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High velocity compaction of ferrous powder

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ABSTRACT

Water atomized pure iron powder was pressed by high velocity compaction technology. The influences of impact velocity on green density, shock wave, compacting and ejection forces, radial springback and strength of compacts were studied. Cross-section images of green compacts were observed by scanning electron microscopy (SEM). A computer controlled universal testing machine was used to measure the green strength of compacts. The results show that impact velocity intensively affects the green density of specimen. As impact velocity increases, the green density and the strength of compacts increase gradually, especially the green strength. In addition, the compacting force and the actuation duration of shock wave increase obviously with the augment of impact velocity, which leads to densification of powder body. No specific relation was found between the ejection force, the radial springback and the impact velocity.

1. Introduction

To prepare powder metallurgy (PM) parts with high density, high strength and high precision has become the research hotspot and the development trend in PM industry. Densification influences material properties considerably, and mechanical properties in particular. New production methods for higher densities in combination with suitable materials and heat treatment open the way to many new applications in PM industry, such as valve seats, hubs, gears, flanges, connecting rods etc [1]. Recent developments, such as explosive compaction, hot isostatic pressing (HIP), surface densification (SD), warm compaction (WC), high velocity compaction (HVC), etc., all contribute to creating PM components with improved mechanical properties. However, the explosive compaction process is limited due to its difficulties concerning explosive used and low productivity. For many high performance applications, HVC single compaction is the most attractive option from a cost/performance point of view [1]. HVC technology could be the next breakthrough in the PM industry for cost-effective, high-density parts [2].

Components production by HVC process has the same steps as uniaxial die-pressing, but the key difference is that the compaction stage of HVC can be 500–1000 times faster, and the hammer speed and the compacting force are higher. For HVC, powder is compacted by high-energy impact delivered by a hammer that the mass ranges from 5–1200 kg traveling at speeds of 2–30 m/s. The powder is compressed in less than 20 ms and further densification is possible by adding multiple impacts as short as 300 ms after each other [3]. Other characteristics of HVC technique are high density, uniform density distribution, low springback and low ejection force and so on.

Various kinds of powder materials were studied using HVC process: iron based powders [3–8], stainless steel powder [9,10], ceramics [11] and polymers [12,13] etc. However the investigators didn't report the effect of impact velocity. In our study, iron powder was pressed by HYP35-7 High Velocity Compaction Machine. How impact velocity affects green density, shock waveforms, compacting force, radial springback and the properties of compacted body etc. was also discussed.

2. Experimental procedures

2.1. Raw material

Water atomized pure iron powder was used due to its extensive application potential. Characteristics and morphology of the powder were shown in Table 1 and Fig. 1 respectively. Before compaction it was mixed with 0.5 wt.% zinc stearate at room temperature and the theoretical pore free density was 7.568 g/cm^3, the pore free density of 7.8 g/cm^3 after sintering. During compaction the mass of filled powder was identical, 130 g.

2.2. Instrument

All specimens were pressed on HYP35-7 High Velocity Compaction Machine as shown in Fig. 2a, which had a maximum capacity of 7 kJ per stroke and the hammer weighing 135 kg, designed by

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Table 1
Characteristics of water atomized pure iron powder

Apparent density	Tap density	Flowability	Particle size distribution (%, in volume)			
(g/cm^3)	(g/cm^3)	(s/50 g)	<46 μm	46–76 μm	76–150 μm	>150 μm
3.10	3.92	25.4	35.1	33.5	25.3	6.1

Hydropulsor Company, Sweden. The die of the machine was floating, whereas the lower punch was mechanically fixed. The placement of the hammer was measured by a position sensor which was located in the impact unit of the machine. Compacting and ejection forces were measured by the load-cell and the force sensor, respectively. The sampling rate of the load-cell was 100 kHz, while it was 1000 Hz for the ejection force measurement. The load-cell, which was a high speed measuring system obtaining very sharp and short peaks, was located on the lower surface of the lower punch, as shown in Fig. 2b. The ejection force sensor was located in the hydraulic system.

The schematic diagram of compaction process was shown in Fig. 2b. It has the same steps as conventional compaction, i.e. filling powder, pre-compacting, compacting and ejecting specimen from die, and the tool design is similar. During the compaction, the equipment was controlled by a computer, and impact velocity could be varied by adjusting the stroke length. The mass of filled powder and the stroke length were input the computer each compaction. The ring samples, with the outer and inner diameters were 60 mm and 30 mm respectively, were prepared as shown in Fig. 3. Three compacts were produced at an impact velocity.

