Understanding the Art of Machining Plastics

By Tom Rohlfs

Machining in the common metals is a widely understood process: choose a suggested insert with standard speeds and feeds and the desired finish is usually obtained. Unfortunately the availability of information on plastic machining is limited. In general, plastic machining is not thought of as an independent process. Molding is done in much higher quantities, keeping the total amount of plastic machining small in comparison to metal machining. Because plastic is soft by nature, part configuration also plays a dominant role in machining methodology.

Engineers are faced with the challenge of designing a plastic part that, because of low quantities, close tolerances and/or unusual shape, requires it to be machined. They will usually turn to a machining data handbook and attempt to apply standard principles. Trouble soon arises.

Those individuals involved in the design and/or procurement of plastic components can successfully address these challenges by choosing the right materials, following through with the proper dimensional tolerancing, handling and addressing other concerns by choosing the right shop for the manufacture of their particular parts.

Material Selection

The first approach to material selection is usually a cost-versus-performance comparison. Decisions concerning chemical resistance, mechanical properties and thermal capabilities are all found in manufacturers' catalogs. In addition, www.Matweb.com can serve as a helpful online data source. Unfortunately, even after this research has been performed, the job of material selection may not be complete. Unlike metals, plastics are not created equal. Each manufacturer approaches the process differently. Consideration in selection needs to go beyond the properties found in the catalogs.

Obtaining high-quality material is the first step in making a high quality part. The integrity of material varies widely between manufacturers. Poor material can be soft, have voids, contamination, color variation and may be poorly annealed. Call your plastic machining specialist. Their business is machining plastics every day. They know which manufacturers to utilize and which to avoid. Engineers may research material through a distributor; however, they are often an unreliable source of information. Distributors are not machinists and may recommend material where their margins are the highest.

In material selection, consideration should be given to stock size. This is especially important as plastic components get larger. For example, Polypropylene rod always comes 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 ¼" stock is .236" +/- 10%). Be certain to research your plastic of choice as stock sizes and tolerances vary between materials.

Once the material and manufacturer is chosen, 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. Unlike the metal industry where most materials are fully traceable, 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 the 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 with 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 with Delrin, varying slightly in mechanical properties. Developed first, with a good marketing campaign, Dupont has been successful in keeping the Delrin trade name alive. By Connecticut Plastics' estimate, 80% of the component prints specify Delrin over acetal. However, a copolymer is many times a better choice especially in sheet form.

Interestingly enough, both distribution and manufacturers have teamed up to fix the problem without the engineering world's knowledge. While Delrin is frequently specified, distributors estimate that 80% of the acetals sold today are copolymers. In fact, the manufacturers now charge more for true Delrin material. Distributors in a lot of cases substitute a copolymer without the end user's knowledge. If Delrin is needed, it is wise to get certification, otherwise specify acetal on the print.

Many materials can be produced with different manufacturing processes. Extruded, casting, and molding are common methods associated with Teflon, nylon, and acrylic. Consideration of the manufacturing process becomes important when determining properties desirable to the component.

Acrylic, in particular, varies in hardness between the cast and extruded sheet. The extruded material is much lower in cost and generally best left to display type work. For superior machining and dimensional stability, specify cast acrylic. Engineers creating prints without a clear designation of 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 that often arises. Typically when the product end user can see the component, color uniformity and repeatability become concerns. 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 a problem in itself. 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 variation in color. Some manufacturer's material is a solid opaque white. Other polypropylene is more of a translucent beige/yellow. Next to each other, these materials do not look to be the same. The opaque white may be confused as a polyethylene. Color variations are such, especially between manufactures, that it is best to communicate directly with your plastic machining specialist to discuss the issue. 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 all from the same manufacturer's stock.

Like a lot of consumer items today, some plastics are manufactured outside the United States. Import acrylics are popular because they are inexpensive. Unfortunately, they are particularly thin on the thickness 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 were cost control is paramount.

For high-end and medical applications it is recommended to specify a domestic source. The material will provide greater stability and better overall machineability.

Tolerancing

A common assumption in designing plastic components is that they cannot be toleranced 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 is 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 however, flame polishing produces the clearest finish on acrylics.

Vapor polishing utilizes a chemical vapor, which attacks the surface of the plastic. Best plastics for this process are polycarbonate, ultem, acrylic, and polysulfone. This process is not for the lay person. Special equipment needs to be utilized to avoid contact with the operator. It is recommended that this process be left to the professionals. When done properly, vapor polishing can provide optical quality finishes.

Mechanical polishing is the most common, 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, like painting is all in the preparation. If the machining 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, companies producing polished plastic components without significant annealing knowledge and experience should be avoided.

Annealing of components is sometimes useful as a stand-alone 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 63. Finishes below 32 micro inches are progressively more difficult--but not impossible--entailing special tooling considerations. Polishing can be expected to improve the finish by 5 micro inches when working below 32.

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. Metal shops employ coolants that work well with 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, contaminated with metal filings.

Handling

Any type of custom-made components should be handled carefully. As one would expect, plastic components are very sensitive. Simple banging against one another can damage the surface and dent corners. 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 dependant. 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 a material continues to emit a gas after it is processed. Delrin is a classic case demonstrating the condition. Delrin components 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. Take a skim cut on a flat sheet and it will curl. In such situations special handling is required. The plastic machine shop has developed special techniques to ensure components will not arrive or 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 special 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 those shops that only do plastics machining.

After you've identified a few shops that specialize in plastics, write down a few details about your particular job. Call them 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 them if they've ever worked in the specific material needed for your job. If your component will be made of PET, and they've never worked in 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 you in a conversation about your material, move on and contact another shop. Don't hesitate to arrange a site visit, and ask questions on site to better understand the capabilities of prospective shops to handle your job. During the visit, ask to see examples of similar components; 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?

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

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