Level Set Model of Microstructure Evolution
in the Chemical Vapor Infiltration Process

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A mathematical model was presented to describe the microstructure evolution during Chemical Vapor Infiltration(CVI) process. During the CVI process, a gaseous reactant infiltrates fibrous preform and deposits solid on fiber surface to form Ceramic Matrix Composites. Our model utilized the front evolution modeling technique to explicitly describe the microstructure evolution inside fibrous preform. This model consisted of a level set equation of Hamilton-Jacobi type, coupled with a boundary value problem of Laplace equation, to model the moving gas-solid interface and the accessibility of porous areas to the gaseous precursor respectively. The deposition rate was reflected by the moving speed of the interface. As an efficient numerical method for detecting the accessibility of pores was developed, the Laplace equation was used to model a process property that affects deposition rate.

Numerical schemes were constructed for this Level Set Model. A second order numerical approximation was used to solve the Hamilton-Jacobi equation; and the Immersed Interface Method was applied to solve the Laplace equation. An efficient numerical algorithm was developed to detect formation and location of inaccessible pores. These numerical techniques allowed robust and efficient numerical simulation of the growing gas-solid interface and captured topological changes of the interface such as merging and formation of inaccessible pores during the CVI process.

Numerical examples were presented for kinetic limit case in two and three dimensions, and for anisotropic front case in two dimensions. And the numerical result was visualized. It showed that this model could accurately predict not only the residual porosity, but also the precise close-off time, location and shape of all pores.