Micro Metal Injection Molding Using Hybrid Micro/Nano Powders

Kazuaki Nishiyabu[1,a], Kenichi Kakishita[1,b], Toshiko Osada[2,c] and Shigeo Tanaka[2,d]

[1]Osaka Prefectural College of Technology, 26-12 Saiwai, Neyagawa, Osaka 572-8572, JAPAN
[2]Taisei-Kogyo Co., Ltd., 26-1 Ikeda-kita, Neyagawa, Osaka 572-0073, JAPAN
[a]kazu@ipc.osaka-pct.ac.jp, [b]kaki_ken1@yahoo.co.jp,
[c]toshiko@taisei-kogyo-net.co.jp, [d]tana@taisei-kogyo-net.co.jp

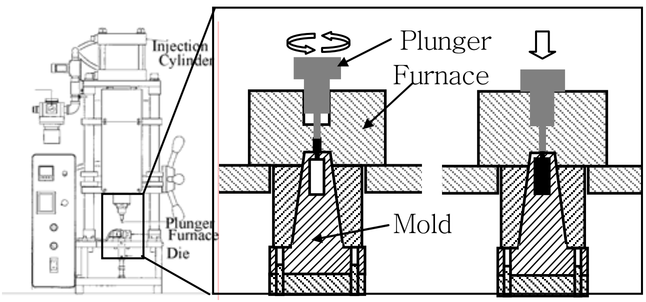
Abstract

This study aims to investigate the usage of nano-scale particles in a micro metal injection molding (μ-MIM) process. Nano-scale particle is effective to improve transcription and surface roughness in small structure. Moreover, the effects of hybrid micro/nano particles, Cu/Cu and SUS/Cu were investigated. Small dumbbell specimens were produced using various feedstocks prepared by changing binder content and fraction of nano-scale Cu particle (0.3 and 0.13μm in particle size). The effects of adding the fraction of nano-scale Cu powder on the melt viscosity of the feedstock, microstructure, density and tensile strength of sintered parts were discussed.

Keywords: micro metal injection molding, ultra fine particle, Cu, surface roughness, grain size

1. Introduction

Micro metal injection molding (μ-MIM) which needs more sophisticated techniques than the conventional MIM has been focusing recently for an application of micro system technology [1]. Authors defined μ-MIM as small sized and fine structured MIM products, whose size is less than 1mm. Further improvements on the quality of μ-MIM products are required in practical productions. The use of finer metal powders is one of solutions to improve the dimensional accuracy and surface roughness of μ-MIM products. It is also expected to inhibit the grain growth by reducing the sintering temperature. In this study, the effects of adding nano powder in μ-MIM process were focuced on the following points. The influence using small powder gives to a microstructure body and possibility of hybrid MIM using nano-scale Cu powder.



(a) Appearance (b) Mixing (c) Injection

Fig. 1. Schematic diagrams of direct mixing-injection moulding machine.

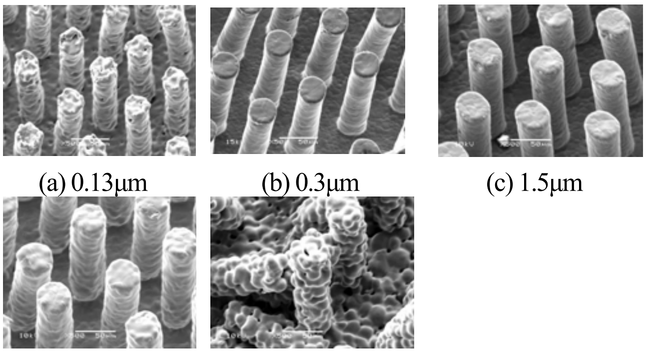
A novel type of mixing-injection molding machine shown in Fig. 1 was used to produce tiny specimens with high trial efficiency using a small amount of feedstock. Nano-scale powder was used for μ-MIM specimen, it is expencive and not for mass production, this type of small injection molding machine is suitable.

2. Effect of particle size on μ-MIM

In order to improve dimensional accuracy and transcription in micro structure for μ-MIM, using small particle is effective because of low sintering temperature and restraining grain growth. On the other hand, small particle has large specific surface which oxidize easily and it is inhibit easy sintering. The materials used for the experiments were five types of pure Cu powders and poly-acetyl based binders. The micro-scale Cu powder is a conventional material manufactured commercially by a water-atomization method (D_{50}=20μm, 7.8μm and 1.5μm). The nano-scale Cu powder, on the other hand, is an ultra-fine material under development produced by a radio-frequency thermal plasma method (De=0.3μm, 0.130μm). In addition we used direct mixing-injection molding machine with PMMA cash register strike films. The green compacts were debound at 400ºC for 2hrs in atmosphere, and sintered at 900ºC for 2hrs in H_2 gas.Fig.2 shows aspect of 5types of sintered specimen. Sintered bodies look nice in spite of 20μm powder. Deformation of 0.3μm is considered to be derived large amount of binder contents.Fig.3 shows surface roughness of micro-structures versus particle size of powder. If a powder diameter became small, as for both green compact and Sintered body, as for the surface roughness, the tendency that became small was able to be provided.Fig.4 shows Radius of edge at micro-structure versus particle size of powder. If a powder diameter became

