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ARTICLE

Influence of Structural Parameters on Tensile Property of Gasar Porous Copper

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Abstract: Gasar porous copper with various structural parameters was made by metal-gas eutectic unidirectional solidification process. The effects of structure parameters on the uniaxial tensile properties of the porous copper were investigated. The fracture morphologies of tensile samples were studied by scanning electron microscope (SEM). Math models and numerical simulation were performed and confirmed by experimental data. Results show that the tensile properties of porous copper depend on porosity and tensile direction. Ultimate tensile strength of samples with the same porosity whose pore axes are parallel to tensile direction is better than that whose pore axes are perpendicular to tensile direction. For the porous copper whose pore axes are parallel to tensile direction, the ultimate tensile strength decreases linearly with increasing of the porosity, indicating that pores have no stress concentration on matrix. While for the porous copper whose pore axes are perpendicular to tensile direction, the ultimate tensile strength decreases significantly as porosity increases. Ultimate tensile strengths from experiments, models and numerical simulations of two kinds of specimens are consistent well.

Key words: Gasar porous copper; unidirectional solidification; tensile property; porosity

Gasar, also known as "metal-gas eutectic unidirectional solidification", is a novel process for producing regular porous materials[1-5]. A variety of pore structures (the porosity between 0.25 and 0.95 and pore sizes between 10 μm and 5 mm) can be produced by controlling the processing parameters, such as melting temperature, the mixture ratio and pressure of the gases and the solidification velocity. These porous metals exhibit uniform mechanical properties due to their special pore structures, which should be distinguished from the conventional porous metals whose pores are almost isotropic and spherical such as sintered materials, foamed materials etc.[4, 6-9].

Little data[10-12] are available on the tensile behaviors of the Gasar porous materials. Simone [10] and Hyun [11] investigated the tensile properties of porous copper made by Gasar process. It was found that the tensile properties of the porous copper showed obvious anisotropy, and the yield strength and the ultimate tensile strength of the ordered porous copper with the pores orientated parallel to the tensile direction decreases linearly with the increase of porosity. But no investigation on a computer simulation of anisotropic tensile properties in Gasar porous copper was carried out. From this point of view, the present work was undertaken to investigate the effects of structural parameters such as porosity, load direction on tensile behaviors of Gasar porous copper. The tensile models were established by Finite Element Simulation for wider range of porosities.

1 Experiment

The fabrication apparatus of the Gasar porous materials consists of a crucible surrounded by an induction heating coil and a mold with water-cooled copper plate as shown in Fig.1. High purity 99.99% copper was melted in a crucible in vacuum, and then high-pressure mixed gas of hydrogen and argon was introduced into the chamber. In order to make the hydrogen sufficiently dissolve and diffuse in liquid copper, the melt was held for 900 s at a given pressure and temperature. Then

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the crucible was rotated by 90º to pour the molten copper into the mold whose bottom plate was cooled down with water circulated through a chiller. Thus, the molten copper was solidified unidirectionally upwards. The ingots obtained were 100 mm in diameter and 60~120 mm in height dependent upon the porosity. The pressures of hydrogen and argon during melting and solidification were changed in order to produce the various specimens with different porosities. Typical cross-section of the porous copper is shown in Fig.2.

Two types of tensile specimens with a gage length of 14 mm and a gage section of 2 mm×3 mm were cut from the ingots by the a spark-erosion wire cutting machine. Fig.3 shows the two types specimens for tensile test at different angles between pore axis and compressive direction. The porosities *p* of the tensile specimens were evaluated through Archimedes' principle.

