Mechanical and metallurgical characterization of AA7075-fly ash composites produced by liquid state method

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ABSTRACT

In the present investigation, AA7075 alloy matrix composites reinforced with different weight fraction of fly ash particulate reinforcement were manufactured through stir casting process. Tensile strength and hardness of the composites and the AA7075 matrix alloy have been analyzed. Microstructural characterization of unreinforced base matrix alloy and the manufactured composite were investigated by an optical microscope (OM) and scanning electron microscope (SEM). OM and SEM images exhibit the nearly homogeneous distribution of fly ash particles in the composite. The mechanical properties of the composite resulted in increased hardness and tensile strength with the increase in a reinforcement content. The superior mechanical properties were achieved at AA7075/12 wt. % fly ash composites.

KEY WORDS: AA7075 alloy, Fly ash, Stir casting, Mechanical Properties, Aluminium Matrix Composites (AMCs).

1. INTRODUCTION

Metal matrix composites (MMCs) find applications in areas like aircraft components, automobile, marine, structural equipments, etc., as they possess combination of properties like superior hardness, enhanced strength and better wear resistance (Chaubey, 2016; Ravichandran, 2015; Sahin, 2011). Aluminum exhibits outstanding and incomparable exclusive properties like superior strength, non-toxic, non-magnetic, non-sparking, low density, light weight and resistance to wear and corrosion (Karaaslan, 2016). Aluminum based metal matrix composites have become more potential in engineering application such as brake disc, drive shaft and cylinder liner, owing to their excellent strength to weight ratio and resistance to high temperature operations (Ashwath, 2016). Several manufacturing processes like centrifugal casting, in situ casting, squeeze casting, stir casting, powder metallurgy, liquid infiltration and compo casting, etc., have been endeavored and discussed to manufacture the particles reinforced aluminum matrix composites (Soy, 2011). Compared to other method, stir casting process is more flexible, simple, convenient and cheap (Mohanavel, 2016). Fly ash is a low-priced reinforcement material compared to traditionally employ ceramic particles like Si_3N_4, TiO_2, B_4C, TiC, TiB_2, Al_2O_3 and SiC. The use of low-priced reinforcement materials will slightly minimize the overall cost of the produced composites and improves its application (Kus, 2015). Otherwise, the effective deployment of the thermal power plant waste will defend the environment. Few studies on production and characterization of aluminum alloys reinforced fly ash particulate composites were reported in the literatures. Kumar (2012), studied mechanical properties of A380-fly ash metal matrix composites fabricated by stir casting method and they have concluded that addition of fly ash particles in aluminum matrix has resulted on enhanced wear resistance, hardness and tensile strength when compared to the A380 matrix alloy. Selvam (2016) described that wear resistance of the AA6061/flyash composites were increased with increasing the wt.% of the fly ash reinforcement in the composite and they have stated that wear rate of the composite decreases linearly with increasing wt.% of fly ash particles. Efzan (2016) prepared LM6 alloy reinforced with various amounts of (0%, 4%, 5% and 6 wt.%) fly ash particles based composite produced by compo casting and they observed that the macro-hardness and the ultimate tensile strength increases with increase in fly ash particles. Ramachandra (2005) produced LM25/fly ash composite by liquid state stir casting technique and stated an remarkable improvement in the tribological and mechanical properties of the produced composite. Selvam (2013), produced AA6061/flyash composite by compo casting technique and evaluate the mechanical and microstructural characterization of the composite. They have concluded that addition of fly ash particles in the aluminum matrix has resulted on 132.21% superior micro-hardness and 56.95% higher tensile strength compared to base alloy. Sudarshan (2008), had identified that the A356-fly ash particles reinforced stir-cast based aluminum composites exhibit improved mechanical properties. Rao (2011), stated on the superior mechanical and corrosion properties of AA2024/fly ash composites were fabricated by stir casting method. A very few examinations is available on the development of fly ash particles reinforced composites by a combination of stir casting process. The present work aims to investigate the mechanical behavior of unreinforced matrix alloy, Al+4% fly ash AMCs, Al+8% fly ash AMCs and Al+12% fly ash AMCs was manufactured by a liquid state processing method. In this article, the results of OM and SEM analyses for the manufactured composites were reported.

2. MATERIALS AND METHODS

AA7075 was chosen as a matrix alloy and the fly ash particles of size 2-8 microns are used as the reinforcement material. The fly ash particles were gathered from Thermal power plant, Tuticorin, Tamil Nadu. Al7075 aluminum alloy has been melted in the graphite clay crucible inside an electrical furnace and fly ash particulates were incorporated in different weight fractions like Al7075+0% fly ash, Al7075+4% fly ash, Al7075+8% fly ash and Al7075+12% fly ash. The measured quantity of fly ash particles were incorporated to the molten aluminium. The temperature of the thaw was maintained at 850^0C. The melt was stirred constantly at 400 rpm and it was being continued for 10 min. Finally, the melt was poured into preheated metal mold. Stir casting setup shown in fig.1.

