11 – Machining, Cutting and Finishing

Safety Precautions

Besides the standard safety rules for mechanical operations, machining, cutting and finishing of plastic parts, unlike metals, can lead to local heating up to the melting point of the plastic or even to its decomposition. It is therefore recommended to follow similar safety work practices as used in the production of plastic parts; namely adequate ventilation of the working area. More detailed information concerning the specific plastic used can be obtained from the Safety Data Sheet of the plastic material. The waste generated generally may not be adequate for recycling due to its potential contamination.

Machining HYTREL®

HYTREL® engineering thermoplastic elastomer is normally made into useful parts by injection moulding, extruding or melt casting. However, prototypes or small production quantities can be machined from blocks or rods of HYTREL®. Also, fabrication of complicated production parts can sometimes be simplified by post-moulding machining operation. This chapter presents some guide-lines for machining HYTREL®.

General

Any method of machining will usually produce a matte finish on parts of HYTREL® engineering thermoplastic elastomer. This finish does not affect the performance of the part unless sliding friction is a critical factor.

Because HYTREL® is elastomeric and highly resilient, high cutting pressure produces local deformation, which in turn can cause part distortion. Therefore, moderate pressure and cutting speeds should be used. Softer grades should be cut with less pressure than harder ones*. Parts should be held or supported to minimize distortion.

HYTREL® is a poor heat conductor; it does not readily absorb heat from cutting tools, as metals do. Frictional heat generated during machining may melt the cut surfaces. Melting can be prevented by cooling the cutting surface, either by directing a tiny jet of high pressure air at the cutting tool or by flooding the surface with water or a water-oil emulsion.

Some guidelines for specific machining operations follow. Even if it is not specifically mentioned in the guidelines, keep in mind that cooling the cut surface will always improve machining.

* Throughout this report, "soft grades" or "soft polymers" refers generally to the grades of HYTREL® that have a flexural modulus below about 240 MPa while "hard grades" or "hard polymers" refers generally to those grades whose flexural modulus is above this value. However, there is no sharp transition point; machining conditions will vary gradually from type to type.

Turning

Standard high-speed steel tools can be used for turning operations. Tools should be very sharp, to minimize frictional heat. A positive rake of 10° on the tool bit is desirable.

Cutting speeds of 2,0 to 2,5 m/s work best when no coolant is used. Heavy cuts can be made at slower speeds, but produce rougher finishes. Cuttings of HYTREL® cannot be chip broken; they remain as one continuous string. When machining soft polymers at high speeds, the cuttings may be tacky on the surface due to frictional heat, and may adhere to or mar the finished surface. Rough cuts produce thicker strings which are less likely to stick to the surface. Harder polymers are easier to cut and yield reasonably good finishes.

Finished sizes are generally achieved by sanding with emery cloth to the desired diameter. Dimensions can be held to 0,125 mm with the soft grades of HYTREL®, and to 0,050 mm on the harder grades.

Long, large diameter parts can be turned satisfacorily if the center is supported to prevent buckling.

Milling

HYTREL® has been milled successfully using a sharp, single blade fly cutter having a 10° back rake and an end mill. With a 76 mm fly cutter, an operating speed of 10 m/s produced good cutting action.

Blocks of HYTREL® must be secured before milling. Use light pressure with a vise, or adhere the part to the table with doubleface tape. Blocks less than 9,5 mm thick are difficult to hold because of distortion.

Drilling

Parts made of HYTREL® engineering thermoplastic elastomer can be drilled with standard high speed twist drills. Drill bits having an included angle of 118° have been used satisfactorily, but lesser angles should improve drilling ability. The drill must be very sharp to produce a clean, smooth hole.

With the hard grades of HYTREL®, good results have been obtained at drill speeds of 500 to 3500 rev/min and cutting speeds of 0,13 to 3,6 m/s. The force required to feed the drill decreases with increasing speed. The softer grades, being more resilient, generally yield a poorer surface finish. Flooding with coolant improves the finish. However, even when using the softest grade of HYTREL® without coolant, no surface melting was observed at a drill speed of 5160 rev/min with drill sizes up to 25 mm diameter.

