Effect of Carbon Addition and Sintering Temperature on Densification and Microstructural Evolution of Sinter-Hardening Alloys Steels

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Abstract

In all conventional sintered PM products, the pores present are of two types, primary and secondary. Primary pores forming during compaction and latter during sintering, due to penetration of formed liquid through the matrix grain boundary. Effect of carbon addition on diffusion of Cu in SH737-2Cu system was investigated. After compaction and transient liquid phase sintering at 1120°C and 1180°C, samples were characterized for densification, showing rise in sintering density and reduction in swelling on carbon addition. Quantitative microstructural characterization (shape factor and pore size) revealed bimodal distribution for 0% carbon, more rounded pores for 0.9% carbon and higher sintering temperature, and pore coarsening at higher sintering temperature.

Key Words : Transient Liquid Phase sintering; SH737-2Cu alloys; Shape Factor and Pore Size Distribution; Pore coarsening

1. Introduction

One of the most common alloying elements used in ferrous powder metallurgy is Copper. Presence of Copper during liquid phase sintering results in compact swelling. This phenomenon has been mostly observed and extensively investigated steel containing less than 20 wt% Cu [1,2]. Kayesser et. al. determined the molten copper penetration through grain boundaries is the greatest contributor in the swelling phenomenon. Dilatometric studies of Fe-C-Cu found the large expansion associated with the Copper growth phenomenon decrease with increasing Carbon content [3].

Pore acts as a stress concentrator and plays an important role in material failure. Formation of secondary pores at the site of original Cu particles is an inevitable consequence of transient liquid phase sintering. Primary porosity is formed during compaction and its size depends on compaction pressure and powder size distribution. Secondary porosity's size and morphology strongly depends on Cu powder size, its homogeneity and sintering temperature.

2. Experimental Procedure

For present investigation, two partially prealloyed powder mixtures were made by a proprietary process developed by Hoeganaes Corp viz.

(a) Fe, 1.4% Ni, 1.25% Mo, 0.42% Mn, 2%Cu : SH737-2Cu
(b) Fe, 1.4% Ni, 1.25% Mo, 0.42% Mn, 2%Cu, 0.9C : SH737-2Cu-0.9C

Powders were pressed at 600 MPa in a 50 tons uniaxial hydraulic press (APEX construction Ltd, UK) to obtain cylindrical pellets (16 mm diameter and 6 mm height). The green compacts were dewaxed in a tubular SiC furnace under N_2-$20H_2$ atmosphere. All the green samples were delubed at 850°C for 30 min. Then the compacts were sintered at 1120°C and 1180°C respectively for 30 min in a tube furnace, with SiC heating element, in N_2-$20H_2$ atmosphere.

After observing densification, sintered samples were mounted and wet polished by cloth polishing using a suspension of 1μm and 0.03μm alumina, for microstructural analysis. At the same time, some basic parameters were determined from quantitative analysis like Shape Factor, pore fraction and Pore size distribution by calibrated image analysis.

$$\textbf{Shape factor} = 4\pi A/P^2$$

where, A = area of pore, P = circumference of the pore

3. Results

The sintering density is observed to vary marginally on addition of carbon. It is seen to drop slightly as sintering temperature increases.

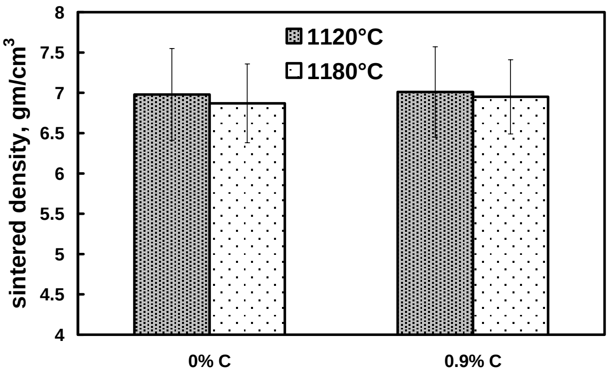


Fig. 1. Effect of sintering temperature and carbon addition on sintering density (gm/cc)

For 0% C In the absence of carbon, we obtain swelling due to the diffusion of copper. As amount of carbon is increased, the sintered density is observed to rise and swelling reduces (a less negative value of densification). Carbon hinders “Copper Growth” increasing in dihedral angle between Fe and Cu.

