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Porosity Behaviour of Insulated Iron Powder Compounds

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The goal of the present paper is to determine the porosity behavior of new development insulated iron powder compounds without and with different additions of aluminum alloy Alumix 321 (5 and 10 wt%). A significant disadvantage of PM processing is the presence of porosity. Pores act as crack initiators and, due to their presence, the distribution of stress is inhomogeneous across the cross-section and leads to the reduction of the effective load bearing area. Quantitative image analysis of investigated material treats pores as isolated plane two-dimensional objects in solid surroundings. To describe the dimensional and morphological porosity characteristics, the dimensional characteristic D_{circle} and the morphological characteristics f_{shape} and f_{circle} were explored. Both the morphology and the distribution of pores shows a significant effect on the cold welding or appropriate bonds between adjacent particles.

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1. Introduction

Iron insulated powder compound (IIPC) belong to the soft magnetic material and represent a potential as a new material in electrical or magnetic technological applications.

In the past activity [1–4], the attention has been devoted to select a material that would have mechanical advantages under heat treatment at the reported temperature. Usually for parts with complicated shapes, final machining operations are frequently necessary. According to the [5], applied mechanical work produces dislocations and stress fields at the component surface. This machining operation causes increasing the coercive force and remanence and raises the level of hysteresis losses. Al–Mg–Si–Cu alloy, as the additional component to the IIPC, induces plasticity to the matrix powder. The magnetic properties are affected by the presence of porosity. It is well-known [6–10] that pores act as crack initiators and, due to their presence, the distribution of stress is inhomogeneous across the cross-section and leads to the reduction of the effective load bearing area. Plastic deformation during the pressing pressure results in higher iron losses. The porosity development is the main goal of the presenting paper.

2. Experimental conditions

The IIPC material (Somaloy 1P 700, Höganäs AB) was blended with different amounts of aluminium alloy (ready-to-press aluminium based powder Alumix 321: Al — 0.95 wt% Mg — 0.49 wt% Si — 0.21 wt% Cu — 0.07wt% Fe — 1.6 wt% lubricant, Ecka Granules). Powder mixtures were homogenized using a laboratory Turbula mixer for 20 min. Three systems were prepared: pure IIPC (A), IIPC with the addition of 5 wt% aluminum alloy (B) and 10 wt% aluminum alloy (C). Unnotched impact energy $55\times10\times10$ mm^3 specimens were obtained using a 2000 kN hydraulic press applying pressure at the 400, 600, and 800 MPa. Densities were evaluated using the water displacement method (Archimedes principle), according to the ASTM B962–08 standards. The microstructural characterization and porosity behavior were performed on unetched specimens using an optical microscope LEICA MPEF4 equipped with an image analyzer and SEM JEOL 7000F. The porosity was classified with the use of a Leica Qwin image analysis system concerning the area and mean diameter of the pores. Optical characterization was carried out on the minimum of 600 pores as an object counts. For the determination of porosity characteristics, 100× magnification for specimens was used.

Both the morphology and the distribution of pores have a significant effect on the mechanical behavior of PM materials. To describe the dimensional and morphological porosity characteristics, the dimensional characteristic D_{circle} and the morphological characteristics f_{shape} and f_{circle}, as well as geometrical aspects, have been identified as the most effective parameters [2]. The description of the parameters is reported as follows:

— D_{circle} is the diameter of the equivalent circle that has the same area as the metallographic cross-section of the pore.

— f_{shape} and f_{circle} reflect the form of the pores.

The f_{shape} represents pore elongation, while f_{circle} depicts pore profile irregularity. Both parameters range between 0 and 1, being equal to unity for a circular pore [4–9].

3. Results and discussion

The morphology and distribution of porosity show (Table I, mainly on the base of D_{circle}) that increasing pressing decreases the pore dimension in IIPC material from

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14.73 μm at 400 MPa to the 11.57 μm at 800 MPa, respectively. On the other hand, materials with aluminum addition reveal that the pore diameter increases with increase of the pressing pressure from 10.4 μm at 400 MPa to the 13.18 at 800 MPa for material B, respectively. Also, for the material C from 12.59 μm at 400 MPa to the 13.92 μm at 800 MPa, respectively. The pore structure (f_{shape} and f_{circle}) shows that pores have round-like shapes and represent regarding shape and distribution non-problematic point of view for a mechanical response.

