United States
Department of
Agriculture

Forest Service

Northeastern Forest Experiment Station

Research Paper
NE-588

1986

Comparison of Glue-Line Quality Between Gang Edging and Straight-Line Ripping

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Manuscript received for publication 21 January 1986.

Abstract

Gang edging with a dip-chain fed gang ripsaw produces gluing surfaces equal to those from a straight-line ripsaw in yellow-poplar (*Liriodendron tulipifera*) and red oak (*Quercus rubra*). Special care in gluing red oak was needed to get shear strengths equal to solid wood values. However, the strength comparisons between sawing methods showed no differences between gang edging and straight-line ripping regardless of gluing procedures.

Introduction

Gang ripping can be used with No. 2 Common lumber to produce more long lengths than the furniture and cabinet industries need (Gatchell et al. 1983, Gatchell 1986, Araman et al. 1982). Gang edging (gang ripsaw arbor set with several pairs of blades at varied spacing) is a key step in the utilization of small-diameter logs for furniture and cabinets through the new System 6 process (Reynolds and Gatchell 1982). Gang edging or gang ripping to glue-line quality edges is required in System 6 and is desirable in the design of new manufacturing sequences for the conversion of lower grades of lumber.

Some potential users of the new System 6 technology have questioned whether the surfaces from gang edging were of comparable quality to the state-of-the-art edges made on the straight-line ripsaw. The general feeling was that gang edging to glue-line quality surfaces might not be possible for the more dense hardwoods. The basic question was whether the wood could be held securely enough during sawing to produce the quality needed. This study was conducted to determine whether a dip-chain fed gang saw could produce glue lines of strengths comparable to those from a straight-line ripsaw.

Materials and Methods

A dip-chain fed gang edger and a straight-line ripsaw were used. The gang edger was a conventional dip-chain fed gang ripsaw set up with five pairs of saws to cut widths from 1½ to 3½ inches in ½-inch increments (Fig. 1). In each pair the right-hand saw was used to make a hogging cut. Each hogging saw blade was made from 0.254-inch-thick steel plate and had a 5/16-inch saw kerf. The left-hand gang edger blades and the straight-line ripsaw blades were made from 0.134-inch-thick plate with a 3/16-inch saw kerf.

Saws in each machine ran at about 3,500 r/min (revolutions per minute). The gang edger had 12-inch diameter saw blades with 30 carbide-tipped teeth per blade and a feed speed of 58 ft/min (feet per minute). The saw tooth hook angle was 20 degrees. The straight-line ripsaw blade was 14