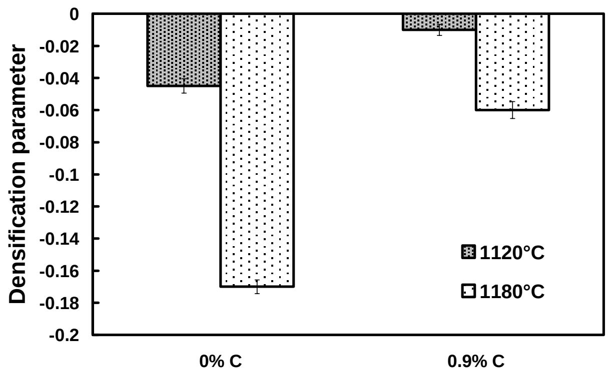
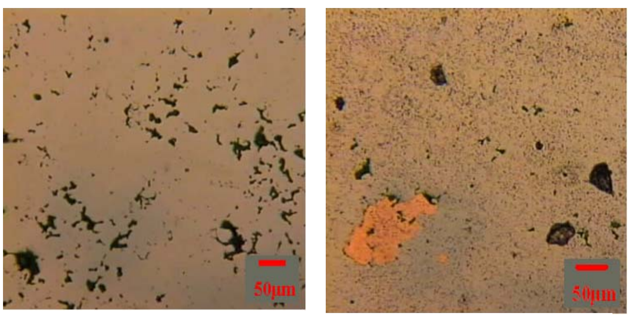


Fig. 2. Effect of sintering temperature and carbon addition on densification parameter.

We obtain a bimodal shape factor distribution in the case of 0%carbon, primarily due to presence of both primary and secondary porosities (right peak is for the primary pores and the left peak for the secondary pores). We obtain a pore volume % varying between 11% to 13%.



0%carbon 0.9% carbon

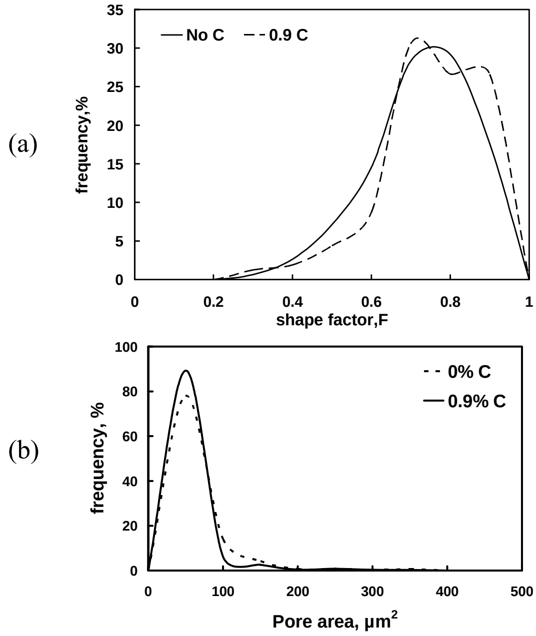


Fig. 3. (a) Shape factor distribution, (b) Pore size distribution for a sintering temperature of 1120°C.

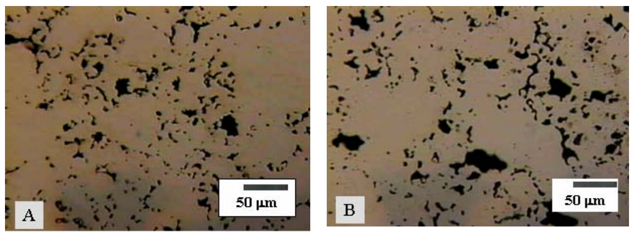


Fig. 4. Optical Microstructures showing pore coarsening occurring at higher sintering temperature (B : 1180°C).

4. Summary

Carbon hinder Copper Growth. We get a bimodal shape factor distribution for 0% C. Overall irregularity of mass of pores decreases with increasing sintering temperature. more rounded pores for 0.9% C and higher sintering temperature, and pore coarsening at higher sintering temperature.

5. References

1. C. Durdallar, “The effect of additions of Cu, Ni and C on the sintered properties of Iron-Base sintered P/M parts”, Progress in Powder Metallurgy, 1969, 25, p.73
2. F. V. Lenel and K. Hwang, “The Mechanical Properties of High Density Iron-Copper alloys from Composite powder”, `Powder Metallurgy Internationals, 1980, 12(20), p.89
3. K. Tabeshfar and G. A. Chadwick, “Dimensional Changes During Liquid Phase Sintering of Fe-Cu compacts”, 1984, Powder Metallurgy, 27(1), p.19