U.P.B. Sci. Bull., Series B, Vol. 79, Iss. 1, 2017 ISSN 1454-2331

EXPERIMENTAL RESEARCH CONCERNING A NEW METHOD TO PRODUCE ALUMINUM ALLOY-GRAPHITE PARTICLE COMPOSITE IN SUPERFICIAL LAYERS

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The paper presents a new method and some experimental results to obtain Al alloy-graphite particle composites in superficial layers. Different amounts of graphite particles were used to cover two types of electrodes: pure aluminum and Al-Si12. Microstructure, particles density, and different mean shape factors (mean sphericity, mean convexity, mean aspect ratio, and mean perimeter) were investigated.

Keywords: aluminum alloy, graphite particles, electrode, electric arc, shape factors

1. Introduction

Aluminum alloys with different graphite particles in superficial layer have received considerable attention, because they represent materials with a large field of potential anti-friction applications. In these composites, graphite improves significantly the tribological properties, because graphite-rich film is formed between sliding surfaces [1, 2].

Aluminum is known as a lightweight metal, ρ = 2698 kg/m^3, Brinell's hardness of 245HB, and thermal conductivity of 210 W/ (m·K).

Natural graphite is a mineral consisting of carbon atoms arranged in flat planes of hexagonal rings stacked on one another and usually varies considerably in crystallinity. It is an excellent conductor of heat, λ = 70-120 W/ (m·K); a very refractory material with a high melting point (3923 K); with the density ρ = 2000 kg/m^3, and the elasticity modulus E= 8-15 GPa.

Aluminium-graphite composites are lightweight materials with very good

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machinability, high thermal conductivity and the possibility to obtain low values of thermal expansion coefficient [3-5].

Electric arc deposition could be a method to obtain composite materials in superficial layers. Interfacial reactions in Al-Gr composites are a major limiting factor in the development of this method.

Reactions between the graphite and the molten aluminum during the electric arc deposition can lead to complementary material degradation and matrix embrittlement, by the appearance of interfacial brittle phases. Al_4C_3 and Al_4C produced by various chemical reactions existed in the Al-C system, but further investigations at atmospheric pressure showed the existence of the Al_4C_3 compound only [6-8].

2. Experimental conditions

Materials

Aluminum was used in this study of chemical composition as listed in Table 1, the major alloying element being silicon.

Table 1

Chemical composition of Al

Elements	Wt.%	Elements	Wt.%
Si	0.434	Ni	0.0179
Fe	0.383	Zn	0.0406
Cu	0.0165	Ti	0.00217
Mn	0.235	Pb	0.0452
Mg	0.333	Sn	0.0638
Cr	0.0193	Ca	0.0035
Al	98.2	-	-

Procedure

Aluminum was cut into six samples having dimensions of 60 x 30 x 20 mm. Two types of electrodes with diameter of 2.5 mm were used: from pure aluminum and Al-Si12.

The electrodes used in the welding process were covered in graphite powder with different weight percentages: 1.5, 3.0 and 4.5 % in two layers. Two layers of aluminum foil weighing 0.4 g separated the layers of graphite.

After that, the electrode was wrapped with a copper wire, Fig. 1. For the electric arc deposition process, it was necessary an electric current of 60 amperes.

After completing the process, these samples were cleaned and cut to obtain test samples of 30 x 20 x 10 mm dimensions. Grinding and polishing all the test samples were the next operations.

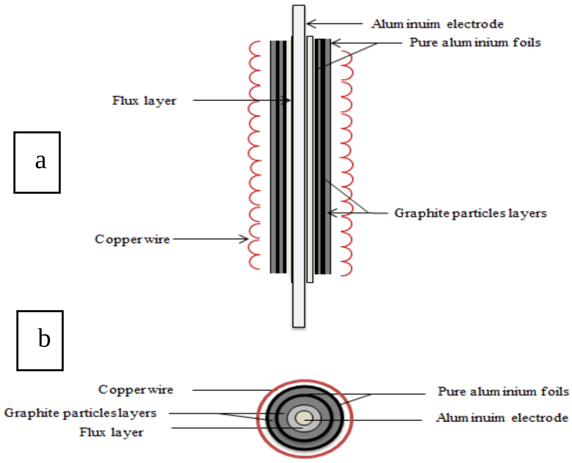


Fig. 1. Electrode covered with graphite used for the electric deposition process: a-covered electrode; b - cross section through the covered electrode.

