

MANUFACTURE OF MESOSCALE GAS BEARING FOR POWER MEMS APPLICATION USING POWDER METALLURGY PROCESS

Hye Moon Lee¹, Chul-Jin Choi¹, Jung-Goo Lee¹, Daejong Kim²

¹Department of Powder Materials, Korea Institute of Materials Science, Changwon, Korea

²Mechanical and Aerospace Engineering, University of Texas at Arlington

Abstract: The specially designed small gas bearings are so complicate and precision in shape and size that it is impossible to manufacture it using the generally used machine work. Thus, we firstly applied a powder metallurgy process, filling mixture of Fe based metal nanopowders and polymer binder into a polydimethylsiloxane (PDMS) polymer mold, to manufacture of mesoscale gas bearings (bearing diameter of 5 mm). This study reports recent progress on manufacturing of the gas bearings applicable to the mesoscale microturbonmachinery using the powder metallurgy process.

Key words: powder metallurgy, polymer mold, nanopowder

1. INTRODUCTION

Many efforts are focused on the production and application of palm-sized mesoscale micro-turbomachinery in micro power generation areas. To manufacture the mesoscale devices, a number of parts, much smaller than the device in size, should be manufactured. A bearing for a high rotation speed, about 600,000 rpm, is one of critical parts for the turbomachinery. The specially designed small gas bearings are so complicate and precision in shape and size that it is impossible to manufacture it using the generally used machine work. Thus, we firstly applied a powder metallurgy process, filling mixture of Fe based metal nanopowders and polymer binder into a polydimethylsiloxane (PDMS) polymer mold, to manufacture of mesoscale gas bearings (bearing diameter of 5 mm). This study reports recent progress on manufacturing of the gas bearings applicable to the mesoscale microturbonmachinery using the powder metallurgy process.

2. EXPERIMENTAL

2.1 Fabrication of PDMS soft mold for gas bearing

Fabrication of PDMS (polydimethylsiloxane) soft mold for gas bearing was done by the process shown in figure 1. A master mold with gas bearing shape, which is produced by an electroplating or LIGA processes, was used for preparation of negative mold for the gas bearing. The master mold was in a Petri dish and PDMS was poured into the dish. The Petri dish with the master mold and PDMS was in vacuum

surroundings for about 30 min to remove the air in PDMS and stored in the dry oven at about 80 °C. The mater mold was demolded from the PDMS in Petri dish, thus the PDMS soft negative mold was fabricated to form a gas bearing consisting of nanopowders.

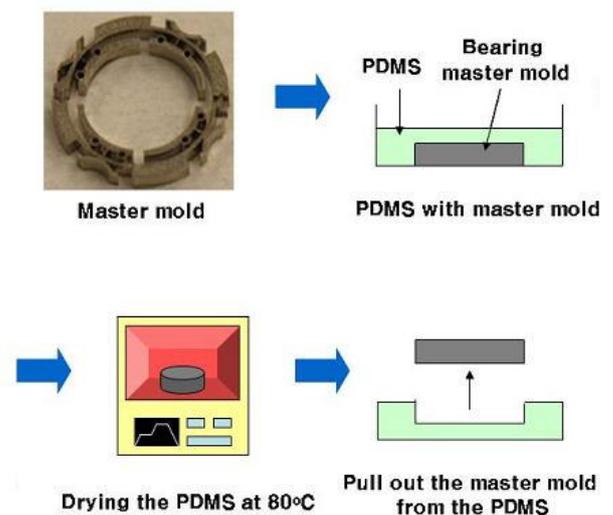


Fig. 1 Process for preparation of PDMS soft mold with gas bearing shape

2.2 Fabrication of nanopowder gas bearing green and sintered parts

Figure 2 shows the process for the preparation of greenparts with shape of gas bearing using 17-4 PH stainless steel nanopowders. The nanopowders mixed with polymer binder were filled into the PDMS mold. The PDMS mold was in vacuum chamber for

removing the air in the mixed nanopowders. For hardening the mixed powders with bearing shape, the PDMS mold with the mixed nanopowders were in dry oven at 80 °C for about more than 4hrs. And the greenparts of gas bearing was demolded from the PDMS mold and annealed at 400 °C for 2 hrs and at 1250 °C for 2hrs for removing the polymer binder and sintering the nanopowders, respectively.

