Net-shape Manufacturing of Micro Porous Metal Components by Powder Injection Molding

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Abstract

A novel production method for porous metal components has been developed by applying powder space holder (PSH) method to metal powder injection molding (MIM) process. The PSH-MIM method has an industrial competitive advantage that is capable of net-shape manufacturing the micro-sized porous metal products with complicated shapes and controlled porosity and pore size. In this study, the small impeller with homogeneous micro-porous structure was manufactured by the PSH-MIM method. The effects of combinations in size and fraction of PMMA particle on dimensional tolerance and variation of sintered porous specimens were investigated. It was concluded that the PSH-MIM method could manufacture commercially micro-porous metal components with high dimensional accuracy.

Keywords : porous metal, metal injection molding, powder space holder method, stainless steel, dimensional accuracy

1. Introduction

Porous metal materials have been widely studied and used, but they are new class of materials with low densities, large specific surface and novel properties in physically, mechanically, thermally, electrically and acoustically. An open cell structure possesses high functional applications. In generally speaking, the cell size tends to be small accordingly as the size of products decrease from meters to millimeters. Also, conventional manufacturing methods can be used with a small subset of methods to create porous materials with a limited range of cell size and porosity. In practical ways, it is very difficult for metals to produce with controlled dimensionally in a few or tens micrometers of cell size and with selected arbitrarily both open and closed cell structures with specified porosity. At the moment, few methods can produce the net-shaped metal components with high production efficiency. Furthermore, it is not easy to control the cell size and its distribution in practice and much more so producing micro-sized porous metal components with complicated shapes and high dimensional accuracy. Metal powder injection molding (MIM) is, on the other hand, a manufacturing method combining the traditional powder metallurgy process and plastic injection molding. It is capable of producing comparatively small precise components with complex shapes from almost all types of materials. Authors have contrived producing metal components with micro-sized porous structure by applying powder space holder (PSH) method to MIM process.

In this study, the small impeller with micro-porous structure was manufactured by the PSH-MIM method, and the effects of combinations in size and fraction of PMMA particle on dimensional tolerance and variation of the sintered porous specimens were investigated.

2. Production of Micro-porous Metals

The concept of production method for micro-porous metals we developed based on MIM process is illustrated in Fig. 1. In highly porous structured MIM products, many spaces require retention after sintering. We have therefore applied PSH method into MIM process. In addition to metal powder and organic binders, the coarsespherical particle made of polymer was used as lost material for formation of fine porous structures in MIM components. Material combination of space holding particle and metal powder in addition to sintering conditions determines principally the porous structure. This production method

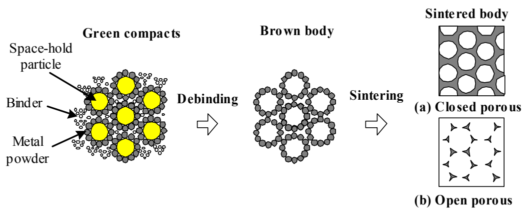
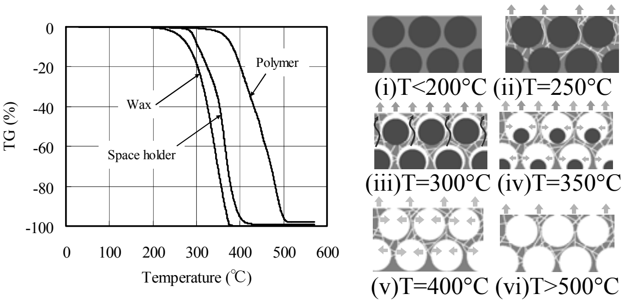


Fig. 1. Powder space holder method for producing micro-porous metals.

proposed is a net-shaped production for micro-porous metal components with three-dimensional complicated shapes and can be applied to most kinds of metal powder, such as stainless steels, aluminum, copper, titanium, nickel and their alloys.

