>
<thead>
<tr>
<th>Disk condition</th>
<th>Load on roller bar</th>
<th>Moisture content</th>
<th>Thickness</th>
<th>Roughness</th>
<th>Tensile strength perpendicular to grain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure-treated</td>
<td>333 (301-366)</td>
<td>114 (108-117)</td>
<td>.093 (.092-.094)</td>
<td>.018 (.017-.018)</td>
<td>9.5 (9.0-9.9)</td>
</tr>
<tr>
<td>Partially dry</td>
<td>255 (253-257)</td>
<td>63 (57-70)</td>
<td>.094 (.094)</td>
<td>.018 (.018-.019)</td>
<td>14.1 (13.2-15.0)</td>
</tr>
</tbody>
</table>

CUT AT 20 FEET PER MINUTE

| Pressure-treated | 382 (364-399) | 108 (106-109) | .085 (.081-.089) | .019 (.017-.021) | 7.1 (6.2-8.1) |
| Partially dry | 326 (273-379) | 63 (56-70) | .094 (.094-.095) | .019 (.019-.019) | 11.1 (11.0-11.2) |

\(^1\)Average values are given first, with the range shown below in parentheses.

Table 2. --Veneer quality of southern pine and yellow-poplar cut at different speeds

<table>
<thead>
<tr>
<th>Cutting velocity</th>
<th>Load on roller bar</th>
<th>Moisture content</th>
<th>Thickness</th>
<th>Roughness</th>
<th>Tensile strength perpendicular to grain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ft. per min.</td>
<td>Lb. per in. of bar</td>
<td>Pct.</td>
<td>In.</td>
<td>In.</td>
<td>Lb.</td>
</tr>
</tbody>
</table>

**SOUTHERN PINE**

| 0.2 | 184 | 103 | .096 | .016 | 13.1 |
| 20.0 | 301 | 108 | .092 | .018 | 9.9 |
| 75.0 | 356 | 110 | .090 | .021 | 7.2 |
| 300.0 | 364 | 106 | .089 | .021 | 6.2 |

**YELLOW-POPLAR**

| 0.2 | 190 | 94 | .094 | .013 | 36.5 |
| 20.0 | 240 | 117 | .094 | .011 | 36.7 |
| 300.0 | 261 | 93 | .094 | .012 | 30.1 |
Thus, the most significant finding in this part of the study was that pinewood with high moisture content (about 110 percent) and cut at high velocity resulted in the largest load on the roller bar, the thinnest veneer, and the weakest veneer in tension perpendicular to the grain.

With this information, it appears that lathe operators who use lower pressure on the roller bar and slower cutting speed when cutting wood having a very high moisture content, such as the sapwood of the species like Douglas-fir, are using good technique.

**Effect of Varying Cutting Velocity With Wet Wood**

This second portion of the study was designed to investigate the effect of cutting velocity in more detail but working only with wood having a high moisture content. Four disks, each 6 inches long, from one southern pine log were used to determine the effect of cutting velocities of approximately 0.2, 20, 75, or 300 feet per minute. All of these disks had been pressure-treated with water prior to cutting so that they had a moisture content of 103 to 110 percent when cut. A similar series of three disks was taken from one log of yellow-poplar. These disks were cut at a velocity of 0.2, 20, or 300 feet per minute. The moisture content of the yellow-poplar was that found in the standing tree. It varied from 93 to 117 percent.

A cutting speed of 0.2 foot per minute represents a condition sometimes used experimentally to study the cutting process in great detail. Conversely, a cutting speed of 300 feet per minute is within the range of common commercial practice. Two other cutting velocities, 20 and 75 feet per minute, were used to determine if there was a trend directly related to cutting velocity.

The load on the roller bar increased with each increase in cutting velocity (table 2). The loads on the pine disk cut at a velocity of 300 feet per minute were approximately double the load when cutting at 0.2 foot per minute. Similarly there was a gradual decrease in the thickness of the pine veneer with increasing cutting velocity. The roughness of the pine veneer increased slightly with increasing cutting velocity. The higher roughness values for veneer cut at 75 and 300 feet per minute were due to slight shelling that occurred at these velocities. Strength of the green veneer in tension perpendicular to the grain gradually decreased as the speed of cut increased.

The second part of table 2 shows how veneer quality varied with cutting velocity when cutting yellow-poplar heartwood at three speeds—0.220, and 300 feet per minute. The load on the roller bar increased with each increase in cutting velocity but was not as great proportionately as occurred when cutting southern pine having high moisture content. The average green veneer thickness of the yellow-poplar did not change within the range of cutting velocities used in this study. In all cases, it was the same as the nominal feed of the knife. Similarly, there was relatively little difference in roughness of the yellow-poplar veneer. what difference there was showed that very slow cutting resulted in slightly rougher surfaces. The average strength in tension perpendicular to the grain for the green veneer of yellow-poplar decreased slightly at the highest cutting velocity.
Figure 2.--Matched southern pine sapwood veneer, that cut at 0.2 feet per minute on the left and that cut at 20 feet per minute on the right. Compression tearing of the springwood was much more common in the springwood cut at the very slow speed of 0.2 feet per minute.

