Abstract

In this study, effects of addition of Mo (0.6, 1.2 and 1.8 wt%) and B (0.2, 0.6 and 1.0 wt%) elements into Fe base metal matrix composites (Fe–0.8 C–2.0 Cu–3.0 Ni (wt%)) were investigated. The composite materials were produced by applying warm compaction and free sintering methods sequentially. Green composites were produced under pressure of 650 MPa at 160 °C. Then, the green products have been sintered at 1050 °C and 60 min sintering time in controlled Argon (Ar) gas atmosphere. After production of the composite samples, induction hardening heat treatment was applied to composite samples. The microstructures of the samples have been examined before and after induction hardening under optical microscopy. Surface hardness and density of the composite samples were measured. The results have showed that the addition of Mo and B elements increases surface hardness of the Fe based composite material. The highest surface hardness has been obtained in the case of Mo=1.8 and B=1.0 composition.

1. Introduction

The application of powder metallurgy (PM) manufacturing processes is growing and often it replaces traditional metal-forming operations because of a near-net shape forming capability, a more efficient material utilization, a relatively low energy consumption and capital cost [1]. In particular, the demand for PM steel components is significantly increasing and different PM steels have found applications, mainly in the automotive industry for engine and transmission systems [1].

In the past few years, surface hardening processes such as gas nitriding [3] plasma nitriding, glow-discharge treatment [4], nitriding and nitrocarburizing [5], as well as surface carburizing [6] treatments have been widely used for surface hardening treatments of P/M parts. Solid carburization, as a traditional carburization method, has a lot of shortages such as poor working condition, long heating duration and low productivity. Then it has been replaced by gas carburization, vacuum carburization, ion carburization and fluid carburization. However, solid carburization can produce parts with simple equipment’s and low cost.

The density of warm compaction material, Fe–4Ni–1.5Cu–0.5Mo, could be higher than 7.25 g/cm³ [7]. Company of Hoeganaes AB had made iron-based materials with strength of 1299 MPa through warm compaction with single sintering [8]. Effect of warm compaction on the property of Fe–Ni–Cu–Mo–C was studied in literature. PM materials of high density, strength and toughness made through warm compaction or die wall lubrication were often reported [9].

In order to improve the mechanical properties, surface compaction methods such as shot peening, deep rolling, laser shock compression as well as different heat treatment processes are used. The purpose of the mentioned procedure is to increase the strength and the wear resistance as well as to achieve a more favorable structure for improved strength carburizing [10].

The aim of this study is to produce Fe-based (Fe-0.8C-2.0Cu-3.0Ni-XMo-YB (%)) metal matrix composite by warm compacting method for gear production. The effects of Mo (%0.6-1.2-1.8) and B (%0.2-0.6-1.0) additions were investigated on the hardness, the density and microstructure properties in induction hardening.
2. Experimental Procedure

The water atomized iron powder together with nickel, copper, molybdenum, boron and graphite with purity higher than 99%, were used for this experiment. The average diameters of particles were in the range of <68 μm for iron, <44 μm for copper, <37 μm for nickel, <88 μm for molybdenum, <15 μm for boron powder and graphite powder. The composition of powder mixture is 0.8 wt.% C, 2 wt% Cu, 3.0 wt% Ni, (0.6-1.2-1.8)wt% Mo, (0.2-0.6-0.8) wt% B, 0.6 wt % zinc stearate and iron base. The chemical composition for different specimens is given in Table 1. In this study, effect of mechanical properties was investigated different amount of Mo and B powder. The powder mixtures were homogenized in a turbula mixer for 30 min.

Table 1. Chemical compositions of materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Fe (wt.%)</th>
<th>Ni (wt.%)</th>
<th>Cu (wt.%)</th>
<th>C (wt.%)</th>
<th>Mo (wt.%)</th>
<th>B (wt.%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>93.4</td>
<td>3.0</td>
<td>2.0</td>
<td>0.8</td>
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<tr>
<td>2</td>
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<td>3.0</td>
<td>2.0</td>
<td>0.8</td>
<td>0.6</td>
<td>0.6</td>
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<tr>
<td>3</td>
<td>92.6</td>
<td>3.0</td>
<td>2.0</td>
<td>0.8</td>
<td>0.6</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>92.8</td>
<td>3.0</td>
<td>2.0</td>
<td>0.8</td>
<td>1.2</td>
<td>0.2</td>
</tr>
<tr>
<td>5</td>
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<td>3.0</td>
<td>2.0</td>
<td>0.8</td>
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<td>6</td>
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<td>7</td>
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<td>8</td>
<td>91.8</td>
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</tbody>
</table>

The pre-heated mixed powders were pressed in a steel mold at temperature from room temperature to 160 °C. Compacting pressure was 650 MPa. Cylindrical specimens were obtained the dimension of 15x10 mm.

The re-pressed compacts were sintered with an argon atmosphere. The specimens were heated to 550 °C at a heating rate 10 °C/min and held at 550 °C for 30 min in order to remove the lubricants. Then, continuously elevating the temperature to 1150 °C and held for 60 min. Then High frequency current is applied to the metal for rapid surface heating. The heated part is rapidly cooled by using any cooling fluids. Parts were heated to 850°C temperature and parts rapidly cooled in high frequency induction bench. All compacts were welded by 2.5 kW, 900 kHz (high frequency) induction system for 10 second.

Mechanical and microstructural studies of the samples were performed.

3. Result And Discussion

3.1. Hardness Result

Hardness tests were conducted in the INSTRON-WOLPERT macro hardness testers. HRA hardness values of the specimens were measured by using 60 kgf loads. Five hardness measurements were carried out for each sample and average value of hardness was presented.

The mean of the hardness values are given in Table 2. The maximum hardness was obtained in sample 9. Hardness values are proportionally increased with the increase of Mo and B added. Boron addition increased the grain thinning and ability to get water. Molybdenum is a strong carbide and nitride-forming element. Since the molybdenum used in conjunction with Ni, the hardness of the material increased. The highest surface hardness has been obtained Mo=1.8 and B=1.0 composition. The maximum hardness was obtained 73.82 HRa after hardening in sample 9.

3.2. Microstructure

Metallographic sections were prepared by grinding, diamond polishing, and etching with %2 Nital for 5–10 s. The metallographic observations were conducted on a metal microscope Nikon Eclipse MA200. The microstructures of samples were examined both before and after hardening. Fig. 1-3 shows the metallographic structure of the samples after nital etching.
After induction hardening the martensite phase is seen as intense in microstructure. Samples were hardened by the center as a small section of material. It leads to grain thinning with the increasing addition of boron. Molybdenum is a strong carbide and nitride-forming element. It increased the hardenability in conjunction with nickel. Martensite and regional bainite structure are increasing with the increase of the amount of molybdenum in the composition.

4. Results

The densities of sintered samples were measured by Archimedes technique and the porosities in the samples were calculated. The warm compaction parameters (P, T and t) were kept constant in this study. So the effect of the density has not been of composite materials. The average ranges from %9-12 porosity ratio of the material. It is necessary to increase the sintering temperature and time to reduce the amount of porosity.

The addition of boron and molybdenum increased the hardness of the material. The increase in molybdenum addition allowed the critical quenching rate to be lower, thus increasing the hardness.

Carbides are also increasing as the amount of added molybdenum increases in the microstructure.

References