Figure.1. Stir casting furnace

Microstructural investigation was carried out on the specimens by using an optical microscope and scanning electron microscope. The micro-hardness was measured using Vickers hardness tester. Micro-hardness was tested on at a load of 0.5kgf and a dwell time of 5seconds. Micro-hardness was measured at four different locations and the average value was taken as hardness of the composite specimens. Fig.2, shows the photograph of hardness specimens. The ultimate tensile strength of the manufactured composites was measured under tension using a fully computerized universal testing machine according to ASTM E8 standards. Fig.3, shows the photograph of tensile test specimens.

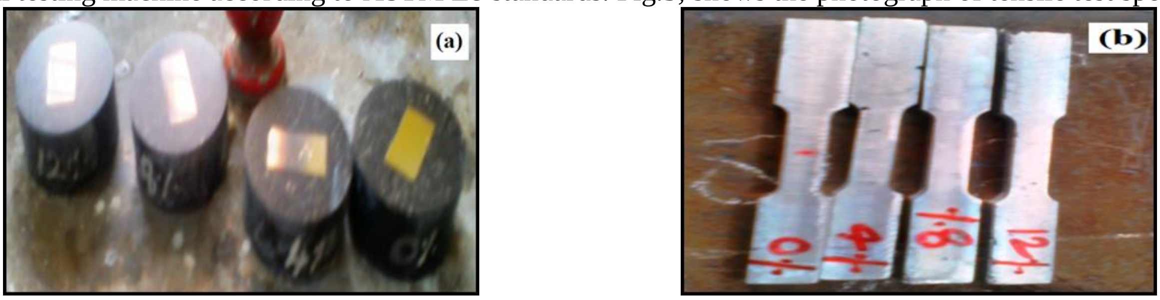

Figure.2 (a). shows the image of hardness specimens and (b) Shows the image of tensile test specimens

3. RESULTS AND DISCUSSION

Microstructural studies: Figure.3, shows the optical microstructure of the AA7075/fly ash composite. Fig 3a. showed the micrographs of as cast AA7075 aluminum alloy. Figure. 3(b-e) shows the distribution of the fly ash particles in the aluminum matrix is fairly uniform. Fly ash particles addition to aluminum melt, which act as nucleating sites during production of composite and thereby leads to decreases the matrix grain size.

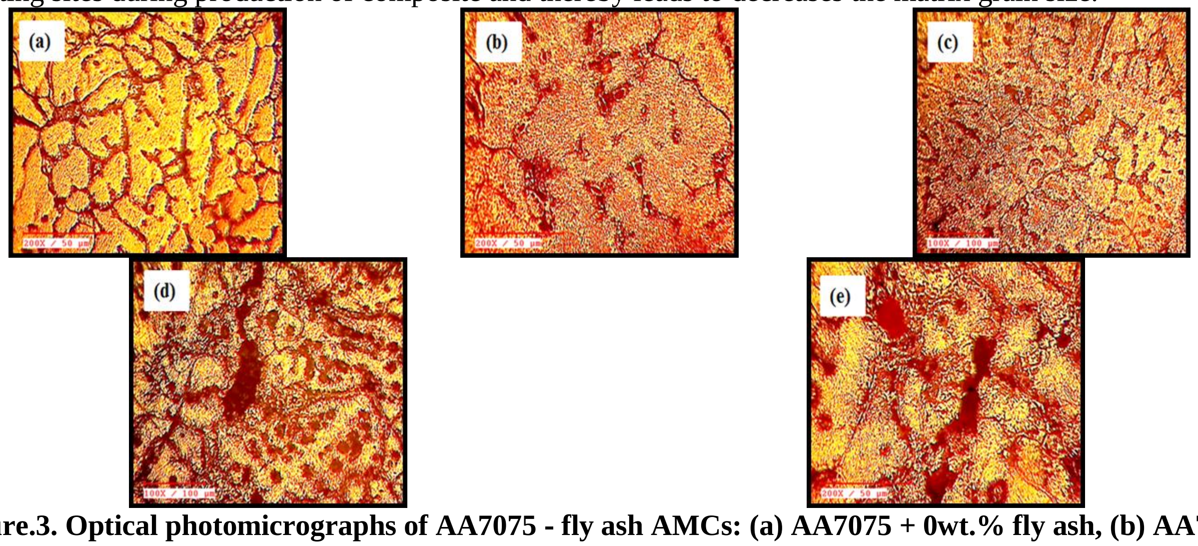

Figure.3. Optical photomicrographs of AA7075 - fly ash AMCs: (a) AA7075 + 0wt.% fly ash, (b) AA7075 + 4wt.% fly ash, (c) AA7075 + 8wt.% fly ash and (d & e) AA7075 + 12wt.% fly ash

