VERIFICATION OF `solidificationMeltingSource fvOptions` FOR THE ISOTHERMAL SOLIDIFICATION

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In this paper, we have simulated a benchmark isothermal solidification problem to verify and document solidificationMeltingSource fvOptions [1]. This fvOption is for the isothermal phase-change (solidification and melting) problems and is based on the fixed grid methodology of Voller and Prakash [2]. In their methodology, Voller and Prakash treat the domain (which consists of solid, liquid, and phase-change regions) as a pseudo porous media with the porosity varying from 1 (in the liquid cells) to 0 (in the solid cells). A unique momentum equation is solved for the whole domain. The equation has a Darcy source term which is handled by the solidificationMeltingSource fvOptions here.

To validate solidificationMeltingSource, we solved a well-know benchmark problem for the isothermal solidification [2]. The benchmark consists of a square cavity which is sketched in Figure 1. The cavity is initially filed with liquid above its freezing temperature; and is cooling from the left while the top and the bottom are isolated. Solidification starts from the left. All the properties and simulation parameters are taken from [2].

Figure 2 is a time sequence which shows the evolution of the solidification. Columns represent different times. At the top row, the color is the solid fraction g_s (= 1 - porosity) and the vectors are the liquid velocity. At the bottom row, the color is the temperature. The solidification front (iso-line $g_s = 0.5$) is superimposed (from the top contours) on the temperature contours at the bottom. One can easily notice that this line lies on the freezing temperature i.e. $T = 0$. Furthermore, regions with $T > 0$ in the bottom row have $g_s = 0$ at the top row: they are fully liquid; similarly, regions with $T < 0$ in the bottom row, have $g_s = 1$ at the top row: they are fully solid. These agreements verify solidificationMeltingSource. We are currently extending the solidificationMeltingSource fvOptions to simulate solidifications taking place at a range of temperatures (instead of a single melting temperature). The extended version of solidificationMeltingSource will be useful to easily simulate solidification of metallurgical binary alloys.

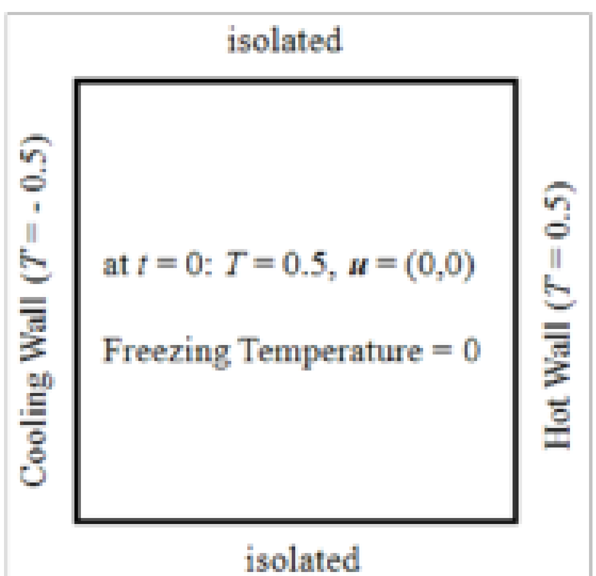

Figure 1: Schematic of the benchmark isothermal solidification problem [2] simulated here to verify solidificationMeltingSource fvOptions.

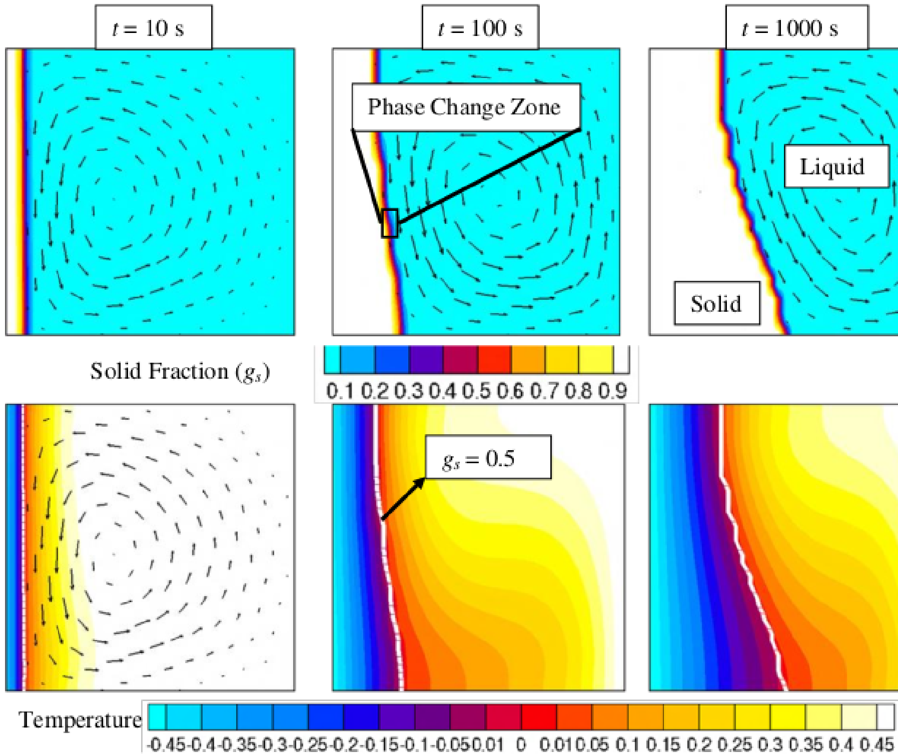

Figure 2: Time sequence showing the evolution of the solidification. Columns represent different times. At the top row, the color is the solid fraction and the vectors are the liquid velocity; At the bottom row, the color is the temperature and the white line is the

References

[1] “”solidificationmeltingsource”, 12 march 2016.” [Online]. Available: https://github.com/OpenFOAM/OpenFOAM-2.3.x/blob/master/src/fvOptions/sources/derived/solidificationMeltingSource/solidificationMeltingSource.H

[2] V. Voller and C. Prakash, “A fixed grid numerical modelling methodology for convection-diffusion mushy region phase-change problems,” *International Journal of Heat and Mass Transfer*, vol. 30, no. 8, pp. 1709 – 1719, 1987. [Online]. Available: http://www.sciencedirect.com/science/article/pii/0017931087903176