Effect of Formation Parameters on Layer Properties in Electron Beam Cladding with Powder Feeder†

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The trend toward more efficient energy and resource utilization, as well as the need for advanced functionality, has led to a growing demand for materials with high erosion and corrosion resistance. For the past few years, the authors have been developing an electron beam cladding method employing a high energy density electron beam and a powder feeder. Thick, hard surfacing layers with high corrosion and erosion resistance were successfully formed on mild steel plates employing the electron beam cladding method and Cr_3C_2/Ni-Cr mixed alloy powder[1-3]. However, there are many parameters for the electron beam cladding, for example beam current, powder feed rate and beam scanning speed etc. In this study the relationships between formation parameters and the properties of layers in electron beam cladding were examined.

Figure 1 shows a schematic drawing of the experimental apparatus. A 30kW-class electron beam welder with an acceleration voltage of 40kV was used as a heat source. The electron beam was focused with two magnetic focusing lenses on the surface of the substrate. A high energy density of 204kW/cm^2 was achieved at the focal point when the output power was 1600W. A SS400 mild steel plate of 3mm in thickness was used as a substrate. A powder feeder was designed to supply mixed powder under the vacuum condition. The chemical composition and particle size of the Cr_3C_2/Ni-Cr alloy powder used for cladding is shown in **Table 1**. The powder was stably supplied at a constant feed rate of 0.4g/sec onto the substrate, which was moving at a constant speed of 5mm/sec. The electron beam was oscillated at an amplitude of 20mm with

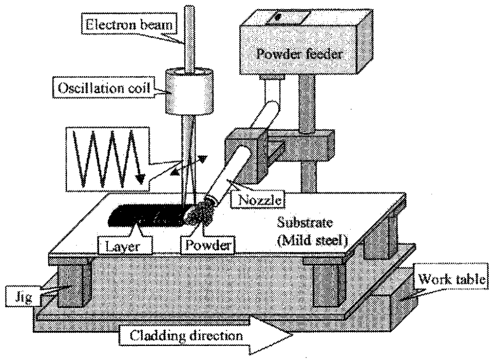

Fig. 1 Schematic drawing of the experimental apparatus

Table 1 Chemical composition of the Cr_3C_2/Ni-Cr alloy powder

Cr_3C_2	Ni-Cr	Particle size (mm)
75%	25%	-45+11

a speed of 1000mm/sec to 2000mm/sec using a deflection coil and function generator. It irradiated the supplied powder and melted it, forming the cladding layer on the substrate. The properties of cladding layers were examined with the optical microscope, Vickers hardness test (load: 300g, load time: 15sec) and ACT-JP sand erosion test (Abrasive: mild steel: 300μm, jet air pressure: 5.0kg/cm^2).

In order to examine the effect of electron beam scanning speed on the formation of the cladding layer, a beam scanning speed was changed against several beam currents under the condition that a mean input heat per unit time and unit area was constant at 1.125J/sec·mm^2 for a constant powder feed rate of 0.4g/sec. The surface appearance and cross sections of Cr_3C_2/Ni-Cr alloy cladding layers formed under three different combination of beam current and beam scanning speed are shown in **Fig. 2**.

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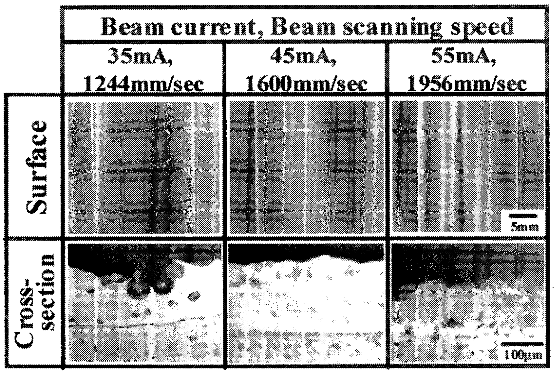

Fig. 2 Surface appearances and cross sections of Cr_3C_2/Ni-Cr alloy cladding layers
(Input heat per unit time and unit area: 1.125J/sec·mm^2)

