DEPOSITION OF M.M.C. COATINGS ONTO ALUMINUM ALLOY PLATE USING FRICTION COATING

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ABSTRACT   In this study, an attempt had been made to deposit an aluminum alloy metal matrix composite (M.M.C.) coatings reinforced with alumina particles, onto a 5083 aluminum alloy plate by friction coating. The process is that a hollow rod of aluminum alloy is used as the surface modification material, in which the hollow section is filled with 5 μm diameter of alumina powders. These alumina powders had been uniformly distributed in the deposited matrix with a refined grains, due to the intensive plastic deformation generated during friction coating process. Since the conventional friction coating process has some innate deficiencies for applying aluminum alloy due to its specific physical attributes, a novel process - friction coating under liquid has been introduced to achieve steady processing.

Keywords : *Friction coating, M.M.C., Reinforced particle, Volume fraction, Hardness*

1. INTRODUCTION

Due to the attractive physical features such as high strength/weight ratio and toughness as well as excellent resistance to corrosion, aluminum alloys has been extensively exploited in aerospace, automobile and other industrial fields. However, only of precipitation strengthening and cold-working hardening methods (sometimes involves grain-refining hardening) are available for strengthening aluminum alloy.

Various surface modification technologies have been developed [1,2] to improve functional properties of aluminum alloy such as wear resistance. Among of these methods, metal matrix composite (M.M.C.) exhibits the unique ability to endure high tensile and compressive stresses by the transfer and distribution of the applied load from the ductile matrix to the reinforcement phase [3,4]. Compared to a continuous fiber reinforced composites, the particle-reinforced composites are inexpensive, relatively isotropic properties and possible to be processed by conventionally continuous processing such as rolling, forging, and extrusion. Furthermore, adhesion wear resistant property is strongly dependent on the uniformity of reinforced particle distribution and space distance between particles [5].

Conventional powder metallurgy methods involving cold pressing and sintering, or hot pressing can be used to fabricate particle-reinforced M.M.C.. A new processing so-called "Cospray process" [4,6] has been given attentions. The reinforced particle volume fraction up to 20% have been incorporated into aluminum alloys. There is an optimum particle size existing in this process. Since the wettablity deteriorates with decreasing the particle size, it is difficulty to spray refined particles by this method. The two processes described above can not be used to modify the localized surface properties on site. As an in situ process for making particle reinforced M.M.C., thermal spray is attractive. However, inherent shortage of fusion method such as higher dilution, porosity et al, are still existing in thermal spray process.

The friction coating is a solid-phase process with the inherent features including negligible dilution of deposited metals, no porous defect, a narrower field of HAZ as well as the fast deposition rate of coatings. The particle-reinforced M.M.C. coating has been deposited onto a conventional material appropriately by friction coating process [7,8]. As a new in situ process for making particle-reinforced M.M.C. coatings, friction coating process will be given more attentions with its development and application increasing.

2. EXPERIMENTAL METHOD

2.1 Experimental equipments and materials

The equipment used in this study was a conventional continuous friction welding machine with a maximum axial load of 6 tons, which was equipped with a sliding stage. The rotational speed and substrate sliding speed were respectively varied in 1200 - 1800 rpm and 2 - 8 mm/sec ranges.

The experimental material was A5052 aluminum alloy as the coating material with a diameter of 20 mm and length 150 mm. The substrate material was A5083 with a width of 50 mm, length of 150 mm and thickness of 12 mm.

Alumina powders with nominal average diameter of 5 μm was used as the reinforced particles, while this type of particles has been generally used as a polishing powder in the mechanical polishing operations.

2.2 Experimental method for making particle-reinforced M.M.C. by friction coating process

A novel in situ process for friction coating has been adapted [7] in this study, although some of commercial M.M.C. rod such as M.M.C. rod manufactured by Cospray process [8], are available to be used as a consumable rod. The hollow consumable rod of A5052 with three holes of 4mm diameter was prepared, and the alumina powders were filled in these holes.

3. RESULTS AND DISCUSSIONS

3.1 Assessment of friction coating process

3.1.1 Deficiencies of conventional friction coating process

When some materials such as aluminum alloy were used as a consumable rod to meet special application requirements, the deficiencies of conventional friction coating process appeared due to the specific attributes of these materials, such as higher thermal conductivity, lower strength.

To understand the characteristics of the conventional friction coating process, the typical process charts of aluminum alloy is shown in Fig.1(a). The related friction parameters is as following: rotation speed 1500rpm, nominal friction pressure (i.e. set data) 50MPa, traverse sliding rate of substrate 4mm/s. As being seen, the displacemental rate of consumable rod is very large under relatively high friction pressure condition shown in Fig.1(a). The practical friction pressure is only about 30MPa although the set pressure is 50MPa. As a result, the conventional friction coating process possesses the attributes as following: (1) The coatings of aluminum alloy is thicker (approximate 4mm generally) even though the traverse sliding rate is more than 4mm/s. (2) The flash generation from the rotating consumable rod is very quick, and it results that the duration of friction coating process is quite limited due to the impingement of flash roll on the chuck. (3) The lack of bonding is liable to occur at the interface shown in Fig.2 due to insufficient friction pressure.

