MACHINIST'S TOOLKIT

Guide to machining plastic parts

Metric system

Specifications to consider when machining high-performance thermoplastic parts, provided by the Technical Services Department

MITSUBISHI CHEMICAL GROUP

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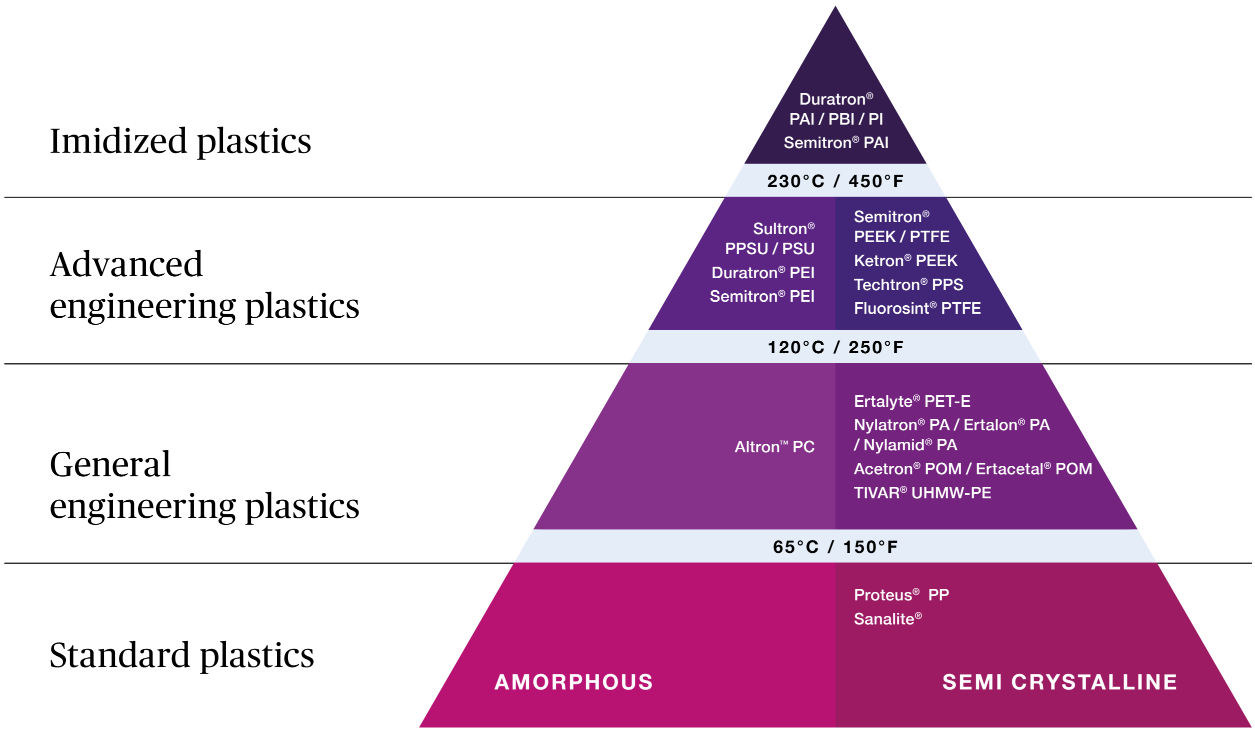
Machining instructions for MCG stock shapes

The stock shapes of Mitsubishi Chemical Group (MCG) Advanced Materials Division can easily be machined on ordinary metalworking and in some cases on woodworking machines. However, there are some points, which are worth noting to obtain improved results.

- Tools must be always kept sharp and smooth; specific polymer group determine the type of tools to be used.
- Feed rates should be as high as possible.
- Tools must have sufficient clearance so that the cutting edge only comes in contact with the plastics material.
- A good swarf removal from the tool must be assured.
- Coolants should be applied for operations where plenty of heat is generated (e.g. drilling).



Keep it cool!

Due to poor thermal conductivity and lower melting properties the main skill is to avoid heat build up and evacuate swarf. This avoids deformation, stress build up or even melting.

- When machining Nylons, UHMW-PE and softer materials- go for maximum feed and speed to get swarf away from tool and avoid swarf build up or wrap around.
- Select tools with large clearance to allow swarf evacuation and deeper cuts.
- Use milling cutters with two or three flute with higher helix.
- Try to use air blast or vacuum venturi.
- HSS works well but solid carbide is stiffer.
- Try to use air blast.
- On glass or carbon fiber use carbide, reduce speed and increase feed rates.

Meech air blasters are ideal

Cooling plastics

Coolants are generally not required for most machining operations (not including drilling and parting off). However, for optimum surface finishes and close tolerances, nonaromatic, water soluble coolants are suggested. Spray mists and pressurized air are very effective means of cooling the cutting interface. Mineral oil based cutting fluids, although suitable for many metals and plastics, may contribute to stress cracking of amorphous plastics such as Altron™ PC, Sultron® PPSU, Duratron® U1000 PEI, and Sultron® PSU.

If using coolant on amorphous materials wash immediately in Isopropyl alcohol and pure water post machining!

Cutting tools

The cutting (polymer) material naturally has a serious effect on the service life of the tool. The MCG Advanced Materials Division recommends the use of HSS, carbide, diamond coated, PCD or CVD cutting tools.