TABLE I

The dimensional and morphological porosity characteristics.

System	Pressure [MPa]	D_{circle} [μm]	f_{shape}	f_{circle}
A	400	14.73	0.4529	0.6050
A	600	14.56	0.4516	0.6102
A	800	11.57	0.4478	0.6070
B	400	10.49	0.4186	0.5810
B	600	12.83	0.4988	0.6062
B	800	13.18	0.4554	0.5419
C	400	12.59	0.4287	0.5124
C	600	13.20	0.4234	0.5570
C	800	13.92	0.5107	0.6078

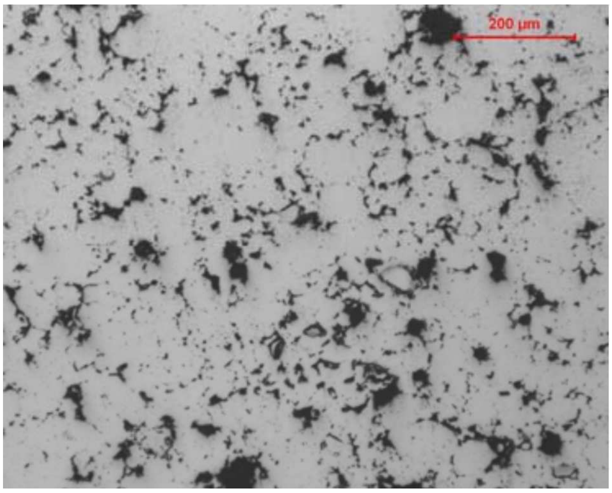

Fig. 1. Microstructure of system A, 800 MPa.

Porosity reduces strength and ductility. Hadrboletz and Weiss [11] suggested that mainly interconnected porosity reduces macroscopic ductility, also causes an increase in the localization of strain in the relatively small regions between particles, while isolated porosity results in more homogeneous deformation [12]. It is clearly presented in Figs. 1–3 that the increase of aluminum alloy content in the iron matrix increases the distribution and volume of aluminum particles. Figures 4–6 after the reduction for identification of porosity structure shows that the pores are oriented near or surrounding the aluminum particles. Also, the distribution of pores is inhomogeneous, because of the broad distribution of particle sizes in the powder mixture, resulting in pore clusters where strain localization [13] may also take place. The IIPC

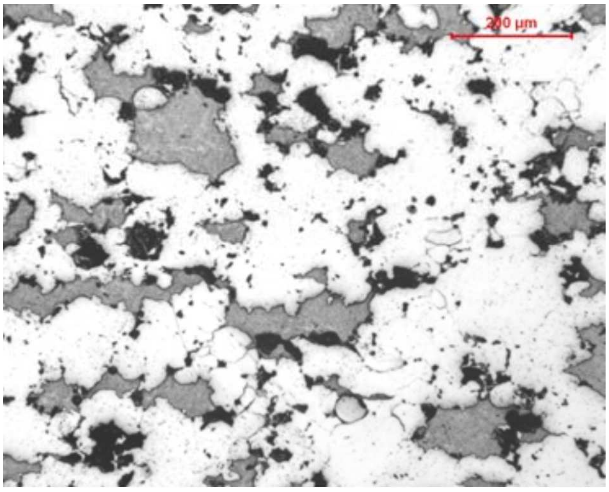

Fig. 2. Microstructure of system B, 800 MPa.

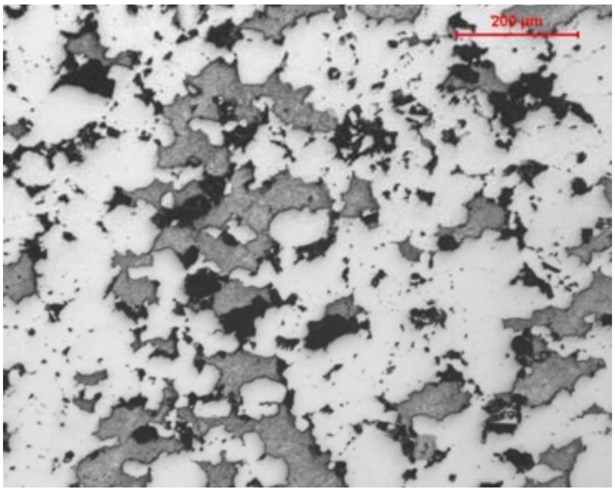

Fig. 3. Microstructure of system C, 800 MPa.

