Journal of Metallurgical and Materials Engineering, Vol.27, No.2, 2016.

Study of the Microstructure and Wear Behavior of an in-situ Al/Al_3Ti Composite Coating on Commercially Pure Aluminum Produced using Aluminum Cored Wires

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1- Introduction

Aluminum and its alloys have attracted the attention of many industries such as electrical machinery, automotive and aerospace industries due to their high strength-to-weight ratio, corrosion resistance and high thermal and electrical conductivity. But, their applications have been restricted due to their low wear resistance. The wear resistance can be increased by modifying the microstructure or chemical composition of the surface layers. One of these surface modification solutions is to produce surface composite coatings. In order to improve the surface wear resistance, surface treatment technologies such as hard anodizing, electroplating and physical vapor deposition could be applied. In most cases, these surface layers are too thin to sustain the applied loads because the thin film can easily break with minor deformation in the aluminum alloy substrate.

Hence, it is necessary to obtain a thick hard coating on the surface of aluminum alloy. Laser and electron beam processing methods can produce thick coatings that are more appropriate for wear applications. However, both these techniques are expensive and require specific setups, e.g. high vacuum. To overcome such difficulties, a number of researchers have used the TIG process to produce hard coatings on different substrates. During the last few decades, most researches have focused on ceramic reinforced aluminum metal matrix composites (MMCs). There are some limitations in the fabrication process of such composites. These limitations include large differences between the coefficient of thermal expansions (CTE) of the aluminum matrix and the ceramic reinforcements, and also high brittleness of the ceramic compounds. Intermetallic compounds with low density and high modulus are a convenient choice when compared to ceramics. Since aluminum intermetallic compounds such as Al_3Ti have a CTE close to aluminum and lower brittleness compared to ceramics, they can be a better choice to overcome the mentioned obstacles.

2- Experimental procedure

Commercially pure aluminum was used as the substrate with dimensions of 80×60×4 mm. Cored wires were used for fabricating a wear resistance coating. Wire drawing method was used to produce these cored wires. At first, the 1050 aluminum alloy strip with a cross-section of 10×0.5 mm was annealed at 400 °C for 1 h. The strip was then passed through different dies with 5 mm, 4.5 mm and 4.1 mm diameters, respectively to give a U- and then O-shaped cross-section. During this process a mixture of titanium and aluminum powders were added to the U-shaped strip. The percent of titanium particles in the cored wire was about 40 wt.%. Using TIG process, the cored wires were deposited on the aluminum substrate. The process parameters were an argon flow rate of 14 $lmin^{-1}$, non-consumable tungsten electrode with a 2.4 mm diameter, AC supply of about 110 A, and welding travel speed of 1.11 mms^{-1}. The microstructure of the composite coating was studied using optical and scanning electron microscopes (SEM). The phases present in the surface coating were investigated by X-ray diffraction (XRD). Microhardness investigations of the composite coating were performed using a microhardness tester with a Vickers indenter with a 10 g load. In order to estimate the wear resistance of the substrate and coating, pin on disc tests were performed. In these tests, the material of the stationary pin was ball bearing steel 52100 with a hardness of 60 HRC. The disk was made from the composite coating. The wear tests were carried out at room temperature under dry conditions, normal load of 36 N, sliding speed of 0.1 ms^{-1} and a sliding distance of 1000 m.

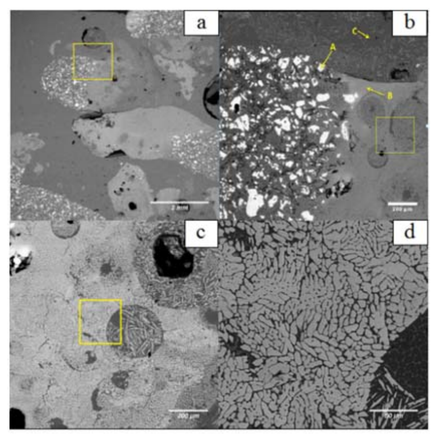

Fig.1 a) SEM micrograph of the microstructure of the coating; b) magnified view of the selected area in (a); c) magnified view of the selected area in (b); d) magnified view of the selected area in (c). The white phase in all the images is titanium, the light gray phase is Al_3Ti, and the dark matrix is aluminum

