Level Set Modeling of Injection Molding

Rekha Rao, Thomas Baer, Lisa Mondy, David Noble, Laura Halblieb, Anne Grillet, and Pin Yang

Sandia National Laboratories*
Albuquerque, NM 87185-0834
rrrao@sandia.gov

Finite element modeling is used to examine injection molding as the basis of a net shape ceramic processing operation. In this process a paste of ceramic particles suspended in a mixture of paraffin wax and polyethylene/polypropylene copolymer is injected into a mold, creating the green ceramic part. The model provides insights into the filling process, to allow optimization of the die shape and to troubleshoot potential creation of material inhomogeneities.

Flow solutions were obtained using a fully-coupled, finite-element based, Newton-Raphson numerical method in both two- and three-dimensional simulations. The process is nonisothermal, and the paste has complex, temperature-dependent rheology and potentially phase separates. Therefore, one challenge of modeling was to determine appropriate constitutive equations that capture relevant phenomenology without being too computationally complex. Three constitutive relationships were examined based on rheological data: 1) Newtonian; 2) a Carreau model, which is shear-thinning and has a WLF [1] temperature dependence; and 3) a continuum-level suspension model with shear-induced particle migration [2].

The level set method of Sethian [3] was used to determine the evolution of the interface with time. This is a front capturing scheme where the location of the free surface is determined by a signed scalar field that advects in time: The zero of this field is the interface location. Material properties vary across the phase interface from the properties of the suspension to the properties of the displaced gas. This variation is handled using a smooth Heaviside function that modulates material properties to account for the change in phase. Surface tension was applied using a continuous surface stress formulation using a smooth Dirac delta function that applies this force only at the interface [4].

We compare the computational studies to idealized flow visualization data in a clear representation of the mold as well as to short-shot data of the actual green ceramic. We also examine the effects of the geometry of the die both numerically and experimentally.

References

[1] William, M.L., R.F. Landel, and J.D. Ferry, "The Temperature Dependence of Relaxation Mechanisms in Amorphous Polymers and Other Glass-Forming liquids," *J. Am. Chem. Soc.,* **77**, 3701, 1955.

[2] R. J. Phillips, R. C. Armstrong, R. A. Brown, A. L. Graham, and J. R. Abbott*, Phys. Fluids A* **4**(1) 30-40, 1992.

[3] J. A. Sethian, *Level Set Methods and Fast Marching Methods*, Cambridge University Press, 1999.

[4] D. Jacqmin, "Three-dimensional computations of droplet collisions, coalescence, and droplet/wall interaction using a continuum surface-tension method," AIAA-95-0833

Keywords: free surfaces, level set, non-Newtonian flows

*Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.