Age Hardening of Al – Cu Alloy – Fly Ash Composites Fabricated by Stir Casting Route

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Abstract

Age hardening of particulate reinforced aluminum alloy matrix composites is a very interesting research area. Aluminum – fly ash composites have been developed for recent years. The age hardening of stir cast product Al – Cu alloy – fly ash composites have been studied. In this research, calcinated coal fly ash powder reinforced Al – 4 % Cu was fabricated by a stir casting technique. Pure aluminum (99,9 %) was melted in the crucible furnace at temperature 750^o C. Fly ash powder was added at melted aluminum and then stirred. During stirring process, temperature of aluminum was maintained at 750^o C. Stirring was done during 10 minute with 420 rpm rotations stirrer blade. Stir cast product of Al – Cu alloy – fly ash with 5, 10 or 15 % wt fly ash reinforcements, subjected to solution treatment at 520 ^{o}C for 6 hours than quenched in water media followed by aging at 180 ^{o}C for 1, 2, 4 hours. Age hardening behavior of the Al-Cu alloy – fly ash composites was analyzed by measuring the hardness of samples at different aging time. Hardness test was examined by Rockwell hardness tester (HRB). The results of this experiment show that the increase of % wt of fly ash from 5 %wt, 10 %wt and 15 %wt the hardness of Al – Cu alloy - fly ash : HRB 30, HRB 27 and HRB 24 respectively. Age hardening processes increase the hardness of composites product. At aging temperature 180 ^{o}C, the raise of aging time from 1 hour to 4 hours increase the hardness of Al – Cu alloy – fly ash composites. Al – Cu alloy with 5 %wt fly ash increasing aging time from: 1 h, 2 h and 4 h, increase the hardness of composites: HRB 53, HRB 56 and HRB 63 respectively.

Keywords: aluminum alloy composites, age hardening, fly ash

Introduction

Aluminium alloys are used in advanced applications because their combination because it's attractive properties compared to others competing materials. However, the scope of these properties can be extended by using aluminium matrix composite materials. The aluminium matrix composites may offer specific advantages compared to un-reinforced Al alloys. Composite materials offer a opportunity to tailor the properties of aluminium. This could include increased strength to weight ratio, improved wear resistance, raised the elastic modulus, controlled coefficient of thermal expansion and improved the fatigue strength. The reinforcement in aluminium matrix composites could be in the form of continuous fibers, discontinuous fibres, whisker or particulates.

In aluminium matrix composites one of the constituent is aluminium or aluminium alloy as matrix. The other constituent is embedded in this aluminium/aluminium alloy matrix and serves as reinforcement is commonly ceramic materials such as SiC, carbon nanotube or Al_2O_3. In recent year the use of coal fly ash as reinforcement of aluminium matrix composite was investigated by many researchers. Rise of amount of fly ash being re-utilized will minimize disposal cost because less area is reserved for disposal. Fly ash is potential to replace some scarce or expensive natural resources. Utilization of fly ash can be in the form of an alternative to another industrial resource, process or application.

Sudarshan et.al (2007) studied dry sliding wear of fly ash particle reinforced A356 Al composites. Aluminum alloy (A356) composites containing 6 and 12 vol. % of fly ash particles have been fabricated. The dry sliding wear behavior of unreinforced alloy and composites are studied using Pin-On-Disc machine at a load of 10, 20, 50, 65 and 80N at a constant sliding velocity of 1 m/s. Results show that the dry sliding wear resistance of Al-fly ash composite is almost similar to that of Al_2O_3 and SiC reinforced Al-alloy [1]. Fly ash particle used as filler in aluminum alloy casting reduces cost and density of casted aluminum alloy. Fly ash in aluminum alloy increases the damping capacity [2]. Aluminum-fly ash composite can be produced by powder metallurgy techniques. The strength of sintered aluminum-fly ash composites decreased with increasing weight percent of fly ash. Hardness of composites product was found increase slightly up to 10 % wt fly ash [3]. Gikunoo reported that addition of 10 and 15 % wt of fly ash decrease the tensile and impact strength of aluminum – fly ash composite [4]. Addition up to 10 wt.% as received fly ash particle (75–100 lm) after preheating in Al–12Si alloy through liquid stir casting. A linear decrease in the density and ultimate tensile strength and a linear increase in electrical resistivity of Al–12Si–fly ash composites have been observed with increasing dispersoid content [5]. Development of aluminum - fly ash composite is limited by mechanical properties of composites product. Aging treatment can significantly increase properties of some of Al alloys and their composites [6]. The time for peak aging of the Al–Cu–Mg alloy and its composites with 5, 15 or 25 vol. % SiC particles, solution treated at 495 ^{o}C for 0.5 h and aged at 191 ◦C has been found to be 3 and 5 h [7]. The present study is aimed at age hardening characteristic of the aluminum – Cu alloy reinforced with fly ash particles produced by stir casting route.

