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Short communication

Microstructure and magnetic properties of high density P/M pure iron

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ABSTRACT

P/M high density pure iron with excellent magnetic properties was prepared by the combination of high density forming technology and heat treatment. The effects of sintering parameters on microstructural evolution and magnetic properties of sintered pure iron were investigated. The results showed that the grain sizes of the samples increased with increasing sintering temperature and time, facilitating the enhancement of permeability and the decrease of coercive force. When the specimens were sintered at 1450 °C for 4 h, the maximum permeability reached 10,746, and saturation induction of 1.85 T and coercive force of 50.12 A/m were achieved.

1. Introduction

Pure iron is a kind of excellent soft magnetic material, which has a high saturation induction ($B_s = 2.15$ T) and low cost, which is widely used in the electronically controlled systems of automobiles, such as ABS sensor rings and pump angle sensors [1,2]. Conventional soft magnetic pure iron was fabricated by the methods of casting and machining. However, mass production of the miniaturization parts with complex shape was greatly limited due to the long production period, low efficiency and high cost. Powder metallurgy is a near-net shaping technique, which is suitable for the production of minimize, complex shaped pure iron parts [3,4]. The main disadvantage for P/M pure iron is its low density which degrades the magnetic properties. The density, maximum permeability and coercive force of the reported P/M pure iron were usually 7.2 g/cm^3, 3500, 199 A/m respectively, which were much lower than that of wrought pure iron ($\rho = 7.87$ g/cm^3,$\mu_m = 12000–16700$, $Hc < 32$ A/m [5–8]. The detail comparison of magnetic properties of powder metallurgy (P/M), metal injection molding (MIM) and wrought pure iron parts with different density are shown in Table 1.

In order to further enhance the magnetic properties of P/M pure iron, this work provides a systematic study on the correlation between microstructural characteristics (porosity and grain size) and magnetic properties of high density pure iron fabricated by PM with water atomization iron.

2. Experimental

Water atomization iron powder (LAP100.29) provided by Laigang Group was selected as raw materials. The raw materials were composed of 60 wt.% coarse particle (−100 mesh), 25 wt.% medium particle (−200 mesh) and 15 wt.% fine particle (−400 mesh). Powder mixture with multi-modal size distribution was used in order to improve the packing density. The characteristics and the morphology of the obtained powder mixture were shown in Table 2 and Fig. 1, respectively. The powder was mixed with 0.5 wt.% binder and then presintered at 700 °C for 1 h to improve the purity and the plastic deformation ability of powder, calling plasticizing treated powder. Subsequently, ring shaped specimens with the outside diameter of 33.15 mm, inside diameter of 22.12 mm and the height of 6.00 mm and with the density of 7.67 g/cm^3 for magnetic measurement were compacted by a YA32-63 type hydropress under the pressure of and 1000 MPa. The specimens were then sintered in the temperature range of 1200–1480 °C under hydrogen atmosphere.

The densities of the samples were measured by the Archimedes method. Microstructures of the sintered samples were observed on MeF3A metallurgical microscope. Grain size was measured from optical microstructure using image tool 3.0. Observation of pore size and shape was conducted on S-360 scanning electronic microscope (SEM). For the measurement of the magnetic properties, ring shaped samples were tested on the NIM-2000S DC soft magnetic properties measuring device. The content of carbon,

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Table 1
Properties obtained for pure iron by P/M, MIM and precision casting [5–9].

Preparation methods	Typical density/(g/cm^3)	B_s/T	Hc/(A/m)	μ_m
P/M	6.8/7.2	1.0/1.3	119.4/199	1800/3500
MIM	7.49/7.72	1.54/1.61	143/159	2790/3840
Wrought	7.87	2.15	<32	12000/16700

Table 2
Characteristics of the modified iron powder.

	Apparent density (g/cm^3)	Tap density (g/cm^3)	Flowability (s/50 g)	Particle size (μm)
Pure iron	3.32	3.87	26.4	70–150

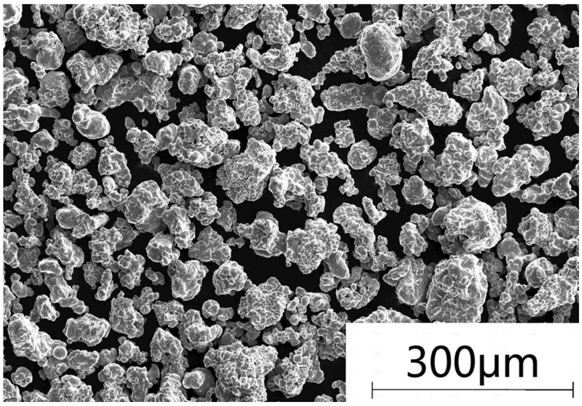

Fig. 1. Morphology of the modified iron powder.

