Helpful Tips On Working With Polycarbonate
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Introduction
Do It With Polycarbonate…

Polycarbonate is a versatile, tough plastic used for a variety of applications, from windows to machine guards. The main advantage of polycarbonate over other types of plastic is unbeatable strength combined with light weight. While acrylic is ten times stronger than glass, polycarbonate is nearly unbreakable. Windows and enclosures are often made of polycarbonate. Add to this the advantage that polycarbonate is just one-third the weight of acrylic, or one-sixth as heavy as glass.

Preparation

The surface protection film can often be left in place during fabrication and all marking-out drawn on the film. The film may also be left in place prior to thermoforming, provided that the sheets have been specifically supplied for this and have a film that is designed to tolerate thermoforming. The film should also be in good condition as any imperfections in the film can cause marks to be transferred to the thermoformed article. It is therefore, the customers’ responsibility to decide whether or not the film should be left in place.
Cleaning

Cleaning of polycarbonate should not generally be required until after fabrication. However, if the product is to be printed, it may be advisable to wash or degrease the surfaces to be printed with isopropyl alcohol (IPA) using a soft cotton cloth. This has the benefit of removing all traces of static charge from the sheet after removal of the film which might otherwise attract dust. If the IPA contains water and water droplets appear after the IPA has evaporated, finish by wiping with a clean, dry cloth.

It is advisable to clean polycarbonate with a soft cloth made from 100% cotton using a mild detergent and water. It is best to use mild dish cleaning preparations. Glass cleaning agents that contain ammonia should be avoided as they will damage the polycarbonate. Use of a mild detergent and water may result in residue build-up. In such cases, commercial spray cleaners which contain specially designed waxes and solvents are available. Polycarbonate sheets should never be cleaned dry as this may cause scratches.

For all general purpose cleaning, polycarbonate should be washed with clean, cold water to which a little mild detergent can be added. The use of any solvents such as methylated spirits, turpentine, white spirit or any proprietary window cleaning products is neither necessary nor recommended.
Machining

Polycarbonate is easy to machine. However, it is important that only light machining cuts are taken and if high speeds are used to achieve good surface quality, it may be necessary to stop the machine periodically to allow the part to cool. Polycarbonate will soften if heated above 130°C and heat build-up due to high friction can cause stress. Therefore, should cooling be required, the use of water or air is recommended during machining.

Routing

Fixed head, moving head or portable standard woodworking routers are suitable for polycarbonate using the same cutter speeds as for wood. Routing can actually be performed dry but all chips or shavings must be cleared and the cutter kept cool. Compressed air directed onto the cutter and work piece would be preferred.

<table>
<thead>
<tr>
<th>Cutter</th>
<th>Spindle Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-12mm diameter or less</td>
<td>ca 24000 RPM</td>
</tr>
<tr>
<td>&gt;12mm</td>
<td>ca 18000 RPM</td>
</tr>
</tbody>
</table>

Cutting Tools

To achieve a good finish when cutting, all tools must be kept sharp. Most conventional tools for use with wood or soft metals are suitable for use with polycarbonate. Most power tools can also be used and HSS tool bits are suitable to achieve a good finish. For longer-life, tungsten carbide tipped blades and tool bits would be beneficial while for accurate work where a high degree of finish is required, diamond tipped tools would be particularly suitable.

For routing, HSS double-edged cutters are preferred, ground and honed with a back clearance angle of about 12° or greater.
Sawing

Powered saws with blades having alternative teeth beveled, as for aluminum, are particularly suitable for polycarbonate as are band saws, jig saws and fret saws. The recommended conditions for sawing polycarbonate are shown below.

<table>
<thead>
<tr>
<th>Saw Type</th>
<th>Optimum Blade Speed (m/min)</th>
<th>Optimum Saw Pitch Teeth/cm</th>
<th>Sheet Thickness</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circular Saw</td>
<td>1800-2400</td>
<td>2-5</td>
<td>All thicknesses</td>
<td>Preferred method for best results</td>
</tr>
<tr>
<td>Carbide tipped</td>
<td></td>
<td></td>
<td></td>
<td>Saw guides as close together as possible to prevent blade twisting</td>
</tr>
<tr>
<td>Band saw</td>
<td>600-1000</td>
<td>1.5-2.5</td>
<td>All thicknesses</td>
<td>Allow blade to stop before withdrawing from saw cut</td>
</tr>
<tr>
<td>Jig Saw</td>
<td>Non-critical</td>
<td>5-6</td>
<td>Up to 6mm</td>
<td></td>
</tr>
<tr>
<td>Fret Saw</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Guillotining

Shear cutting using a guillotine is possible with polycarbonate but not recommended for thickness of more than 4mm as the cut edge may become rough and distorted. The sheets must be well clamped and should be sheared at room temperature, but not lower than 15°C.
Die Cutting

Polycarbonate can be die cut with steel rule dies. The steel rules must be kept sharp and the cut should be completely through the sheet with a stroke that will prevent damaging the cutting rule. Trials are recommended prior to full production to achieve the optimum setting.