3. Results and discussions

Optical micrographs for the cross-section of specimens are shown in Figs. 2 and 3. A higher amount of graphite particles incorporation and distribution can be observed in the aluminum melt when the amount of graphite particles which cover the electrode is increased. The graphite amount together with the silicon from the base material and copper wire which covered the electrode can contribute to an improved distribution.

The distribution of graphite particles was improved by using an Al electrode with 12% Si and covered in graphite particles. The increasing of Gr_p percentage which covered the electric arc electrode led to the increase of particles density, this being illustrated in Fig. 4. Aluminum with graphite particles usually forms carbides when these particles come into contact with the metallic bath, the adhesion energy being of 1000…. 1200 J/m^2 [9].

In Fig. 2, higher amount of graphite particles incorporated and distributed in the matrix can be observed. Alloying elements such as Si, Cu, and Mg affected the incorporation of Gr_p into the melt. The copper wire which was added over the electrode is an important factor for the improvement of wetting conditions. So, copper coating of Gr_p can enhance greatly the wettability and forms a good interface bonding between Gr_p and aluminum. It was revealed that when Cu appears in the matrix, it forms a liquid which flows into porous areas and helps in reducing the porosity.

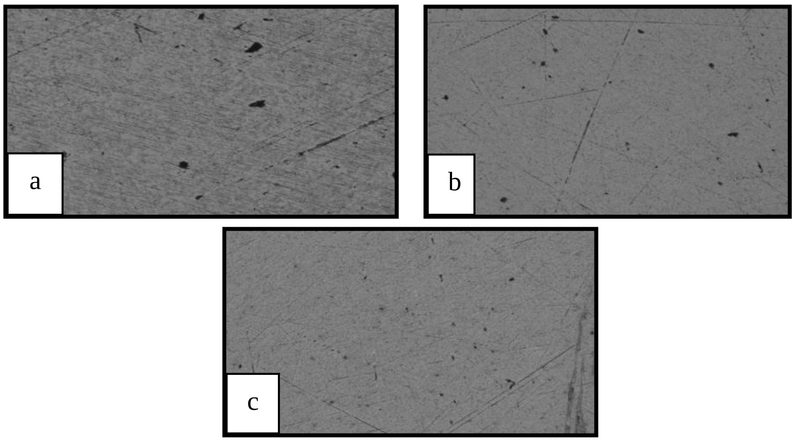


Fig. 2. Optical micrographs of graphite particle - Al composite, by using an Al-Si12 electrode covered with graphite particles (a- 1.5 wt. %, b- 3 wt. %, c-4.5 wt. %) [50X].

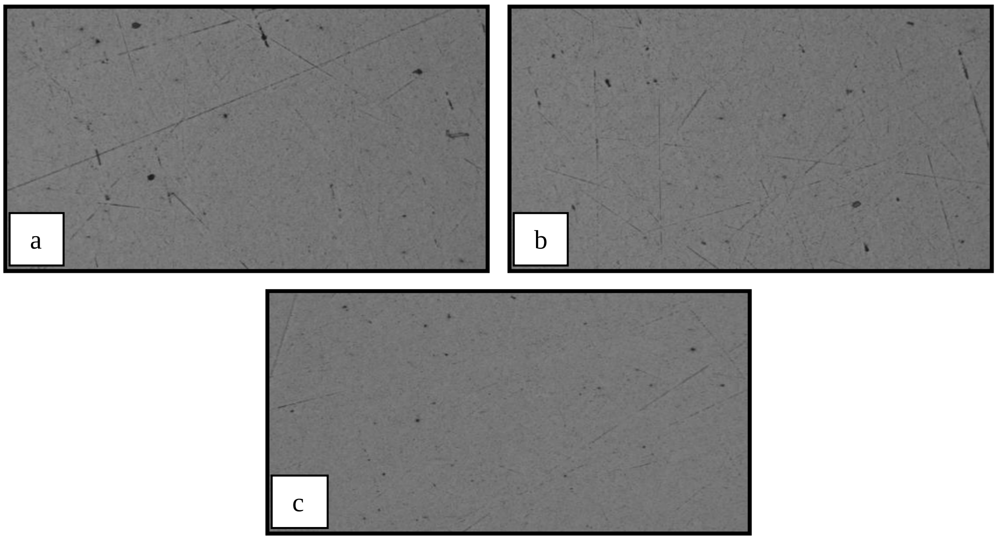


Fig. 3. Optical micrographs of graphite particle - Al composite by using a pure Al electrode covered with graphite particles (a- 1.5 wt. %, b- 3 wt. %, c-4.5 wt. %) [50X].

