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CHARACTERIZATION OF SS316L FOAM USING TAPIOCA STARCH BY COMPACTION METHOD

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ABSTRACT

In this work, porous 316 L Stainless Steel (SS316 L) has been prepared by powder metallurgy route which is compaction method. This method compromises a lot of advantages including of easy processing method, very economic and environmentally friendly. Furthermore, the compaction method does not involve usage of toxic chemicals and capable to produce porous structure for variety of applications. The methods studied are compaction method and organic material as a binder. The organic material can easily burn out during sintering process and chemically stable. The SS316 L foams were fabricated in this study using starch as space holder. The SS316 L samples were prepared by varying the SS316 L composition from 40 wt%, 45 wt% and 50 wt%. Then, sintering process was conducted in high temperature at 1200^{o}C in a vacuum furnace. The mechanical properties and pore structures were investigated by SEM. Archimedes was used to measure bulk density and porosity of samples. The 40 wt% SS316L shows the lowest value of bulk density and highest porosity with 3.19 g/cm^3 and 10.61 %, respectively. The 50 wt% SS316L shows the highest value of bulk density and lowest porosity with 6.46 g/cm^3 and 1.77 %, respectively. The sample with 50 wt% were produced a good and finer structure with micro and macropores and struts comparing to other composition.

Keywords: Keywords: Space holder; metal foam; composition;

INTRODUCTION

Nowadays, open-celled metal foams especially 316 L Stainless Steel (SS316L) is widely used in various industries such as nuclear, defense, petrochemical, electronic and electrical, industrial, medical office equipment, chemical, production of medical devices, hardware, marine and power generation [1,2,3]. These are because they have good properties of corrosion-resistant, specific strength to weight ratios, significant damping, excellent impact energy absorption and sound absorption properties) [1,4,5]. Thus, depending on the requirements of the applications, porous steels with controlled microstructures such as varying porosity fraction, pore size, distribution of pores and interconnected pore are being produced via powder metallurgy routes.

The pore structure parameters like adjustment of pore shape, porosity fraction, distribution of pores depending on the shape, size and volume fraction of space holder were depending on suitable selection of the powders and space holders [6,7]. Selection of fabrication process plays an important role in controlling the microstructure and resulting properties of porous metals.

Among a variety of processes, one of the popular approaches adopted for fabrication of porous steels includes use of space holder particles which burn out during heat treatment and leaving porosity in the sample. A wide variety of space holders such as polymeric material [8], carbamide, urea [9,10], sodium chloride (NaCl) [11], crystalline sugar cane [12], sodium fluoride, potassium carbonate (K2CO3), polymethyl methacrylate (PMMA) [13], ammonium hydrogen carbonate (NH4HCO3) [14] and even magnesium [15,16] have been successfully used in fabrication of porous metal.

The structures, physical characteristics and applications of starch make it a good material as a space holder. Once the temperature is raised, the starch can easily be burnt out because it is an environmentally friendly organic polymer [17]. Spherical starch particles are suitable for space holder technique; moreover, starch is cheap and readily available. It is much more reliable and chemically stable than other space holders.

EXPERIMENTAL

The SS316 L powder and space holder were mixed together using ball milling machine for 15 minutes to 20 minutes. The mixture is compacted adequately, so that it is strong enough to be hold. The finished sample is sintered in vacuum furnace ($1x10^{-6}$mbar per capacity of vacuum condition). The compositions for SS316L are 40 wt%, 45 wt% and 50 wt% while the remaining percentage is starch powder as a space holder and polyethylene glycol (PEG) as a binder.

The powder mixture is compacted by applying 8 tons of pressure [18] using Carver Hand Press machine. The vacuum furnace is used during the sintering stage in order to avoid oxidation or the effect of oxygen to the stainless steel [6] was reduced to the samples. The samples were held at 450 ^{o}C and 1200 ^{o}C for 2 hours to sinter the SS316 L powders. The heating and cooling rate were kept at 2 ^{o}C/min and 5^{o}C/min, respectively. Next, using Wire - EDM (Wirecut) machining, the sintered samples were cut due to focus on the evaluate macropores. The sintered samples were characterised by means of Scanning Electron Microscopy (SEM).

