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Manufacturing of Cast Metal Foams with Irregular Cell Structure

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Abstract

Metallic foams are materials of which the research is still on-going, with the broad applicability in many different areas (e.g. automotive industry, building industry, medicine, etc.). These metallic materials have specific properties, such as large rigidity at low density, high thermal conductivity, capability to absorb energy, etc. The work is focused on the preparation of these materials using conventional casting technology (infiltration method), which ensures rapid and economically feasible method for production of shaped components. In the experimental part we studied conditions of casting of metallic foams with open pores and irregular cell structure made of ferrous and non-ferrous alloys by use of various types of filler material (precursors).

Keywords: Metallic foam, Precursor, Casting, Irregular cell structure

1. Introduction

Cellular materials are widespread in everyday life and are used for cushioning, insulating, damping, constructing, filtering purposes and many other applications. Highly porous materials are known to have a high stiffness combined with a very low specific weight. For this reason cellular materials frequently occur in nature as constructional materials (e.g. woods and bones). The fact that even metals and metallic alloys can be produced as cellular solids or metal foams is not as well-known as the possibility to foam more traditional engineering materials such as polymers, ceramics or glass. Metallic foams offer interesting perspectives due to the combination of properties which are related to the metallic character on the one and to the porous structure on the other hand [1].

2. Methods of metallic foam production

Since the discovery of porous metallic materials numerous methods of production have been developed. Some technologies are similar to those for polymer foaming, others are developed with regard to the characteristic properties of metallic materials, such as their ability to sintering or the fact that they can be deposited electrolytically [2].

According to the state, in which the metal is processed, the manufacturing processes can be divided into four groups. Porous metallic materials can be made from [3, 4]:

- liquid metal (eg. direct foaming with gas, blowing agents, powder compact melting, casting [5], spray forming)
- powdered metal (eg. sintering of powders, fibres or hollow spheres, extrusion of polymer/metal mixtures, reaction sintering)
- metal vapours (vapour deposition)
- metal ions (electrochemical deposition)

Porosity may achieve 30% to 93% depending on the method of production and material used. By changing the process parameters it is possible to obtain porous structure with various sizes and shapes of pores and with different types of arrangement (regular or irregular - stochastic) [3].

3. Properties and utilization of metallic foams

Foams and other highly porous materials with cell structure are known for a combination of many interesting physical and mechanical properties (Fig. 1).

Fig. 1. Applications of metallic foams [6]

4. Experimental

The attention in this work is paid to preparation processes of metal foams from a liquid phase by a common foundry process. The use of financially less costly methods for manufacture of castings from ferrous and non-ferrous metals too will allow to get an affordable material. At the same time the foundry process enables the production of highly complex parts including hollow castings. Experimental work is based on the manufacture of metal foams with using precursors. In this case for their preparation such materials were used which are commonly used nowadays in foundries for manufacture of moulds and cores.

4.1. Infiltration of molten metal into mould filled with precursors

Infiltration of metal into the mold is made by pouring of liquid metal into the mold filled with inorganic or organic particles. The irregular structure of pores, we are dealing with, can be achieved by use of various types of precursors, which fill the mould cavity.

Precursors must meet certain criteria. Particularly, they must be made of material, which preserves its shape at impact of the molten metal (sufficient strength, low abrasion, refractoriness) and they must allow also good disintegration after casting.

The possibility to control of the cellular structure produced (pore size, porosity, etc.), is the very important advantage of the use of a foundry technique to manufacture metallic foams, however the precursors are made.

In the experiment we made castings with irregular cell structure with use of precursors based on conventional molding mixtures (organic types).

4.2. Precursors - Croning process

Core particles were then manufactured from molding mixture (respectively from reject cores made by Croning process). Final globular shape of core precursors was achieved by spliting in to small pieces (10 – 30 mm) and followed by tumbling. A mould cavity was filled with these precursors. Mold was made from commonly used green sand (i.e. bentonite bonded molding mixture) - see Fig. 2 - 4.