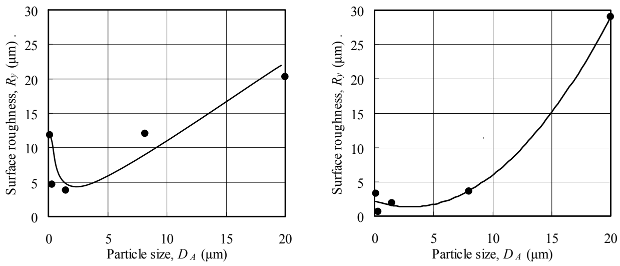
© Korean Powder Metallurgy Institute

small, as for Radius of edge, the tendency that became small was able to be provided.



(a) 0.13μm (b) 0.3μm (c) 1.5μm (d) 8μm (e) 20μm

Fig. 2. SEM images of sintered bodies.



(a) Green compact (b) Sintered body

Fig. 3. Surface roughness of micro-structured parts versus particle size of Cu powder.

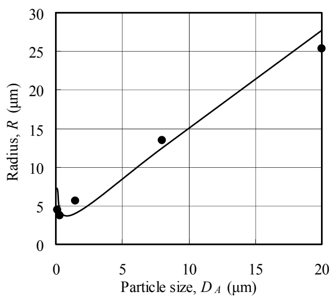
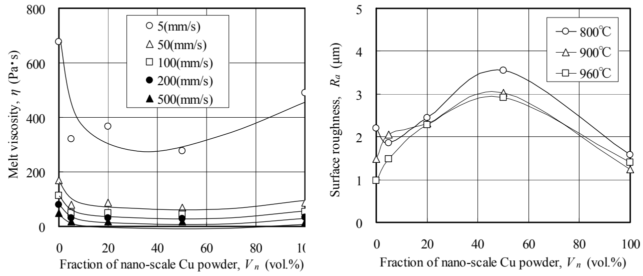


Fig. 4. Radius of edge at micro-structure versus particle size of powder.

3. Effect of Hybrid Micro/Nano Cu powders

Nano size poder was useful for micro structure to improve the surface roughness, however, it is expencive to use nano size powder whole specimen. Hybrid micro/nano powder is considered to be effective for micro structure. The materials used were two types of pure Cu powders and poly-acetyl based binders. The micro-scale Cu powder (D_{50}=7.8μm). The nano-scale Cu powder, (D_e=130nm). Direct mixing-injection molding machine with wide-dumbel mold were used for experiment. The green compacts were debound at 400ºC for 2 hrs in atmosphere, and sintered at 800ºC, 900ºC and 960 ºC for 2 hrs in H_2 gas.

Fig.5 shows the effects of nano-scale Cu powder loading on melt viscosity of the feedstock and surface roughness of sintered parts. By moderate addition of nano-Cu powder decrease melt viscosity, but soughness roughness could not be modified.



(a) Melt viscosity (b) Surface roughness

Fig. 5. Effects of nano-scale Cu powder loading.

4. Effect of Hybrid Micro-SUS316L/Nano-Cu powders

In previous work, Cu added stainless steel was investigated to clarify the effect of Cu added content and sintering temperature on the mechnical proerpties and functional performance such as anti-bacteria and resist corrosion for the stainless steel by metal injection molding. Micro-scale stainless and Cu powders were used in the study. Relative density and tensile strength of Cu added specimen shows lower than those of without Cu specimen. There occur small void where Cu solved out. In this study, on the other hand, specimen used were micro-scale SUS316L powder, nano-scale Cu powder and wax based binder. Using nano-scale powder will avoid large size of void made by micro size powder. Effect of particle size of added Cu would investigate by observation of small void.

5. Conclusion

In order to improve dimensional accuracy, transcription, and surface roughness of μ-MIM specimen, nano-scale powders were used. Nano size powder is effective to improve the transcription and surface roughness. Moreover, effect of hybrid micro/nano particles, Cu/Cu and SUS/Cu were investigated. Small dumbbell specimens were produced using various feedstocks prepared by changing binder content and fraction of nano-scale Cu particle. The effects of adding the fraction of nano-scale Cu powder on the melt viscosity of the feedstock, microstructure, density and tensile strength of sintered parts were investigated.

6. References

1. R.Ruprecht, T.Gietzelt, K.Muller, V.Piotter, J.Haußelt, Microsystem Technologies 8, 351-358 (2002).

© Korean Powder Metallurgy Institute