18th European Mechanics of Materials Conference (EMMC18)
April 4 - 6, 2022, Oxford, UK

Constitutive Modelling of Alpha and Beta Transitions in Amorphous Polymers

Davide S.A. De Focatiis and Grace M. Owen

Faculty of Engineering, University of Nottingham, University Park, Nottingham, UK

(enzddf@nottingham.ac.uk)

The behaviour of polymers and their composites can vary significantly between quasi-static conditions and impact events, as well as at low and high temperatures. A lack of sufficient understanding of these differences and their underlying physical origins can prevent optimisation of material properties with respect to components in service. A constitutive model that can simulate a very broad range of rates and temperatures is a major challenge, but clearly desirable to describe the full spectrum of the mechanical behaviour of polymers. This work forms part of a wider project aiming to contribute to the understanding of the behaviour of polymers at high rates of strain, here focusing on the development of a physically based model and representations of the alpha and beta transitions in amorphous polymers. The modelling work carried out at the University of Nottingham is supported by experimental measurements and techniques from the University of Oxford.

Our basis is the Oxford glass-rubber constitutive model [1], suitable for modelling across the alpha transition. To account for structural change within the polymer, the glass structure is defined in terms of a fictive temperature. Previous implementations of the model employed an approximate semi-empirical description of the evolution of fictive temperature [2], but here we broaden the range of applicability by reverting to differential equations to describe both physical ageing and mechanical rejuvenation and discuss the challenges that this creates. As the model is extended to increasingly high strain rates and/or lower temperatures, the influence of the secondary transition, the beta transition, starts to become significant, affecting not only the yield process and the associated Eyring plots, but also the shift factors that relate the mechanical (and structural) relaxation times. A novel approach to the inclusion of the beta transition will be proposed here, with a description of both an alpha structure and a beta structure, each with its own fictive temperature and evolution equations.

REFERENCES

[1] C.P. Buckley and D.C. Jones, *Polymer (Guildf)* 36(17):3301–3312, 1995.
[2] J.J. Wu and C.P. Buckley, *J Polym Sci Part B Polym Phys* 42(11):2027–2040, 2004.