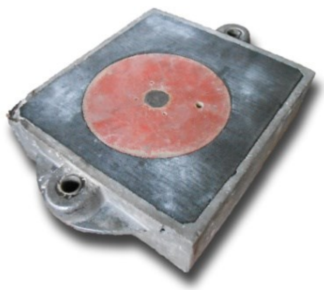

Fig. 2. Mold made from commonly used green sand

Fig. 3. Mold filled with precursors

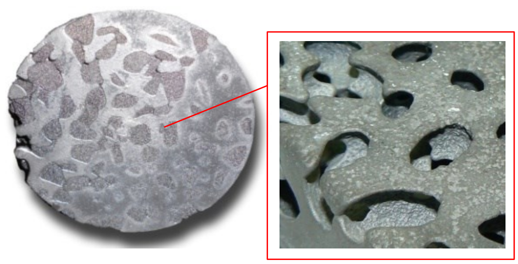

Fig. 4. Final casting and detail of its structure

Porosity of produced castings amounted to 60%. Precursors allow good disintegration after casting.

The disadvantage of these precursors is their irregular shape, which is determined by uneven tumbling of the cullet due to nonuniform hardening of the default core mixture. Therefore, new technology of precursors manufacturing has been proposed – use of molding mixture bonded by furan resin. This way of manufacturing of precursors should ensure the achievement of the same size, shape and the resulting characteristics of precursors.

4.3. Precursors – Furan molding mixture

To create these precursors were used as core box plastic grille (Fig. 5). By using this core box cubes of a side of 25 mm were created. These cubes were followed by tumbling. The proposed technology ensures the production of precursors of the same size, shape and properties.

Materials used fore casting were cast iron with lamellar graphite (EN GJL-200), AlSi10MgMn [7] and CuSn10 (see Fig. 6 – 9) .There were two types of castings – a cuboid (I) and a cylinder (II).

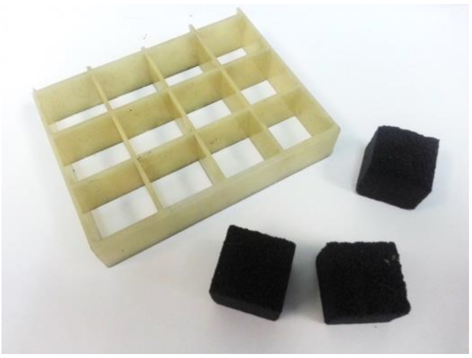

Fig. 5. Core box and created cubes

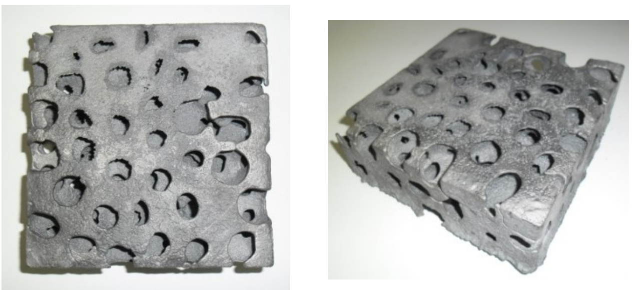

Fig. 6. Casting (cast iron with lamellar graphite) – type I

Fig. 7. Casting (cast iron with lamellar graphite) – type II

Fig. 8. Casting (CuSn10) – type I

Fig. 9. Casting (AlSi10MgMn) – type II

Porosity of produced castings amounted to 63%. Precursors allow good disintegration after casting.

On the Fig. 10 and 11 we can see a comparison of the two types of precursors.

Fig. 10. Precursors – Croning process (irregular shape and size)

Fig. 11. Precursors – Furan molding mixture (regular shape and size)

5. Conclusions

Metal foams are progressive materials with continuously expanding use. Mastering of production of metallic foams with defined structure and properties using gravity casting into sand or metallic foundry moulds will contribute to an expansion of the assortment produced in foundries by completely new type of material, which has unique service properties thanks to its structure, and which fulfils the current demanding ecological requirements. Manufacture of foams with the aid of gravity casting in conventional foundry moulds is a cost advantage process which can be industrially used in foundries without high investment demands.

The principle of the above-mentioned technology is the infiltration of liquid metal into the mold cavity filled with precursors. This technology enables the production of shaped castings – metallic foams with irregular cell structure. In the production of precursors can moreover be assumed using of the material, which would be in other cases waste - reject cores or excess molding mixture.

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