Available online at www.sciencedirect.com
ScienceDirect

JOURNAL OF IRON AND STEEL RESEARCH, INTERNATIONAL. 2014, 21(8): 793-796

Compressive Behavior of Porous Titanium Fiber Materials

Shi-feng LIU[1,2], Zheng-ping XI[2], Hui-ping TANG[2], Xin YANG[3], Zhao-hui ZHANG[1]
(1. School of Metallurgical Engineering, Xi'an University of Architecture and Technology, Xi'an 710055, Shaanxi, China; 2. State Key Laboratory of Porous Metals Materials, Northwest Institute for Nonferrous Metal Research, Xi'an 710016, Shaanxi, China; 3. Xi'an University of Technology, Xi'an 710045, Shaanxi, China)

Abstract: Porous titanium fiber materials with the fiber sizes of 70−120 μm in diameter were prepared by vacuum sintering technology. The morphology and compressive properties of porous titanium fiber materials were investigated by using a scanning electron microscope (SEM) and an MST 858 compression testing machine in quasi-static condition. The results show that porous titanium fibers form complex micro-networks. The stress-strain curves of porous titanium fiber materials exhibit elastic region, platform region and densification region and no collapse during platform region. The yield strength of porous titanium fiber materials decreases with increasing the porosity and increasing the fiber diameter.

Key words: porous titanium fiber material; compressive behavior; energy absorption; porosity
DOI: 10.13228/j.boyuan.issn1006-706x.20140029

Porous titanium fiber materials have recently received considerable interest due to not only their good corrosion resistance and high strength, but also low density, good filtration and separation characteristics[1−5]. Porous titanium fiber materials have been applied to the filtration, noise reduction by sound absorption, electromagnetic shielding, high efficient combustion, and heat transfer enhancement due to a series of their special functions resulting from their unique three-dimensional fibrous framework and fully connected porous structure.

Porous titanium can be manufactured by loose powder sintering, adding pore-forming materials, organic foam impregnation and rapid prototyping, but these methods have some disadvantages such as easy contamination, impurity phases, non-through holes, powder particles and metallurgical defects including cracks and bond-free connected points, resulting in no tension and even brittleness of porous titanium materials[6−10]. Porous titanium materials with the porosities of 42%−82% were prepared using titanium wires by different winding methods[11−13]. The results showed that the higher the sintering temperature and the longer the soaking time, the better the porous structure. In the compression testing, the porous titanium materials exhibited the same elastic-plastic behavior as other porous materials. The porous titanium materials also had good toughness, high strength and appropriate modulus of elasticity in the tensile and distortion tests. Zou et al.[14] found that the porous titanium materials prepared by sintering using titanium fiber had high strength, excellent biocompatibility, corrosion resistance and load-bearing properties as medical implants. The connectivity of three-dimensional porous structure enabled the bone tissue to grow inwards, which attracted much attention of scientists in related fields. It was difficult to test tensile property of porous titanium with high porosity, so compression properties were used to research the mechanical properties of porous titanium. However, mechanical model under uniform compression can not be applied to porous titanium fiber material. So the research of porosity is very meaningful for the compressive mechanical properties. Through the research on the deformation process of porous titanium fiber material, the influence of porosity on compression properties of porous titanium fiber materi-

Foundation Item: Item Sponsored by National Natural Science Foundation of China (51304153); Natural Science Foundation of Shaanxi Province of China (2012JM6017)
Biography: Shi-feng LIU, Doctor Candidate, Associate Professor; **E-mail**: liushifeng66@126.com; **Received Date**: January 21, 2014

als was analyzed.

In the present study, the porous metal materials were prepared using pure titanium wires with diameters of 70—120 μm by vacuum sintering technology. The effect of the porosity of porous titanium fiber materials on their compressive behaviors was investigated through quasi-static compression tests. A scanning electron microscope (SEM) was applied to characterize the pore morphology of the porous titanium fiber materials.

1 Experimental

Pure titanium fiber with diameter of 70—120 μm was used as the research materials. The chemical composition of the as-received materials in mass percent is shown in Table 1. Titanium fiber with a mesh structure was molded and then sintered at 1000—1300 ℃ for 1—2 h in a vacuum sintering furnace (vacuum lower than 10^{-2} Pa), followed by furnace cooling. The porosities were controlled in the range of 40%—80%. Effects of titanium fiber diameters, sintering temperature and porosity on compression properties were studied.

Table 1 Chemical compositions of titanium fiber mass%

C	N	H	Fe	Ti
3	1	1.4	2	92.6

The porosity of materials can be calculated by direct weighing volume method using the formula as follows.

$$P=1-m/V\rho_s \quad (1)$$

where, P, m, V and ρ_s are the porosity, mass, volume and density of porous material, respectively.

The contents of oxygen and nitrogen in porous titanium fiber materials before and after sintering were determined by a TC-600 oxygen/nitrogen determinator. The morphology of porous titanium fiber materials was observed using a Jeol-JMS 6460 scanning electron microscope. The cylindrical specimens with a diameter of 5 mm and a length of 10 mm were used for the compression tests. The compression tests were conducted on an MTS 858 compression testing machine with compression rate of 0.5 m/min at room temperature.

2 Results and Discussion

Fig. 1 (a) shows the typical appearance of the porous titanium fiber materials sample with porosity of 60.2% before compression. Figs. 1(b) to 1(d) show the morphology after sintering. It can be seen from Fig. 1(b) that the pores structures are very complex and fabric-like distribution with cross connections between the fibers which further form many sintering points. As shown in Figs. 1(c) and 1(d), the pores of materials may be surrounded by three or more titanium wires with cross-connected points which can form sintering points after sintering. A continuous fiber skeleton may contain many sintering points which are important to the mechanical properties of materials.

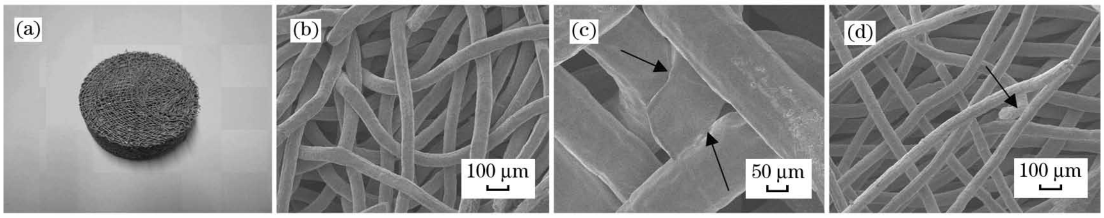

Fig. 1 Typical appearance of specimen before compression (a) and SEM photos of porous titanium fiber material sample (b), (c) and (d)

The typical compressive stress-strain curve of porous titanium fiber material is shown in Fig. 2. It reveals three deformation stages within the whole regime. There is a linear elastic region under very small strain and this regime is identified as stage I. Once the strain reaches the critical value, a large yield platform region appears, which is denoted as the stage II. This is then followed by considerably increased work-hardening rates, defining the stage III, i. e., the densification region. The compressive stress-strain behavior of porous metal fiber materials is similar to that of porous foam metal materials which is composed of three stages including elastic region, platform region and densification region based on the Gibson-Ashby theory[15]. The longer platform region in the curve indicates that porous metal fiber materials have strong ability to absorb energy.

In order to analyze the change of oxygen and nitrogen contents in the porous titanium fiber materials before and after sintering, the oxygen/nitrogen determinator was used. The results showed that the