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Electron Beam Cladding of Titanium on Stainless Steel Plate†

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Abstract

Fundamental characteristics of electron beam cladding was investigated. Titanium foil of 0.2mm thickness was cladded on stainless steel plate of 3mm thickness by scanning electron beam. Surface roughness and cladded layer were analyzed by surface roughness tester, microscope, scanning electron microscope and electron probe micro analyzer. Electron beam conditions were discussed for these fundamental characteristics. It is found that the energy density of the electron beam is one of the most important factor for cladding.

KEY WORDS : (Electron Beam) (Cladding) (Titanium)

1. Introduction

Recently cladding of high quality and expensive materials on poor quality and cheep materials has been required for making new composite materials having high corrosion resistivity, high wear resistivity and so on. Although research works using laser beam or electron beam have been performed[1-4], fundamental characteristics have not yet been revealed.

In this report, fundamental characteristics of electron beam cladding of Titanium foil on stainless steel SUS304 are investigated. Surface roughness and cross sections of cladding layers are analyzed for energy density of the electron beam.

2. Experimental procedure

2.1 Cladding materials

Usually, powder is used for the type of cladding materials, which are feeding on the beam irradiation spot of base materials by a powder feeder[3]. However, for fundamental research, powder materials have many undefined parameters such as powder size, powder shape, homogeneity, surface contamination and so on. Feeding of powder to the beam spot on base materials has also some difficulties of feeding speed and so on to make uniform cladding thickness. Therefore, for simplicity, thin foil was selected for this experiment. In this report, cladding materials was 0.2 mm thickness Titanium foil and base material was stainless steel SUS304 of 3mm thickness. Titanium foil was simply put and fixed on SUS 304 plate.

2.2 Electron beam scanning method

Figure 1 shows a block diagram of the electron beam scanning system. The electron beam is scanned to square shape by X and Y deflectors with two independent function generators (X: triangular wave; Y: saw tooth wave) and power amplifiers as shown in **Fig. 1**. **Figure 2** shows some cladding results for various scanning patterns. Amplitudes of X- and Y-direction were set to constant of 20 mm and 50mm, and electron beam conditions were V_b

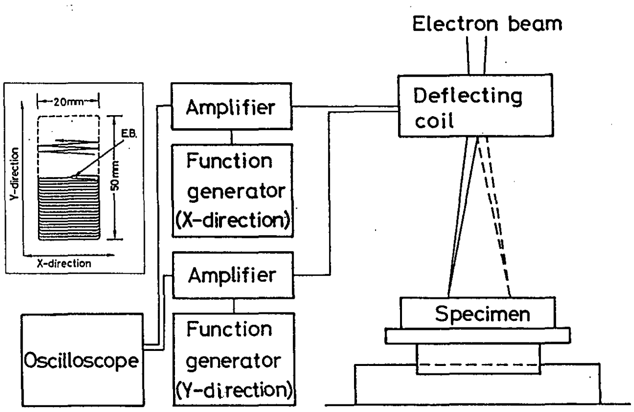

Fig. 1 Electron beam scanning system.

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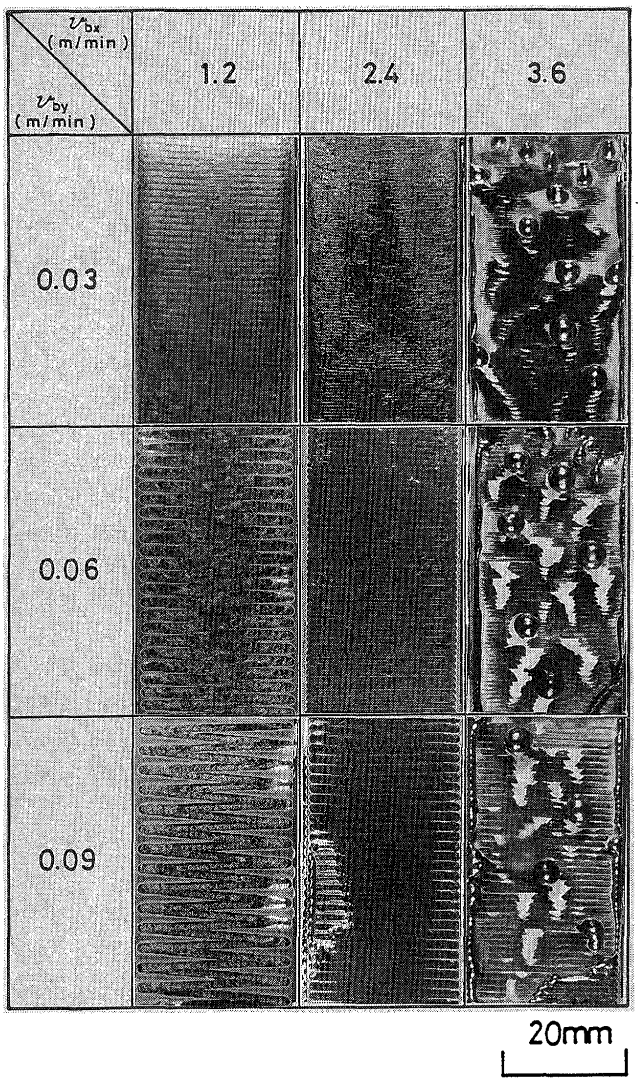