2.3 Observation of green and sintered parts

Surfaces of green and sintered parts were observed by an optical microscope for investigate structures of green and sintered parts in detail and shrinkage rate.

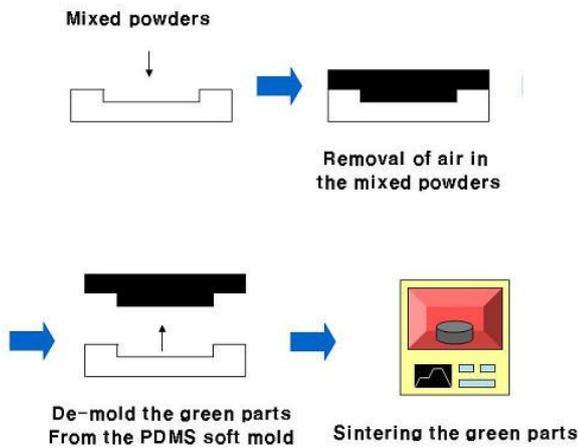


Fig. 2 Process for preparation of nanopowder gas

3. RESULTS AND DISCUSSION

Figure 3 shows the PDMS soft mold for forming the gas bearing greenparts consisting of nanopowders. The gas bearing is very complex and small structures, but the negative pattern for the bearing is very clean in the PDMS mold. After the master mold de-molding process from the PDMS mold, very tiny PDMS films cover some parts of the negative pattern. It is very important to remove them using a solvent. In order to remove the tiny film, we rinsed the PDMS soft mold using solvent (Dibutyl Phthalate). Via this process, we could get the PDMS soft mold with very clean gas bearing pattern.

The greenpart fabricated by filling the 17-4 PH stainless steel powders mixed with polymer binder into the PDMS soft mold is shown in figure 4 (a), and the sintered bearing is shown in figure 4 (b). As described previously, the gas bearing consists of very complicate and minute structures. In the green and sintered parts shown in figure 4, almost all the structures are clearly embodied. When the

greenparts are annealed at 1250°C for 2 hrs, the volume of the bearings decrease due to removal of polymer binder and air in the green parts. Thus, it is very important to investigate the shrinkage rate for fabricate the gas bearing with an accurate size. In order to investigate the shrinkage rate for the gas bearing manufactured by powder metallurgy process, we measured 5 different parts of the green and sintered parts and compare the sizes for greenparts with them for sintered parts. The shrinkage rate for the gas bearing manufactured by the powder metallurgy process was about 11.6%. Generally, the shrinkage rate for a specific structure fabricated by nanopowders is about 10-20%. Shrinkage rate increases with quantity of polymer binder and porosity in greenpart structures. This indicates that the quantity of polymer binder is very sound for fabricate the gas bearing and the porosity of greenparts is not serious.