- HSS- High-speed Steel tools work well with many plastics.
- Carbide tools are preferred for longer production runs
- Polycrystalline diamond (PCD) or Chemical Vapour Deposition (CVD) diamond tip tooling are essential when machining glass and/ or carbon fiber reinforced or graphite filled materials.
- Machining Duratron® CU60 PBI, Duratron ® PI or Fluorosint ® MT-01 PTFE, Polycrystalline diamond tooling provides optimum results, carbide tipped tools can then be used in case of very short production runs.

Billeting/ Cutting

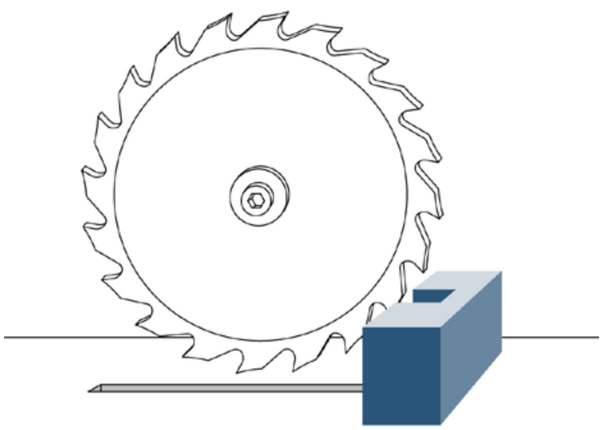
- Circular, band, reciprocating and guillotine saws are generally suitable for cutting thermoplastics
- Set of teeth (clearance between teeth side and body of cutter) must be as large as possible to prevent material closing and trapping blade
- Teeth per inch (TPI) must be suited for material:
  - soft low temperature materials need low TPI
  - filled and thinner materials require higher TPI

Reinforced materials such as Ertalon® 66 GF30 PA66, Duratron® T4301 PAI, Duratron® T4501 PAI, Duratron® T5530 PAI, Ketron® HPV PEEK, Ketron® GF30 PEEK, Ketron® CA30 PEEK Techtron® HPV PPS, Semitron® ESd 410C PEI and Semitron® ESd 520HR PAI are preferably cut with a band saw with a tooth pitch of 4 to 6 mm (Duratron® CU60 PBI, Duratron® PI and Fluorosint® MT- 01: 2-3 mm).

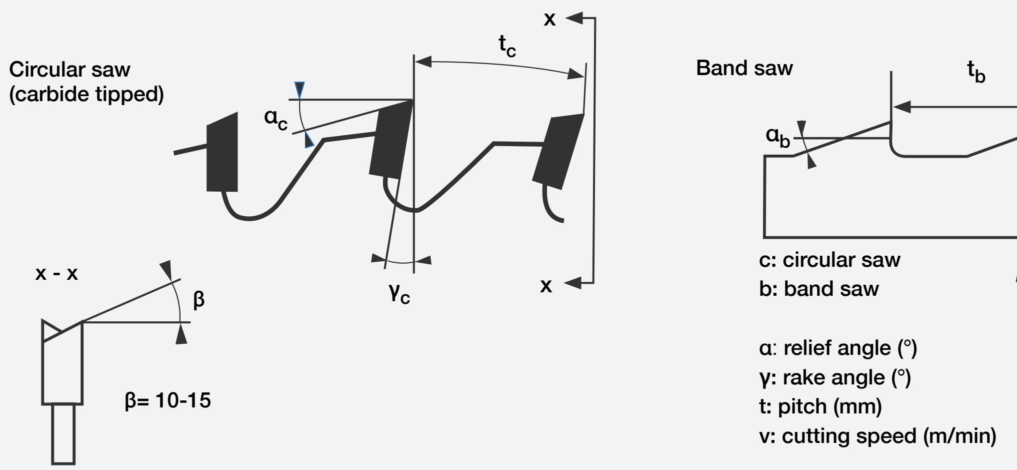
Do not use standard circular saws as this usually leads to cracks!

Clamping tools

- Plastics are more ‘elastic’ so squeeze when clamped
- They can bow more easily
- Less force required to cut and there
- Vacuum systems work well for routing and light milling
- Double sided tape can be used for small thin parts
- Invest in high quality clamps for routing and milling



