LMS Seminar

2 June 2022 at 2:00 pm - Room Jean Mandel

Micromechanics of oriented polymers: from structure to anisotropy

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ABSTRACT

The mechanical response of a polymer material, including the mode of failure and the time-scale on which it occurs, is strongly influenced by its microstructure, which is formed during processing. This holds in particular for semi-crystalline polymers in which structural features, such as the degree of crystallinity, crystal type, size and orientation, may vary drastically depending on subtle details of the manner in which the polymer is shaped into the final product and for short fiber-reinforced polymers, where the fiber orientation distribution is formed in the processing stage and is usually heterogeneous within a product. For both these materials, often an oriented microstructure is formed, leading to anisotropic yield and failure kinetics. To improve product performance, a fundamental and quantitative understanding of how these anisotropic properties depend on the structure is required. A quantitative structure-property relationship in combination with an accurate model for structure development during flow has the potential to predict the mechanical performance of a product based on the chosen processing conditions.

Multiscale micromechanical modelling approaches for the response and in particular the stress-dependence of the rate of plastic deformation, i.e. the yield kinetics, for oriented structured polymers are presented. The modelling approach for semi-crystalline materials is based on a mean field framework, accounting for the crystalline phases, which are modelled by crystal plasticity and oriented amorphous domains. A full field micromechanical modelling approach is adopted to capture the effect of fiber distribution on the anisotropic yield kinetics of a short fiber-reinforced polymer. The resulting macroscopic orientation and rate-dependent behavior of both the semi-crystalline and the fiber-reinforced material show a striking resemblance and are described with a dedicated anisotropic visco-plastic constitutive model. This model captures well the factorizable dependence of the yield stress on orientation and on deformation rate that is observed experimentally.

BIOGRAPHY

Hans van Dommelen is Associate Professor of Micromechanics in the Department of Mechanical Engineering at the Eindhoven University of Technology (TU/e). He received his PhD at the TU/e in 2003 and has been a visiting scientist at the Massachusetts Institute of Technology, the University of Virginia, and Cambridge University. His research interests are micromechanics of materials: structure-property relations for both mechanical and functional material behavior, with applications ranging from nuclear fusion reactors to 3d printing, and structured polymers.