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CHARACTERISTICS OF LASER
CUTTING KEVLAR LAMINATES

By R. A. Van Cleave

Published January 1979

Topical Report
G. W. Edman, Project Leader

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SUMMARY

The CO₂ laser cutting process is an improved method for producing fuzz-free edges in Kevlar 49 (registered trademark of Du Pont Corporation) and epoxy resin laminates. However, earlier work at Bendix with laser cutting these laminates was directed toward satisfying specific product needs rather than developing practical cutting techniques. A general knowledge of laser cutting characteristics was needed to provide a broader base for laminate cutting to support the Kevlar laminate fabrication development program and to reduce start-up time for new applications.

Laser cut tensile samples have been compared to machined samples to determine the effect of the two processes on the material. Tests show that the tensile strength was not affected by use of the laser. The machining process leaves a straight edge cut, with the fibers displaced by the tool cutting force. Although the laser operation does not move the fibers, it does produce a jagged edge with up to 0.08 mm depth of disturbed surface, which makes dimensional inspection more difficult.

Pockets, or partial depth cuts, were produced in Kevlar laminates by scanning the work under a pulsed beam. The bottom surface was textured with a poor surface finish. Depths can be controlled and repeated to within 0.5 mm.

The power required to cut laminates ranging from 1.0 to 9.5 mm in thickness was determined. Using presently known techniques and a 1000-W CO₂ laser, the maximum Kevlar/epoxy thickness that can be cut satisfactorily is 9.5 mm. Edge taper and kerf width in the various laminate thicknesses also was established. Edge taper increases with thickness and ranges from 0.06 to 0.22 mm. Kerf width also increases, ranging from 0.11 to 0.21 mm.

The number of layers of material for a 3.1-mm thickness was varied from 14 to 20, and cutting power requirements were determined. The power increases uniformly from 135 to 160 W, but kerf width and edge taper remained constant.

Various tooling aids were developed. A focusing lens mounting device was developed to allow protection of the expensive lens with less costly optical flats. Also, a nozzle was developed to concentrate the cover gas more directly at the work surface to improve cutting performance. Holding fixtures and tapes were prepared to cut various test sample patterns in support of the Kevlar/epoxy laminate fabrication project.

Kevlar cloth was cut with only a slight amount of carbon deposit present. A pulsed beam was used, and the material was moved at a speed of 34 mm/s.

The fumes produced during laser cutting of Kevlar/epoxy laminates were compared to the combustion products. Laser cutting produced about 70 percent fewer products, indicating a more complete combustion because of the higher temperature and shorter exposure time. A toxic product produced during laser cutting was benzene, a potential carcinogen; thus, adequate fume exhausting must be provided.

Additional activity is planned to refine known cutting techniques, such as reducing edge taper and char; improving the pocket cutting capability; and studying the effects of nozzle design, cover gas, focal length, and focus point location on cutting performance.

DISCUSSION

SCOPE AND PURPOSE

The purpose of this project is to develop the cutting characteristics of a CO₂ laser for use in manufacturing Kevlar/epoxy laminates. The laser cutting process previously has been proven to be an improved technique for producing burr-free edges in this material, but a general knowledge of the cutting performance is needed to provide a broader base for laminate cutting. Kevlar/epoxy composite material processing variables, such as cutting power requirements, kerf width, and edge taper, need to be established to reduce start-up time for new product requirements and to advance manufacturing and testing capabilities.

PRIOR WORK

Laser cutting processes have been developed for various products, but previous efforts were concentrated on satisfying product requirements rather than developing general cutting techniques.¹

ACTIVITY

A 1000-W CO₂ laser was used in this work. The laser can deliver power continuously or pulsed, at a maximum rate of 1000 Hz. The beam is directed to a work table that is controlled with a two-axis system using Mylar tape for data input. All tests were run using argon cover gas; a 127-mm focal length, zinc selenide focusing lens, with the focal point located at the top surface of the laminate, was used.

Material Effects

Several tests have been conducted to examine the effect of laser cutting on material properties. During the cutting process, the focused beam causes the material temperature to rise to the point of vaporization in a short period of time. The test approach was to compare laser-cut samples to machined samples.

Nine laser-cut and nine machined tensile samples with a gage width of 3.2 mm were prepared from a 3.5-mm-thick laminate made from a prepreg of epoxy and Kevlar 49 fabric (Style 181). The laser samples were cut at 34 mm/s with 175 W of power; the machined samples were cut using an end mill with the material sandwiched between aluminum sheets. Failure of both type of samples typically occurred outside the gage length. Tensile strength testing

resulted in an average modulus of 34 GPa and an average tensile strength of 580 MPa for the laser-cut samples. For the machined samples, the average modulus was 31.9 GPa, and the average tensile strength was 550 MPa.