Tolerances may be difficult to hold. HYTREL® has an "elastic memory" which causes it to close in on holes that are cut into it. As a result, finished dimensions of holes will generally be slightly smaller than the drill size, unless drill whip occurs. To meet exact dimensions, use slightly oversize drills, or hone the hole to size. In test drillings, finished hole size obtained with a 12,7 mm diameter drill bit ranged from 12 mm – 5% undersize – at low speed to 13 mm – 3% oversize – at high speed.

Tapping or threading

Because of the tendency of HYTREL® to close in on holes (see Drilling), tapping threads is impossible with the softer grades and very difficult with the harder grades. Designs which require tapping of HYTREL® should be avoided.

External threads can be cut using a single point tool. However, binding and distortion are frequently encountered when threading parts of HYTREL®.

Band sawing

The following types of blades have been used satisfactorily to saw HYTREL® engineering thermoplastic elastomer:

- 1,6 teeth per cm, raker set;
- 1,6 teeth per cm, skip tooth, raker set;
- 4 teeth per cm, raker set.

Cutting speeds ranging from 0,7 to 30 m/s have been used.

At low speeds, cutting efficiency is reduced and more power is required. At high speeds, less force is needed to feed the stock. Optimum cutting speed with a 1,6-tooth raker blade is about 18 m/s. Slight melting has been observed when using a 4-tooth blade at 30 m/s, indicating that finer teeth cause more frictional heat at high speeds.

Flooding the saw blade with coolant produces a good clean cut because little or no frictional heat is developed.

When a saw that is not equipped with coolant is used, blades that have a wide tooth set are suggested to minimize frictional heat.

Cutting can be improved by wedging the cut open to prevent binding of the blade.

Machining chart for HYTREL® engineering thermoplastic elastomer

Machining Operation	Types of HYTREL®	Preferred Tools	Optimum Cutting Speed	Suggestions
Band Sawing	All Grad	1,6 to 4 tooth per cm blade, raker set	18 m/s	Wedge cut open to prevent binding. Flood saw blade with coolant.
Turning	All Grades (Harder grades are easier to work with)	Standard high-speed steel tools with positive rake of 10° on the bit	2,0 to 2,5 m/s when no coolant is used	Tools should be very sharp. Sand with emery cloth to final dimensions.
Milling	All Grades	Single blade fly cutter having a 10° back rake	10 m/s	Tools should be very sharp. Secure stock for milling.
Drilling	All Grades (Harder grades are easier to drill)	Standard high-speed twist drills	0,13 to 3,6 m/s for harder grades	Use slightly over-size drills or hone to final size. Use coolant for smoother finish.
Tapping	Hardest grades only	–	–	Tapping of HYTREL® is extremely diffcult because polymer tends to close in on holes cut into it. Avoid designs that require tapping.

Machining and Cutting of DELRIN®

DELRIN® can be machined on standard machine shop equipment by sawing, milling, turning, drilling, reaming, shaping, threading and tapping. It is easier to perform these operations on DELRIN® than on the most machinable brass or aluminium alloys.

It is seldom necessary to use cutting oils, water or other cutting aids except in the common wet band sanding operation where water feed is normally used. Machinability is excellent at slow-speed / fast-feed and slowfeed / fast-speed using standing cutting tools. In most cases standard chip breakers on tools perform adequately.

Sawing

Standard power tools such as band saws, jig saws and table saws can be used without modification for sawing DELRIN®. The speed of the saw blade is generally not critical; however, it is important that the teeth in the saw blades have a slight amount of set. DELRIN® is a thermoplastic material and, therefore, frictional heat will cause it to melt so that it is necessary to provide tooth clearance when sawing.

Drilling

Standard twist drills are suitable for use with DELRIN®. The long lead and highly polished lands of the so-called plastic drills are desirable when drilling DELRIN®. However, the leading edges of these drills are usually ground flat and should be modified by changing the drill lip angle to cut rather than scrape.