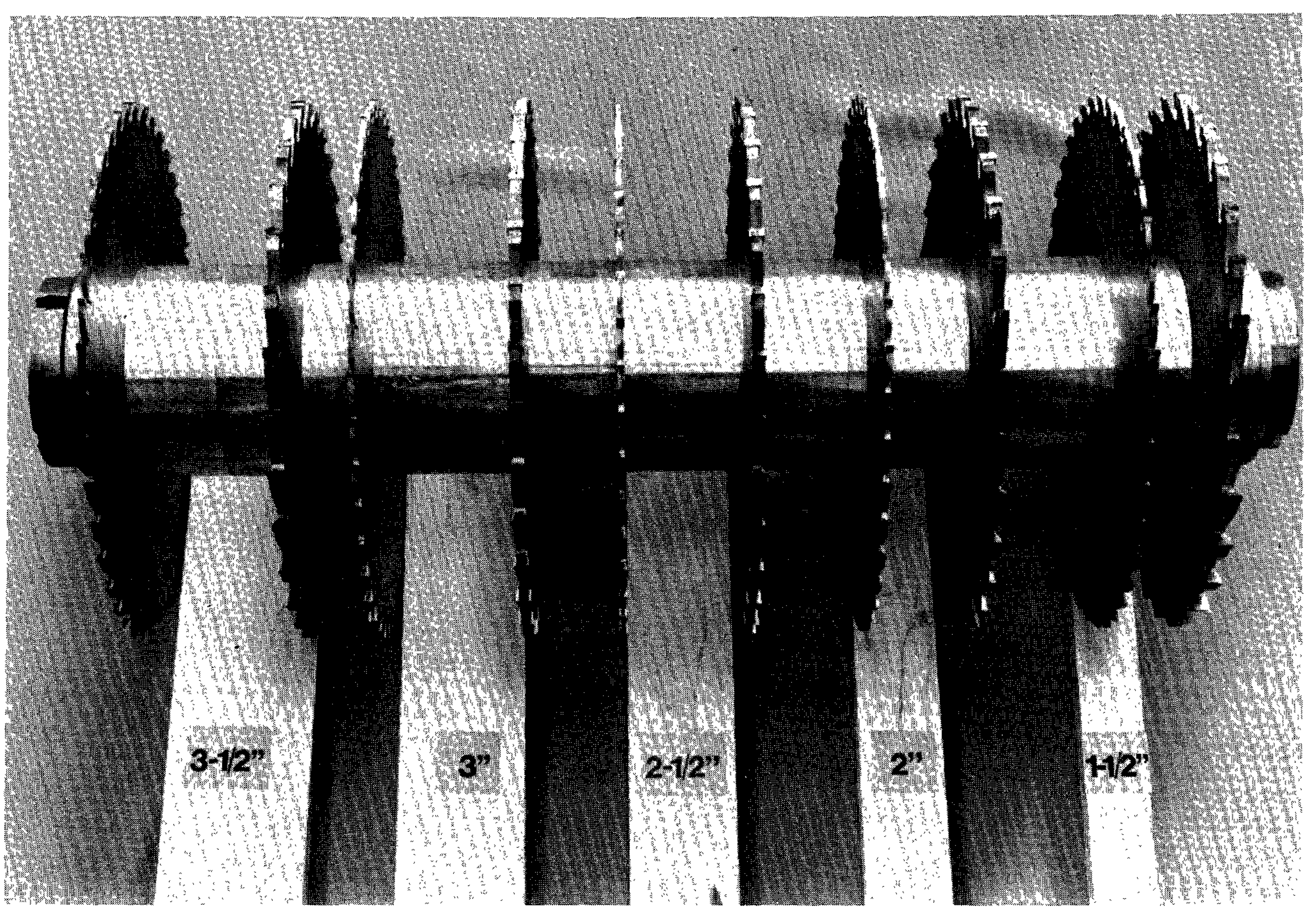

Figure 1.—The arbor of the dip-chain fed gang edger contains five pairs of blades.

inches in diameter with 36 carbide-tipped teeth, and the feed speed was 65 ft/min. The hook angle was 10 degrees. The combination of feed speed, saw diameter, number of saw teeth, and saw r/min resulted in a bite per tooth for all blades of 0.007 inch.

The analysis of glue-line strength was based on two separate studies. The first approximated our routine panel lay-up procedures. We made panels of three lengths containing pieces of three different widths sawed from lumber taken at random from an existing supply. A diffuse porous hardwood, yellow-poplar—*Liriodendron tulipifera*, and a ring porous hardwood, northern red oak—*Quercus rubra*, were used. When the results showed about a 20 percent reduction in shear strength between solid wood and glued-up panels in oak, a second study was run. The second study was very closely controlled and attempts were made to ensure that each panel was constructed as identically as possible with all others. All panels in both studies were glued using the same room-temperature setting polyvinyl acetate adhesive.

Study One—Routine Panel Lay-up Procedures

To compare glue lines from the gang edger and straight-line ripsaws with routine panel lay-up procedures, edges were prepared with each machine and included in each panel as shown in Figure 2. We ran enough pieces of 4/4 yellow-poplar and red oak rough dimension, at about 7 percent moisture content, through the gang edger to lay up 24-inch-wide panels in combinations of 1½-, 2½-, and 3½-inch-wide pieces. To produce the straight-line ripped edge, gang edged pieces were randomly selected and a rip cut was made about ¼ inch in from one edge. Panel lengths were 21, 33, and 60 inches. We made enough panels so that each piece width group was glued up first, second, or last in the lay-up sequence. Each of these arrangements was replicated twice. Thirty-six panels were made (2 species × 3 lengths × 3 lay-up sequences × 2 replications).

