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Casting Routes for Porous Metals Production

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Abstract

The last decade has seen growing interest in professional public about applications of porous metallic materials. Porous metals represent a new type of materials with low densities, large specific surface, and novel physical and mechanical properties, characterized by low density and large specific surface. They are very suitable for specific applications due to good combination of physical and mechanical properties such as high specific strength and high energy absorption capability. Since the discovery of metal foams have been developed many methods and techniques of production in liquid, solid and gas phases. Condition for the use of metal foams - advanced materials with unique usability features, are inexpensive ways to manage their production. 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. The aim of research conducted at the department of metallurgy and foundry of VSB-Technical University Ostrava is to verify the possibilities of production of metallic foams by conventional foundry processes, to study the process conditions and physical and mechanical properties of metal foam produced. Two procedures are used to create porous metal structures: Infiltration of liquid metal into the mold cavity filled with precursors or preforms and two stage investment casting.

Keywords: Innovative foundry technologies and materials, Product development, Metal foams

1. Introduction

Over the past two decades, opportunities for the use of porous metals have increased in many research and industrial applications. Growing interest is related to the specific characteristics of this material. Porous metals represent a new type of materials which fulfils the current demanding ecological requirements (in particular on the area of weight reduction) and has unique service properties thanks to its structure with low densities, large specific surface, and useful combination of physical and mechanical properties.
To properly identify metallic foam, according to J. Banhart [1], one has to distinguish between:

- **Cellular metals**: the most general term referring to metallic body in which any kind of gaseous voids are dispersed. The metallic phase divides the space into closed cells which contain the gaseous space.
- **Porous metals**: a special type of cellular metal restricted a certain type of voids. Pores are usually round ones and isolated from each other.
- **Metal foams**: a special class of cellular metals that originate from liquid metal foams and, therefore, have a restricted morphology. The cells are closed, round or polyhedral and they are separated from each other by thin films.
- **Metal sponges**: morphology of a cellular metal, usually with interconnected voids.

The material offers particularly the following properties and possibilities of application:

- reduction of weight: porous metals themselves are lightweight and when connected with thin ribs, they can achieve the same values of mechanical strength as it is required for conventional heavy structures
- absorption (damping) of energy, the most promising feature: it uses the ability of this type of material to deform under a constant and relatively low stress, and thus to absorb in the relatively small volume large amounts of energy. This property can be used in transport, especially in personal vehicles for protection of the interior in the case of car crash (e.g. aluminium foam materials, produced in small series for the Audi 07, and dampers for railway production [2]).
- absorption of sound and vibrations - substitute of organic foam materials in an environment with extreme thermal and mechanical stress;
- thermal insulation: metallic porous materials retain high mechanical properties even at high temperatures and even when exposed to flames they do not release any organic vapours;
- protection against explosions and impacts, both for non-military and military purposes:
- exchange of heat or electricity: metallic porous materials with open structure have very large specific surface area, which gives them better exchange capabilities. Nickel foam material, used as electrodes in rechargeable batteries for portable devices (mobile phones, laptops) are manufactured in series production.
- medicine, which uses porous metals for bone and dental implants - (titanium metallic foams), the structure of which is closer to the structure of human bone, and titanium is well tolerated by the organism.

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.
According to the state, in which the metal is processed, the manufacturing processes can be divided into four groups (Fig. 1). Porous metallic materials can be made from liquid metal, from powdered metal, metal vapours, or from metal ions [2].

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 stochastic).

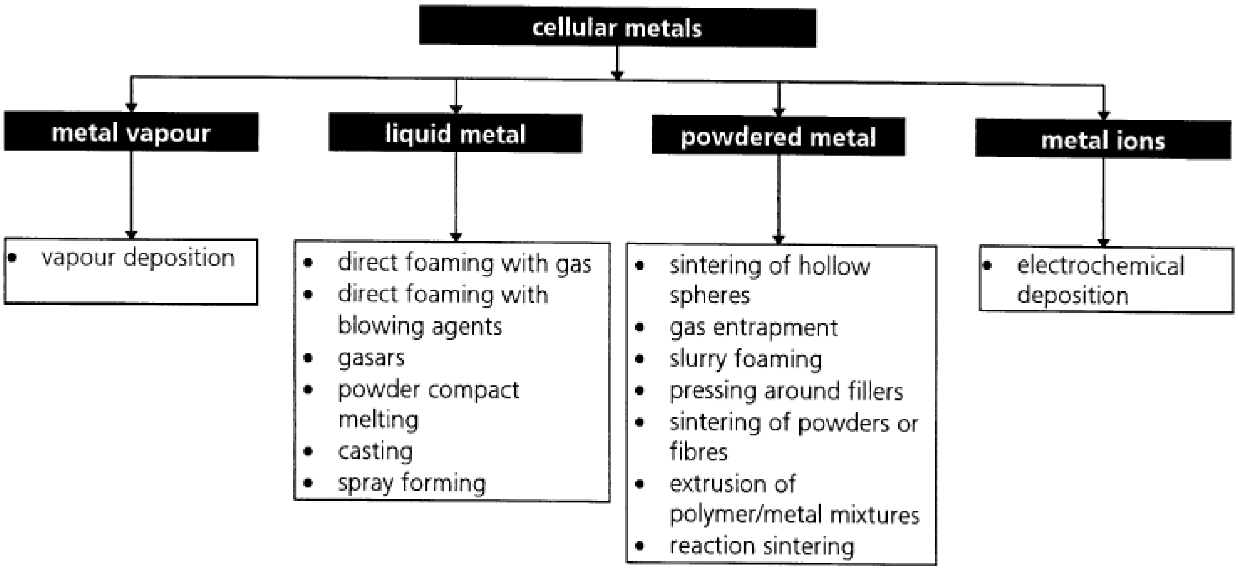

Fig. 1. Methods for production of metallic foams [2]

