

FABRICATION GUIDELINES

The following guidelines are presented for those machinists not familiar with the machining characteristics of plastics. They are intended as guidelines only, and may not represent the most optimum conditions for all parts. The troubleshooting quick reference on page 42 should be used to correct undesirable surface finishes or material responses during machining operations.

All Quadrant materials are stress relieved to ensure the highest degree of machinability and dimensional stability. However, the relative softness of plastics (compared to metals) generally results in greater difficulty maintaining tight tolerances during and after machining. A good rule of thumb for tolerances of plastic parts is $\pm .001$ " per inch of dimension although tighter tolerances are possible with very stable, reinforced materials.

When machining Quadrant stock shapes, remember...

- ➔ Thermal expansion is up to 10 times greater 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 differences, you may wish to experiment with fixtures, tool materials, angles, speeds and feed rates to obtain optimum results.

Getting Started

- ➔ Positive tool geometries with ground peripheries are recommended
- ➔ Carbide tooling with polished top surfaces is suggested for optimum tool life and surface finish. Diamond coated or polycrystalline tooling provides optimum surface finish when machining Celazole® PBI.
- ➔ Use adequate chip clearance to prevent clogging
- ➔ Adequately support the material to restrict deflection away from the cutting tool

Coolants

Coolants are generally not required for most machining operations (not including drilling and parting off). However, for optimum surface finishes and close tolerances, non-aromatic, water soluble coolants are suggested. Spray mists and pressurized air are very effective means of cooling the cutting interface. General purpose petroleum based cutting fluids, although suitable for many metals and plastics, may contribute to stress cracking of amorphous plastics such as PC 1000 Polycarbonate, PSU 1000 Polysulfone, Utem® 1000 PEI, and Radel® R PPSU.

MACHINING TIPS

- Coolants are strongly suggested during drilling operations, especially with notch sensitive materials such as Ertalyte® PET-P, Torton® PAI, Celazole® PBI and glass or carbon reinforced products.
- In addition to minimizing localized part heat-up, coolants prolong tool life. Two (flood) coolants suitable for most plastics are Trim 9106CS (Master Chemical Corporation-Perrysburg, OH) and Polycut (Tulco - Savannah, GA). A generally suitable mist coolant is Astro-Mist 2001A (Monroe Fluid Technology-Hilton, NY).

Turning

Turning operations require inserts with positive geometries and ground peripheries. Ground peripheries and polished top surfaces generally reduce material build-up on the insert, improving the attainable surface finish. A fine grained C-2 carbide is generally best for turning operations.



Drilling

The insulating characteristics of plastics require consideration during drilling operations, especially when hole depths are greater than twice the diameter.



Small diameter holes
(1/32" to 1" diameter)

High speed steel twist drills are generally sufficient for small holes. To improve swarf removal, frequent pull-out (peck drilling) is suggested. A slow spiral (low helix) drill will allow for better swarf removal.

Large diameter holes (1" diameter and larger)

A slow spiral (low helix) drill or general purpose drill bit ground to a 118° point angle with 9° to 15° lip clearance is recommended. The lip rake should be ground (dubbed off) and the web thinned.

It is generally best to drill a pilot hole (maximum 1/2" diameter) using 600 to 1,000 rpm and a positive feed of 0.005" to 0.015" per revolution. Avoid hand feeding because of the drill grabbing which can result in microcracks forming. Secondary drilling at 400 to 500 rpm at 0.008 to 0.020" per revolution is required to expand the hole to larger diameters.

A two step process using both drilling and boring can be used on notch sensitive materials such as Ertalyte® PET-P and glass reinforced materials. This minimizes heat build-up and reduces the risk of cracking.

1. Drill a 1" diameter hole using an insert drill at 500 to 800 rpm with a feed rate of 0.005" to 0.015" per revolution.
2. Bore the hole to final dimensions using a boring bar with carbide insert with 0.015" to 0.030" radii at 500 to 1,000 rpm and a feed rate of 0.005 to 0.010" per revolution.



Table 17: Fabrication Guidelines for All Quadrant Materials Turning and Drilling Operations