RESULTS & DISCUSSION

The SS316 L foams with 40 wt%, 45 wt% and 50 wt% of compositions were successfully produced pores structure and struts. The pore morphology with 250X magnification are observed by SEM are shown in Figure 1.

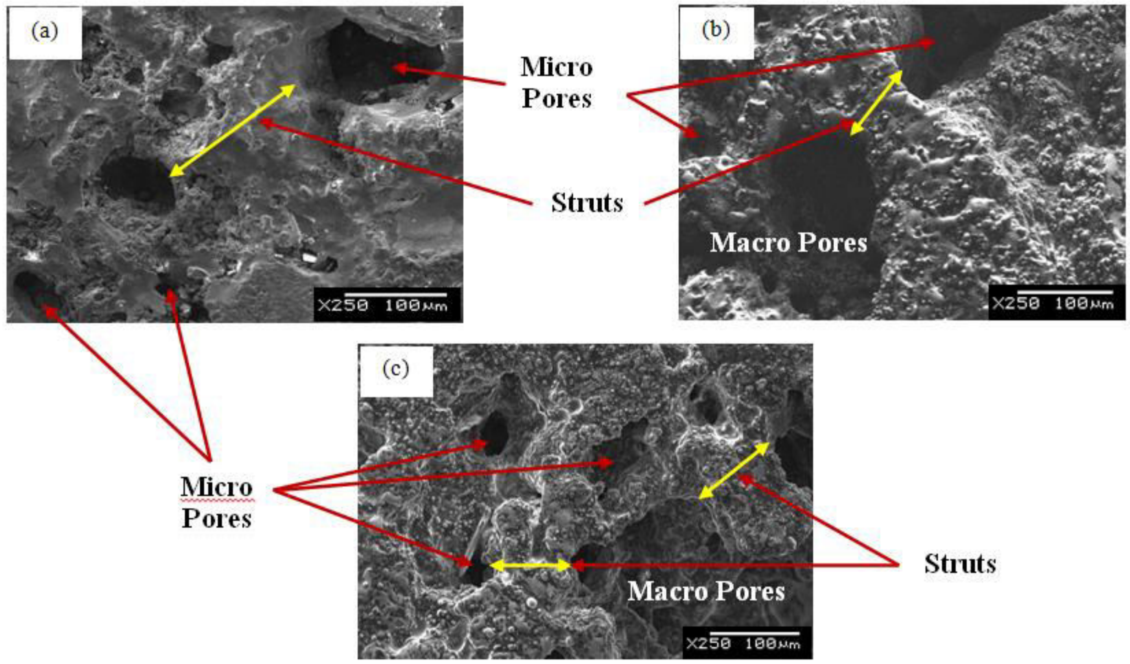

Figure 1: SEM micrographs of SS316 L foam for (a) 40 wt %, (b) 45 wt % and (c) 50 wt % SS316 L foam

Here, it is clear that there are two types of pores which are micropores and macropores and the struts were formed. The sample with 40 wt% of SS316 L as viewed as Figure 1(a) showed that the micropores and struts of the SS316L clearly produced. Then, the sample with 45 wt% SS316 L as shown in Figure 1(b) showed the struts and macropores well-developed. Lastly, a well-structure macropores and struts were formed in the sample 50 wt% of SS316. However, there are also some micropores in the structure as shown in Figure 1(c). The macropores are a result of starch decomposition. They are the result of partial sintering of the SS316 L powders. Here, with compaction method, the sample 50 wt% of SS316 L that sintered in vacuum furnace at 1200 ^{o}C is the best result exhibiting good and thicker struts and macropores can be obtained.