Small amount of Gr_p is deposited in aluminum by electric arc when using 1.5 wt. % $Gr_{p.}$ The pure Al electrode is covered due to the absence of alloying elements. These alloying elements can reduce the melt temperature of the matrix and melt the matrix in short time.

In Fig. 3, the graphite particles size is relatively large at 1.5 wt. % addition. It is observed that higher amounts of graphite particles are incorporated and distributed into the melt of aluminum alloy when the percentage of graphite particles covering the electrode is increased. The amount of graphite layers and copper wire with respect to the electrode type can also contribute to the distribution of particles

Incorporated Gr_p into the aluminum melt is increasing with the increase of weight percentage on the electrode to 3 wt. %. Fine particles of Gr_p in uniform distribution appear at 3 and 4.5 wt. percentages %.

The distribution of graphite particles is improved in Al alloy by Al-Si12 electrode covered with graphite particles. The increasing of Gr_p percentage covering the electrode appears to be increasing the particles density. This is illustrated in Fig. 4.

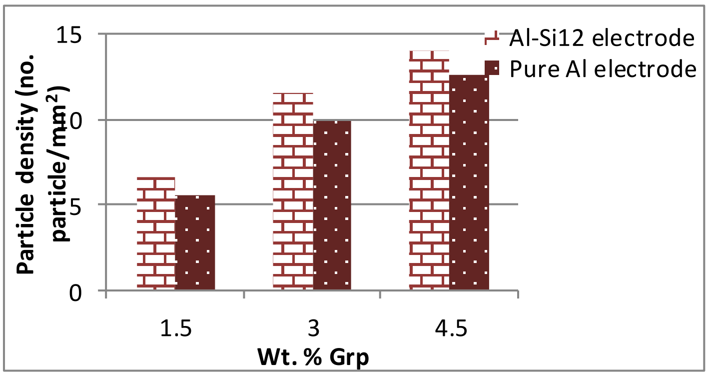


Fig. 4. Particles density of Gr_p in the composite material obtained by using the electric arc deposition method.

The particle density increased with increasing the graphite amount. The silicon element in electrode improved the incorporation of the graphite particles with Al alloy and confirmed the particles density. Usually, silicon was formed in the metastable phase with graphite or was adsorbed on the surface of the graphite particles reducing the floatation velocity. In samples melted by Al-Si12 electrode the particles density is higher than in the samples melted by pure Al electrode with respectively 17 %, 13.6 % and 10.6 % at 1.5, 3 and 4.5 wt. % Gr_p.

In Figs. 5, 6, 7 the effect of graphite percentage on mean convexity, mean sphericity, mean aspect ratio, and mean perimeter respectively is obvious.

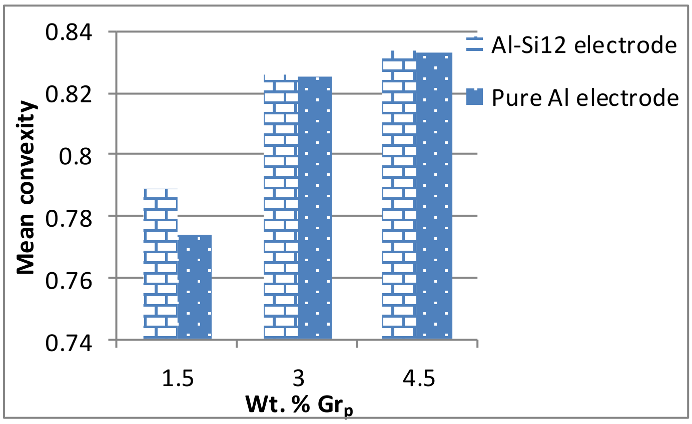


Fig. 5. Effect the Gr_p content on mean convexity

The electrode type has no effect on mean convexity especially at graphite 3 wt. % and 4.5 wt. %. But, at 1.5 wt. %, the mean convexity for the melted sample and deposited by Al-Si12 electrode is higher than for the sample melted by pure Al electrode (2% only). At the same time, the mean convexity increases 6% when the graphite content increases from 1.5 wt. % to 4.5 wt. %.

