CONSTITUTIVE MODELING OF THE DENSIFICATION OF METAL POWDER DURING COMPACTION

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Powder metallurgy, or P/M, is a process for forming metal parts by compacting and heating metal powders to just below their melting points. Although the process has been existed for more than 100 years, over the past quarter century it has just become widely recognized as a robust process for producing high-quality parts for a variety of important applications. This success is due to the advantages the process offers over other metal forming technologies such as forging and metal casting, advantages in material utilization, shape complexity, near-net shape dimensional control, among others. The powder compaction is the most critical stage in the P/M manufacturing process. Final part density, homogeneity, and strength are highly affected by this crucial operation. According to Khoei and Lewis [1], a successful model for powder compaction process should reflect the frictional and compressible-densification yielding characteristics of the powder.

In this paper we present a microstructure-plasticity model mixed with a cap-plasticity theory to perform numerical simulation of powder metallurgy compaction process. This model consists of mechanical constitutive equations of the plastic deformation of the powder aggregate and the deformation-induced hardening of the particles. Constitutive equations are developed in a macroscopic continuum framework in which we assume the porous medium as a macroscopically equivalent isotropic, homogenous continuum with the relative density (or void volume fraction) as a scalar internal state variable. The anisotropic effects due to orientation and shape of the grains or voids are assumed to be small and are neglected at this moment. The elastic domain is defined by a set of two yield surfaces, the failure envelope and isotropic hardening cap surfaces of the Modified Drucker-Prager/Cap model originally proposed by DiMaggio and Sandler [2]. To capture the different microstructure and mechanical changes during the densification process, the density distribution is dependent on the combination of many factors such as geometrical shape, mechanical properties of the powder, and powder-tool frictional behavior [3].

The model is implemented into a finite element code through user-defined material routines. Comparison and validation with experimental data are shown to demonstrate that the densification behavior can be accurately describe during the compaction process.

References

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