Technical information

ACRYLITE® extruded sheet (FF)

#13 Laser Machining

This brief gives advice for:

- **Equipment**
- **Procedures**
- **Trouble Shooting**

Equipment

CO_2 lasers, used in appropriate applications, are powerful and cost effective tools for cutting ACRYLITE® sheet. Small complex parts with clean, sharp inside corners, and parts of any size which require cutting tolerances of less than 0.005"/ft. can be cut with a laser and left with a polished edge finish. Because laser-cutting offers a narrow kerf (0.010-0.020"), tremendous shape and size capability, as well as a clean polished, dust free cut, it is the premier choice for many quality applications.

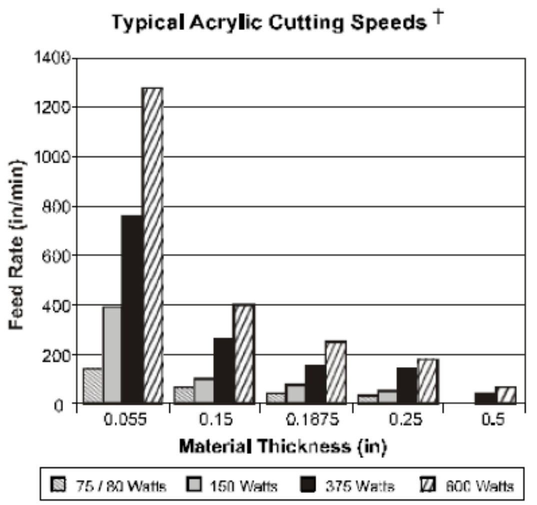
The Design of a CO_2 Laser

CO_2 lasers work by emitting a beam of parallel light that has a wavelength of 10.6 micron. This wavelength of light is absorbed well by non metals. When the beam of light or energy is focused through a lens to a very small point, it vaporizes the material in its path. This focused laser beam can be held stationary over an xy-axes positioning table or it can be positioned over a stationary surface using a "flying head" configuration. A flying head set-up means that the laser beam moves over the work on one or two axes through the use of mirrors and mechanical positioning equipment. The controllers, PC's and software used to control the positioning of the laser and the work are very similar to the hardware and software used with other CNC machining equipment. This makes designing for and using the laser cutter no more difficult than working with any other CNC machine.

Procedures

Setting Up To Cut ACRYLITE®

There are three basic variables involved when cutting with a laser, each affecting the quality of the cut and the resultant level of stress in the material being cut: the power of the laser, the feed rate, and the pulse rate. These can all be adjusted to allow for different material, material thicknesses and edge finishes. To cut ACRYLITE® sheet, a laser as small as 40 watts can be used for thicknesses up to approximately ¼". To get good edge quality with a small laser, however, you must slow the feed rate to approximately 20 inches/minute. For thicker sheet or faster feed rates, a larger laser is needed. A 180-watt laser will provide fast economical cutting of most thicknesses of acrylic sheet using only about 75% power. Laser machines with higher wattage, 500 to 1000 watts, permit higher feed rates and cutting with multiple heads at one time.



† Data taken from "Laser Processing of Plastic Sheet" by Tim Christopherson, Plastics Fabricating & Forming, September/ October 2000.

Trouble Shooting

Increasing the power of the laser at a given feed rate usually will result in a more glossy finish, but it also increases the level of stress in the edge of the sheet. A faster feed rate with a more rapid pulse rate will generally result in an edge with lower stress but a less glossy surface.

The pulse rate of a laser (measured in pulses per second – pps) is the rate at which a laser "fires". The beam of the laser is actually a series of small bursts or pulses, not a continuous stream. The pulse rate can be controlled in two ways: proportionally to time or proportionally to distance traveled. While the pulse rate proportional to time method is more common and easier to program initially, this method usually results in burned inside corners. The xy-controller takes longer to make a corner than a straight line so the corners (particularly the inside corners) absorb too much energy and tend to melt and become over-stressed. This is an important consideration when cutting notch sensitive materials like acrylic and polycarbonate. Inside corners are always weak, high load areas. Everything possible should be done to reduce stress or notches in these areas. Making the pulse rate proportional to the distance traveled eliminates much of this problem. As the controller slows the feed rate at the corners, the pulse rate slows down, keeping constant the amount of energy emitted at a given point on the cut.