Four laser-cut and three machined discs, 28.7 mm in diameter, were prepared from a 6.9-mm-thick Kevlar/epoxy laminate and tested for interlaminar tensile strength. A force was applied across the thickness to cause a separation between adjacent layers. Average interlaminar tensile strength of the laser-cut and machined samples was 19.3 and 17.4 MPa, respectively.

Pin bearing load tests were conducted on two types of laminates.² For the first test, six rectangular samples, 76 by 25 mm, were laser cut from the 6.9-mm-thick laminate. A 6.4-mm-diameter hole, with the centerline 4.7 mm from one of the 25-mm sides, was drilled in each, three using the laser, and the other three machined. For the second test, ten samples were cut from 3.4-mm-thick laminates made from Kevlar/epoxy prepreg. Holes of the same size, but located 19 mm from the edge, were drilled in the samples; five were laser drilled, and five were machined. In both tests, a 6.35-mm-diameter pin was placed in the hole and a force applied to the pin in the direction of the edge until failure. Load strength for the laser cut samples averaged 181 MPa (4.7 mm distance) and 241 MPa (19 mm distance); for the machined samples, average strength was 167 MPa (4.7 mm distance) and 257 MPa (19 mm distance).

A sample was prepared from a Kevlar/epoxy laminate to compare the laser and machined edges. The laser edge was cut with 500 W at 34 mm/s, and the machined edge was cut with an end mill. Micrographs of the two edges before vapor blasting are shown in Figure 1.

The machining process produces an edge straight within 0.02 mm, but the fibers are displaced by the cutting forces within a band approximately 0.04 mm back from the edge. Laser cutting produces an edge not as straight as the machined edge, but the fibers were not moved because the forces generated during machining are not present during laser cutting. However, the laser cut does produce surface voids of as much as 0.08 mm at resin-rich areas; the heat generated by the laser raises the temperature sufficiently to cause vaporization of the epoxy but not of the Kevlar fibers in the resin-rich areas adjacent to the kerf width.

Tensile strength, interlaminar tensile strength, and bearing load strength properties of Kevlar/epoxy laminates are not degraded by the laser cutting process, as compared to a machining process. The laser, however, does produce a jagged edge of up to 0.08 mm depth, which causes some problems in obtaining accurate measurements.

LASER CUT

MACHINED

Figure 1. Laser-Cut and Machined Edges in Kevlar/Epoxy Laminates, 100X

Pocket Cutting

Pockets of various depths were laser cut in 6.4-mm-thick laminates made from Kevlar/epoxy prepreg. The pocket contour was generated by moving the work under the beam in incremental movements, so that the entire pocket area was scanned by the beam. Cutting speed was 25 mm/s, and cutting time was only about 1 minute. The incremental moves programmed were 0.25 mm. The beam generally was pulsed, with a duty cycle of 10 ms on and 5 ms off to prevent excessive heat damage to the top surface. The pocket size programmed measured 13 by 25 mm (Figure 2).

Two different techniques were tested. The first was to maintain the focal point of the beam constant at the top surface of the work and vary the power to change power density and, thereby, penetration. The second technique was to hold the power level constant and vary the focal point location relative to the top surface. Both techniques were successful.

The cutting process did not vaporize all the material; instead, it left behind a thick residue of char. The char can be removed by scraping with a piece of shim stock or a similar tool and vapor blasting with 1000-grit glass beads. The bottom surface of the pockets was textured or pitted to a depth ranging from 0.05 to 0.3 mm; the amount of penetration ranged from 1 to 5.6 mm (Figures 3 and 4). Results of this test indicate that producing square corner pockets in Kevlar/epoxy laminates is feasible. Pocket depth penetration can be controlled for a repeatable cutting process. Optimum cutting features and techniques will be studied further.

Cutting Power Requirements

The power required for cutting 1.17- to 9.5-mm-thick Kevlar/epoxy laminates was established (Figure 5). Power values reported are based on readings made from the original equipment power meter, calibrated to represent power at the work surface rather than at the laser output windows. The meter was calibrated using an integrating sphere power analyzing technique.³ The focusing lens was zinc selenide with a 127-mm focal length. Power levels shown are set points; actual values needed for each application will vary with a change in the beam mode or in the condition of laser cavity mirrors, work station bending mirrors, or the focusing lens.