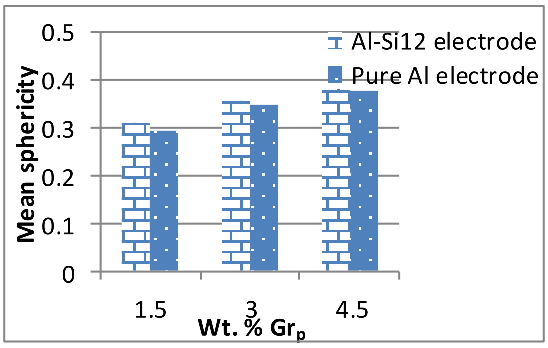
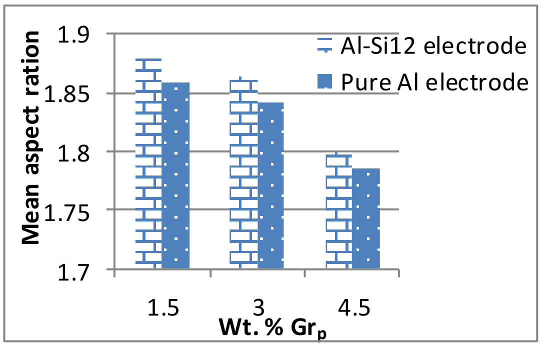


Fig. 6. Effect the Gr_p content on mean sphericity



Fig, 7. Effect the Gr_p content on mean aspect ratio

During the electrical arc process, fluidity of Al melt increased. This caused low porosity and decreasing in the aspect ratio. For the samples melted by pure Al electrode, the mean aspect ratio decreased by 3.8 % between 4.5 wt. % and 1.5 wt. % Gr_p, while for the samples melted by Al-Si12 electrode, the aspect ratio decreased with 4.2 % respectively. The silicon plays an important role as some chemical compounds can be found at the boundary of particle.

Mean sphericity increased with increasing the percentage of graphite particles. For samples the melted by pure Al electrode and Al-Si12 electrode, the mean sphericity increased by 23 %, between 1.5 wt. % and 4wt. % Gr_p. For the sample prepared by using pure Al electrode, the mean sphericity increased by 19 % when using Al-Si12 electrode. The brittle characteristic contributes to friction between the particles and turns the particles shape into sphere.

Fig. 8 shows the slight effect of the type of electrode on mean perimeter. The increase in the graphite particle percentage from 1.5 wt. % to 4.5 wt. % leads to the increase in mean perimeter by 17 % for the sample melted by Al-Si12 electrode and by 23 % for sample prepared by pure Al electrode.

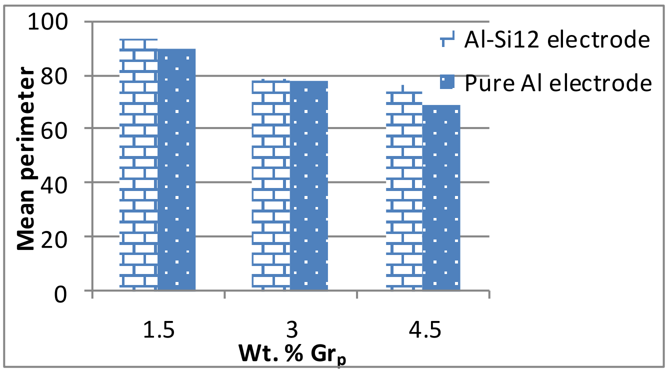


Fig.8. Relation between the Gr_p percentage in Al and mean perimeter.

5. Conclusions

The conclusions can be pointed out as follows:

- The copper wire which was added over the electrode is an important factor for the improvement of wetting conditions.
- The samples melted and deposited by Al-Si12 electrode have particles density higher than of the samples melted by pure Al electrode with 17 %, 13.6 %, 10.6 % at 1.5, 3 and 4.5 wt. % Gr_p respectively.
- The type of electrode does not affect the mean convexity, especially at graphite content 3 wt. and 4.5 wt. %. But, at 1.5 wt. %, the mean convexity for the sample obtained by using Al-Si12 electrode was higher than for the sample obtained by using pure Al electrode. At the same time, the mean convexity increased by 5-7 % when the graphite content increased from 1.5 wt. % to 4.5 wt. %.
- When the particle shape is approaching to the sphere, the value of aspect ratio is diminishing. Therefore, the aspect ratio is decreasing with the increase of

Gr_p percentage because the aspect ratio is maximum length to minimum length.

- The increase in the graphite particle percentage from 1.5 wt. % to 4.5 wt. % leads to the decrease in mean perimeter by 18 % for the sample obtained by using an Al-Si12 electrode and by 23% for the sample obtained by using a pure Al electrode.

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