Important Considerations When Cutting ACRYLITE®

No matter how sophisticated the controller or how fast the feed rate, edge stress will always be a consideration in certain applications. Any time a sheet of acrylic or polycarbonate is heated, the possibility of heat stress exists. This problem is greatest when only part of the sheet is heated, which is the case with laser cutting. The interface on the non-heated body of the sheet and the rapidly heated, rapidly cooled edge of the laser cut sheet is susceptible to crazing. These highly stressed areas extend approximately 0.010-0.050" (depending on thickness) into the sheet. They are very susceptible to crazing from contact with incompatible solvents or from high mechanical stress, for instance, due to bending.

Adjusting the feed rate, pulse rate, and power can minimize the edge stress problem. Lower power and a slow pulse rate, combined with a relatively rapid feed rate, reduces the amount of energy or heat which is absorbed by the sheet. Thereby, reducing both the amount of stress and the distance that the stress extends into the sheet. These conditions, however, will result in a less glossy edge finish. In some circumstances, it may be practical to scrape or machine away the stressed areas.

Gas Assist and Vacuum Table

Most high-powered lasers come equipped with a vacuum hold-down table and a gas assist stream. The type of gas used, the flow rate of the gas assist stream, as well as the efficiency of the vacuum table in removing vapors can influence the quality of the laser cut that is achieved. Good gas flow across the laser cut combined with an effective vacuum will help to remove vapors which can damage the work piece, result in small flames and charring, or leave behind unwanted residues.

Laser Cuttable Masking

Masking performance is an important consideration when selecting acrylic sheet for your application. If masking does not adhere well, parts can be damaged or scratched during fabrication and the efficiency of the fabrication process itself can be reduced. At other times, masking can be difficult to remove resulting in extra labor and cost. The proper choice of masking for each type of fabrication process can help to minimize problems.

Traditionally, paper masking has been the masking of choice for laser cutting. It will not fuse to the acrylic at the edges of the laser cut sheet. Its strong consistent adhesion will prevent the masking from lifting while handling and laser cutting, protecting the acrylic sheet's surface from the hot, corrosive gases generated by the laser. Laser cuttable polyethylene masking is now available on acrylic sheet.

For maximum laser cutting efficiency and output, a specially formulated light adhesive polyethylene masking can be used. This masking removes very easily from a laser cut part, yet offers sufficient adhesion to withstand most ordinary handling. Although it is rarely a problem, this type of masking may lift in areas where the laser is prone to idle for excess periods of time due to the masking's light adhesive formula. This can occur at the beginning of a laser cut or when making a very tight radius cut. Lifting is easily prevented by using a "lead in" at the beginning of the laser cut and by reducing the pulse rate or power when tight radius bends are negotiated.

For a pristine, polished edge, a specially formulated nonadhesive polyethylene masking is available. Because all adhesive-based maskings will leave some residue on a laser cut edge, they can slightly reduce the polished appearance of the laser cut edge. For applications demanding the very highest appearance polished edge, a non-adhesive "laser cuttable" masking is recommended. This type of masking may be a little more difficult to remove from the laser cut part than an adhesive based masking, but will provide a slightly higher quality polished edge. It is also slightly more resistant to edge lift. If lift does occur, similar steps can be taken as those described above.

Another consideration with regards to masking is wrinkles. In order to retain the original optics of the sheet being cut, the masking, particularly the masking on the top of the piece, must be wrinkle-free. If the masking is not in contact with the sheet at the point of the cut, the hot laser gases will be trapped between the masking and the sheet, etching the surface. Etching is often not a problem on the bottom of the sheet because most xy-tables use a vacuum hold down system. The vacuum effectively removes the hot gases from the bottom of the sheet before they can cause any damage.

Maintenance

Like all sophisticated equipment, laser cutters require regular maintenance for optimum performance. It is a good practice to note the power setting required to cut a given thickness of material at a specific cutting speed. Over time, the power setting must be raised or cutting speeds reduced, due to the laser optics becoming dirty and out of focus. As this occurs cut quality will also degrade. Regular maintenance by a qualified technician will help maintain cutting efficiency and quality.

