OPTIMISATION OF METHOD FOR PRODUCTION OF CAST METALLIC FOAMS WITH IRREGULAR CELL STRUCTURE

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Abstract

Since the discovery of porous metallic materials numerous methods of production have been developed. Porous metallic materials can be made from liquid metal, from powdered metal, metal vapours, or from metal ions. The aim of the paper is to introduce casting methods of manufacturing of metallic foams from aluminum alloys. The works deals with an optimisation of procedure for production of cast metallic foams with use of disposable evaporate pattern for investment casting. The experimental part stresses the solution of metal fluidity into complicated cavity of the pattern, which is an exact negative of the initial model of polymeric foam. Author gives detail description and subsequent verification of individual factors influencing the obtained structure and properties of final castings.

Keywords: Porous metal, aluminum alloys, microstructure, casting.

1. INTRODUCTION

It is known that foams and other highly porous materials with cellular structure combine a number of interesting physical and mechanical properties, such as high stiffness at low density, high thermal conductivity, capability of energy absorption and others [1]. Use of the foam material is optimal when at least two or more of its advantages are used simultaneously [2].

The most important parameters of these porous materials are the following ones: porosity, pore diameter and their size, distribution, shape, orientation, degree of interconnection of pores. The resulting properties of the metallic foam depend on these parameters, namely the material thermal conductivity, its ability to dampen vibrations or to absorb energy.

Cellular metallic materials are finding an increasing range of applications. A decision, whether a suitable porous metal or metal foam can be found to solve a given problem, depends on many conditions, summarised here by the following keywords [1]:

- **morphology:** type of needed porosity (open versus closed), amount of needed porosity, size scale of desired porosity, total required internal surface area of cellular material;
- **metallurgy:** metal or alloy or required microstructural state;
- **processing:** possibilities for shaping the foam or cellular solid or for manufacturing composites between the foam and conventional sheets or profiles;
- **economics:** cost issues, suitability for large volume production.

The first point, in particular, is crucial for any evaluation of cellular metallic material applications. Many applications require that a medium, either liquid or gaseous, is able to pass through the cellular material. There may be a need for various degrees of ‘‘openness’’, ranging from ‘‘very open’’ for high rate fluid flow to ‘‘completely closed’’ for load-bearing structural applications, and appropriate materials satisfying these conditions have to be found. Normally, a difference is made, depending on the fact whether the application is ‘‘functional’’ or ‘‘structural’’, the difference between these two notions is, however, rather gradual. The question, which metals or alloys are suitable for manufacture of the given type of cellular structure, is also important.

Structural, load bearing parts have to be light because otherwise they would be made from conventional massive metals or alloys [3, 4].

2. CASTING METHOD OF METAL FOAM PRODUCTION

Investment casting with use of pattern made of polymer foam is used for production of metallic foam with open pores, which copies the shape of the polymer foam (see **Fig. 1**). A polyurethane foam cavity is first filled with sufficient refractory material, such as plaster (or a mixture of mullite, phenolic resins and calcium carbonate). The assembly is then heated to 800 ºC, to fire the plaster and remove the polyurethane foam. Molten metal (aluminum alloy) is then poured into the mould - again, combinations of vacuum and high pressure casting can be used to ensure full infiltration. The plaster is then dissolved, to give a net-shape metal foam with an identical structure to the original polymer foam [5].