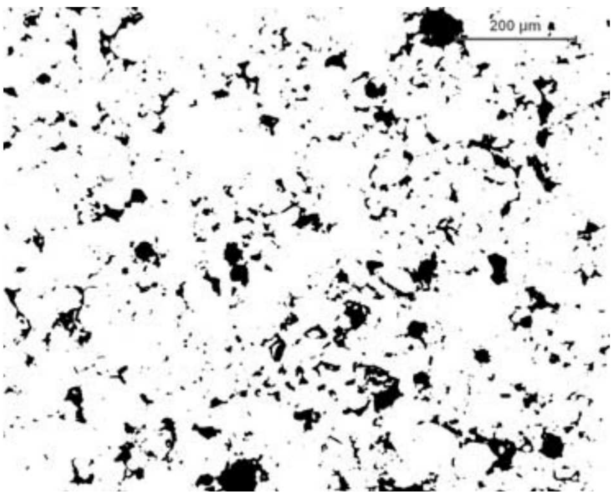

Fig. 4. Microstructure of system A, 800 MPa, after software rendering.

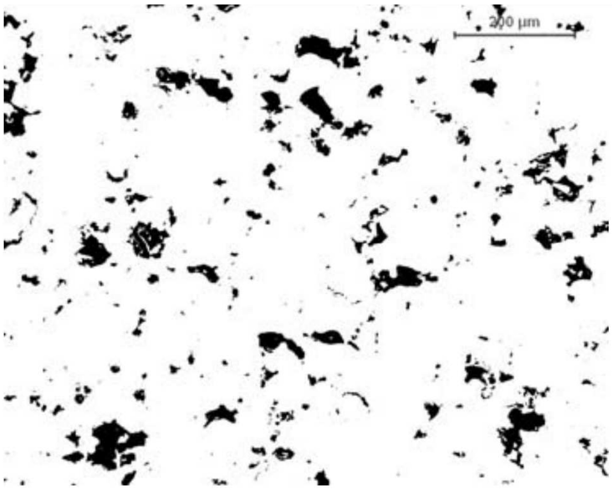

Fig. 5. Microstructure of system B, 800 MPa, after software rendering.

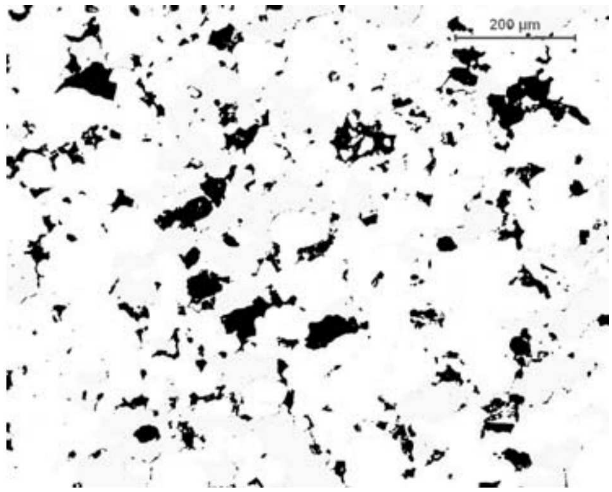

Fig. 6. Microstructure of system C, 800 MPa, after software rendering.

cannot be sintered since each particle has to be electrically insulated from the other one [14]. Therefore, the cold welding or appropriate bonds between adjacent particles was strongly influenced by pore sizes as well as pore distribution. Strong bonds were necessary for the achieving of desirable strength and ductility.

4. Conclusions

1. Regarding porosity, both the morphology and the distribution of pores shows a significant effect on the cold welding or appropriate bonds between adjacent particles.

2. Regarding microstructure, with increase aluminum alloy content in iron matrix increase the inhomogeneous distribution of pores, resulting in pore clusters.

Acknowledgments

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