The Trailing Edge

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Techniques for Working with Acrylic

There are many resources available in books, magazines, and YouTube videos to learn techniques for working with wood. Likewise, there are resources available, with a lot from EAA, to learn how to cut, form, and weld steel, as well as how to cut, form, and rivet aluminum. However, sometimes you need to work with plastics, especially when transparent parts are required. I have found information on how to work with plastics to be much more difficult to find. This article is my attempt to address this.

References

1. Bingelis, Tony, "Stretch Forming Plexiglas Parts", *Sport Aviation*, March 1988, p. 32
2. Bingelis, Tony, "Working With Acrylics",*The Sportplane Builder* (the blue book), p. 192
3. *Working With Plexiglas*, Rohm & Haas Company, Philadelphia PA, 1947.
4. *Plexiglas Forming*, https://youtu.be/JHm2askiCAQ?si=PFHC2lbmbvipbNT0 , erbman89b, YouTube.

What Is Acrylic?

According to Wikipedia, "**Poly**(**methyl methacrylate**) (**PMMA**) is a synthetic polymer derived from methyl methacrylate. It is a transparent thermoplastic, used as an engineering plastic. PMMA is also known as **acrylic**, **acrylic glass**, as well as by the trade names and brands **Crylux**, **Hesalite**, **Plexiglas**, **Acrylite**, **Lucite**, and **Perspex**, among several others. This plastic is often used in sheet form as a lightweight or shatter-resistant alternative to glass. It can also be used as a casting resin, in inks and coatings, and for many other purposes.

It is often technically classified as a type of glass, in that it is a non-crystalline vitreous substance—hence its occasional historic designation as acrylic glass." (Wikipedia, "Poly(methyl methacrylate)")

Acrylic can be formed easily using heat, but it scratches fairly easily. It is reasonably resistant to petroleum distillates, such as avgas.

Polycarbonate (trade name Lexan) is a different type of plastic. It is best used flat, though it can be bent in a sheet metal brake. Heat forming requires drying the plastic first to drive out absorbed water. Otherwise, the absorbed water will cause milky bubbles in the plastic. Polycarbonate is prone to crazing, especially when under stress or in contact with petroleum distillates, such as avgas.

Where Can I Buy Acrylic?

Of course, you could go to your source for everything airplane, Aircraft Spruce & Specialty. Acrylic is available in clear in thicknesses of 0.060, 0.080, or 0.118 inch. It is available in sizes up to 4 feet by 8 feet, though that size will probably cost you oversized shipping. Acrylic is also available in smoked and green at the 0.118 thickness.

For other sizes and thicknesses, you can try McMaster-Carr (https://www.mcmaster.com/). They have a lot of options in clear. Colors are also available for certain sizes.

Home Depot also sells acrylic sheets, generally in thicknesses of 0.093, 0.118 and 0.220, with clear and some colors available.

You could try looking for acrylic at sign shops, but you may have to buy the entire 4x8 sheet.

Finally, you can always try your favorite Internet search engine to find other possible suppliers.

Where ever you by your acrylic, it's not going to be cheap.

How Do I Cut Acrylic?

In general, acrylic can be cut using tools suitable for cutting metal. However, you will need to avoid anything that will cause the acrylic to heat up excessively. The first time I tried to cut acrylic I used a reciprocating Dremel jigsaw/scroll saw. The blade cut on the down stroke, but continued to heat up the acrylic on the up stroke. The acrylic got hot enough that it melted the kerf closed behind the blade, which kind of defeated the objective of making a cut. A saber saw or reciprocating saw should probably be avoided, as the significant vibration will probably crack the acrylic.

A bandsaw with a high tooth pitch, such as a metal cutting blade, can work well on acrylic. The single direction of the cutting teeth carries the heat of cutting away from the acrylic, and the blade has a chance to cool as it travels

around the blade path. Avoid a low tooth pitch blade (large teeth), as the large teeth may take too big of a cut and fracture the plastic.

For straight cuts, a circular saw blade can be used to good effect. I have successfully used a "7-1/4 inch x 70-teeth Steel Demon Carbide-Tipped Saw Blade for Thin Metal" in my handheld circular saw, and a "8 in x 54-teeth Steel Demon Carbide Tipped Saw Blade for Thin Metal" in my bench top table saw.

Abrasive cutting wheels can be used when other methods cannot be used. I used an abrasive cutting wheel to trim the windshield for the Bearhawk, as it was impossible to feed this large formed piece of plastic through a band saw. Take care not to leave the cutting wheel in contact with the acrylic for too long and overheat the plastic.

