Getting the best results:

What you need to know about machining plastics
Machining plastics is an art.

Whereas achieving the desired finish for machined metals is a fairly straightforward process, techniques for machining plastic aren’t as well understood. Further, plastic machining volumes don’t nearly approach those of plastic injection molding, so the information available is relatively limited.

When engineers are faced with designing a plastic part that must be machined – because of low quantities, close tolerances, and/or unusual shape – they’ll usually turn to a machining data handbook and attempt to apply standard principles. That’s when trouble arises.

Individuals involved in the design or procurement of plastic components can successfully address the challenges of selecting the right materials, proper dimensional tolerancing, handling, and other concerns by choosing the right shop for the manufacture of your unique plastic parts.

**Material Selection**

Obtaining high-quality material is the first step in fabricating a high-quality part.

Information to support decisions concerning chemical resistance, mechanical properties and thermal capabilities can be found in manufacturers’ catalogs. MatWeb (www.matweb.com) is another helpful data source. However, the job of material selection may not be complete even after you’ve performed this research.

This is because unlike metals, plastics are not created equally. Each manufacturer approaches the process differently, and material integrity varies widely between manufacturers. Poor material can be soft, have voids, contamination, color variation and may be poorly annealed.

Rely on your plastic machining specialist to help you select a plastics supplier. Their business is machining plastics every day, so they know which material manufacturers to utilize and which to avoid. Although you may wish to research material through a distributor, keep in mind distributors are not machinists; further, they may recommend their higher-margin materials.

In material selection, consideration should be given to stock size. This is especially important as plastic components get larger. For example, polypropylene rod is always oversized. Some acetal rods are centerless ground to +.002/-0 or +.005/-0 in small sizes, with large diameters oversized. Acrylics in sheet form are frequently available in metric sizes with a 10% tolerance (example .25” stock is .236” +/- 10%). Be certain to research your plastic of choice as stock sizes and tolerances vary between materials.

Once you have chosen the material and manufacturer, define it well on the print. Use the trade name and ASTM specification to guarantee the material is purchased from an approved source. Add a note to require material certificate of conformance for verification. Material certification directly from the manufacturer is the best guarantee; don’t settle for distributor material certification.

In the metal industry most materials are fully traceable, but plastics have not reached that level of sophistication. Traceability is frequently lost in the plastic distributor’s stock. For high-end medical applications, careful research is necessary to ensure lot traceability. Contact manufacturers directly to discuss their certification levels. Depending on their business focus, manufacturers can offer varying traceability on different products.

**Common Mistakes in Material Specifications**

DuPont developed acetal (trade name Delrin®) in the 1950s. Acetal is the most popular machining plastic and has solid performance characteristics. Delrin is a homopolymer. Because of centerline porosity problems, a copolymer was developed, also called acetal (under other trade names). The copolymer is considered an equivalent to Delrin, varying slightly in mechanical properties.

Developed first, with a good marketing campaign, DuPont has been successful in keeping the Delrin trade name alive. In our experience, 80% of component prints specify Delrin over acetal. However, a copolymer is often a better choice, especially in sheet form.

Interestingly, distributors and manufacturers have teamed up to fix the problem. Although Delrin is frequently specified, distributors estimate that 80% of the acetics sold today are actually copolymers. In fact, manufacturers now charge more for true Delrin material. Distributors in many cases substitute a copolymer without the end user’s knowledge. If Delrin is needed, we recommend you get certification; otherwise, specify acetal on the print.

Consideration of the material manufacturing process becomes important when determining properties desirable to the component. Materials are often produced via several different processes. Extrusion, casting, and molding are common methods associated with Teflon®, nylon, and acrylic. Acrylic, in particular, varies in hardness between the cast and extruded sheet.

The extruded material is much lower in cost, and generally appropriate for display-type work. For superior machining and dimensional stability, you should specify cast acrylic. Engineers creating prints without a clear designation of the acrylic type run the risk of a component not meeting expectations. Similar principles are applicable to nylon and Teflon components. Extruded nylon is a better choice for smaller parts. Cast nylon has its place for near net shapes and larger components.

Plastic color is another consideration. Typically, color uniformity and repeatability become concerns when the component can be seen by the
product end user. As a carbon additive, black is an easy choice. Within a material type, black is very consistent with little variation between lots or manufacturers. White is problematic. Some materials are offered as natural, which may or may not be white; others are offered in white, which may not really be white. Still others are offered in both natural and white. Polypropylene is an excellent example of a material with color variation. Some manufacturers’ material is a solid opaque white. Other polypropylene is more of a translucent beige/yellow. Next to each other, these do not appear to be the same material. The opaque white may be confused as a polyethylene. Color variations are such, especially between manufacturers, that it is best to discuss the issue with your plastic machining specialist. Realize that color may not be repeatable from a single manufacturer from lot to lot, or through material size changes.

Natural ABS is notorious for unstable coloring. The material can run from near-white to yellow in different sizes from the same manufacturer’s stock. Like a lot of consumer items today, plastics are manufactured across the globe. Non-U.S. acrylics are popular because they are relatively inexpensive. Unfortunately, these plastics are particularly thin, running at the bottom of the tolerance band. They also may not be as stable and usually have more internal stress. This material is very suitable for the display industry, where cost control is paramount. For high-end and medical applications we recommended you specify a U.S. source. The material will usually provide greater stability and better overall machinability.

**Tolerancing**

A common assumption in designing plastic components is that they cannot be tolerated as close as metal parts. The real difference between metals and plastics is plastics are more impacted by material choice and part configuration. Under the right conditions, it’s possible to run components +/- .0002. In opposing situations, holding +/- .005 is challenging.

