Contribution ID: **539** Type: **Oral Presentation**

Influence of Pore Morphology on Mechanical Properties of Second Gradient Materials

Wednesday, 1 June 2022 12:00 (15 minutes)

Porous materials with heterogeneous porous structures possess a wide range of mechanical, thermal, or electrical properties. Therefore, they are widely used in different engineering fields, such as energy-storage technology, geothermal engineering, and bio engineering. Considering the strong influence of pore morphology on material properties and their diverse application, over the years variety of homogenization techniques based on averaging different fields, such as stress, strain, and deformation energy density, have been developed to efficiently transfer material properties from micro to macro scale. For porous materials with complex pore morphology, most homogenization techniques fail to capture the absolute size and distribution of the pores as they are based on classical continuum theory. To account for the pore shapes and variability in the pore distribution besides the porosity, in this study, we adopt a higher-order asymptotic homogenization method. The advantage of higher-order homogenization becomes apparent when developing complex multiscale structures is best described by incorporating higher-gradient effects. This can be especially observed in biological materials that are highly heterogeneous (e.g. bone tissue) and have hierarchical structures that demand higher-gradient effects to be included in modeling their mechanical responses as well as in their multi-physics simulations. The higher-order scheme is an extension of the first-order computational homogenization framework where the use of a generalized continuum enables us to introduce the length scale into the material constitutive law and capture the absolute size of the pores and pore distribution. By employing this model, we studied a set of numerical problems with different combinations of porosity, pore shapes, and distributions. The results show a strong influence of pore shape on the effective material properties, with some shapes having a more noticeable impact than others (e.g., circle and square pores have an almost identical effect). However, analysis of pore distribution demonstrates little to no effect on effective material properties. Moreover, we observed that even for isotropic matrix material, different pore shapes will produce different material behavior, such as elliptic pores producing orthotropic material behavior while circular and square pores lead to cubic material behavior. Furthermore, the results for higher-order parameters show a strong influence of the pore shape/distribution and the size of the representative volume element.

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Participation

Online

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Session Classification: MS07

Track Classification: (MS07) Mathematical and numerical methods for multi-scale multi-physics, nonlinear coupled processes