Material	Relative Machinability (1 to 10 1=easiest)	Turning			Drilling**	
		Depth of Cut	Speed Feet/Min.	Feed, In./Rev.	Nominal Hole Diameter	Feed, In./Rev.
Acetron® GP	1	.150" deep cut	500-600	.010-.015	1/16"	.007-.015
Delrin®, Delrin® AF	1	.025" deep cut	600-700	.004-.007	1/8"	•
Delrin® AF Blend	1				1/4"	•
Nylon 101	1				1/2"	.015-.025
Nylatron® GS, GSM	1				3/4"	•
Nylatron® GSM Blue	1				1"	.020-.050
Nylatron® NSM	1				1 1/2"	•
MC® 901, MC® 907 Nylon	1				2" or larger	•
PC 1000 Polycarbonate	3					
PSU 1000 Polysulfone	3					
Ultem® 1000 & 2300 PEI	7					
Fluorosint® 500	1	.150" deep cut	350-500	.010-.015	1/16"	.007-.015
Fluorosint® 207	1	.025" deep cut	500-600	.003-.008	1/8"	•
					1/4"	•
					1/2"	.015-.025
					3/4"	•
					1"	.020-.050
					1 1/2"	•
					2" or larger	•
Ketron® PEEK	5	.150" deep cut	600-1000	.010-.016	1/16"	.002-.005
Ketron® PEEK 30% GF	7	.025" deep cut	600-700	.004-.007	1/8"	•
Ketron® PEEK 30% CF	7				1/4"	•
Ketron® PEEK HPV					1/2"	.004-.008
					3/4"	•
					1"	.008-.012
					1 1/2"	•
					2" or larger	•
Ertelyte® PET-P	2	.150" deep cut	500-600	.010-.015	1/16"	.002-.005
Ertelyte® TX		.025" deep cut	600-700	.004-.007	1/8"	•
					1/4"	•
					1/2"	.015-.025
					3/4"	•
					1"	.020-.050
					1 1/2"	•
					2" or larger	•
Techtron® PPS	3	.150" deep cut	100-300	.010-.020	1/16"	.007-.015
Techtron® HPV	6	.025" deep cut	250-500	.005-.010	1/8"	•
Ryton® PPS	5				1/4"	•
Ryton® BG PPS					1/2"	.015-.025
					3/4"	•
					1"	.020-.050
					1 1/2"	•
					2" or larger	•
Torlon® 4203 PAI	5	.025" deep cut	300-800	.004-.025	1/16"	.007-.015
Torlon® 4301 PAI	5				1/8"	•
Torlon® 4501 PAI	6				1/4"	•
Torlon® 4503 PAI	6				1/2"	.015-.025
Torlon® 4540 PAI	6				3/4"	•
Torlon® 5530 PAI	8				1"	.020-.050
					1 1/2"	•
					2" or larger	•
Celazole® PBI	10	.025" deep cut	150-225	.002-.006	1/2" or larger	.015-0.25

** The recommended speed for drilling operations is 150 to 200 ft./min.

FABRICATION GUIDELINES

Threading and Tapping

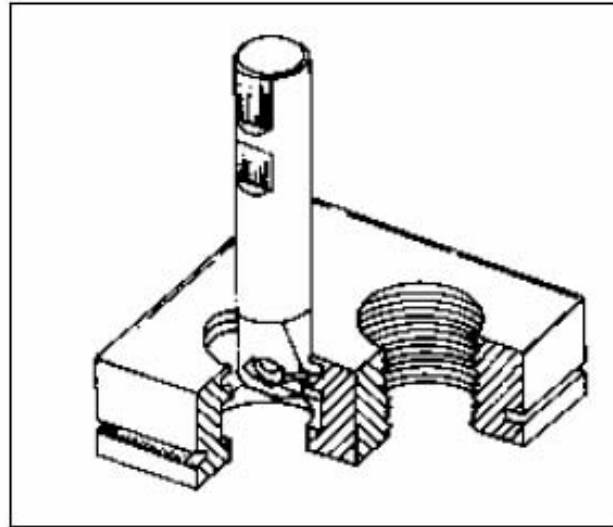
Threading should be done by single point using a carbide insert and taking four to five 0.001" passes at the end. Coolant usage is suggested. For tapping, use the specified drill with a two flute tap. Remember to keep the tap clean of chip build-up. Use of a coolant during tapping is also suggested.

Milling

Sufficient fixturing allows fast table travel and high spindle speeds when end milling plastics. When face milling, use either high positive or high shear geometry cutter bodies.

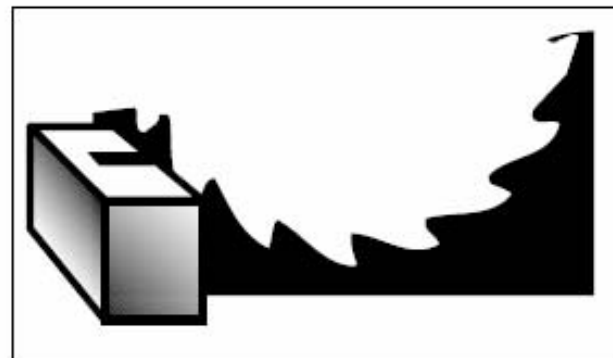
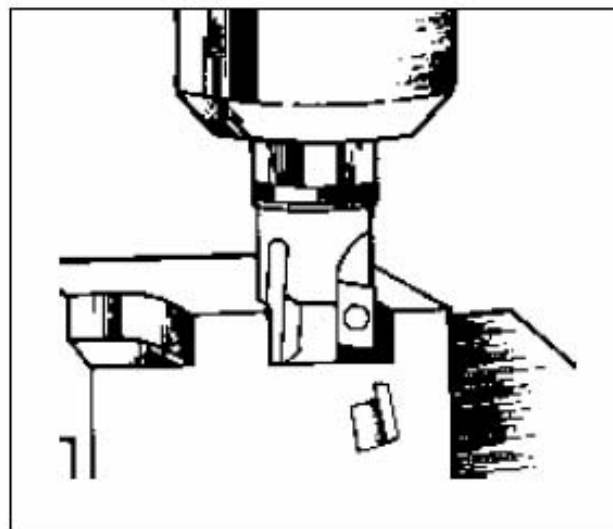
Sawing