A vinyl-backed rubber adhesive electroplating masking tape was used extensively to cover the laminate prior to cutting for this and other tests. The tape reduces the carbon deposit clean-up time of the top surface of the samples and minimizes the flame given off as the cutting products are ignited by the beam.

Figure 2. Pockets Cut in Kevlar/
Epoxy Laminates to
Various Depths, Cutting
Time 60 s

Kerf Width and Edge Taper

The kerf width and edge taper have been determined for various thicknesses of Kevlar/epoxy prepreg laminates. The kerf width can be thought of as the effective beam cutting diameter (not the actual beam diameter) and must be known to program contour-generating numerically-controlled tapes. The cut is typically wider at the top surface than at the bottom because of the decreasing power density through the thickness as the power is consumed in vaporizing the material and because of the divergence of the focused beam as it departs from its focus point.

Defining edge taper and kerf width proved to be difficult and results are questionable because of the jagged edge produced by laser cutting. The technique used was to laser cut a 12.7-mm-wide by 19.1-mm-long rectangle, using the minimum power required for each laminate thickness (Figure 6). Both the rectangular plug and its hole were measured for length and width at the top and bottom surfaces to determine the kerf width and edge taper (Figure 7). Cutting speed was 34 mm/s, and a cover gas of argon was applied coaxially with the beam. Dimensions at the bottom edges were measured with a micrometer, and those at the top were taken optically at 10X magnification. Results are given in Figures 8 and 9.

Layer Variation

The number of layers of Kevlar/epoxy prepreg was varied to determine the effect on laser cutting performance. Thickness of the laminate was held constant at 3.1 mm, and the number of

Figure 3. Laser Cutting Pockets by Varying Power Setting

layers was 14, 16, 18, and 20. The kerf width and edge taper varied less than 0.008 mm (less than the dimensional measuring accuracy), but the power required to cut through increased from 135 W for the 14-layer sample to 160 W for the 20-layer sample (Figure 10).

Protective Lens Mount

During the laser cutting process, the focusing lens and lens coating are susceptible to damage, either by foreign material deposition during actual cutting or by the metal sparks generated during focus finding. The foreign material will absorb the laser energy and melt the coating; also, it can pit the zinc selenide substrate. Because the cost of this lens is relatively high (\$600 to replace and \$150 to recoat), a protective lens mounting device was designed as a modification of some existing sketches and fabricated. The protective lens mount provides for installation of a 38.1-mm-diameter by 2-mm-thick zinc selenide flat below the focusing lens to shield against sparks and a 35.6-mm flat above the lens to shield the top from foreign material. Initial

Figure 4. Laser Cutting Pockets by Varying Focal Point Location

cost of the flats is \$180 each in limited quantities. The flats can be replaced periodically at less expense than replacement of the focusing lens.

Nozzle Design

When Kevlar/epoxy laminates are cut with the laser, argon is used as a cover gas. A nozzle was designed and fabricated to concentrate the cover gas to an 8.0-mm-diameter coaxial with the laser beam and to provide a shower of gas parallel to the beam (Figure 11). Initial testing has shown that less power is required to cut when using the nozzle. Total effect on cutting and optimum nozzle design will require additional study.

Figure 5. Power Requirements for Cutting Through Kevlar/Epoxy Laminates

Cloth Cutting

Cutting of Kevlar cloth has been tested. Efforts have been concentrated on eliminating the carbon residue by cutting one layer at a time. The best results were obtained by moving the work at 34 mm/s, pulsing the beam with a duty cycle of 2 ms on and 1 ms off, and using a peak power of 18 W. The edge of the fiber was blackened, but the surface of the cloth was only slightly discolored by the carbon residue.

Figure 6. Kevlar/Epoxy Test Samples
for Finding Edge Taper
and Kerf Width

Hole Cutting

Holes ranging from 0.51 to 19.05 mm in diameter were cut in 6.35-mm-thick Kevlar/epoxy laminates to develop the feed rate applicable to varying hole sizes. The method selected for the hole-generating process is shown in Figure 12, and recommended cutting speeds and beam diameters are given in Table 1. The data shown are based on visual appearance and hole sizes as determined with gage pins. These recommendations are based on a first try cutting effort; hole cutting techniques, beam diameters, and cutting speeds will be studied in greater detail.

