Formation of Cr_3C_2/Ni-Cr Alloy Layer by an Electron Beam Cladding Method and Evaluation of the Layer Properties†

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The trend toward more efficient utilization of energy and resource, as well as the need for advanced functionality, has led to a growing demand for materials with high erosion and corrosion resistance. Chemical coating methods using heavy metals are no longer a viable choice because of global environmental concerns and the threat of environmental pollution. Thus, there is a pressing need for new surface modification technologies that can form surface layers with superior functional properties. The authors have been developing an electron beam cladding method employing a high energy density electron beam and a powder feeder[1-3]. In this report, a hard surfacing layers with high corrosion and erosion resistance were successfully formed on mild steel employing the electron beam cladding method with Cr_3C_2/Ni-Cr mixed alloy powder, and their properties were examined.

Figure 1 shows a schematics drawing of the experimental apparatus. A 30kW-class electron beam welder with acceleration voltage of 40kV was used as the heat source. The electron beam was focused by two magnetic focusing lenses to achieve a high energy density of over 200kW/cm^2 at a focal point when the output power was 1600W. A powder feeder designed to work stably under vacuum conditions supplied mixed powder. In order to form a hard surfacing layer with high corrosion and erosion resistance, Cr_3C_2/Ni-Cr alloy powder was used. The chemical composition of the Cr_3C_2/Ni-Cr alloy powder is shown in **Table 1**.

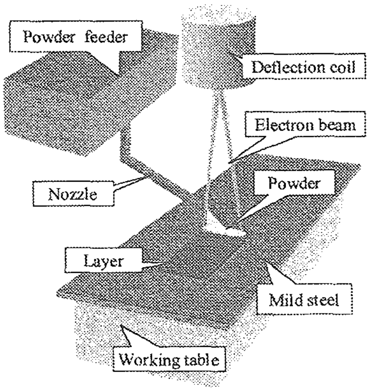

Fig. 1 Schematic drawing of the experimental apparatus

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

Cr_3C_2	Ni-Cr	Particle size (μm)
50%	50%	8.8-55

SS400 mild steel plate was used as the substrate. The powder was stably supplied at a constant feed rate of 0.4g/sec onto the substrate, which moved at a constant speed of 5mm/sec. The electron beam was oscillated at an amplitude of 20mm using a deflection coil and function generator. The Cr_3C_2/Ni-Cr alloy layer was formed on the substrate by the irradiation of the scanning electron beam at a high speed of 1600mm/sec.

The cladding layers were examined using optical microscope, electron probe micro analyzer (EPMA),

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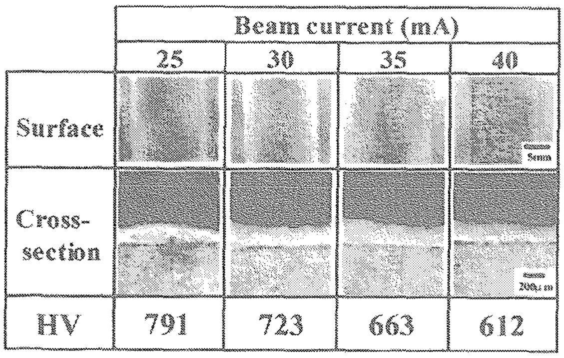

Fig. 2 Surface appearance, cross section and Vickers hardness of Cr_3C_2/Ni-Cr alloy cladding layers

Vickers hardness test (load: 300g, load time: 15sec), sand erosion test (ACT-JP method, Abrasive: mild steel, jet air pressure: $5.0kg/cm^2$) immersion corrosion test (corrosion solution: H_2SO_4 aqueous solution, corrosion time: 10 hours).

The surface appearance, cross section and Vickers hardness of Cr_3C_2/Ni-Cr alloy cladding layers formed at a variety of beam currents are shown **Fig. 2.** At a beam current of 25mA, porosity occurred and un-melted powder was recognized on the surface of the cladding layer. Layers without porosity were obtained at beam current of 30mA and 35mA. The layer's thickness was about 100μm. At a beam current of 40mA, however, the substrate material mixed with the surface layer. The Vickers hardness of the Cr_3C_2/Ni-Cr alloy layer formed at a beam current of 25mA was 791HV. However, with increasing beam current, Vickers hardness of the Cr_3C_2/Ni-Cr alloy layer decreased. This is thought due to decomposition of the Cr_3C_2 particles as a high-hardness component by electron beam irradiation.

Figure 3 shows the EPMA results with the Kα lines of Cr, Ni, Fe and C for the Cr_3C_2/Ni-Cr alloy layer formed at a beam current of 30mA. The Cr_3C_2 particles are evenly dispersed within the matrix of the Ni-Cr alloy. There is no mixing of iron with the cladding layer.

Figure 4 shows the results of immersion corrosion tests and a sand erosion tests for SUS304 steel plate, SS400 steel plate and a Cr_3C_2/Ni-Cr alloy layer formed under the optimum beam condition of 35mA. The specimens were immersed in a 50% H_2SO_4 aqueous solution for 10 hours and the amount of corrosion was measured. The corrosion rate of

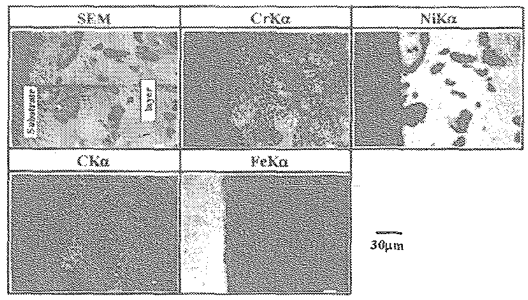

Fig. 3 EPMA results of Cr_3C_2/Ni-Cr alloy layer

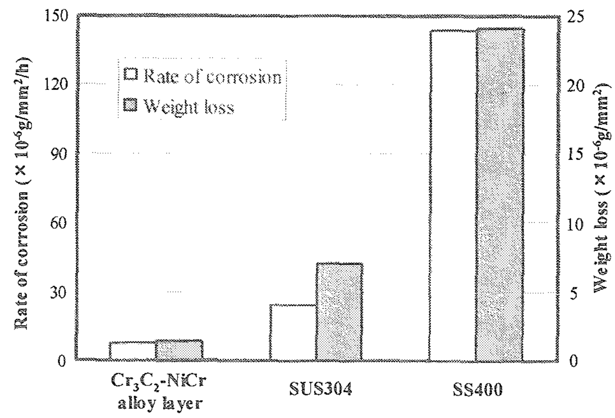

Fig. 4 The results of an immersion corrosion test and sand erosion test for Cr_3C_2/Ni-Cr alloy layer

the Cr_3C_2/Ni-Cr alloy layer was very low, being only 25% that of stainless steel and 7% that of mild steel. In the sand erosion test, the abrasive (mild steel, 450HV) was sprayed onto the specimen surface with a high speed, and the erosion resistance was determined by specimen weight loss.

The erosion loss of the Cr_3C_2/Ni-Cr alloy layer was also very low, being only 30% that of stainless steel and 5% that of mild steel.

By using the electron beam cladding method, a Cr_3C_2-NiCr alloy layer with a high hardness of 791HV as well as high erosion and corrosion resistance was successfully formed on mild steel plate.

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