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TOWARDS STRUCTURE-PROPERTY RELATIONSHIPS FOR POLYMERIC FOAMS

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ABSTRACT

The macroscopic constitutive behaviour of polymeric foams is the result of a subtle interplay between the intrinsic material behaviour of the polymer basis-material and the complex microstructure that is present in the foams. The macroscopic constitutive behaviour of polymeric foams is determined by (i) the intrinsic constitutive behaviour of the polymeric material and (ii) the complex microstructure. The intrinsic behaviour is strain-rate dependent and should accurately describe large deformations, up to plastic yield, followed by strain softening and strain hardening. Because of the 3D microstructure, local deformation mechanisms exist that determine the global behaviour. The macroscopic properties are directly dependent on the local microstructure and the deformation and localisation mechanisms that occur at this level.

Foams that are loaded in compression show, also in the macroscopically linear elastic regime, bending of cell walls, followed by a plateau region, depending on the type of foam, elastic buckling (elastomeric foam), plastic deformation (polymeric foam) or brittle fracture (hard foam) [1]. The plateau region is largely responsible for the energy-absorbing properties of the foam since in the condensation regime cells are compressed further. For loading conditions that deviate from compression, other deformation mechanisms can play a role, leading to different behaviour in tension and compression [2–3]. In the past, mostly idealised microstructures have been used to derive analytical expressions for the mechanical behaviour of foams [1]. However, it appeared that morphological defects lead to a different mechanical response [4], such that refinements are necessary.

The objective of this work is to investigate the structure-property relationship for polymeric foams. Results of a combined numerical-experimental approach aimed at the characterisation of the constitutive behaviour of polymeric foams are shown. The approach is based on a combination of (i) three-dimensional experimental characterisation, using high-resolution CT-scans and (ii) automatic 3D mesh generation based on these scans, as developed in the field of bone-biomechanics. The CT images of the cellular microstructure are converted into a 3D finite element distribution [5–6]. This way, representative volume elements (RVEs) are created with which the local heterogeneous behaviour of polymeric

foams is modelled. Furthermore, (iii) an advanced constitutive equation is used for the constituent polymeric materials. This quantitative 3D viscoelastic model has been developed for amorphous polymers [7]. The model can describe the behaviour of polymeric materials in a range of loading conditions and circumstances (deformation rates, temperatures, times) [8-9]. Finally, (iv) micromechanical and multiscale modelling techniques are employed to predict the macroscopic response. In addition to describing the macroscopic response of these foams in a range of loading conditions, the approach enables a quantification of the role of the microstructure for the resulting macroscopic properties.

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