Strain-rate dependence of polymer foams: experiments and simulations

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Introduction
Nowadays, the demand for energy absorbing and lightweight materials is increasing. To accurately describe the mechanical response of foams, an important phenomenon, the strain-rate dependence, is studied. The rate dependence of these foams originates from the interplay between the intrinsic material behaviour and the micro-structure (Fig. 1).

Fig. 1 The mechanical response of a foam depends on both the polymer base material and the micro-structure.

Goal
To determine the contribution of the intrinsic material behaviour to the rate dependence of foams.

Approach
In order to characterize the rate dependent behaviour of foams, compression experiments and simulations at different strain rates are carried out. For the latter, a hybrid experimental-numerical approach is used to determine the stress-strain response (Fig. 2).

Fig. 2 Hybrid experimental-numerical approach, based on X-ray Computed Tomography (CT) for the characterization of the micro-structure and mechanical characterization of the intrinsic material behaviour. Finally, the microstructure and constitutive model are combined in FE simulations.

Experiments & Simulations
Results from the compression experiments at different strain rates of a Polyurethane (PU) foam are shown in Fig. 3a. When comparing the rate dependence of the collapse stress of different PU foams, a similar trend is found for different densities indicating a direct contribution of intrinsic material behaviour (Fig. 3b).

Fig. 3 Stress-strain response the PU foam for \( \dot{\varepsilon} = 10^{-2} \sim 10^{1}[1/s] \) (a) and the strain-rate dependence of the collapse stress for different densities (b).

For the simulations, a foam is characterized with X-ray CT. For the constitutive model, the EGP-model with material properties of well characterized Polycarbonate (PC) are used [1]. The stress-strain response (Fig. 4a) is similar as found for the experiments. Fig. 4b shows the rate dependence of the collapse stress (foam) and yield stress (solid PC).

Fig. 4 The stress-strain response for \( \dot{\varepsilon} = 10^{-2} \sim 10^{1}[1/s] \) (a) and the strain-rate dependence of the collapse stress of the foam and base material (b).

Conclusion
Both experiments and simulations show that the rate dependence of foams is dominated by the intrinsic material behavior. Other influences, like flow of air through the structure, are negligible.

References