special focus

How to be successful designing with machinable plastics

PLASTICS FABRICATING & MACHINING

by Jim Hebel

As a design engineer, machinist or simple user; have you ever experienced a failure when using plastic components? Certainly you were counting on all the great benefits that come from using advanced engineered plastics. You counted upon the weight reduction and improved wear life for higher system efficiency. You anticipated the noise reduction and even looked forward to the elimination of lubrication for maintenance free service. Perhaps you were even counting upon some of the intangible benefits such as electrical or thermal insulation, or even the improved corrosion resistance. No doubt that you were giddy with excitement as you looked forward to improving the performance of your component, machine or system, all the while recognizing the greater productivity and higher efficiencies which can be achieved with plastics. But what went wrong? Why did the part fail? Was it really a "cheap" piece of plastic that just didn't live up to the hype?

Actually, such failures happen more than we think for those of us who live in the world of engineered plastics. When engineers and designers experience these set-backs, they are no doubt left with a poor opinion and an unjust attitude toward plastic solutions. Please understand that many of these failures are the result of some common mistakes that are easily avoidable. Most premature plastic component failures are the result of one of the following conditions:

- Excessive temperature exposure
- Excessive chemical exposure
- Improper design clearance
- Cracking due to impact or fatigue
- Inability to hold desired tolerances
- Too much material movement — i.e., bowing or warping

In most application failures the material is not at fault. The above failures are the direct result of either:

- Incorrect material selection (using the wrong material for the job) or
- Poor component design
- Not fully taking into consideration the actual operational environment

What's important to understand is that component design with plastics is much different than with traditional materials like metals. To achieve all the great benefits of using plastics; one should ensure the right material is selected. Coupled with that, understanding a few simple design tips will make all the difference between failure and success.

Material selection

Choosing the right material is critical to the success of your component. Plastics inherently have a chemical make-up which means they are suitable for some applications and not-so suitable for others. In addition, plastics' temperature and chemical exposure range is a key factor in the decision process. While this may seem like a very daunting task, some suppliers have made it easy. For example, our company utilizes its own Material Selection Triangle to help designers pick the right material for their application.

Materials on the left of the Selection Triangle are known as "amorphous" materials, while plastics grouped on the right side are known as "semi-crystalline" materials. Amorphous materials are inherently better suited for structural applications, while semi-crystalline materials are better suited to dynamic wear applications. Also, semi-crystalline materials have much better chemical resistance than amorphous materials.

You will also notice on the Selection Triangle that as you travel vertically there are divisions. These divisions are based on performance. The dominant performance criterion for this selection tool is temperature capability. Materials located higher on the triangle offer greater temperature resistance. Keep in mind that as you go up the triangle, in general other performance criteria also improve such as chemical resistance, dimensional stability, and strength and stiffness at temperature. Understand-

MATERIAL SELECTION EXAMPLE

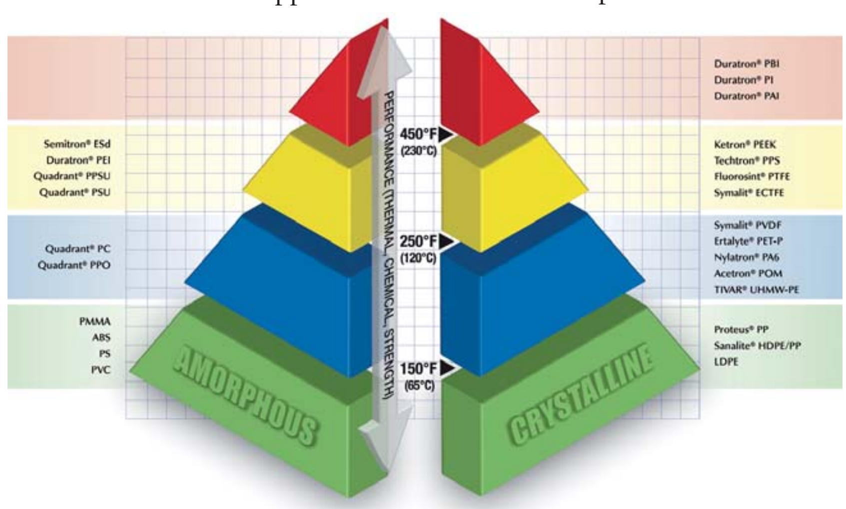
Application: Bearing in a 300°F environment with exposure to mild acids.

Step 1: Knowing the application is a bearing, one should choose a semi-crystalline material on the right side of the Selection Triangle.

Step 2: Based on temperature and chemical extremes, one should position themselves vertically on the triangle. Aggressive chemicals along with a 300°F environment would put you in the advanced engineered plastic family or the yellow section.

With two simple steps you can see that you have narrowed your selection to just a few basic materials. Potential choices include Ketron® PEEK or Techtron® PPS, both excellent options for high temperature bearings.

Step 3: Make final material selection based on load requirements, dimensional stability needs, or any other design specifics that are required. These design specifics will also help guide your material selection toward any required filler package.



ing where a material sits on the Material Selection Triangle will allow you to pick the right material for your application.

Design modifications and the right approach

Making modifications to your design can also make the difference between failure and success with plastics. Let's cover a few topics where common problems are encountered. These topics include machining, tolerance expectations, strength and toughness and proper clearance.