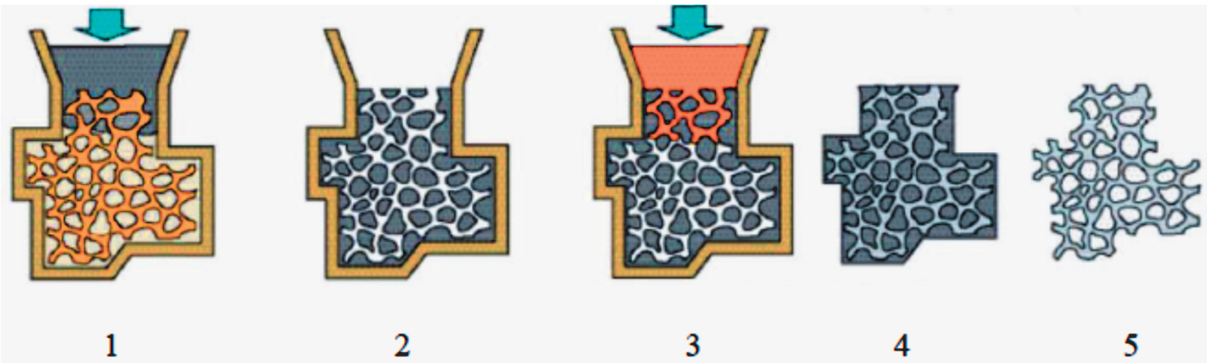

Fig. 1 1 - polymer foam infiltrated with plaster, 2 - removed polymer, 3 - infiltrated with metal, 4 - metal foam in mould, 5 - removed mould, final metal foam. Source: [6]

3. POLYMER FOAM

Polymeric foams are used in numerous application areas. They are used as filters, isolators or noise suppressors. They may contain two dominant forms of pores, namely open or closed pores.

Particularly the choice of suitable foam has a cardinal influence on the final shape and properties of metallic foam. It depends both on the actual material, from which the foam is made, and on its porosity or on thickness of the fibres.

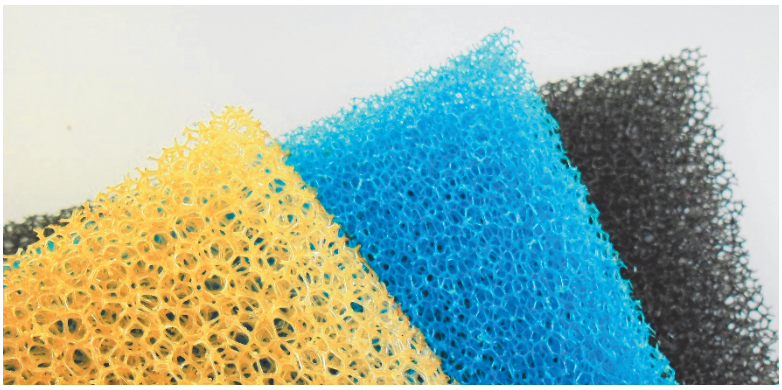

Fig. 2 Examples of various types of used polymeric foams

For manufacture of patterns for investment casting, which are then used to create the metallic foam, polymeric foams are used with a fully open structure, i.e. that they do not contain any closed cells. Such types of foams are produced by thermal reticulation process, in which all of the cell membranes, which remained after the foaming, are broken and they coalesce with cell ribs (see **Fig. 2**).

The actual ratio of foam ribs makes only 3 - 5 % of the volume of foam, depending on the type of foam.

It is, however, impossible to guarantee at the reticulation process the fibre thickness of the polymeric foam. Small thickness of the fibres in the polymeric pattern may then cause for example a non-penetration of metal into narrow cavities of the plaster pattern, which is an exact negative of the original model. It is therefore necessary to ensure a bigger thickness of the fibres in the polymeric foam, and thus in the resulting metallic foam.

3.1 Surface treatment of polymeric foam

Particularly the issue of penetration of metal into the pattern cavities is crucial in the technology using the polymeric pattern. Several possibilities exist for increasing the penetration of metal, e.g. heating of the pattern to a higher temperature (800 °C), modification of the gating system, die casting. If these methods fail, it is then necessary to influence the penetration by modifying the pattern as such - by changing the thickness of the polymeric foam fibres.

Two procedures for increasing the thickness of the foam pattern fibres were verified - soaking of the pattern into wax and spraying the pattern with one or two layers of acrylic paint (see **Fig. 3**).