2.3. Test methods

Densities were measured with Archimedes' law. Diameters of samples were measured by a micrometer after demould, five measured values for every specimen. The morphologies were observed with scanning electron microscopy (SEM).

Impact velocities can be calculated according to Eq. (1):

$$v = \sqrt{2Fh/m} \tag{1}$$

where v is the impact velocity, m/s; F is the hydraulic oil pressure applied on the hammer, kN; h is the stroke length which is the distance between start position and impact position, mm; m is the mass of the hammer, kg. For the HYP35-7 High Velocity Compaction Machine, the F is 76.087 kN and the m is 135 kg. Due to F and m are constants, impact velocities are easily adjusted by varying the stroke length, h.

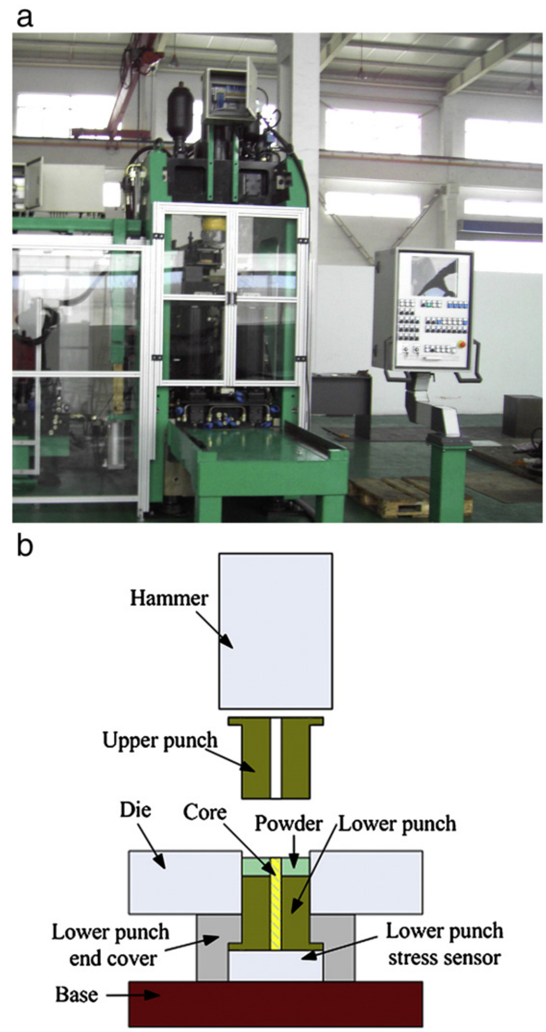

Fig. 2. HYP35-7 High Velocity Compaction Machine (a) and the schematic diagram of compaction process (b).

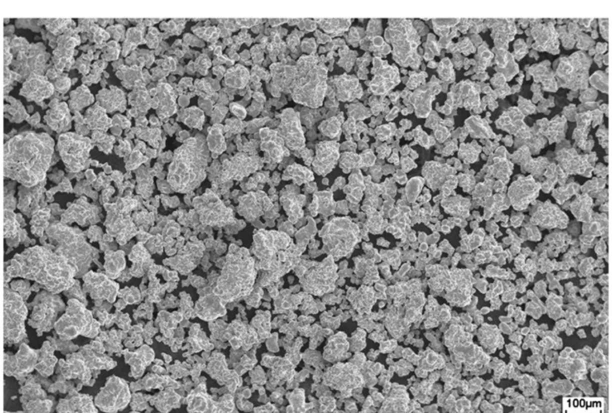

Fig. 1. Image of iron powder.

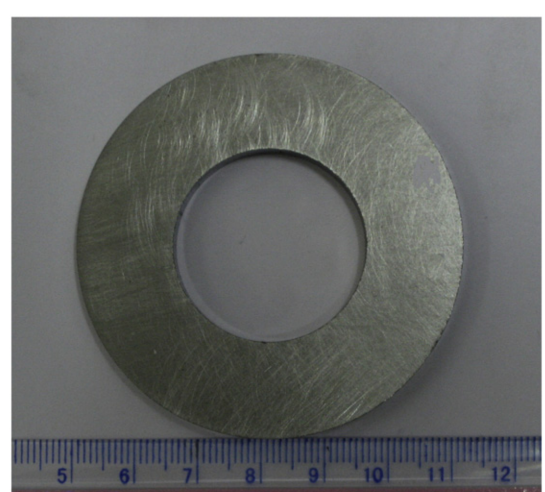

Fig. 3. Image of the ring specimen.