Data sawing



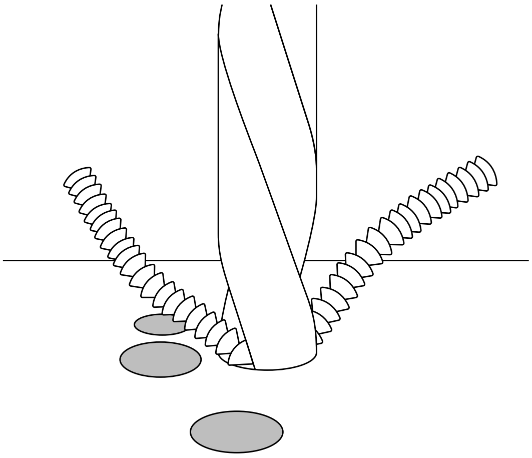
	α_c	γ_c	t_c	v_c	α_b	γ_b	t_b	v_b
Ertalon® PA / Nylatron® PA, TIVAR® UHMW-PE	10 - 15	0 - 15	8 – 45	1,000-3,000	25 - 40	0 - 8	4 - 10	50 - 500
Ertacetal® POM, Semitron® ESd 225	10 - 15	0 - 15	8 – 45	1,000-3,000	25 - 40	0 - 8	4 - 10	50 - 500
Ertalyte® PET, Duratron® T4203 / 4503 PAI, Ketron® 1000 PEEK, Ketron® TX PEEK	10 - 15	0 - 15	8 – 25	1,000-3,000	25 - 40	0 - 8	4 - 10	50 - 400
Altron™ PC, Sultron® PPSU, Duratron® U1000 PEI, Sultron® PSU	10 - 15	0 - 15	8 – 25	1,000-3,000	25 - 40	0 - 8	4 – 6	50 - 400
Ertalon® 66 GF30 PA6, Duratron® T4301 / T4501 / T5530 PAI, Ketron® HPV / GF30 / CA30 / VMX PEEK, Techtron® HPV PPS, Semitron® ESd410C / 520 HR	10 - 15	0 - 15	8 – 25	1,000-3,000	25 - 40	0 - 8	4 – 6	50 - 200
Duratron® CU60 PBI, Duratron® PI, Fluorosint® MT-01 PTFE	10 - 15	0 - 15	8 – 25	1,000-3,000	25 - 40	0 - 8	2 – 3	25 - 100
Fluorosint® 135 / 207 / 500 PTFE, Semitron® ESd 500HR	10 - 15	0 - 15	8 – 25	1,000-3,000	25 - 40	0 - 8	4 – 6	50 - 200

Troubleshooting sawing

DIFFICULTY	MELTED SURFACE	ROUGH FINISH	BURRS AT EDGE OF CUT	CRACKING OF CHIPPING OF CORNERS	CHATTER
Common cause	• Tool dull or heel rubbing • Insufficient side clearance • Feed rate too slow • Spindle speed too fast	• Feed too heavy • Incorrect clearance angles • Sharp point on tool (slight nose radius required) • Tool not mounted on center	• No chamfer provided at sharp corners • Dull tool • Insufficient side clearance • Lead angle not provided on tool (tool should ease out of cut gradually, not suddenly)	• Too much positive rake on tool • Tool not eased into cut (tool suddenly hits work) • Dull tool • Tool mounted below center	• Too much nose radius on tool • Tool not mounted solidly • Material not supported properly • Depth of cut too heavy (use 2 cuts)

Drilling

Plastics can build up heat very easily during drilling operations, especially when hole depths are greater than twice the diameter. Therefore a cooling liquid is generally recommended.



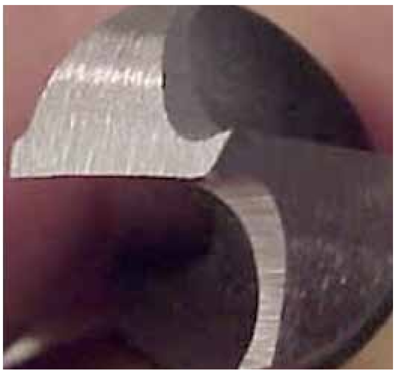
Small diameter holes (0.5 – 25 mm diameter)

High speed steel twist drills generally work well. In order to improve heat and swarf removal, frequent pull-outs (peck-drilling) are necessary. A slow spiral (low helix) drill will allow for better swarf removal.

Large diameter holes (25 mm diameter and larger)

It is advised to use drills with a thinned web (dubbed drill) in order to reduce friction and hence heat generation. Drill large holes stepwise: a bore diameter of 50 mm e.g. should be made by drilling successively with Ø 12 mm and Ø 25 mm, then expanding the hole further with larger diameter drills with a single boring tool.

For pilot holes for internal threads always check actual cutting size of drill. Most plastics close up after drilling. This can make taps tight.



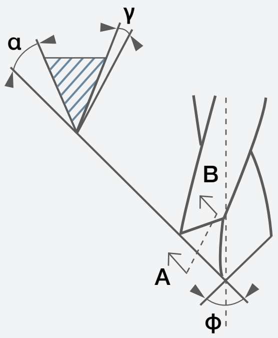
Thinning of web is recommended on larger drills

Insert drill on solid pieces with right inserts

Spade drills can be useful

Data drilling

Section AB



ϕ: top angle (°)
α: relief angle (°)
γ: rake angle (°)
s: feed (mm/rev.)
v: cutting speed (m/min)

