Study on dissimilar metal fabrication with direct metal lamination by using arc discharge

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Abstract

The direct metal lamination is one of the additive manufacturing process using the arc welding technology; where the molten metal made by the arc discharge is accumulated successively in this process. In this study, two kinds of dissimilar metal fabrication were conducted. One is aluminium alloy and titanium alloy. Another is stainless steel and Ni based alloy. The boundaries of dissimilar metal structures were investigated. As a result, it is suggested the possibility of the fabrication with more than one kind of metallic material by direct metal lamination.

1. Introduction

Additive manufacturing process, which can fabricate complicated shapes from 3D-CAD data, has become popular for making prototypes. Additive manufacturing is expected to fabricate not only prototypes but also machine parts and die tools[1]. Direct metal lamination using arc discharge has been developed by the authors' research group [2] as a novel additive manufacturing process. An arc welding unit with a CNC milling machine, are also being developed [3].

In this process, the metallic materials are melted and accumulated by arc welding technology. Figure 1 shows the lamination mechanism. Welding wire is fed to the welding torch tip and it works as a positive electrode. The welding wire tip and manufactured object are melted by the arc discharge caused between wire tip and manufactured object. Molten metal is dropped on the molten pool of the manufactured object. As the welding torch moves along the aimed path, accumulated molten metal is solidified and deposited. Therefore, various metallic materials can be used with this process. The strength is comparable to the bulk material, so metallic products with high strength can be fabricated rapidly. So this process can reduce the quantity of the removed material at finishing process and is especially expected to fabricate large-size dies and a single machine part which needs high-strength.

In the additive manufacturing process, more than one kind of material can be used during fabrication process. The metal parts which are fabricated with more than one kind of material can have various good mechanical properties such as high strength, light weight, durability, thermostability, etc… In this study, two kinds of dissimilar metal fabrication were conducted. One is Al-5Mg and Ti-6Al-4. Another is stainless steel 20Cr-9Ni-0.03C and Ni based heat resistance alloy Ni-20Cr-3Mn-Nb. Aluminium alloy and Titanium alloy are widely used in aircraft industry. Stainless steel and nickel based alloy were used in power plant industry. However, in dissimilar metal welding, it is problem that intermetallic alloy is formed in the boundary between two metals [4]. The boundaries of dissimilar metal structure were investigated by element analysis using EPMA and Vickers hardness test.

2. Experimental Procedure

Figure 2 shows the direct metal lamination machine. It has four axes X, Y, Z and B. A welding torch is attached on Z axis. Welding torch movement is controlled with PC based controller. The Z-axis is controlled to keep the distance between the welding torch tip and the accumulating point to be constant. A substrate, on which the manufacturing object is accumulated, is fixed to the base block on the table.

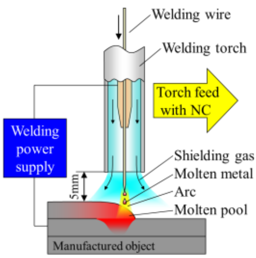


Figure 1: Lamination mechanism

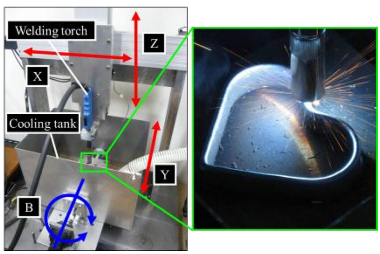


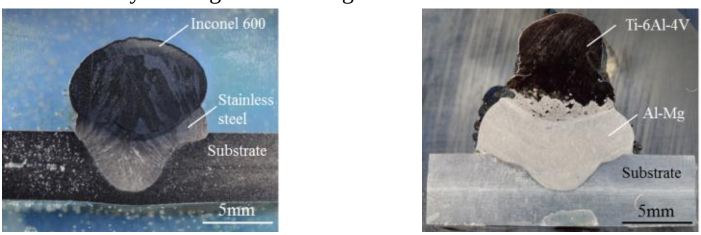
Figure 2: Direct metal lamination machine

