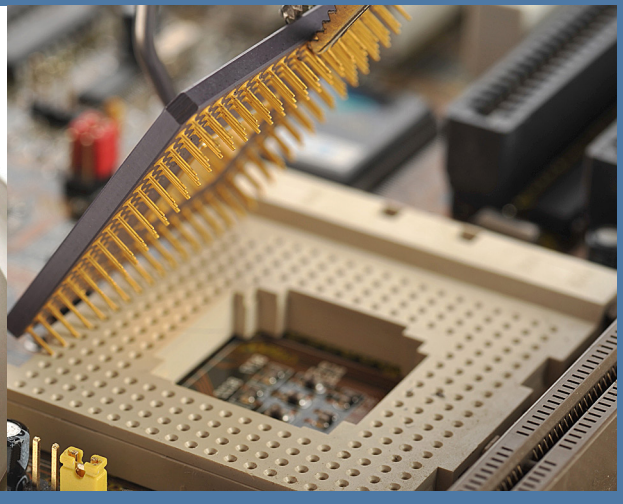
PERFORMANCE ADVANTAGES OF PEEK (polyetheretherketone)



Curbell Plastics, Inc.
High Performance Materials White Paper
Dr. Keith Hechtel, DBA – Author

CURBELL PLASTICS

PEEK (polyetheretherketone) is one of the most technologically advanced high performance polymers that is commercially available as sheet, rod, tube, and film stock.

Engineers often turn to plastics when they are looking for low cost materials to replace metals in their designs. Since common polymers such as polypropylene, nylon, acetal, and polycarbonate typically cost less than $3.00 per pound, a cost savings can often be achieved by selecting one of these plastics for an application. That being said, there are times when neither metals nor standard plastic materials will perform in a demanding critical-service application and high performance polymers, often costing more than 10 times the price of conventional plastics, are required.

PEEK (polyetheretherketone) is one of the most technologically advanced high performance polymers that is commercially available as sheet, rod, tube, and film stock. The purpose of this article is to describe the performance advantages of PEEK and the benefits of specifying PEEK for demanding applications.

COMPARING POLYMER PROPERTIES

When evaluating the advantages of PEEK compared with other thermoplastics, it is helpful to review the properties of the unfilled base polymer with the properties of other commercially available plastics such as polypropylene, nylon, and acetal.

As shown in Figures 1 and 2, the room temperature tensile strength and flexural modulus (bending stiffness) of PEEK are considerably higher than those of the other polymers shown. These differences become even more pronounced when one compares property values at elevated temperatures. The notched Izod impact strength of PEEK, which measures the toughness of the material, is comparable to that of polypropylene, acetal, and nylon as shown in Figure 3.

HDT (heat deflection temperature) is a measure of the temperature at which a plastic material will soften under a specified load in laboratory conditions. Figure 4 shows the HDTs of several polymers including PEEK. Clearly PEEK has a higher HDT than the other plastics shown, which is one indication that it can be used at temperatures where other polymers would quickly fail.

