TECHNICAL NOTE

Laser Cladding of TiC Dispersed Ni-Cr Composite Layer on Carbon Steel†

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KEY WORDS : (Laser Cladding) (Composite) (TiC) (Ni-Cr alloy) (Wear) (Corrosion)

1. Introduction

The advantage of a composite material is to allow a new function by combining two or more materials with different functions, such as a combination of a matrix matetrial and a dispersion particle material. A cladding of the composite material has a high potential as a surface modification process by adding the new function or capability to the substrate surface. Laser beam process is suitable for making such composite cladding layers[1-5] as well as plasma arc processes [6-8].

In this study, in order to improve the wear and corrosion resistances of carbon steel, laser cladding was utilized to make a TiC particle-dispersed Ni-Cr composite layer by irradiating CO_2 laser beam on a precoated layer of a mixture of TiC and Ni-Cr alloy powders.

An increase in wear resistance is expected by adding TiC hard particles to Ni-Cr alloy layer on carbon steel as well as an increase in corrosion resistance.

2. Experimental Procedures

Plain carbon steel (SS400) of 50mm × 50mm × 8mm was used as a substrate. As a cladding powder, a mixture of Ni 80mass%-Cr 20mass% alloy powder of 10 to 45 mm grain diameter and TiC ceramic powder of 2 to 3 mm grain diameter was used with TiC mixture ratio up to 100mass%.

The powder mixture was precoated on the substrate surface using an acrylic binder and then dried on a hot plate prior to irradiation by the laser beam. The amount of precoated powder was 0.5 g/cm^2.

Figure 1 shows a schematic illustration of the laser cladding process with a CW CO_2 laser beam of a multi mode. A defocused beam was used to prevent laser-induced plasma, and the optimum beam focusing point, Ddf was set at 30 mm above the substrate surface by a preliminary experiment. Moreover, a beam scanning perpendicular to the specimen traveling direction with 10Hz in frequency and 6 mm in width was employed to assure an uniform distribution of cladding materials in the layer as well as a wide width of the layer.

Wear resistance of the cladded layer was evaluated by the Ohgoshi wear test with a rotating counter roller made of SUJ2 at a rotating speed of 4.36 m/s, wear load of 31.4 N and wear distance of 100 m. In addition, corrosion resistance was evaluated qualitatively by the neutral salt spray test.

3. Results and Discussions

Figure 2 shows the combined effect of traveling speed and TiC mixture ratio in precoated layer on the formation of a composite cladded layer at a laser power of 2.0kW.

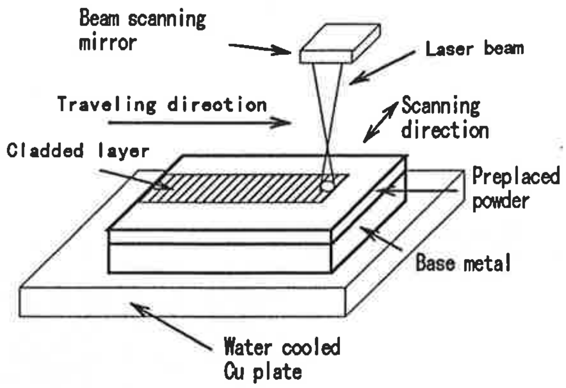

Fig. 1 Schematic illustration of laser cladding process.

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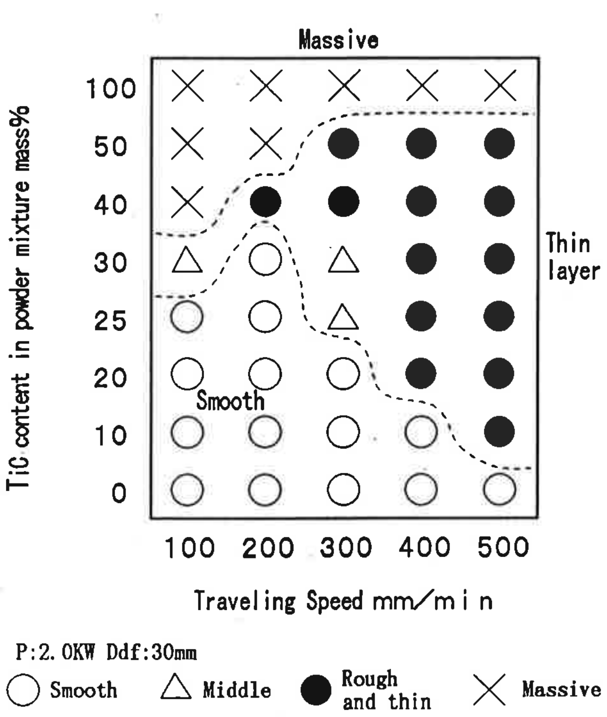

Fig. 2 Combined effect of traveling speed and TiC content in the powder mixture on the surface appearance of the composite.

