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MECHANICS OF METALLIC FOAMS: A FRACTAL APPROACH

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ABSTRACT

A fractal approach was proposed to investigate the meso structures and size effect of metallic foams. For a series Al foams of different relative densities, the information dimension method was applied to measure meso structures. The generalized sierpinski carpet was introduced to map the meso structures of the foam according to specific dimension. The results show that the fractal-based model can not only reveal the variation of yield strength with specimen size, but also bridge the meso structures and mechanical properties of Al foams directly.
Key words: metallic foams; fractal; size effect; meso structures

INTRODUCTION

Cell structure is an important factor that affects the mechanical properties of metallic foams. Unlike honeycombs and some other cellular solids which have sequential and periodical cell structures, metallic foams are inherently disordered in the cell level: non-equally sized and various shaped cells, non-equally dimensioned and curvy cell walls, random pores and cracks, etc. It's difficult to extract a representative cell and build periodic and ordered models. Fractal has been widely used in the disordered systems in many sciences. Mandelbrot[1], who has made a solid foundation for the fractal theory, used fractal to analyze the fracture surface. Fractal was also employed to investigate the structures and mechanical properties of heterogeneous materials [2~3]. In this paper, the cell morphology of Al foams is proved to be a fractal of self-similar in a certain scale, therefore a fractal approach is introduced to bridge the morphological parameters of cell structures and the mechanical properties of metallic foams.

MESO STRUCTURE AND FRACTAL CHARACTERIZATION

A series of Al foams with different relative densities and meso structures was investigated in this paper. The binary images of different cell morphologies are given in Figure 1.According to the fractal theory[4], being a fractal geometry, the perimeters and areas of cells should obey where P and A are the perimeter

$$P \sim A^{D/2} \tag{1}$$

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$$F = \sigma_0 A_0 = \sigma_0^* A_n \tag{6}$$

where σ_0 is the applied stress, A_0 is area of specimen cross section, σ_0^* and A_n are stress and area of cell walls respectively. Suppose at the yield state the stress also satisfy Eq. (6), according to Eqs (5) and (6), one gets yield stress

$$\sigma_0 = \sigma_0^* (\frac{1}{p^n})^{2-D_{cs}} \tag{7}$$

for the foams. $1/p^n$ can be decided by the lower limit of fractal ℓ_0

$$\frac{1}{p^n} = \frac{\ell_0}{\alpha d} \tag{8}$$

where αd is the side length of specimen cross section, d is the mean diameter of cells. By introducing fractal, the size effect model[5] can be rewritten as

$$\sigma_0 = \sigma_0^* (\frac{\ell_0}{\alpha d})^{2-D} \frac{(\alpha - \frac{1}{2})^2}{\alpha^2} \tag{9}$$

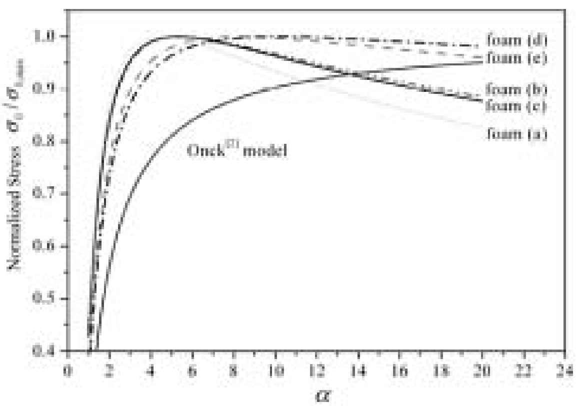

Figure 4. Size effect of Al foams when incorporating fractal.

The size effect model given by Onck[5] is based on honeycombs, which are composed of periodic and sequential cells. By introducing the fractal dimension, the revised model incorporated stochastic meso structures of foams. Size effects of Al foams in Figure 1 were plotted in Figure 4 according to Eq.(9), expressed with the dimensionless yield stress normalized by peak yield stress $\sigma_{0,max}$. The yield stress rises with specimen size at initial stage, then declines gradually. This interesting phenomenon need to be proved by experiments.

CONCLUSIONS

The cell morphology of Al foams is a fractal in a certain scale. Using information dimension method, the meso structures of a series of Al foams with