The Influence of Powder Size on Mechanical Properties of Small MIM Parts

Noriyuki Yasui[1,a], Hiroshi Satomi[2,b], Hiroshi Fujiwara[3,c], Kei Ameyama[4,d], Yoshimitsu Kankawa[2,e]

[1]Graduate School of Ritsumeikan University, Japan
[2]Mold Research Co., Ltd., 270-5,Aoji-cho,Kusatsu, Shiga, Japan
[3]Research Organaization of Science and Engineering Ritsumeikan University, Japan
[4]Department of Mechanical Engineering, Faculty of Science and Engineering Ritsumeikan University, Japan
[a]rm011015@se.ritsumei.ac.jp, [b]satomi@moldresearch.co.jp, [c]hfv25008@se.ritsumei.ac.jp,
[d]ameyama@se.ritsumei.ac.jp, [e]kankawa@moldresearch.co.jp

Abstract

The relationship between the powder particle size change and a mechanical property of the Metal Injection Molding (MIM) product was examined in detail. The XRD results indicate that the diffraction peaks of BCC appeared in compacts of powder particle size of 4 to 10μm as well as the bulk SUS630. However, the diffraction peaks from both BCC and FCC were observed in the compact with powder size less than 3μm. TEM observation revealed that the powder with those BCC/FCC two phase structure have a finely dispersed SiO_2 precipitates. Because the Si is ferrite stabilizing element, decrease of Si composition in the matrix phase by the SiO_2 precipitation resulted in formation of the retained austenite. Therefore, controlling the elements such as Si as well as oxygen decrease is very important to obtain a normal microstructure in ultra-fine powder (<3μm) injection molding.

Keywords : Ultra-Fine Powder, Metal Injection Molding, SUS630, small MIM parts

1. Introduction

Metal Injection Molding is an advantageous technique as a shaping method for the fabrication of small parts[1)]. The powder particle size in conventional MIM technology is more than 10μm so that the sintered compact with poor surface roughness needs to grind in the post-processing. To obtain a smooth surface and superior mechanical properties at the same time, using an ultra-fine powder is quite attractive for a new MIM technology. In the present study, ultra-fine powders are provided for MIM process, and the surface roughness, microstructure and mechanical property of the MIM products are examined. The relationship between the powder particle size and mechanical properties of the MIM product was discussed in detail.

2. Experimental

Ultra-fine SUS630 powders were made by the water atomaise method. Four different sizes of the powders, A (2.7μm), B (4.1μm), C (5.9μm), and D (10.0μm), respectively, were provided to the examination. Table 1 shows chemical composition of the powders. The binder used for molding is mixture of polyethylene, a polypropylene, and a polyacetal. The green was prepared by the heat mixing of powder and these thermoplastic resin with the addition of paraftin wax.The test pieces were injection molded at 160℃ to form the green compact. The compacts were sintered at various temperatures after removing the organic materials in the green. Relative density, surface roughness and hardness of the compacts were measured. Microstructure was characterized. by XRD, SEM and TEM/EDS.

Table 1. Chemical composition of powders (mass%).

	C	Si	Ni	Cr	Cu	O(ppm)	Fe
A	0.051	0.82	4.25	15.72	3.23	6900	bal
B	0.049	0.86	4.24	15.69	3.23	3800	bal
C	0.051	0.81	4.22	15.70	3.33	3800	bal
D	0.051	0.81	4.22	15.70	3.32	3600	bal

3. Results and Discussion

Figure 1 shows the relationship between sintering temperature and the relative density of the compact of A, B, C, and D. Finer powder compacts show higher density at lower temperature. Even at 1323K, ultra-fine powder compacts, A and B, indicate significantly higher density compared to the conventional size powder compact D Fig.2 indicates that the average surface roughness (Ra) decreases with decreasing particle size. The average surface roughness of 1μm or less was achieved by compact of

powder particle with the size under 5.9μm. Fig.3 shows the relationship between the powder particle size and hardness of compact sintered at 1523K. In B, C, and D powders the hardness of compacts increase with decreasing particle size. However, the hardness of compact A is smaller than that of compact B in spite of its smaller powder size. The XRD results of the compact sintered at 1523K is shown in Fig.4. A result of SUS630 bulk material is also demonstrated in the figure. The diffraction peaks from BCC structure can be observed in the compacts B, C, D and the bulk material. In the compact A, however, the diffraction peaks not only from BCC but FCC structures can be detected.The BCC structure is attributed to martensite phase which usually forms in the SUS630, and it results in higher hardness.

