Laser Surface Alloying of Plasma Sprayed Coatings with Steel Substrate†

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KEY WORDS: (Laser Surface Alloying) (Plasma Spraying) (Molybdenum) (Intermetallic Compound)

Plasma-sprayed coatings are widely used as the coatings of functional components. However, there exist some defects in coatings, such as micropores, microcracks and nonbonded interface area between lamellae, which decrease the properties of coatings, such as resistance to wear, corrosion, impact and so on. Therefore, an improvement of the properties of coatings is necessary in order to make greater use of coatings. Furthermore, the coatings with new characteristics are expected to be able to form by hybridizing of plasma spraying with laser beam irradiation.

Molybdenum is one of the most common alloying elements added to steel to improve their mechanical properties. Then, we have studied the laser alloying of Mo into steels.

Figure 1 shows the laser-plasma spraying system used in this study. Plasma spraying gun and working table are installed inside of a chamber equipped with exhaust systems. The laser source used is a 1kW CO_2 gas laser. The beam was focused to a spot of about 0.7 mm using a ZnSe lens of 380 mm focal length.

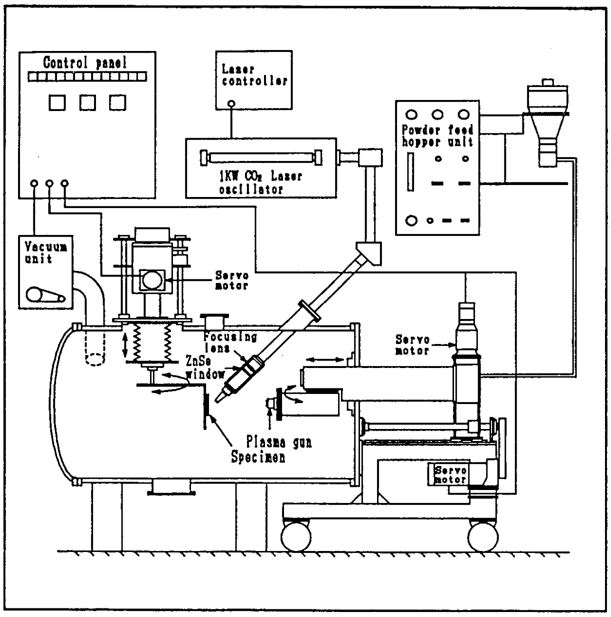

Fig. 1 Schematic diagram of laser-plasma spraying apparatus

Spraying powders used in this experiment were commercially available Mo powders. The coatings were sprayed onto sand-blasted SS41 steel of a size of $60 \times 100 \times 3$ mm. Before spraying the chamber is evacuated to about 1 Torr and then purged to 100 Torr with Ar gas. During spraying, a pressure of 100 Torr is maintained in Ar atmosphere. Immediately after spraying, laser treatment was carried out. **Table 1** shows the plasma spraying and laser irradiation conditions.

Figure 2 shows the cross sections of as-coated and laser treated Mo coatings respectively, where traverse speed (v) is 17 mm/sec and laser power are 350 W and 600 W. It is recognized that alloying layer of Mo coating treated at a laser power of 600 W is formed widely compared with treated one at a laser power of 350 W. Nonbonded interface between lamella and micropores in Mo coating disappear, but large porosities exist. Porosities in alloying layer may be formed by concentrating micropores in Mo coatings.

Figure 3 shows SEM micrographs of the same sample given in Fig. 1, EDX line analyses of both Mo and Fe, and a Vickers hardness (Hv_{50}) distribution with depth from the

Table 1 Conditions of plasma spraying and laser irradiation

Plasma	Plasma power	[kW]	40
	Spray distance	[mm]	450
	Traverse speed	[mm/s]	95
Laser	Laser power	[W]	600
	Defocus (F=380)	[mm]	±0
	Traverse speed	[mm/s]	6～20

† Received on May 7, 1991
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Transactions of JWRI is published by Welding Research Institute of Osaka University, Ibaraki, Osaka 567, Japan

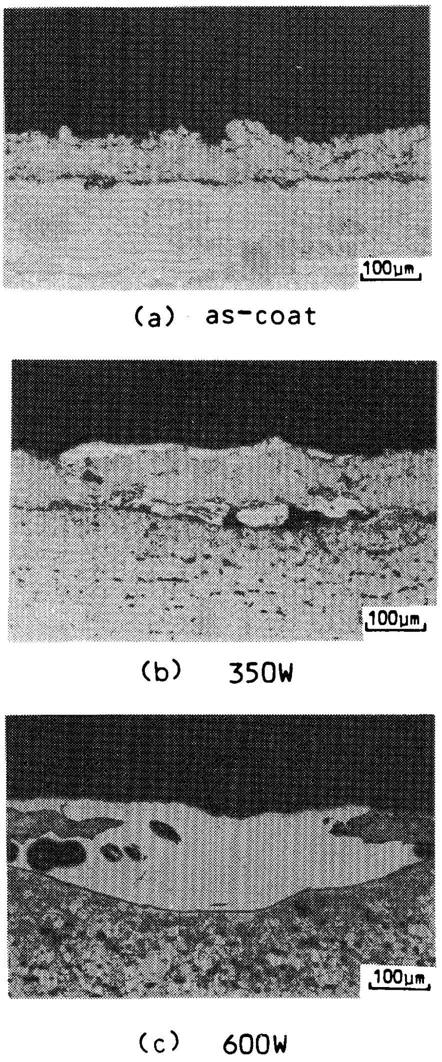

Fig. 2 Cross sections of Mo coatings alloyed with SS41 substrate by laser irradiation (v = 17 mm/s)

