Materials and Design 85 (2015) 275–281

Contents lists available at ScienceDirect

Materials and Design

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

Primary investigation on sound absorption performance of highly porous titanium foams

P.S. Liu *, H.B. Qing, H.L. Hou

Key Laboratory of Beam Technology and Material Modification of Ministry of Education, College of Nuclear Science and Technology, Beijing Normal University, Beijing 100875, China

ARTICLE INFO

Article history:
Received 12 March 2015
Received in revised form 19 June 2015
Accepted 20 June 2015
Available online 28 June 2015

Keywords:
Porous metal
Metal foam
Titanium foam
Sound absorption

ABSTRACT

A novel sort of cellular titanium foam, whose total porosity was achieved as high as 86%–90% and main pores were spherically millimeter-scaled, was recently prepared successfully by an improved foaming method of melting the metallic powder. This titanium foam showed a good performance of sound absorption, and its sound absorption coefficient could be more than 0.6 in the sound-wave frequency range of 3150–6300 Hz and even exceed 0.9 at the resonance frequency. The main mechanism of sound absorption for this foam should be of interference silencing due to the surface reflection when the sound wave frequency is lower than about 4250 Hz, and the viscous dissipation when the frequency is higher than about 4250 Hz. A reticular product with millimeter-scaled pore size and about 90% porosity was also made by means of slurry-immersed sintering, and the resultant titanium foam might display an effect for sound absorption, but on the whole, its absorption was evidently inferior to that of the cellular product. The corresponding sound absorption coefficient could not be above 0.2 until sound-wave frequency is higher than 3150 Hz, keeping a relatively low value except for resonance occasion only, on which it could reach up to around 0.9 at about 4000 Hz.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

With a small bulk density and good comprehensive properties, the metal foam is a kind of porous material integrating structural and functional actions, and may be widely applied to a large number of fields, such as in aerospace, electronics, communications, transportation, atomic energy, medicine, environmental protection, metallurgy, machinery, building, electrochemical and petroleum–chemical industries, dealing with the lightweight structure, noise reduction, energy absorption, shock attenuation, electromagnetic shielding, heat insulation, fire resistance, heat exchange and biomedical engineering [1–4]. The relative researches have mainly focused on aluminum foams, which have had a number of applications, in particular, in the aerospace, automobile, ship and construction industries, as well as the military engineering. With a higher melting point, better heat insulation and more excellent corrosion resistance than aluminum foams, titanium foams could be more suitable for a more rigorous demand on ambient temperature and service environment, particularly in aviation, spaceflight and military. For instance, the functional material that has a more powerful ability to withstand high temperatures than aluminum foams may be needed when it needs to be used as the lightweight and denoising structure for aerospace science and technology, and the engineering material that is more resistant to corrosion than aluminum foams may be needed when it needs to be used as the lightweight and silencing structure in the briny environment. In the present work, the titanium foam is developed to be intended for use in these harsh conditions.

Titanium has its own virtues of light weight, high specific strength, good corrosion resistance and nice biocompatibility, etc., but the researches on titanium foams have been reported far less than on aluminum foams. A lot of methods can be successfully used to obtain aluminum foams, but not so for titanium foams. On the principle, many good methods to produce metal foams could be hopeful to make the titanium foam. However, titanium foams would, in practice, be prepared usually by powder sintering, and the products have been developed usually with a porosity that is not quite high and generally lower than 70% [5–9]. Because of high melting point and easy oxidation for titanium, the preparation technology for titanium foams needs to be different from that for aluminum foams, and the resultant porous structure, pore size and pore morphology would have their own characteristics.

Titanium foams are attractive for structural and biomedical applications [5,10,11], especially for implant applications [12–16]. Unlike aluminum foams, they cannot be easily produced in the liquid state due to the high melting temperature, and the current techniques for their processing are mainly based on powder metallurgy, including the powder sintering and the pressurized pore expansion [5]. At present, titanium foams are studied mostly on the application in porous titanium alloy implant materials, and relatively few on that in structural engineering materials. As for porous implant materials, the pores thus should be interconnected three-dimensionally to provide enough space for the attachment and proliferation of new bone tissues and

* Corresponding author.
E-mail address: Liu996@263.net (P.S. Liu).

http://dx.doi.org/10.1016/j.matdes.2015.06.118
0264-1275/© 2015 Elsevier Ltd. All rights reserved.

to facilitate the transport of body fluids [15]. Accordingly, their properties are researched mainly on the biological performance and the relative mechanical characterization of the implant titanium foam with an interconnected open-cell porous structure, in main view of medical implant applications [9,17–20]. As compared with this open-cell reticulated structure, cellular titanium foams have been quite rarely investigated [16]. Furthermore, all these researches are far less than that on aluminum foams. By comparison, titanium foams are relatively devoid of the systematic study, in particular on the physical property. For example, the reported study on their acoustic or thermal property has not yet been found even until now. For the consideration of other more potential engineering applications, more researches are necessary on variously structured titanium foams as well as their primary properties, including physical and mechanical properties. Besides, metal foams have been developing for lower bulk density and higher porosity on the basis of meeting the requirement of mechanical properties, especially in cases where the structural weight reduction is the key factor. Therefore, two sorts of highly porous titanium foams, with cellular or reticular structures, were firstly prepared in the present work, and their sound absorption performance, one of the most elementary physical properties, were preliminarily investigated for these foams.

