Mechanical Engineering
Master's Defense

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A Study of Multiaxial Polymer Response to Failure Based on Submicrocrack Accumulation

A three-dimensional constitutive relationship for polymeric materials based on the kinetic theory of strength is suggested. The theory is specifically developed for the material polymethylmethacrylate or PMMA. The approach arises from the desire to model material response according to the microphysical state of the material which can be described by an accumulation of submicrocracks in the material. Submicrocracks contribute to inelastic macroscopic strain in the material while also affecting the elastic material properties.

The development of a unified three-dimensional constitutive law and failure criterion begins by first extending a one-dimensional failure criterion based on the kinetic theory of strength to handle multiaxial loads. Bond rupture at the molecular scale, resulting in submicrocracks, is driven by a scalar effective stress that incorporates fully three-dimensional stress states. A new three-dimensional submicrocrack constitutive relation was then developed as a function of normalized submicrocrack accumulation and stress. Viscoelastic effects were also introduced in the three-dimensional constitutive model.

The proposed three-dimensional constitutive relation was evaluated by comparing its strain response against experimental data for multiple stress histories. The theory is capable of capturing the complex inelastic response of PMMA under multiaxial loads to failure. Moreover, failure loads exhibit rate, time, and path dependence.

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