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Abstract

This practical, nonstatistical experiment using commercial equipment demonstrated that nominal 3/4-inch composite panels for furniture consisting of a particleboard core, high density melamine crossbands, and walnut veneer face plies can be cut with a carbon dioxide/airjet-assisted laser to produce surfaces with minimal nonparallelism and char compared to previous attempts. The best cuts were obtained by focusing the beam at the panel surface, using 400 to 500 watts of laser output power, and cutting at 20 in./min. A jet-assist pressure of air at 60 psig, a jet nozzle diameter of 0.050 inch, and a beam focal length of 7.5 inches yielded better cuts than other conditions tested.

The production of composite wood products in the United States has continued to expand over the last 10 years (1). Annual production of particleboard in 1985 was estimated at 3.3 billion ft.³, 3/4-inch basis. Additionally, 6.3 billion ft.³ of hardboard (1/8-in. basis) and 700 million ft.³ of medium density fiberboard (MDF) were produced. Many composite board products have surface treatments or laminates added to produce special properties or appearances.

These composites are conventionally cut into rectangular pieces or intricate shapes using carbide, metal-ceramics, or diamond tools. Unique machining problems exist, e.g., more electrical energy is required than when cutting many composite products. This is attributed to the presence of adhesives, higher density, and a nonhomogeneous structure. Tool wear and associated cost are also substantial because of resin, sand, and other foreign materials.

These factors suggest the need to introduce new machining methods. High energy lasers have recently been developed that offer a number of potential advantages over conventional machining methods: lasers 1) produce a

small kerf (approximately 0.025 in.) with no tool wear in the conventional sense; 2) have a low noise level; 3) can start and stop cutting in any location; 4) do not produce sawdust; and 5) can be readily coupled with computer numerically controlled automated production systems.

Because the process is relatively new, little information is available for laser cutting composite wood products, which have traditionally proved difficult compared to solid wood. Composite wood products (particleboard, particleboard with overlays, and even plywood) typically yield extremely rough, highly charred, deeply burned, and uneven (nonparallel) cut surfaces. An effective laser cutting system must employ carefully selected machine variables to yield acceptable cutting speeds and reasonably parallel, smooth surfaces with minimal char. These quality characteristics depend on such board properties as density, optical absorption, type of resin, particle size and shape, laminate, and board thickness (2).

In the research reported here, we attempt to provide some practical information on selecting laser machining variables to improve parallelism while also reducing char and burning of cut surfaces in one type of wood veneer laminated particleboard common in furniture.

Method

A nominal 600-watt, TEM₀₀, commercially designed carbon-dioxide laser coupled to a precision computer-controlled X-Y table was used in the study. A standard single-

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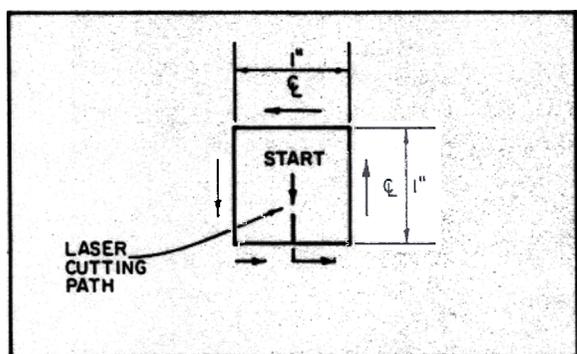
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lens beam-delivery system, designed to accommodate slight variations in board thickness, was equipped with an airjet evacuation assembly.

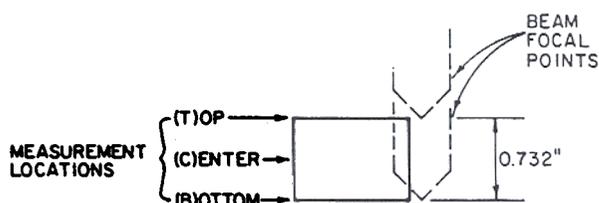
Three factors were considered in this practical experiment: 1) nominal laser output power (400, 500, and 600 watts); 2) cutting speed (10 and 20 in./min.); and 3) two locations of the beam focal point within the thickness of the board (Fig. 1A). Other laser-cutting factors such as type of jet-assist gas, TEM mode, and external beam diameter were held constant.

The composite was a homogeneous particleboard with a density of 45 pcf, a 1/36-inch-thick walnut surface veneer, and a 0.32-inch-thick crossband of high density melamine. The overall thickness of the 5-ply configuration of face and back veneer, the two crossbands, and the particleboard interior was 0.732 inch. From previous experience, this type of composite represents a material extremely difficult to cut with a laser.

Based on preliminary experiments, a laser beam focal length of 7.5-inches provided the best quality cut and was held constant. Also held constant was the jet-assist nozzle aperture diameter (0.56 in.) and air pressure (60 psig).



B



A

Figure 1. — A. Edge view of specimen. B. Top view of board and specimen.

The closest possible proximity of the nozzle to the board surface yielded best performance.

The X-Y table was computer-programmed to cut 1-inch square specimens as measured between the true center-line focal points of the laser beam from the sample board. The direction of cut, starting in the center of the 1-inch square specimens, is shown in Fig. 1B and followed the path shown for each variable of power, speed, and focal point location. In total, about 15 specimens were produced for each of the 3 experimental variables. After cutting, the specimen width was measured with a caliper along each of the four corner cardinal directions at the top, center, and bottom of the cut surface to an accuracy of 0.001 inch (Fig. 1A) and the result for each width location was averaged.

