Micro-porous Nickel Produced by Powder Metallurgy

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Abstract

Micro-porous nickel (Ni) with an open cell structure was fabricated by powder metallurgy. The pore size of the micro-porous Ni approximated 30 µm and 150 µm. For comparison, porous Ni with a macro-porous structure were also prepared by both powder metallurgy (pore size 800 µm) and the traditional chemical vapour deposition method (pore size 1300 µm). The mechanical properties of the micro- and macro-porous Ni samples were evaluated using compressive tests. Results indicate that the micro-porous Ni samples exhibited significantly enhanced mechanical properties, compared to those of the macro-porous Ni samples.

Keywords : Nickel, micro-porous structure, powder metallurgy, mechanical properties

1. Introduction

Porous metals are receiving increasing attention in recent years due to their high specific mechanical properties and unique functional properties, such as high stiffness in conjunction with very low specific weight or good permeability combined with high specific surface area [1]. Among these lightweight porous metals, porous Ni materials are highly interested since they possess characteristics that can be exploited for multifunctional applications such as electrodes of Ni cadmium and Ni metal hydride batteries for electric vehicles, catalysts, diesel particulate filters, silencers and so on [2,3].

Many fabrication processes have been developed to produce porous metals during the recent years [4]. The most common methods are either via the addition of a foaming agent into the molten materials [5] or powders, or through bubbling gas into the molten metals or powders directly [6]. The porous metals produced by these methods are very limited in controllability of pore size and porosity. The inhomogeneity in pore size and porous structure may cause difficulties in testing and interpreting of the intrinsic mechanical behaviour of porous metals. Furthermore, the pore size of porous metals investigated to date varies from hundreds of microns to several millimetres. There is little work on porous metals with a micro-porous structure. Therefore, it is critical to develop new fabricating process for porous Ni materials with fine and homogenous porous structures, which enables a more precise predicting of the mechanical deformation behaviour, and also enhanced mechanical performance. In the present study, porous Ni with a micro-porous structure and various porosities were prepared by powder metallurgy. The mechanical properties were investigated by compressive tests.

2. Experimental and Results

The micro-porous Ni samples were prepared by a special powder metallurgical process, which included the adding of a space-holding material [7]. Ni powder with a particle size of 3 µm and a purity of 99.9 % was prepared as starting material. Ammonium bicarbonate powder was used as the space-holding material. Three kinds of particle size levels, i.e. 30 µm, 150 µm and 800 µm were selected for the ammonium bicarbonate powder in order to attain porous Ni samples with different pore sizes. Various nickel powder to space-holding particle ratios corresponding to each kind of space-holding particle size were selected in order to obtain the predetermined porosities. The process consisted of three main steps as mixing of starting materials, compacting and heat treatments. The heat treatments were carried out in two steps. The first step was performed at 200 ^{o}C holding for 2 h to vaporise the space-holding material; and the second step was carried out at 1100 ^{o}C holding for 2 h for sintering the Ni powder into a porous structure. Porous Ni samples with the micro-porous structures were obtained after heat treatments. For comparison, porous Ni with a macro-porous structure and a pore size of 1300 µm was also prepared by the traditional CVD method in this research [8]. Compressive tests were carried out on the porous nickel samples at room temperature with an initial strain rate of $10^{-3}s^{-1}$.

The micrographs of the porous Ni samples with the micro-, and macro-porous structures are shown in Fig. 1.

The porous Ni sample shown in Fig. 1 (a) was fabricated by the traditional CVD method, and samples shown in Fig. 1 (b), (c) and (d) were fabricated by powder metallurgy. SEM observation and image analysis indicated that the average pore size for the porous Ni samples were 1300 μm, 800μm, 150 μm and 30 μm for Fig.1 (a)-(d), respectively.

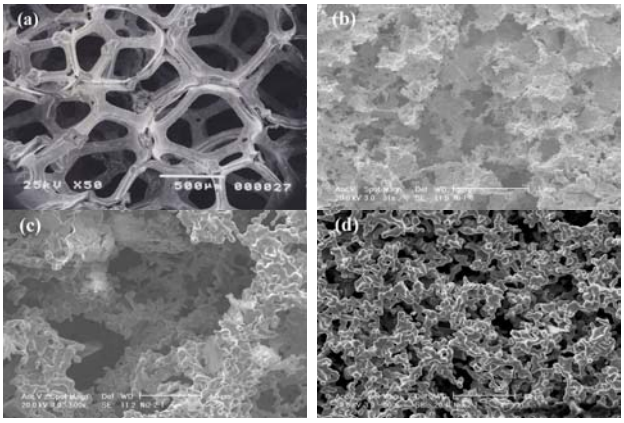

Fig. 1. SEM micrographs of the macro and micro - porous Ni samples: (a) pore size 1300 μm, (b) pore size 800 μm, (c) pore size 150 μm, and (d) pore size 30 μm, respectively.

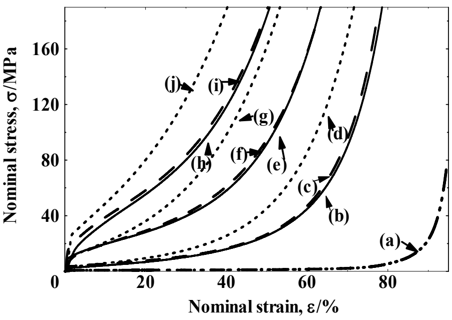

Fig. 2. The nominal stress – nominal strain curves of the porous Ni samples (a)-(j): (a) pore size 1300 μm, porosity 95%, (b) pore size 800 μm, porosity 80%, (c) pore size 150 μm, porosity 80%, (d) pore size 30 μm, porosity 80%, (e) pore size 800 μm, porosity 70%, (f) pore size 150 μm, porosity 70%, (g) pore size 30 μm, porosity 70%, (h) pore size 800 μm, porosity 60%, (i) pore size 150 μm, porosity 60%, (j) pore size 30 μm, porosity 60%.

Fig. 2 shows the nominal stress - nominal strain curves of the porous Ni samples with micro-, and macro-porous structures. It can be seen that the nominal stress of the porous Ni samples increased with the decreasing of the porosity of the sample regardless of the changes in the pore size.

Furthermore, the porous Ni samples with micro-, and macro-porous structures exhibited different deformation behaviours. The porous Ni sample with a macro-porous structure showed the typical deformation behaviour of a porous metal. The porous Ni sample with a pore size ranged from 150 to 800 μm showed similar deformation behaviours: the stress-strain curve exhibited an initial elastic deformation region; then followed by a long plateau deformation region, and finally a densification deformation region. However, the micro-porous Ni foams with pore size of 30 μm showed different deformation behaviour, i.e. the stress – strain curves showed an initial elastic deformation stage also, but there is not a long plateau deformation stage. The stress increased gradually with the increasing of the strain. This kind of deformation behaviour is similar to that of a solid material. It can be concluded that the porous Ni samples with a micro-porous structure exhibited enhanced strength than that of the porous Ni sample with a macro-porous structure.

3. Summary

Porous Ni samples with the micro-porous structure were successfully fabricated by a powder metallurgical process. Results indicated that the porous Ni samples with a micro-porous structure exhibited obviously enhanced mechanical properties compared to those porous Ni sample with the macro-porous structures.

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4. References

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