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High-strain-rate testing of reinforced polyetherether ketone

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A variety of techniques are used to test and understand how fiber-filled thermoplastics behave when impacted or subjected to high rates of deformation.

Polyetherether ketone (PEEK) is a high-strength, semicrystalline thermoplastic that is used in demanding polymer applications owing to its high strength, relative chemical inertness, and resistance to elevated temperatures. Both glass-fiber- and carbon-fiber-reinforced formulations are available. Data on the high-strain-rate properties of other fiber-reinforced thermoplastics such as polypropylene and nylon have been reported.[1,2] However, because fiber-reinforced PEEK materials have not been in use as long as other fiber-reinforced thermoplastics, their high-strain-rate properties have not—to our knowledge—been published, despite the potential for impact loading conditions in at least some applications (e.g., automotive and car seat components).

In our work,[3] we selected a 30% glass-fiber-reinforced PEEK as an example material, and tested it under slow- and high-strain-rate conditions. We acquired the glass-fiber-reinforced PEEK from Quantum Advanced Engineering Plastics in the form of one-half-inch-diameter, continuously extruded rods.[4] We machined cylindrical compression specimens with the cylinder axis oriented to either the longitudinal axis of the rod (the direction of fiber orientation) or transverse to the fiber direction. According to the manufacturer, the overwhelming majority of the glass fibers are oriented along the axis of the cylindrical rod. We tested the specimens in compression over a range of strain rates. We also tested samples of unreinforced PEEK obtained from another source (Advanced Polymer Technologies). Although the bulk and matrix material formulations are not the same, we believe that the comparison may still be of interest.

We performed compression tests at different strain rates using universal test machines. The data obtained from those tests are shown in Figure 1. Hysteresis cycles, and cycles of loading and unloading, were included in these tests to provide a measure of energy dissipation. Samples tested in the transverse direction display reduced stiffness and initial yield strength compared with the samples tested in the axial direction. The strength of the material becomes approximately the same as compressive strain increases. Interestingly, the differences between all three materials—bulk, orientation in fiber direction, and orientation in transverse direction—are relatively small.

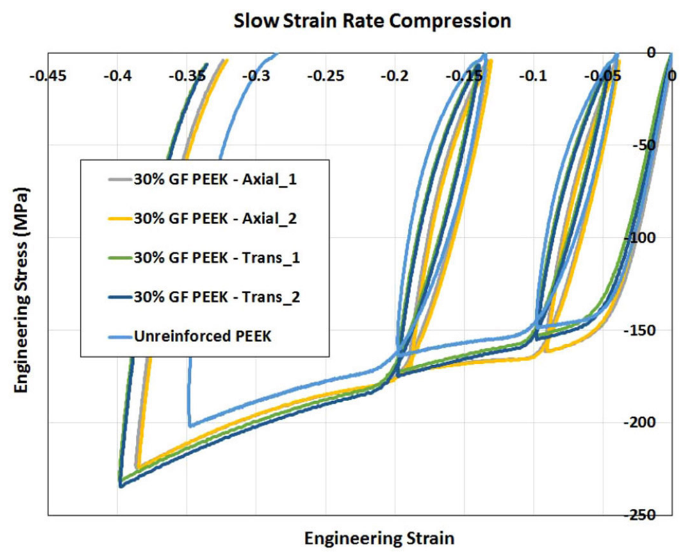

Figure 1. *Compressive stress/strain at a strain rate of 0.01 inverse seconds for 30% glass-fiber-reinforced polyetherether ketone (PEEK) and unreinforced PEEK samples. The reinforced samples were tested in both the transverse (trans) and axial directions. GF: Glass fiber.*

Split Hopkinson pressure bar (SHPB) systems have previously been used successfully to characterize the high-strain-rate behavior of thermoplastics.[5,6] In our SHPB system for this testing we used 6061-T6 aluminum striker, incident, and transmission bars. The results of high-strain-rate, SHPB compression tests on the reinforced PEEK in the two fiber orientations, and on a sample of unreinforced PEEK, are provided in Figure 2. The unreinforced material demonstrates a lower initial stiffness, but ultimately reaches a deformation resistance close to

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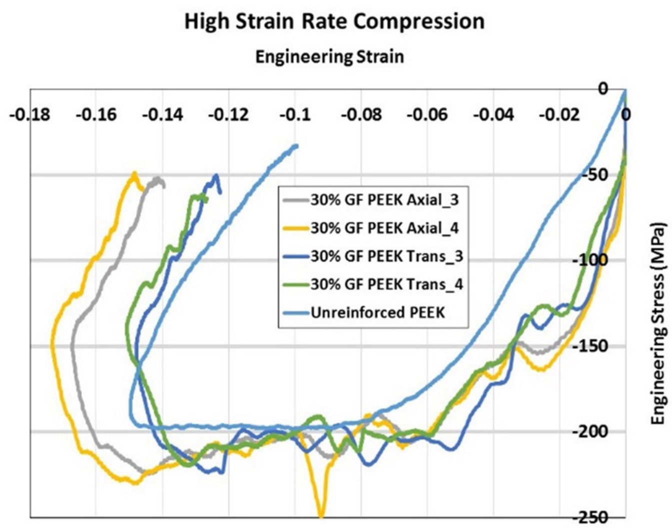

Figure 2. *Compressive stress/strain at an approximate strain rate of 800 inverse seconds for the 30% glass-fiber-reinforced PEEK and unreinforced PEEK samples.*

that of the reinforced materials. The approximate strain rate achieved in these experiments was 800 inverse seconds.

In summary, it is possible to evaluate the high-strain-rate deformation of fiber-reinforced polymers, with the result that the variation in rate dependence can be determined as a function of orientation. The 30% glass-fiber-filled PEEK we characterized in this work did not show significant variation in rate dependence at orthogonal material directions and high strain rates. Differences between the fiber-reinforced material and bulk PEEK showed lower elastic moduli and yield strength. It will be instructive to compare energy absorbed before failure between the bulk and fiber-reinforced PEEK. We did not examine the sensitivity of this dependence as a function of glass fiber content or temperature as it was outside of the scope of this study. It would be useful, in particular, to determine whether a strong temperature dependence exists based on the PEEK thermoplastic matrix. We intend to examine this temperature effect in the next iteration of reinforced PEEK experimentation.

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