Permeability-porosity relationship in a stochastic model of partial melting

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We present a model for calculating permeability of a porous solid-melt polycrystal during melting. Unlike to previous two-phase models, a solid framework is used that does not have a regular geometry nor a typical grainsize. Instead, we use a polycrystal that is created on the basis of a stochastic nucleation and growth process for first-order phase transformations as the starting state for partial melting. It is a polycrystal with continuously distributed grainsizes and random grain locations.

Permeability is then estimated through flow simulation on the constructed 3D porous two-phase body using the Lattice-Boltzmann (LB) technique. The LB method describes fluid motion with the interaction of a massive number of particles following simple local rules, rules that recover the Navier-Stokes equation at the macroscopic scale [Rothman and Zaleski, 1997].

It is known that the LB flow simulation is able to handle successfully very complex 3D pore geometries [Keehm et al., 2004]. Here, the investigated porous framework shows a fractal-like geometry near to percolation of either melt or solid phase. The flow simulation is done with an assigned pressure gradient ∇P across opposite faces of cubes. From the local flux, the volume-averaged flux $\langle q \rangle$ is then calculated using Darcy's relationship

$$\langle q \rangle = -\frac{\kappa}{\eta} \nabla P$$

where κ is the (wanted) macroscopic permeability and η is the dynamic viscosity of the melt.

References:

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