Figure 1. Tensile Strength (psi) of PEEK and other thermoplastics

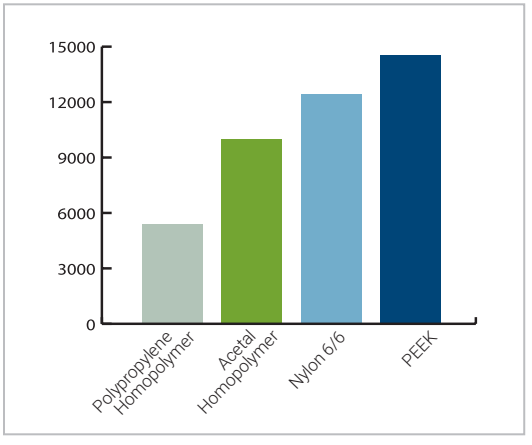


Figure 2. Flexural Moduli (kpsi) of PEEK and other thermoplastics

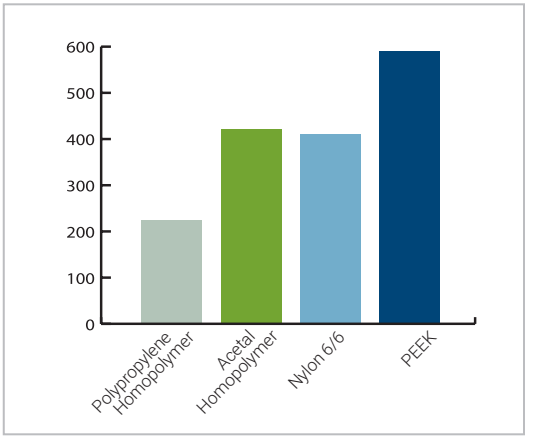


Figure 3. Izod Impact Strength (ft-lb/in) of PEEK and other thermoplastics

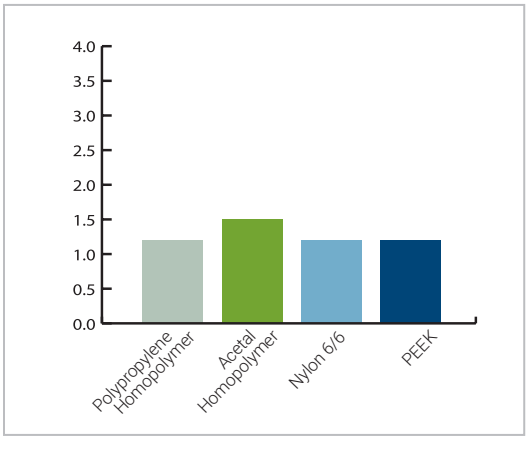
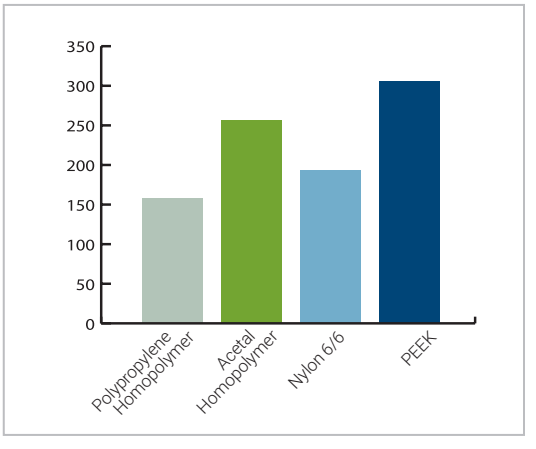


Figure 4. Heat Deflection Temp. @ 264 psi (°F) of PEEK and other thermoplastics



MAINTAINING MODULUS

To further illustrate the high temperature capability of PEEK, Figure 5 shows how the flexural moduli (bending stiffness) of nylon 6/6 and PEEK vary as a function of temperature. Nylon, like many common plastics, loses much of its mechanical stiffness once the material is heated to 176 F°. In contrast, PEEK maintains most of its stiffness up to temperatures approaching 300 F°. PEEK's ability to maintain stiffness at elevated temperatures is one of the reasons that it is so often specified for high temperature applications in the aerospace, semiconductor, medical, and food processing industries.

The stiffness of PEEK can be greatly increased by adding various fillers and reinforcements including glass or carbon fibers. Figure 6 shows the flexural modulus of unfilled PEEK as well as 30% glass fiber filled PEEK and 30% carbon fiber filled PEEK at various temperatures. As shown on the graph, the addition of glass reinforcement essentially doubles the stiffness of PEEK and the addition of carbon fiber more than quadruples the stiffness of the material. In fact, the room temperature flexural modulus of carbon fiber filled PEEK is 3300 kpsi, one of the highest values of any commercially available thermoplastic.

