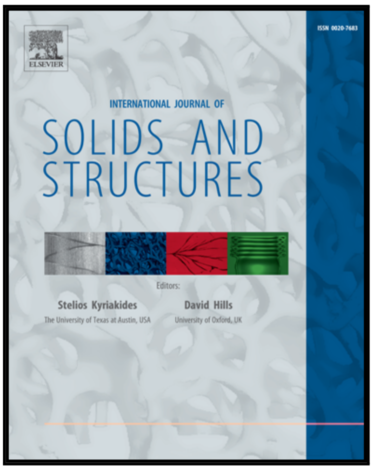

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A micromechanical framework and modified self-consistent homogenization scheme for the thermoelasticity of porous bonded-particle assemblies

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Abstract

Thermoelasticity of porous bonded-particle assemblies is modeled within a micromechanical framework that considers damage at the inter-particle interfaces. Connections between void space and interface damage are developed and incorporated into a modified self-consistent homogenization (M-SCH) scheme that includes a contribution to the mean strain field from local displacement discontinuities over interfacial void spaces. The M-SCH scheme is developed for particles of a general ellipsoidal shape with anisotropic elastic and thermal expansion properties. Two types of porosity are distinguished: (1) dispersed inter-particle porosity and (2) isolated porosity. A means of separating out the relative contributions of each type of porosity to the homogenization scheme is provided, and an explicit expression is obtained for an effective damaged interphase thickness as a function of the dispersed porosity and the particle morphology. Numerical examples are provided for quartz bonded-particle assemblies in order to examine the influence of the porosity type on the predicted elastic moduli. The model is also calibrated to the neutron diffraction measurements provided by Yeager et al. (2016) of triclinic TATB crystal lattice orientation (texture) and lattice strain induced under thermal loading. The model simulations of lattice strain are compared with the measurements, and the predicted statistical distributions of inter-particle displacement discontinuities and contact tractions within the assembly are examined.

Keywords: Damage, Porosity, Anisotropic, Texture, Eshelby tensor, Imperfect interface

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1. Introduction

Bonded-particle assemblies, also called bonded-granular assemblies, typically contain to some degree inter-particle void spaces comprising a dispersed porosity. These inter-particle void spaces lead to an essentially different description of the microstructure (cf. Oda et al. 1982, Chang et al. 1989, Liao et al. 1997) than classical matrix-inclusion descriptions (cf. Mura 1987, Nemat-Nasser and Hori 1993), where for the case of particle assemblies, non-uniform contact due to the void spaces may cause particles to be less constrained in some directions and have stress concentrations at particle contacts (e.g., as described in Chang and Bennett 2015, Bennett and Borja 2018).

Various approaches for incorporating the thermoelastic effect of inter-particle porosity into homogenization theory have been proposed (e.g., Burridge and Keller 1981, Zhao et al. 1989, Arbogast et al. 1990, Dormieux and Kondo 2005, Vincent et al. 2009). The approach taken herein differs from these previous approaches by considering that the inter-particle porosity effectually makes the particle interfaces to some degree imperfect, i.e., damaged, such that they can be described by the concept of imperfect inter-particle

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