

Technical Manual, June 2012

Makrolon[®] Solid Polycarbonate Sheets

Machining

1. General remarks

Tools

Makrolon[®] sheets can be machined using the standard tools commonly used for metal and woodworking. We recommend carbide-tipped tools. Above all, it is important to use sharp cutting tools with the right geometry.

Cooling

No cooling is required during the normal machining of Makrolon[®] sheets. In the event of local overheating during machining – e.g. when drilling through very thick materials – we recommend cooling with water or oil-free compressed air.

Oil emulsions and cutting oils should not be used when machining Makrolon[®] as these may contain additives to which Makrolon[®] is not resistant, resulting in stress crack formation.

Dimensional accuracy

The coefficient of linear expansion of Makrolon[®], at 0.065 mm/m°C, is significantly higher than for metal or glass. For this reason, dimensions should always be checked at room temperature.

Remember that shrinkage of approx. 3 to 6 % depending on thickness occurs when the material is heated above the glass transition temperature (approx. 145 °C) for the first time.

Protective Masking

Makrolon[®] sheets are provided with a PE masking film to protect the smooth surfaces from damage during transport and fabrication.

Please leave the film on the sheet during machining. Solar radiation and weathering may influence the properties of the film and make it very difficult to remove later on (possible formation of adhesive residues).

Our **standard protective masking film is not suitable for exposure to thermal loads**, and does not allow thermoforming with good results. The film should therefore be removed from the sheets before processes such as drying, hot line bending and/or thermoforming.

We have specially manufactured, unprinted grades of film that allow the sheets to be fabricated with the protective masking left on.

Marking

Marking out drill holes, cut edges etc. should be done on the protective film. If marking is required, use a soft pencil or felt-tip pen. Marking tools should not be used as the tracing mark has a notching effect, and a higher load at this point may cause the sheet to crack.

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2. Sawing

Hand saws

Standard hand saws may be used to cut Makrolon® sheets. A saw with fine spacing between the teeth should be used.

Circular saws

Using a circular saw is the easiest way to cut Makrolon® sheets.

Experience has shown that carbide-tipped circular saw blades produce the cleanest cuts. The spacing varies from fine for thin sheets to coarse for thicker materials. Ensure that no shavings are left on the cutting surface as these could damage the protective film and scratch the Makrolon® sheets.

When handling sheets less than 1.5 mm thick use a thick underlay board or a pair of shears instead of a circular saw.

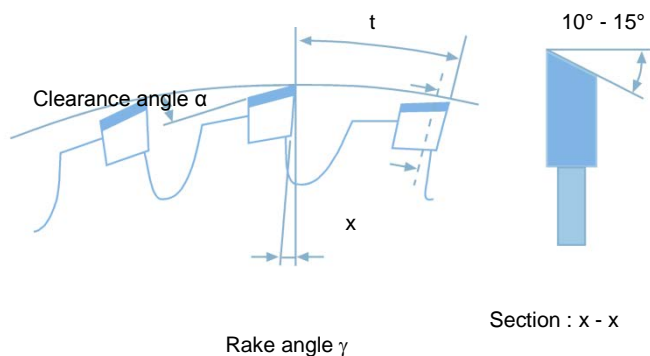


Fig. 1: Circular saw blade

Ribbon saws

Ribbon saws are ideal for curved cutting of formed parts or irregular shapes. To achieve a clean cut edge it is important to work on a solid cutting surface. A wide spacing is required when working with thick materials.

For higher quality cut edges, circular saws or milling cutters achieve a better result than ribbon saws.

