Diffuse Interface Models for Metal Foams

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Abstract

Metal foams are cellular material of considerable interest because of their potential applications in many fields of the industry. These materials can offer attractive combinations of low density, high stiffness to weight ratio, good energy absorption and vibration damping capacity. There are many technologies by which a foamed mechanical component can be produced. A well-established process is starting with a molten metal, then introducing solid particles as blowing agents in order to create gas bubbles inside the metal, and finally filling a mold cavity. The successive solidification of the resulting system will give the characteristic cellular structure of the foamed component, represented by many voids in a metallic matrix.
The foaming process of a metal is a complex operation which needs to be closely controlled in order to guarantee the wanted properties, by avoiding the formation of defects in the structure of the material. During the foaming process, solid particles and gas bubbles are transported in the liquid metal and important physical interactions arise between the different phases. Bubbles will interact between them, modifying their geometry and volume due to the surface tension effects. Also, it has been shown how solid particles get confined into bubble walls during foam expansion where they generated a repulsive force (o disjoining pressure) against further cell thinning. The laws of fluid mechanics will govern the behavior of this physical system which would take into account the simultaneous presence of three phases, the liquid metal, the gas bubbles and the solid particles.
On the other hand, a mayor understanding of the foaming process could be obtained if we are able to describe and then simulate the main phenomena occurring during the flowing of foam in a mold. In this work we use COMSOL Multiphysics® version 4.3b and apply the diffuse interface methods of the phase field technique available in the CFD module, in order to model the properties of metal foams and describe the movement of the gas-liquid interfaces. To analyze a practical case, foams represented by a number of bubbles moving in a laminar Poiseuille flow are chosen as tests and then simulated. To reduce the complexity of the two-phase time dependent computations a 2D geometry is implemented. Real values of densities and viscosities for the gas and the liquid metal are used. Surface tension effects are considered and repulsive forces between neighboring bubbles are expressed through the disjoining pressure. The computational solution is obtained in the gas and the liquid region, for different values of the Capillar number Ca and other parameters characterizing the system under study. To solve the resulting system of equations we use the BDF time dependent solver and the MUMPS direct solver for the integration in space.

The numerical results show that diffuse interface methods are effective to model this kind of complex phenomena and that fundamental mechanisms due to surface tension effects and disjoining pressure are well reproduced. Finally, these numerical findings let us to foresee the inclusion of other physical phenomena in a more comprehensive future model.

Reference

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