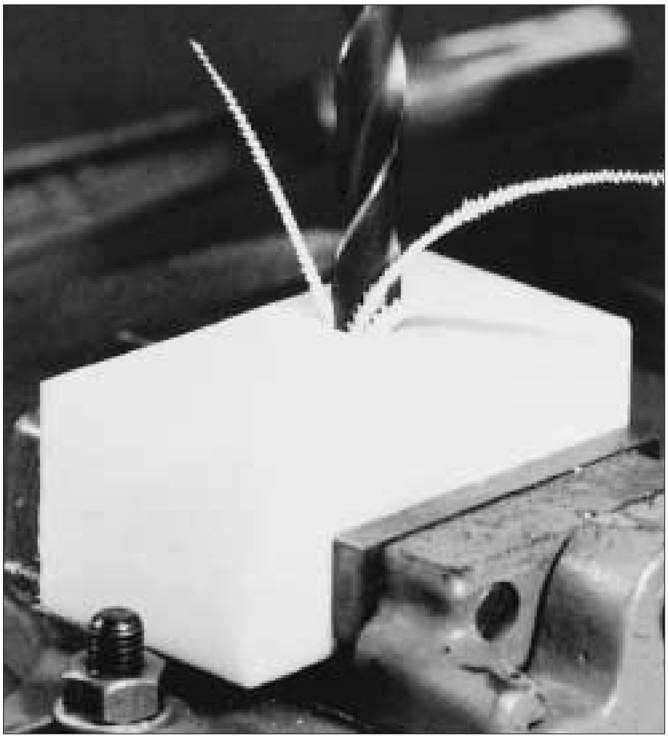


Fig. 11.01 **Drilling Machining conditions: Cutting speed, 1500 rpm; ∅ 13 mm, std. 118° twist drill; medium feed. No coolant. Material – DELRIN® 500.**

If the drilling is performed at very high rates, the use of a coolant such as water or a cutting oil to reduce the frictional heat generated may be desirable. Where coolants are not used, the drill should be occasionally withdrawn from the hole to clean out the chips and prevent overheating. Holes can be drilled on size providing the drills are kept cool.

Turning

DELRIN® may be turned on any conventional metal working lathe. The tool bits should be ground as they normally are for working with free cutting brass. A back rake and a large chip breaker will be helpful in most cases to eliminate drag or interference. As with other materials, the best finish will be obtained with a high speed and a fine feed.

In some cases where the length of the material to be turned is large and the diameter of the piece is small, it will be necessary to use steady rests to eliminate whipping of the material. If the rotational speed of the work is high, it will probably be necessary to supply a coolant to the steady rest to carry off the frictional heat generated thereby.

Milling

Standard milling machines and milling cutters may be used with DELRIN® providing the cutting edges are kept very sharp. When using end mills, it has been found desirable to use single fluted mills which have greater chip clearance and generate less frictional heat.

Shaping

DELRIN® can be used on standard shapers without any modification to the machinery or the tools. Excellent results can be obtained with this type of equipment.

Reaming

DELRIN® can be reamed with either hand or collar reamers to produce holes with good finish and accurate dimensions. In general, reamers of the expansion type are preferred. Due to the resiliency of DELRIN®, cuts made with a fixed reamer tend to be undersize unless at least 0,15 mm is removed by the final reaming.

Threading and tapping

DELRIN® can be threaded or tapped with conventional equipment. On automatic or semi-automatic equipment, self-opening dies with high-speed chasers can be used. The use of a lubricant or coolant has not been found necessary, but in some cases, on very high-speed operations, it may be of assistance. Threads may be cut in DELRIN® on a lathe using conventional single-pointed tools. As with metals, several successive cuts of 0,15-0,25 mm should be made. Finish cuts should not be less than 0,15 mm because of the resiliency of DELRIN®. When threading long lengths of rod stock, it is necessary to use a follow rest or other support to hold the work against the tool.

Blanking and punching

Small flat parts such as washers, grommets and non-precision gears (1,5 mm or less in thickness) often can be produced more economically by punching or stamping from a sheet of DELRIN®. Conventional dies are used in either hand- or power-operated punch presses. With well-made dies, parts of DELRIN® may be blanked or punched cleanly at high speeds. If cracking occurs, it can usually be avoided by pre-heating the sheet.

Finishing of DELRIN®

Burr removal

Although there are several ways of removing burrs, it is better to avoid forming them. This is best accomplished by maintaining sharp cutting edges on tools and providing adequate chip clearances. Where only a few parts are being made, it is often simplest to carve or scrape off burrs with hand tools. If burrs are not too large, they can also be removed with vapour blast or honing equipment. Care must be taken to avoid removing too much material. Still another method of removing burrs on parts of DELRIN® is through the use of commercial abrasive tumbling equipment. The exact grit-slurry make-up and tumbling cycle are best determined by experimentation.