A common method that is frequently advertised is to cut acrylic in a similar fashion as glass. That is to scratch the sheet to create a weak spot, then bend the sheet with the scratch in tension so that it snaps along the scratch. I'm not a big fan of this method, as I have not had good luck with it. Tools are sold for this purpose, but it doesn't work with just a single pass. Multiple passes must be made to make the scratch rather deep. This only really works for straight cuts. It can be difficult to keep the hand-held cutter from deviating from the straight scratch and possibly damage the part. When snapping the part, the plastic doesn't always break along the scratch, leaving little pieces hanging outside the scratch, which are then difficult to grab to snap off. Also, the fractured edge is not very smooth. Both of these issues result in a lot of sanding to dress the edges properly.

Finally, absolutely DO NOT TRY TO CUT ACRYLIC WHILE COLD! Doing so is just asking for cracks because the plastic will be brittle. The acrylic must be at least at room temperature when cutting.

How Do I Drill Acrylic?

To safely drill a hole in acrylic you should use purpose made twist drill bits for drilling plastic. These bits have a specially ground point, a 60° included tip angle, a 0° rake angle, and the shoulder relieved for drilling acrylic sheet to prevent fractures, chipping or cracking. This results in a scraping action instead of a cutting action. Using a regular twist drill bit will generally chip the plastic around the hole. It is possible to modify regular drill bits with a grinder if you understand what the result is supposed to be. Appropriately modified drill bits can be purchased from Aircraft Spruce & Specialty and other suppliers.

For larger holes, a standard step bit can be used.

Don't use your acrylic drill bits for anything other than plastic. Trying to use them on metal will not be effective and will damage the drill bits.

Dressing the Edges

Whatever method you use to cut the acrylic, it will leave an edge that is rough to some degree. This roughness can be considered as micro-cracks, which can very probably grow to large cracks if not addressed. Acrylic is essentially brittle to some degree, which means that small cracks under stress will tend to become large cracks. The solution is to smooth the edges. Tools are sold which are scrapers for acrylic edges, which when drawn over the edge will smooth it and possibly round off the corners. The acrylic edge can also be smoothed with a metal file. However, the simplest approach seems to be a sanding block with 320 grit sandpaper, the same kind you would use on wood.

How Do I Attach Acrylic?

To join acrylic to acrylic, the preferred method is to use a cement. The cement works in a similar fashion to plastic model cement on styrene plastic. The cement is a solvent, typically with a viscosity similar to or less than water. The low viscosity lets the cement wick in between close fitting parts by capillary action. The cement partially dissolves the acrylic, allowing joining surfaces to intermingle. Once the solvent evaporates, the joining surfaces become one piece of plastic.

Acrylic cement tends to be available where acrylic is sold. The cement I have used recently is Weld-On 4, which I purchased from Amazon.

Weld-On 4 is listed as “fast set”, with a working time of 1-2 minutes and a fixture time of 3 minutes. Weld-On 3 is listed as “very fast set”, with a working time of 1 minute and a fixture time of 2 minutes. Because Weld-On 3 is very fast setting, in high humidity it is more likely to leave white marks, also called “blushing”, much like nitrate or butyrate dope. The slower setting of Weld-On 4 is more tolerant of humidity, allowing moisture more time to escape.

Since part of the cementing process requires the solvent to evaporate, you might expect that acrylic cement would have an elevated amount of volatile organic compounds (VOCs), and you would be correct. Therefore, it cannot be shipped to certain locations, such as Los Angeles, San Bernardino, Orange or Riverside counties in California. If you are in one of these counties, or just prefer lower VOCs, you can order Weld-On 4SC.

Something about Weld-On 3/4/4SC is considered hazardous, so it can only be shipped by ground transport. Plan ahead or be patient.

If you need to fill gaps, possibly because your parts are not tight fitting, it is possible to purchase a thickened cement. I once bought some from an outfit that sold it for building aquariums. I would tell you where, but they no longer exist.

Acrylic can be joined with cyanoacrylate cement (super glue), but the bond is between the cement and the plastic, rather than plastic to plastic. This could be used for permanent bonding to wood or metal, and would probably work best if the surfaces are scuffed.

To join acrylic to fiberglass, simply scuff the acrylic, then bond it in with the fiberglass and resin.

For removeable connections to aluminum, wood, or other types of frames, machine screws can be used through holes in the acrylic. However, acrylic expands and contracts at significantly different rates from aluminum, wood, and other materials. Thus, the holes in the acrylic around the screws must be significantly larger than the screws to allow room for expansion and contraction. Do not use the screws directly on the acrylic. Use a large washer or a sheet of other material. When installing the screws, tighten the screw until snug, then back it out 1/4 to 1/2 turn to relieve the stress. The machine screw will need to be mated with a locknut or locking nutplate to prevent backing out.

