Available online at www.sciencedirect.com
ScienceDirect
Procedia Chemistry 19 (2016) 234 – 240
Procedia Chemistry

5th International Conference on Recent Advances in Materials, Minerals and Environment (RAMM) & 2nd International Postgraduate Conference on Materials, Mineral and Polymer (MAMIP), 4-6 August 2015

Effect of NaCl as a space holder in producing open cell A356 aluminium foam by gravity die casting process

S.F. Aida , M.N. Hijrah, A.H.Amirah, H. Zuhailawati , A.S. Anasyida*

School of Materials and Mineral Resources Engineering, Universiti Sains Malaysia, Engineering Campus, 14300 Nibong Tebal, Pulau Pinang, Malaysia

Abstract

Gravity die casting is the technique which enables fabrication of open-cell A356 aluminium foam as a suitable absorber material with good quality performance. A356 aluminium alloy was used with varies amount of sodium chloride (NaCl) particles as a space holder to fabricate the aluminium foam using gravity die casting. Microstructural analysis, porosity and density were investigated in this study. As the addition of the NaCl space holder increases, porosity increases leading to decreasing density of the foam. Aluminium foam with 30 wt.% NaCl showed moderate porosity among the others foam.

Peer-review under responsibility of School of Materials and Mineral Resources Engineering, Universiti Sains Malaysia

Keywords: open cell foam ; normal casting ; space holder ; microsturucture

* Corresponding author. Tel.: +06-04-599-5216; fax: +06-04-593-1011.
E-mail address: anasyida@usm.my

Peer-review under responsibility of School of Materials and Mineral Resources Engineering, Universiti Sains Malaysia
doi:10.1016/j.proche.2016.03.099

1. Introduction

Modern research in engineering is focused on developing new materials and composites for the purpose of producing structural elements of lower density and equal performances. Lighter elements are used in structures for the purpose of weight reduction and saving of energy. In order to achieve this goal, metal foams have been developed.

The casting technique is well suited for the production of uniform and fine open-cell foams of lower melting-point metals such as aluminium[1]. Given its low cost[2], its chemical inertness in contact with aluminium, its relatively high melting point and its ease of dissolution in water, sodium chloride (NaCl) is often used as the preform or space holding filler material for aluminium foams.

When metallic foams are used at an elevated temperature in the interconnect applications, the relatively high thermal expansions of the metals would be problematic, causing thermal stress which may lead to failures of the components. For that, casting process is one of the possible approaches to improve physical and thermal properties of Al foams[3].

2. Experimental procedures

A356 aluminium alloy was prepared using Al-Si ingot containing 11.5 wt.% Si. Then pure aluminium and pure magnesium were added with Al-Si ingot to form composition of A356 aluminium alloy. The materials were melted in graphite crucible placed into the bottom loading furnace at 850ºC with temperature increment rate of 25ºC/minutes for about two hours to homogenize the molten mixture and then soaking at 680ºC for 30 minutes. After mixing, a uniform distribution of particles in the molten aluminium was acquired. The molten aluminium alloy was cast into cylindrical mild steel mold of 200 mm in length and 50 mm in diameter producing A356 aluminium alloy. Then, the chemical compositions, microstructure and phase identification of A356 aluminium alloy were determined by XRF, optical microscope and XRD, respectively. A356 aluminium alloy foam then was prepared according to the composition listed in Table 1.

Table 1 : Composition ratio of salt to melt mixture

Ratio (NaCl : A356 Alloy)	0.2 : 1	0.6 : 1	1 : 1
Normal casting (in grams)	10 : 50	30 : 50	50 : 50

In order to prepare A356 aluminium alloy foam, the prepared A356 aluminium alloy is placed in graphite crucible and melted at 850ºC in the melting furnace for about two hours. Then, the molten A356 aluminium alloy was cooled down to 680ºC. At the same time, NaCl salt particles were weighted according to its ratio and preheated at 680ºC for 15 minutes in a heating furnace before added in the molten A356 aluminium alloy. Then, the NaCl was added according to the ratio as shown in Table 1. The salt/melt (NaCl/A356 alloy) mixture was manually stirred for one minute to distribute the NaCl particles uniformly in the molten A356 aluminium alloy. During casting process, argon gas was purged at 1.0 l/min for one hour to ensure a homogenous distribution of NaCl in the composite. The molten of A356 aluminium alloy containing NaCl was left to cool down in the crucible at room temperature for 30 minutes. Then, the sample with round-shaped NaCl/A356 composite was removed out from the crucible. All the samples of NaCl/A356 composite were leached in water at 90ºC for about 1 hour per sample to remove NaCl particles, producing open-cell aluminium foams.