surface. Vickers hardness of as-coating of Mo is about 284 Hv, showing no diffusion area in the interface region. At a laser power of 600 W, there formed alloying layer composing of the elements of Mo and Fe in SS41 substrate. The hardness of the uniform alloying layer is about 700 Hv, and it is larger than both Mo coating and Fe substrate because of alloying Mo coating with Fe. At a laser power of 350 W, the hardness of the alloying layer is as same as that at 600 W, however, the thickness of the alloying layer is only about 10 μm.

Figure 4 shows the change in the Vickers hardness of laser alloying layer with Mo coating thickness (t). In Fig. 4, the hardness of the alloying layer increased with the increase of the thickness of Mo coating at any traverse speed of laser irradiation. It is considered that the quantity of Mo in the alloying layer influences on the hardness of alloying layer.

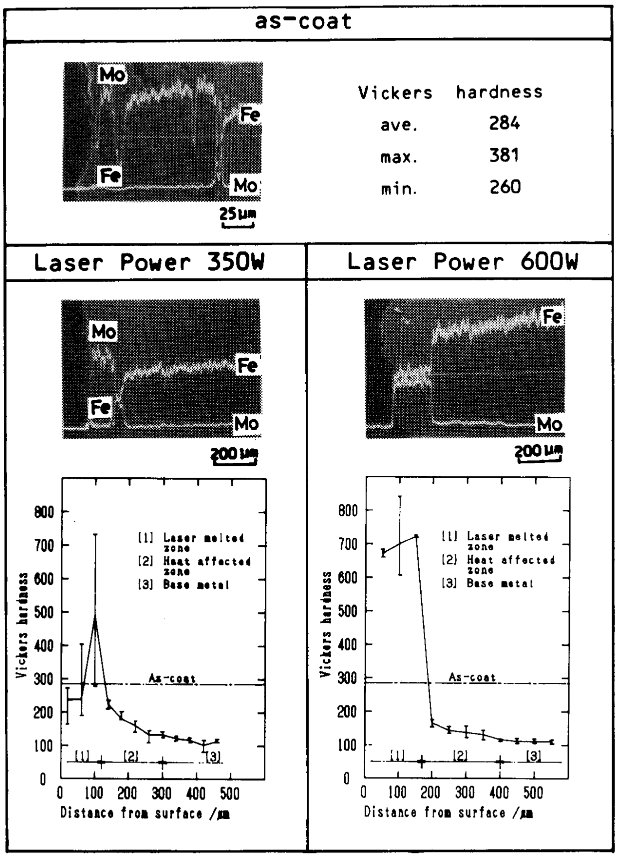

Fig. 3 Vickers hardness distribution and EDX analysis of Mo coatings alloyed with SS41 substrate by laser irradiation (v = 17 mm/s)

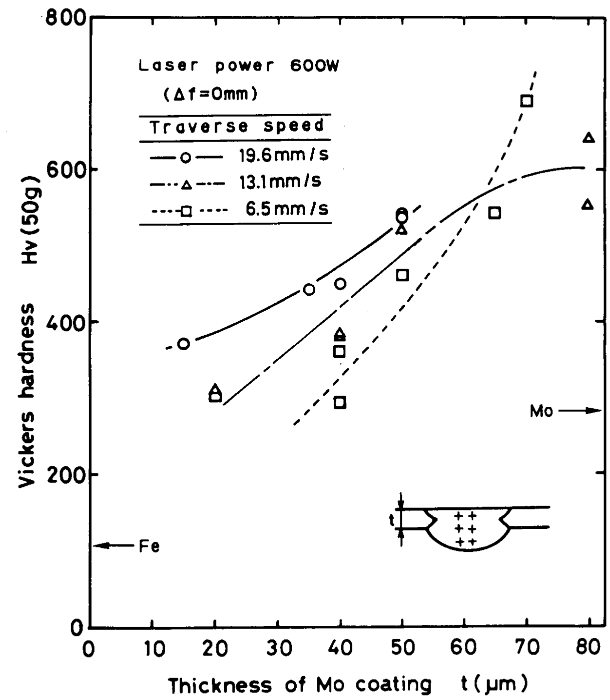

Fig. 4 Effect of the thickness of as-coating on Vickers hardness (Hv) of laser alloying layer