How Do I Heat Form Acrylic?

Simple bends in acrylic can be made by heating the acrylic with a heat gun. For complex shapes, the acrylic can be heated in an oven to soften it, and then stretched over a mold. To form the position light lens for my Bearhawk, the acrylic was stretched over the actual wingtip before the fiberglass was cut. See the YouTube video mentioned above.

The mold should be covered with fabric, such as a cotton T-shirt (don’t use polyester—it will melt), felt or flannel. This will allow a path for the heated gasses to escape.

Tony Bingelis says that you will need a Contour Restraining Template to keep the bottom edges from pulling away from the form. This can be simply a piece of plywood that duplicates the shape of the bottom of the plug with a clearance all around to allow for the thickness of the acrylic.

Start with a piece of acrylic much larger than the final part.

You will need a frame or at least handles to hold the acrylic. Tony Bingelis shows a rectangular frame of two pieces of plywood with bolts only on two opposing sides. I used two strips of wood on each end of the acrylic, sandwiching the ends of the acrylic. This gives something to hold onto while stretching the acrylic.

You will need something like a sheet of aluminum to place under the acrylic while heating in the oven. As the acrylic softens, it will droop. If it droops on the wire racks of the oven, the racks will probably leave marks in the plastic. Drooping onto a smooth sheet of aluminum should not leave any marks. This will also help the acrylic to heat evenly and not burn.

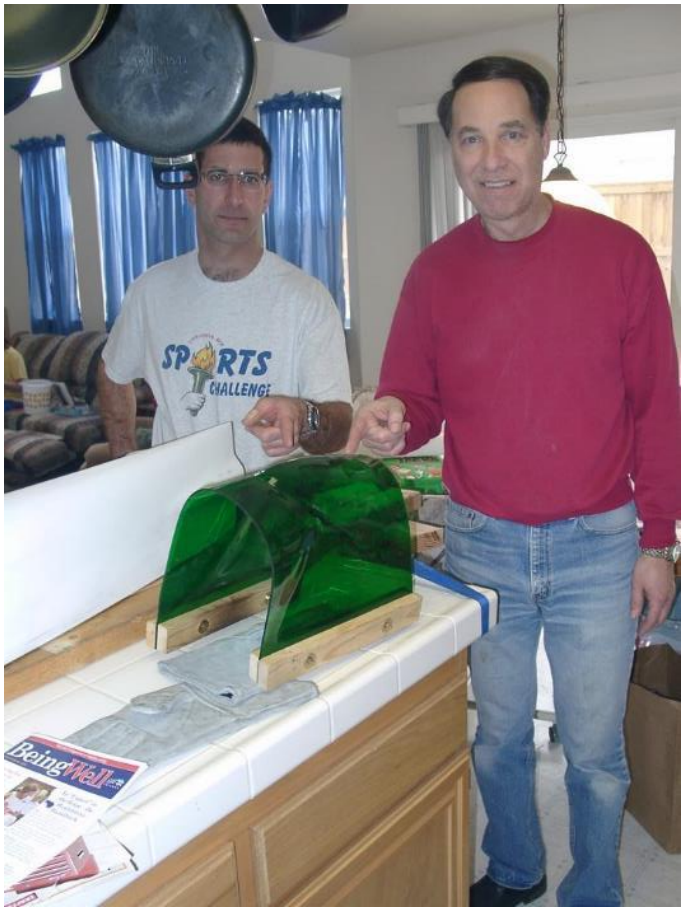
Place the acrylic into a cold oven, then turn the oven on to 350 degrees Fahrenheit (177 degrees Celsius). After 5 to 7 minutes, the acrylic will begin to get rubbery and may sag. You may see a few bubbles begin to appear near the edges. Using oven mitts or welder's gloves, grab the frame or handles and pull the acrylic out of the oven. The wood will be too hot to touch even though it is not burning and you think of it as an insulator. Don't be surprised if you have to peel the aluminum sheet off of the acrylic if they are in contact.

Quickly stretch the floppy acrylic over the form. Have a helper press the Contour Restraining Template to press the acrylic against the form. Now you just have to hold this in place as the acrylic cools. If you are impatient, you can try using a vacuum or shop vac set up to blow air over the acrylic to cool it. Don't be too aggressive or it might cause undesirable results.

Note that acrylic that has been heated and cooled will shrink about 2 percent and will get slightly thicker.