Fumes

The organic fumes produced during laser cutting of a Kevlar/epoxy laminate were analyzed using a mass spectrometer, and the results were compared to the combustion products of burning Kevlar/epoxy laminates. The laser cutting process produces hydrocarbons, CO₂, toluene, xylene, benzene, water, and a trace of phenol. At least 25 products are produced during combustion, including (from most to least abundant) CO₂, phenol, dihydro-methyl-benzofuran, isopropyl phenol, amine, acetone, benzene, phenylene diamine, dimethyl pyrrole, aldehydes, alkyl pyrrole, propanol, methyl piperidine, toluene, xylene, substituted phenols, and a trace of hydrogen cyanide. Of these products, benzene, identified by OSHA as a potential carcinogen, is potentially the most hazardous component. Proper exhaust must be maintained to avoid long-term exposure to the cutting products.

The laser produces fewer products, probably because the material temperature rise is greater and occurs almost instantly, causing a more complete combustion of the polymer.

Figure 7. Kerf Width and Edge Taper Definition

Applications

A laser cutting process was developed and incorporated on a 3.56-mm-thick by 73.2-mm-diameter part made from Kevlar/epoxy prepreg. The laser cutting process, replacing two bandsaw, one lathe, and two drilling operations, yields 16 parts per panel rather than the nine previously obtained (Figure 13).

The panel is clamped in position, and the two holes and outer diameter for each of the 16 parts are cut automatically. Cycle time for each part is 20 s; total time for each panel is 5 min. The accuracy of the numerically-controlled table and the narrow kerf width (0.10 mm) permitted closer positioning of the parts for an increased yield and material savings. Use of laser cutting reduced the total time required to manufacture this product by 59.4 percent.

Fixtures and numerical control tapes were developed for cutting a variety of test sample configurations from various sized flat laminates. Figure 14 shows a typical pattern which has been cut in approximately 4 min. A rotary fixture and process also were developed to cut tensile test samples and hoop strength rings from cylinders up to 300 mm in diameter. Tensile samples are cut at 34 mm/s, and rings are cut at up to 300 mm/s.

ACCOMPLISHMENTS

Many of the processing variables of CO₂ laser cutting of Kevlar/epoxy laminates were studied and defined. Minimum power requirements, kerf width, edge taper, feed rate, and hole and pocket cutting information were developed, which will decrease start-up time required for processing new Kevlar/epoxy products. The mechanical properties of the laminate are not affected by the laser cutting process.

Figure 8. Edge Taper Versus Thickness for Laser-Cut Kevlar/Epoxy Laminates

Figure 9. Kerf Width Versus Thickness for Laser-Cut Kevlar/Epoxy Laminates

Several patterns were generated for cutting test samples to support evaluation of Kevlar/epoxy laminates. Tooling was developed to increase cutting performance and reduce laser operating costs.

Figure 10. Effect on Cutting Power of Changing the Number of Layers of a Constant Thickness (3.1 mm) Kevlar/Epoxy Laminate

FUTURE WORK

Additional work is planned in several areas. Pocket and hole cutting techniques will be refined, and methods of reducing edge taper will be investigated. The effects of nozzle design, cover gas, focal length, and focal point location on cutting performance will be studied. The temperature profile or heat affected zone of the material during laser cutting will be determined, and reduction of char will be attempted by cutting in an oxygen-free atmosphere.

Figure 11. Nozzle for Coaxial and Parallel Flow Cover Gas

Figure 12. Laser Hole Cutting Technique

Table 1. Recommended Cutting Speeds
and Kerf Width for Laser-
Cutting 6.35-mm-Thick
Kevlar/Epoxy Laminates

Hole Size (mm)	Cutting Speed (mm/s)	Kerf Width (mm)
0.5	17	0.6
1.0	17	0.6
1.5	23	0.2
1.8	23	0.1
2.0	23	0.1
2.5	23	0.2
3.5	23	0.2
3.8	23	0.1
5.0	34	0.1
6.4	34	0.1
7.6	34	0.1
10.2	34	0.1
12.7	34	0.1
15.2	34	0.1
19.0	34	0.1

Figure 13. Kevlar/Epoxy Part Cut With a Laser

Figure 14. Test Sample Pattern, 200 by 200 mm

REFERENCES

¹R. A. Van Cleave, Laser Cutting of Kevlar Laminates (Topical Report). Bendix Kansas City: BDX-613-1877, September 1977 (Available from NTIS).

²R. E. Allred, Behavior of Kevlar 49 Fabric/Epoxy Laminates Subjected to Pin Bearing Loads. Albuquerque: Sandia Corporation Report SAND 77-0347, April, 1977 (Available from NTIS).

³L. D. Wonnell, Universal Monitor for CO2 Lasers (Conference Paper). Presented at Electro-Optical Systems Design Conference, October 25-27, 1977 (Available from NTIS).

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PLASTICS: Laser Cutting

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