Band sawing is versatile for straight, continuous curves or irregular cuts. Table saws are convenient for straight cuts and can be used to cut multiple thicknesses and thicker cross sections up to 4" with adequate horsepower. Saw blades should be selected based upon material thickness and surface finish desired.



MACHINING TIPS

- Rip and combination blades with a 0° tooth rake and 3° to 10° tooth set are best for general sawing in order to reduce frictional heat.
- Hollow ground circular saw blades without set will yield smooth cuts up to 3/4" thickness.
- Tungsten carbide blades wear well and provide optimum surface finishes.



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Table 18 : Fabrication Guidelines—Milling and Sawing

	End Milling / Slotting				Face Milling (C-2) Carbide Tool			Sawing			
	High Speed Steel (M2, M7)	Depth of Cut	Speed, Ft./Min.	Feed, In./Tooth	Depth of Cut	Speed, Ft./Min.	Feed, In./Tooth	Material Thickness	Tooth Form	Pitch Teeth/in.	Band Speeds Ft./Min.
Acetron® GP Acetal Delrin® 150 Acetal, Delrin® AF Delrin® AF Blend Nylon 101, Nylatron® GS Nylon, Nylatron® GSM, GSM Blue Nylatron® NSM MC® 901 Nylon, MC® 907 Nylon	1/4"	0.250	270-450	0.002	0.150	1300-1500	0.020	<1/2"	Precision	10-14	3,000
	1/2"	"	"	0.003	0.060	1500-2000	0.005	1/2"-1"	"	6	2,500
	3/4"	"	"	0.005				1"-3"	Butress	3	2,000
	1", 2"	"	"	0.008				3"	"	"	1,500
	1/4"	0.050	300-500	0.001							
	1/2"	"	"	0.002							
PC 1000 Polycarbonate PSU 1000 Polysulfone Ultem® 1000 PEI Ultem® 2300 PEI	1/4"	0.250	270-450	0.002	0.150	1300-1500	0.020	<1/2"	Precision	10-14	4,000
	1/2"	"	"	0.003	0.060	1500-2000	0.005	1/2"-1"	"	6	3,500
	3/4"	"	"	0.005				1"-3"	Butress	3	3,000
	1", 2"	"	"	0.008				3"	"	"	2,500
	1/4"	0.050	300-500	0.001							
	1/2"	"	"	0.002							
Ketron® PEEK Ketron® PEEK HPV	1/4"	0.250	270-450	0.002	0.150	500-750	0.020	<1/2"	Precision	8-14	4,000
	1/2"	"	"	0.003	0.060	"	0.005	1/2"-1"	"	6-8	3,500
	3/4"	"	"	0.005				1"-3"	Butress	3	3,000
	1", 2"	"	"	0.008				3"	"	"	2,500
	1/4"	0.050	300-500	0.001							
	1/2"	"	"	0.002							
Fluorosint® 500 Fluorosint® 207	1/4"	0.250	270-450	0.002	0.150	500-700	0.010	<1/2"	Precision	8-14	3,000
	1/2"	"	"	0.003	0.060	550-750	0.005	1/2"-1"	"	6-8	2,500
	3/4"	"	"	0.005				1"-3"	Butress	3	2,000
	1", 2"	"	"	0.008				3"	"	"	1,500
	1/4"	0.050	300-500	0.001							
	1/2"	"	"	0.002							
Techtron® PPS Techtron® HPV Ryton® PPS	1/4"	0.250	270-450	0.002	0.150	1300-1500	0.020	<1/2"	Precision	8-14	5,000
	1/2"	"	"	0.003	0.060	1500-2000	0.005	1/2"-1"	"	6-8	4,300
	3/4"	"	"	0.005				1"-3"	Butress	3	3,500
	1", 2"	"	"	0.008				3"	"	"	3,000
	1/4"	0.050	300-500	0.001							
	1/2"	"	"	0.002							
Torlon® PAI	1/4"	0.50	270-450	0.002	0.035	500-800	.006-.005	<1/2"	Precision	8-14	5,000
	1/2"	"	"	0.003				1/2"-1"	"	6-8	4,300
	3/4"	"	"	0.005				1"-3"	Butress	3	3,500
	1", 2"	"	"	0.008				3"	"	"	3,000
	1/4"	0.050	300-500	0.001							
	1/2"	"	"	0.002							
Ertelyte® PET-P Ertelyte® TX	1/4"	0.250	270-450	0.002	0.150	1300-1500	0.020	<1/2"	Precision	10-14	5,000
	1/2"	"	"	0.003	0.060	1500-2000	0.005	1/2"-1"	"	6	4,300
	3/4"	"	"	0.005				1"-3"	Butress	3	3,500
	1", 2"	"	"	0.008				3"	"	"	3,000
	1/4"	0.050	300-500	0.001							
	1/2"	"	"	0.002							
Celazole® PBI	1/2"							3/8"-1"	Precision	10	3,000
	3/4"							1"-2"	Butress	10	1,500
	1", 2"										
	1/4"	0.015	250-350	0.002	0.015	250-350	.002-.006				