Fig. 2 Examples of scanning pattern and cladded surface.

= 40kV, I_b = 8mA and a_b = 0.9. Scanning speed of X-direction v_{bX} was varied from 1.2 to 3.6 m/min and scanning speed of Y-direction v_{bY} was varied from 0.03 to 0.09 m/min. Although cladding was possible at v_{bX} = 1.2m/min and v_{bY} = 0.03m/min, scanning time became too long in this case to be over 100 seconds. On the other hand, at v_{bX} = 3.6m/min, cladding was not possible at present beam conditions. Therefore, v_{bX} = 2.4m/min and v_{bY} = 0.06m/min was selected for beam scanning pattern in this experiment.

3. Results and discussion

3.1 Surface appearance

Figure 3 shows surface appearances when cladding layer was formed. Outside of this area, Titanium was gathered to be small particles and did not formed a cladding layer as shown in **Fig. 4**. Results of surface roughness test are shown in **Fig. 5** for several beam current. In Fig. 5(a) ~ (d), scale of surface roughness is enlarged 500 times to X and Y directions. Surface roughness was around 1 μm and did not depend on beam current. Also **Fig. 6** shows surface roughness for various a_b value. Surface roughness was around 2 μm and depended on a_b value. When a_b value was 1.0, roughness was relatively high. This is thought that beam overlap ratio at a_b = 1.0 is smaller than that of a_b = 0.9 and 1.1 because a beam diameter of a_b = 1.0 is smaller than that of a_b = 0.9 and 1.1.

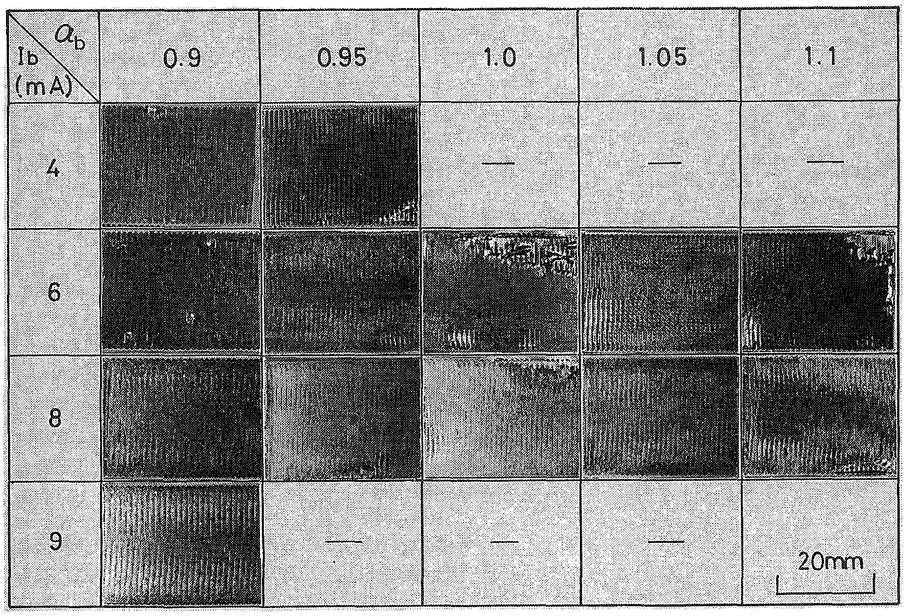

Fig. 3 Surface appearances of cladding layers.