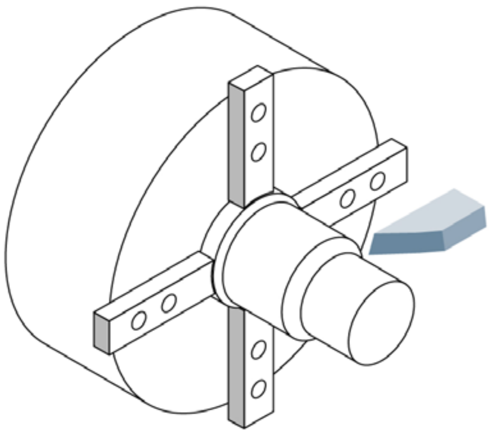
	α	γ	ϕ	s	v	MATERIAL TOOL
Ertalon® PA / Nylatron® PA, TIVAR® UHMW-PE	5 - 10	3 - 5	90 – 120	0.1 - 0.3	50 – 100	HSS steel or carbide
Acetron® / Ertacetal® POM Semitron® ESd 225	5 - 10	3 - 5	90 – 120	0.1 - 0.3	50 – 100	HSS steel or carbide
Ertalyte® PET, Duratron® T4203 / 4503 PAI, Ketron® 1000 PEEK, Ketron® TX PEEK	5 - 10	3 - 5	90 – 120	0.1 - 0.3	50 – 80	Carbide
Altron™ PC, Sultron® PPSU, Duratron® U1000 PEI, Sultron® PSU	5 - 10	3 - 5	90 – 120	0.1 - 0.3	50 – 100	Carbide
Ertalon®66 GF30 / Nylatron® GF30 PA66 Duratron® T4301 / T4501 / T5530 PAI, Ketron® HPV / GF30 / CA30 / VMX PEEK, Techtron® HPV PPS, Semitron® ESd 410C / 520 HR	5 - 10	3 - 5	90 – 120	0.1 - 0.3	50 – 80	Carbide or PCD/ CVD
Duratron® CU60 PBI, Duratron® PI, Fluorosint® MT-01 PTFE	5 - 10	3 - 5	90 – 120	0.1 - 0.3	25 – 50	Carbide or PCD/ CVD
Fluorosint® 135 / 207 / 500 PTFE, Semitron® ESd 500HR	5 - 10	3 - 5	90 – 120	0.1 - 0.3	50 - 100	Carbide

Troubleshooting drilling

DIFFICULTY	TAPERED HOLE	BURNED OF MELTED SURFACE	CHIPPING OF SURFACES	CHATTER	FEED MARKS OR SPIRAL LINES ON INSIDE DIAMETER
Common cause	• Incorrectly sharpened oil • Insufficient clearance • Feed too heavy	• Wrong type drill • Incorrectly sharpened oil • Feed too light • Web too thick	• Feed too heavy • Clearance too great • Too much rake (thin web as described)	• Too much clearance • Feed too light • Drill overhang too great • Too much rake (thin web as described)	• Feed too heavy • Drill not centered • Drill ground off-center
	OVERSIZE HOLES	**UNDERSIZE HOLES**	**HOLES NOT CONCENTRIC**	**BURR AT CUT-OFF**	**RAPID DULLING OF DRILL**
	• Drill ground off-center • Web too thick • Insufficient clearance • Feed rate too heavy • Point angle too great	• Dull drill • Too much clearance • Point angle too small	• Feed too heavy • Spindle speed too slow • Drill-off too leaves nib which deflects drill • Web too thick • Drill speed too heavy at start • Drill not mounted on center • Drill not sharpened correctly	• Dull cut-off tool • 2. Drill does not pass • completely through piece	• Feed too light • Spindle speed too fast • Insufficient lubrication from coolant

Tapping/ Turning threads

- Use of spiral taps is recommended (not straight)
- Where possible use Rigid tap CNC Cycles
- Check pilot drill size
- Go for high quality taps where possible
- Turning threads should be straight forward
- Tools do not have to be as rigid as metal cutting tools



Grades for grooving inserts

Stellram grades SP4030 and SP0436 for grooving inserts are PVD-coated grades with a micrograin substrate. They are designed for machining at higher speeds and lower feeds. There grades are ideal for use on stainless steels and ductile materials. See **inch** and **metric** grade descriptions.

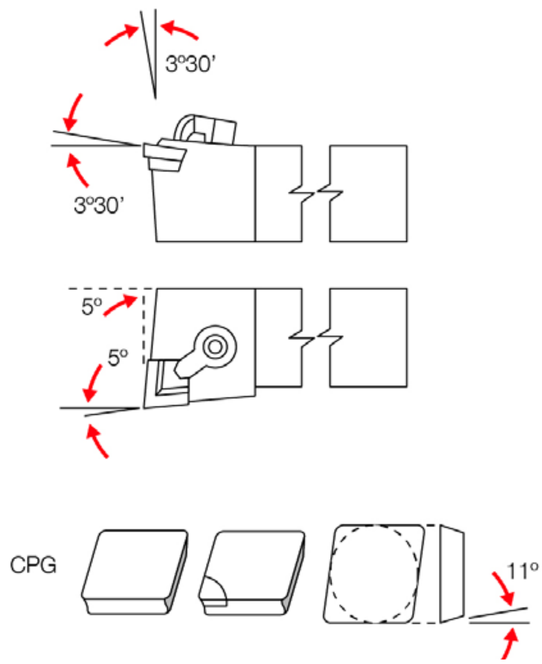
Ultra-Mini internal grooving tools

Our Ultra-Mini grooving inserts and tool holder's portfolio features replaceable carbide inserts with minimum bores down to 0.157" and groove widths from 0.039" to 0.078". The inserts are designed for internal machining of small diameters and are available in a range of reaches and groove width-to-length ratios. See the full inch and metric Ultra-Mini tool offering. Also see inch and metric Mini-Cut for internal grooving.

Turning

Tip Geometry

The continuous chip stream produced when turning and boring many thermoplastics can be handled well using a compressed air powered suction system (directly disposing the swarf into a container), in this way avoiding the chip wrapping around the chunk, the tool or the workpiece.