Figure 5. Flexural Modulus vs. Temperature

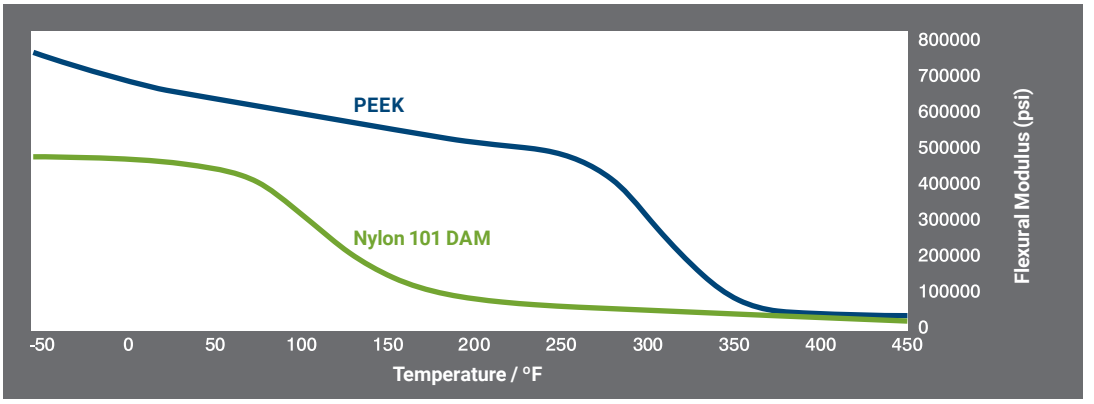
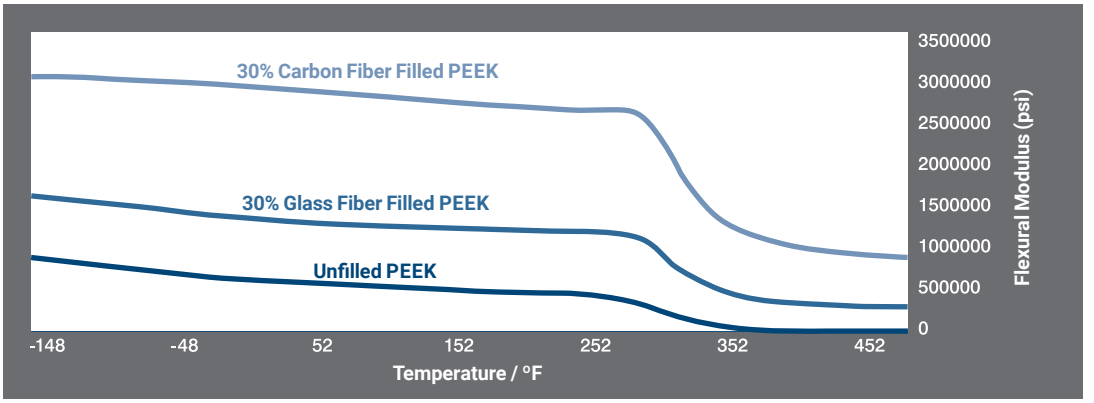


Figure 6. Effects of Various Reinforcements



DIMENSIONAL STABILITY THROUGHOUT A BROAD TEMPERATURE RANGE

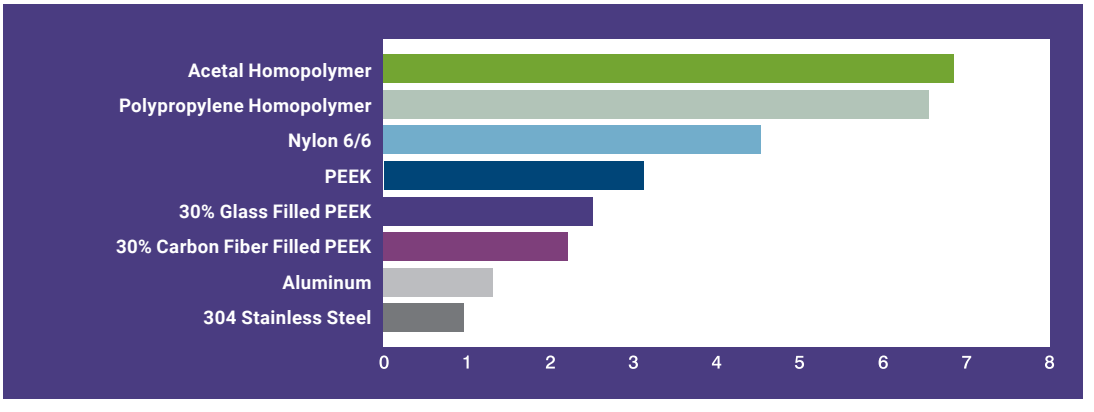
Plastic materials are inherently less stable than metals and ceramics. Maintaining tight tolerances is a continuing challenge for designers and fabricators of plastic components. There is some complexity to this issue since changes in the dimensions of a plastic part can be due to thermal expansion, moisture absorption, swelling from chemical exposure, residual stress, or creep strain. In most instances, it is likely that several of these factors operate together to change the dimensions of a plastic part.

One of the key advantages of PEEK is its dimensional stability compared with many other plastic materials. Figure 7 shows the CTE (coefficient of linear thermal expansion) of unfilled PEEK, 30% glass filled PEEK, 30% carbon fiber filled PEEK, and several other materials. As shown on the graph, unfilled PEEK will grow at approximately half the rate of other thermoplastics when heated. Filled grades of PEEK exhibit even lower CTEs, which are comparable to those of some industrial metals.

One of the key advantages of PEEK is its dimensional stability compared with many other plastic materials.

This low rate of thermal expansion can greatly simply designs when mating metal and plastic parts must stay within tolerance throughout a broad operating temperature range. It is for this reason that PEEK is often selected for tight tolerance applications in the aerospace and semiconductor industries.