Morphology and microstructure of NaCl particles and open cell A356 aluminium foams were studied through optical stereo zoom microscope Kunoh Robo and scanning electron miscroscopy (SEM). Density measurement of A356 aluminium foam with different amount of NaCl was performed using densitometer.

3. Results and discussion

Fig. 1 shows the morphology of NaCl particles with angular cubic shape. The NaCl particles varied in sizes and shapes. The stereo micrographs of open cell A356 alloy foam with different amount of NaCl is shown in Fig. 2. It can be observed that all the samples have a homogenous distribution of pores which are equivalent to particle sizes of NaCl space holder. A similar finding has been reported by[4], who have claimed that the pores distribution for aluminium foams was controlled by the space holders.

From Fig. 2, by arranging the open cell of A356 Al foams from smaller to larger size and quantities of pores, it was found that the arrangement follows this sequence: A356-10NaCl, A356-30NaCl and A356-50NaCl foams. From the findings, by increasing the weight percentage of NaCl particles, aluminium foam with larger size and higher quantities of pores can be obtained. For the foams fabricated using high percentage of NaCl space holder, such as in the case shown by A356-50NaCl foam, too much of NaCl particles caused the particles to be connected to each other[5]. This observation indicated that the presence of higher weight percentage of NaCl space holder generated interconnected pores. The numerous channels between cells make aluminium foams suitable for absorption application[6].

Pore size and distribution is one of the important observations in analyzing the morphology of foam. Fig. 3 shows SEM micrographs of pore distribution in A356 Al foam. The SEM micrographs of A356 Al foam showed that well distributed pores can be achieved. It is clear that the amount of primary solid particles (α-Al) surrounding the salt particles decreased as the amount of NaCl particles increased. This caused the salt particles to form continuous (interconnected) pore network rather than isolated pore. As discussed earlier in stereo microscope observation, the size and quantities of the pores in aluminium foams increased as the addition of NaCl space holder increases. The isolated pores are obvious in A356-10NaCl foam compared to other foams. Whereas, interconnected pores can be observed as the quantities of NaCl particles increased especially in A356-50NaCl foam. The average pore size of A356 Al foams were measured by SEM and tabulated in Table 2. The pore size produced was in the range of 204 µm to 224 µm. A356-50NaCl has the highest percentage of NaCl particles showed the largest pore size. High amount of NaCl particles caused the pores to form interconnection network to each other with a close distance[7].