2. Casting methods of metal production

2.1. Two stage investment casting

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. A polyurethane foam cavity is first filled with sufficient refractory material such as plaster (or a mixture of mullit, phenolic resins and calcium carbonate). The assembly is then heated to 700ºC, to fire the plaster and remove the polyurethane foam. Molten metal is then poured onto the mould - again, combinations of vacuum and high pressure 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 [3]. The company ERG, Inc., California, produces with use of this technology metallic foam with the trade name Duocel already since 1967 [4]. Foam porosity ranges from 80 to 97%, with pore sizes of 4.3, 2, 1 and 0.5 mm. Foams Duocel are of high quality, however, the disadvantages of the production process are the high costs, complexity of the manufacturing process and low production volumes.

Fig. 2. Application of two stage investment casting for production of cast metal foam (obtained porosity 97%) at the Department of metallurgy and foundry VSB-TU Ostrava [5]

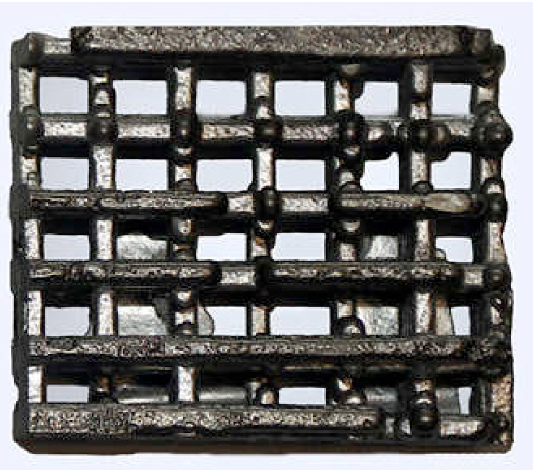

Fig. 3. Application of two stage investment casting for production of casting with with regular cellular structure (obtained porosity 60-68%) at the Department of metallurgy and foundry VSB-TU Ostrava [5]

2.2. Infiltration method

Porous metals can be produced also by the method, when the liquid metal is poured into a mould filled with inorganic or organic particles, called precursors which may remain in the casting (syntactic foam), or which are removed (most often by leaching or annealing depending on the type of precursor). Precursors can be removed only in case if their content is so great that all the precursors are interconnected. In the case of spherical precursors, this network has a topology similar to the foams obtained by the introduction of a gas into a liquid. The main characteristic of the method using precursors (filling the mold cavity) is irregular structure and random distribution of pores through the volume of the casting. The maximum porosities which can be achieved using different types of precursors are limited to values below 80%.[1]

Fig. 4. Open pore casting (organic precursor removed by annealing) VSB-TU Ostrava [5]

Fig. 5. Open pore casting before annealing VSB-TU Ostrava [5]

Regular pore structure can be acheaved using different types of preforms which fill the mold cavity. [6], [7], [8]. Preform with celular structure (Fig. 6) can be used like a core and that make possible to create castings with solid surface layer (Fig.7).

As precursors (or preforms) can be used many different materials e.i vermikulite, fired clay pellets, soluble salts, loose bulks of expanded clay granules, sand pellets, foamed glass spheres etc[2]. 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 preform or precursors are made.

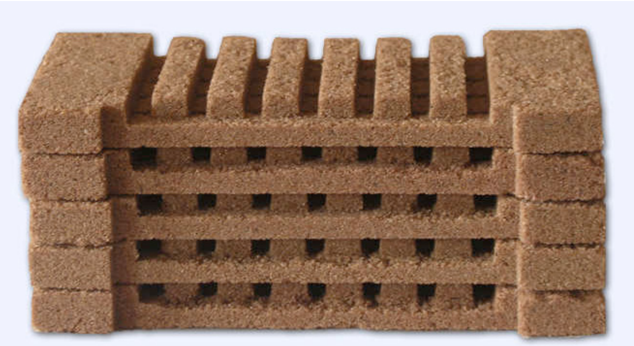

Fig. 6. Preform with regular pore structure VSB-TU Ostrava [5]

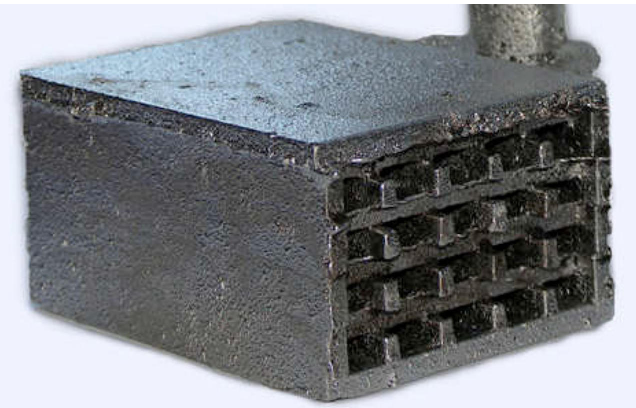

Fig. 7. Casting with regular pore structure and solid surface layer VSB-TU Ostrava [5]

3. Conclusion

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.

Acknowledgement

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