In laying up the panels, glue was applied with a flexible stick that produced a thick, bubble-free glue spread. Glue was applied to only one side of the glue line. Pieces were layed up with the first and last pieces directly in contact with the glue clamps. A pressure of 200 lb/in^2 (pounds per square inch) at the glue line was applied, and panels were left in the clamps for at least 1½ hours. The finished panels were cured for at least 2 weeks before samples were taken for testing.

The block shear test (ASTM 1984) was modified since testing was restricted by the thickness of the panels. The panels were first sanded to 0.75 inch. The block shear sample dimensions we used are shown in Figure 3. The shearing cross section was 0.75 × 1.5 inches or 1.125 square inches. Three, five, and seven shear block samples were taken from each of the 21-, 33-, and 60-inch test glue lines,

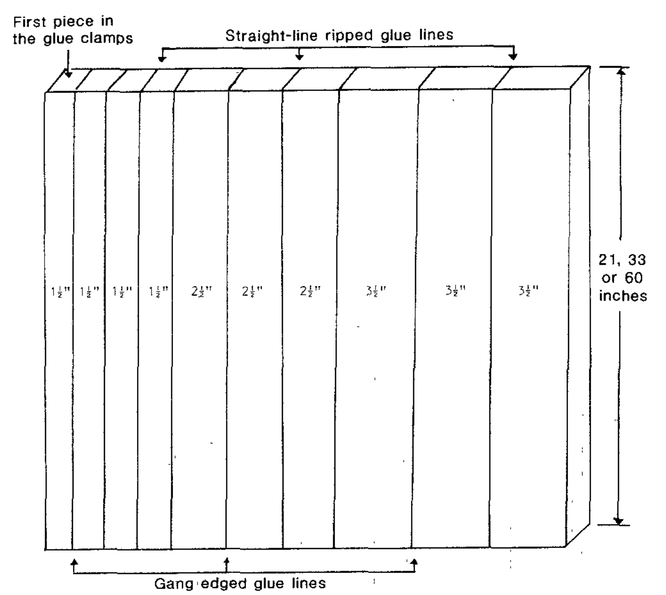

Figure 2.—Study One blank layout sequence 1. Sequence 2 had the 1½-inch strips on the right side (layed up last) of the panel. Sequence 3 had the 3½-inch-wide strips layed up first and the 2½-inch strips layed up last.

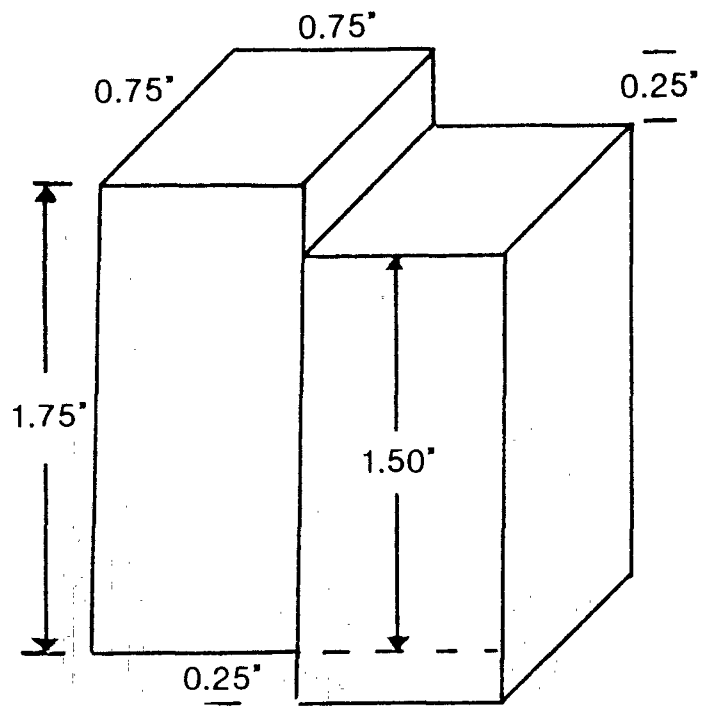

Figure 3.—Dimension of the block shear samples.

respectively. Samples were removed at positions equidistant from the panels' ends and from each other along the glue line. An equivalent number of solid wood samples were taken along two of the panel's 3½-inch strips.

