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Uniaxial Compression of SiO_2 Glass Cylinders: Analysis Using Stress-independent Material Coefficients

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Abstract

Glass cylinders made of the vitreous silica type Suprasil 1 were exposed to axial stress at nominal compressive strain rates from -10^{-5} to -10^{-2} per second in a servohydraulic press at constant temperatures ranging from 1273 K to 1648 K. Subsequently, the stress was allowed to relax. True viscoelasticity is applied for evaluation of the experimental results and closed-form solutions demonstrate that the interpretation as a single-element Maxwell model renders Young's modulus readily measurable along with the tensile viscosity. The significant contribution of elasticity is found to be inherent in glass even at elevated temperatures. This very distinct property did not receive general recognition before and has been neglected in the majority of earlier studies on glass upsetting.

The analysis reveals that the Young's modulus decreases with a rise in temperature, if the nominal strain rate is held fixed, and with a reduction in nominal strain rate at constant temperature. The viscosity can be characterized as a function of the temperature either by a Vogel-Fulcher-Tammann-Hess equation or by an Arrhenian fit. The findings when fed into a FEM programme reproduce the recorded force histories quite well.

However, the present study reveals that the experimental data of Young’s modulus depend on the stress. The results prove unambiguously the failure of linear viscoelasticity for this particular loading case. The full implications are reserved for a subsequent publication dealing with important consequences for glass rheology.

Keywords: glass rheology, viscoelasticity, parallel plate rheometry, Maxwell model, vitreous SiO_2