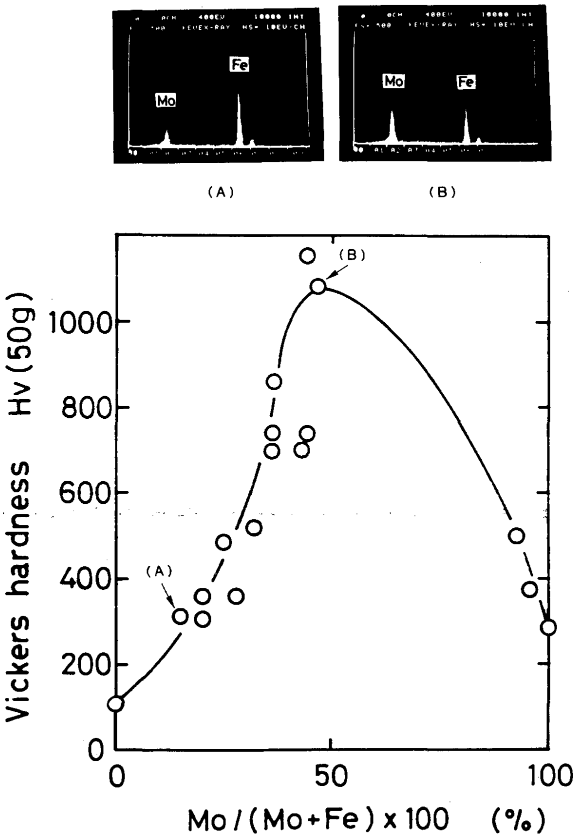

Fig. 5 Effect of a Mo ratio by EDX point analysis on Vickers hardness of laser alloying layer

Figure 5 shows the change in a Vickers hardness with a ratio of Mo in Fe-Mo alloy obtained by EDX spot analyses. When a ratio of Mo is a certain value of about 50%, the hardness of the alloying layer shows maximum of about 1000 Hv. However the hardness decreases with the increase of either Mo or Fe. Therefore, the hardness of Mo coating alloyed with Fe by laser irradiation is dependent on greatly the Mo content of alloying layer.

Figure 6 shows SEM micrographs of the alloying layer with different hardness, depending on the existence of white strings and gray parts. These white strings and the gray parts enclosed with the white strings were analyzed quantitatively by EPMA. Fe/Mo ratio (at%) was 1/2 in the white strings and Fe/Mo ratio (at%) was 7/3 in the internal gray parts. As shown in Fig. 6, the hardness of the alloying layer decreases with the decrease of white strings. The hardness of the alloying layer (a) where wide and large white strings exist is 820 Hv; in the region (b) where white strings width is small, it is 580 Hv; in the region (c) where few white strings exist, it is 430 Hv.

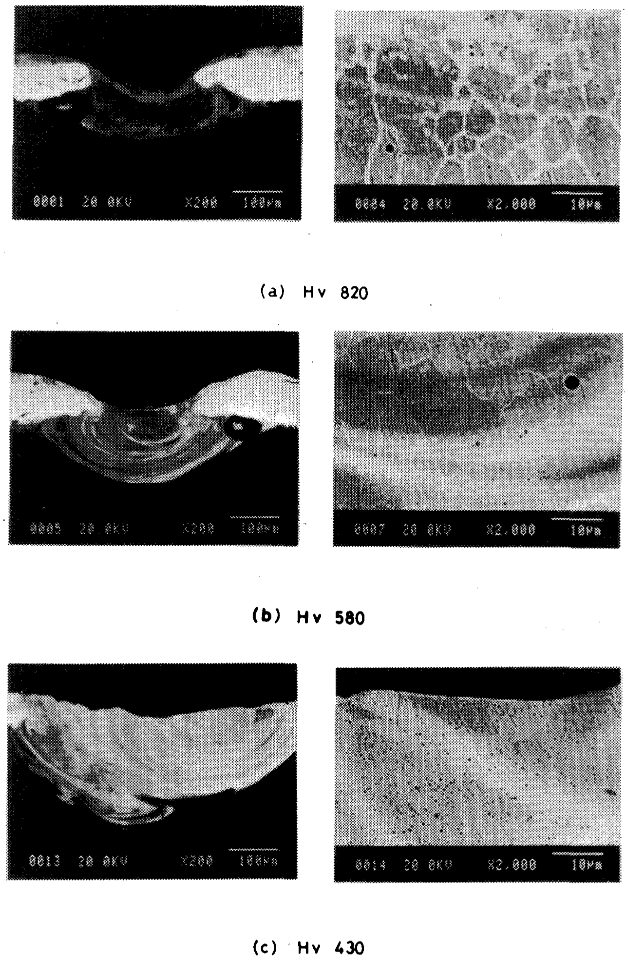

Fig. 6 SEM microstructure dependence of hardness of laser alloying Mo coatings

As a result of the above, the hardness of the laser treated Mo coating on steel substrate depends greatly on a quantity of intermetallic compound of Fe/Mo = 2/1.