The block shear samples were placed into a constant temperature (70°F)-humidity (66 percent) cabinet until a constant weight was obtained. A standard shearing tool was used to test the maximum load at failure for each sample at a head speed of 0.02 inch per minute. Maximum shear strength in pounds per square inch was determined for each block shear sample. Moisture content was determined immediately after shear testing.

Study One—Results and Discussion

A preliminary examination of the data for individual samples showed that there was no loss in shear strength across the width of the panels due to lay-up procedures. Thus, even though it takes almost 3 times as long with our techniques to spread the glue on a 60-inch-long piece as on a 21-inch-long piece, our procedures were adequate for good glue bond formation.

Average shear strength values for red oak and yellow-poplar are given in Table 1. Moisture content at the time of test was about 11 percent. A statistical analysis showed no significant difference between glue joints prepared with either the straight-line ripsaw or the gang edger. There was also no significant difference between the pairs of blades in the 1½-, 2½-, or 3½-inch bays of the gang edger.

As expected, the red oak shear strength values were higher than those for yellow-poplar. The values for the glued-up and solid wood yellow-poplar samples were about the same reflecting the more uniform nature (diffuse porous with thin rays) of this less dense wood. We did not, however, expect to find a 20 percent strength reduction when comparing red oak glued samples to solid wood samples. There may have been an interaction of small shear block size and the weakening effects of pronounced earlywood vessels or large rays that are typical of red oak. There was no increasing or decreasing trend in the strengths of individual samples as we proceeded from the first glue line to the last glue line in a panel. Thus, if there was some machining, gluing, or testing procedural error, it was consistent enough not to show up in the comparisons of the two sawing methods.

As the glue-line preparation procedures were considered equivalent for the two sawing methods (gang edging and straight-line ripping), all values for each method were averaged to obtain indicator values with standard deviations for length (Table 2). We include standard deviations in Table 2 to give the reader an appreciation for the variability of the

Table 1.—Average shear strength values for red oak and yellow-poplar wood and glue lines

Species	Panel length	Strip width	Gang edger[a]	Straight-line ripsaw[a]	Solid wood[b]
	Inches	*Inches*		*Average shear strength (lb/in²)*	
Red oak	21	1.5	1,788	1,901	2,301
		2.5	1,693	1,798	2,301
		3.5	1,812	1,891	2,301
	33	1.5	1,635	1,622	2,088
		2.5	1,640	1,720	2,088
		3.5	1,632	1,670	2,088
	60	1.5	1,632	1,559	2,087
		2.5	1,659	1,739	2,087
		3.5	1,645	1,581	2,087
Yellow-poplar	21	1.5	1,291	1,240	1,367
		2.5	1,295	1,267	1,367
		3.5	1,286	1,310	1,367
	33	1.5	1,302	1,300	1,320
		2.5	1,323	1,301	1,320
		3.5	1,321	1,333	1,320
	60	1.5	1,260	1,201	1,284
		2.5	1,286	1,332	1,284
		3.5	1,289	1,295	1,284

[a]Glue-line averages for the 21-, 33-, and 60-inch panel lengths were determined from 18, 30, or 42 block shear samples, respectively.
[b]Solid wood averages for the 21-, 33-, and 60-inch panel lengths were determined from 36, 60, or 84 block shear samples, respectively.