Figure 7. CTE (Coefficient of Linear Thermal Expansion) of PEEK and other Engineering materials (in/in/°Fx10^{-5})



NOTEWORTHY CHEMICAL AND STEAM RESISTANCE

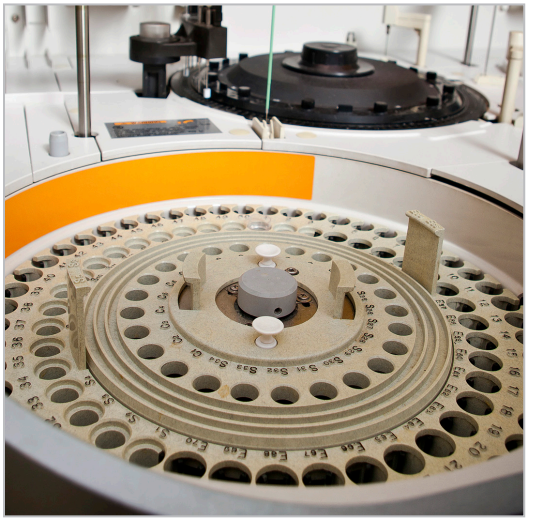
Many plastic materials will quickly degrade when exposed to chemicals including hot water and steam. The results of chemical attack can include environmental stress cracking, loss of mechanical properties, swelling, discoloration, or in extreme cases a complete dissolving of the plastic material. These negative effects can be exacerbated at elevated temperatures and when mechanical stress is applied to the plastic part being exposed to the chemical.

PEEK has among the best chemical resistance of any thermoplastic material. It is often used in applications where parts are exposed to aggressive chemicals, hot water, and steam. More detailed information regarding the chemical resistance of PEEK can be found on Curbell Plastics' website, www.curbellplastics.com.

PEEK has among the best chemical resistance of any thermoplastic material.

RADIATION RESISTANCE

Certain wavelengths of electromagnetic radiation including gamma radiation can be very damaging to most plastic materials. The effects of radiation on plastics can include discoloration, loss of tensile strength, and embrittlement (loss of tensile elongation). A number of scientific studies, including a 1987 article by Tsuneo Sasuga and a 1996 article by Kirstin Heiland, have shown that PEEK has outstanding resistance to gamma radiation. (See the references section at the end of this article for bibliographical details of these studies.) Because of this, PEEK is often used in scientific and power generation applications where performance in radiation environments is required.



PEEK is often specified for scientific equipment applications because of its purity and excellent chemical resistance.

PEEK is an excellent insulating material for high performance electrical connectors.

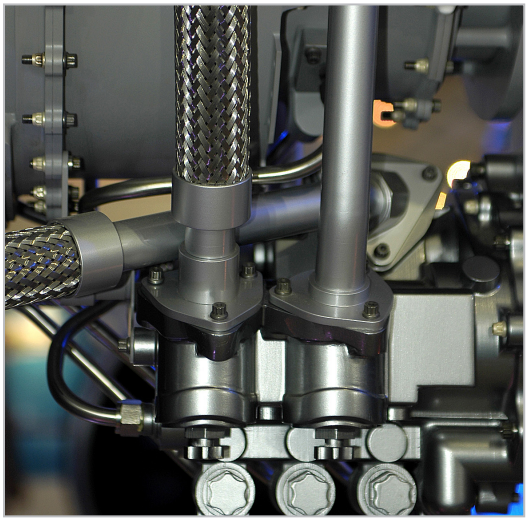
ENHANCED FRICTION AND WEAR PERFORMANCE

PEEK is available with a number of additives that enhance its tribological (friction and wear) properties. These include combinations of PTFE, graphite, and carbon powder as well as other proprietary fillers. The effect of these additives include a dramatic reduction in the coefficient of friction of the material, improved wear life, and a higher limiting PV (pressure-velocity) rating compared with the base polymer. These “bearing grades” of PEEK, such as TECAPEEK® PVX and Ketron® HPV, are often used in friction and wear applications that involve elevated temperatures, high loads and/or speeds, or corrosive chemicals that would quickly degrade metal or conventional thermoplastic bearing materials.

