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Microstructural evolution in investment casted open-pore aluminum-based alloy foams

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Abstract

In the present study open-pore metal foams of the high purity alloys AlSi7 and AlZn11Mg1 as well as the technical purity alloys AA5019 and AA7050 are manufactured by investment casting. Subsequently, their microstructural evolution is characterized at different distances to the deadhead to illustrate the influence of the depth-dependent cooling conditions.

Keywords: Aluminium; Open-pore foam; Investment casting; Microstructure; Metallography; Hardness.

1. Introduction

Open-pore metal foams possess attractive properties due to their highly porous structure in combination with its base material. Hence, this group of material is of great interest for different fields of application. Although much has been reported about metal foams, the focus was primarily on their manufacturing methods, effective properties (mechanical, thermal, etc.) and characterization of the foam-like structure, but their microstructure has been covered rarely. However the microstructure does have a grave effect on the effective properties for which reason the microstructural evolution in investment casted open-pore Al foams are investigated as follows.

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2. Aim of investigations

Investment casted open-pore metal foams mostly show a microstructure different to other conventional casting methods. On the one hand this is due to the small dimensions of the single strut cross section and on the other hand it is due to the slow cooling velocity of the plaster mold. Especially materials with a low melting point such as aluminum can undergo a partial heat treatment. Hence, the microstructure does in most cases not exhibit a common cast structure. This phenomenon is however depending on the alloy. For this reason, in the present study, different open-pore Al foams are manufactured and subsequently characterized. The characterization of the microstructure is carried out by microscopical methods and by hardness tests. All these methods are applied at three different distances to the deadhead to illustrate the influence of the depth-dependent cooling conditions by comparing it with literature data of near-equilibrium solidification and principal precipitation processes for each alloy. Based on these experiments, the post-casting properties of different alloys can be evaluated and a first prediction of how different open-pore Al foams have to be heat treated to achieve the postulated properties can be deduced.

3. Experimental

3.1. Materials

The starting materials for this work are aluminum alloys in high purity and technical purity. The high purity alloys are AlSi7 (obtained from Aalen University, GER) and AlZn11Mg1 (obtained from Ruhr-University Bochum, GER) and the technical purity alloys are commercial AlMg5 (5019) and AlZn6MgCuZr (7050). Their compositions analyzed by X-ray fluorescence spectrometry is shown in Table 1.

3.2. Processing

Open-pore Al foam samples are in-house fabricated by investment casting as described similarly by Wang et al. (2001) and Yamada et al. (1999). A commercial reticulated open-pore polymer foam (obtained from Reisgies Schaumstoffe GmbH, GER) with a pore density of ρ_P = 10 ppi is used as preform. By a thermal-additive process (Matz et al. (2014)), this preform is treated to achieve a relative density of $\rho_{rel} \approx$ 12,5% ± 0,2%. The preform in its dimensions of $50 \cdot 45 \cdot 20$ mm^3 is infiltrated by plaster. In a next step the plaster mold is heated in an incineration furnace at ϑ = 360 °C for dewaxing and at ϑ = 720 °C to pyrolyze the polymer preform and to strengthen the mold.

The metallurgical processing is carried out by centrifugal casting (cf. Müller et al. (2013)). The starting material is placed in a pre-heated crucible and vacuum melted. At ϑ = 880 °C, the casting is induced and the mold, which is preheated at $\vartheta \approx$ 400 °C, is infiltrated by the melt. After t = 10 min the mold is removed from the casting machine whereupon the cooling takes place at atmospheric conditions. In a last step the samples are cleaned by water jet and Tetranatriumethylendiamintetraacetate ($C_{10}H_{12}N_2Na_4O_8$).

3.3. Microstructural characterization

Microstructural characterization is investigated at three different sections of the open-pore Al foam samples as shown in Figure 1. Thereby, the impact of the casting process and the alloy composition on the microstructure of the metal foam as function of the cooling process can be determined.

Table 1. Chemical composition of aluminum alloys (mass fraction).

Alloy	Si	Fe	Cu	Mn	Mg	Zn	Cr	Ti	Zr	Al
AlSi7	7.54%	0.09%	0.05%	–	–	0.03%	–	0.01%	–	Bal.
AlZn11Mg1	0.05%	0.02%	0.02%	–	0.99%	11.28%	–	–	–	Bal.
AlMg5	0.28%	0.39%	0.21%	0.17%	5.32%	0.13%	0.12%	0.12%	–	Bal.
AlZn6MgCuZr	0.17%	0.14%	2.42%	0.08%	2.13%	6.25%	0.05%	0.05%	0.13%	Bal.