DESIGNING WITH PLASTICS: A Practical Guide for Engineers

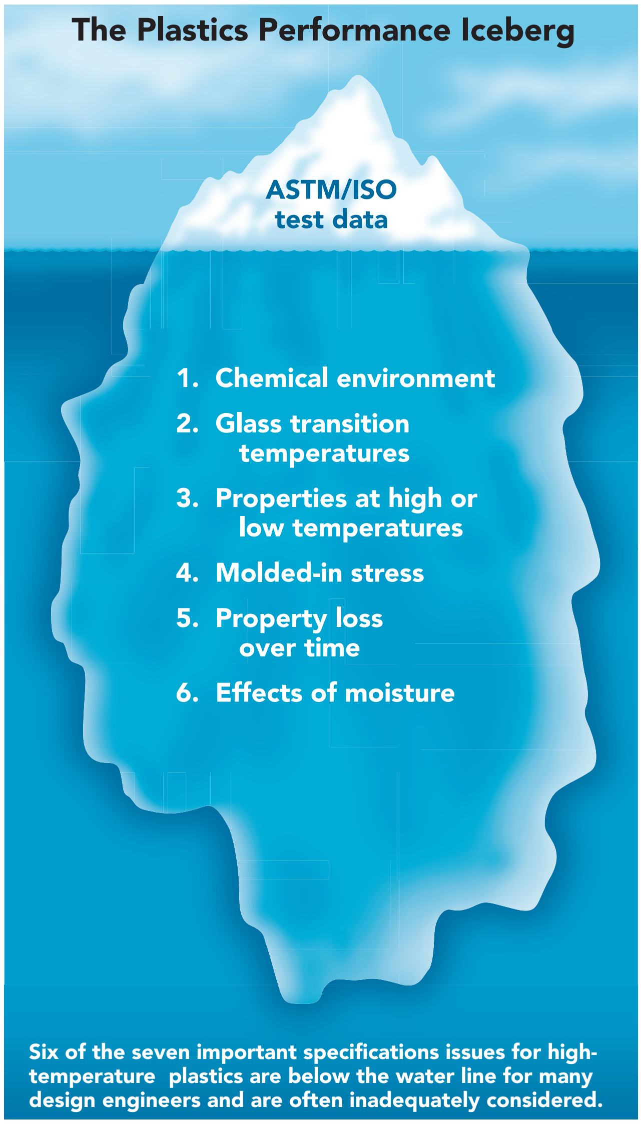
High-temperature plastics—Can they really take the heat?

Information on data sheets is great for predicting how test bars will react at room temperature to specific conditions. But in the real world? Read on.

One of the least understood and most erroneously specified areas in the design field is high-temperature plastics. The phrase is widely used but difficult to define. What plastics can genuinely be called "high temperature"? What are high temperatures? The answers can differ dramatically, depending on the application and the plastic.

The minimum definition: They are plastics that have usable mechanical properties at an elevated temperature. The irony is that very few suppliers of high-temperature plastics publish that information on data sheets. Instead, what you find are mechanical properties based on ASTM or ISO tests conducted at room temperature.

"If you're designing a load-bearing part for a high-heat application, you must understand how the operating temperature will affect the properties that are critical to the application," comments Greg Warkoski, process technology manager for Solvay Advanced Polymers, Alpharetta, GA. "Although data sheets don't have specific information like this, you can usually get what you need from your resin supplier."



Six of the seven important specifications issues for high-temperature plastics are below the water line for many design engineers and are often inadequately considered.

And that's just the tip of the performance iceberg for the unwary design engineer.

These issues can also create obstacles during material selection and the design process:

- Poor understanding of test methods and what the results really mean;
- Failure to factor in the chemical environment and the effects of moisture;
- Excessive reliance on single-point data instead of performing mechanical analysis over a range of temperatures—and a range of times, when appropriate;
- Poor understanding of how changes in temperature affect plastics with different chemistries; and
- Failure to consider stresses and other problems caused by processing or design (product and mold).