Filing and grinding

A mill file with deep, single, cut, coarse curved teeth, commonly known as a “Vixen” file, is very effective on DELRIN®. This type of file has very sharp teeth and produces a shaving action that will remove DELRIN® smoothly and cleanly. Power-driven rotary steel burrs or abrasive discs operating at high speeds are effective in finishing parts of DELRIN®. Standard surface grinders and centreless grinding machines can also be used to produce smooth surfaces of DELRIN®.

Sanding and buffing

DELRIN® can be wet sanded on belt or disc sanding equipment. After sanding to a smooth finish, the surface may be brought to a high polish by the use of standard buffing equipment. Care should be used in these operations to avoid excessive feeds which tend to overheat the DELRIN®.

The buffing operation normally consists of three steps: ashing, polishing and wiping.

The ashing is done with a ventilated wheel of open construction which can be made up of alternating layers of 30 cm and 15 cm diameter muslin discs. In this way, an ashing wheel of 10 to 12 cm in thickness may be built up. The ashing wheel is kept dressed with a slurry of pumice and water during the buffing operation.

The part of DELRIN® is held lightly against the wheel and kept in constant motion to prevent burning or uneven ashing. Speed of the wheel should be approximately 1000 rpm for best results.

The polishing operation is performed in a similar manner and on a similarly constructed buffing wheel. The difference is that the wheel is operated dry and a polishing compound is applied to half the surface of the wheel. The other half remains untreated.

The part of DELRIN® is first held against the treated half of the wheel for polishing and then moved to the untreated side to wipe off the polishing compound. Optimum speeds for the polishing wheel range from 1000 to 1500 rpm.

Safety precautions

Fine shavings, turnings, chips, etc., should be cleaned up and not allowed to accumulate. DELRIN® acetal resin will burn, and an accumulation of chips could create a fire hazard.

Annealing of DELRIN®

Annealing is not generally required as a production step because of added cost and difficulty in predicting dimensions. If precision tolerances are required, parts should be moulded in hot moulds (90-110°C) to closely approach the natural level of crystallinity and minimize post-mould shrinkage.

Annealing is suggested as a test procedure in setting up moulding conditions on a new mould to evaluate post-mould shrinkage and moulded-in stresses. The change in part dimensions during annealing will closely represent the ultimate change in part size in use as the part reaches its natural level of crystallinity.

Most manufacturers of stock shapes anneal their product to relieve stresses. However, further annealing may be required during machining of parts with close tolerances to relieve machined-in stresses, especially following heavy machining cuts. Annealing of machined parts normally precedes final light finishing or polishing cuts.

Air annealing

Air annealing of DELRIN® is best conducted in air-circulating ovens capable of maintaining a uniform air temperature controllable to ±2°C. In air, one hour at 160°C is required to reach the same degree of annealing as is achieved in 30 minutes in oil at 160°C because heat transfer takes place more slowly in air than in oil. Annealing time is 30 minutes for part heat up to 160 ± 2°C and then 5 minutes additional time per 1 mm of wall thickness.

Oil annealing

Recommended oils are ‘‘Primol’’ 342* and ‘‘Ondina’’ 33* or other refined annealing oils. Parts may be annealed at a ‘‘part’’ temperature of 160° ± 2°C. Annealing time at 160°C is 5 minutes per 1 mm of wall thickness after parts reach annealing bath temperature (15-20 min).

Thorough agitation should be provided to assure uniform bath temperature and to avoid localized overheating of the oil. The latter condition may cause deformation or even melting of the parts. Parts should contact neither each other nor the walls of the bath.

Cooling procedure

When annealed parts are removed from the annealing chamber, they should be cooled slowly to room temperature in an undisturbed manner. Stacking or piling, which may deform the parts while they are hot, should be delayed until parts are cool to the touch.

Machining and Cutting of ZYTEL®

ZYTEL® can be machined using techniques normally employed with soft brass. Although the use of coolants, such as water or soluble oils, will permit higher cutting speeds, coolants are generally not necessary to produce work of good quality. Since ZYTEL® is not as stiff as metal, the stock should be well supported during machining to prevent deflection and resultant inaccuracies. Parts should normally be brought to room temperature before checking dimensions.