The thickness of sheet that can be die cut is anything up to 3.0mm. For die cutting of printed sheets, the printed side should be facing upwards towards the cutting knives.

Laser Cutting

Polycarbonate may be laser cut although the cut usually looks burnt and internal stress may result due to the high local temperatures. When laser cutting, it may be necessary to carry out a short annealing cycle at a temperature of 130°C for around 1-2 hours.

Drilling

Conventional twist drills for use with wood are suitable for use with polycarbonate and hole-saws may be used for larger holes greater than 12mm diameter. However, it is advisable to re-grind twist drills to give a zero rake. A small pilot hole should be drilled first to locate the drill and where possible, the work should be supported by a back stop made from either scrap polycarbonate or wood to prevent splintering the exit hole.

Cooling is recommended, using water or air, for any deep drilling and swarf should be removed at regular intervals.
Screwing and Tapping

Standard taps and dies may be used for cutting screw threads in polycarbonate although the process should be performed slowly and no lubricants should be used. 2-flute taps are recommended over 4-flute taps as they generate less heat whilst tapping and provide better clearance for chip discharge. Wherever possible, coarse threads are preferred as they are less liable to damage. If frequently dismantling, threaded metal inserts would be recommended.

Finishing

Machining marks can be removed by scraping with a sharp blade set at 90° or sanding then polishing. Bench mounted, portable or belt sanders may be used carried out dry with only light pressure applied. After sanding it will be necessary to anneal the work if bonding or any surface decoration is to be applied.

Polishing

There are commercial spray cleaners available which contain specially designed waxes and solvents for polishing glazed surfaces in polycarbonate. The cleaners leave a glossy, protective layer that is anti-static and dust repelling. The ideal procedure is to polish every one to two weeks using a soft 100% cotton cloth.
Thermoforming

To thermoform polycarbonate correctly it must be heated uniformly. Optimum heating times and temperatures will depend upon a number of factors, including thickness of the sheet, the type of mold being used and the degree of stretching required but forming should always be done when the temperature is above the glass transition temperature (Tg) which is approximately 150°C.

Pre-Drying

Before thermoforming, the polycarbonate sheet must be pre-dried at 125°C. The duration of pre-drying will be dependant upon the amount of humidity absorbed by the sheet and by its thickness. The best method to determine the appropriate pre-drying time would be to:

► Cut 2-3 small pieces from a sheet in a sample batch.
► Place these pieces in an oven at the pre-drying temperature (125°C).
► At pre-determined intervals of 2-3 hours, take a piece out and heat it to the forming temperature (170°-180°C).
► Check for appearance of bubbles – if no bubbles appear after 10 minutes the sheet is dry.
► If bubbles do appear, additional pre-drying time is necessary.
► Repeat the test in order to determine the appropriate pre-drying time required.
Heating

As a general rule, a pre-dried polycarbonate sheet can be safely heated up to 180°–190°C and at this temperature behaves in a manner that enables it be formed into complex shapes with tight curves and deep draw.

Except when local bending, the entire area of the sheet should be uniformly heated with an air circulating oven with accurate temperature control preferred. Vertical hanging is the recommended method with suitable hanging clamps to suspend the sheets along their longest dimension.

As an alternative to air oven heating, certain infra-red heaters can be used such as those with quartz or ceramic elements. However, these do heat the surface of polycarbonate very quickly, so heaters and heated platens must be designed to give uniform heating under controlled conditions to prevent overheating and degradation of the sheet.

Shrinkage

When polycarbonate sheet is heated it will exhibit more shrinkage along the direction of extrusion and very little across the direction of extrusion. It is difficult to give precise figures for shrinkage which will depend on the thickness and heating time but as a rule, sheet up to 2mm in thickness may exhibit shrinkage of up to 5%.
Cooling

After thermoforming, the polycarbonate sheet can be lifted off the mold at a temperature of around 90°C and to prevent warping, moldings can be placed in cooling jigs or counter-bowed if necessary until room temperature is achieved.