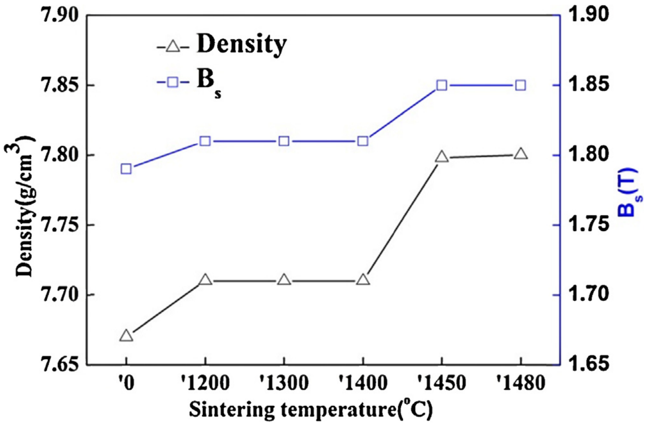

Fig. 2. Effect of sintering temperature on density and B_s.

nitrogen and oxygen was determined by NCS CS-2008 and ON-3000 carbon, and nitrogen–oxygen analyzer.

3. Results and discussion

3.1. Effect of sintering temperature

Fig. 2 shows the effect of sintering temperature on density and saturation induction (B_s) of the specimens sintered at 1200–1480 °C for 1 h. It is observed from Fig. 2 that the density reaches 7.71 g/cm^3 after sintering at 1200 °C. There is little increase in density when the sintering temperature ranged between 1200 °C and 1400 °C. In the case of 1450 °C, the density reaches 7.80 g/cm^3 in a very short time. When the sintering temperature (1450 °C) is higher than 1393 °C, allotropic transformation of pure iron occurred, from γ-Fe to δ-Fe [10]. This phase transformation enhances the diffusion of atoms, and assists in the rearrangement

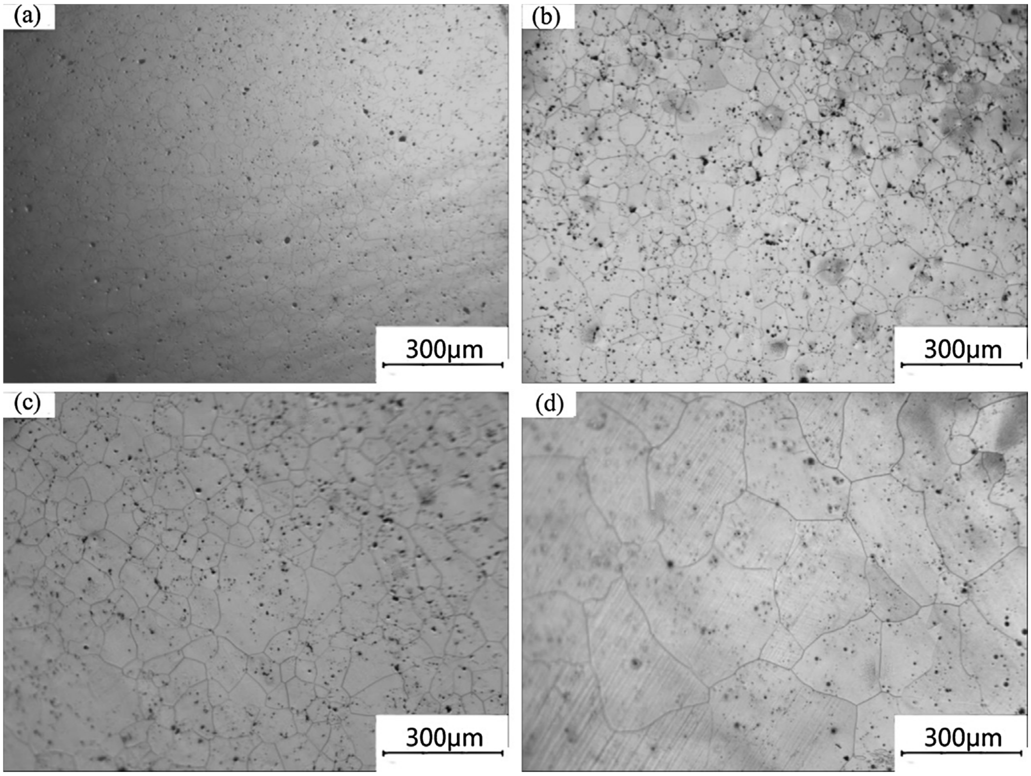

Fig. 3. Effect of sintering temperature on microstructure: (a) green compact (b) 1200 °C, (c) 1300 °C, and (d) 1450 °C.