Gluebond strength of laser cut wood

Technical Note

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Abstract

The degree of strength loss when gluing laser cut wood as compared to conventionally sawn wood and the amount of additional surface treatment needed to improve bond quality were assessed under normal furniture plant operating conditions. The strength of laser cut oak glued with polyvinyl acetate adhesive was reduced to 75 percent of sawn joints and gum was reduced 43 percent. It was concluded that for this adhesive a treatment between light sanding and jointing would be needed to glue laser cut wood, depending on species and laser characteristics.

In conventional furniture production, hardwood logs are first sawn into lumber with defects randomly located throughout the board. The lumber is dried and then remanufactured into appropriate sizes with the defects removed by ripping and crosscutting. This operation, executed in the furniture "rough mill" department, is considered labor intensive and wasteful. Saw kerf losses alone waste substantial volumes of lumber.

The Southern Forest Experiment Station is developing an Automated Lumber Processing System (ALPS) to more efficiently produce the same parts.[1] In the ALPS process, lightly surfaced boards containing defects are scanned by optical image analysis methods. A computer identifies and locates the defects. ALPS then uses the image-derived defect data to compute a board cutting pattern to yield the maximum number of parts for a given cutting bill.

Parts are cut from the board by a numerically controlled high-power laser directed by the computer. Laser cutting advantages include a small kerf and the ability to start and stop cutting at any location. Lastly, parts are scanned for quality and sorted by size with a computer-controlled manipulator. Residue is chipped and used as fuel.

While most parts are machined into solid furniture ~~components, some are edge-glued to form panels. Laser~~ cut wood surfaces are slightly charred and multi-mode high power lasers yield surfaces that are not as smooth or dimensionally accurate as conventionally sawn surfaces. These factors may diminish strength to unacceptable levels unless the laser cut surfaces are remachined before bonding.

The objectives of this preliminary evaluation were to assess (under factory conditions) the degree of gluebond strength loss using laser cut wood relative to conventionally sawed wood and to determine the level of additional surface treatment needed to meet industrial strength standards.

Experimental design and method

Two species were considered in the experiment—red oak and sweetgum.

For each species, specimens for edge-gluing were cut by 1) conventional sawing, 2) laser cut with no surface treatment, and 3) laser cut followed by light sanding of the cut surface.

Sufficient material was cut to provide 3 replications between glued pieces and 12 replications within each piece.

Five hundred board feet FAS southern red oak and 500 board feet FAS sweetgum were obtained and surfaced two sides to 1-inch thickness. The S2S material was then cut into 2-foot-long, random width, clear specimens and conditioned to a uniform 7 percent moisture content.

[1]McMillin, C. W., R. W. Conners, and H. A. Huber. 1984. ALPS—A potential new automated lumber processing system. Forest Prod. J. 34(1):13-20.

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Experimental material, randomly chosen, was cut into 1-inch-wide strips along the grain with a nominal 15 kW, electric discharge, convectively cooled, multimode, CO_2 laser system. The wave length of the output beam was 10.6 microns and the cavity optics produced an annular shaped beam with an out-to-inner diameter ratio of 2:1. As the beam was focused by cooled, concave, metal mirrors rather than transmission optics, providing a coaxial jet assist was impossible. Rather, the jet was positioned just outside the focal cone of the beam with the jet exit approximately 1/4 inch from the material surface. The jet impingement point was just below the top surface of the board on the leading edge of the advancing cut.

A number of preliminary cuts using a range of optics, jet-assist diameters, and gases was used to establish cutting conditions that gave relatively high feed speeds with reasonable dimensional accuracy. The conditions ultimately selected were laser output power— 8 kW; beam focal length— 24 inches; jet diameter— 0.023 inch; gas— nitrogen; gas supply pressure— 250 psi; cutting speed— 40 fpm for sweetgum and 36 fpm for red oak. A second group of red oak and sweetgum boards were ripped into 1-inch-wide strips using a straight-line ripsaw. Such sawn surfaces are normally glued without additional treatment.

Prior to bonding, half the laser cut samples were lightly sanded with a belt sander using two passes on 80 grit garnet paper. Sample pairs from the three classes were glued in an air actuated commercial panel clamp using a modified polyvinyl acetate adhesive under normally accepted factory conditions.

The pairs of glued strips were cut into shear specimens as described in ASTM D 905-49 except that the shear surface was approximately 1 square inch. The actual failure surface was measured after testing and used to calculate the shear strength.

Results

Figure 1 illustrates the sawn, laser cut, and laser cut/sanded surfaces prior to gluing. The ripsawn surfaces were typical of those obtained in commercial practice. As expected, laser cut surfaces were blackened and contained a powdery char. Surface quality was somewhat better, with less char in sweetgum than red oak. In oak, the large vessels at the beginning of annual rings burned more readily than did the small vessels later in the growing season, leaving shallow grooves parallel to the board surface.

