Materials and Design 32 (2011) 4786–4793

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Modeling failure modes of isotropic three-dimensional reticulated porous metal foams under several typical loads

P.S. Liu [a,*], H.Y. Du [a,b]

[a] Key Laboratory of Beam Technology and Material Modification of Ministry of Education, College of Nuclear Science and Technology, Beijing Normal University, Beijing 100875, China
[b] Research Institute of Jilin Electric Power Company Limited, Changchun 130021, China

ARTICLE INFO

Article history:
Received 4 February 2011
Accepted 16 June 2011
Available online 24 June 2011

Keywords:
B: Metal foams
E: Mechanical properties
M: Feature modeling

ABSTRACT

Three dimensional reticulated porous metal foams are widely used engineering materials. A failure model with the simplified structure of these porous materials has been established, and the failure modes have been analyzed for the corresponding porous components under several typical loads, which include torsion, shearing and bending. The failure modes cover the tensile fracture, the shearing and the buckling of the strut, which may lead to the final destruction of the whole porous structure. The mathematical relationships, which characterize different failure modes, have been derived for the strut failure resulting from loading for these porous components under the above loading conditions. The results also show that the failure mode is related with the material species for these materials under the above loads. The tensile fracture of the strut will occur for the porous body with metallic materials in most cases, and the shearing fracture of the strut may occur for that in a relatively little cases. Moreover, the elastic buckling, the elastic–plastic buckling and the edge yielding may also occur on the strut of porous bodies when certain conditions are met.

1. Introduction

Being engineering materials with sound properties, porous metal foam structures could be applied in the field of separating, filtering, gas-distributing, acoustic absorbing, vibration damping, packaging, shielding, heat exchanging, bio-implanting, electrochemical process, light structures, etc. [1–3]. Special requirements on mechanical properties of porous metal foams are needed in engineering application, especially when used as light-weight structures. A lot of researches [4–20], including some preliminary works [13,14,16–20] from the authors of this paper, have been carried out on the mechanical behaviors of porous metals. Traditional researches are focused on the tensile and compressive properties of porous materials, among which are mainly on the compression property of the close-cell structures [4,5]. Furthermore, there are also some researches on the loading behaviors of close-cell structures, such as the bending property of the porous copper prepared by unidirectional solidification [9], the shear response of the aluminum foam [10] and the bending behavior of the aluminum foam [15]. Comparatively, a few researches have been carried out on the mechanical behavior of porous materials under torque [4] and no helpful result has been obtained. On the other hand, open-cell structures are required for porous metals in the application of biomedicine [7]. For an example, artificial bones need an open-pore environment for growing tissues and a certain ability for bearing loads, which include compression, bending, torsion etc. Here the bending strength and the torsional strength are important factors in the application of these materials [11]. However, only a few experimental studies could be found in this aspect [6,8,11]. Presently, the researches on torsional, bending and shearing behaviors are far from enough for open-cell metal foams and their components. In the works of the present authors, the uniaxial tensile property is primarily investigated for porous materials in Ref. [13], and the mechanical model is analyzed for metal foams under biaxial tension in Ref. [14]. Afterwards, the mechanical relations are successively found for porous metal foams under uniaxial and biaxial loads of collective tension and compression in Ref. [16], for that under triaxial loads in Ref. [17] and for that under several typical loads in Ref. [18]. Moreover, the failure by tensile or shearing fracture mode of the pore-strut is primarily investigated for metal foams under compression in Ref. [19], and the failure by buckling mode of the pore-strut is studied for metal foams under compression in Ref. [20]. Based on the works of Refs. [18–20] and combined with the corresponding calculation result of the octahedron model [13], the possible failure modes of the strut have been further analyzed in this paper for the porous components of reticulated open-cell metal foams under torsional, bending and shearing loadings, which could also be helpful for strength design of this kind of materials under the above loads.

* Corresponding author. Tel.: +86 10 62206024; fax: +86 10 62231765.
E-mail address: Liu996@263.net (P.S. Liu).

0261-3069/$ - see front matter © 2011 Published by Elsevier Ltd.
doi:10.1016/j.matdes.2011.06.029