Materials and methods

In this research, the fly ash as reinforcement powders was obtained from Suralaya power plant. Composition of the coal fly ash was tested by atomic absorption spectroscopy (AAS). The composition of the coal fly ash shows in Table 1. Before used as reinforced powder, the fly ash (FA) was calcinated at temperature 850 ^{o}C, at atmosphere for 3 h. The calcinated FA and as received FA were analyzed by XRD. XRD patterns of calcinated and as received FA are shown in Figure 1. Al – 4% Cu alloy was used as matrix. Specimens were made of melting of aluminum in crucible furnace at temperature 750 ^{o}C. Al – 4 % Cu alloy was produced by adding 4 % wt Cu powder in melt aluminum. Calcinated fly ash powders were added into the aluminum melted and stirred for 10 minute at 420 rpm rotation stirrer blade. During stirring process, the aluminum temperature was maintained at 750 ^{o}C.

Table 1. Composition of Fly Ash

Compound	Weight
SiO_2	45.51
Al_2O_3	30.35
Fe_2O_3	8.71
CaO	5.49
MgO	2.75
Na_2O	1.45
MnO	0.1
K_2O	0.64
others	until 100 %

Solutioning process of Al – Cu alloy - fly ash composite was conducted in programmable furnace at temperature 520 ^{o}C for 6 hours. To make super saturated solid solution, the specimens quenched in water media. Aging processes have been carried out at temperature 180 ^{o}C for 1, 2 and 4 hours aging time. Hardness of composites was tested by Rockwell Hardness Test methods.

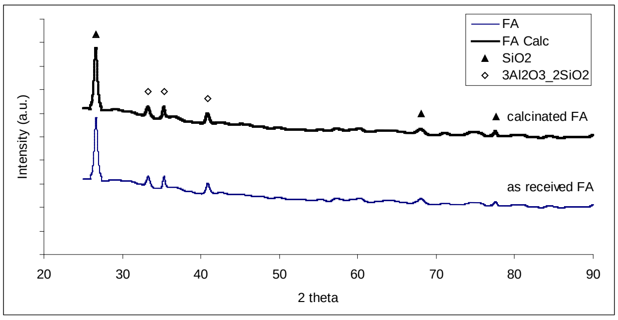

Figure 1. XRD patterns of calcinated and as received of FA

Results and discussions

According to ASTM standard, fly ash obtained from Suralaya power plant is classified as type C. XRD patterns of calcinated and as received of FA shows in Figure 1. The XRD patterns show that the calcinated fly ash consists of quartz (SiO_2) and hematite (Fe_2O_3) as the major components. XRD analysis also shows that calcinated process do not change the crystalline phase of fly ash. Scanning electron micrograph of fly as is shown in Figure 2. It can be concluded that morphology of fly as is spherical and micro sphere with 0.5 – 7.2 µm diameter.

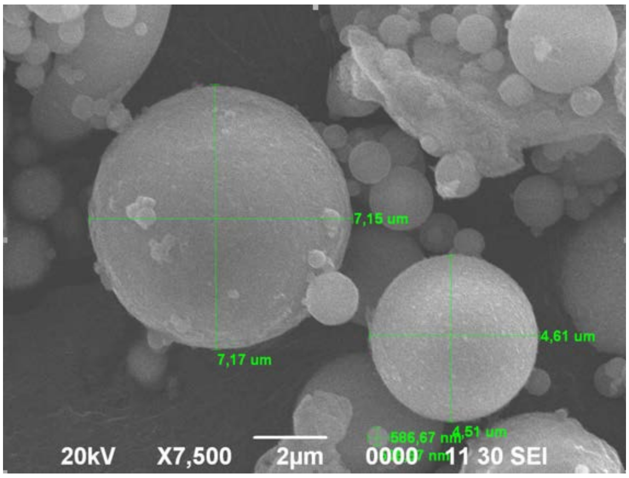

Figure 2. Scanning Electron Micrograph of calcinated fly ash.