It is a key technology in PSH method to remove the space holding particles for making spherical spaces. The debinding mechanism is shown in Fig. 2. Fig. 2 (a) shows the thermalgravimetric curves of binder constituents, such as wax, polymer and PMMA particle, and Fig. 2 (b) shows the schematic drawing of debinding process in each temperature. At 250°C, Wax starts to decompose, and it makes many paths for degassing around PMMA particle. Then, at 300°C, PMMA decomposes along with wax. As further increasing in temperature, a large amount of PMMA and polymer decompose simultaneously around 350°C. Finally, over 500°C, all of binder constituents and PMMA particles have been decomposed. This is a basic debinding mechanism in our material system.



(a) TG curves of binder and space holder. (b) Schematic drawing of debinding process.

Fig. 2. Debinding mechanism in two components binder system of PSH method.

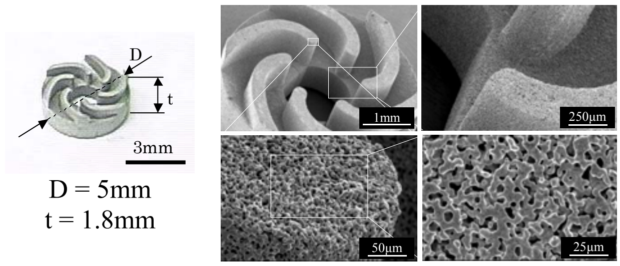
3. Experimental Procedure

The metal powders are austenitic stainless steel, 316L (3 μm in mean diameter, Atmix Co., Ltd., PF-2F) produced by water-atomization method. The binder is from paraffin wax and polyacetal family. Spherical particles with 10 μm or 40 μm in mean diameter (Soken Chemical Co., LTD., MX-1000 or Ganz Chemical Co., LTD., Ganz Pearl GM-4003) made of polymethylmethacrylate (PMMA) were used for holding the space. These materials were co-mixed and palletized.

The small impeller with porous structure as shown in Fig. 3(a) was produced by injection molding to demonstrate the feasibility of producing the porous metal components with three-dimensional complicated shapes. The debinding and sintering were sequentially processed in the vacuum furnace (Shimadzu Mectem Inc., VHSgr, 40/40/100-M). The surface structure was observed, and the dimenions of sintered specimens were measured.

4. Results and Discussions

Fig. 3(b) shows SEM images on the surface of small impeller. It is visible that the micro-sized porous structure was formed homogeneously with subglobular pores but interstices between particles. The pore size is around less than 10 μm. These results suggest that it is desirable for small components required for high dimensional accuracy to use finer metal powder, though the porous components with complicated shape can be produced by the PSH-MIM method. Fig. 4 shows the dimensional torelance and CV value for diameter of sintered specimens, respectively. The small impeller with micro-porous structure could be manufactured with high dimensional accuracy that the dimensional torelance of diameter is less than ±10 μm. The measurements of diameter show that the open cell structure (60vol.% PMMA) specimens have dimensional accuracy much lower than dense (0vol.% PMMA) and closed cell structure (30vol.% PMMA) ones. The reason simply comes from the fact that open cell specimens are larger in sintered shrinkage than closed ones.



(a) Geometry (b) SEM images on the surface

Fig. 3. Small impeller specimen.

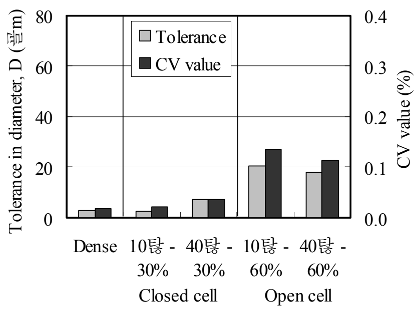


Fig. 4. Dimensional torelance and CV value for diameter of sintered specimens.

5. Summary

Small impeller shaped micro-porous metal components were produced by applying a powder space holder method to MIM process, and dimensional accuracy were evaluated in this study. The results show that the sintered porous productas can be manufactured with the high dimensional accuracy as well as dense MIM ones. Therefore, the net-shaped manufacturing micro-porous metal components with complex three-dimensional shapes could be achieved.