Turning tips

- Machines should have cavernous area for swarf
- Avoid conveyor belts
- For Tubes you can bore one end and put a blank in to support clamp force of jaws
- Consider fixed pressure jaws on new machines
- Crawford Collets very good for plastic
- Use tip designed for non-ferrous metals such as Aluminum or Brass
- Best finish is achieved with 0.8 rad on tips
- Use hand diamond tools to polish grind marks
- Sometimes it is worth grinding insert tips on top face to sharpen front edge
- For improved tolerances, rough out large sections and leave for 24 hours
- Most diameters will grow so aim for lowest dimension when setting
- Consider doing capability studies on your machines
- Use sliding head for small long sections

Troubleshooting turning

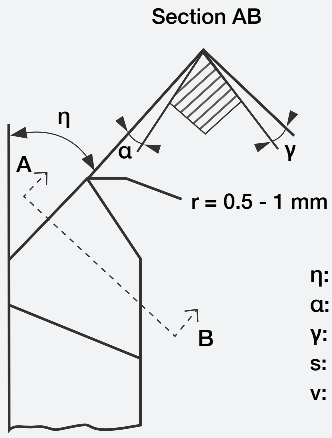
Turning & Boring

DIFFICULTY	MELTED SURFACE	ROUGH FINISH	BURRS AT EDGE OF CUT	CRACKING OFCHIPPING OF CORNERS	CHATTER
Common cause	• Tool dull or heel rubbing • Insufficient side clearance • Feed rate too slow • Spindle speed too fast	• Feed too heavy • Incorrect clearance angles • Sharp point on tool (slight nose radius required) • Tool not mounted on center	• No chamfer provided at sharp corners • Dull tool • Insufficient side clearance • Lead angle not provided on tool (tool should ease out of cut gradually, not suddenly)	• Too much positive rake on tool • Tool not eased into cut (tool suddenly hits work) • Dull tool • Tool mounted below center	• Too much nose radius on tool • Tool not mounted solidly • Material not supported properly • Depth of cut too heavy (use 2 cuts)

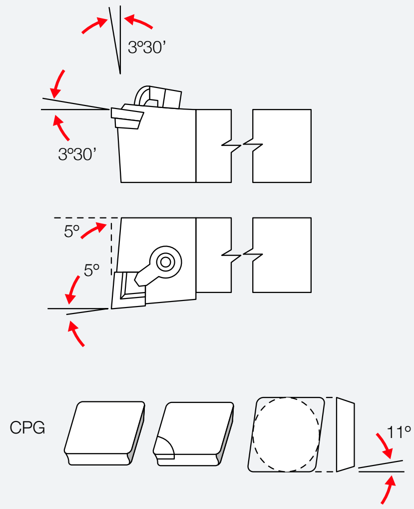
Parting (Cutting-off)

DIFFICULTY	MELTED SUR-FACE	ROUGH FINISH	SPIRAL MARKS	CONCAVE OR CONVEX SURFACES	NIBS OR BURRS AT CUT-OFF POINT	BURNS ON OUTSIDE DIAMETER
Common cause	• Dull tool • Insufficient side clearance • Insufficient coolant supply	• Feed to heavy • Tool improperly sharpened	• Tool rubs during its retreat • Burr on point of tool	• Point angle not great enough • Tool not perpendicular to spindle • Tool deflecting • Feed tool heavy • Tool mounted above or below center	• Point angle not great enough • Dull tool • Feed too heavy	• No chamfer applied before cut-off • Dull tool

Data turning



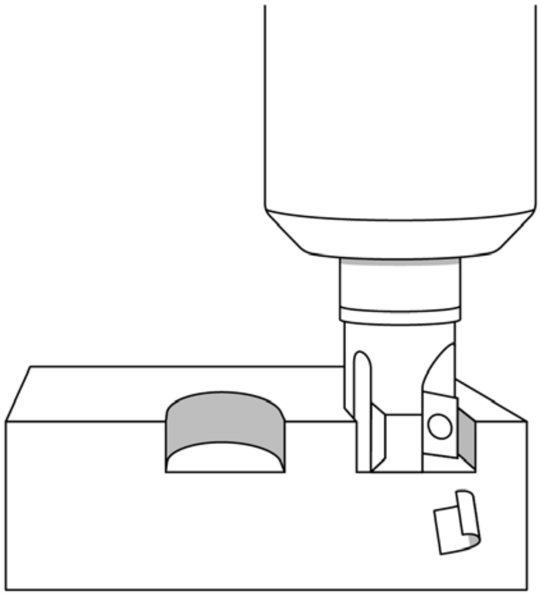
η: slide cutting edge angle (°)
α: slide relief angle (°)
γ: rake angle (°)
s: feed (mm/rev.)
v: cutting speed (m/min)