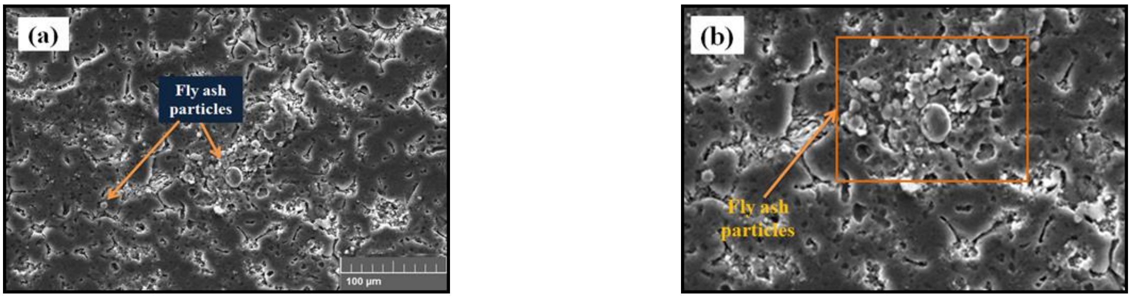

Figure.4 (a-b). SEM micrographs of AA7075 - fly ash AMCs

SEM micrographs of the AMCs : Figure.4 (a-b), shows the SEM micrograph of AA7075/fly ash composite. This images reveal the nearly uniform distribution of fly ash particles in the composites. Suitable stirring begins the particles to be homogeneously spread in the melt. The uniform particle distribution is mainly favorable to the improved mechanical properties of composites.

Hardness of the AA7075/fly ash AMCs: From figure.5, it is noticed that the micro hardness of the manufactured composite is linearly improved with the increase in fly ash particle addition. The remarkable increase in hardness may be due to the good bonding between the matrix and the reinforcement and also the nearly uniform distribution of fly ash particles in the matrix alloy. The Al7075/12 wt. % fly ash composites shown the higher hardness when compared to the matrix alloy. This result is a good agreement with the result of (Moses, 2014).

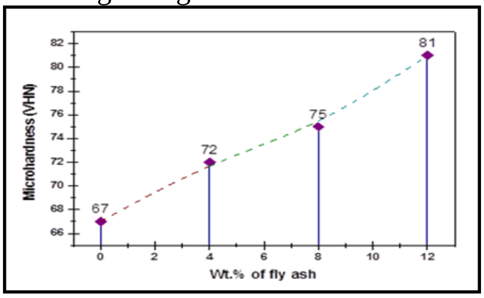

Figure.5. Variations of hardness with wt.% of fly ash particles

Tensile strength of the AA7075/fly ash AMCs: Figure.6. Displays the variation of tensile strength of Al7075 matrix alloy and manufactured composite. The increased tensile strength of the AMC may be ascribed to presence of fly ash particles. The 12 wt. % fly ash/Al7075 AMCs revealed the higher tensile strength of 181 MPa. It is observed that manufactured composites reveals superior tensile strength when compared with as cast base alloy. The UTS of the composites steadily increased with increasing in weight fraction of reinforcement particles. Moreover, the fly ash particles can successfully act as obstruction to dislocation movement. Thereby it improves the tensile strength of the composites. This result is a good agreement with the result of (Ravichandran, 2016).

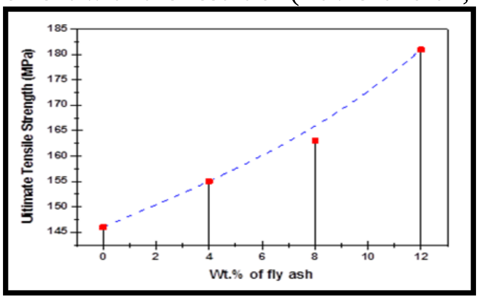

Figure.6. Variations of tensile strength with wt.% of fly ash particles

4. CONCLUSIONS

The significant conclusions of the experiment on AA7075/fly ash composites were as follows:

- AA7075 alloy based aluminum matrix composites containing fly ash have been successfully manufactured with different weight fraction by stir casting process.
- The microstructural analysis revealed the nearly uniform distribution of the fly ash particles in the matrix.
- Improved micro-hardness and tensile strength are observed with an Al7075 alloy having twelve weight fraction of fly ash addition.
- The mechanical properties of the composites are found higher than that of the base matrix alloy.

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