Tool design

Cutting tools used for ZYTEL® should be sharp and have plenty of clearance. The necessity of sharp cutting edges and easy elimination of chips cannot be emphasized too strongly. Dull tools, or tools having edges which scrape rather than cut, will cause excessive heat. Tools without sufficient clearances for ready removal of chips will cause the chips to bind and melt.

As in the case of metals, carbide and diamond tipped tools can be used to advantage when machining ZYTEL® on long production runs.

Sawing

Conventional power equipment, including band saws, jig saws and table saws can be used without modification for sawing ZYTEL®. However, it is important that the teeth in all saw blades, bands, and circular saws have a slight amount of ‘‘set”. The socalled hollow ground ‘‘plastic saws’’ whose teeth have no ‘‘set’’ will not give satisfactory performance with ZYTEL®.

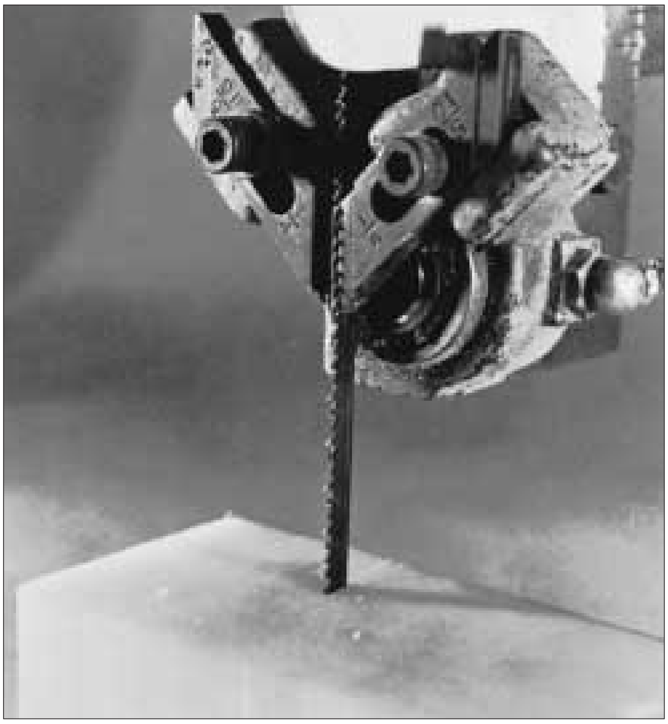
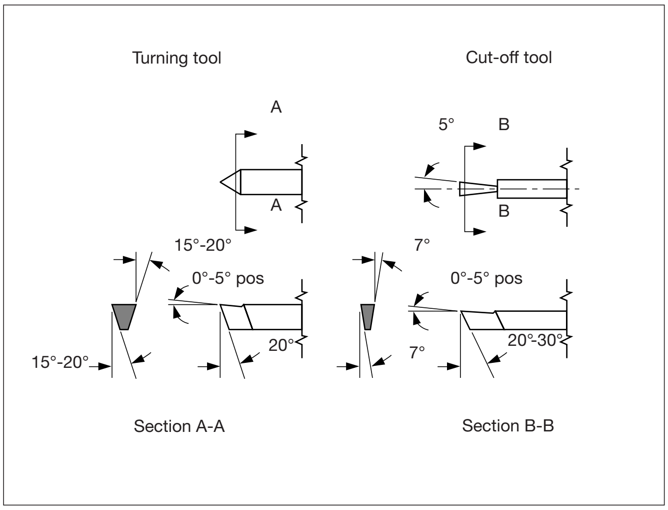


Fig. 11.02 **Sawing Machining conditions:**
Saw speed, 1200 m per min; blade, 6 mm wide, 4 teeth per cm; No coolant.
Material – ZYTEL® 101 – 35 mm thick.

More frictional heat is developed when sawing ZYTEL® than with most other plastics, so that ample tooth clearance should be provided to prevent binding and melting.

Although ZYTEL® can be sawed without coolant, the use of coolants will permit faster cutting rates.



* SUPPLIERS OF ANNEALING OILS-EUROPE
‘‘Primol’’ 342 and ‘‘Primol’’ 355 (Esso) ‘‘Ondina’’ 33 (Shell) White Oil N 15 (Chevron).

