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Effect of Al_2O_3 Nano Particles on Properties of Al-$CaCO_3$ Foam Produced by Powder Metallurgical Route

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Effect of Al_2O_3 Nano particles on properties of Al-$CaCO_3$ foam produced by powder metallurgical route

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Abstract

Aluminum foam is a group of advanced materials with interesting properties such as: light weight, high energy absorption and recyclability. In this study, Calcium Carbonate as a foaming agent in quantities of 10 and 15 wt. % was added to Al- 5wt. % Al_2O_3 Nano composite powder mixture. In order to produce foams from foamable precursors, foaming temperatures varied from 950 °C to 1050 °C according to the decomposition temperature of $CaCO_3$. The results revealed that maximum compressive strength and yield stress of Al-Alumina Nano composite foam was higher than Al non reinforced foam. Moreover, the influence of Al_2O_3 Nano particles on structure of pores was investigated by analyzing the microscopic images of the foams.

Keywords: Nano particles, Aluminum foam, powder processing, Al_2O_3 powder, compressive strength

1. Introduction

Porous metals are e new class of engineering materials that gaseous cavities are dispersed in their structures , Ashby et al. (2000). Today; these materials are widely used in various fields of industry and research including medical implants, filters and bumpers. Al foams because of their remarkable properties have been considered by many researchers, some of these features are great energy absorption, excellent stiffness-to-weight ratio and Low thermal conductivity , Divandari et al. (2006).

There are many different methods to produce Aluminum foams. Powder metallurgy (PM) route based on thermal decomposition of foaming agent (Hydrides or carbonates) is the most appropriate way for fabrication of Porous Al foams. Flexibility in the choice of metal for foaming process and Possibility of production of composite and alloying foams are some of characteristics of PM method. In the powder metallurgy route, the compaction of a mixture of Al powder with a foaming agent is heated to a temperature above its melting point in a metal die. This temperature is

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selected according to the decomposition temperature of foaming agent. The released gas makes the precursor to expand and creates pores in the sample. Calcium carbonate is a cheap foaming agent and can be a good alternative to expensive hydrides like TiH_2 and ZrH_2.

In order to increase the stability and strength of metal matrixes, ceramic particles (Al_2O_3, SiC, TiC and…) can be added to metal foams , Kennedy and Asavavisithchai (2004). Alumina is used as an appropriate stabilizer for Al matrix because it is chemically neutral to Aluminum, Prabhu, et al. (2006). Kennedy , Kennedy and Asavavisitchai (2004) showed that Al precursors reinforced with TiB_2 particles have more expansion during foaming process and result illustrate that their compressive strength and energy absorption are higher than non-reinforced Al foams. Asavavisithchai, Asavavisithchai and Opa (2010) reported that addition of TiC micro particles leads to increase strength of the cell walls.

In the present study, Al foams with 5 wt.% Nano particles of Al_2O_3 were produced in various foaming process conditions. Calcium carbonate was used as foaming agent in 10 and 15 wt.%. The results of microscopic images and compressive tests revealed the properties of Al foams reinforced with Nano Alumina.

2. Experimental

2.1. Materials and methods

Pure Aluminum powder with average 100 µm particle size was used as the matrix material. Alumina powder and $CaCO_3$ powder with the mean particle size of 35 nm and 45 µm respectively were used as reinforcement and foaming agent. The purity of $CaCO_3$ was higher than 99%. Electron-microscopic images of the initial powders are shown in Fig. 1.

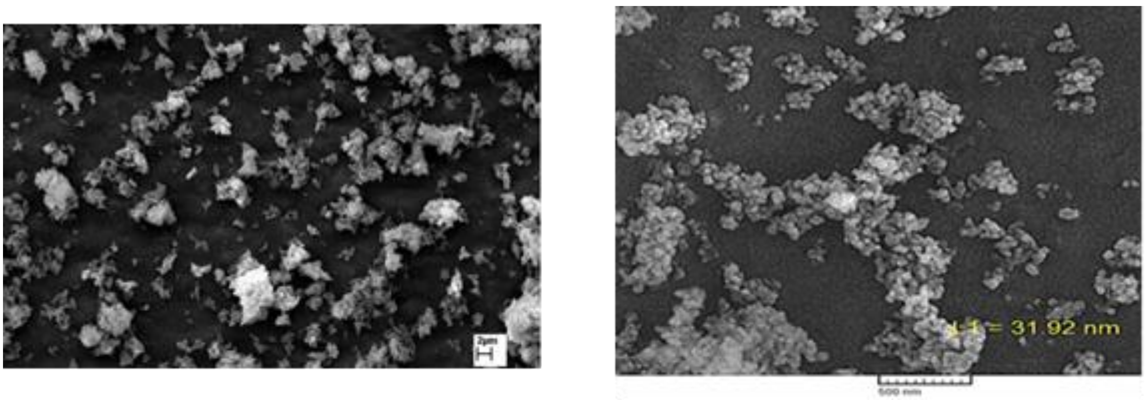

Fig. 1. SEM micrographs of starting powders (a) $CaCO_3$; (b) Nano particles of Al_2O_3.

