Micromechanics of the yield behaviour of semi-crystalline PEEK

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Abstract

Thermoplastics are a class of polymers that can be moulded and reshaped repeatedly upon heating and cooling, making them sustainable, cost-effective, but also easy to process. The mechanical properties of thermoplastic polymers strongly depend on the processing conditions, which affect molecular orientation, in the case of amorphous as well as semi-crystalline polymers. For these materials, it is of key importance to understand the relationship between microstructure, isotropic or oriented, and their mechanical properties.

PEEK is a high-performance technical semi-crystalline thermoplastic, with attractive high-temperature properties. In load-bearing technical applications, the mechanical performance, including time-to-failure, depends on the yield kinetics, i.e. the rate- and temperature dependence of the yield behaviour, of the polymer. In the yield behaviour of PEEK, a combined effect of evolving texture of the crystalline phase and mechanical rejuvenation of the aged amorphous phase can be observed.

In this work, a micromechanical model for the mechanical performance, in particular the yield behaviour, of PEEK based on its microstructure is developed. For this purpose, a mean-field micromechanical model that has previously been applied successfully to other semi-crystalline polymers, is employed and characterized for PEEK, using experimental results. For this purpose, also fully amorphous samples were manufactured and used for a direct characterization of the amorphous phase, which was not previously possible for other semi-crystalline systems. With a careful characterization based on the semi-crystalline yield kinetics and post-yield behaviour, the contributions of the amorphous phase, in which the aged state rejuvenates upon deformation, and the crystalline phase, of which the slip activities evolve due to texture changes, is systematically unravelled.

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