2. Preparation of titanium foams

With nickel as the main alloy element, the titanium foam could be prepared by using the titanium–nickel alloy powder or the mixed powder of titanium and nickel as the main raw material. The melted powder foaming method [4] could be adopted to make the cellular titanium foam, but it was greatly improved in order to get a high porosity product with cellular structure in this work. In the present process, the dehydrogenated titanium powder (Fig. 1(a)) and the electrolytic nickel powder (Fig. 1(b)), with the granularity both of −300 mesh and the mass ratio of 75:25–85:15, were firstly mixed together in a mixing machine for 2 h to get the evenly mixed metallic powder. To such mixed powder, a certain amount of the foaming agent and adhesive were then added according to the desired porosity of the product. After uniformly mixing again, the resultant mixture was pressed in a mold to give a prefabricated product. This prefabricated product was afterwards dried and placed (together with the mold) in a non-oxidizing environment, and quickly heated to 1000–1200 °C then rapidly cooled after it had been at the high temperature for a certain length of time. During this process, the foaming agent carried out a thermal decomposition and released the gas to form a cellular structure with spherical pores. The resultant finished products of highly porous titanium foam are shown in Fig. 2(a) and (b) as the examples, with the total porosity of about 90%. From the pore size and shape it could be directly informed that the macroscopically spherical pores with a millimeter-scaled size should have resulted from the decomposition of the foaming agent to release the gas: those macroscopic pores are interconnected due to a sufficiently high porosity of the product. Fig. 2(c) shows the microporous structure of the cell wall corresponding to the porous product, revealing a good bond of the solid phase. In Fig. 2(c), the irregular tiny pores with micron-scaled size should have been caused by the thermal decomposition of the organic additive such as the adhesive, and these pores could further improve the connectivity between those macroscopically spherical pores. The tiny pores existing in the cell wall would not be conducive to the strength of the product, but contribute advantageously to the sound absorption property of the product.

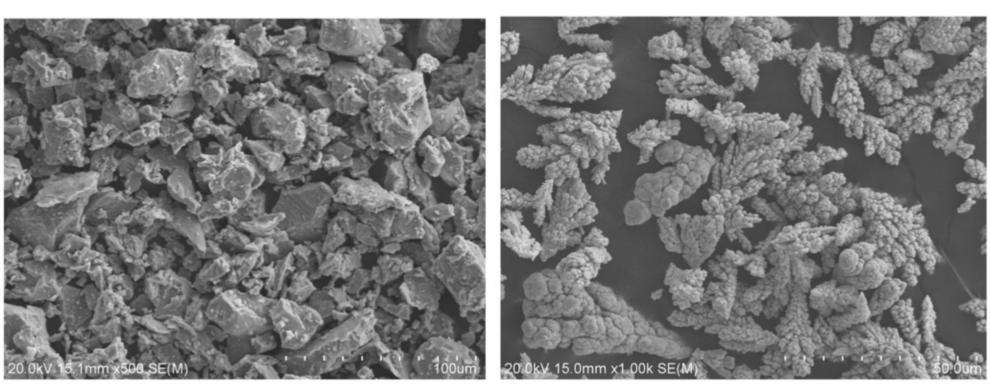
The reticular titanium foam was prepared by using the slurry-immersed sintering method [4]. During the preparation, the evenly mixed metallic powder mentioned above was added with a certain amount of the adhesive to make a desired slurry, into which the polymer matrix was then immersed to obtain a composite product. After drying, the resultant prefabricated product was sintered at 800–1000 °C in a vacuum furnace for more than 2 h, and the resultant product sample with a porosity of about 90% is shown in Fig. 3. This figure shows the main pores (Fig. 3(a)) of the porous product are interconnected with the size of about 1–2 mm, and the corresponding three-dimensional reticular structure presents to be mainly dependent on the original polymer matrix (Fig. 3(b)).

An X-ray diffractometer of X'PertPRO MPD type made by PANalytical Company in Holland was used to examine and analyze the mixed raw material of metallic powder and the obtained product of titanium foam, with the radiation source of Cu k_α, the scanning voltage of 40 kV and the scanning current of 40 mA, and the results are shown in Fig. 4. The characteristic spectra of titanium and nickel in Fig. 4(a) reveal that there was no phase transformation for the mixed raw material of metallic powder after mechanical mixing, and their relative intensity shows the most composition of titanium contained in this mixed raw material. The relative intensity of the diffraction peak of titanium in Fig. 4(b) is still quite high for the product of titanium foam, accounting for the phase of titanium still predominant in the product; the characteristic spectrum of the metallic nickel phase disappears and that of a new phase of $NiTi_2$ comes forth, indicating that almost all the metallic nickel had reacted with a part of titanium in the mixed raw material to generate the new phase at a high temperature in the preparation process. This composition is in agreement with the analytical result from the phase diagram of titanium–nickel alloys.

3. Sound absorption property of titanium foams

3.1. Experimental method

The sound absorption coefficient test system of JTZB type made by the Beijing Century Jiatong Technology Development Limited Company



(a) (b)

Fig. 1. Morphologies of the raw metallic material: (a) titanium powder; (b) nickel powder.

Download English Version:

https://daneshyari.com/en/article/828297

Download Persian Version:

https://daneshyari.com/article/828297

Daneshyari.com