3- Results and discussion

Fig. 1 shows the microstructure of the composite coating at difference magnifications. It was found that the coating is composed of three different zones with different brightness contrasts indicating different constituent phases. The composition of the various zones analyzed by energy dispersive X-ray spectroscopy (EDS) are shown in Table 1. The EDS results reveal that the white phase is titanium, which

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has attracted some nitrogen from the air despite the use of a shielding gas, the light grey phase is Al_3Ti and the dark grey phase is aluminum. The X-ray diffraction pattern for the coating is shown in Fig. 2. This pattern shows that some of the titanium has reacted with aluminum to form Al_3Ti but some unreacted titanium still remains; aluminum, Al_3Ti and titanium particles are the main phases in the composite coating.

The wear tests were carried out for the coated sample and the aluminum substrate. The average friction coefficient values for the composite coating and the aluminum substrate are respectively 0.47 and 0.8. Therefore, the cladding coating has decreased the friction coefficient of the substrate.

Table. 1 The EDS analysis results for the different zones seen in the coating

Phase	Compositions (at. %)		
	Al	Ti	N
White phase	-	55.21	44.79
Light grey phase	75.55	24.45	-
Dark grey phase	100	-	-

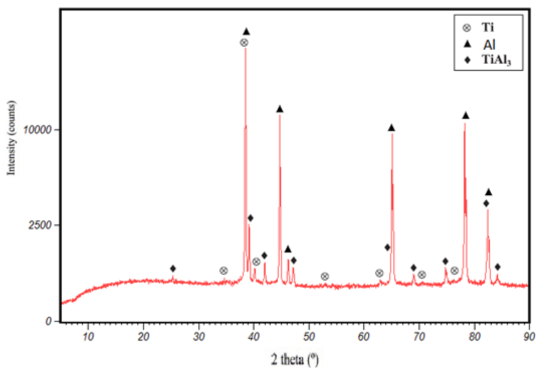

Fig. 2 X-ray diffraction pattern for the coating

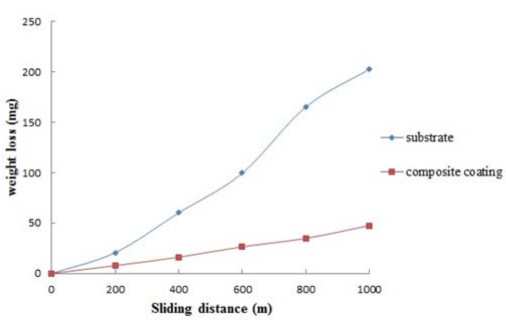

Fig. 3 Wear weight loss as a function of sliding distance

The wear weight loss data for the composite coating and the untreated substrate are presented in Fig. 3. The composite coating had a lower volume loss as compared to the untreated substrate, i.e. the surface composite coating improved the wear resistance of the aluminum substrate.

The microhardness of the difference phases in the composite coating was measured and are shown in Fig. 4. The microhardness values of the Al_3Ti, titanium and aluminum matrix are respectively 300 HV, 175 HV and 40 HV. The microhardness value of untreated substrate is 23 HV. The presence of the Al_3Ti phase has led to an increase in the wear resistance and hardness.

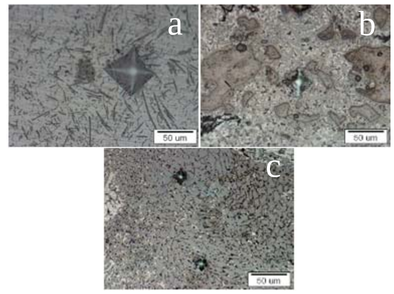

Fig. 4 The microhardness of the difference phases; a) aluminum matrix (40 HV); b) titanium phase (175 HV); c) Al_3Ti intermetallic dendrites (300 HV)

4- Conclusions

An Al/Al_3Ti surface composite coating hs been produced on commercially pure aluminum using aluminum cored wire filled with a mixture of titanium and aluminum powders and TIG process. The microstructure of the cladding coating is composed of aluminum, titanium as well as Al_3Ti phases. The presence of Al_3Ti has led to an increase in the wear resistance of the coating. A maximum microhardness value of about 300 HV was measured for the coating which is about13 times higher than the hardness of the substrate material. The average friction coefficient values for the composite coating and the aluminum substrate are respectively 0.47 and 0.8.