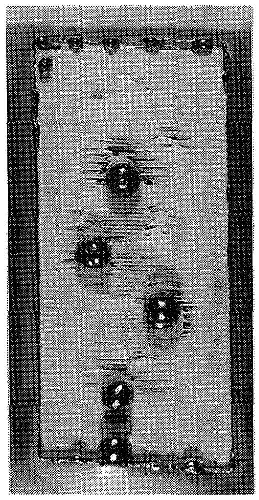

Fig. 4 Surface appearance when Titanium layer was not formed.

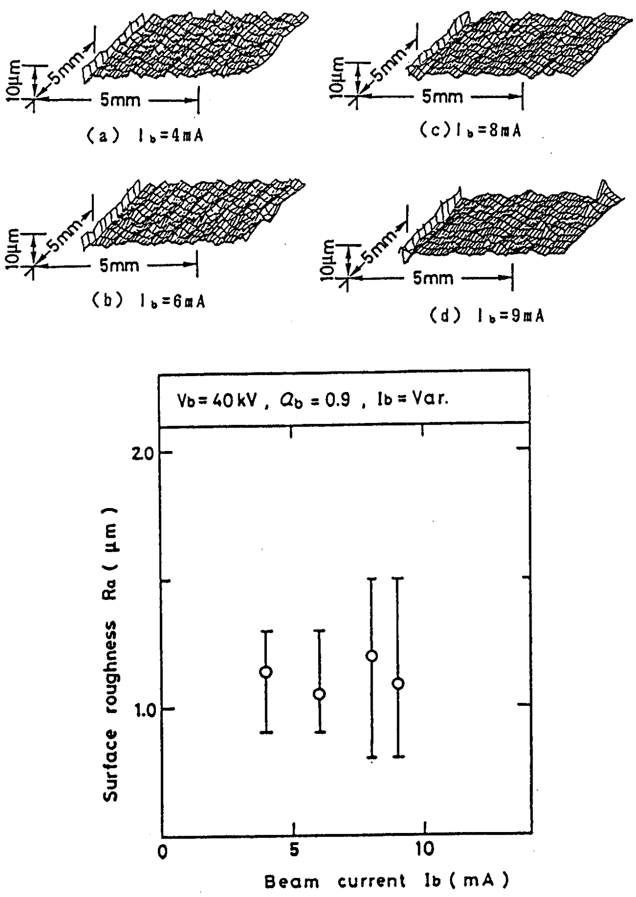

Fig. 5 Surface roughness test for various beam current.

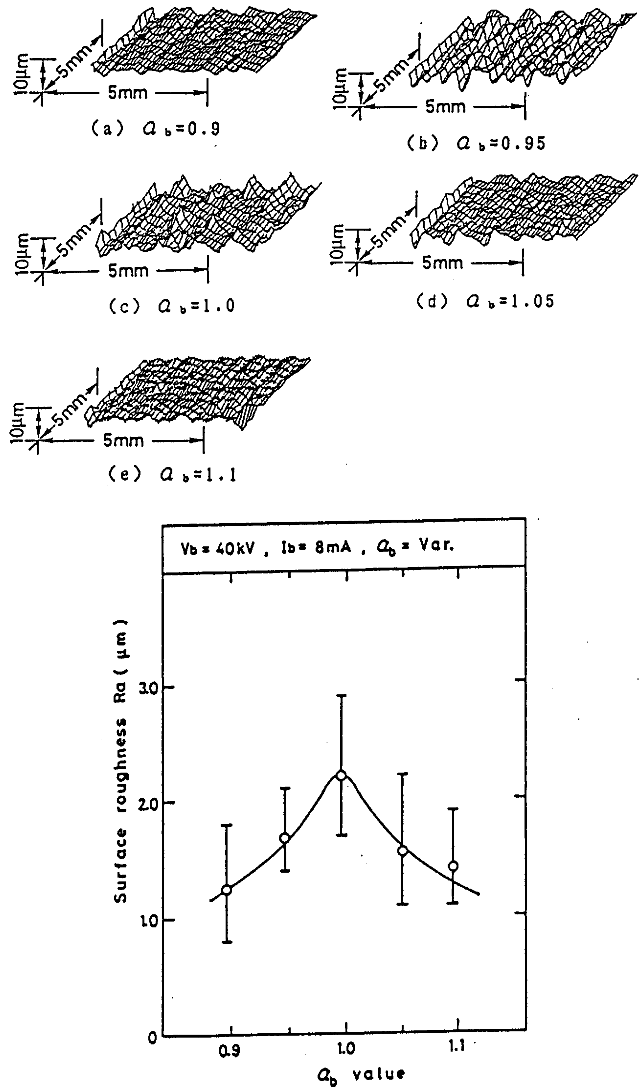

Fig. 6 Surface roughness test for various a_b value.