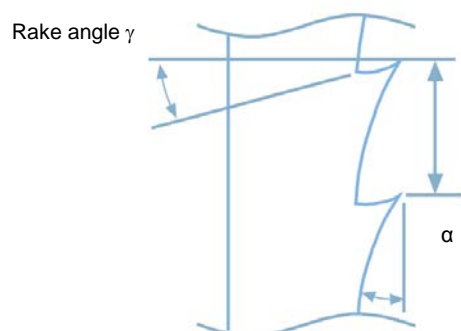


Fig. 2: Ribbon saw

Trouble-shooting

Fused cut edge:

- Check tool sharpness
- Check cutting speed and reduce if necessary
- Check rate of advance and reduce if necessary
- Cool if necessary

Notched cut edge:

- Check tool sharpness
- Check tool geometry
- Improve cutting surface (use an underlay if necessary)

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	Ribbon saw	Circular saw
Clearance angle α	20 - 40°	10 - 30°
Rake angle γ	0 - 5°	5 - 15°
Cutting speed v (m/sec)	10 - 17	17 - 50
Spacing t (mm)	1.5 - 3.5	2 - 10

3. Cutting and punching

Makrolon® sheets up to 3mm thick are easy to cut and punch, producing a good cut result. How thicker the sheet, the poorer the quality of the cut and the greater the risk of cracking.

Good results can be obtained using a sharp shearing tool with a wedge angle of max. 45°, with clearance between the tool and the cutting surface of 0.01 to 0.03 mm (see Fig. 3)

If you require smooth cut edges it is better to saw or mill Makrolon® sheets with a thickness of 1.5 mm upwards.

When punching close-tolerance holes, allowance must be made for shrinkage if machining is to be followed by heat treatment of over 145 °C. This means that the hole should be measured approx. 5 % larger than actually required. How bigger the hole and the thicker the sheet, the lower the tendency for the sheet to shrink. Good results are obtained using symmetrically ground shearing tools.

For punching/cutting Makrolon® sheets that are more than 1.5 mm thick, we recommend asymmetrically ground blades. To achieve right angles, blades ground on one side with a wedge angle of 30° should be used. Make sure that the base plate (polyamide or polyethylene HDPE with a high molecular weight) remains in place and is properly centered with the punching tool to ensure clean cut edges.

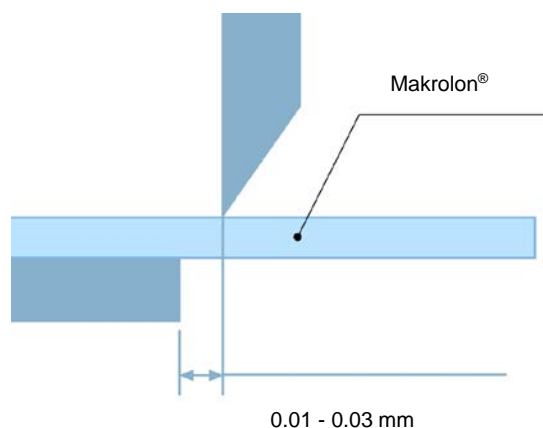


Fig. 3: Clean cut edges - clearance between blade and supporting surface: 0.001 - 0.03 mm

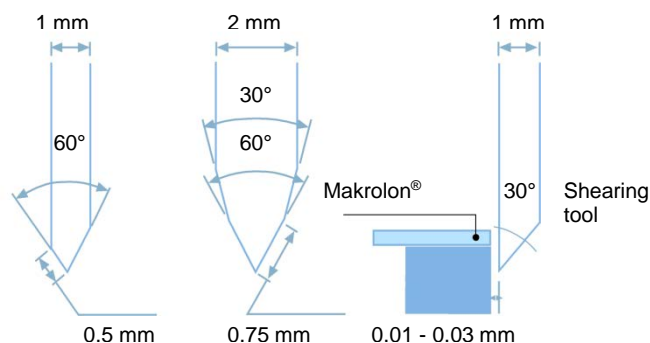


Fig. 4: Depending on sheet thickness, various different types of cutter are recommended for punching.

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4. Drilling

Standard drills used for metalworking are perfectly suitable for machining Makrolon[®]. Make sure that the cutters on the drill are sharp. Cooling during drilling is generally not necessary.