Drilling

ZYTEL® can be drilled satisfactorily with conventional twist drills. The included point angle should be 118° with 10°–15° lip clearance angles. So-called ‘‘plastic drills’’ or ‘‘brass drills’’ will not perform satisfactorily with ZYTEL®. Such drills have their leading edge ground flat in order to obtain a ‘‘scraping’’ action. In ZYTEL® this results in overheating and possible seizing. However, the long lead and highly polished lands of the ‘‘plastic drills’’ permit chips to readily flow from deep holes. This is a very desirable feature when drilling ZYTEL®. By modifying the drill lip angle to cut rather than scrape, these drills will work very well on ZYTEL®. Heavy feeds should be used, consistent with desired finish, to prevent excessive heat resulting from scraping rather than cutting.

Fig. 11.03 **Drilling Machining conditions:**
Drill size, 10 mm;
Speed 1000 rpm; No coolant.
Material – ZYTEL® 101 – 35 mm thick.

Coolants should be used where possible when drilling ZYTEL®. Where coolants are not used, the drill should be frequently withdrawn from the hole to clean out the chips and prevent overheating. Holes can be drilled on size providing the drills are kept cool.

Reaming

ZYTEL® can be reamed with conventional types of reamers to produce holes with good finish and accurate dimension. Reamers of the expansion type are preferred. Because of the resiliency of ZYTEL®, cuts made with a fixed reamer tend to be undersize. It is difficult to remove less than 0,05 mm when reaming ZYTEL®. Although the reamer will pass through the hole, no stock will be removed, and the hole will remain at the original dimension after the reamer is removed. At least 0,15 mm should be removed by the final reaming if a hole of correct size is to be produced.

Threading and tapping

ZYTEL® can be threaded or tapped with conventional equipment. Though desirable, the use of a lubricant or coolant when threading or tapping ZYTEL® is not always necessary.

Threads may be cut in ZYTEL® on a lathe using conventional single-pointed tools. As with metals, several successive cuts of 0,15-0,25 mm should be made. The finish cut should not be less than 0,15 mm, because of the resiliency of the material. When threading long lengths of rock stock, it is necessary to use a follow rest or other support to hold the work against the tool.

In production tapping, it is freqently desirable to use a tap 0,15 mm oversize unless a self-locking thread is desired.

Fig. 11.04 **Turning Machining conditions:**
Lathe speed, 980 rpm;
cutting speed 185 m/min; feed 0,15 mm;
depth of cut, 2,5 mm; No coolant.
Material – ZYTEL® 101 – 60 mm diameter.

Turning

ZYTEL® can be turned easily on any standard or automatic metal working lathe. No special precautions need be observed, although, as in other machining operations, tools should be very sharp. Tool bits should be ground as for soft brass; with a back rake to give free removal of the continuous chip, and with a large clearance to eliminate drag or interference. Chip breakers are not generally effective with ZYTEL® because of its toughness. A pick-off can be used as an aid in separating the turnings where desired. As with other materials, the best finish will be obtained with a high speed and fine feed.

Milling

ZYTEL® can be readily milled using conventional cutters providing the cutting edges are kept very sharp.
Where possible, climb milling should be used to minimize burring the ZYTEL®. Cutting speeds in excess of 30 m/min and heavy feeds in excess of 230 mm/min have been used successfully.

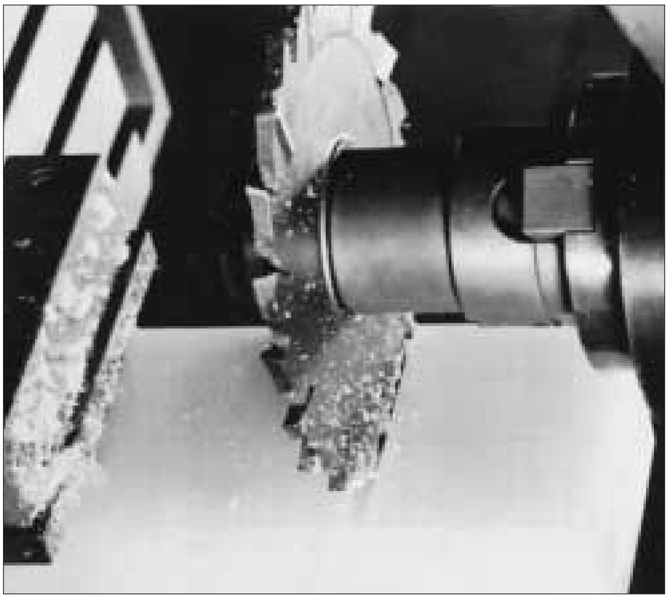


Fig. 11.05 **Milling** **Machining conditions: Cutting speed, 250 m/min; 100 mm cutter; 2,5 mm spindle; feed 150 mm/min. Depth of cut, 0,25 mm; No coolant. Material – ZYTEL® 101.**