**Polishing**

The three most common methods of polishing are flame, vapor and mechanical. Flame polishing utilizes a hot flame to flow a surface, specifically on acrylics. Operator skill is critical with this method, as it is similar to coloring with a marker. When done properly, flame polishing produces the clearest finish on acrylics. Vapor polishing utilizes a chemical vapor, which attacks the surface of the plastic. The best plastics for this process are polycarbonate, Ultem®, acrylic, and polysulfone. We recommended this process be left to professionals. Special equipment needs to be utilized to avoid contact with the operator. Skilled vapor polishing can provide optical quality finishes.

Mechanical polishing is the most common polishing process, easiest to do, and useful on any plastic. This method tends to leave very fine scratches on the surface and will usually look nice, but is not acceptable for optical work.

One caveat: Polishing is all in the preparation. You should be aware that if the machine is not done correctly, all the polishing in the world will not fix the components. Avoid machine shops that subcontract the polishing. The quality is inevitably subpar. These shops do not have the knowledge or skill to properly prepare the plastic component for polishing. Polished components should be made entirely at a single location for best results.

**Annealing**

Annealing and polishing go hand-in-hand. Without an annealing step, some plastic components will deteriorate from stress cracking. Stress cracking occurs from surface stresses caused by the polishing process. As a rule of thumb, avoid companies producing polished plastic components without significant annealing knowledge and experience. Annealing of components is sometimes useful as a standalone process. For critical applications requiring maximum plastic stability and crack avoidance, consider requiring stress relieving as part of the manufacturing process.

**Finish**

Some applications require superior finish to function properly. It is a matter of material choice and part configuration. Plastic compositions like Teflon frequently produce a porous surface, limiting the smoothness possible. Other plastics burnish well. Where required, 32 micro inches is achievable on a regular basis with only slightly more effort than the standard sixty-three. Finishes below 32 micro inches are progressively more difficult - but not impossible – and entail special tooling. Polishing can be expected to improve the finish by five micro inches when working below thirty-two.

**Contamination**

Contamination can come from coolants and metal filings - and can pose serious problems to quality, durability and appearance of machined plastic parts. Plastic machine shops are knowledgeable and utilize the correct plastic-compatible coolants. These aren’t necessarily the same coolants appropriate for metals. Some high-quality metal coolants on the market today will actually stress crack plastic components. For the more sensitive materials, the coolant will not only potentially inhibit the machining quality, but will attack the plastic while in contact with the solution.

Material chips from previous jobs are typically present in machine tools. While metal shops that also machine some plastics frequently struggle with this problem, plastic machine shops are rarely, if ever,
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contaminated with metal filings.

Handling
Any type of custom-made components should be handled carefully. Plastic components are very sensitive, and surfaces and corners easily damaged. Your plastic machining specialist is well-versed in handling delicate components. Extra care is normally taken during the manufacturing process through to packaging for shipment.

Stability Concerns
Like machining, plastic stability is strongly impacted by part configuration and material dependence. Stability relates to three characteristics: thermal expansion, off gassing, and material stress. Thermal expansion is material-dependent. Materials such as PEEK and Torlon® are on the low side for plastics while polypropylenes on the high end. With some close tolerance work in large components, simple body heat is sufficient to cause it to move out of tolerance.

Off gassing is a process where material continues to emit a gas after it is processed. Delrin components, for example, left in a sealed container for a few weeks will emit a strong odor of formaldehyde. Formaldehyde is a key ingredient in Delrin’s makeup. This off gassing actually reduces mass, allowing certain configurations to shrink.

Material stress is the least controllable and most troublesome characteristic. For example, skim cuts on a flat sheet will curl. In such situations special handling is required. Plastic machine shops have developed special techniques to ensure components will not become warped and distorted. Consider discussing the particular requirements with your plastic machining specialist.

Choosing the Right Shop
Knowledge of the plastics manufacturing process can be helpful when selecting the right shop for a plastics-machining job. Extra time and research should be invested if the part has unique specifications or is highly technical.

First and foremost, narrow your search to those shops that specialize in plastics machining. They will provide you with a better and more consistent overall job. While metal shops can do plastics machining, particularly the most basic jobs, they often encounter problems regarding best material choice, contamination, burr control and overall quality. If you are seeking above-average to excellent quality, or if there’s a particular tolerance or surface finish you’re looking for, seek out shops that only do plastics machining.

After you’ve identified a few shops that specialize in plastics, write down some details about your job. Call the shops and ask to talk about your needs and about their approach. Start with a few basic questions, such as how they address burr control, a common problem in plastics machining.

Ask the machine shop if they’ve ever worked in the specific material needed for your job. If your component will be made of polyethylene terephthalate, and they’ve never worked with PET or they respond that they “work with all kinds of materials”, just not the one you need - avoid them. Ask them about the particular properties of your material, what it costs, how it behaves under different conditions. If they cannot engage in a conversation about your material, move on and contact another shop.

Don’t hesitate to arrange a visit to prospective shops, and ask questions on site to better understand their capability to handle your job. During the visit, ask to see examples of similar components and inquire about how they were produced. Were the projected deadlines for delivery met? Did they encounter any specific problems during the manufacturing process? Do they anticipate any potential challenges in meeting your job requirements?

Finally, make sure the facility is clean, well-run and well-organized. Seek out shops with modern machines and knowledgeable leaders. After all, companies that specialize in plastics machining only exist because there is a class of high-quality parts out there - parts too difficult for your average shop - which require some specialization to produce. PEP