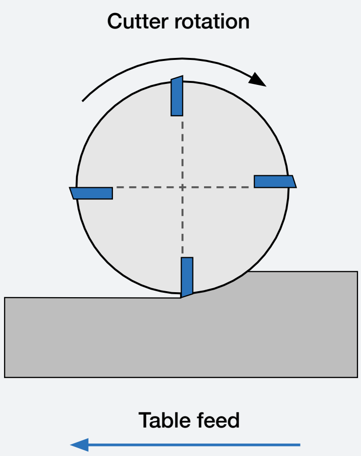
	α	γ	η	s	v	MATERIAL TOOL
Ertalon® PA / Nylatron® PA, TIVAR® UHMW-PE	5 – 15	0 - 10	0 - 45	0.05 - 0.5	200 - 500	HSS steel or carbide
Acetron® / Ertacetal® POM Semitron® ESd 225	5 – 15	0 - 10	0 - 45	0.05 - 0.5	200 - 500	HSS steel or carbide
Ertalyte® PET, Duratron® T4203 / 4503 PAI, Ketron® 1000 PEEK, Ketron® TX PEEK	5 – 15	0 - 10	0 - 45	0.05 - 0.5	200 - 400	Carbide
Altron™ PC, Sultron® PPSU, Duratron® U1000 PEI, Sultron® PSU	5 – 15	0 - 10	0 - 45	0.05 - 0.4	200 - 400	Carbide
Ertalon®66 GF30 / Nylatron® GF30 PA66 Duratron® T4301 / T4501 / T5530 PAI, Ketron® HPV / GF30 / CA30 / VMX PEEK, Techtron® HPV PPS, Semitron® ESd 410C / 520 HR	5 – 15	0 - 10	0 - 45	0.05 - 0.3	100 - 200	Carbide or PCD/CVD
Duratron® CU60 PBI, Duratron® PI, Fluorosint® MT-01 PTFE	5 – 15	3 - 5	0 - 45	0.05 - 0.2	25 - 100	Carbide or PCD/CVD
Fluorosint® 135 / 207 / 500 PTFE, Semitron® ESd 500HR	8 - 12	0 - 5	0 - 45	0.05 - 0.4	150 - 400	Carbide

Milling

- Machines should have cavernous area for swarf.
- Use milling cutters with less teeth, higher helix and good clearances.
- Avoid conveyor belts.
- For milling machines consider vacuuming dry chips.
- Use of Vacuum plates recommended for plate parts.
- Parts can be further supported with surrounds on vacuum plate.
- Avoid machining too much on one side of flat plates.
- Even stress out where pockets are required on one side with opposing face grooves.
- Consider using round billets in some cases to overcome small volume restrictions.

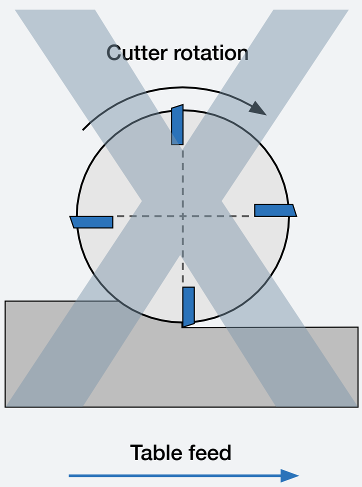


Climb milling (recommended)



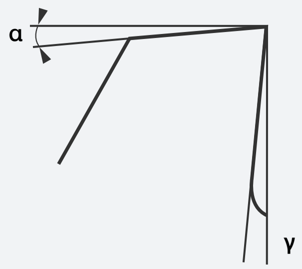
Small break, less heat, better finish

Conventional milling (not recommended)



Large break, more heat, worse finish

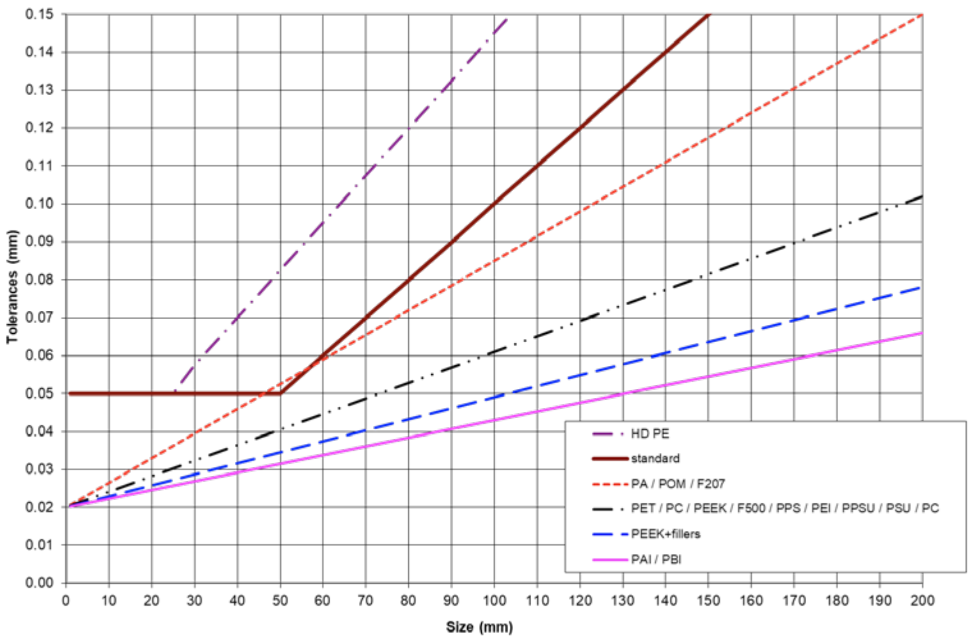
Data milling



α: relief angle (°)
γ: rake angle (°)
s: feed (mm/tooth)
v: cutting speed (m/min)

