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Influence of particle size on heat affected zone in laser cladding

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Abstract

Laser cladding is one of the useful surface coating methods for improving the quality of wear and corrosion resistance of material surfaces. Compared with other conventional surface coating methods, such as plasma thermal spray and transferred arc welding, laser cladding can produce much better coatings with minimum dilution and well bond to the substrate. When cladding layer is produced, heat affected zone (HAZ) is formed in the substrate. In order to reduce the area of HAZ, heat input needs to be reduced. In this study, influence of particle size on HAZ was investigated. The cladding layers were produced at various heat input and particle size. Ni-Cr-Si-B alloy powder with the average particle size were 30, 40 and 55 µm were deposited on the C45 carbon steel substrate. The area of HAZ was measured with optical microscope. The results showed that the cladding layers with well attached to the substrate were produced at smaller heat input by using smaller powder material. The area of HAZ with 30 µm powder was about 30% smaller than that with 55 µm powder

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1. Introduction

In many industrial applications, engineering components require a high quality surface. For example, a high resistance to wear and corrosion can extend the service life of a component. Ni-Cr-Si-B alloy is generally used in hard facing alloys for engines or industrial components to provide wear resistance. This alloy has traditionally been deposited by thermal spray (I. Hemmati et al., 2013). However, a dense metallurgically bonded Ni-Cr-Si-B layer cannot be produced using a thermal spray process. Recently, it has been suggested that laser cladding can produce dense metallurgically bonded coatings on substrates with minimal heat input into the work piece (A. Conde et al., 2002 and G. Xu et al., 2006).

Although heat input is small in laser cladding, heat affected zone (HAZ) is formed in the substrate. HAZ lowers the strength of substrate (T. Baldridge et al., 2013). In order to reduce HAZ area, heat input needs to be reduced. However, when heat input is too small, cladding layer cannot be produced because of poor wetting. It is needed to optimize the heat input in laser cladding.

In laser cladding, powder material is melted from the top of powder bed. Melted powder material heats and melts the substrate. When substrate is heated by melted powder, HAZ is formed. Optimal heat input depends on the temperature of melted powder. It is considered that the temperature of the powder material is easy to be increased as the particle size becomes small. So, it is considered that optimal heat input decreased as the particle size becomes small.

In this study, Ni-Cr-Si-B alloy powder with the average particle size of 30, 40 and 55 μm were deposited on the C45 carbon steel substrate. Heat input was varied to investigate the dependency of particle size on the HAZ area. The area of HAZ was measured with optical microscope.

2. Experimental

Laser cladding experiments were carried out using a diode laser system as shown in Fig. 1. The beam spot size was 2600×300 μm^2. The laser beam was focused onto the powder material and scanned along the short axis using an XY stage. A Ni-Cr-Si-B alloy powder with the average particle size of 30, 40 and 55 μm was used. The particle size distribution and SEM images of powder with several particle size are shown in Fig. 2 and 3, respectively. The powder material was placed on a C45 carbon steel substrate. The thickness of powder bed was 200 μm.

A cladding layer was produced at various heat input by changing scanning speed of laser beam. The heat input was changed in the range from 150 to 250 J/cm. The power density of the laser beam was 3.9×10^4 W/cm^2. The surface and cross section of the layer is observed with optical microscope. The area of HAZ was measured.

3. Results and discussion

Optical microscope images of the cladding layer surface with the particle diameter of 30, 40 and 55 μm are shown in Figs. 4 (a), (b) and (c), respectively at the heat input of 162.5 J/cm. Cladding layer formed with 30 μm powder was well attached to the substrate. When 40 and 55 μm powder was used, cladding layer was not formed because of poor wetting. A cladding layer is formed at the heat input of 200 and 250 J/cm with the 40 and 55 μm powder, respectively. These results indicate that cladding layer can be produced at lower

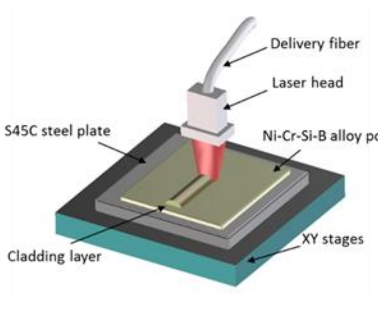

Fig. 1 Experimental setup.

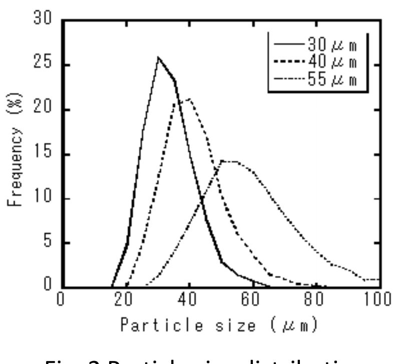

Fig. 2 Particle size distribution.

Fig. 4 Opticlai images of cladding layer surface (a) 30, (b) 40 and (c) 55 μ m.

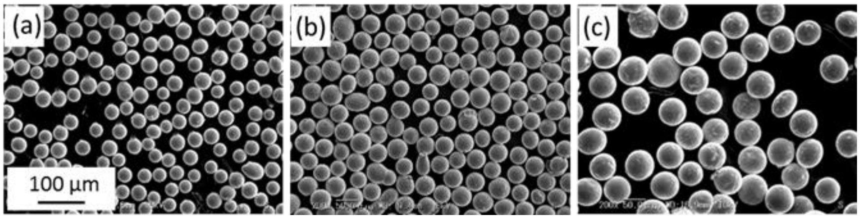

Fig. 3 SEM images of powder material (a) 30, (b) 40 and (c) 55 μ m.

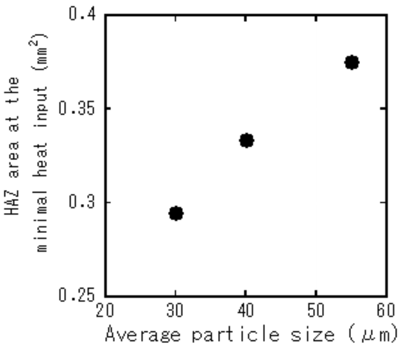

Fig. 5 HAZ area at the minimal heat input as a function of average particle size.

heat input as the particle size became small. This means that wettability of melted powder was improved as the particle size became small. It is considered that temperature of the particle can be easy to be increased by using smaller particle because the volume of particle became small. As a result, cladding layer can be produced lower heat input as the particle size became small.

The HAZ area became smaller by using smaller powder because cladding layer can be produced at lower heat input. The dependence of HAZ area on particle diameter is shown in Fig. 5. The area of HAZ was 0.29, 0.33 and 0.37 mm^2 with the 30, 40 and 55 μm powder, respectively. These results show that HAZ area can be reduced by using smaller powder.

4. **Conclusion**

Ni-Cr-Si-B alloy powder with the particle diameter of 30, 40 and 55 μm was deposited on the C45 carbon steel substrate. Cladding layer well attached to the substrate was produced at lower heat input by using smaller powder material. Cladding layer was produced at the heat input of 162.5, 200 and 250 J/cm with the

30, 40 and 55 µm powder. The HAZ area became smaller by using small powder material because minimal heat input to produce cladding layer was decreased.

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