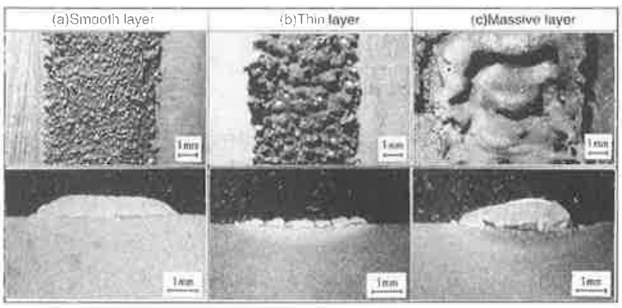

Fig. 3 Typical appearance and cross-section of TiC particulate composite layer, (a) TiC: 30%, F: 200mm/min, (b) TiC: 40%, F: 400mm/min, (c) TiC: 50%, F: 200mm/min.

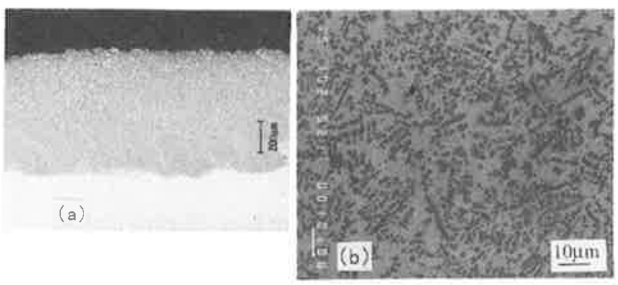

Fig. 4 Microstructure on cross-section of TiC particulate composite layer, TiC: 30%, F: 200mm/min.

The optimum cladding condition areas are indicated by a mark (○) which shows a good layer with a smooth surface, enough thickness and a good adhesion with the substrate.

Thin layer (●) and massive or globular layer (×) have a poor adhesion as shown in **Fig. 3** showing these three typical features of the surface and cross-sections of the cladded layers.

A good cladded layer can be obtained at low traveling speed and low TiC content because the heat input is sufficient to melt the substrate and assure good adhesion of the layer with the substrate.

Figure 4 shows the distribution of TiC particles in a cladded layer made at the optimum condition of TiC 30mass% and 200 mm/min travel speed. An optical micrograph (a) in Fig.4 shows a dense layer of 0.7 to 0.8 mm thickness, without cracks and porosity within the layer and the boundary between the layer and substrate. The distribution of TiC particles of 2 to 3 mm diameter is uniform throughout the layer as shown in (b) taken by SEM, and the volume fraction of TiC particles reached 41.4%.

Wear rate,Ws(mm3/Nm) of the composite cladded layers evaluated by the Ohgoshi test are shown in **Fig. 5** compared with the substrate SS400 and the Ni-Cr layer without TiC. Wear rate of the Ni-Cr layer increased to about twice that of the substrate because the Ni-Cr layer has a soft and adhesive feature due to its austenitic structure. On the contrary,TiC addition decreased the wear rate with increasing TiC content, and reached about one ninth of that of the substrate and one twentieth of that of the Ni-Cr layer with TiC 30mass%.

It is well known that hard particles, distributed densely and implanted strongly into the matrix, act effectively to prevent the composite materials from wear attack.

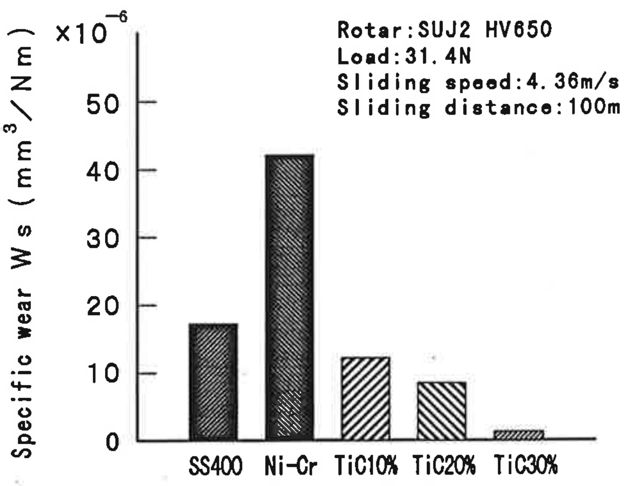

Fig. 5 Effect of TiC content on wear rate Ws of composite layer compared with the Ni-Cr layer and the SS400 substrate (2kW, F: 200mm/min, Ddf: 30mm).

Moreover, after the neutral salt spray test with a 24 hours exposure time, both the Ni-Cr layer and the TiC composite layer showed almost no trace of corrosion, irrespective of TiC content, and qualitatively almost the same corrosion resistance as that of SUS 304 austenitic stainless steel tested at the same condition.

Quantitative evaluation and analysis by measuring polarization curves are being included in further work.

4. Conclusions

A TiC particle-dispersed Ni-Cr composite layer can be cladded on carbon steel by irradiating a CW CO2 laser beam on a precoated powder layer, consisting of a powder mixture of Ni 80mass% - Cr 20mass% alloy and TiC powder up to 30 mass%. This composite cladded layer improved both the wear resistance and corrosion resistance of the carbon steel by about 9 times that of the substrate in wear resistance and almost the same order as SUS304 austenitic stainless steel in corrosion resistance.

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