To make clear the differences of properties in these compacts, a TEM/EDS examination has been carried out. In result, the compact A had an extremely different micro-structure; that is, fine dispersed particles were observed in the FCC austenite matrix. TEM/EDS revealed that those dispersed particles were SiO_2 precipitates. This result implies that a large amount of oxygen on the powder surface, as indicated in Table 1, consumed Si solute atoms in the powder. In other words, because Si stabilizes ferrite (BCC) in steels[2], decrease of the Si results in poor BCC transformation from FCC even after the heat treatment.

It is noteworthy that applying ultra-fine powders to MIM improves the surface roughness as well as mechanical property. However, to obtain superior mechanical properties to the conventional powder size MIM process, preventing from surface oxidation and controlling of alloy elements at the powder fabrication are quite significant.

4. References

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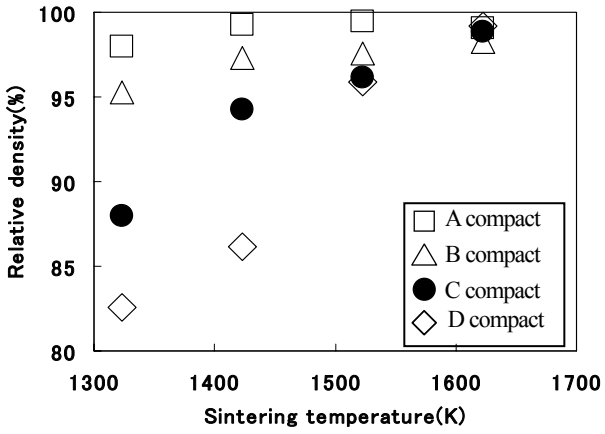

Fig. 1. Relationship between a sintering temperature and a relative density in the sintered compact.

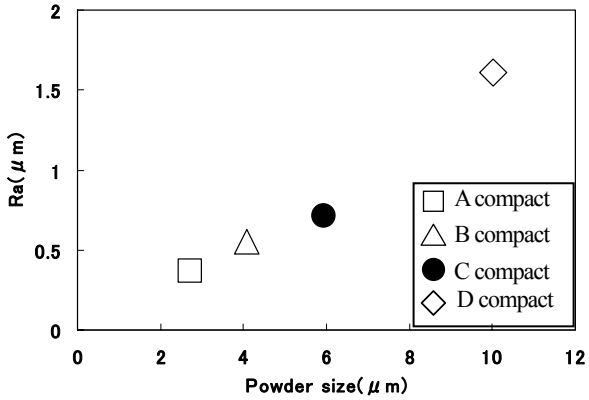

Fig. 2. Relationship between particle size and average surface roughness (Ra) of compacts.

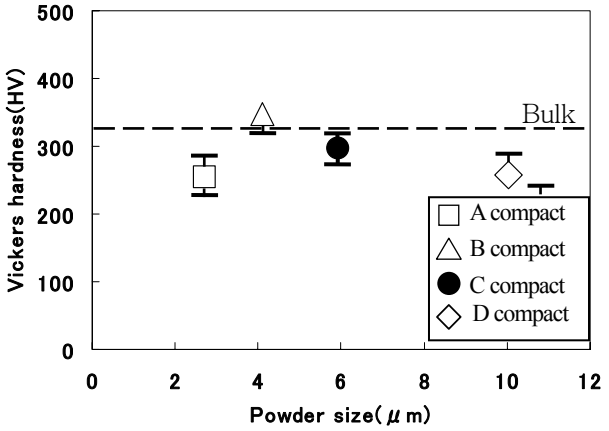

Fig. 3. Relationship between powder size and hardness of compacts at 1523K.

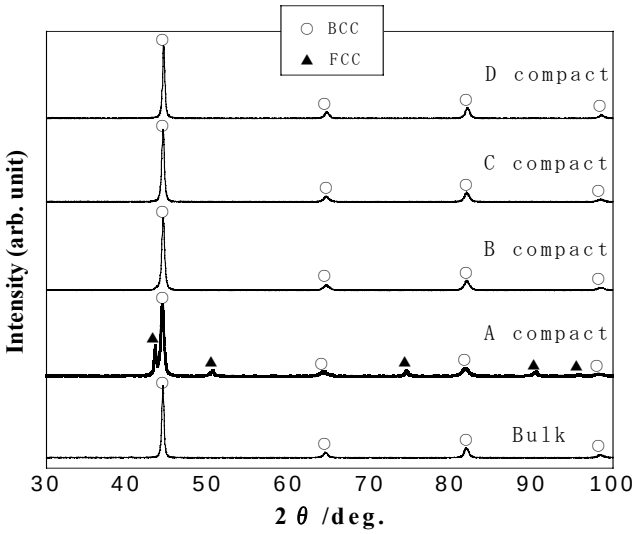

Fig. 4. The X-ray diffraction patterns of compacts at 1523K.