Dynamic Observation of Electron Beam Cladding by High Speed Video Camera†

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Materials with improved abrasion and corrosion resistance are needed to meet the requirements of global pollution and lower energy consumption. In order to improve material surface properties, it is very important to develop new surface finishing technologies which can form such coating surfaces.

In the previous report[1, 2], it was described how a cermet coating with high abrasion and corrosion resistance could be formed by the electron beam cladding method. Although there are many parameters in electron beam cladding conditions such as electron beam current, powder feed rate, beam scanning pattern etc., the relations between these parameters and cladding layer properties have not yet been revealed. In this report, fundamental phenomena in electron beam cladding were observed dynamically by using a high speed video camera to analyze the formation process of cladding layers.

An electron beam welder with a maximum output power of 30kW (Acceleration voltage: 70kV, Beam current: 430mA) was used as a heat source. A powder feeder developed to work under vacuum condition was used to supply cermet powder to the substrate of structural steel SS400 of 3mm thickness. As a coating material, 75mass% Cr_3C_2/Ni-Cr alloy powder (METCO, AMDRY5260) was used which was usually used for thermal spraying. A high speed video camera (NAC, HSV1000) was used to take high speed photography of the formation phenomena in electron beam cladding from an observation direction shown in **Fig 1**. An irradiation area of electron beam of 1cm x 1cm was observed from the rear of the cladding direction as shown in Fig 1. A 2kW xenon short arc lamp was used as an illuminator and was set at the upper observation window of the vacuum chamber. Filming speed was 500 field/sec and shutter speed was 1/2500 sec.

Figure 2 shows a typical high speed image and its schematic drawing. The horizontal bright line at the center of the image represents the electron beam irradiation line and the bright spot at the center of the irradiation line is the electron beam irradiated spot. The upper dark part of the image shows the un-melted powder, and the lower bright part shows the cladding layer formed.

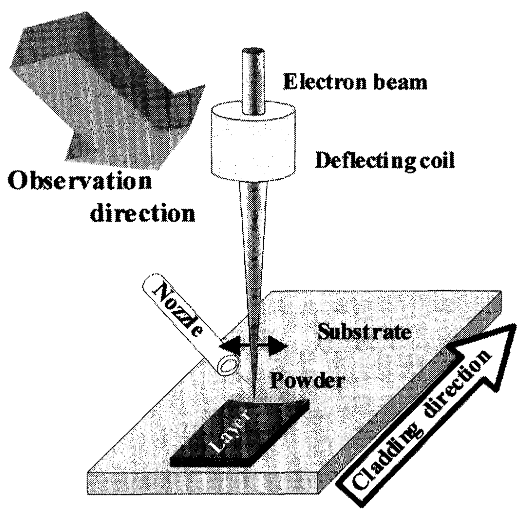

Fig. 1 Observation direction of electron beam cladding by a high speed video camera

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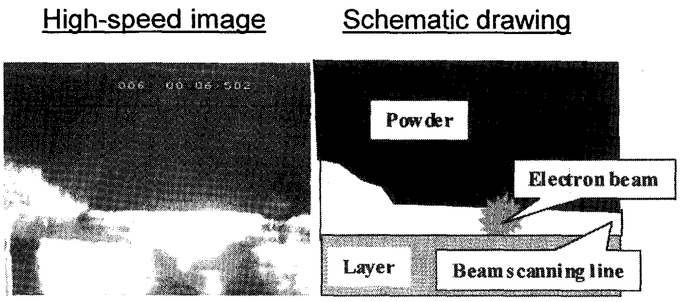


Fig. 2 High-speed image of electron beam cladding and its schematic drawing

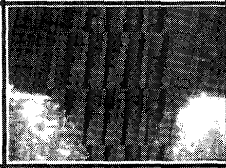
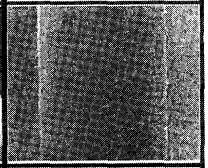
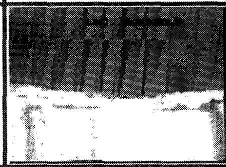
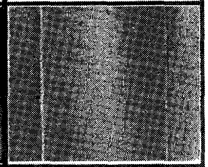
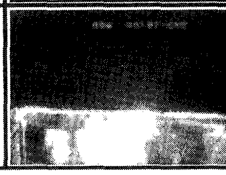
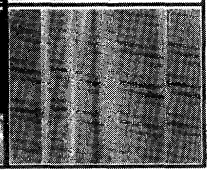
Beam current Scanning speed	High-speed image	Surface
35mA 1244mm/sec		
45mA 1600mm/sec		
55mA 1956mm/sec		

Fig. 3 High-speed image and surface appearance of Cr_3C_2/Ni-Cr alloy layer at various cladding conditions

The relation between powder feed rate and powder supply condition was examined. The cladding phenomena at constant powder feed rate was observed at various positions of the powder feeder nozzle. It was found that a good cladding layer could be formed when the powder was supplied within ±2mm of the center of the electron beam irradiation line.

The relation between cladding phenomena and electron beam condition was examined. Both electron beam current and its scanning speed were changed so as to provide the same heat input per unit time and unit area. The cladding phenomena and surface appearance of the Cr_3C_2/Ni-Cr alloy layer formed under the condition of a constant heat input of 1.125J/sec $\cdot$ mm^2 are shown in **Fig.3**. At a beam current of 45mA and a beam scanning speed of 1600mm/sec, supplied powder was expanded uniformly and melted to form a good cladding layer. At a beam current of 35mA and a beam scanning speed of 1244mm/sec, however, supplied powder was not fully melted and un-melted powder was observed. It is thought that the beam power density is too low and is insufficient to melt all the powder. On the other hand, at a beam current of 55mA and a beam scanning speed of 1956mm/sec, a large molten pool was generated in the center of the cladding layer, forming an irregular hump at the center line of the cladding layer. It is thought that the high beam scanning speed cannot expand the feeding powder uniformly.

The formation process of cladding layer is thought to be as follows. The Cr_3C_2/Ni-Cr alloy powder supplied from the powder feeder is irradiated by the electron beam at high power density, and causes rapid melting. This causes the generation of strong metal vapor stream which pushes the supplied powder toward the beam scanning direction and expands it uniformly. The electron beam irradiates the uniformly expanded powder at high speed. Only a small amount of supplied powder is melted rapidly and solidified quickly because the scanning speed of electron beam is very high. The powder is melted and solidified many times repeatedly, melting the whole depth to the bottom of supplied powder as a result of overlapping the scanning electron beam many times on the same area.

References

1) N. Abe, M. Tsukamoto, S. Miyake, F. Kuriyama, J. Morimoto and M. Tomie: Trans. of JWRI, Vol. 30, No.1, 2001, p135.
2) N. Abe, M. Tsukamoto, S. Miyake, F. Kuriyama, J. Morimoto and M. Tomie: Trans of JWRI, Vol. 30, No.2, 2001,p 117.