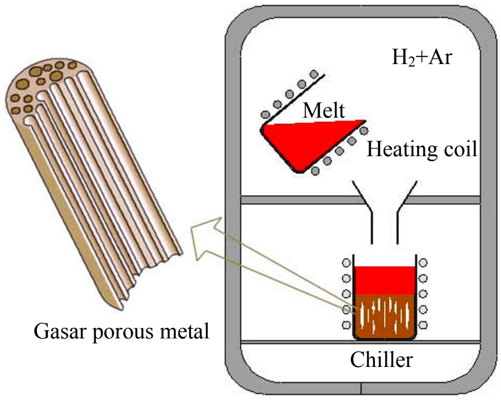

Fig.1 Schematic drawing of the fabrication apparatus for Gasar porous materials

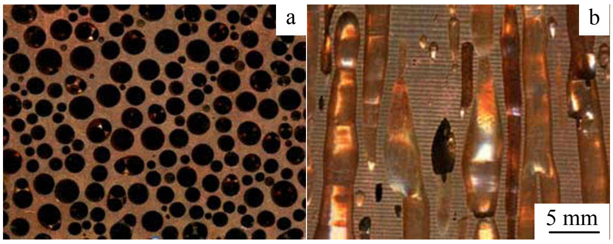

Fig.2 Optical micrographs on the cross section (a) and the longitudinal section (b) of Gasar porous copper

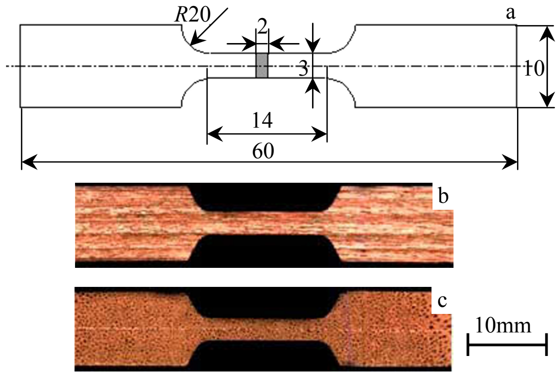

Fig.3 Size of tensile specimen (a) and specimens with pore axils: (b) parallel and (c) perpendicular to tensile direction

Tensile tests were performed on the specimens in an Instron Universal Testing Machine (Model AG-IS10 KN) at room temperature. The crosshead speed was 1 mm/min. The strains were calculated from the actuator displacement and the initial specimen length, taking into account the displacements within the testing machine. The 0.2% offset yield strength and the ultimate tensile strength were evaluated from the stress-strain curve.

3D infinite element models whose pore axes are parallel and perpendicular to loading direction are shown in Fig.4. It was assumed that pores had the same diameter and were distributed in base with a regular hexagonal shape. Material parameters related to model in FES were from solid pure copper fabricated by metal-gas eutectic unidirectional solidification[10]. Young modulus is 8×10^{10} Pa, and Poisson's ratio is 0.32. Meanwhile, MISO model was used in FES to give accurate material features. Distance loading method was applied in FES. Loading rate 1 mm/min was set as the same as the value of experimental test.

2 Results and Discussion

2.1 Stress-strain curve

Typical stress-stain curves for the Gasar porous copper specimens with 0.31 porosity and different tensile directions are shown in Fig.5. The curves show a linear elastic behavior at small stains, followed by yield and stain hardening up to the peak stress. The stress-strain curves of the porous copper with the pores axis parallel and perpendicular to the tensile direction agree well with the results reported by Simone [10] and Hyun [11].

When the direction of the pore axis is parallel to the tensile direction, the smooth stress-stain curves is almost indistinguishable from the curves of the corresponding nonporous metals. In the case that the direction of the pore axis is perpendicular to the tensile direction, the stress-stain curves become jagged after the stage of stain hardening. This fact indicates that the pores cause different levels of stress concentration under two types of tensile tests. The inference can be firmly supported by stress nephogram as shown in Fig.6.

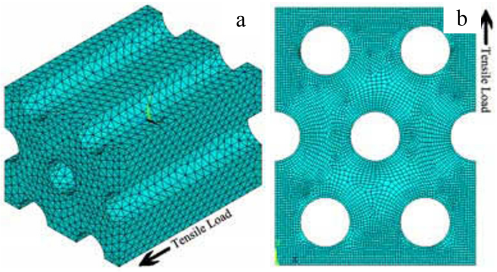

Fig.4 Models for finite element simulation: pore axes are parallel (a) and perpendicular (b) to tensile direction