The effect of % wt of calcinated coal fly ash on hardness of composite is shown in Figure 3. It's shown that hardness of composites decrease with increasing of % wt fly ash. The hardness of 5 %, 10 % and 15 % wt fly ash are HRB 30, HRB 27 and HRB 24 respectively.

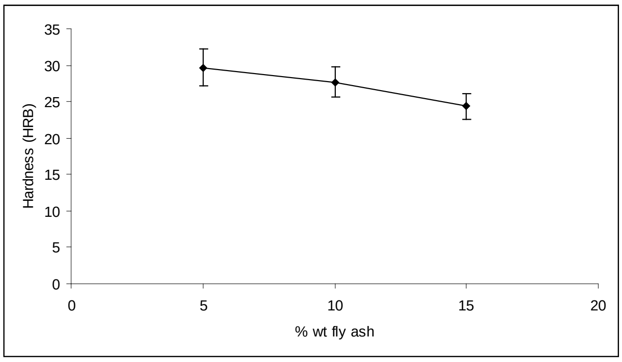

Figure 3. Effect of % wt fly ash on hardness of Al – Cu alloy – fly ash composite

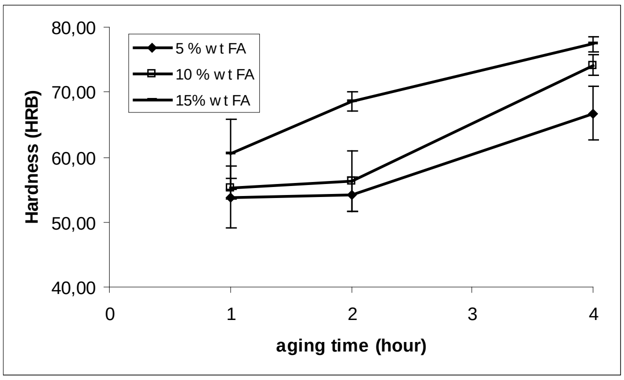

Figure 4. Effect of aging time on hardness of Al – Cu alloy – fly ash composites.

Figure 4. shows the effect of aging time on hardness of Al-Cu alloy-fly ash composites. Up to 4 hours, the hardness of composites increases with increasing of aging time. There is a different hardness characteristic at non precipitation hardened composites with precipitated hardened composite as shows at Figure 5. Non heat treat composite, increasing % wt of fly ash, the hardness of composite decrease. Age hardened composites, increasing % wt fly ash increase the hardness of composites. It can be seen that with increasing % wt of fly ash, the aging kinetics in the composite accelerates.

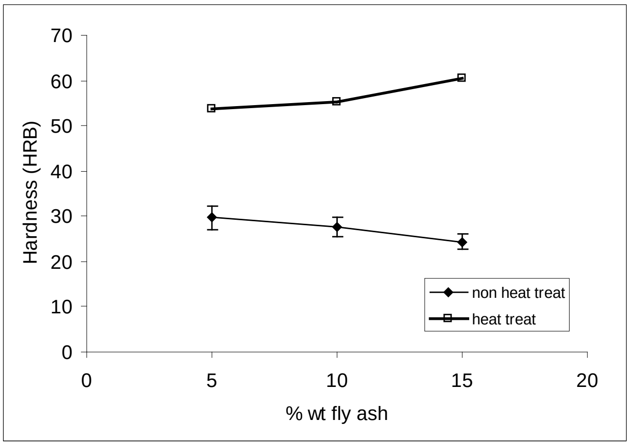

Figure 5. The hardness of non heat treat and heat treat (temperature: 180 ^oC, aging time 1 h) of composites.

Conclusions

The aging behaviour of the Al - Cu alloy reinforced with 5 %, 10 % and 15 % fly ash particles was studied after solution treatment at 520 ^oC for 6 h, and aging time 1, 2 and 4. The conclusions derived from this study can be given as follows:

a. The hardness of the A1-Cu alloy-fly ash composite decreases with increasing of % wt of fly ash. The results of this experiment show that increasing of %wt of fly ash from 5 %wt, 10 %wt and 15 %wt the hardness of Al – Cu alloy - fly ash: HRB 30, HRB 27 and HRB 24 respectively.
b. Precipitation hardening, increase the hardness of A1-Cu alloy-fly ash composite. The raise of aging time form 1, 2 and 4 hours, increase the hardness of composite.
c. Precipitation hardened of A1-Cu alloy-fly ash composite, increasing % wt of fly ash the hardness of composite increase

Acknowledgments

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