Modeling of Expanding Metal Foams

B. Chinè[1], M. Monno[2]

[1]Laboratorio MUSP, Macchine Utensili e Sistemi di Produzione, Piacenza, Italy; School of Materials Science and Engineering, Costa Rica Institute of Technology, Cartago, Costa Rica
[2]Politecnico di Milano, Dipartimento di Meccanica, Milano, Italy

Abstract

Metal foams are interesting materials with many potential applications. They are characterized by a cellular structure represented by a metal or metal alloy and gas voids inside (Fig.1). A common metallic cellular material is aluminum foam which can be produced metallurgically by heating a precursor, made of aluminum alloy and TiH2 as foaming agent, in a furnace. In this case, the foaming process involves the heating of the solid precursor containing the embedded gas source that, upon temperature increasing, releases H2 gas and drives the foaming process.

The complexity of the foaming process of a metal and the number of parameters to control simultaneously demand a preliminary and hugely wide experimental activity to manufacture foamed components with a good quality. The development of computational models could help to reduce experimental works and costs, although the task is very challenging.

The complex physical phenomena arising during the foaming process can be modeled by recurring to the mechanics principles, particularly to the simultaneous conservation laws for the energy, momentum and mass transport. Attention is demanded by the presence of a dynamic interface between the gas bubbles continuously originating and the surrounding liquid. Other phenomena are represented by the growth, coalescence and collapse of the gas bubbles.

In this work we use COMSOL Multiphysics® to model a simplified metal foam expansion during mold filling. Flow, heat and mass transport phenomena with surface tension effects are considered in the model, which is assumed to be two-dimensional. We start modeling and simulating a foaming process by considering an isothermal bubble expansion. Then, we model a more realistic non-isothermal metal foaming process inside a furnace, represented by a number of H2 bubbles expanding in liquid aluminum. In both cases the flow is assumed to be laminar and compressible. A Stokes flow regime is considered. Fig. 2 shows a model of a metal foam made by seven gas bubbles and aluminum metal. To control coalescence phenomena, the diffusion of species in the system is also taken into account by using the Fick's law. Phase field techniques are set up to describe the movement of the interfaces in the foam.

The numerical findings of the simulations show that the computational models, based on COMSOL Multiphysics® can be effective for modeling the foaming process of a metal. Other physical mechanisms such as heating and cooling rates, drainage, disjoining pressure and final

solidification of the foam could be included for more comprehensive models. But in the latter case, when developing more complete models for a foaming process, computational requirements should be also considered.

Reference

B. Chinè and M. Monno, Multiphysics modeling of a metal foam, Proceedings of 2012 European Comsol Conference, Milan, (2012).
B. Chinè and M. Monno,, Diffuse interface models for metal foams, Proceedings of the 2013 Comsol Conference in Rotterdam, (2013).
Comsol AB, Comsol Multiphysics-CFD Module, User's Guide, Version 4.3b, (2013).
Comsol AB, Comsol Multiphysics-Chemical Reaction Engineering Module, User's Guide, Version 4.3b, (2013).
Comsol AB, Comsol Multiphysics-Heat Transer Module, User's Guide, Version 4.3b, (2013).
C. Körner, Integral Foam Molding of Light Metals, 124. Springer-Verlag, Berlin Heidelberg (2008).
P. Yue, J.J. Feng, C. Liu and J. Shen, Diffuse-interface simulations of drop coalescence and retraction in viscoelastic fluids, Journal of Non-Newtonian Fluid Mechanics, 129, 163-176 (2005).
D. Weaire D. and S. Hutzler S., The physics of foams, Oxford University Press, Oxford (1999).

Figures used in the abstract

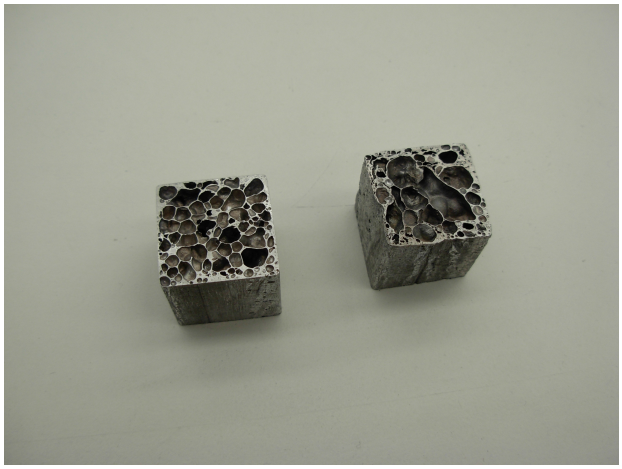

Figure 1: Aluminum foams

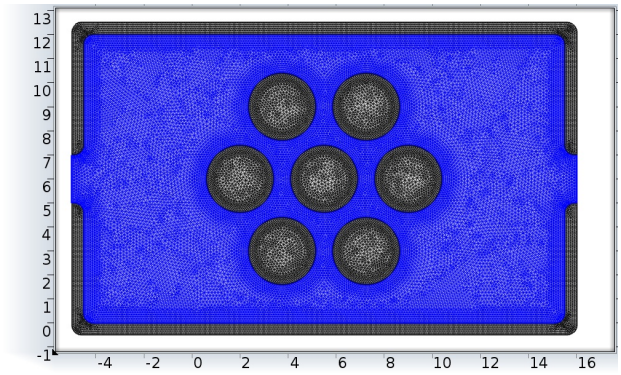

Figure 2: Model of a metal foam in a mold

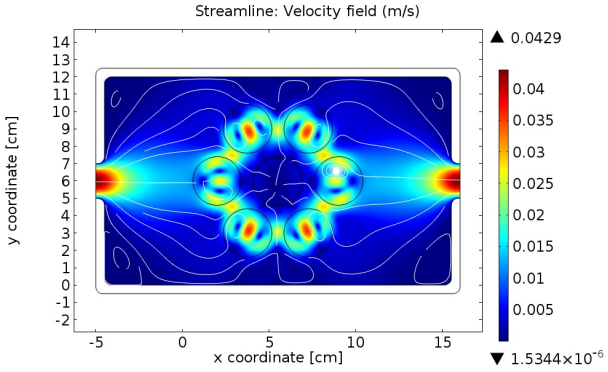

Figure 3: Streamlines for an expanding metal foam