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Characterizing Solid Glass in Bending, Torsion and Tension: High-Temperature Dynamic Mechanical Analysis up to 950 °C

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Abstract : Dynamic mechanical analysis (DMA) is a powerful method to characterize viscoelastic properties and phase transitions for a wide range of materials. It is often used to characterize polymers and their temperature-dependent behavior, including thermal transitions like the glass transition temperature Tg, via determination of storage and loss moduli in tension (Young's modulus, E) and shear or torsion (shear modulus, G) or other testing modes. While production and application temperatures for polymers are often limited to several hundred degrees, material properties of glasses usually require characterization at temperatures exceeding 600 °C. This contribution highlights a high temperature setup for rotational and oscillatory rheometry as well as for DMA in different modes. The implemented standard convection oven enables the characterization of glass in different loading modes at temperatures up to 950 °C. Three-point bending, tension and torsional measurements on different glasses, with E and G moduli as a function of frequency and temperature, are presented. Additional tests include superimposing several frequencies in a single temperature sweep ("multiwave"). This type of test results in a considerable reduction of the experiment time and allows to evaluate structural changes of the material and their frequency dependence. Furthermore, DMA in torsion and tension was performed to determine the complex Poisson's ratio as a function of frequency and temperature within a single test definition. Tests were performed in a frequency range from 0.1 to 10 Hz and temperatures up to the glass transition. While variations in the frequency did not reveal significant changes of the complex Poisson's ratio of the glass, a monotonic increase of this parameter was observed when increasing the temperature. This contribution outlines the possibilities of DMA in bending, tension and torsion for an extended temperature range. It allows the precise mechanical characterization of material behavior from room temperature up to the glass transition and the softening temperature interval. Compared to other thermo-analytical methods, like Dynamic Scanning Calorimetry (DSC) where mechanical stress is neglected, the frequency-dependence links measurement results (e.g. relaxation times) to real applications

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