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IntACT

Recent Developments to the Porous Microstructure Analysis (PuMA) Software

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1 Introduction

The Porous Microstructure Analysis (PuMA) software [1, 2] is an open source framework for image-based simulation, primarily used to determine effective properties based on material microstructure. PuMA was originally developed for the study of NASA thermal protection materials; however, many of the solvers in PuMA have applicability to a broad range of materials science applications.

PuMA version 3.2 computes material surface area, pore diameters, effective thermal conductivity, continuum and rarefied tortuosity, and permeability. For anisotropic materials, PuMA can estimate material orientation and compute anisotropic thermal conductivity and elasticity.

In this talk, a brief overview of the PuMA software and underlying methods will be presented, as well as some recent and ongoing developments, including the use of immersed boundary methods for image-based simulation and the development of a new weave segmentation tool, called TomoSAM.

2 Cut-Cell method for heat and mass transfer

For simulations on complex microstructures, traditional unstructured meshing techniques often prove to be difficult and time-intensive. Voxel-based solvers, which represent the surface as a staircase structure, are relatively simple to implement but can lose accuracy when feature resolution is poor. In this work, we present a novel 3D cut-cell method for solving the variable coefficient Poisson equation on complex microstructures, suitable for the determination of effective thermal conductivity or tortuosity of a material. The method uses a Marching Cubes/Marching Squares surface reconstruction to create cut-cells and determine geometric quantities. A flux-correction method [3] is extended to 3D, with least squares gradient reconstruction, to solve for the boundary fluxes in the cut-cells. Verification cases show the solver achieves globally 2nd order accuracy on complex microstructures.

3 TomoSAM

TomoSAM, a module of the PuMA software, has been developed as a plugin for 3D Slicer, a software platform used for 3D image processing and visualization. It utilizes the Segment Anything Model (SAM) [4], a deep learning model capable of identifying objects and generating image masks based on minimal user input. This feature enables efficient segmentation of complex 3D datasets, particularly of woven materials, from tomography or similar imaging methods, reducing the need for manual segmentation.

References

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