>> POST MACHINING ANNEALING

When should parts be annealed after machining to ensure optimum part performance?

Experience has shown us that very few machined plastic parts require annealing after machining to meet dimensional or performance requirements.

All Quadrant stock shapes are annealed using a proprietary stress relieving cycle to minimize any internal stresses that may result from the manufacturing process. This assures you that the material will remain dimensionally stable during and after machining.

Machined-in stress can reduce part performance and lead to premature part failure. To prevent machined-in stress, it is important to identify the causes.

Machined-in stress is created by:

- ➔ Using dull or improperly designed tooling
- ➔ Excessive heat – generated from inappropriate speeds and feed rates
- ➔ Machining away large volumes of material – usually from one side of the stock shape

To reduce the potential for machined-in stress, review the fabrication guidelines for the specific material. Recognize that guidelines change as the material type changes.

Benefits of Post-Machining Annealing

- **Improved Chemical Resistance**
Polycarbonate, polysulfone, and Ultem® PEI, like many amorphous (transparent) plastics may be annealed to minimize stress crazing. Torton® PAI also benefits from post machining annealing. Annealing finished parts becomes more important as machining volume increases. Annealing after machining reduces "machined-in" stresses that can contribute to premature failure.
- **Better Flatness and Tighter Tolerance Capability**
Extremely close-tolerance parts requiring precision flatness and non-symmetrical contour sometimes require intermediate annealing between machining operations. Improved flatness can be attained by rough machining, annealing and finish machining with a very light cut. Balanced machining on both sides of the shape centerline can also help prevent warpage.
- **Improved Wear Resistance**
Extruded or injection molded Torton PAI parts that require high PV's or the lowest possible wear factor benefit from an additional cure after machining. This curing process optimizes the wear properties. Only PAI benefits from such a cycle.

Table 20 : Post Machining Air Annealing Guidelines

Material	Heat Up	Hold	Cool Down	Environment
Type 6 Nylons	4 hours to 300°F	30 minutes per 1/4" thickness	50°F per hour	Oil or Nitrogen
Type 6/6 Nylons	4 hours to 350°F	30 minutes per 1/4" thickness	50°F per hour	Oil or Nitrogen
Ertalyte® PET-P	4 hours to 350°F	30 minutes per 1/4" thickness	50°F per hour	Oil or Nitrogen
Acestron® GP Acetal	4 hours to 310°F	30 minutes per 1/4" thickness	50°F per hour	Nitrogen or Air
Delrin®	4 hours to 320°F	30 minutes per 1/4" thickness	50°F per hour	Nitrogen or Air
PC 1000 Polycarbonate	4 hours to 275°F	30 minutes per 1/4" thickness	50°F per hour	Air
PSU 1000 Polysulfone	4 hours to 330°F	30 minutes per 1/4" thickness	50°F per hour	Air
Radel® R PPSU	4 hours to 390°F	30 minutes per 1/4" thickness	50°F per hour	Nitrogen or Air
Ultem® PEI	4 hours to 390°F	30 minutes per 1/4" thickness	50°F per hour	Air
Techtron® PPS	4 hours to 350°F	30 minutes per 1/4" thickness	50°F per hour	Air
Ketron® PEEK	2 hours to 300°F 2 hours to 375°F	60 minutes per 1/4" thickness 60 minutes per 1/4" thickness	50°F per hour	Air
Torton® PAI	4 hours to 300°F 4 hours to 420°F 4 hours to 470°F 4 hours to 500°F	1 day 1 day 1 day 3 to 10 days	50°F per hour	Air

Finish machining of critical dimensions should be performed after annealing.

Important: Annealing cycles have been generalized to apply to a majority of machined parts. Changes in heat up and hold time may be possible if cross sections are thin. Parts should be fixtured during annealing to prevent distortion.

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