Blanking and punching

Small flat parts such as washers, grommets and non-precision gears, 2 mm or less in thickness, often can be produced more economically by punching or stamping from an extruded ZYTEL® strip than by injection moulding. Conventional dies are used in either hand or power operated punch presses.

With well-made dies, ZYTEL® may be blanked or punched cleanly at high speed. If cracking occurs, it can usually be overcome by preheating the strip or by soaking it in water until approximately two percent moisture has been absorbed.

Finishing of ZYTEL®

Burr removal

Some machining operations tend to create burrs on the part. Although there are a number of ways to remove burrs, it is better to avoid forming them. This is best accomplished by maintaining sharp cutting edges and providing plenty of chip clearances.

Where only a few parts are being made, it is often simplest to carve or scrape off the burrs with hand tools.

If the burrs are not too large, they can be successfully removed by singeing or melting. In singeing, the burrs are burned off by playing an alcohol flame across the part. The burrs can be melted by directing hot nitrogen gas 290°C briefly across the part surface. The part should be exposed to the flame or gas very briefly so as not to affect the dimension of the part.

Fine burrs can also be removed with vapour blast or honing equipment. Where dimensions are critical, care should be taken to avoid removing too much material.

Commercial abrasive tumbling equipment is also used for deburring parts of ZYTEL® but the tumbling cycle is normally much longer than with metal parts. Although the exact grit slurry make-up for a particular part can best be determined by experimenting. The grit content by volume is usually twice the volume of parts of ZYTEL®.
A detergent is also added to the watergrit mixture to prevent the parts from being discoloured by the grit.

Filing and grinding

Because of the toughness and abrasion-resistance of ZYTEL® nylon resins, conventional files are not satisfactory. However, power-driven rotary steel burrs operating at high speeds are effective. Abrasive discs used on a flexible shaft or on a high-speed hand grinder will remove stock from ZYTEL® parts quickly and efficiently. Use of a coolant is generally desired for this type of operation.

A mill file with deep, single-cut, coarse, curved teeth (commonly known as a “Vixen” file), as is used for aluminium and other soft metals, is very effective on ZYTEL®. This type of file has very sharp teeth and produces a shaving action that will remove ZYTEL® smoothly and cleanly.

Sanding and buffing

ZYTEL® can be wet sanded on belt or disc sanding equipment. After sanding to a smooth finish, the surface may be brought to a high polish by use of standard buffing equipment. The buffing operation is normally considered as three steps: ashing, polishing and wiping.

Ashing is done with a ventilated wheel of open construction, made up of alternating layers of say 200 and 460 mm diameter muslin discs. In this way, an ashing wheel of some 100 to 130 mm in width may be built up. The ashing wheel is kept dressed with a slurry of pumice and water during the buffing operation.

The part of ZYTEL® is held lightly against the wheel and kept in constant motion to prevent burning or uneven ashing. Speed of the wheel should be approximately 1000–1200 rpm for wheels of 300 to 400 mm diameter. It is essential that the wheel be operated slowly enough to retain a charge of the slurry.

The polishing operation is performed in a similar manner and on a similarly constructed buffing wheel, the difference being that the wheel is operated dry and a polishing compound is applied to half the surface of the wheel, the other half remaining untreated. The part of ZYTEL® is first held against the treated half of the wheel for polishing and then moved to the untreated side to wipe off the polishing compound. Optimum speeds for the polishing wheel range from 1000 to 1500 rpm for a 400 mm diameter wheel.

Annealing of ZYTEL®

When annealing of ZYTEL® is required, it should be done in the absence of air, preferably by immersion in a suitable liquid. The temperature of the heat-treating liquid should be at least 28° C above the temperature to which the article will be exposed in use – a temperature of 150° C is often used for general annealing. This will ensure against dimensional change caused by uncontrolled stress-relief occurring below this temperature. The annealing time required is normally 5 minutes for 1 mm of cross section. Upon removal from the heat-treating bath, the part should be allowed to cool slowly in the absence of drafts; otherwise, surface stresses may be set up. Placing the heated article in a cardboard container is a simple way of ensuring slow, even cooling.