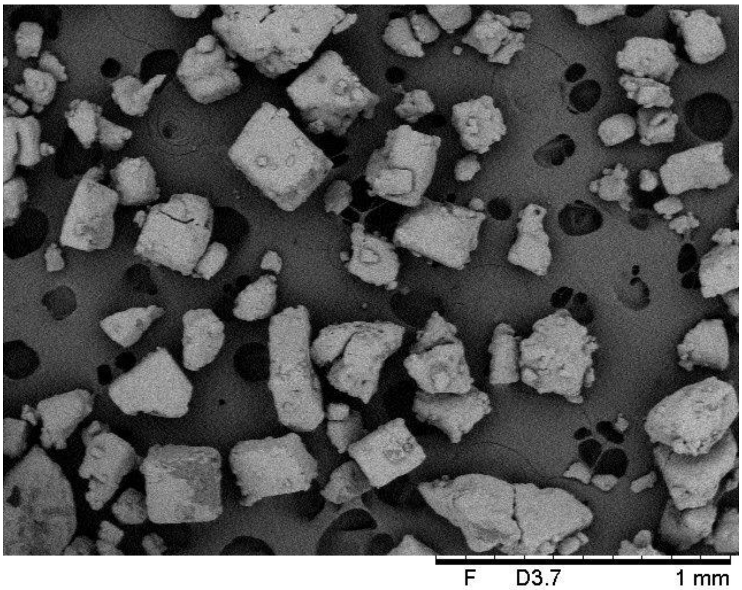

Fig. 1. SEM micrograph of angular cubic NaCl particles

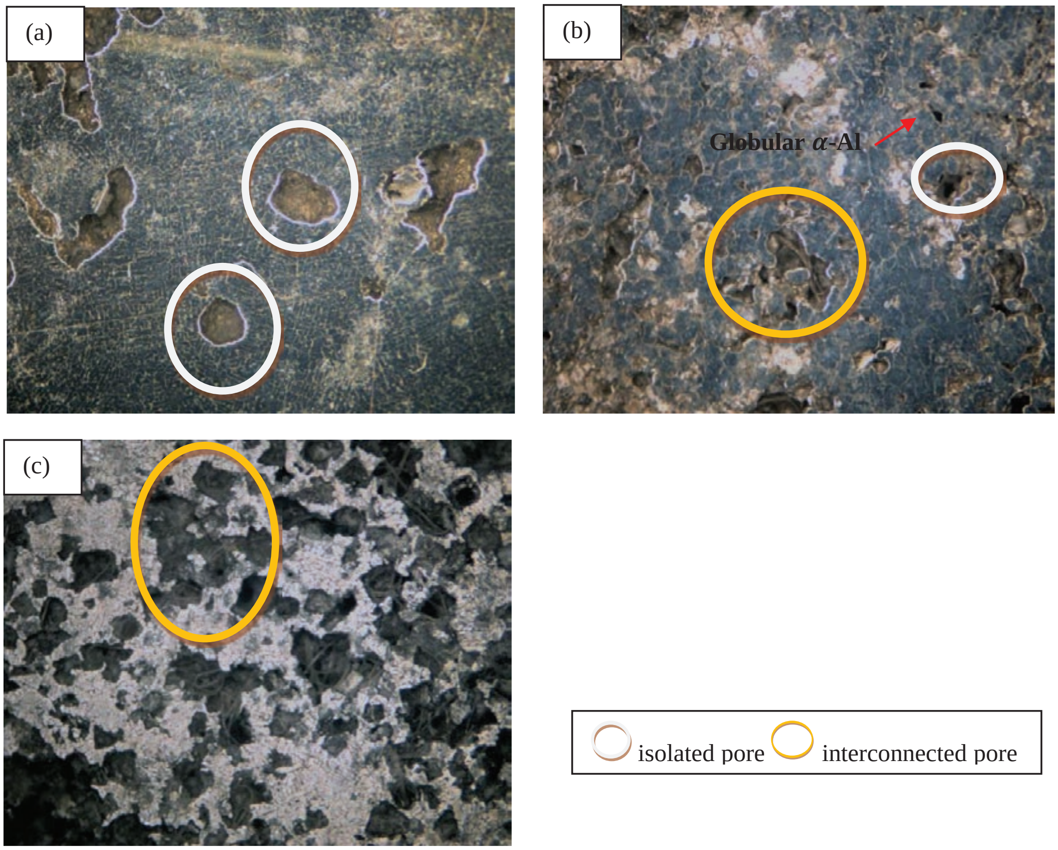

Fig. 2. Stereo micrographs of open cell A356 aluminum foams at magnification scale of 20×with different composition of NaCl g (a) A356-10NaCl, (b) A356-30NaCl, (c) A356-50NaCl

