SIMULATION OF REACTIVE MELT INFILTRATION FOR THE MANUFACTURE OF CERAMIC MATRIX COMPOSITES

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Reactive Melt Infiltration (RMI) is a process that may be used for the manufacture of ceramic-matrix composites in which a molten metal such as silicon infiltrates a porous substrate. The infiltration is driven by capillary forces and by the structural geometry of the porous substrate. In the case where the substrate contains carbon, molten silicon may react with it to form a silicon carbide phase. Consequently, the geometry and associated properties such as porosity and permeability evolve during the capillary rise. Competition between capillary rise and reaction may lead to a "choking off" effect that should be avoided. Capillary rise may be simulated with macroscopic models derived from Darcy's [e.g., Nelson 2000, Sangsuwan 1999], Washburn's [e.g., Muscat 1994, Yang 2000] or Richards' [e.g., Einset 1996-a, 1996-b, 1998] laws which require the knowledge of permeability (identified against Dullien's [1977] and Patro's [2007] models). As pointed out by Dullien [1977], in pore networks there are parallel paths, so the rate of capillary rise is calculated in a single tube with periodic stepwise changes in diameter. In each portion of the tube a Poiseuille flow is considered. These models reveal that the apparent capillary diameter for the rate of capillary rise is several orders of magnitude smaller than the pore diameter corresponding to the peak of the mercury intrusion porosimetry curve. The permeability is considered to be proportional to the apparent diameter calculated from the rate of capillary rise due to the capillary network model of the pore structure used. In order to determine the characteristic scales responsible for capillary rise in granular media, a microscopic investigation on organized geometries was undertaken. Simulations of two-phase flows with a Volume Of Fluid approach at microscopic scale were investigated with CFD code Thétis (developed at I2M, Bordeaux) that accounts for wetting and capillary effects on objects with a complex shape. The characteristic data were used in Einset's macroscopic model. This model is based on conservation laws (quantity of silicon, energy, free volume). In Einset's original model [1996-a, 1996-b, 1998], the source term for the reaction between molten silicon and carbon is linked to the velocity of the front, so "choking off" effect cannot be properly described. Consequently, Einset's model was modified to take into account an explicit reactive law. The simplest choice is to assume a first order reaction rate for silicon saturation in the porous medium. Results of different simulations are discussed.

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