	α	γ	s	v	MATERIAL TOOL
Ertalon® PA / Nylatron® PA, TIVAR® UHMW-PE	5 – 15	0 - 15	≤ 0.5	200 - 500	HSS steel or carbide
Ertacetal® POM, Semitron® ESd 225	5 – 15	0 - 15	≤ 0.5	200 - 400	HSS steel or carbide
Ertalyte® PET, Duratron® T4203 / 4503 PAI, Ketron® 1000 PEEK, Ketron® TX PEEK	5 – 15	0 - 15	≤ 0.4	150 - 300	Carbide
Altron™ PC, Sultron® PPSU, Duratron® U1000 PEI, Sultron® PSU	5 – 15	0 - 15	≤ 0.4	200 - 400	Carbide
Ertalon® 66 GF30 PA6, Duratron® T4301 / T4501 / T5530 PAI, Ketron® HPV / GF30 / CA30 / VMX PEEK, Techtron® HPV PPS, Semitron® ESd 410C / 520 HR	5 – 15	0 - 15	≤ 0.3	75 – 150	Carbide or PCD/CVD
Duratron® CU60 PBI, Duratron® PI, Fluorosint® MT-01 PTFE	5 – 15	0 - 15	≤ 0.15	25 - 100	Carbide or PCD/CVD
Fluorosint® 135 / 207 / 500 PTFE, Semitron® ESd 500HR	5 – 15	0 - 15	≤ 0.3	100 - 250	Carbide

Best tolerances at MCG Engineered Solutions



These extra-precise tolerances can require special tooling and challenging machining steps which may lead to extra costs.

SIZE	HDPE	PET/ PC/ PEEK/ FL500/ PPS/ PEI / PPSU/ PSU/ PC	PA/ POM/ FL207	PEEK WITH FILLERS	PAI / PBI
1	0.05	0.02	0.02	0.02	0.02
5	0.05	0.02	0.02	0.02	0.02
10	0.05	0.02	0.03	0.02	0.02
15	0.05	0.03	0.03	0.02	0.02
20	0.05	0.03	0.03	0.03	0.02
25	0.05	0.03	0.04	0.03	0.03
30	0.06	0.03	0.04	0.03	0.03
35	0.06	0.03	0.04	0.03	0.03
40	0.07	0.04	0.05	0.03	0.03
45	0.08	0.04	0.05	0.03	0.03
50	0.08	0.04	0.05	0.03	0.03
60	0.10	0.04	0.06	0.04	0.03
70	0.11	0.05	0.07	0.04	0.04
80	0.12	0.05	0.07	0.04	0.04
90	0.13	0.06	0.08	0.05	0.04
100	0.15	0.06	0.09	0.05	0.04
110	0.16	0.07	0.09	0.05	0.05
120	0.17	0.07	0.10	0.05	0.05
130	0.18	0.07	0.10	0.06	0.05
140	0.20	0.08	0.11	0.06	0.05
150	0.21	0.08	0.12	0.06	0.05
160	0.22	0.09	0.12	0.07	0.06
170	0.23	0.09	0.13	0.07	0.06
180	0.25	0.09	0.14	0.07	0.06
190	0.26	0.10	0.14	0.08	0.06
200	0.26	0.10	0.15	0.08	0.07

Thread inserts

Most of our engineering do not need thread inserts, but where there are strong vibrations or repeated clamping and unclamping.

Most popular is self tapping – Tappex although be cautious

- If using slotted inserts – pre tap some of thread
- Check that there is no closure after insertion
- Consider inserts with cross hole to cut

Some can be heat inserted but this is slower and ok for GEP

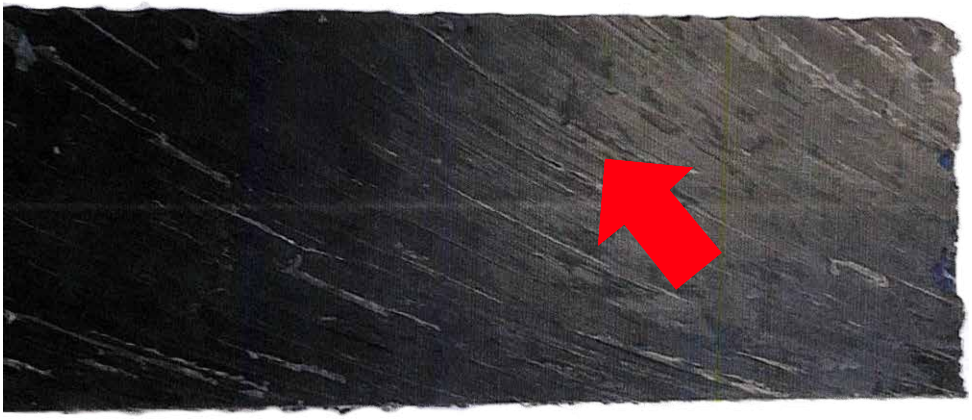
- Use of spiral taps is recommended (Not Straight)
- Where possible use Rigid tap CNC Cycles
- Check pilot drill size
- Go for high quality Taps where possible
- Turning threads should be straight forward
- Tools do not have to be as rigid as metal cutting tools

Deburring

- Most common is to use sharp knives or rotary hook
- Important to have sharpness
- Counter sink tools like this are recommended as they do not cut too deep or chatter
- Hard plastics can be lightly abraded with Wet & Dry
- Rotary stones can be effective on some plastics
- Hot air good for complex GEP profiles

