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Production of micro-porous austenitic stainless steel by powder injection molding

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The powder space holder (PSH) and powder injection molding (PIM) methods have an industrial competitive advantage that is capable of net-shape production of the micro-sized porous parts. In this study, a micro-porous austenitic stainless steel part was produced by the PSH–PIM process. Spherical poly(methyl methacrylate) (PMMA) particles were used as a space holder material. The effects of fraction and average size of PMMA on properties of sintered micro-porous austenitic stainless steel samples were investigated. It was shown that the fraction and average size of PMMA could be controlled properties.

Keywords: Powder injection molding; 316L stainless steel powder; Porous metal

Powder injection molding (PIM) is a novel process, which combines plastic injection molding and conventional powder metallurgy (PM) technologies. This technique combines the advantages of the plastic injection molding with the material versatility of the traditional powder metallurgy, producing highly complex parts of small size, tight tolerance, and low production cost. The process overcomes the shape limitation of traditional powder compaction, the cost of machining, the productivity limits of isostatic pressing and slip-casting, and the defect and tolerance limitations of conventional casting. Mechanical properties of a well-processed powder injection molded material are indistinguishable from cast and wrought material. The PIM process is composed of four sequential steps: mixing of the powder and organic binder, injection molding, debinding (binder removal), and sintering [1].

Porous metal materials have been widely studied and used, but they are a new class of materials with low densities, large specific surface and novel properties useful in a variety of applications because of the easily tailored properties [2,3]. An open cell structure is useful for applications such as heat exchangers and heat sinks as thermal managements, medical implants, filters, and electrodes in biological and chemical reactions. Conventional press-sinter manufacturing methods can be used with a small subset of methods to create porous materials with a limited range of cell size and porosity [4,5]. In practical ways, it is very difficult to produce metals with controlled pore sizes in the tens of micrometers with both open and closed cell structures with specified porosity. Currently, few methods can produce net-shaped metal components with high production efficiency. Furthermore, it is not easy to control the cell size and its distribution in practice and even harder to produce micro-porous metal and ceramics components with complicated shapes and high dimensional accuracy [4–6].

In recent studies, the thermal decomposition temperature of PMMA and the best sintering temperature of mixtures of aluminum powders and PMMA powders have been optimized experimentally [4–7]. Nishiyabu et al. [4,5] investigated the manufacturing parameters (size and fraction of PMMA particle, and bending properties of micro-porous graded structure) of commercially micro-porous metal components by PIM. Their study showed that PMMA particles can be decomposed in the debinding stage and that micro-porous metal components can easily be manufactured by PIM. Xie et al. [7] investigated the thermal decomposition

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temperature of PMMA and the best sintering temperature of mixtures of aluminum powders and PMMA powders. Effects of the porosity and pore size on the Young's modulus and strength are discussed. Gain et al. investigated effect of PMMA particles on pore size and shape of porous yttria-stabilized zirconia ceramic parts [6]. All results showed that the PMMA particles as space holder material can use micro-porous metal parts. However, the effect of fraction of PMMA particles on compression properties of micro-porous metal components produced by PIM has not been explained.

In the present study, the micro-porous structure 316L grade austenitic stainless steel was produced by the PIM method. A micro-porous structure possesses high functional applications such as heat exchangers, heat sinks, biomedical implants, filter materials, and chemical reaction. The effects of fraction and average size of a PMMA particle on density, porosity, and elastic modulus of the micro-porous sintered samples were investigated. A schematic illustration of the manufacturing process of micro-porous stainless steel parts is shown in Figure 1. In a conventional PIM process, the feedstock materials mix metal powder and binders, debinding and sintering processes for PIM parts. In addition to metal powder and organic binders, the coarse spherical particles made of polymer were used in the formation of controlled porous structures in PIM parts. Material combination of space-holding particles and metal powders in addition to sintering conditions determines principally the porous structure.

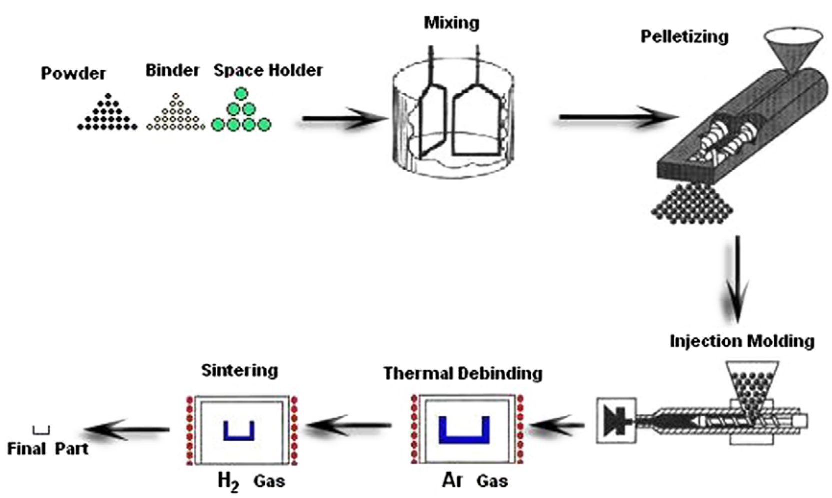

Figure 1. Processing steps of production of micro-porous austenitic stainless steel by PIM.

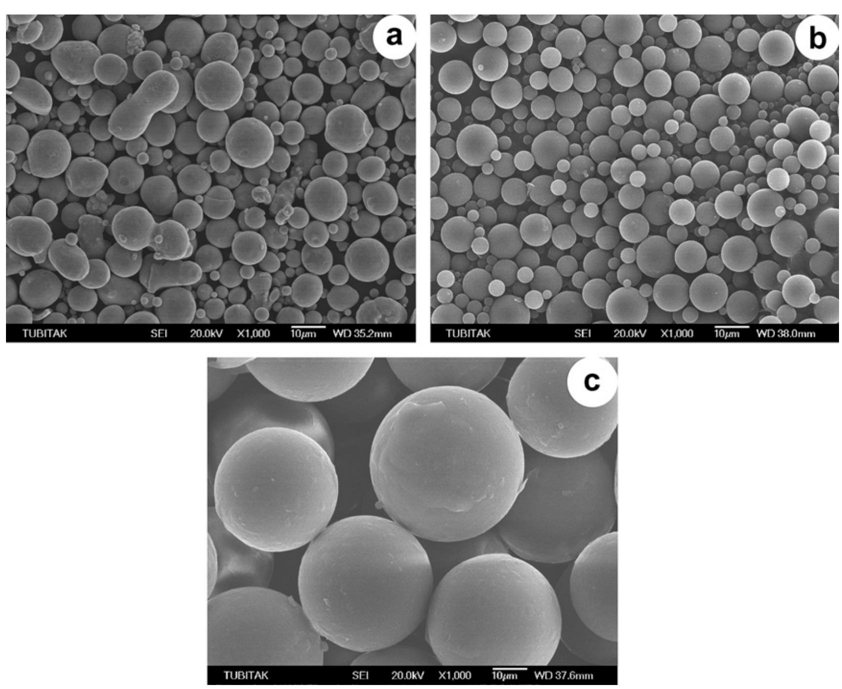

Figure 2. Scanning electron micrograph of 316L stainless steel powder and PMMA particles: (a) 316L stainless steel, (b) PMMA particles (average size 10 μm), (c) PMMA particles (average size 41 μm).