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This certificate is awarded for paper entitled as

An Investigation of Using Sodium Nitrate as a Foaming Agent of Production Close Cell Aluminum Foam via Powder-Compact Foaming Technique

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Which was presented in

Iran International Aluminium Conference 2016
11-12 May, Tehran, Iran

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IIAC
Iran International Aluminium Conference

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Proceedings of Iran International Aluminium Conference (IIAC2016)
May 11-12, 2016, Tehran, I.R. Iran

An investigation of using sodium nitrate as a foaming agent of production close cell aluminum foam via Powder-Compact Foaming Technique

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Abstract: This article describes a method named Powder-Compact Foaming Technique to produce close cell aluminum foams. Porous Al was fabricated by decomposing of sodium nitrate powders at initial compacted precursor. At the first Al and $NaNO_3$ powders were mixed together and then compacted to initial precursor. At the final the precursor put in the sintering furnace. The gas released during sintering and also the mushy aluminum was the source of the produced pores. The effect of initial compacting pressure, heating temperature and weight ratio of powders have been investigated. Visual inspection and scanning electron microscopy (SEM) were utilized to characterize the porous samples. Analyzing the properties of the aluminum foams showed that the optimum weight fraction for blending initial powders was %2 wt. $NaNO_3$. In addition, if the initial compacting pressure of the powders was decreased to below 250MPa, the foaming process did not take place properly. The optimum time and temperature of this process were 15 min at 680◦C.

Keywords: Aluminum Foam, Close Cell, Powder-Compact Foaming Technique, sodium nitrate

Introduction

Metal foams show outstanding properties: Low weight, high rigidity, high energy absorption capacity, high damping capacity, etc. They have attracted strong industrial and scientific interest during the last decade. A variety of methods has been developed to produce foams and the development of new, more sophisticated methods is still going on [1- 3]. Generally, these methods fall into four broad classes consist of using vapour deposition, electrodeposited from an aqueous solution, liquid state, and solid state processing. Some produce open-cell foams; others produce foams in which the majority of the cells are closed. Among which these processes, the methods that use metal powders are the most widely used. These methods have a good control over the porosity distribution and pore morphology. In this case, some investigators have used the melting compacted powder (MCP) to manufacture metal foams [4]. The MCP is based on the mixing of blowing agent powder with base metal powder and then heating in the temperature near melting point of base metal. This method consists of mixing of metal and blowing agent powders like TiH_2 and pressing into a green compact under an appropriate pressure. Compacted powders then are sintered at a temperature a little above the melting point of metal. The blowing agent powders decompose and the precursor started to expand during heating and metal foam produced.

TiH_2 is the most commonly used material as a blowing agent in MCP for producing aluminium foam. In addition of high price of TiH_2, the decomposition temperature of this material is not near the melting point of aluminium [5, 6]. The decomposition temperature of TiH_2 is about 450◦C; whereas the melting point of aluminium is 660◦C. In this condition the gas releasing from TiH_2 cannot completely expand the precursor.

Some researchers used prior heat treatment to raise the decomposition temperature of TiH_2 [5]. Coating of TiH_2 is also used to prevent the early decomposition [5, 6].

In this work, $NaNO_3$ has been used as a blowing agent material for produce close-cell aluminium foam using melting compacted powder (MCP). According to suitable decomposition temperature of $NaNO_3$, it is decomposed near the melting point of aluminium during the heating process and also the phase generated from the reaction of aluminium and oxygen cause to superior strength. The structural characteristics of close-cell aluminium foam have been investigated.

Experimental Procedure

The raw materials used in the melting compacted powder (MCP) for fabrication of close-cell aluminium foam are the Al (size<65μm, purity> 99%) and $NaNO_3$ (size<60μm, purity> 99%) in powder form. MCP consists of the mixing, compacting, heating and expanding stages shown schematically in Fig. 1.

Al and $NaNO_3$ powders were first mixed together with a weight fraction of nitrate 1, 2, 3, 4, and 6%. The blended powder was then compacted to the net-shape performs under 100, 150, 200, 250 and 300 MPa pressure. The compacted specimens then heated at 580, 630, 680 and 730◦C in a heat resistance electric furnace with a non-oxidizing atmosphere for expansion. The codes and foaming condition of all specimens are summarized in table 1.

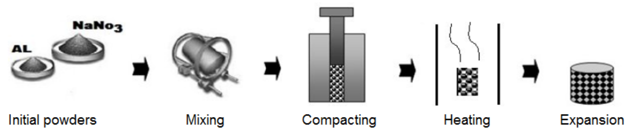

Fig. 1. Schematic of the melting compacted powder (MCP) for fabrication of close-cell Al foams

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Table 1. The codes and foaming condition of all specimens

Code	Compacting pressure (MPa)	Heating Temperature (◦C)	Weight percent of $NaNO_3$ (wt%)
1	100	680	2
2	150	680	2
3	200	680	2
4	250	680	2
5	300	680	2
6	250	580	2
7	250	630	2
8	250	680	2
9	250	730	2
10	250	680	1
11	250	680	2
12	250	680	3
13	250	680	4
14	250	680	6

For determination of thermal behaviour of $NaNO_3$, the TGA and DTA test was done. Fig. 2 shows the result of TGA and DTA. As it can be seen the vapour point of $NaNO_3$ is about 663◦C. This temperature is near the melting point of pour aluminium.