General rules

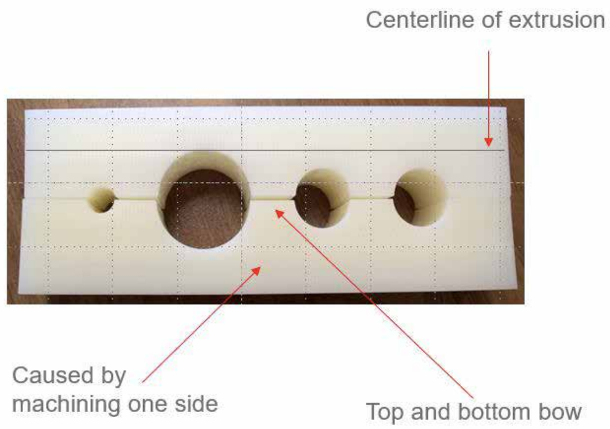
- Consider rod as well as plate
- Machine equal to nit line
- If you have to machine pockets perform intermediate steps



Example

Solutions

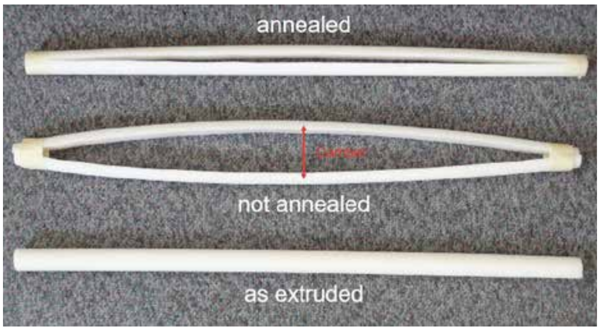
1. Use Cast Nylon Plate
2. Cut section from so that center of extrusion is through symmetrical section. (90° to cut out)
3. Start with thickest plate and move extrusion line away from machined features.
4. Machine slots/ grooves in opposite face.
5. Balanced machining on both sides of the shape´s centerline can also help prevent warpage.



Annealing

Better flatness and tighter tolerances

Extremely close–tolerance parts requiring precision flatness and non-symmetrical contour sometimes require intermediate annealing between machining steps. Improved flatness can be attained by rough machining, annealing and finish machining with a very light cut.



Annealing tips

When pre-machining, leave enough oversize to allow machining to final sizes after annealing.

Fixturing parts to desired shape or flatness during the entire annealing cycle often proves advantageous.

Do not unfix until parts have completed entire annealing cycle and cooled down slowly to the touch.

Make sure that temperatures are uniform and within ± 3°C all over the oven or the oil bath at all times during annealing process.

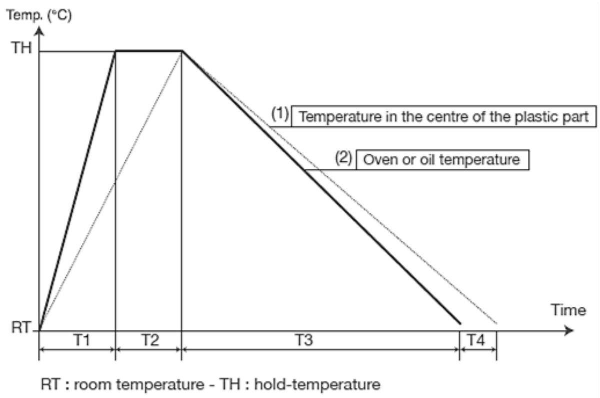
Recommended annealing procedure

T1: Heat-up time (heating rate: 10-20 °C/h)

T2: Hold-time
depends on the wall thickness: 10 min/mm

T3: Cool-down time (cooling rate: 5-10 °C/h)

T4: Additional time required to establish room temperature
depends on the wall thickness: 3 min/mm



MATERIALS	HEAT-UP	HOLD TEMPERATURE	HOLD-TIME (T2)	COOL DOWN	ENVIRONMENT*
PA	10 – 20°C / h	150°C	10 min / mm	5 – 10°C / h	air, nitrogen or oil
POM	10 – 20°C / h	150°C	10 min / mm	5 – 10°C / h	air, nitrogen or oil
PET	10 – 20°C / h	150°C	10 min / mm	5 – 10°C / h	air, nitrogen or oil
PE- (U)HMW	10 – 20°C / h	120°C	10 min / mm	5 – 10°C / h	air, nitrogen or oil
PC	10 – 20°C / h	130°C	10 min / mm	5 – 10°C / h	air or nitrogen
PEEK	10 – 20°C / h	250°C	10 min / mm	5 – 10°C / h	air or nitrogen
PPS	10 – 20°C / h	200°C	10 min / mm	5 – 10°C / h	air or nitrogen
PPSU	10 – 20°C / h	200°C	10 min / mm	5 – 10°C / h	air or nitrogen
PEI	10 – 20°C / h	200°C	10 min / mm	5 – 10°C / h	air or nitrogen
PSU	10 – 20°C / h	170°C	10 min / mm	5 – 10°C / h	air or nitrogen

Summary

When machining MCG stock shapes remember...

- Thermal expansion rate is up to 10x higher with plastics than metals
- Plastics lose heat more slowly than metals, so avoid localized overheating
- Softening (and melting) temperatures of plastics are much lower than metals
- Plastics are much more elastic than metals

Because of these significant differences you may wish to experiment with fixtures, tool materials, angles, speeds and feed rates to obtain optimal results.

Get in touch

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