Development of Stainless Steel (SS316L) Foam with Different Composition using Compaction Method

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Abstract
In this study, the fabrication of open cellular stainless steel (SS316L) foams by using an innovative spacer which is crystalline sugar through compaction method was investigated. Powder metallurgy process needs to go through the mixing, pressing, sintering and analysis. The selected composition of SS316L was 50 wt % and 55 wt % SS316L while the remaining percentages are foaming agent or binder. Then, sintering process was conducted in the tube furnace. The SS316L foams were characterised using X-Ray Diffraction (XRD) and Energy Diffraction X-ray (EDX). The XRD was detected Austenite stainless steel. Then, the detected elements in the SS316L foam were O, K, Mn, Cr, Fe, Mo and Al.

Keywords: Porous structure, powder metallurgy, foam, sintering, opened cell

Introduction

Metallic foams, principally stainless steel (SS316L) foams, have extended biomedical applications, because of their great low densities and special characteristics [1, 2]. They have high specific strength to weight ratios, stiffness, excellent impact energy absorption, and significant damping [1-4]. Examples of their structural applications include lightweight panels, crash energy absorption, and noise control for automotive industry, and functional applications for implants due to their excellent physical and mechanical properties, silencers, filters, heat exchanger and energy absorbers [1, 2, 4].

Basically, the space holder particles are mixed with metallic powders, then compacted and finally removed during or before sintering. A different space holder material that widely used is polymeric material, urea, sodium chloride, crystalline sugar cane, sodium fluoride, carbamide, ammonium hydrogen carbonate, magnesium and even tapioca [5–7].

Experimental Method

Initially, the polyethylene glycol (PEG) added SS316L powder and crystalline sugar are first mixed thoroughly to achieve a homogeneous mixture. After the powders were mixed properly, the powder mixture is compacted using Carver Hand Press machine by applying 8 tons of pressure. Next, removed of the space holder from the samples and sintered. The samples were held at 450°C and 1200°C for 2 hours to sinter the stainless steel powders. During sintering process, the heating rate and cooling rate were kept at 2°C and 5°C/min, respectively.

Results & Discussion

The crystalline sugar, applied as the space holder particles, well defining the pore size during compacting of the SS316L mixture. Table 1 shows the elemental analysis of the sintered 50 and 55 wt % SS316L foam using EDX method. Generally, SS316L should consist of Cr, Ni, Mo, Mn, C and Fe. However, the EDX analysis performed in all samples with composition of 50 and

55 wt % SS316L show the presence of O, Al, Mn, K, Fe, Cr, C, S and Si.

Table 1: Composition of SS316L foam determined by EDX method

Element \ Composition	50 wt %	55 wt %
O	✓	✓
Mn	✓	✓
K	✓	✓
Fe	✓	✓
Cr	✓	✓
Si	-	✓
C	✓	-
Al	✓	-
S	✓	-
Mo	✓	-
Ni	-	✓

The standard composition of the Mo and C in the SS316L are less than 3% and 0.03% respectively. Therefore, in 55 wt % of SS316L metal foam produced, the elements were not detected. Fig. 1 shows the XRD result for before and after sintering process as follows as the pattern of PDF 2007: 00-033-0397 (Austenitic SS) which was chromium iron nickel carbon ($FeCr_{0.29}Ni_{0.16}C_{0.06}$) and iron chromium (FeCr). Available presence iron (Fe), nickel (Ni), chromium (Cr) and oxygen (O). These elements form compounds that are present in the SS316L metal foam such as iron nickel (Fe_2O_3). The SS316L foams show two main diffraction peaks related to the (110) and (111), while the other elements were not detected.

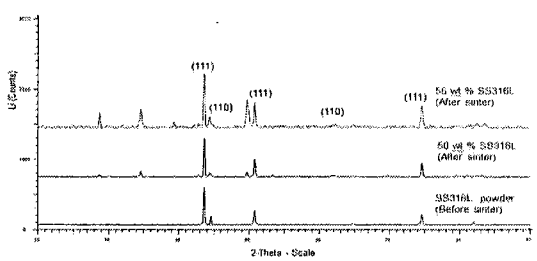

Fig. 1: Results of XRD analysis

Existence of elements in the SS316L metal foam were further strengthened with the EDX results also indicates the presence of the elements Fe, Ni, Cr and O in the metal foams content produced (see Table 1).

Conclusion

Stainless steel foams have been successfully fabricated using an innovative spacer, crystalline sugar through powder metallurgy. For further research, the compressive strength of these samples will be investigated.

References

[1] M.F. Ashby, A.G. Evans, N.A. Fleck, L.J. Gibson, J.W. Hutchinson, N.H.G. Wadley, Metal foams: a design guide. USA: Butterworth-Heinemann; 2000.

[2] Banhart J. Manufacture, Characterization and applications of cellular metals and metal foams. Prog Mater Sci (2001); 46:559–632.

[3] Surace R, De Filippis LAC, Ludovic AD, Boghetich G. Influence of processing parameters on aluminum foam produced by space holder technique. Mater Des (2009); 30: 1878–85.

[4] S. Ahmad, A. Muchtar, J. Sahari, K. R. Jamaludin, M. H. I. Ibrahim, H. M. Nor, I. Murtadhahadi, U. Tun, H. Onn, and B. Pahat, Producing of titanium foam using titanium alloy (Al_3Ti) by slurry method, pp. 1–8.

[5] N. Wenjuan, B. Chenguang, Q. Guibao, W. Qiang, Processing and properties of porous titanium using space holder technique. Mat. Sci. Eng. A506, 148 (2009).

[6] A. Bansiddhi, D.C. Dunand, Shape memory NiTi foams produced by solid state replication with NaF. Intermetalics 15, 1612 (2007).

[7] A. Bansiddhi, D.C. Dunand, Shape memory NiTi foams produced by replication of NaCl space holders. Acta Biomat. 4, 1996 (2008)