Available online at www.sciencedirect.com
ScienceDirect
Acta Metall. Sin. (Engl. Lett.) Vol.20 No.4 pp277-283 Aug. 2007

ACTA
METALLURGICA SINICA
(ENGLISH LETTERS)
www.ams.org.cn

DYNAMIC COMPACTION OF PURE COPPER POWDER USING PULSED MAGNETIC FORCE

H.P. Yu and C.F. Li*
National Key Laboratory for Precision Hot Processing of Metals, Harbin Institute of Technology, Harbin 150001, China
Manuscript received 22 November 2006; in revised form 16 January 2007

The compaction of pure Cu powder was carried out through a series of experiments using dynamic magnetic pulse compaction, and the effects of process parameters, such as discharge energy and compacting direction, on the homogeneity and the compaction density of compacted specimens were presented and discussed. The results indicated that the compaction density of specimens increased with the augment of discharge voltage and time. During unidirectional compaction, there was a density gradient along the loading direction in the compacted specimen, and the minimum compaction density was localized to the center of the bottom of the specimen. The larger the aspect ratio of a powder body, the higher the compaction density of the compacted specimen. And high conductivity drivers were beneficial to the increase of the compaction density. The iterative and the double direction compaction were efficient means to manufacture the homogeneous and high-density powder parts.
KEY WORDS *magnetic pulse compaction; copper powder; compaction density; electromagnetic forming*

1. Introduction

The powder compaction technology is an advanced method to manufacture modern mechanical parts that exhibit high efficiency, high quality, high precision, and reduced energy consumption[1]. The optimization and development of powder metallurgy and compaction technology has become the hotspot of research in powder metallurgy industry, and the key to promote the application and development of the powder material is to develop an efficient technology to produce powder parts that exhibit high density, high performance, and nearly net shape[2,3].

An efficient method to produce high-density powder parts is compacting powder materials using intensive impact load[4]. DMC (dynamic magnetic compaction) is a method that is used to carry out the compaction of powder using dynamic magnetic pulse force and can be used to manufacture metal powder, ceramic powder, composite powder *etc.*[5,6]. With respect to the energy control and the efficiency of

*Corresponding author. Tel.: +86 451 86413970.
E-mail address: haipingy@hit.edu.cn (H.P. Yu)

production, DMC is found to be superior to other powder compaction methods, and it also overcomes the shortcomings of the explosive compaction in terms of safety and control of the explosive energy. Therefore, the method can be widely used to compact ultrafine powder[4,5].

The DMC technology is playing an important role and is becoming a very promising method in the consolidation of superconductive materials[7] and in the preparations of nanopowder compact[8], and the optimally processed compacts showed fine and homogeneous bulk structure without any grain growth. The method has been used for the preparations of the metal-glass composite. The composite, magnetically consolidated at 450°C, exhibited a remarkably high room-temperature tensile ductility of 28% combined with high tensile strength of 1.1GPa[9]. The studies in Refs.[10,11] show that the DMC method has been applied to the compaction of a dry nanopowder to densities up to 0.5–0.7 of the theoretical one at 0.1–1.6GPa, yielding grains with submicron (0.1–0.3μm) dimension.

For the high-voltage DMC, the discharge voltage is thousands volts in comparison with the DMC with low voltage (discharge voltage is only hundreds to more than one thousand volts)[3,12]. Due to the modern insulating ability and control technology, the operators need not be very concerned about processing safety. The magnetic cushion effect must be considered in DMC with large capacitance (up to thousands microfarads) of the low-voltage DMC because the opposite magnetic force is harmful to the driver movement and the loss of the magnetic energy will not be negligible during the powder compaction. The high-amplitude and high-frequency stress wave, derived from the magnetic force with high voltage and low capacitance, may be beneficial to the powder compaction.

In this study, a series of compacting experiments of pure copper powder has been conducted using DMC. Effects of discharge energy, aspect ratio of powder body (the ratio of diameter to height), drivers, compacting direction, and other factors on the compaction density of the compacted specimens are investigated. The results can provide guidelines to the researches on the compaction of many types of ultrafine powders by DMC.

2. Experimental Facility and Setup

The DMC experiments (Fig.1) were carried out using electromagnetic forming machine at Harbin Institute of Technology, China. The parameters of the machine are shown as follows: type EMF-56, max. discharge energy 56.0kJ, highest discharge voltage 30kV, capacitance 192μF, resistance of circuit 7.5mΩ, and inductance of circuit 0.33μH. The microstructure of the compacted specimens was observed under electron microscope (Hitachi S-570). Granularity of the copper powder used is 50μm. Fig.1 shows the schematic of the experimental setup. DMC involves passing an electrical current pulse through the pancake coil placed in proximity to the driver. The electric pulse generates a high magnetic field around the coil that induces an eddy current in the driver as well as an associated secondary magnetic field. The two fields are repulsive and the forces of magnetic repulsion push the driver, with the amplifier and punch moving downward together. And then the power body is compacted by the punch, which is embedded in the amplifier. The amplifier, the punch, and the die are made up of 45 steel and are not heat treated. The pancake coil is made up of rectangular section copper wire, whose dimensions are shown as follows: outer diameter 86mm, coil height 30mm, wire width 5mm, wire height 10mm, interval of turns 0.5mm, and 15 turns.

The main aim of this article is to study the density of the compacted specimens by dynamic magnetic pulse force. Therefore, the compaction density is selected as the evaluating indicator. The density