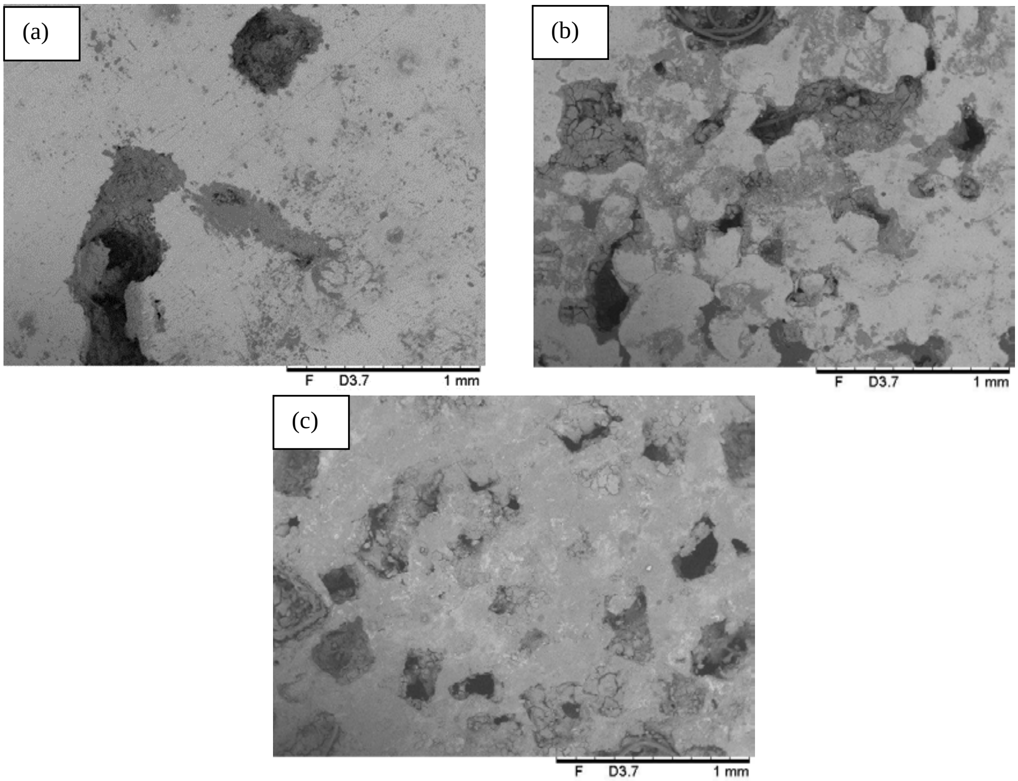

Fig. 3. SEM micrographs of A356 aluminum open cell foam with different composition of NaCl; (a) A356-10NaCl, (b) A356-30NaCl, (c) A356-50NaCl

Table 2. Pore size distribution in A356 aluminum open cell foams

Sample	A356-10NaCl	A356-30NaCl	A356-50NaCl
Average pore size (μm)	203.90	209.40	223.60

Fig. 4 and Fig. 5 show the density and porosity of open cell A356 aluminium foams with different amount of NaCl (0, 10, 30 and 50 wt.%). A356 solid alloy has the highest density of 2.69 g/cm^3. The A356 alloy have the density of 2.5 – 2.7 g/cm^3, respectively[8]. The density of A356 Al foam decreased with the increasing amount of NaCl. The decreased in density can attributed to the larger pore sizes as shown in Table 2, i.e higher addition of NaCl gave larger pores, and thus lower density. The foam with the highest percentage of 50 wt.% NaCl, A356-50NaCl foam exhibited the lowest density compared to other foams (2.49 g/cm^3) . Fig. 5 shows the porosity of A356 Al foam with various amount of NaCl. Solid A356 Al alloy has 0.22 % porosity. Aluminium foams has the porosity in the range of 1.26 - 7.84 % and it increases with the increase in amount of NaCl. This might be due to the larger pore size formation and distribution during casting process. The highest porosity was achieved by A356-50NaCl foam which recorded a value of 7.84 %. The reduction of density in A356 Al foam was caused by the high volume of pores present in the foam. This result indicated that by increasing amount of NaCl particles in aluminium alloy body, the number of pores increases, thus lower the density of the foam.

