Microstructural Characteristics of Electrical Discharge Alloying Silicon Modified Layer on Spheroidal Graphite Cast Iron

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In this study, electrical discharge alloying process is used to modify the surface of ferritic spheroidal graphite (SG) cast iron. The surface modification of SG cast iron with electrical discharge alloying is used to examine the effect of discharge current on the thickness, hardness and surface roughness of the surface modified layer while the pulse duration, duty factor, electrode polarity (negative electrode) and the electrode composition (Fe-75mass%Si) are fixed. Experimental results reveal that the thickness of the surface modified layer tends to increase as the discharge current increases. In addition, the microstructure of the layer consists of fine dendritic crystals and tiny graphite particles. The results of EPMA compositional analysis indicate that the silicon element was contained in the electrode effectively dissolved in the alloying layer of SG cast iron and the content of the dissolved electrode elements decreases gradually from the discharge surface to substrate bulk. The Si concentrations and micro-hardness of the alloying layer also increase with the discharge current. The results of X-ray diffraction on the Si alloying layer show that α phase, ε phase and metastable phase of FeSiC are the main compositional phases.

Keywords: electrical discharge alloying, spheroidal graphite cast iron, silicon alloying layer

1. Introduction

Ferritic spheroidal graphite (SG) cast iron has many good qualities such as excellent castability, machinability and low cost etc. Because of its broad application range and frequent use, surfaces of work pieces made of this material often suffer corrosion, wear and high temperature oxidation in many cases of application. Therefore, it has become the common objective of numerous researchers to propose a surface modification method that can increase the durability of work pieces without losing the inherent properties of the material. In order to promote the cases of application of SG cast iron, it is essential to develop a simple and fast surface modification technique that produces SG cast iron with a surface resistant to corrosion, wear and high temperature oxidation. Electrical discharge alloying (EDA) is a surface modification method with a conventional electrical discharge machining (EDM) machine. The electrode and the substrate bulk are molten with the electric are between them. The molten electrode droplets, metal powder suspended in dielectric fluid, and/or decomposed dielectric elements transfer to a molten discharge crater of a substrate surface to form an alloyed layer. The EDA modified layer, which is obtained relatively rapidly, possesses sufficient engineering thickness and hardness. The thickness and hardness of this modified layer can be controlled by EDA parameters which include discharge, pulse duration and duty factor. Furthermore, selecting the electrode material can readily control the composition of the modified layer. Therefore, manipulating the EDA parameters and selecting applicable alloying materials can achieve a surface chemistry with improved resistance to wear, corrosion, a high temperature oxidation and corrosion failures. The EDA process in this study is to examine the silicon alloying surface modification of ferritic SG cast iron, silicon alloying surface modified layer is obtained with Fe-75mass%Si alloy electrode materials. The machining parameters (pulse duration and duty factor) are fixed for EDA process and the aim of the study is to investigate the relationships between the discharge current and the microstructural characteristics of the alloying surface modified layer.

2. Experimental procedure

2.1 Specimen preparation

The SG cast iron used in this study is listed in Table 1. The material was prepared by melting high-purity pig iron, ferrosilicon, and silicon steel scrap in a high frequency induction furnace. The spheroidizing treatment was performed with Fe-45 mass% Si-8 mass% Mg-2.5 mass% RE and inoculated with Fe-75 mass% Si in a ladle at 1450°C. Finally, the melts were poured into Y-shaped mold with dimensions of 30×100×150 mm in the parallel section. All specimens were fully ferritized before being machined into test specimens. The ferritization procedure followed a typical two-stage isothermal treatment, in which all specimens were maintained at 930°C for 3 hours, then furnace cooled to 730°C for a second isothermal holding of 5 hours and finally furnace cooled to room temperature. Specimens were etched with 5% nital etchant and the optical microstructure of the specimens as shown in Figure 1.

2.2 Electrical discharge alloying process

The process was used to investigate the alloying layer resulted from the rapid solidification of residual molten materials on the surface by the insulation liquid following electrical discharge machining (EDM) and to examine the effects of the Fe-75mass%Si electrode and machining parameters. Figure 2 reveals the dimension of the alloying specimens. The EDM machine was used in the EDA process. The schematic diagram of the EDA process is shown in Figure 3 while the electrical discharge conditions were listed in Table 2.

Table 1 Chemical composition of the SG cast iron (mass%).

<table>
<thead>
<tr>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Mg</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.35</td>
<td>3.24</td>
<td>0.140</td>
<td>0.060</td>
<td>0.010</td>
<td>0.042</td>
<td>bal.</td>
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