GAS-POWDER DEPOSITION OF BORON CARBIDE

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The carbon–boron compound B₄C is widely used in many fields of engineering [1] because of its high hardness and excellent wear resistance [1–3]. At temperatures exceeding its melting point (2450°C), however, boron carbide decomposes with the evolution of free carbon in the form of graphite, and consequently considerable difficulties arise in the application of wear-resistant coatings of this compound to components by the usual arc deposition techniques [4]. In view of this, there is considerable interest in the possibility of depositing boron carbide at lower temperatures.

In the present work, an attempt was made to deposit boron carbide by a gas-powder technique (Eutalloy process [5]). In this process, use is made of an oxyacetylene torch with a device for feeding a filler powder into the gas mixture. The boron carbide employed in our experiments was of No. 10 particle size and contained 72.8% B and 21.6% C. St. 3 mild steel specimens 36 × 20 × 6 mm in size were used as substrates in the deposition experiments.

Prior to deposition, the specimen surface was heated with a reducing torch flame to a "sweating" temperature. Next, the powder feed passage was opened, releasing the powder and enabling it to be projected through the flame and deposited on the specimen surface. Visual examination of the formation of deposited layers revealed that the coating process consisted of several stages. At first, the boron carbide particles were embedded in the softened substrate metal, which became fluid and spread over the specimen surface. During subsequent impregnation with boron carbide, the pool thickened and gradually became covered with a solid "crust," to which the boron carbide particles no longer adhered. When the surface saturation point was reached, the process was stopped and the specimens were rapidly cooled in water to preserve their structure and obtain a fine grain.

An investigation of the state of aggregation of boron carbide particles which reached the specimen surface after passing through the torch flame established that they were in the solid state and showed no signs of melting (Fig. 1a and b). During spray deposition, the boron carbide reacted with the iron, presumably according to the reaction B₄C + Fe → FeB + C, resulting in the formation of borides and carbon. These in turn reacted with the iron, yielding an iron carboboride. Evidence in support of this sequence of reactions is provided by the results of earlier investigations [6–8], in which carboboride phases with the cementite crystal lattice were obtained by various methods; in the cementite lattice, boron atoms may

Fig. 1. No. 10 boron carbide particles before (a) and after (b) passage through oxyacetylene flame.
replace up to 80% of the carbon atoms, resulting in the formation of the ternary compound Fe₃(C, B) [7, 9]. The melting and spreading of the metal was probably linked with the process of formation of the carboboride, which formed a low-melting-point eutectic. During the subsequent impregnation of the molten metal pool with boron carbide, the melting point of the alloy steadily rose, causing it to solidify as a crust.

The deposited layer (Fig. 2) comprised a eutectic zone and a zone of dendrites, while on its surface there were fairly densely distributed inclusions of boron carbide particles. The structure of the eutectic zone was characterized by the presence of patterns; these were probably the areas of boron carbide particle penetration, which had acted as diffusion centers for the reaction products of the boron carbide and iron (Fig. 3b). Similar regions of traces of boron carbide decomposition were found also in the dendritic zone (Fig. 3a).

A study of microhardness distribution in the deposited layer and basis metal revealed that the microhardness steadily fell with decreasing distance from the fusion zone (Fig. 4). In the basis metal, the microhardness continued to decrease up to a certain distance, indicating that carbon and boron atoms had diffused into the metal to a depth of 0.2 mm. The microhardness of the dendrites and eutectic regions was approximately the same, ranging from 550 to 1200 kg/mm² depending on the distance from the fusion zone. The microhardness of the boron carbide grains located on the surface of the deposited layer was 5100 kg/mm². The structure of the deposited layers was free from graphite inclusions, testifying to the absence of products of boron carbide decomposition resulting in the formation of free carbon and also to the fact that no graphitization had taken place during the deposit formation process.

<table>
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<tr>
<th>Alloy</th>
<th>C</th>
<th>Si</th>
<th>Cr</th>
<th>Mn</th>
<th>Ni</th>
<th>W</th>
<th>B</th>
<th>Fe</th>
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<td>PG-KhN80SR2</td>
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<td>3.0</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td>bal.</td>
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<tr>
<td>Mixture 1</td>
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<td>0.748</td>
<td>8.77</td>
<td>0.75</td>
<td>8.01</td>
<td>1</td>
<td>0.51</td>
<td>bal.</td>
</tr>
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TABLE 1