In the first step of the process, pure Al powder and 5wt. % of Al_2O_3 powder were milled for 3 hours with the speed of 250 rpm in a planetary ball mill under argon atmosphere. Then the Nano composite powder mixture was mixed with 10 and 15 wt.% of $CaCO_3$. The prepared mixed powders were cold pressed at 500 MPa in a SPK steel cylindrical mold with a diameter of 20 mm the produced precursors were sintered at 530 °C for 1 hour. Sintering could increase the strength of samples. Foaming process as the final step was done at 950 °C and 1050 °C under argon atmosphere. Foaming temperatures were chosen higher than the temperature of decomposition of $CaCO_3$, so released gas created pores in the produced samples.

2.2. Evaluation methods

To study the microstructure of the foams, microscopic images of cross sectioned samples were analyzed. Surface percentages of porosities were calculated by MIP, image processing software. Compression test of produced foams was performed by ZWICK (Z250) device at a nominal strain rate of 10^{-3} s-1 according to JIS standard. Stress- strain curves of samples showed the effect of Al_2O_3 Nano particles on mechanical properties of Al foams.

3. Results and discussion

In this research, foaming parameters such as weight percent of $CaCO_3$, foaming temperature and influence of Alumina on structural and mechanical characteristics of foams have been studied.

Microstructure of Al foam reinforced with 5 wt. % indicates porosities with larger cells compared with pureAl foam. This is according to previous studies. Figure. 2 shows this result in Al foams with 10 wt. % $CaCO_3$ and foaming temperature of 950 °C.

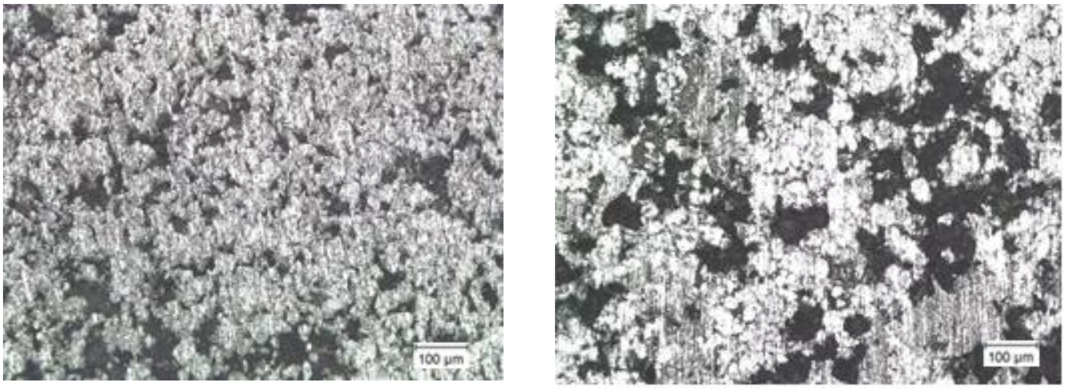

Fig. 2. Microstructure of Al- foams (a) without Al_2O_3; (b) with 5 wt. % Nano particles of Al_2O_3.

In higher amount of foaming agent, more released gas makes more pores. So in the present study, increasing of $CaCO_3$ from 10 to 15 wt. % increases the porosities from 41.40 % to 48.60 %. Microstructures of Aluminum Nano composite foams with different amounts of $CaCO_3$ are represented in Fig 3. Decomposition reaction of $CaCO_3$ is shown in Eq. 1 , Byakova, et al. (2014)

$$CaCO_3(s) = CaO(s) + CO_2(g) \qquad \Delta G^{\circ} = 168.40 - 0.143T \quad (kJ/mol) \qquad (1)$$

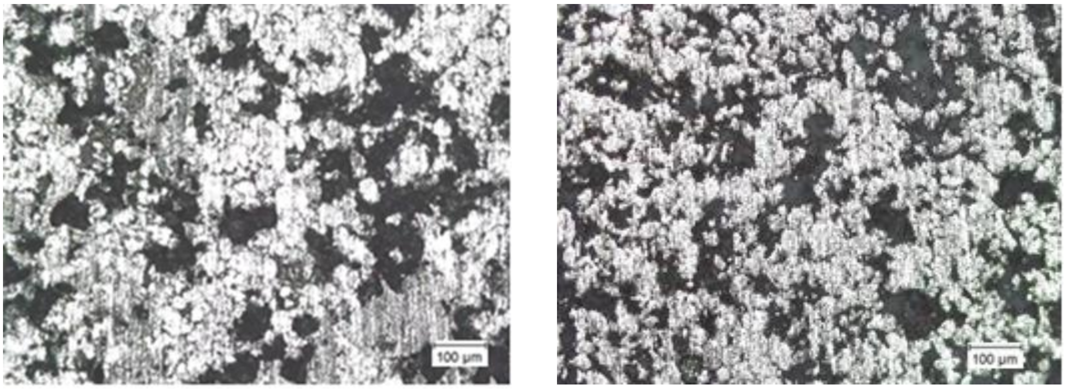

Fig.3. Optical microscopic images of nano composite Al- foams with (a) 10 wt. % $CaCO_3$; (b) 15 wt. % $CaCO_3$.