Green acrylic ready for heating. Wood 1x2s are bolted to each end of the acrylic to be used as handles. This version was suspended over wood 2x4s. Later iterations would be suspended over an aluminum sheet. The apparent light bulb on the acrylic is a reflection of the oven bulb.

The acrylic was stretched over the mold, handling it by the handles with welding gloves or oven mitts. The Contour Restraining Template presses the acrylic against the mold. The vacuum hose set to blow is used to cool the acrylic.



The molded lens after molding and before trimming

How Do I Smooth the Rough Surface Caused by Forming or Polish Out Imperfections?

As mentioned before, a cut edge should be dressed to minimize microcracks. This can be done with a scraper, but can easily be done with a sanding block and 320 grit sandpaper, the same type you use on your woodworking projects.

I have seen some videos on YouTube claiming that you can use a propane torch on the edges to slightly melt the acrylic to smooth and clarify the plastic. I'm not sure I can recommend this method, as it seems that too little is not enough and too much will damage the part, and the difference between not enough and too much is rather small.

A higher workload but far more reliable method is progressive sanding. The idea is to sand out the imperfections, then continue sanding with progressively finer grits to remove the scratches from the previous grit of sanding. While 320 grit is considered pretty fine for woodworking, it is actually rather coarse for acrylic. When I formed the position light lenses for the Bearhawk, I used 320 grit to remove the roughness on the inside that was left by the felt that was covering the mold during forming.

After smoothing the major imperfections, the acrylic will be essentially opaque, and you will wonder if it will ever be transparent again. You must have faith in the process. Sand the part with 600 grit, following that with 1000 or 1200 grit. These grits should be available at your favorite hardware store or McMaster-Carr. For finer grits, you will need something like the Micro Mesh kit, available at Aircraft Spruce & Specialty. Another alternative is kits sold for restoring yellowed headlights. The Micro Mesh kit includes sandpaper in grits of 1500, 1800, 2400, 3600, 4000, and 6000. These grits are typically used wet with water to help carry away the removed plastic particles. A foam block is provided to use on relatively flat or convex surfaces. A liquid abrasive is included for use after all of the sandpaper grits, but I haven't found it to really be necessary. Don't skip any grits—you won't like the results. Each grit removes the larger scratches from the previous grit, but will leave smaller scratches of its own. If you skip a grit, the sandpaper will be too fine to remove the previous scratches, and it won't get better with even finer grits.

What Causes Crazing/Cracking?

Residual stress will leave the plastic prone to cracking. If you have to bend the plastic significantly to fasten it into place, the outside surface will be left in tension. Eventually, the little molecules will seek to relieve that tensile stress by letting go of each other, leaving a microcrack that will continue to grow into a significant crack.

Ultraviolet radiation, usually from sunlight exposure, will sunburn the arms of the little molecules, and in pain they will let go of their neighbor's hand, again starting a microcrack.

A post on http://www.keskydee.com/aviation/archives/digest584.txt (which no longer exists) stated "Yes, that's right and as I understand it, if a plain piece of Lexan is bent (without heating it) - even to a generous radius - and held in that form, the bending tension(-) introduced will lower the surface tension(+) of the material. If solvents(-) then are applied, the surface tension lowers even more and cracks can be initiated. A simple test with a scrap bit of Lexan, a bench vise and a few drops of gasoline might explain things better.....squeeze the Lexan piece lengthwise until it buckles, then put on some gasoline on the outside. Tempering the Lexan will however improve things and is also recommended for loaded Lexan parts. The preferred forming method - warm forming - includes some drying pre-treatment to avoid the humidity absorbed by the Lexan to form tiny bubbles within the material when making sharper bends. Data sheets from Polycarbonate/Lexan manufacturers should have all infos and figures. Unfortunately, the story about Lexan is not quite as good as you might wish. After several years in the sunlight, even the gentle bend around the 1 inch tube on my windscreen has started to craze near the side. It also does not like petrol. It becomes very brittle after very short contact."

How Do I Minimize the Crazing?

1. Smooth all edges and all scratches using a scraper or sandpaper.
2. Do not bend parts to install, leaving residual stress. This was done on some covers for the Fightin' Skywagon's landing light covers. The Lexan covers were cracked within 50 hours. Of course, the cowling is a high vibration environment, which doesn't help the situation at all.
3. Make the holes around fasteners (screws, bolts) big enough that the plastic can move around without contacting the fastener.
4. Don't clean the plastic with any products containing petroleum distillates. Cleaners/polishes are readily available that are made specifically for plastic. I have used Plexus (available from Aircraft Spruce & Specialty) to good effect over the years.

- Russ Erb