• **Machining**: One area that leads to failures yet is often over-looked or not even considered is plastic machining. Parts that are fabricated via machining are exposed to heat generation from tool contact. Excessive heat generation during machining is one of the largest problems I see and can lead to material brittleness, excessive burring, poor surface finish and rapid tool wear. Keeping a component cool during machining is critical. The use of water-soluble coolants is recommended along with proper cutting tools with the right inserts and geometries. Machining feeds and speeds are also critical to ensure proper cutting of the plastic is being recognized. I recommend for the best results, follow the procedures as outlined in our Machinist Handbook. Included are tips on peck drilling of holes, use of pie-jaws and climb milling versus conventional milling. This handy tool offers starting points, crucial tips and review of common mistakes which are sure to help even the most experienced machinist.

• **Tolerance expectations**: Some designers are caught off guard when their plastic components do not meet their tolerance expectations. This can be the result of unexpected machining tolerances or perhaps material movement while in application. While machining tolerances can vary depending on material selection, a general rule of thumb is one can expect to hold 0.1 to 0.2 percent tolerance on all dimensions coming off the cutting machine. While, tighter tolerance control can be achieved by some of the materials located higher on the Material Selection Triangle, machining again can again play an important role. Despite the best stress relieving techniques, plastics inherently have some level of internal stress. Cutting into the material will release this stress and result in undesirable material movement.

For tighter tolerances a "roughing" method of machining will help one achieve their desired outcome. This technique involves rough machining a component to approximately .030" (of final dimensions) on all dimensions, then leaving the part sit for 24 to 48 hours. This will allow the plastic to inherently stress relieve as it moves to a steady state position. Follow this up with a light finish machine and the part will remain very stable. This technique eliminates the need for stress relief cycles utilizing special ovens and the introduction of unnecessary heat histories which can embrittle your plastic.

• **Increased strength and toughness**: Have you experienced failure from cracked or broken parts? Many people believe plastics just aren't tough enough for their application. Plastics certainly can handle impact situations, but component design is critical. With plastics, I always recommend eliminating any sharp angles just to be safe. Where possible, design in a minimum radius of .020" to .030" which will provide significant strength and toughness to your material.

Be aware that putting threads into plastic can be a failure just waiting to happen. If not done correctly, threads can be numerous small sharp angles where concentrated loads can easily result in the formation of cracks. Our company always recommends utilizing a "coated" tap when threading into plastics. Actually this is the only time we recommend the use of coated tooling. In this case, the coating dulls the tap enough that the result is a radius applied to the root of the threads. These radii improve thread strength significantly.

• **Proper clearance**: In dynamic applications, like bearings, self-lubricated polymers offer maintenance free performance and extended wear life. However, to fully recognize these benefits, proper running clearance is critical. Remember that plastics have a higher coefficient of linear thermal expansion (CLTE) than traditional metals. That means that plastics will move more with exposure to heat — i.e., frictional heat, environmental. This is no problem, as long as proper clearance is designed into your plastic bearing. I always recommend using our Design and Fabrication Guide for proper bearing design. This booklet gives a step-by-step breakdown based on material selected and estimated application conditions including bearing size, environment and shaft speed.

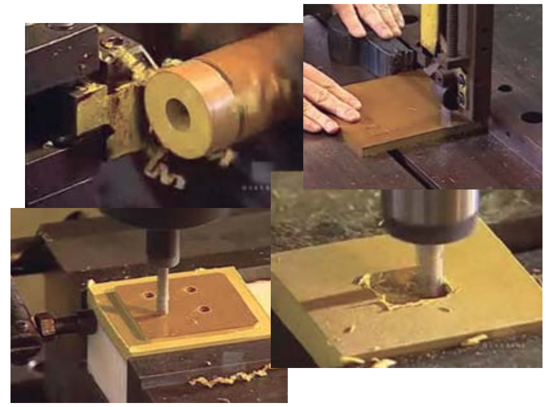
Conclusion

To readily achieve success with plastics, consider a few additional items of note. When selecting and designing with machineable plastics also look for mechanical property data generated from stock shape materials, not resin data from injection molded samples. Processing differences also mean property differences which can affect your design. Utilize a supplier that has documented ISO quality systems and the capability to provide lot-to-lot traceability, specification review and material certifications. Look for a supplier that also offers technical safety net, including design and material selection assistance which will help to shorten your own plastics learning curve.

In summary, if you have experienced failures with machineable plastics, reconsider the material you selected. Is it the right material for the application? Or was it the result of one of the common design or machining flaws noted above. Many companies around the world are achieving success with plastics and directly influencing their bottom-line through increased productivity and efficiency gains. With the right approach and the right materials, you can too. ■

An excellence resource for videos on machining advanced engineering plastic materials can be found at www.quadrantplastics.com and search for "Machinist Toolkit." Topics covered include fly-cutting, sawing, tool selection, turning and drilling.

Quadrant's Machining & Design Tools: Their Design & Fabrication Guide and their compact Machinist Handbook offer great tips and are downloadable under "Support" at www.quadrantplastics.com.



Jim Hebel is manager of technical service and application development for Quadrant EPP USA Inc. For further information, contact Quadrant EPP USA Inc., 2120 Fairmont Avenue, P.O. Box 14235, Reading, PA 19612 USA; (800) 366-0300, (610) 320-6600, fax (610) 320-6868, e-mail: americas.epp@qplas.com, www.quadrantplastics.com