Table 1 gives the average results for strength of adhesive bonds in shear by compression loading. Other factors, such as delamination, appearance, and dimensional stability were not considered. Bond strength of sawn surfaces averaged 1,900 psi for red oak and 1,662 psi for sweetgum. The strength of untreated laser cut wood was significantly diminished. Bond strength of red oak was reduced 75.3 percent to 469 psi and sweetgum was reduced 43.1 percent to 945 psi. The better performance of sweetgum may be attributed to its smoother surface and reduced char. Light sanding removed some

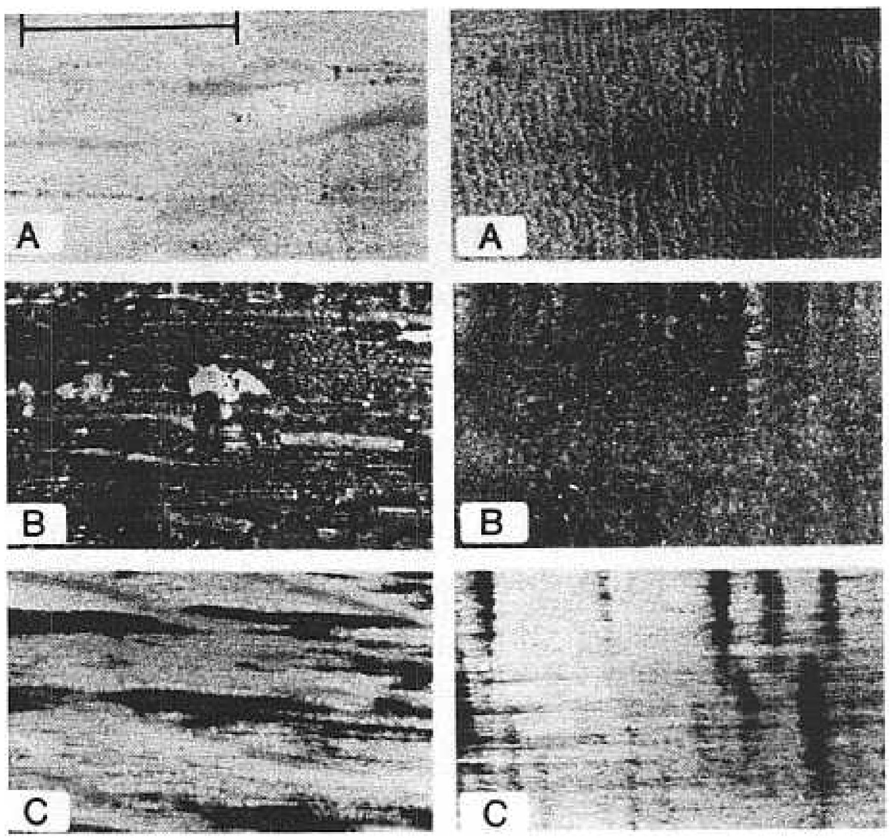

Figure 1. — Typical sawn (A), laser cut (B), and laser cut/sanded (C) surfaces of red oak (left) and sweetgum (right) prior to bonding. The scale mark in figure A (left) is 1 cm and applies to all illustrations in Figure 1.

TABLE 1. — *Strength of adhesive bonds in shear for two species.*

Machining method/treatment[a]	Shear strength	Strength loss as percentage of sawn strength
	(psi)	(%)
	RED OAK	
Sawn/none	1,900	0
Laser/sanded	1,246	34.4
Laser/none	469	75.3
	SWEETGUM	
Sawn/none	1,662	0
Laser/sanded	1,138	31.5
Laser/none	945	43.1

[a]Machining method/treatment values were tested separately for each species by Duncan's multiple range test. All are significantly different at the 0.05 level.

surface discontinuities and most char. Strength loss of sanded samples was 34.4 percent for red oak and 31.5 percent for sweetgum.

The results for red oak agree with another preliminary test using a 400 watt single mode CO_2 laser with transmission optics and a coaxial jet. In this test, sample boards were cut at 14 fpm to yield shear specimens cut by laser (no treatment), laser (light brushing), laser (light sanding), laser (jointed). Strength loss as a percentage of planed strength was 76.4, 66.7, 20.3, and 0, respectively.

For the laser, adhesive, and gluing conditions used here, a surface treatment between light sanding and jointing will be required to edge-glue laser-cut wood into panels. The extent of treatment would depend on species and characteristics of the laser cutting system. For panel parts, the narrow kerf advantage associated with laser cutting will be somewhat offset by treatment losses to improve dimensional accuracy and to remove char. Light sanding could increase a 0.030-inch laser kerf by 0.006 inch (0.003 in. per side) while jointing might increase the kerf by 0.010 inch (0.005 in. per side) or more.

It is probable that other laser systems, adhesives, adhesive formulations, or bonding conditions would yield different results. Since gluability of laser cut wood is of concern in the ALPS process, additional studies of greater scope should be undertaken.