Iron Based PM Cellular Materials-Manufacturing, Properties and Applications

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Abstract

Cellular metals based on Iron have been intensively investigated during the last two decades. Because of the significant decreasing of the structural density of Iron based cellular structures, numerous technologies have been developed for their manufacturing. Besides the tremendous weight reduction a combination with other properties like energy and noise absorption, heat insulation and mechanical damping can be achieved. This contribution will give an overview about the latest state in Iron based cellular materials, including technologies in manufacturing, properties and potential applications.

Keywords : cellular metals, metal hollow sphere structures, direct typing, highly porous materials

1. Introduction

Cellular metals are a new class of materials which have been the focus of numerous scientific studies over the past few years. The increasing interest in cellular metals is due to the fact that the introduction of pores into the materials significantly lowers the density. These highly porous materials also possess combinations of properties which are not possible to achieve with other materials. Besides the drastic weight and material savings that arise from the cell structure, there are also other application-specific benefits such as noise and energy absorption, heat insulation, mechanical damping, filtration effects and also catalytic properties. Cellular metals are hence multi-functional lightweight materials.

In principle, cellular metals can be manufactured from the gas, liquid or solid phases. Current the most advanced methods involve powder metallurgical processes.

The main focus during the last two decades has been made in manufacturing, characterization and evaluation of Al-based foams. But within the last 10 years numerous groups around the world have been engaged in Iron/Steel based cellular material. Iron based cellular structures are of interest because of their cheap material costs, their unlimited alloying opportunities, their high material compatibility to existing devices, machines and vehicles, their widespread potential for functional and structural applications and their simplified recycling.

2. Manufacturing of Iron based PM cellular materials

Iron based cellular structures have been manufactured from solid, liquid and gaseous state. The most promising PM manufacturing routes are:

- powder coating, casting and vapour condensation of templates
- metal fibre structure technologies
- powder space holder methods
- metal hollow sphere technology
- slurry gelation technology
- direct typing process
- slip reaction foam sintering process

The methods mentioned above cover a wide range of Iron based materials, open and closed cell structures with pore sizes between µm and mm range and total porosities up to 98 %.

Metal Hollow Sphere Technology (MHS)

The manufacturing of metal hollow sphere structures is characterized by a three step process involving powder coating of an organic carrier (mostly Styrofoam spheres), a shaping step and a debindering/sintering step. (1.) Features of the MHS technology are its suitability for a wide range of materials and a broad cell size spectrum (0.5–10 mm); while the spheres shell thickness can be varied in the range from 20 µm up to 1000 µm. The shell can be full dense sintered, porous sintered as well as a graded sintered structure. The major feature of Iron based MHS-structures is the low specific weight, which can reach 0.25 g/cm³ (~97% structural porosity!). A further characteristic is their good energy absorption behaviour. Figure 1 shows results of adhesive and sintered Iron based MHS-structures. Both MHS-structures are in the same range of specific energy absorption up to a density of around 0.4 g/cm^3. The energy values seam to be independent on the sphere diameter. (2.)

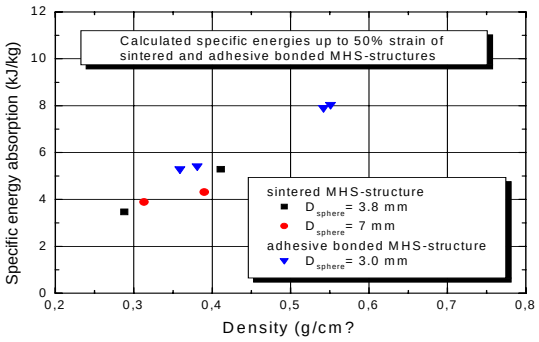

Fig. 1. Energy absorption of sintered and adhesive bonded MHS-structures in dependence of the structural density of low alloyed steel MHS (Fe-0.5%C).

Investigations of the sound absorption of sintered 316L MHS-structures have been performed using the Kundt'sche tube, a cold chopper engine as well as by hot engine tests. The results have shown that MHS-structures reveal a significant higher sound dissipation up to 1000Hz compared to glass wool. The sound level could be reduced of about 10-15dB. Furthermore a significant weight saving (up to 30%) in comparison to the state of the art muffler have been pointed out. (3.)

Direct Typing of Iron Based Cellular Structures

The most recent development work has involved the manufacturing of Iron based cellular structures by direct typing. The base manufacturing process involves layer-wise build up of cellular structures. The design of the highly porous structures has been created by CAD followed by fabrication of different types of masks for the typing process.

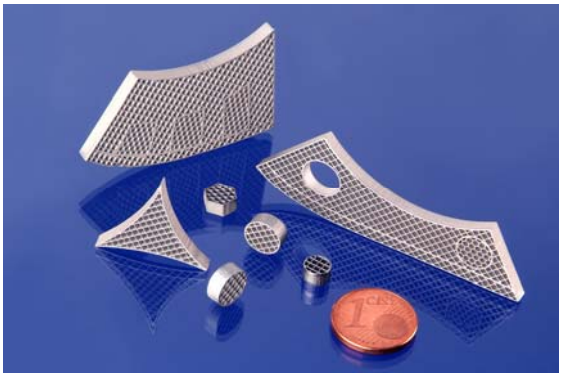

Fig. 2. Direct typing structures of 316-St.Steel.

After layer-wise generation of the structure a subsequent polymer-removal and an additional sintering step is necessary (4.). The Figure 2 shows direct typing structures made of 316 stainless steel.

Direct typing is a promising process for manufacturing of small, precise cellular structures. The advantages of the process are the large shape diversity (Figure 2), precise and dimensionally stable structure, whose properties can be calculated/predicted and the development of real 3-D cellular structures.

3. Potential applications

Because of the unique properties of Iron based cellular structures (low density, excellent sound absorption, thermal insulation, energy absorption, high specific surface area, mechanical damping), there is a high potential for applications into the near future for the vehicle industry (diesel soot filtration, energy absorption, sound dissipation, heat insulation) for machine constructions (acoustic and mechanical damping, weight reduction), for process engineering (weight reduction, sound absorption, catalytic reaction, thermal insulation, filtration, infrared burners).

4. Summary

During the last two decades numerous technologies have been developed in the manufacturing of Iron based cellular structures. To date the most promising methods are the powder space holder method, the in situ gas evolution and sintering, the powder coating/ sintering and casting of templates (PU-foams), the metal fibre structure technology and the metal hollow sphere method. Important Iron based alloys are stainless steels (316L, 304, 314, 310), the heat resistant FeCrAl-base alloys as well as low alloyed Iron like Fe-3%Cr-0.5%Mo or Fe-0.5%C-0.5%P.

5. References

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