PTFE

Forming and Fabrication

When extreme tolerance must be specified, or when product shapes are very complex, or when just one or two prototypes are required, the machining of PTFE shapes becomes a logical means of fabrication.

All standard operations—turning, facing, boring, drilling, threading, tapping, reaming, grinding, etc.—are applicable to PTFE shapes. Special machinery is not necessary.

When machining parts from PTFE shapes, either manually or automatically, the basic rule to remember is that these resins possess physical properties unlike those of any other commonly machined material. They are soft, yet springy. They are waxy, yet tough. They have the cutting "feel" of brass, yet the tool-wear effect of stainless steel. Nevertheless, any trained machinist can readily shape PTFE to tolerances of ±0.001 in and, with special care, to ±0.0005 in.

Choose Correct Working Speeds

One property of PTFE shapes strongly influencing machining techniques is their exceptionally low thermal conductivity. They do not rapidly absorb and dissipate heat generated at a cutting edge. If too much generated heat is retained in the cutting zone, it will tend to dull the tool and overheat the resin. Coolants, then, are desirable during machining operations, particularly above a surface speed of 150 m/min (500 fpm).

Coupled with low conductivity, the high thermal expansion of PTFE shapes (nearly 10x that of metals) could pose supplemental problems. Any generation and localization of excess heat will cause expansion of the fluoropolymer material at that point. Depending on the thickness of the section and the operation being per- formed, localized expansion may result in overcuts or undercuts and in drilling a tapered hole.

Machining procedures then, especially working speeds, must take conductivity and expansion effects into account.

Surface speeds from 60–150 m/min (200–500 fpm) are most satisfactory for fine-finish turning operations; at these speeds, flood coolants are not needed. Higher speeds can be used with very low feeds or for rougher cuts, but coolants become a necessity for removal of excess generated heat. A good coolant consists of water plus water-soluble oil in a ratio of 10:1 to 20:1.

Feeds for the 60–150 m/min (200–500 fpm) speed range should run between 0.05–0.25 mm (0.002–0.010 in) per revolution. If a finishing cut is the object of a high-speed operation (e.g., an automatic screw-machine running at 240 m/min [800 fpm]), then feed must be dropped to a correspondingly lower value. Recommended depth of cut varies from 0.005–6.3 mm (0.0002–0.25 in).

In drilling operations, the forward travel of the tool should be held to 0.13–0.23 mm (0.005–0.009 in) per revolution. It may prove advantageous to drill with an in-out motion to allow dissipation of heat into the coolant.

Properly Shape and Use Tools

Along with working speeds, choice of tools is quite important to control of heat buildup. While standard tools can be used, best results come from tools specifically shaped for use with PTFE shapes. The table below presents shape information important to proper single-point tool design:

Top rake	0–15° positive
Side rake and side angle	0–15°
Front or end rake	0.5–10°

Boring tools normally require the higher angles listed.

The quality of a tool's cutting edge not only influences the amount of heat generated, but it also controls tolerances in a different way. A tool that is not sharp may tend to pull the stock out of line during machining, thereby resulting in excessive resin removal. On the other hand, an improperly edged tool tends to compress the resin, resulting in shallow cuts.

An extremely sharp edge is, therefore, highly desirable, especially for machining work on filled compositions. "Stellite" and carbide-tipped tools will help to minimize required resharpening frequency.

To partially compensate for tool wear, it is helpful to grind tools with a slight nose radius. All drills, either twist or half-round, should have deep, highly polished flutes.

Adequate material support is also important, especially when machining long, thin rods of PTFE. If support is not provided, stock flexibility may lead to poor results.

Another characteristic of PTFE shapes will be noted immediately after beginning any turning operation. Rather than chips and ribbons of removed stock, as encountered during the machining of most materials, a PTFE resin turns off as a long, continuous curl. If this curl is not mechanically guided away from the work, it may wrap around it, hampering the flow of coolant, or worse, forcing the work away from the tool. On an automatic screw machine, a momentary withdrawal of the tool from the stock will suffice.

Rules for Dimensioning and Finishing

Normally, PTFE shapes are machined to tolerances of about 0.13 mm (±0.005 in). While closer tolerances are occasionally required, they usually are not necessary. The natural resiliency of these resins allows machined parts to conform naturally to working dimensions. For example, a part with an interference can be press-fitted at much lower cost than that required for final machining to exact dimensions, and the press-fitted part will perform equally well.

Closer Tolerances

When it is necessary to produce shapes with extremely close tolerances, it is usually essential to follow a stress- relieving procedure. By heating a fluoropolymer resin stock to slightly above its expected service temperature (but below 327°C [621°F]), initial stresses are relieved.

Holding this temperature for 1 hr per 2.5 cm (1 in) of thickness, followed by slow cooling, completes the initial annealing step. A rough cut will then bring the stock to within 0.38–0.76 mm (0.015–0.030 in) of final dimensions. Reannealing prior to a final finishing- cut will remove stresses induced by the tool.

A transition occurs in PTFE resin, resulting in a 1–1.5% increase in volume as temperature is increased through the neighborhood of 19□C (66°F). This must be considered when measuring a part for a critical application.

Measuring Tolerances

Personnel should exercise caution when measuring tolerances on parts machined from PTFE shapes; in general, results will be better if the measuring instruments do not exert excessive pressure on the piece.

For example, a micrometer used by inexperienced personnel could easily read 0.13–0.25 mm (0.005–0.010 in) under the true dimension because of the compressibility of the PTFE resin being used. Optical comparators are often useful in eliminating this type of error.

It is best to check dimensions at the expected service temperature, but temperature compensations will suffice if this is not practical. Parts machined to final size and measured at room temperatures or below will not meet specifications at higher temperatures. The reverse is also true.

Surface Finishes

Surface finishes better than 0.4 µm (16 µin) are possible on parts made with PTFE shapes, but rarely are needed because of the resin's compressibility and low coefficient of friction. Precision-honed and lapped cutting tools will produce a 0.4-µm (16-µin) surface when required; standard equipment yields a finish of about 0.8 µm (32 µin).

Lapping compounds may be used, but these as well as grinding compounds may become embedded in the fluoropolymer and may prove to be very difficult to remove. Contaminants from machinery not used exclusively for PTFE shapes can also embed in the material surface.

Safe Handling

As with all organic polymers exposed to high temperatures, good safety practice requires the use of adequate ventilation when processing PTFE fluoropolymer material. The heated fluoropolymer should be kept enclosed, or exhaust ventilation should be used, to prevent inhalation of fumes and gases that may arise. Heating may produce fumes and gases that are irritating or toxic.

Similarly, care should be taken to avoid contamination of smoking tobacco or cigarettes with fluorine-containing resins. Precautions are to be used in the handling, processing and use of PTFE or other fluoropolymer resins. Before using PTFE, read the Material Safety Data Sheet and the detailed information in the Society of the Plastics Industry publication, "Guide to the Safe Handling of Fluoropolymer Resins." Copies may be obtained from your sales representative.