It was not considered sufficient to merely cut through the board. Speed of cutting, although important, was not the primary concern because laser cutting systems are not economically dependent on speed alone. All lasers cutting thick material yield conically shaped beams. Thus, in this study, the laser's ability to cut was defined in terms of divergence of cut, that is, the difference in the measured specimen width between the entry of the laser beam on the board surface to the point where the beam exited the lower surface. The greater the measured deviation from the two parallel planes, the lower the quality cut. For example, if the specimen width at the top, midpoint, and bottom of the cut were identical, the cut would be considered of the highest quality (i.e., the cut surfaces were parallel to the beam axis). As another example, if the specimen width at midpoint was less than the width at the top and bottom, the cut surface was curved or bellowed. Nonparallelism of the cut surfaces could also be detected by comparing the width dimension divergence between the top and bottom of the cut. Other important cut surface characteristics such as smoothness and degree of char were beyond the scope of this study and were only briefly considered in a subjective manner.

Results

Table 1 shows average measured specimen dimensions (based on cutting nominal 1-in. squares), divergence of specimen dimension between center and top and bottom and top positions, and average divergence for the factorial combinations of laser output power, cutting speed, and position of the focal point. While the data presented in Table 1 represent many observations, no rigorous statistical analysis was attempted. Rather, simple averages were used to indicate trends.

When averaged over all levels of power, cutting speed,

TABLE 1. — Highest quality cuts using laser variables of power, feed speed, and focal point.

Power (W)	Cutting speed (in./min.)	Beam focal point	Measurement position			Divergence		Average divergence
			Top	Center	Bottom	Center minus top	Bottom minus top	
400	10	Bottom	.966	.969	.966	+ .003	+ .020	+ .012
400	20	Top	.962	.962	.969	+ .000	+ .007	+ .004
500	10	Bottom	.963	.964	.965	+ .001	+ .022	+ .012
500	20	Top	.976	.978	.985	+ .002	+ .009	+ .006
600	10	Bottom	.960	.963	.969	+ .003	+ .029	+ .016
600	20	Top	.972	.976	.985	+ .004	+ .013	+ .009
Averages			.970	.972	.987	+ .002	+ .017	+ .010

and focal position, the width of specimens increased from 0.970 at the top to 0.972 inch in the center area to 0.987 inch at the bottom of the specimen for a total nonparallelism of 0.017 inch. When all machining variables and measuring positions were averaged, the nonparallelism was only 0.010 inch. Increasing cutting speed beyond the laser powers used here yielded negative results and was not considered. The average divergence between center and top and between the bottom and top measurements was always positive indicating a fan-shaped beam configuration regardless of the machine variables used. Possibly the level of divergence may have been the result of overheating associated with the airjet-assist system used in the study. The average kerf width required to cut nominal 1-inch square specimens about the central beam totaled only 0.024 inch, substantially less than the 0.125 inch required by many typical circular saws.

When the divergence for measurement positions between the center and top and the bottom and top were averaged over all focal points and cutting speeds, divergence increased slightly with increasing power. Average divergence was 0.008, 0.009, and 0.013 inch for powers of 400, 500, and 600 watts, respectively. The differences are rather small, but these simple averages suggest that merely increasing power does not improve the quality of cut.

When divergence was averaged over all levels of power and focal points, the higher cutting speed of 20 in./min. yielded less divergence than did the slower speed of 10 in./min. The respective values were 0.006 and 0.013 inch. The slower cutting speed probably allows excess heat buildup and thus more burn and char than the faster speed where heat is more readily dissipated.

When the difference between focal points was compared, averaged over all measurement positions, cutting speeds, and powers, placement of the laser beam focal point at the board surface gave better quality (0.006-in. divergence) than when placed at the bottom surface (0.013-in. divergence). No tests were made with the focal point located at the midpoint of the board thickness, but this would likely have yielded an intermediate result.

Char was present on the cut surface of test specimens. The level of char and burning was not deemed overly serious considering that previous attempts to cut composite materials with a laser were virtually unsuccessful in all aspects. Previous studies by the authors indicate that the

depth of char in solid wood is only a few thousands of an inch and can readily be removed by light sanding or jointing (3), although kerf loss is increased slightly. With such removal, reasonably acceptable gluebond strengths were obtained in an industrial environment with conventional adhesive. Considering the limitations of the equipment and experimental variables used, the cut surfaces were judged relatively smooth in light of previous unsuccessful attempts to laser cut composites. Edge sharpness was good and there was no surface chipping.

Conclusions

This practical, nonstatistical experiment using commercial equipment has shown that a nominal 3/4-inch 5-ply composite panel for furniture consisting of a particle-board core, high density melamine crossbands, and walnut veneer face plies can be cut with a carbon dioxide/airjet-assisted laser to yield surfaces with minimal nonparallelism and char compared to previous attempts.

For the material and cutting conditions in this study, the best quality cuts (measured in terms of divergence from parallelism from the beam axis) were obtained by focusing the beam on the surface of the board, using 400 to 500 watts of laser output power, and cutting at a speed of 20 in./min. These preliminary tests indicated that best results were obtained with a jet-assist pressure (air only) of 60 psig, a jet nozzle diameter of 0.050 inch, and a beam focal length of 7.5 inches.

The optimum feed speed used here is less than found in conventional cutting because establishing the ability of the laser to produce cuts of reasonable quality was considered of paramount importance. Higher cutting speeds are potentially possible with different system configurations. These preliminary results suggest that further research on the laser cutting of wood is warranted.

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