Table 2.—Study one—shear strength average values for red oak and yellow-poplar glued-up and wood samples (standard deviation in parentheses)

Species	Panel length	Gang edger[a]	Straight-line ripsaw[a]	Solid wood[b]
	Inches		*Average shear strength (lb/in^2)*	
Red oak	21	1,765(226)	1,863(171)	2,301(260)
	33	1,636(174)	1,669(171)	2,080(192)
	60	1,647(208)	1,626(238)	2,087(278)
Yellow-poplar	21	1,291(133)	1,279(139)	1,367(155)
	33	1,315(176)	1,312(146)	1,320(179)
	60	1,269(168)	1,272(158)	1,284(256)

[a]Glue-line averages for the 21-, 33-, and 60-inch panel lengths were determined from 54, 90, or 126 block shear samples, respectively.
[b]Solid wood averages for the 21-, 33-, and 60-inch panel lengths were determined from 36, 60, or 84 block shear samples, respectively.

data. Ninety-five percent of all individual sample values will be within plus or minus 2 times the standard deviation. Larger deviations, therefore, show a wider range of values. The results clearly show that the dip-chain fed gang edger produces glue lines in oak and yellow-poplar that are equivalent to those obtained from a straight-line ripsaw. In oak, the 33- and 60-inch average shear strength values were very similar. The averages for the 21-inch panels were higher, but this was attributed to the higher average shear strength for the wood from which they were made. The averages for the yellow-poplar glued-up samples were very similar, ranging from 1,269 to 1,315 lb/in^2.

Study Two—Close Production Control

Because the red oak glued samples in Study One were 20 percent lower in average shear strength than the solid wood samples, a partial retest was done under close production control. Boards from an available kiln-dried red oak lumber supply were selected for straightness of grain and 4-inch-wide strips were sawed out. These were crosscut to pieces 33 inches long and passed through the 3-inch-wide pair of saws. Each panel contained three pieces, two of which were re-edged on the straight-line ripsaw and glued together. The other glue line was made from gang-edged surfaces. Panel construction is given in Table 3. Ten panels were glued up as shown in Figure 4 using the following procedures for each:

Table 3.—Study two—shear strength of glued up and solid red oak samples, in pounds per square inch

Panel No.	Panel construction: 3 pieces same strip	3 pieces same board	Random pieces	Glue joint preparation: Gang edger Average[b]	Gang edger Standard deviation	Straight-line ripsaw Average[b]	Straight-line ripsaw Standard deviation	Solid wood Average[c]	Solid wood Standard deviation
5	*			2,233	376	2,374	242	2,253	400
2	*			2,412	142	2,265	124	2,253	378
3[a]		*		2,161	334	2,192	270	2,402	274
4[a]		*		2,418	224	2,154	98	2,402	274
1		*		2,302	263	2,254	280	2,287	373
6		*		2,329	211	1,817	271	2,283	444
7			*	2,205	245	2,369	253	2,367	302
8			*	2,100	198	2,019	498	2,248	471
9			*	1,993	312	1,890	199	2,056	599
10			*	2,012	113	1,864	483	2,223	481

[a]Panels 3 and 4 were made from six pieces from one board. Therefore, a single mean and standard deviation based on 34 samples were computed for the solid wood from both.
[b]Average of seven values.
[c]Average of 17 values.