The sample 40 wt% SS316L as shown in Figure 1(a) was detected pores and rough struts. The 45 wt% SS316L, the struts were well-developed as shown in Figure 1(b). Lastly, as refer as Figure 1(c), a well-structure of pores and struts were formed in sample 50 wt% SS316L. Then, the thicker struts were formed in sample 50 wt% SS316L comparing to other compositions. German (1996) believed that the necks grow at the particle contact occurred during sintering process. At this stage, in high of the temperature, the densification process occurs and the gradual formation of the necks have yielded dense and closed the microstructure with decreasing porosity [1].

The results of porosity and bulk density formation obtained as shown in Figure 2.

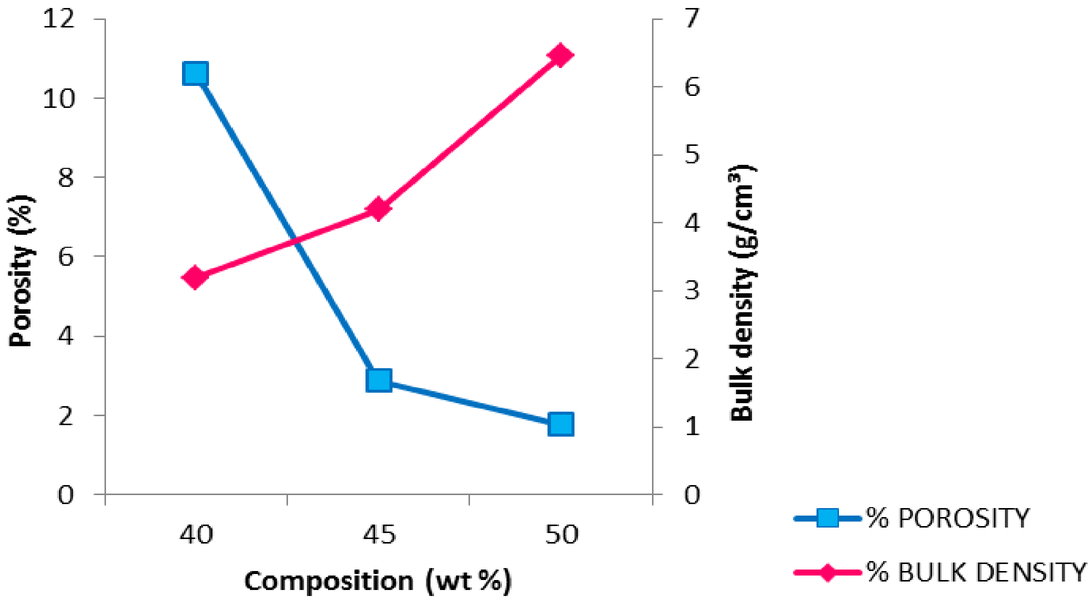

Figure 2: Porosity and bulk density formation at different composition that sintered in vacuum furnace at T = 1200 °C

Figure 2 shows the result of the porosity and bulk density of compacted SS316L that sintered in vacuum furnace at 1200 °C. Based on Figure2, samples with 40 wt% produced the highest porosity and lowest bulk density which are 10.61 % and 3.19 g/cm^3. The lowest porosity and highest bulk density which are 1.77 % and 6.46 g/cm^3 were obtained in 50 wt%. The result viewed that the porosity and bulk density are proportional inversely from 40 wt% to 50 wt% of SS316L. Ahmad (2010) believed that the high temperature causes the gradual formation of the neck has in which yielded dense and closed the microstructure with decreasing porosity. As was proven as the literature review, once the sintering temperature is high, the percentage of porosity was decreased the value of bulk density was increased [1].

CONCLUSION

The sample 50 wt% of SS316L that sintered in vacuum furnace at 1200 °C had been successfully fabricated using starch through compaction method, exhibiting good and thicker struts and macropores can be obtained with the percentage porosity and bulk density of 1.77 % and 6.46 g/cm^3. Further research on different space holder with different sintering temperature and the compressive strength of these samples will be investigated.

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