Spraying with one layer of paint appeared to be the most effective procedure. The series of thus manufactured of castings manifested a minimum scrap factor, good penetration in castings. The amount of sprayed coating was determined by weighing the sample before and after application of the paint (see **Table 1**). The average weight of the sprayed coating was 0.65 g.

Table 1 Evaluation of the mass of the sprayed coating

coating	sample 1 [g]	sample 2 [g]	sample 3 [g]	sample 4 [g]	sample 5 [g]
before application	1.9859	1.9862	1.9539	1.9913	2.0173
after application	2.6007	2.6104	2.5844	2.6145	2.7799
mass	0.6148	0.6242	0.6305	0.6232	0.7626
Ø	0.65106				

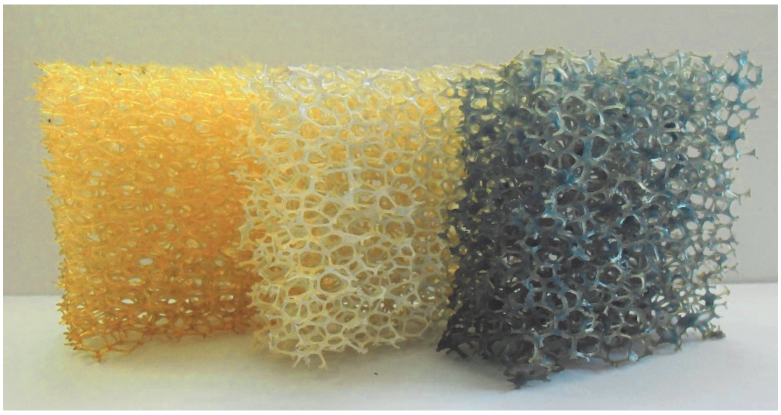

Fig. 3 Surface treatment of patterns; from the left: original foam, layer of paint, layer of wax

CONCLUSIONS

At application of the technology using polymeric foam as a disposable evaporate pattern the molten metal is poured into the cavity of the plaster pattern, which is an exact negative of the original foam model. This cavity is thus very complicated. We therefore encounter a non-penetration of metal into the entire cavity of the pattern.

Several possibilities for increasing metal penetration were verified, such as heating of the pattern to a higher temperature (800 °C), modification of the gating system, die casting. Another option for influencing the metal penetration consists in modification of the foam pattern as such - by changing the thickness of the polymeric foam fibres.

Two procedures were proposed for increasing the thickness of the foam pattern fibres - soaking of the pattern into wax and spraying of the pattern with one or two layers of acrylic paint.

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Individual forms of the pattern and of the resulting casting can be seen in **Fig. 4.**

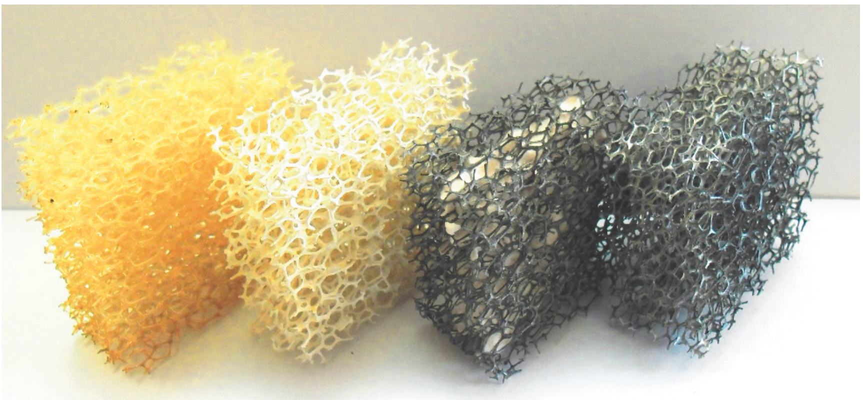

Fig. 4 Overview of individual steps of manufactured of metallic foam; from the left: polymeric foam, polymeric foam with applied coating for an increase of fibre thickness, cast filter extracted from the plaster pattern, cleaned metallic filter

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