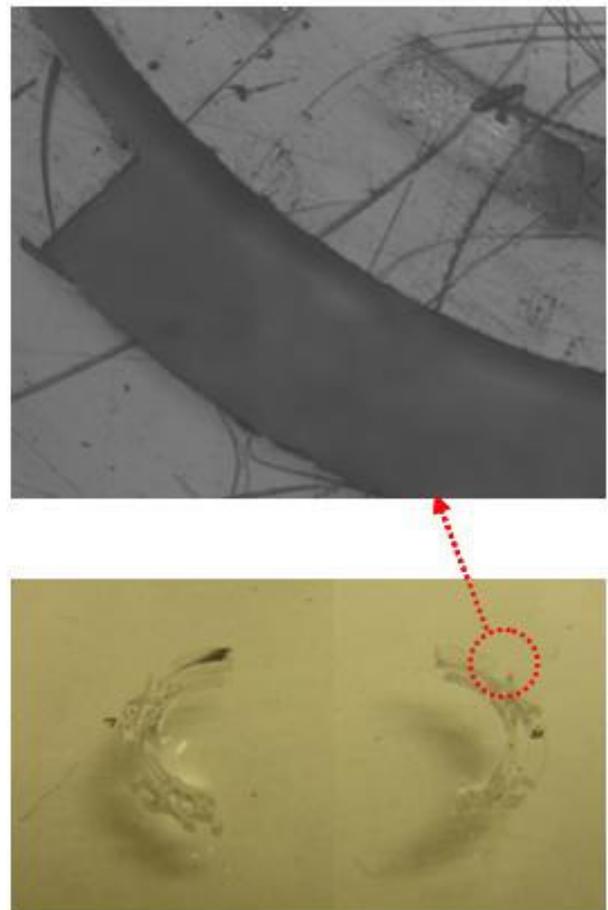


Fig. 3 PDMS soft mold for forming the gas bearing



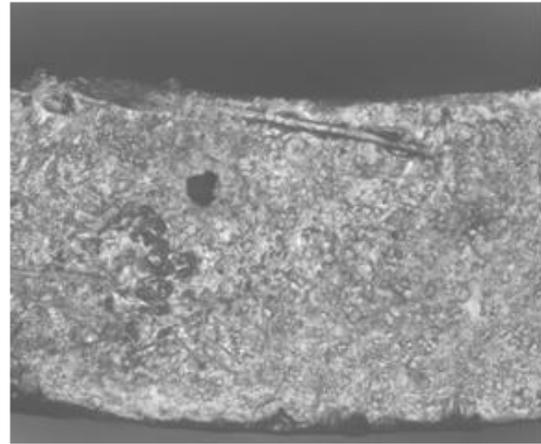
(a) Greenpart



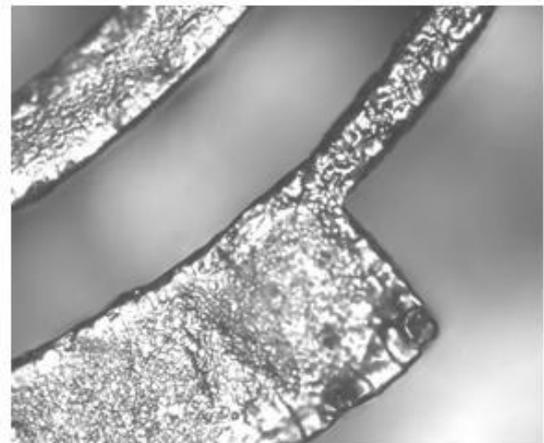
(b) Sintered part

Fig. 4 Green and sintered parts for gas bearing fabricated by powder metallurgy process

Even though the shrinkage rate is sound, porous remained in green parts has significant effects on the size tolerance of the sintered gas bearing. Thus we observe the surface of the green and sintered parts, and the optical microscope pictures are shown in figure 5. As seen in the figure 5, porous was not found in the surface for both parts. But relatively large defects were found in green parts. This is because kinds of particulate pollutants were located in the PDMS soft mold. Consequently, it is concluded that the powder metallurgy process using nanopowders is expected to be applicable to fabricate tiny and complex structures. In order to apply tiny and complex structures fabricated by the powder metallurgy process to the industries, more advanced investigations for mechanical properties(stiffness and sumping), physical properties (hardness, sintered density) is necessary.



(a) Greenpart



(b) Sintered part

Fig. 5 Optical microscope pictures for the surfaces of green and sintered parts

4. CONCLUSION

The gas bearing is so complicate and precision in shape and size that it is very difficult to manufacture it using the generally used machine work. In order to settle the difficulty, we applied the powder metallurgy process to the fabrication of the specially designed very small gas bearings for high rotation speed (600,000RPM) turbo machine. In order to apply the powder metallurgy process to the fabrication of the gas bearing, 4 different steps, such as fabrication of PDMS soft mold for forming the gas bearing, preparation of nanopowder with polymer binder, compaction of the mixed nanopowders into the PDMS mold, and annealing process of greenparts with gas bearing shape, are necessary. By removing the tiny film covering the

embodied gas bearing pattern, very clean PDMS soft mold could be fabricated. The mixed nanopowders consisting of 70 wt.% of 17-4 PH stainless steel nanopowders and 30 wt.% of polymer binder was proper to form the greenparts with gas bearing shape. Annealing process set at 400oC for 2 hrs and 1250oC for 2 hrs was very effective in removal of the polymer binder and enhancement of its hardness. Accordingly, it is concluded that the powder metallurgy process used in this study is expected to be very applicable to the fabrication of small machinery parts with very complicate shapes.

REFERENCES

- [1] Kim J.-S., Jiang K, Chang I. Pressure free fabrication of 3D microcomponents using Al powder, 2006 *Adv. Eng. Mater.* **8**, 38-41
- [2] Kim J-S., Jiang K., Chang I. A net shape process for metallic microcomponent fabrication using Al and Cu micro/nano powders, 2006 *J. Micromech. Microeng.* **16**, 48-52