In order to achieve steady friction coatings, a great deal of attempt involving continuous rod feed system and flash constraint fitting bush [9] has been made. However, this kind of bush is too complicated for practical use. It is necessary to search the other method.

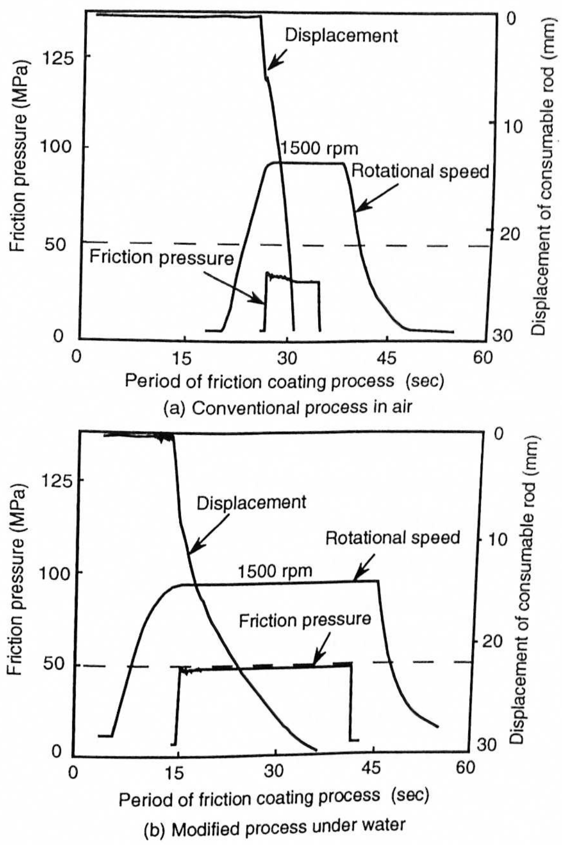


Fig.1 Process charts for Al alloy coating by friction in both conditions of in air and under water

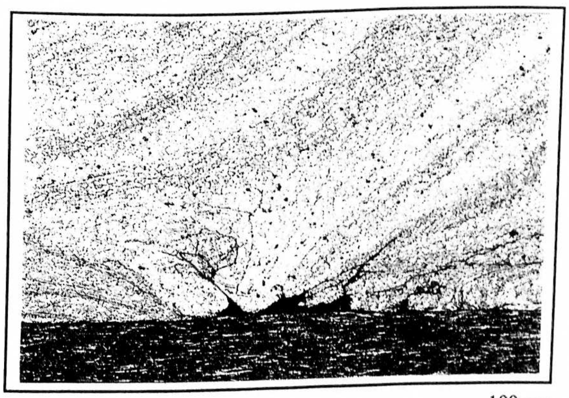


Fig.2 Typically bonding defect occurred at interface during the conventional friction coating process

3.1.2 Friction coating process under liquid

In this study, in order to deposit the aluminum alloy M.M.C. coatings onto the aluminum alloy plate, the sufficient friction pressure is necessary. An alternative process - friction coating under liquid has been developed. Water has been used in this study as a preliminary trial. The modified process chart in the same parameters is shown in Fig.1(b) comparing with the conventional friction coating process. It is obviously that the duration of process has been extended, and the friction pressure has been controlled. Although the thickness of coatings by modified process decreased (~ 0.8mm), the width of coating increased up to 35mm comparing with the width of 25mm deposited by the conventional process. Furthermore, the integrity of bonding has also been modified shown in Fig.3 due to increasing in practical friction pressure, the oxidation has not been observed in the coatings. The volume and height of flash roll generated from the rotating consumable rod decreased considerably.

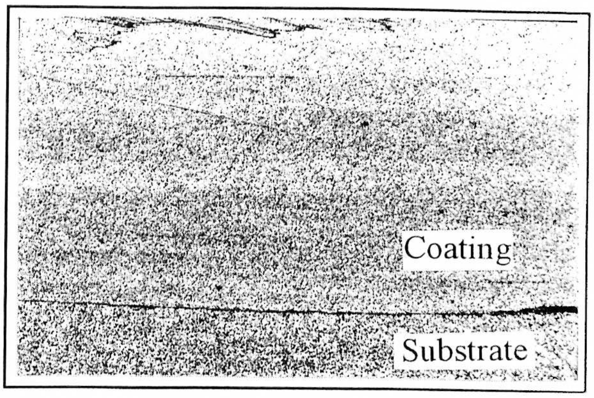


Fig.3 Sound bonding has been achieved by the modified friction coating process

The advantages of friction coating under liquid are considered as following: (1) It is possible to adjust the friction energy into the consumable rod and substrate by changing the alternative liquid with differently physical attributes such as specific heat of liquid. (2) It becomes possible to use the liquid as a liquid shield atmosphere to deposit an active metals. (3) It is also possible to deposit a quenched coatings using an ordinary hardenable steel due to the quick-cooling effect of liquid.