(M 132 798)
Discussion

A possible explanation of the different degrees of response of the southern pine and yellow-poplar is the amount of remaining air space in the wood when it was cut. Table 3 shows that pine with a 110 percent moisture content has only 27 percent remaining air space while yellow-poplar with 100 percent moisture content has 43 percent remaining air space. With the same percent of compression by the roller bar, it would be expected that hydraulic water pressure in the wood will be greater when cutting pine at 110 percent moisture than when cutting yellow-poplar at 100 percent.

| Table 3.--Calculated air space in the disks of wood used in this experiment |
|---------------------------------|-----------------|-----------------|-----------------|
| Species                        | Specific gravity | Moisture content | Void volume    | Remaining air space |
| Baltic pine                    | 0.45            | 110             | 65             | 27              |
| Yellow-poplar                  | 0.37            | 100             | 72             | 43              |

1Based on green volume and ovendry weight.

Figures 2 and 3 show a rather striking effect of cutting velocity on the appearance of the veneer. In figure 2, springwood cut at a very slow speed was roughened by a phenomenon described by Leney (7) as compression tearing. Compression tearing occurred almost exclusively in the low-density springwood portions of the veneer. The summerwood appears to be smoothly cut at both slow and fast cutting speeds.

The southern pine veneer sample cut at 20 feet per minute (fig. 2) actually has slightly greater roughness depressions, but the roughness is of a different character than that which occurred at the slowest speed. Here, the roughness appears to be caused by splitting ahead of the knife and into the bolt in the springwood areas. The pine samples cut at 75 and 300 feet per minute were similar to the one at the 20-foot rate, except slight shelling occurred in some of the samples cut at the higher speeds.

Figure 3 shows a similar phenomenon with yellow-poplar veneer. The sample cut at 0.2 foot per minute has surface roughness caused by compression tearing. The sample cut at 300 feet per minute shows practically no compression tearing. Yellow-poplar veneer cut at 20 feet per minute was similar in appearance to the veneer cut at 300 feet per minute.
Figure 3.--Matched yellow-poplar heartwood veneer cut at 0.2 feet per minute on the left and 300 feet per minute on the right. The slower cutting resulted in more compression tearing of the springwood.

(M 132 811)
Castings of the knife edge indicated it had an edge of about 5 microns prior to cutting. After cutting, the width of the edge of the knife did not exceed 7 microns. Accordingly, our results agree with those of Prokes (8). As stated in the review of literature, he found an increase in roughness of low-density wood when cutting at slow speeds. This roughness was minimized at cutting speeds greater than about 160 feet per minute. Extrapolating from Prokes’ results, we could expect that the phenomena illustrated in figures 2 and 3 for the very slow cutting would have been more pronounced had we used a duller knife.

One question that has not been satisfactorily determined is what happened to the veneer thickness that was lost when cutting saturated southern pine disks at high velocity? In an attempt to gain more information about this phenomenon, all of the veneer samples in the first part of the study were dried and measured for thickness. The veneer was then soaked for a week in water, boiled, and remeasured for thickness. Samples from all four groups lost 0.003 inch in thickness during drying to a moisture content of about 10 percent. When the samples were rewet and boiled, they recovered to the same thickness that they had just after cutting.

It was thought that if the veneer had been over-compressed, boiling might restore the buckled fibers to their original shape and some veneer thickness would be recovered. As this did not happen, either the veneer was compressed beyond the elastic limit so that it could not recover with boiling, or possibly the veneer was deflected into the care of the bolt. One other possibility would be lost motion in the lathe due to high loads that occurred in some cutting conditions. More detailed studies of this phenomenon are needed to establish what does happen to cause loss in veneer thickness when very high loads are imposed by the pressure bar during cutting.

Further study should be made to determine how to overcome the problems caused by high moisture content in the wood and high cutting velocity. Changing the pressure-bar setting and heating the wood are two possibilities.

This and other studies (5, 6) indicate that the quality of veneer cutting is probably related to pressure against the bar during cutting. When the pressure bar is set to stops, as is common on commercial lathes, the pressure against the bar generally varies widely when cutting a single bolt. It may be possible to obtain consistently uniform cutting by setting the bar with pressure rather than to stops.

**Summary**

This study indicates that the quality of southern pine veneer rotary-cut at room temperature with high compression by a roller bar is directly related to the cutting velocity and moisture content of the wood. In general, high moisture content and high cutting speed resulted in high loads on the roller bar, thin veneer, and veneer weak in tension perpendicular to the grain. Yellow-poplar was not as sensitive to changes in cutting velocity as southern pine. Compression tearing of soft springwood was more pronounced at very slow cutting speeds than at moderate to high cutting speeds.
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