GENERAL INFORMATION:
Un-reinforced thermoplastics can be machined using high speed steel tools. For glass-reinforced materials, carbide-tipped tools are necessary. In all cases, only correctly sharpened tools should be used.

Due to the low thermal conductivity and low melting temperatures of plastics, good heat removal must be ensured through proper chip removal and cooling with clean dry air or a mild water-based cooling fluid.

MACHINING GUIDELINES

DIMENSIONAL STABILITY:
To produce dimensionally accurate parts, it is important to use stress-relieved raw materials. Otherwise, machining operations may result in the release of stresses, which can distort part geometry.

If large volumes of material must be removed, intermediate annealing may be necessary after rough machining to relieve thermal stresses. Annealing times and temperatures for specific materials can be obtained from Curbell Plastics upon request.

Materials with high moisture absorption such as nylon may have to be conditioned before processing. This involves drying the material and then allowing it to reach equilibrium moisture content.

Most plastics have a much higher coefficients of thermal expansion than metals. Close tolerance parts should be manufactured in temperature-controlled environments. Parts intended for use in high temperature or low temperature environments should be designed with tolerances that allow for dimensional changes due to thermal expansion.

MACHINING METHODS:

1. TURNING
Fine, C-2 grade carbide inserts are recommended for turning.

Polished top surfaces will help to reduce material build-up, allowing for better surface finishes.

Cutting edges should have generous relief angles and negative back rake to minimize any rubbing action.

Rough cuts should be run at a feed rate of 0.015 IPR and finish cuts should be run at a feed rate of 0.005 IPR or less.

2. MILLING
HSS tooling works well for most thermoplastics. Carbide tooling is recommended for reinforced materials.

High spindle speeds and table travel are possible with adequate clamping. Care is required when clamping stock to the mill bed to prevent deformation/springing of the material.

Standard roughing end mills work well for roughing cuts. Finish cuts should be made using either 2 flute or 4 flute mills, depending on the material and chip characteristics.

For inside pockets, end mills with rounded corners should be used whenever possible. This will prevent the finished piece from having sharp inside corners, which can potentially be areas of stress concentration.

3. DRILLING
More heat is generated in drilling than in most other machining processes. Heat reduction is critical to minimize machined-in stress.

A 90° to 118° drill point angle with a 9° to 15° lip angle is usually sufficient for most plastic materials. Acrylic drilling requires a 0° rake angle.

The back side of plastic parts should be supported to prevent chipping during drilling. Drilling into unsupported areas should be avoided.

The feed rate should be reduced when the drill gets close to exiting the material.

Deep hole drilling requires "peck drilling" for proper chip clearance and heat dissipation. The drilling depth should not be allowed to exceed 3-4 times the drill diameter before withdrawal.

Drills must be sharp. Incorrectly sharpened or dull drills can induce high levels of stress into the workpiece.

Proper chip ejection is critical. Poor chip ejection will cause frictional heat buildup.

Signs of improper drilling techniques include:

- Cracks
- Crazing
- Melted surfaces
- Poor finishes
- Dimensional changes (typically undersize holes)

4. SAWING
Thick-walled parts should be sawed with relatively thin blades to avoid excessive frictional heat generation.

Well-sharpened, strongly offset saw blades are recommended.

Specially designed blades are available to optimize cutting for many plastic materials including nylon and acrylic.

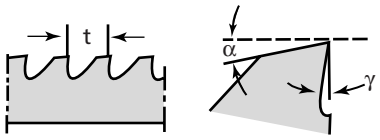
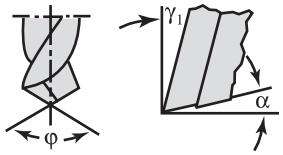
5. THREAD CUTTING
Threads are best cut using thread chasers. Burring can be avoided by using twin-toothed chasers.

Die cutters are not recommended as re-cutting can be expected during removal of the cutter.

A machining allowance, dependent on the material and hole diameter, should be taken into account when using tap drills.

6. SAFETY PRECAUTIONS
Failure to use proper machining techniques can result in localized overheating, which can degrade plastic materials. This may result in the release of potentially harmful decomposition products, which should be removed from the air by an appropriate exhaust system. Tobacco products should be kept out of the production area due to the risk of poisoning from the decomposition products of certain plastics.