3. Dissimilar metal lamination

A single straight bead was made with austenitic stainless steel material on the substrate made of similar material. Another bead, whose material was Ni based alloy, was made on the stainless steel bead after the stainless steel bead being cooled to room temperature. Similarly, Ti-6Al-4V bead was made on the Al-5Mg bead. The substrate was made of Al-5Mg alloy. Figure 3 shows the cross-section of the beads and Fig. 4 shows the microstructure. As shown Figure 3(a) and Figure 4(a), boundary between stainless steel and Ni based alloy was clearly observed. On the other hand, shown in Figure 3(b). Figure 4(b), Al-5Mg and Ti-6Al-4V was not separated clearly. That is, it is considered that the layer where Al-5Mg, Ti-6Al-4V and intermetallic alloy was mixed, was observed. Element analysis and Vickers hardness tests were conducted. Figure 5 shows the results of the element analysis using EPMA.

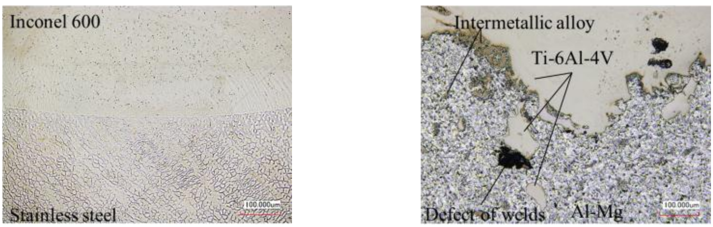
Figure 6 shows the results of the Vickers hardness tests. From Figure 5(a) and Figure 6(a), the boundary layer thickness of stainless steel – Ni based alloy was about 20μm. The hardness of boundary layer was slightly small but almost equal to stainless steel and Ni based alloy. As shown in Figure 5(b) and

Figure 6(b), the boundary layer thickness of Al-5Mg – Ti-6Al-4V was about 2mm. In this layer, content of elements changes with repeated increase and decrease. The hardnes of boundary layer changed from about 70HV to 560HV by lacation because Al-5Mg, Ti-6Al-4V and intermetallic alloy exsit. The hardness of Ti-6Al-4V and intermetallic alloy was high but Al-5Mg was low.



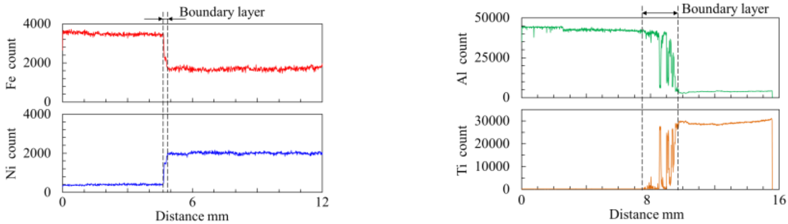
(b) Stainless steel – Ni based alloy (a) Al-5Mg – Ti-6Al-4V

Figure 3: Cross-section of the beads



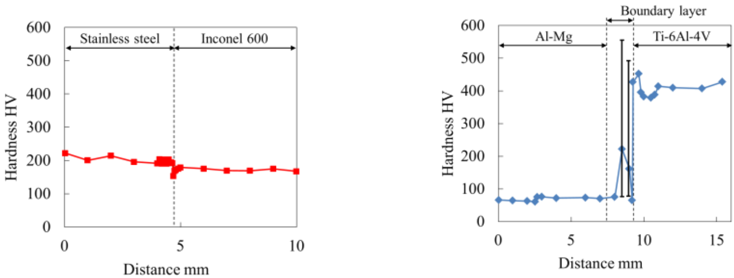
(a) Stainless steel – Ni based alloy (b) Al-5Mg – Ti-6Al-4V

Figure 4: Microstructure of the metal



(a) Stainless steel – Ni based alloy (b) Al-5Mg – Ti-6Al-4V

Figure 5: Element analysis using EPMA



(a) Stainless steel – Ni based alloy (b) Al-5Mg – Ti-6Al-4V

Figure 6: Vickers hardness

4. Conclusions

(1) The boundary layer thickness of stainless steel – Ni based alloy lamination was about 20µm and hardness was almost equal to other area.

(2) Al-5Mg, Ti-6Al-4V and intermetallic alloy were mixed in the boundary layer between Al-5Mg and Ti-6Al-4V. The hardness of the boundary layer changes by lacation because Al-5Mg, Ti-6Al-4V and intermetallic alloy were mixed.

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