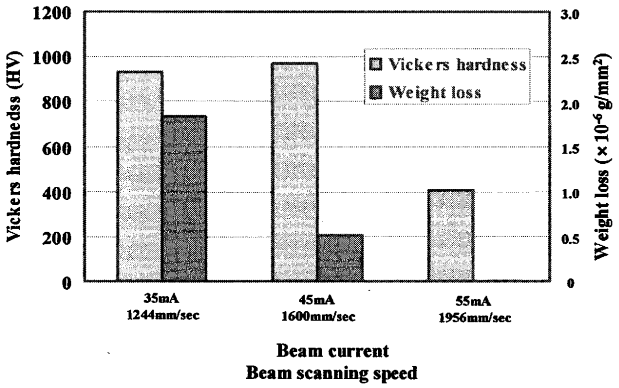

Fig. 3 Vickers hardness and weight loss of Cr_3C_2/Ni-Cr alloy cladding layer

At a beam current of 35mA and beam scanning speed of 1244mm/sec, porosity occurred and un-melted powder was recognized on the surface of the cladding layer. At 45mA-1600mm/sec, a good cladding layer without porosity and un-melted powder was obtained. The layer thickness was about 180μm. At 55mA-1956mm/sec, there was an irregular hump at the center of the cladding layer and the substrate material mixed into the cladding layer. The thickness of cladding layer decreased to 100μm. **Figure 3** shows the Vickers hardness and the weight loss in the erosion test of Cr_3C_2/Ni-Cr alloy cladding layers. At a beam current of 45mA and a beam scanning speed of 1600mm/sec, the Vickers hardness of the cladding layer showed a high hardness of 967HV. At 35mA-1244mm/sec, the Vickers hardness of cladding layer was 900HV. At 55mA-1956mm/sec, the Vickers hardness of cladding layer was only 400HV. The reason for this low hardness is thought to be the decomposition of Cr_3C_2 particles as high-hardness components and mixing of substrate material with the cladding layer by the electron beam melting of the substrate. The weight loss of the

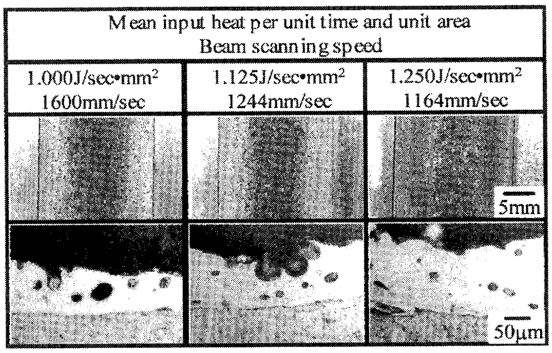

Fig. 4 Surface appearances and cross sections of Cr_3C_2/Ni-Cr alloy cladding layers (Beam current: 35mA)

cladding layer formed by a beam current of 45mA and a beam scanning speed of 1600mm/sec was very low, however the layers formed at 35mA-1244mm/sec and at 55mA-1956mm/sec show a high weight loss. The high weight loss for 35mA-1244mm/sec cladding layer is thought to be due to the porosity, and that for 55mA-1956mm/sec is thought to be due to the low hardness.

In order to examine the effect of mean input heat per unit time and unit area, the beam scanning speed was changed at a constant beam current of 35mA. The surface appearance and cross sections of Cr_3C_2/Ni-Cr alloy cladding layers formed at a mean input heat per unit time and unit area of 1.000, 1.125 and 1.250J/sec·mm^2 are shown in **Fig. 4**. With increasing input heat the amount of un-melted powder at the center of the cladding layer decreased, however un-melted powder still remained at an input heat up to 1.250J/sec·mm^2. Furthermore, at a mean input heat of 1.250J/sec·mm^2 and a beam scanning speed of 1164mm/sec, substrate material also mixed with the cladding layer.

It is found that beam current and beam scanning speed are both important factors for layer formation in the electron beam cladding method. When beam current and beam scanning speed are low, un-melted powder remains on the surface of the cladding layer. When beam current and beam scanning speed are high, there is an irregular hump at the center of cladding layer and the substrate material mixes with the cladding layer. This causes a decrease of the hardness and erosion resistance of the cladding layer.

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