The results of compression tests in Fig. 4 indicate that in a constant weight percent of foaming agent, Nano particles of Al_2O_3 leading to increase of compressive strength and energy absorption of Al foams. Compressive curves of theses foams demonstrate that a first elastic area and then drop in stress is occurred and in the plateau regime stress stays approximately constant with increasing strain. After that, densification is happened slightly only for Al foam reinforced with Al_2O_3 Nano particles. Presence of brittle particles of Al_2O_3 and $CaCO_3$ causes brittle fracture of cell walls. Al foams that produced at 1050 °C had some surface cracks so; compression tests were done only on samples which manufactured at 950 °C.

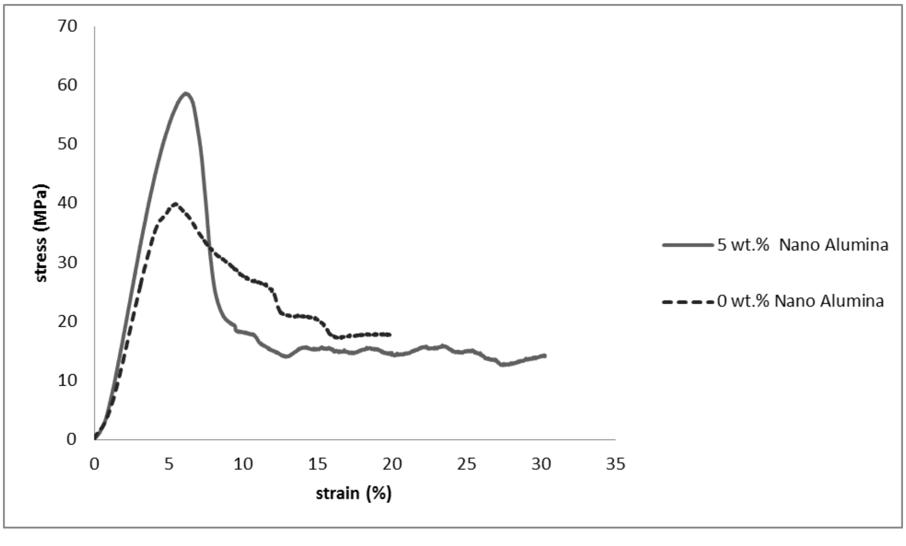

Fig.4. Compressive behavior of pure Al foam and Al- 5 wt.% Alumina Nano composite foam with about 40 % porosity.

4. Conclusion

Al- Al_2O_3 Nano composite foams were produced successfully by powder metallurgy and Influence of alumina particles was studied. Microstructural investigation of produced foams showed that Al foam reinforced with 5 wt.% Nano particles of Al_2O_3 has coarser porosities compared to pure Al foam. Ceramic particles of Al_2O_3 improve mechanical properties of foams and maximum compressive strength and energy absorption capability of Al- 5 wt.% Al_2O_3 foam is significantly higher than Al foam without Al_2O_3. Higher amounts of $CaCO_3$ increased percentage of pores. In this research Al foams have 40 to 50 % porosities with sizes in micron.

References

Asavavisithchai, S., and Opa, A., 2010. Effect of TiC particles on foamability and compressive properties of aluminium foams. Chiang Mai J. Sci 37, 213-221.

Ashby, M.F., Evans, T., Fleck, N.A., Hutchinson, J., Wadley, H., and Gibson, L., 2000. Metal Foams: A Design Guide: A Design Guide Elsevier.

Byakova, A., Kartuzov, I., Gnyloskurenko, S., and Nakamura, T., 2014. The Role of Foaming Agent and Processing Route in Mechanical Performance of Fabricated Aluminum Foams. Advances in Materials Science and Engineering 2014.

Divandari, M., Golpaygani, V., and Shahverdi, H., 2006. Metal foams Science and Technology university of IRAN.

Kennedy, A., and Asavavisitchai, S., 2004. Effects of TiB_2 particle addition on the expansion, structure and mechanical properties of PM Al foams. Scripta Materialia 50, 115-119.

Kennedy, A., and Asavavisithchai, S., 2004. Effect of Ceramic Particle Additions on Foam Expansion and Stability in Compacted Al - TiH_2 Powder Precursors. Advanced Engineering Materials 6, 400-402.

Prabhu, B., Suryanarayana, C., An, L., and Vaidyanathan, R., 2006. Synthesis and characterization of high volume fraction Al–Al_2O_3 nanocomposite powders by high-energy milling. Materials Science and Engineering: A 425, 192-200.