When working with relatively large drilling depths we recommend using water or compressed air and/or regularly withdrawing the drill from the hole to reduce heat and remove shavings.

Oil/water emulsions or cutting oils should not be used when drilling through Makrolon[®] sheets. Standard circle-cutting equipment (e.g. circle cutters or compass saws) is suitable for large-scale drilling. The drill holes should be smooth and as free as possible of notches or rough areas to ensure secure fastening.

Recommended angles for drilling:

Clearance angle α	5 - 15°
Rake angle γ	0 - 5°
Point angle	110 - 130°
Helix angle β	19 - 40°
Cutting speed	15 - 30 m/min
Feed	0.1 - 0.3 mm/rev

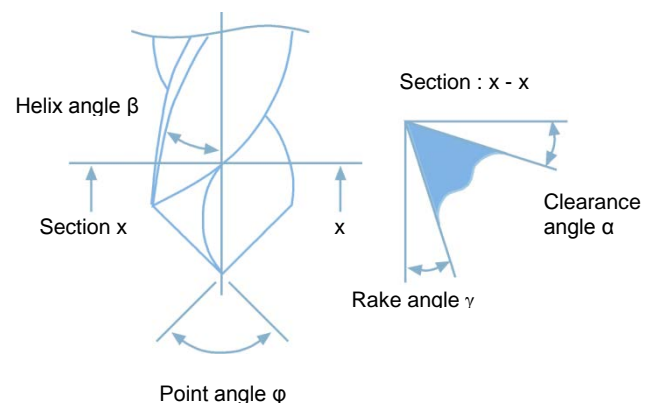


Fig. 5 Drills for Makrolon[®] sheets

5. Milling

Makrolon[®] sheets are easy to process using milling machines. The choice of milling machine depends on the type of machining required. Ensure that your tool has good chip clearance and sharp cutters.

Recommended angles for milling:

Clearance angle α	5 - 10°
Rake angle γ	0 - 10°
Cutting speed	100 - 500 m/min
Feed	0.1 - 0.5 mm/rev

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6. Laser cutting

Various designs of laser can be used for the thermal cutting of Makrolon® sheets – with or without film. Lasers are particularly suitable for cutting complex contours. To achieve a bubble-free cut edge, the Makrolon® sheets need to be pre-dried after which it is recommended that they be conditioned.

Laser beam cutting of Makrolon® sheets that are more than 2 mm thick leads to colouring at the edges.

7. Grinding

Makrolon® sheets can be ground either dry or wet using industrial abrasives to prepare for polishing. The contact pressure between the grinding tool and the workpiece should be kept low to avoid melting.

When grinding it is recommended that you use different grits in succession (e.g. in the sequence 150, 240 and 400).

Polishing

Medium-density riding polishing wheels with a peripheral velocity of 20 to 30 m/s can be used to polish Makrolon® sheets with alkalifree polishing pastes.

A clean polishing wheel without polishing paste is then used to complete the polishing process.

Large-surface polishing should be avoided.

Decorating

Before treating Makrolon® sheets – e.g. by coating, screen printing or thermoforming – we recommend removing any loose particles of dirt or dust adhering to the surface using ionized air.

The **low surface adhesion of Makrolon® AR** sheets makes decorating very difficult. The **mat side of Makrolon® NR is not suitable** for printing.

Coating and printing

Once cleaned, Makrolon® may be coated and printed without any other pre-treatment.

Care should be taken to ensure that the coatings and printing inks are chemically compatible with Makrolon®. Otherwise, the properties of Makrolon® may be impaired. Various manufacturers can provide suitable ink systems. The manufacturer's instructions should be followed at all times. We recommend only using sheets that have a plain, self-adhesive protective film on them in order to avoid colour and adhesive residues that could prevent or disrupt the printing process. Claims for this are not due to material error and cannot therefore be accepted.

Hot embossing

Makrolon® sheets may be heat embossed with embossing film.