Vacuum Forming

Polycarbonate is ideally suited to the vacuum forming process as it has high extensibility and therefore, high definition within the mold. It is preferable to use automatic machines that grip the sheet from all sides during the entire process.

Vacuum forming with pre-drying may be carried out using shallow molds and in this case the sheet temperature should not exceed 160°C. Uneven heating, resulting in local heating above 160°-165°C may cause bubbles to appear in the overheated area.

Molds

For long production runs and high quality mold detail, cast aluminum molds cored for water cooling are recommended. A smooth, matt finish is preferred and all dust must be kept clear of the mold surfaces to prevent dust marks. Mold temperatures should be maintained at between 90° – 100°C.

Note: all times and temperatures will vary from that stated when thermoforming polycarbonate mirror.
Drape Forming

Unaxial bent parts can be achieved by drape forming over molds made out of wood or aluminum and covered with felt. Polycarbonate sheets should be heated to 150°C with only slight pressure necessary to drape the sheet over the positive mold. The sheet should be placed over the mold immediately after heating and left to cool down in room temperature.
Hot Line Bending

Hot line bending requires that the polycarbonate sheets are softened along a narrow line by a strip heater, usually a hot wire. When the shaping temperature is reached, not below 155°C (maximum temperature 167°C) the sheet can be bent to an angle several degrees larger than the desired angle, dependant upon the degree and rate of cooling. Trials should be performed on small samples to determine the appropriate value before proceeding to full production. For sheets thicker than 3mm, double-sided heating is recommended.

Hot line bending can be performed with the film on the sheet except when working on a thickness of 6mm or more. For thicker sheets the heating time and temperature on the surface of the sheet will be too high causing the film to melt locally. However, it is possible to remove the film along the bend line before forming so that most of the sheet remains protected.

Stress generated by local line bending can lead to stress-cracking or crazing especially if the sheet is then bonded or decorated. However, stress can usually be reduced, else eliminated by the process of annealing.

After parts have been cooled, they can be checked for impact resistance by hitting the bend line with a heavy hammer with the bend line up. Breakage of the part would indicate that the bending temperature was too low.

Metal contact heaters may not be suitable for use with polycarbonate as they may stick to the surface of the sheet and cause marks.
Cold Line Bending

Polycarbonate sheets may also undergo cold line bending, albeit a specific procedure is to be followed.

First of all, the sheet should be cut to its pre-bending size and the edges finished so that they are smooth with no saw marks or roughness that may initiate a crack along the bend line. The sheet should then be bent at a relatively high speed with the surface protection film in place. To achieve the desired angle, the sheet should be bent 20-40° larger than the desired angle. Again, trials would be recommended on small samples to determine the appropriate value before proceeding to full production.

It is also recommended to use the appropriate tools designed for use with plastic sheets and to have a knife and anvil that possess a good polished surface with no projections or splinters. The knife should have a straight parallel profile with a rounded tip having a radius of 4-6mm - the thicker the sheet, the larger the radius required. It is also important that care is taken not to squeeze the sheet between the knife and anvil when bending. Squeezing of the sheet will cause a bend that may induce high stresses and subsequently, reduce the impact resistance of the product.

Polycarbonate sheets may also be installed with a stressed curve to create an arch or dome as long as the curve and resulting stress is within a specified limit, calculated by the radius being at least 200 times that of the sheet thickness as shown below.

<table>
<thead>
<tr>
<th>Desired Radius (mm)</th>
<th>Thickness Required (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>3</td>
</tr>
<tr>
<td>800</td>
<td>4</td>
</tr>
<tr>
<td>1000</td>
<td>5</td>
</tr>
<tr>
<td>1200</td>
<td>6</td>
</tr>
<tr>
<td>1600</td>
<td>8</td>
</tr>
</tbody>
</table>
Annealing

It is advisable to anneal all polycarbonate sheet components before bonding, painting or printing.

A rapid annealing cycle which is reliable, especially for thin sheets, is to pre-heat the oven to 130°C, anneal for 1-2 hours, then remove the parts from the oven and allow to cool to room temperature.

Additional Information

Important notice: The information and statements herein are believed to be reliable but are not to be construed as a warranty or representation for which we assume legal responsibility. Users should undertake sufficient verification and testing to determine the suitability for their own particular purpose of any information or products referred to herein. No warranty of fitness for a particular purpose is made.

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