MACHINING GUIDELINES

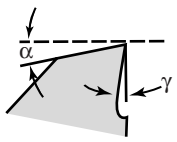
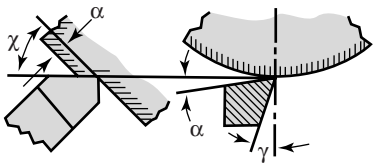
	SAWING				DRILLING				
					 The angle of twist of the drill bit should be approximately 12˚ to 16˚				
	α	γ	v	t	α	γ	φ	v	s
	Clearance Angle (°)	Rake Angle (°)	Cutting Speed (ft/min)	Pitch (in)	Clearance Angle (°)	Rake Angle (°)	Point Angle (°)	Cutting Speed (ft/min)	Feed (mils/rev)
ABS	15-30	0-5	980	0.078-0.315	8-12	10-30	90	165-650	0.008-0.012
Acetal (copolymer)	20-30	0-5	1640-2600	0.078-0.197	5-10	15-30	90	165-650	0.004-0.012
Acetal (homopolymer)	20-30	0-5	1640-2600	0.078-0.197	5-10	15-30	90	165-650	0.004-0.012
Noryl	15-30	5-8	980	0.118-0.315	8-10	10-20	90	165-320	0.008-0.012
Nylon 6	20-30	2-5	1640	0.118-0.315	5-15	10-20	90	165-490	0.004-0.012
PAI	5-10	0-3	2600-2950	0.118-0.50	5-10	5-10	120	260-320	0.008-0.004
PBT	15-30	5-8	980	0.118-0.315	5-10	10-20	90	165-320	0.008-0.012
PEEK	15-30	0-5	1640-2600	0.118-0.197	5-10	10-30	90	160-650	0.004-0.012
PET	15-30	5-8	980	0.118-0.315	5-10	10-20	90	165-320	0.008-0.012
Polycarbonate	15-30	5-8	980	0.118-0.315	8-10	10-20	90	165-320	0.008-0.012
Polyethylene	20-30	2-5	1640	0.118-0.315	5-15	10-20	90	165-490	0.004-0.012
Polypropylene (homopolymer)	20-30	2-5	1640	0.118-0.315	5-15	10-20	90	165-490	0.004-0.012
Polysulfone	15-30	0-4	1640	0.078-0.197	3-10	10-20	90	65-260	0.004-0.012
PPS	15-30	0-5	1640-2600	0.118-0.197	5-10	10-30	90	160-650	0.004-0.012
PTFE	20-30	5-8	980	0.078-0.197	10-16	5-20	130	790-650	0.004-0.012
PVDF	20-30	5-8	980	0.078-0.197	10-16	5-20	130	790-650	0.004-0.012
Radel® R	15-30	0-4	1640	0.078-0.197	3-10	10-20	90	65-260	0.004-0.012
Ultem®	15-30	0-4	1640	0.078-0.197	3-10	10-20	90	65-260	0.004-0.012
Vespel®	5-10	0-3	2600-2950	0.100	0.50	5-10	90-120	260-320	0.022-0.006
Reinforced materials	15-30	10-15	650-980	0.118-0.197	6	5-10	120	260-320	0.004-0.012

SPECIAL MEASURES:

- Preheat material to 250ºC
- Caution when using coolants, susceptible to stress cracking
- Use carbide-tipped tools

Heat before sawing:
From 2.25" - PEEK, PPS
From 3.25" - PET, PBT
From 4.00" - Nylon 6

Heat before drilling:
From 60mm diameter - PEEK, PPS
From 80mm diameter - PET, PBT
From 100mm diameter - Nylon 6

	MILLING			TURNING				
	 The feed can be up to 0.55mm/tooth			 The nose radius r must be at least 0.5 mm				
	α	γ	v	α	γ	χ	v	s
	Clearance Angle (º)	Rake Angle (º)	Cutting Speed (ft/min)	Clearance Angle (º)	Rake Angle (º)	Side Angle (º)	Cutting Speed (ft/min)	Feed (mils/rev)
ABS	5-10	0-10	980-1640	5-15	25-30	15	650-1640	0.008-0.020
Acetal (copolymer)	5-15	5-15	920-1640	6-8	0-5	45-60	980-1960	0.004-0.015
Acetal (homopolymer)	5-15	5-15	920-1640	6-8	0-5	45-60	980-1960	0.004-0.015
Noryl	10-20	5-15	980	5-10	6-8	45-60	980	0.004-0.020
Nylon 6	10-20	5-15	920-1640	6-10	0-5	45-60	920-1640	0.004-0.020
PAI	2-5	0-5	300-330	2-5	0-5	7-10	320-390	0.002-0.003
PBT	5-15	5-15	980	5-10	0-5	45-60	980-1300	0.008-0.015
PEEK	5-15	6-10	920-1640	6-8	0-5	45-60	920-1640	0.004-0.020
PET	5-15	5-15	980	5-10	0-5	45-60	980-1300	0.008-0.015
Polycarbonate	10-20	5-15	980	5-10	6-8	45-60	980	0.004-0.020
Polyethylene	10-20	5-15	920-1640	6-10	0-5	45-60	920-1640	0.004-0.020
Polypropylene (homopolymer)	10-20	5-15	920-1640	6-10	0-5	45-60	920-1640	0.004-0.020
Polysulfone	2-10	1-5	920-1640	6	0	45-60	1140-1300	0.004-0.012
PPS	5-15	6-10	920-1640	6-8	0-5	45-60	920-1640	0.004-0.020
PTFE	5-15	5-15	920-1640	10	5-8	10	490-1640	0.004-0.012
PVDF	5-15	5-15	920-1640	10	5-8	10	490-1640	0.004-0.012
Radel® R	2-10	1-5	920-1640	6	0	45-60	1140-1300	0.004-0.012
Ultem®	2-10	1-5	920-1640	6	0	45-60	1140-1300	0.004-0.012
Vespel®	2-5	0-5	300-330	2-5	0-5	7-10	320-390	0.002-0.010
Reinforced materials	15-30	6-10	260-330	6-8	2-8	45-60	490-650	0.004-0.020