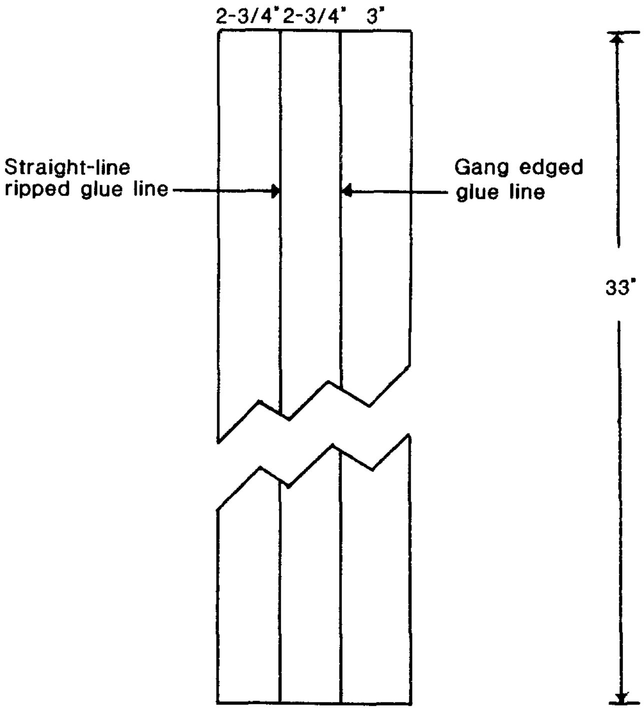

Figure 4.—Study Two blank layout.

1. Edges were prepared by sawing.
2. Within 10 minutes of sawing, glue was applied with flexible sticks to achieve a thick, continuous, bubble-free spread on one side of the glue line.
3. Square steel tubing was used between the glue clamps and the outside panel edges to ensure even pressure distribution.
4. A 1-minute closed assembly time was employed before application of 200 lb/in^2 clamp pressure.
5. Clamp time equaled 1 hour 30 minutes.

The next panel was begun only after the preceding panel was in the glue clamps. The panels were cured for at least 1 week before surfacing and for at least 2 weeks after surfacing before shear samples were prepared. The average moisture content at the time of testing was 8.5 percent.

Study Two—Results and Discussion

The shear strength value averages and standard deviations for the close production control red oak samples are given in Table 3. A statistical analysis showed no significant differences among the panels or between the dip-chain fed gang edger and the straight-line ripsaw at the 5 percent significance level.

In general, the greatest variability occurred in the solid wood samples. Rays formed a plane of weakness in one direction and earlywood vessels formed a plane of weakness at right angles to the rays. The thin (0.75 inch) samples gave these planes unusual importance when the plane of shear was lined up with either rays or earlywood. Figure 5 shows two solid wood samples taken a few inches apart along the grain from the same piece of wood. Sample 5-10C was the weakest sample of the entire study with a shear strength of 745 lb/in^2. About three-fourths of the failure surface was in or on both sides of a single ray. Sample 5-9C was taken from the same strip of wood just a few inches away. The orientation of the rays appeared to angle out of the shear plane enough so that other wood elements were brought into play. The result was a shear strength of 2,587 lb/in^2, one of the higher values of the study.

Figure 6 shows characteristic failure of solid wood (no glue line) samples when the rays and shear plane are not aligned. The failure shown has run out to the unsupported end of the sample. The saw tooth appearance of the broken surface is the result of failure going across a growth ring at or very near a ray, then turning at right angles along the earlywood of the next growth ring before again turning at right angles along another ray. In studies such as this, a predetermined orientation of the growth rings to the shear plane is not possible. It is a source of variation that is worth mentioning, however.

The solid wood and glued-up average shear strength values were about the same in Study Two. These averages were:

	Shear strength (lb/in^2)	
	Average	*Standard deviation*
Gang edger	2,217	280
Straight-line rip	2,120	343
Solid wood	2,268	441

As a comparison of the standard deviations shows, the glued-up samples varied less than did the solid wood samples. This was not entirely unexpected. As mentioned earlier, a ray or a zone of earlywood vessels contained in most or all of the plane of failure will cause low strength values. The chance of this occurring when two different pieces of wood are bonded together is considered to be far less likely than when solid wood pieces alone are considered. In a practical sense, we cannot really do better than equal the properties of the wood itself.