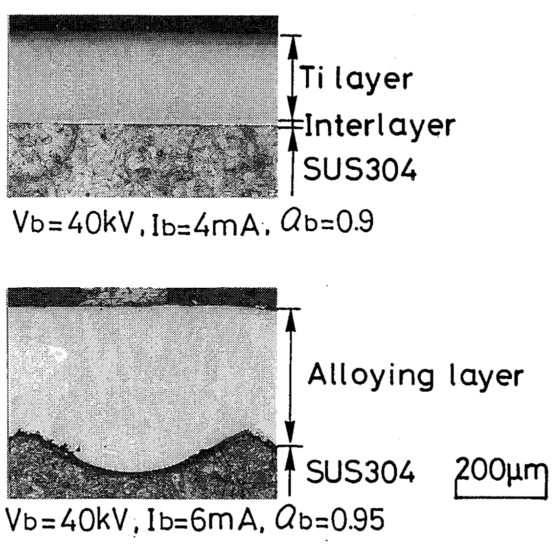

Fig. 7 Microscope photographs of cross sections of cladding layers for two different beam conditions.

3.2 Cross section

Figure 7 shows typical cross sections of microscope photographs of specimens shown in Fig. 3. **Figure 8** shows typical results of scanning microscope and electron probe micro analysis around the border of these two layers. It is seen that at $a_b = 0.9$ and $I_b = 4$mA, Titanium layer and SUS304 is clearly separated by a very thin interlayer and SUS304 is little melted. On the other hand, at $a_b = 0.95$ and $I_b = 6$mA, a large amount of SUS304 is melted and mixing layer of Titanium and SUS304 is formed. Cladding layers formed at $a_b = 0.9$ and $I_b = 6$mA, $a_b = 0.95$ and $I_b = 4$mA, $a_b = 1.05$ and $I_b = 6$mA, $a_b = 1.1$, $I_b = 6$mA are the former type and two layers also separated clearly. On the other hand, Cladding layers formed at $a_b = 1.0$, $I_b = 6 \sim 8$mA and $a_b = 0.9 \sim 1.1$, $I_b = 8$mA where the energy density is higher than the former cases show the latter type and mixing layer is formed.

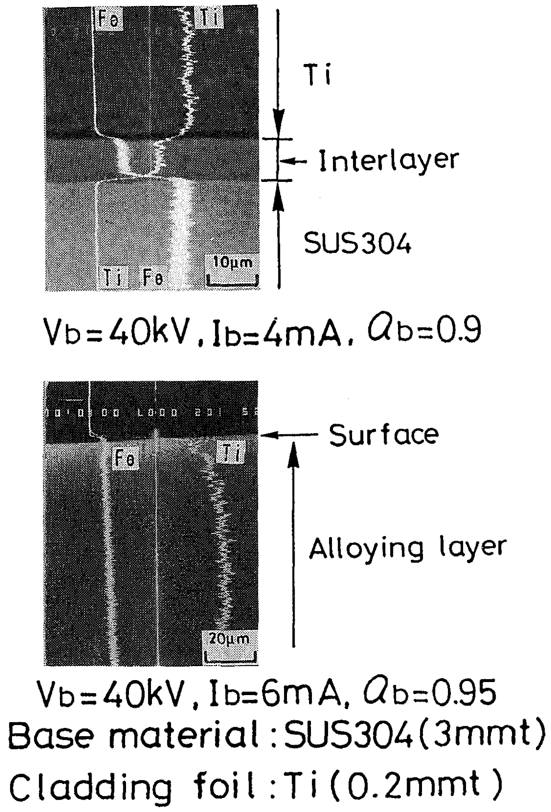

Fig. 8 SEM and EPMA results around the border of cladding layer and base material.