The choice of liquid to be used as the heat-transfer medium should be based on the following considerations:

- Its heat range and stability should be adequate.
- It should not attack ZYTEL®.
- It should not give off noxious fumes or vapours.
- It should not present a fire hazard.

High boiling hydrocarbons, such as oils or waxes, may be used as a heat-transfer medium if the deposit left on the surface of the moulded item is not objectionable, as in the case of parts which will be lubricated in use.

Recommended oils are "Ondine" 33 (Shell) and "Primol" 342 (Esso). Experimental work has also shown the suitability of annealing in an oven using a nitrogen atmosphere, although this does require special equipment.

The heat-treating bath should be electriccally heated and thermostatically controlled to the disired temperature. For best thermal control, heat should be supplied through the sidewalls as well as through the bottom of the vessel. A large number of small items is best handled by loading them into a wire basket equipped with a lid to prevent the parts from floating, and immersing the basket in the bath for the required period of time.

For applications where the maximum temperature will be 70° C or less, acceptable stress-relief can be obtained by immersion in boiling water. This method also has the advantage that some moisture is absorbed by the ZYTEL®, thus partially conditioning the piece. For stress-relief, 15 minutes per 3 mm of cross-section is sufficient. Longer times will be required if the piece is to be moisture-conditioned to or near equilibrium.

Moisture-conditioning

The most pratical method of moisture-conditioning for use in air, where 2,5% water is to be incorporated, is a simple immersion in boiling water. However, this method does not give true equilibrium, since excess moisture is taken on at the surface, and can only redistribute itself with time. One suggested procedure is to put about 3 to 4% water by weight into the parts. The excess will evaporate from the surface in time. Boiling times to 3% moisture are shown in Figure 11.06.

An excellent method for preparing a few parts for test is to heat in a boiling solution of potassium acetate (1250 g of potassium acetate per 1 l of water). A covered pot and a reflux condenser should be used to maintain the concentration of the solution. Density of solution 1,305-1,310 at 23° C. A maximum of 2,5% moisture is absorbed by the ZYTEL®, no matter how long the treatment is continued. The time required varies from 4 hours, for a thickness of 2 mm, to 20 hours, for a thickness of 3 mm.

Soaking in boiling water is a good method for moisture-conditioning parts to be used in water or aqueous solutions. The part is exposed until saturation is essentially complete, as shown by the saturation line in Figure 11.06. For thick sections (3 mm or more), it is more practical to condition the piece only partially, since absorption becomes very slow beyond 4 or 5%.

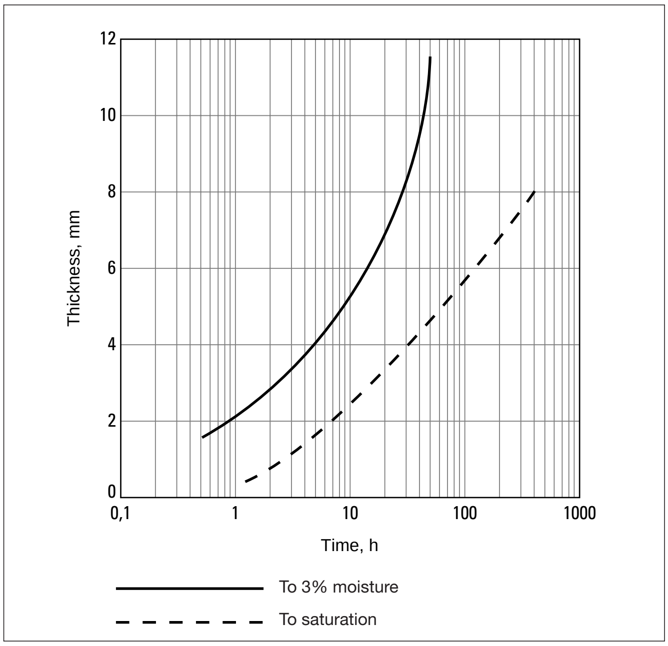


Fig. 11.06 **Moisture conditioning of ZYTEL® 101 (time of immersion in boiling water)**