"When you perform an ISO or ASTM test, you end up with results that are directly related to the condition of the test," comments James Beau-

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regard, president of Plastics Technology Laboratories Inc. of Pittsfield, MA. "But when you take a design out into the field, there are a lot of other things occurring that must be taken into consideration."

Rule of thumb: **It's generally acceptable to use 9-18 degrees Fahrenheit below the HDT as the maximum short-term operating temperature.**

CHEMISTRY BASICS

Start your material selection process with a review of polymer fundamentals that can affect product life. Polymers comprise two molecular structures: amorphous (randomly ordered) and crystalline (highly ordered). For all practical purposes, thermoplastics are either amorphous polymers or semi-crystalline polymers, which have both amorphous and crystalline regions.

One of the major differences between these two types is how they respond to changes in temperature.

Amorphous polymers—such as polycarbonates and polysulfones—do not have defined melting points, but rather ranges at which they soften. This is called the glass transition temperature (T_g). Semi-crystalline polymers—such as nylons—have glass transition temperatures (T_g) as well as sharp melting points (T_m).

"This has to be taken into consideration when selecting a material because semi-crystalline polymers lose a significant amount of their mechanical properties when heated above the T_g, especially if they're not reinforced," says Solvay Advanced Polymers' Warkoski. Example: AMODEL® polyphthalamide is a semi-crystalline engineering plastic that has a heat distortion temperature of around 250F when unfilled and about 530F when filled.

Because T_g is a fundamental property of the base polymer, it usually isn't included on data sheets. Instead, you find the heat deflection temperature (HDT) of the finished resin. HDT is used to determine short-term heat resistance and distinguishes between materials that are able to support a load at an elevated temperature. At this temperature, a test bar shows a specified deformation under a load of 264 psi. It is generally acceptable to use 9-18F below the HDT as the maximum short-term operating temperature. Specific information on D648-04 Standard Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position is available at www.astm.org. The corresponding test from the International Organization for Standardization (ISO) is ISO 75-1:2004, and is available at www.iso.org.

HDT (also called DTUL) is a snapshot of thermal properties at a single temperature point. Maintenance of properties over time at elevated temperatures is crucial for applications with continuous heat. The chemical environment, such as oil or gasoline, can also dramatically affect mechanical properties, particularly at elevated temperatures. These are just a few of the issues that design engineers must consider when specifying plastics for load-bearing applications at high temperatures.

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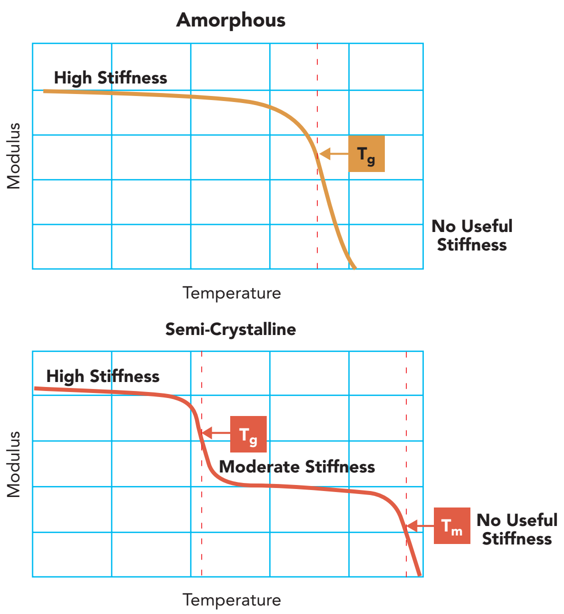
Pay Attention to Glass Transition Temperatures



The graphs show typical changes in modulus for amorphous and semi-crystalline plastics as temperature changes. Glass transition temperatures typically are not included in standard data sheets used by design engineers.

This series will be continued in the April 4, 2005, issue of Design News. *The next report will cover the importance of the UL continuous use Relative Thermal Index test, the role of chemical atmosphere, and effects of moisture. For more information on high-temperature plastics from Solvay Advanced Polymers, visit http://rbi.ims.ca/4388-500.*

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