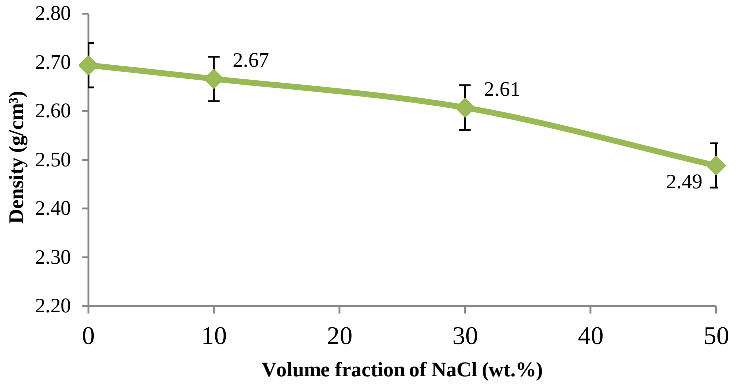

Fig. 4. Density of cast A356 aluminium foam

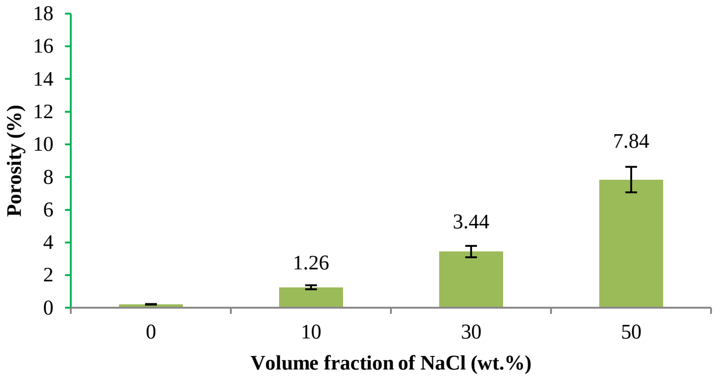

Fig. 5. Porosity of cast A356 aluminium foams

4. Conclusion

Open cell A356 aluminium foam was successfully produced by gravity die casting with pore sizes in the range of 204 µm to 224 µm. Pores distribution in A356 aluminum foams was controlled by amount of NaCl space holder. Greater amount of NaCl particles generates interconnected pores. The density of A356 Al foam decreases and porosity increase with the increasing amount of NaCl.

Acknowledgement

The authors would like to acknowledge the grant provided by the Ministry of Education through the FRGS 201/PBahan/6071303.

References

1. L. P. Lefebvre, J. Banhart, and D. C. Dunand, "Porous metals and metallic foams: Current status and recent developments," *Advanced Engineering Materials*, vol. 10, no. 9, pp. 775–787, 2008.

2. R. Jamshidi-Alashti, M. Mohammadi Zahrani, and B. Niroumand, "Use of artificial neural networks to predict the properties of replicated open-cell aluminum alloy foam via processing parameters of melt squeezing procedure," *Materials and Design*, vol. 51, pp. 1035–1044, 2013.
3. E. Wichianrat, Y. Boonyongmaneerat, and S. Asavavisithchai, "Microstructural examination and mechanical properties of replicated aluminium composite foams," *Transactions of Nonferrous Metals Society of China (English Edition)*, vol. 22, no. 7, pp. 1674–1679, 2012.
4. B. Jiang, N. Q. Zhao, C. S. Shi, and J. J. Li, "Processing of open cell aluminum foams with tailored porous morphology," *Scripta Materialia*, vol. 53, no. 6, pp. 781–783, 2005.
5. Z. Hussain and N. S. A. Suffin, "Microstructure and Mechanical Behaviour of Aluminium Foam Produced by Sintering Dissolution Process Using NaCl Space Holder," *Journal of Engineering Science*, vol. 7, pp. 37–49, 2011.
6. R. Surace, L. A. C. De Filippis, A. D. Ludovico, and G. Boghetich, "Influence of processing parameters on aluminium foam produced by space holder technique," *Materials and Design*, vol. 30, no. 6, pp. 1878–1885, 2009.
7. R. Surace and L. De Filippis, "Investigation and Comparison of Aluminium Foams Manufactured by Different Techniques," *Advanced Knowledge Application in Practice*, pp. 95–118, 2010.
8. H. Sevik and S. C. Kurnaz, "Properties of alumina particulate reinforced aluminium alloy produced by pressure die casting," *Materials & Design*, vol. 27, no. 8, pp. 676–683, 2006.