3.3 Effect of power density

Figure 9 is summarized above results and shows the relation of power density of electron beam and the thickness of pure Titanium layer. Below a power density of 0.05kW/mm^2, electron beam cannot penetrate 0.2mm thickness Titanium foil and paste it on SUS304. On the other hand, over a power density of 0.12kW/mm^2, electron beam melt a large amount of SUS304 making mixing layer of Titanium and SUS304. It is found that the power density is an important factor for the formation of good cladding layers. In order to make sure this result, electron beam cladding was performed with different electron beam focusing conditions. The results on different beam focusing conditions of $V_b = 70$kV, $D_o = 353$mm and $V_b = 40$kV, $D_o = 233$mm (Previous experiment was performed at $V_b = 40$kV, $D_o = 353$mm) are also plotted in **Fig. 9** as marks ● and ▲. On both cases, the condition of good cladding is dropped into the area mentioned above. Furthermore, cladding was performed against different foil thicknesses. **Figure 10** shows the results on thickness of 0.1mm and 0.3mm. As shown in this figure, required beam power density for increasing thickness is also increasing linearly. This means that in order to good cladding layer, an electron beam must have optimum energy density to penetrate that foil immediately and melt little base material. When the power density is too high, electron beam melts a large amount of base material making mixing layer.

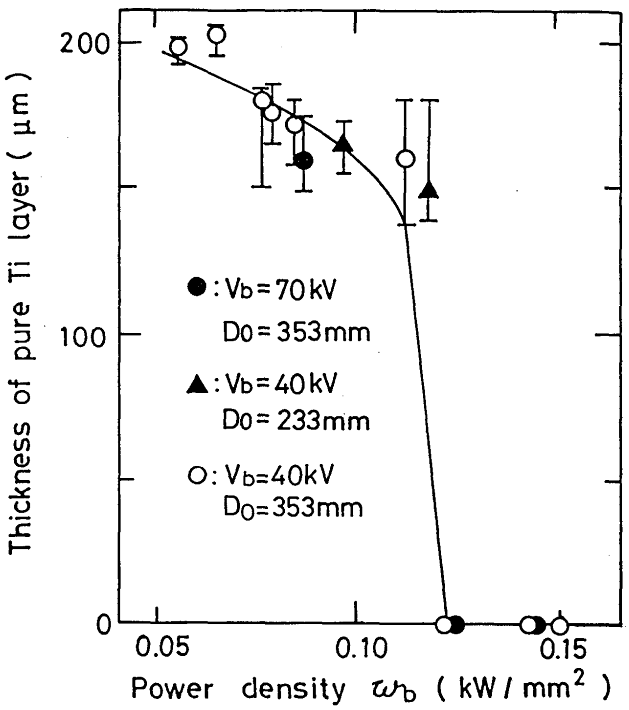

Fig. 9 Relationship of power density and thickness of pure Titanium layer.

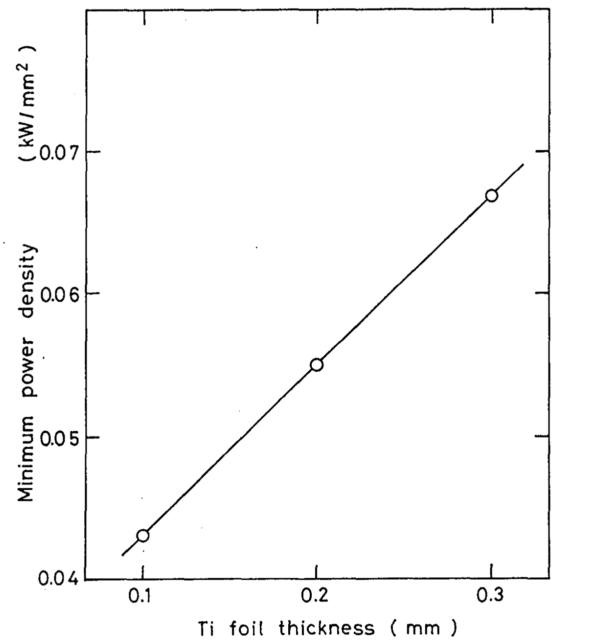

Fig. 10 Relationship of minimum power density for cladding and thickness of foil.

4. Conclusion

Titanium foil of 0.1～0.3 mm thickness was successfully cladded on SUS304 of 3mm thickness by electron beam scanning. It is found that the energy density is an important factor of good cladding. In order to obtain good cladding layers, electron beam must have the energy density which penetrate the foil immediately and melt little base materials. At present experiment, energy density of 0.05 ～ 0.12kW/mm^2 is required for 0.2mm thickness Titanium foil.

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