Safety

While lasers are high-powered sophisticated tools, they are no more or less dangerous than any other piece of shop equipment when properly installed and operated. Standard safety glasses are often all that is necessary for eye protection. However, not all standard safety glass is opaque to 10.6-micron light (i.e., optical density of 5 at 10,600 nanometers), common to some lasers. ANSI Standard Z136.1 states that safety eyewear must be labeled with the wavelength and optical density protection factor.

An exhaust system is needed to remove the potentially harmful vapors produced when the material is cut. Depending on the material cut, it may be necessary to filter the vapors before exhausting them outside. As with any other piece of equipment, proper knowledge of operating and safety procedures is necessary before using a laser cutting system.

Emissions

A number of scientific investigations have been performed by various researchers to determine the amount and type of emissions that result from laser cutting acrylic. Despite these efforts, it is impossible to predict the exact by-products and their concentrations in the emission gases generated by laser cutting acrylic.

These depend upon the laser parameters, processing parameters, cover gases, exhaust method, and exact composition of the acrylic polymer. Additionally, these studies do not include the effects of the protective paper or polyethylene masking provided on acrylic sheet, nor do they include the possible impact of coatings.

When laser cutting acrylic, most of the decomposed acrylic is converted into its constituent monomers. In most ACRYLITE® sheets, these monomers include over 90% methylmethacrylate and the remainder, methacrylate. Many suppliers of acrylic also employ ethylacrylate in their acrylic formulations. (Ethylacrylate is included by the National Toxicity Program in its list of substances that may be anticipated to be carcinogens. The International Agency for Research on Cancer lists ethyl acrylate as a probable carcinogen.)

During independent scientific research, Heferkamp, Goede, Engel, and Wittbecker found that of the plastics they tested, acrylic resulted in the lowest aerosol generation (<10 mg/m^3). Their work also indicated that over 90% of the emissions from laser cutting acrylic were gaseous methylmethacrylate monomer.

Troughton, Sims, Ellwood and Taylor found, in addition to methylmethacrylate monomer, small amounts of toluene, methy-2-methyl-3 pentenoate, xylene, trimethyl benzene and alkanes. They found no PAH's which was contrary to the earlier findings of Ball, Kulik and Tan.

Evonik Cyro recommends installing adequate ventilation equipment to ensure employee exposures are below regulated levels. Consideration should be given to environmental regulations if exhausting the gases outside. Manufacturers of laser cutting equipment can provide guidance on the collection and handling of laser emissions.

Sources

H. Haferkamp, M. Goede, K. Engel and J. S. Wittbecker, "Hazardous Emissions: Characterization of CO_2 Laser Material Processing," Journal of Laser Applications, 1995, 83-88, 7.

John M. Kokosa, "Hazardous Chemicals Produced by Laser Materials Processing," Journal of Laser Applications, 1994, 195-201, 6.

Mike Troughton, Jake Sims, Peter Ellwood and Helen Taylor, "Fume Emissions From Laser Cutting and Hot Gas Welding of Plastics."

"Cutting Without Emission," Industrial Laser Review, Sept. 1995, 159.

Fire Precautions

ACRYLITE® sheet is a combustible thermoplastic. Precautions should be taken to protect this material from flames and high heat sources. ACRYLITE® sheet usually burns rapidly to completion if not extinguished. The products of combustion, if sufficient air is present, are carbon dioxide and water. However, in many fires sufficient air will not be available and toxic carbon monoxide will be formed, as it will when other common combustible materials are burned. We urge good judgement in the use of this versatile material and recommend that building codes be followed carefully to assure it is used properly.

Compatibility

Like other plastic materials, ACRYLITE® sheet is subject to crazing, cracking or discoloration if brought into contact with incompatible materials. These materials may include cleaners, polishes, adhesives, sealants, gasketing or packaging materials, cutting emulsions, etc. See the Tech Briefs in this series for more information, or contact your ACRYLITE® sheet Distributor for information on a specific product.

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Evonik Cyro LLC
299 Jefferson Road, Parsippany, NJ 07054 US
Phone +1800 631 5384
www.acrylite.net www.acrylite-shop.com