3.2 Microstructures observation of composite coatings

It is known that the characteristics of particle-reinforced M.M.C. is dependent on the volume fraction of reinforced particle v_p and particles distribution in the matrix. The nominal v_p of consumable rod used is 12 % with reinforced particles of diameter 5 μm in this study, which is calculated from the cross-section area ratio of hole to consumable rod filled with reinforced particles.

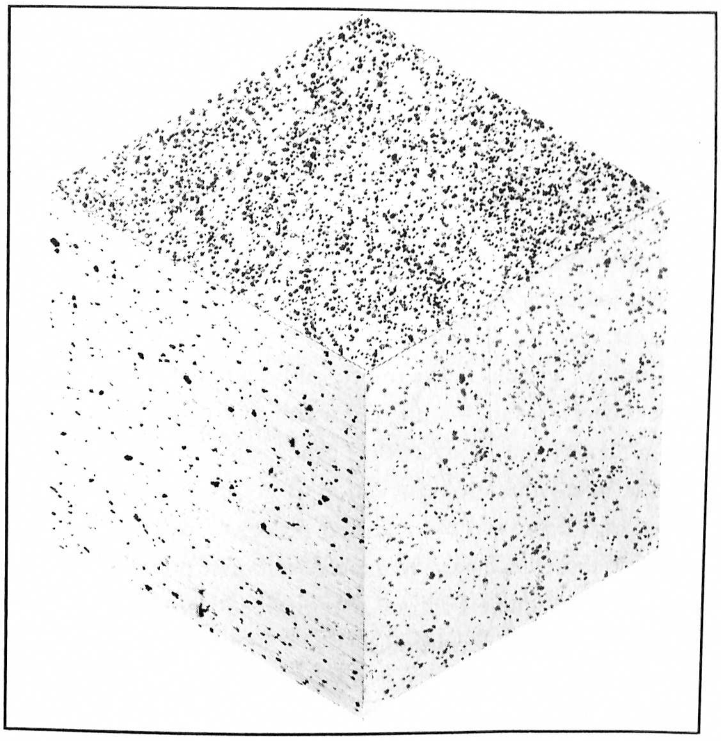
As-polished (not etched) 25μm

Fig.4 Aggregation of reinforced particles at interface during the conventional friction coating process

The Microstructure observations of M.M.C. coatings on three mutually perpendicular sections have been made to clarify the size and distribution of reinforced particles under both processes. This observation has been carried out under the as-polished condition of specimens.

The aggregation phenomenon of reinforced particles at the interface has been observed in the coatings deposited by the conventional process as shown in Fig.4. It is referred to the insufficient of friction pressure, and it will deteriorates the bonding strength with substrate. The similar phenomenon has not been observed in coatings by modified process under water.

On the other hand, as shown in Fig.5, the reinforced particles in matrix of coatings deposited by the modified process are more refined than those by the conventional process. It is correlated with that the practical friction pressure in modified process becomes sufficient, and it results in the more intensive plastic deformation. Eventually, the reinforced particles has been refined.



As-polished (not etched) 50 μ m

X: Direction of deposition.
Y: Direction of increasing in width.
Z: Direction of increasing in thickness.

Z X Y

Fig.5 Distribution of reinforced-particles on three dimensional sections in coatings matrix by modified process under water

3.3 Hardness variations

The coatings hardness test in vickers has been carried out. Although the reinforced particles can improve the matrix properties at high temperature and wear-resistance, it can not promote the hardness to great extent. The result is that the hardness of M.M.C. coatings deposited under water is higher than substrate, although the hardness of coatings matrix is less than substrate plate. It is referred to the effect of grain-refined strengthening occurred during the modified process.

4. CONCLUSIONS

To improve the surface properties of substrate, various surface modification technologies has been proposed and applied. Friction coating is a solid-phase process with inherent features of negligible dilution, no porosity et al. In this study, an available approach has been used by the modified friction coating process under water. As a preliminary study, there are some further works need to be done to stabilize the process. The conclusions of this study are summarized as follows:

(1) To deposit some materials coatings, such as aluminum alloy, the conventional friction coating indicates some deficiencies. The modified process which is performed under water can overcome the deficiencies. The sound coatings of aluminum alloy have been achieved with refined grains. Furthermore, although the thickness of coating deposited by modified process decreases to 0.8mm, the width of coating extends up to 35mm comparing to width of 25mm deposited by conventional process.
(2) The microstructure observation of composite coatings shows that the reinforced particles in coatings deposited by modified process, are more uniform distribution and more refined size than those deposited by the conventional process. Microstructure observation reveals that the 12% v_p (volume fraction of reinforced-particles) M.M.C. coatings reinforced with 5μm alumina powder are achieved.
(3) The hardness test indicates that although the hardness of coating material is lower than substrate, the hardness of M.M.C. coating deposited is higher than substrate due to the refined grain strengthening occurred during modified friction coating process under water.

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