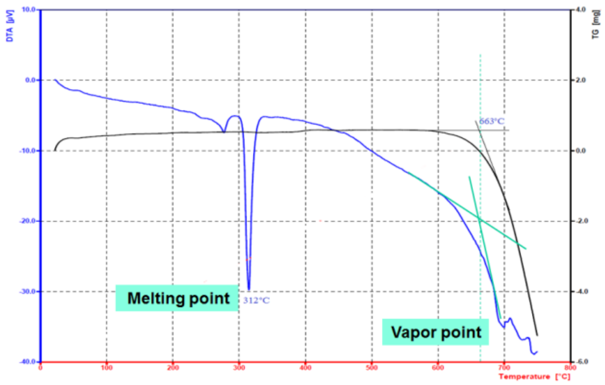

Fig. 2. Thermal behaviour of $NaNO_3$ in TGA and DTA analysis

The samples were then subjected to metallographic examination. The pore morphology and the bounding conditions of cell walls were also studied by Scanning Electron Microscopy (SEM).

Results and Discussions

Compacting pressure

Fig. 3 shows the appearance of metal foams with different in compacting pressure. As it can be seen, foaming could happen in only the specimens with over 250 MPa compacting pressure. In other specimens the oozing was happen. This phenomenon is maybe due to the low strength of these precursors. In low compacting pressure (<250 MPa), the gas releasing from nitrate in heating process could not imprisonment in the molten aluminium. Infect the densification of powders was not sufficient to shear off the oxide layers from the individual particles and to create a metallic bonding and a gas-tight structure. Instead the liquid was squeezed out by the evolving gas and no bubbles were formed.

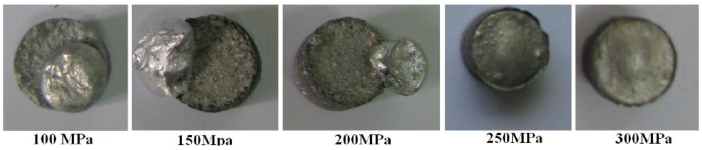

Fig. 3. The appearance of metal foams with different in compacting pressure

Heating temperature

In Fig. 4 the effect of heating temperature was shown. In specimens that heated over 680◦C, oozing has been happened. It is also can be seen that in lower temperature, the expansion could not be completed. In high temperature, the fluidity of molten aluminium is too high. Therefore, the gas generated from nitrate decomposition can move easily, unify and exit with molten metal. In the specimens that heated in low temperature, the pasty metal cannot be fully formed and therefore the gas cannot expand and shape it. In this condition most of the generated gas from nitrate decomposition pass throws the aluminium powders without expanding them.

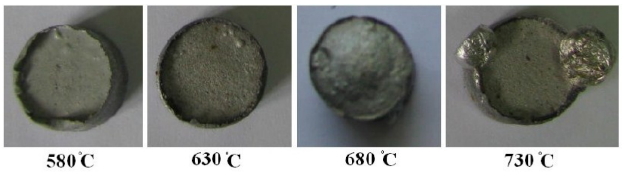

Fig. 4. The appearance of metal foams with different in heating temperature

Weight percent of $NaNO_3$

When the weight percent of foaming agent was too high, the pressure of produced gas in heating process became too high and cause to distortion of specimen. On the other hand in very low percent of blowing agent, the produced pressure is too low and expansion cannot be fully happen. Fig. 5 shows the appearance of specimen that produced in different weight percent of nitrate. As it can be seen in this figure the optimum weight percent of nitrate is 2%wt.

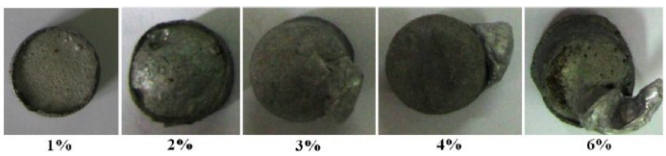

Fig. 5. The appearance of metal foams with different weight percent of nitrate

Pore morphology

The cell structures of the aluminium foams produced by MCP which has a porosity of 60% and cell sizes of 150–300µm are shown in Fig. 6. The foam exhibits relatively uniform distributed close cells and continues network of well-bonded Al matrix.

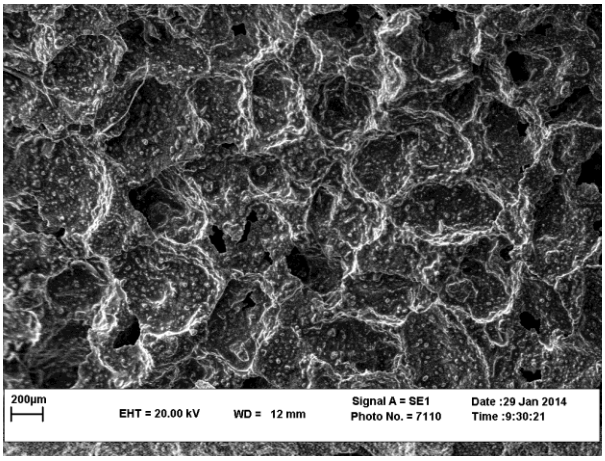

Fig. 6. The cell structures of the aluminium foams produced by MCP

Conclusion

The possibility of fabricating aluminium foams via MCP by using $NaNO_3$ as a blowing agent was assessed. The findings so far in this investigation can be summarized as follows:

1. The possibility of fabricating aluminium foams with $NaNO_3$ via MCP was confirmed.

2. The minimum compacting pressure for foaming aluminium was 250 MPa.

3. The optimum heating temperature was evaluated between 650 - 680 ◦C.

4. The weight percent of nitrate in initial materials must be about 2wt%.

Acknowledgment

The authors wish to thank Materials Research Group of Iranian Academic Center for Education, Culture and Research (ACECR), Mshhad beanch for assist this work.

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