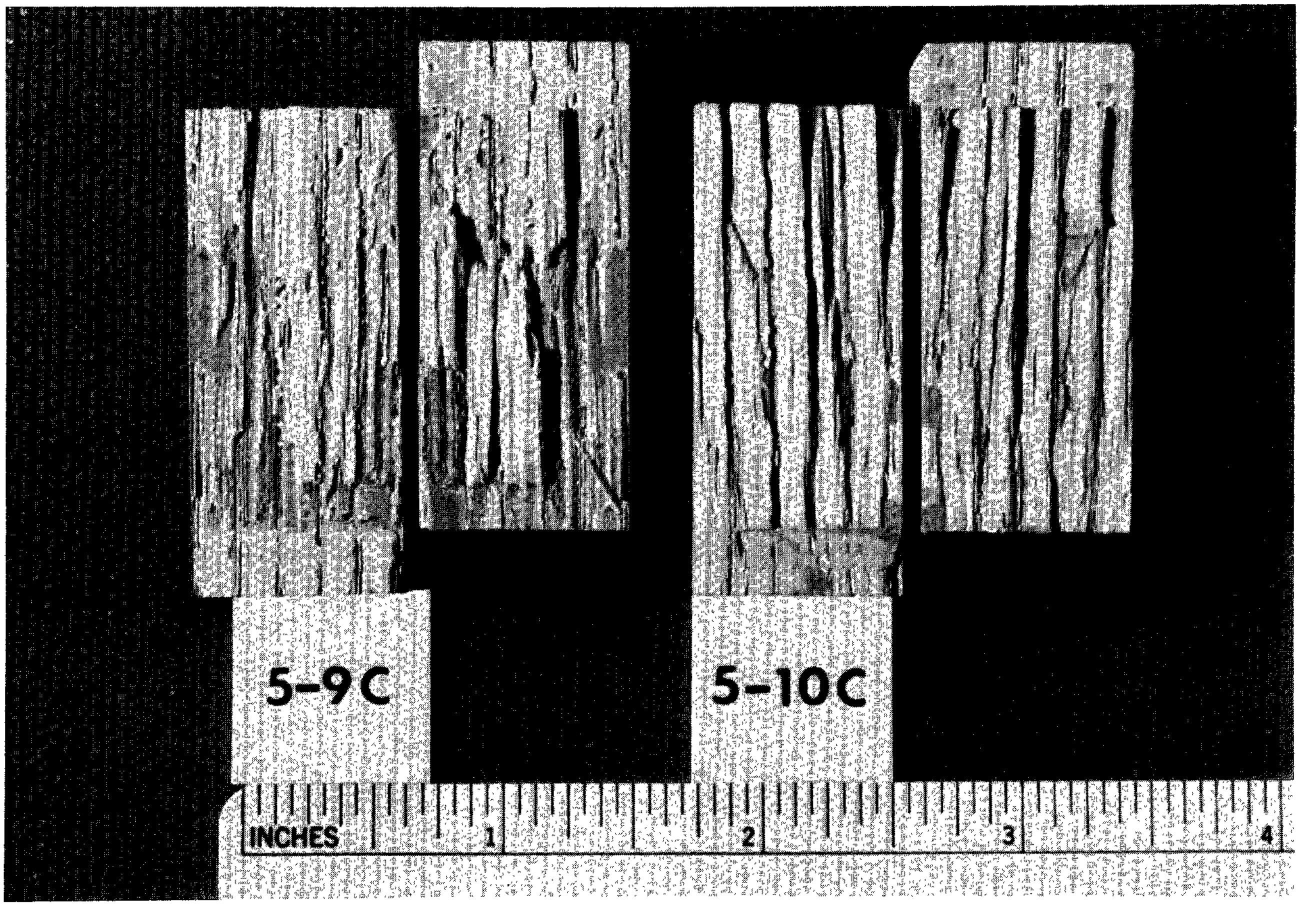

Figure 5.—One of the strongest (5-9C) and the weakest (5-10C) solid wood samples came from the same piece of wood and were only a few inches apart along the grain.