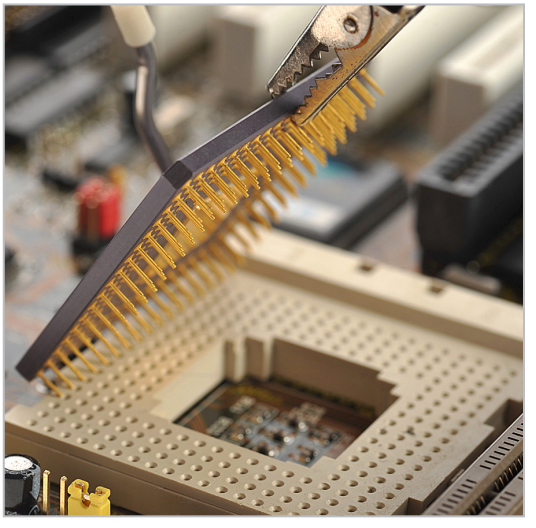
FLAMMABILITY CHARACTERISTICS

Many plastics will readily burn and some polymers will produce toxic decomposition products. This precludes their use in certain industries, such as the aerospace industry where fire safety is an extremely critical design issue. PEEK resists combustion and it has achieved a UL94 V-0 vertical burn rating for wall sections as thin as 0.125". This makes the material an ideal choice for many applications where flammability is of concern.

It should be noted that flammability, smoke, and toxicity are complex design issues and detailed materials data should be reviewed prior to selecting any thermoplastic for an application where flammability is a consideration.



PEEK is often used for aerospace valve components because of its outstanding chemical resistance, creep resistance, and wear properties.



PEEK has seen wide use in semiconductor test equipment because of its dimensional stability and outstanding wear resistance.

HIGH PURITY IN DEMANDING APPLICATIONS

A number of critical service applications such as food processing machinery, surgical instruments, semiconductor machinery, and space flight hardware require components made from high purity materials so that they will not contaminate the products or systems that they come into contact with. PEEK is an extremely pure material. It is available in grades that meet the most stringent standards including FDA compliance for direct food contact and USP Class VI compliance for use in medical equipment.

The low outgassing characteristics of PEEK are described in NASA's technical database for selecting spacecraft materials. PEEK has seen extensive use in space flight applications.

New grades of PEEK may be good candidates for your application.

EXCITING NEW GRADES

Leading plastics extruders and compression molders such as Röchling, Ensinger, and Mitsubishi Chemical have commercialized new formulations and processes that further enhance the performance of their PEEK products. Examples include ceramic-filled PEEK sheet materials with improved mechanical properties and dimensional stability and spin-molded PEEK tubing with thin walls and low levels of residual stress. Information on these grades of PEEK can be found on Curbell Plastics' website, www.curbellplastics.com.

We invite engineers and designers who are interested in new materials technologies to contact Curbell Plastics to discuss your specific application requirements and explore which new grades of PEEK may be good candidates for your application.

PEEK REFERENCES AND FURTHER READING

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ABOUT THE AUTHOR

Dr. Keith Hechtel is Director of Business Development for Curbell Plastics, Inc., based in Orchard Park, NY. Dr. Hechtel has a Master of Science degree in Industrial Technology, a Doctor of Business Administration degree, and more than 35 years of plastics industry experience. Much of his work involves helping companies to identify plastic materials that can be used to replace metal components in order to achieve quality improvements and cost savings. Dr. Hechtel is a recognized speaker on plastic materials and plastic part design. He has conducted numerous presentations for engineers, designers, and fabricators in both industrial and academic settings.

TECHNICAL EXPERTISE

Curbell white papers are intended to provide engineers and designers with basic information about the engineering polymers available as sheet, rod, tube, and film stock from Curbell Plastics. We invite you to contact Curbell via e-mail at **technicalsupport@curbellplastics.com** to discuss applications in detail.

ABOUT CURBELL PLASTICS

For more than 80 years, Curbell Plastics has been one of the nation's leading providers of plastic sheets, rods, tubes, and films, as well as fabricated parts, adhesives, and prototyping materials. Our customers range from small local businesses to large Fortune 500 companies and government agencies. We partner with organizations in dozens of industries, including aerospace, pharmaceutical, machinery manufacturers and sign fabricators. At Curbell, we understand the unique demands of each market and have the expertise to help you meet your business needs. Whether your objective is to reduce manufacturing costs, improve productivity, or increase product reliability, Curbell can help.

OUR CAPABILITIES

Our branch network includes sales and warehouse locations throughout the United States. We offer a number of value-added services including custom cutting, fabrication, packaging, and kitting, as well as warehousing for just-in-time delivery. With Curbell, you get the plastics you want and the peace of mind you need, from technical support and design assistance at the earliest stages of product design, through production and after-sale support for each product we sell.

PUT US TO WORK FOR YOU

At Curbell, we are committed to providing the highest level of service to our customers. We recognize the urgency of customer needs, and we pride ourselves on providing quick and proactive solutions. Our tag line says it all – we appreciate the opportunity to earn your business and we invite you to "***Put us to work for you***."

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