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Densification Behavior of Iron Powder during Cold Stepped Compaction

C.S. Kang[1, a], S.C. Lee[2,b], K.T. Kim[3,c], O. Rozenberg[4,d]

[1]Department of Mechanical Engineering Pohang University Science and Technology Pohang 790-784, Korea
[2]Department of Mechanical Engineering Pohang University Science and Technology Pohang 790-784, Korea
[3]Department of Mechanical Engineering Pohang University Science and Technology Pohang 790-784, Korea
[4]Bakul Institute for Superhard Materials NAS of Ukraine Kiev 04074, Ukraine
[a]kcs0107@postech.ac.kr, [b]yanus@postech.ac.kr, [c]korean@postech.ac.kr, [d]boris@ism.kiev.ua

Abstract

Densification behavior of iron powder under cold stepped compaction was studied. Experimental data were also obtained for iron powder under cold stepped compaction. The elastoplastic constitutive equation based on the yield function of Shima and Oyane was implemented into a finite element program (ABAQUS) to simulate compaction responses of iron powder during cold stepped compaction. Finite element results were compared with experimental data for densification, deformed geometry and density distribution.

Keywords : cold stepped compaction, densification behavior, finite element analysis

1. Introduction

Many researchers have proposed new processes to fabricate parts with the shape of hollow cylinder. Sivakumar *et al*. [1] produced graded hollow cylinders by using alcohol and slurries containing mullite and molybdenum (Mo) powders by centrifugal molding technique. Nagae *et al*. [2] produced hollow Al alloy and Ni-Cr parts by pulse discharge pressure sintering and compared it with normal solid parts. Recently, Rozenberg *et al*. [3] proposed cold stepped compaction process to produce parts with the shape of hollow cylinder.

The present paper reports on densification behaviors of iron powder during cold stepped compaction. The yield function by Shima and Oyane was implemented into the user subroutine UMAT of ABAQUS. Finite element calculations were compared with experimental data for densification, deformed geometry and density distribution of iron powder under cold stepped compaction. The distributions of hydrostatic pressure and the Mises stress of iron powder under cold stepped compaction were also studied.

2. Experimental and Results

Constitutive equation

A yield function Φ for a porous material can be written as [4]

$$\Phi(\sigma,\bar{\varepsilon}_m^p,D)=\left(\frac{q}{\sigma_m}\right)^2+\left(\frac{p}{\sigma_m f}\right)^2-D^{2n}=0 \quad (1)$$

where $p(=\sigma_{kk}/3)$ is hydrostatic stress, $q(=\sqrt{3\sigma'_{ij}\sigma'_{ij}/2})$ is the effective stress and σ_m is the equivalent stress of a matrix material. Also, *n*, *D* and *f*, respectively, denote a material constant, relative density and a function of relative density.

Materials, Specimens and Uniaxial compression

An iron powder with an average particle size of 80 μm was used in this work. We obtained properties from solid iron produced by hot isostatic pressing (HIP) of iron powder in this work.

Uniaxial stress-stain responses of the matrix material of iron powder and steel for the sleeve were obtained from uniaxial compression by using an MTS servohydraulic testing machine.

$$\text{Steel: } \sigma_m = 187 + 640.9(\bar{\varepsilon}_m^p)^{0.38551} \quad (2)$$

$$\text{Iron powder: } \sigma_m = 183 + 508.8(\bar{\varepsilon}_m^p)^{0.39641} \quad (3)$$

The curves represent the relationship between the flow stress and the logarithmic strain for iron powder matrix material and steel under uniaxial compression.

Cold stepped compaction

To fabricate the iron preform, iron powder was poured into a die, then powder was compacted by double action pressing under the axial stress. After double action pressing, the iron preform with a sleeve inside was fitted in a die (Fig.1). Then the broach was inserted into the sleeve. Thus, iron powder is compacted due to sleeve deformation in the radial direction.

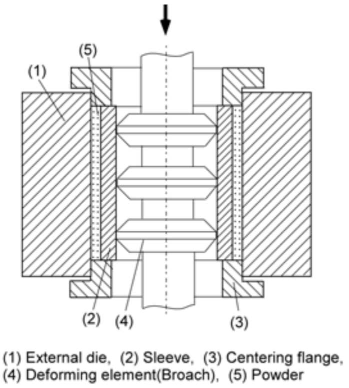
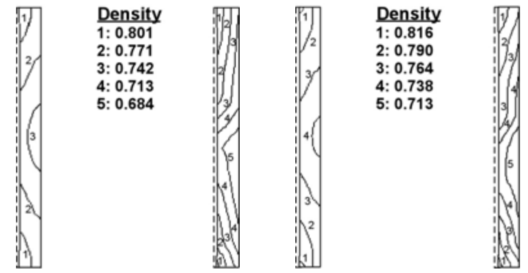
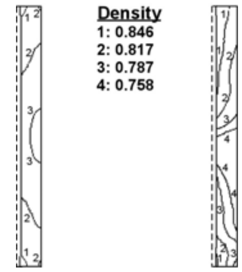


Fig. 1. A shematic drawing of a fixture for radial pressing.



(FEM) (Experiment) (FEM) (Experiment)

(a) 1.10 mm (b) 1.50 mm



(FEM) (Experiment)

(c) 2.25 mm

Fig. 2. Comparisons between finite element calculations and experimental data for relative density contour plots of an iron powder compact under cold stepped compaction when radial displacement of the sleeve is (a) 1.10 mm, (b) 1.50 mm and (c) 2.25 mm.

Fig. 2 shows comparisons between experimental data and finite element calculations for relative density contour plots of iron powder compacts under cold stepped compaction. In Fig. 2, we observe that the agreement is good between the finite element calculations and experimental data for iron powder compacts under cold stepped compaction. Relative density shows the highest at the inner corner and the lowest at the outer middle region of the iron powder compact.

In deformed shapes of iron powder compacts, we observe that the thickness of the upper and lower region is thicker than the middle's. This is caused by the difference in relative density between the upper and lower corner and the middle region of the preform under double action pressing and by the effect of friction between the powder compact and the centering flange under cold stepped compaction.

3. Summary

This paper reports on densification behavior of iron powder during cold stepped compaction. Experimental data were compared with finite element results by using the yield function of Shima and Oyane.

Finite element calculations by using the yield function of Shima and Oyane agree reasonably well with experimental data for iron powder under cold stepped compaction.

Relative density is observed the highest at the inner corner and the lowest at the outer middle region of the iron powder compact.

Due to the difference of relative density of the preform and the effect of friction between the iron powder compact and die during cold stepped compaction, the thickness of the powder compact in the radial direction becomes thinner as going from upper and lowder to middle.

4. References

1. R. Sivakumar, T. Nishikawa, S. Honda, H. Awaji and F.D. Gnanam, J. Eur. Ceram. Soc. 35 No.23 (2003) 765-772.
2. T. Nagae, J. Jpn Soc. Powder Metall. 45 (1998) 169-171.
3. O. Rozenberg, J.A. Techanov and S.E. Seikin, On Some Regularities of the Surface Plastic Deforming at Deforming Broaching, Universum, Tula State University, Keiv, Ukraine. (2004)
4. S. Shima and M. Oyane, Int. J. Mech. Sci. 18 (1976) 285-291.