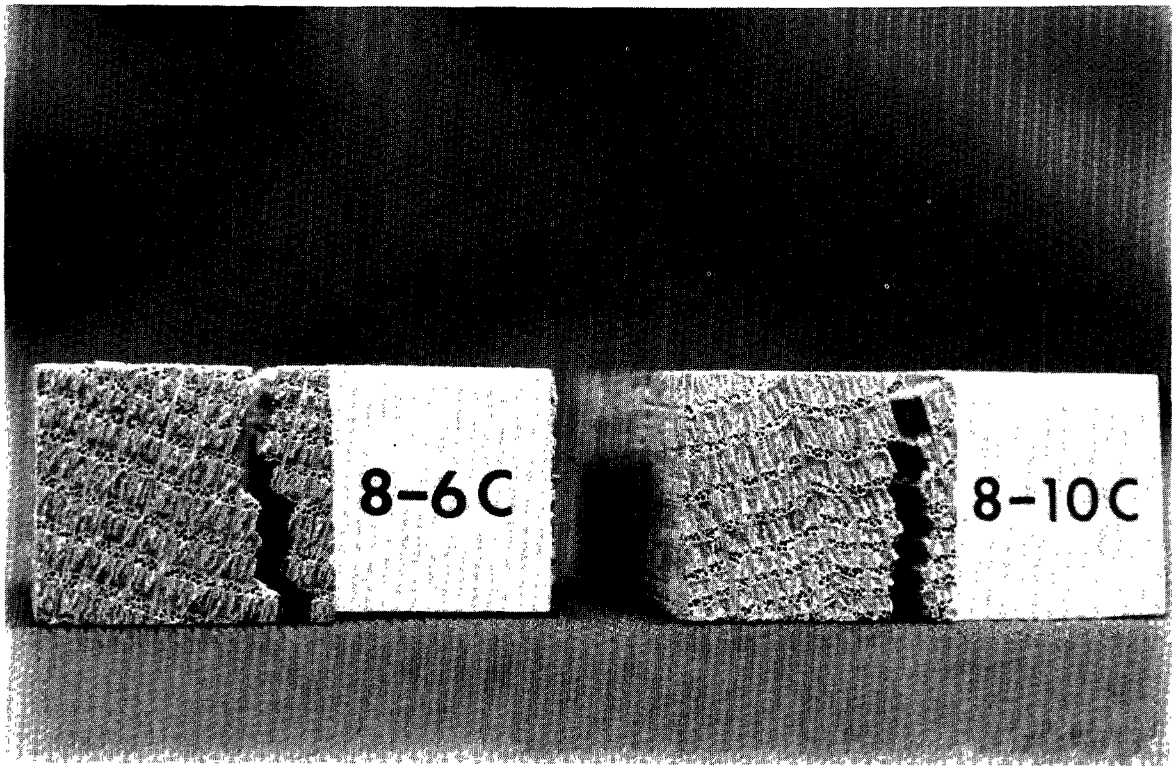

Figure 6.—Shear failure tends to run along rays and in the earlywood vessel zone giving a saw-toothed appearance to the failure on the unsupported end (label covers supported end of shear sample).

Summary

To be able to gang rip lumber to glue-line-quality edges is an important hardwood processing capability. The dip-chain fed gang edger or gang ripsaw is superior to roller fed gang saws in holding wood stock steady during sawing. However, potential users have questioned whether the dip-chain fed saw can produce glue-line surfaces equal in quality to those from a state-of-the-art straight-line ripsaw when machining hardwoods. The results of this study clearly show that these saws produce glue joints of equal strength in yellow-poplar and red oak in lengths from 21 to 60 inches.

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☆U.S. GOVERNMENT PRINTING OFFICE:1986-605-026/40013

Gatchell, Charles J.; Olson, James R. **Comparison of glue-line quality between gang edging and straight-line ripping.** Res. Pap. NE-588 Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1986. 7 p.

Gang edging with a dip-chain fed gang ripsaw produces gluing surfaces equal to those from a straight-line ripsaw in yellow-poplar (*Liriodendron tulipifera*) and red oak (*Quercus rubra*). Special care in gluing red oak was needed to get shear strengths equal to solid wood values. However, the strength comparisons between sawing methods showed no differences between gang edging and straight-line ripping regardless of gluing procedures.

ODC 836.1

Keywords: Furniture, panels, rough mills, lumber processing

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