Porous Metal structures made by sintering: processes and applications

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1. Introduction

Porous metals can be described as functional materials for applications in the field of filtration, flame arresters, silencers, structures for gas dispersion in liquids, components for drying processes, air bearings, oil-lubricated bearings and, today still in an early development stage, for burners, heat exchangers and filters for micro filtration. In this sense the porous material is defined by open interconnected porosity in components made from metal powder using different PM-techniques. Although a large variety of metals are used today, most of all products are made of bronze and stainless steels. However, applications for superalloys, titanium and aluminium started to grow recently. The basic technical advantage of porous metal structures is the optimum combination of several properties in one product: high mechanical strength combined with ductility, good corrosion resistance, high performance of filtration, well defined porosity and controllable permeability from low to very high fluxes. Besides these characteristics some additional features of porous metals are important to mention: Using PM-net shaping techniques a wide variety of geometries, sizes and even combinations of different materials can be realised. The materials are in principal weldable or joinable and can be easily machined. Metal powders are available in big quantities and "to go the metal way" means less problems for the future under all aspects of recycling, pollution and environment.

The paper gives a description of several important PM-shaping techniques, discusses some problems of the characterisation of porous metal structures and properties and presents some typical examples of applications. The various methods of production have been discussed in several papers and handbooks [1].

2. Design for function

For the optimisation of filter elements, total porosity is less important than the total amount of open pores connected to outer surfaces of the filtration component. This interconnected porosity contributes to the effectivity of the porous part. To produce appropriate porous parts the operation conditions and the performance profile have to be well understood. Most components can be attached to the following three groups of application: filtration, flow control and distribution of gases or liquids

PM-metal filter elements offer the following features [2]:

- shape stability, i.e. self supporting as structural elements even at high pressure difference of the flow medium.
- good fatigue, impact and shock pressure resistance compared to other filter elements (paper, plastic, ceramics, etc.).
- high temperature and thermal shock resistance. Bronze filters can be used up to 400 °C, high alloy steel filters up to 600 °C, and special alloys up to 950°C. In this respect sintered metal filters are far superior to all organic materials and also to ceramics, when thermal shock resistance is required.
- chemical stability against acids and (alcalic) solvents.
- high separation reliability when used as depth filters in contrast to area filters such as textiles, paper and wire mesh.
- a wide range of well defined pore size distributions from 0.5 µm to 200 µm using metal powders. In the range of 3 µm to 40 µm, fibre filters are particularly superior compared to wire mesh elements of corresponding capacity.
- good back pressure flow and excellent cleaning potential using high pressure-superheated steam, chemicals, or burn-off processes.

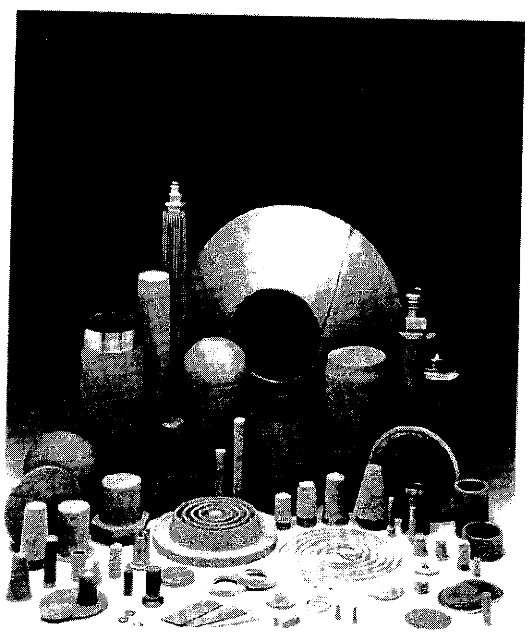

Figure 1: Highly porous products manufactured by powder metallurgy

Additional aspects in favor of highly porous powder metal products are emphasized by increasingly more restrictive environmental legislation requesting the recycling or cleansing instead of producing waste. These advantages are of growing importance for selecting competing of technical products.

3. PM-Manufacturing processes and appropriate alloys

In general the production always consists of two steps: compaction/moulding and sintering. If during the shaping process a binder is used, it has to be removed before or during sintering. Most of all products today are manufactured by one of the following processes:

- loose pack/gravity sintering (bronze)
- axial/isostatic compaction and (vacuum-) sintering (stainless steels, steels, superalloys, titanium, aluminium)
- AS-process for asymmetric designed filters
- sintering of woven felt made from fine stainless steel fibres

4. Porous elements made from sintered metal powders or fibre

Process and chemical engineering are the widest field for the application of porous sintered metal components. In this context filtration means the separation of particles from liquids or gases. The properties of such filter elements can be described by the partition ratio and the separation power. Sintered PM-filters operate by depth filtration using the total porous volume. This is a difference to other filter materials which only act as surface filters. This difference leads to some superiority of the PM-products, because the volume filtration operates more thoroughly due to the combination of several physical interaction processes. The main active force in depth filtration is caused by the velocity reduction of the particle flow in the pore channels and sticking of the particles to the wall surfaces by adhesive forces. For metal depth filter fiber and powder based material can be used. Whether a filter operates as a depth or a surface filter depends on the particle distribution in the fluid and the pore size distribution of the filter element.

5. Porous elements with low pressure drop

Because of their unique properties, metal filter composite structures are extensively applied in a multitude of different applications. Besides the well-known advantages of stainless steel filter cartridges the wall thickness of 2-3 mm, which is necessary for the self supporting system, causes a high pressure drop. The wall thickness has to provide sufficient mechanical strength but is not absolutely necessary for particle retention. If the right filter selection was done, the separation of particles takes place on the surface of the filter material and in the first tenths of a millimetre of the wall thickness. The other requirements on a filter element are a high flow rate and a good back flushing performance.

To achieve high flow rates without loosing retention performance a lot of different developments of asymmetric composites have been done in the past. These are powder/powder, powder/screen, fibre/screen and powder/fibre [3] composites. All of these different types have their special advantages and limitations. In many cases in the past only the fibre/screen composite has found it's own market for filter applications.

Sheet filters made from metal fibre felt are backed up by a coarse wire grid, which does not influence the filtration behaviour. The metal fibre felt elements have in general, compared to sintered metal powder structures, a thinner wall thickness (1-2 mm for fibre, 4-6 mm for powder) and for a similar fineness and pressure drop they offer a 6-8 times higher permeability. The reasons for this difference are different pore size distributions and higher total porosity. Pores sizes can be tailored between 5 µm to 200 µm.

The new developed product called SIKA-R ... AS (Asymmetric) is a powder/ powder composite [4] consisting of a coarse metal powder which is the support material and a thin active filter layer (< 200 µm) of the same alloy. The support material is produced by axial pressing for plate geometries and isostatic pressing for filter cartridges. The thin metallic membrane is applied in a separate process step. The support material and the active filtration layer are diffusion bonded during the sintering process. The newly developed AS-process is a P/M process to produce porous structural parts and coatings and allows the processing of very fine metal powders.

6. Methods for characterisation and QA of porous structures

The procedures for the characterisation of porous structures [5] have to be related to the application. In general porosity (density), pore size and pore size distribution are of interest. In special cases, noise reduction, pressure drop, particle retention or more complex pore size analysis is necessary. In house designed and constructed high speed test rigs allow a safe check of porous elements in relatively short times. Especially for the comparison of different filtering media (e.g. grades of different suppliers or comparison with non PM-materials) sophisticated analysis equipment is absolutely necessary.

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