Effect of fly ash content in Aluminum matrix composite through stir casting method on mechanical and physical properties

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Abstract Metal Matrix Composite (MMC) is a potential innovation material to meet the requirements required in various applications. such as in the aerospace, automotive and mining sectors. Stir casting has been known widely as a methode to produce MMC. In this study, Alumunium alloy and fly ash is utilized as matrix composite and reinforced phasing, respectively. Effect for mechanical and physical properties are investigated for the addition fly ash (4, 8 and 12wt%). Alumunium alloy melt with fly ash is stirred with 350 rpm for 5 minutes and poured into the mold at temperature of 800°C. Hardness, impact and density test are performed to investigate the characterization of specimen. The experimental results show that maximum value is obtained at 8 wt% fly ash with 65.83 HB, 11. 8 Joule, 14.299 Kgf/mm^2 and 2.7 g/cm^3 for hardness, impack, tensile strenght and density, respectively.

Keywords: Aluminum, fly ash, stir casting, composite, mechanical properties

1. Introduction

Aluminum alloys has been widely utilized in various application such as aerospace, automotive and mining process [1-3]. Aluminum alloy is potential material owing mechanical and physical such as strength, density and corrosion resistance [2]. Occasionally, special part of structure running in extreme condition such as high temperature, cyclic loading and under impact loading. In those condition aluminum alloy component is required to improve mechanical properties.

Fly ash is material residual obtained from coal combustion which is classic problem surrounding power plant. Fly ash has a density of 1 g / cm³ and comprising to SiO_2, Al_2O_3, Fe_2O_3 and oxide content such as Mg, Ca. The chemical, mechanical properties, morphology and size of fly ash is potential material to replace classic materials to produce glass and ceramic part. In term of environmental and ecological problem, the utilization on fly ash as raw material is expected has contribution reduce waste that is generated by power plants.

MMC (Metal Matrix Composite) is consist of metal as matrix and reinforcement particle. In term of Aluminum alloys as matrix, commonly known as Aluminum Matrix Composite (AMC). AMC is a type of Metal Composite Material with aluminum alloys as the matrix and ceramic materials such as SiO_2, Al_2O_3 as reinforcement particles [4, 5]. AMC has a prospective development that is promising, based on its good characteristics, such as high hardness and strength.

Commonly, Fabrication of MMC can be classified into liquid and solid state processing methods. Liquid processing method comprising to squeeze casting, compo casting, stir casting and infiltration method while solid state processing techniques consist of; friction stir processing, diffusion bonding, spray deposition. Stir casting method is most valuable because of its simplicity and applicable to mass

production. Moreover, stir casting as common casting method also has applicable to produce near net shape part.

Some parameter processes play important role during stir casting conducted such as stirring time, pouring temperature, mixing time, speed of blade and reinforcement particle composition [6, 7]. Previous works reported by some authors that composition of SiC and Fly ash has the most significant contribution to determine of hardness properties [5, 8]. Some efforts have been conducted to improve mechanical and physical properties of aluminum alloy through stir casting route [5, 6, 8-11]. The increasing of percentage of fly ash in aluminum alloys (Al/3Cu/8.5Si) has effects to increase the strength properties. On the other hand, some properties such as ductility and impact strength tend to decrease as reported by the other author [12].

The objective of this research is to produce Aluminum matrix composite with fly ash as reinforcement particle through stir casting route. The addition of percentage of fly ash is investigated in term of mechanical properties effect of AMC. The microstructure and mechanical properties of the fabricated AMC were studied.

2. Experimental procedure

In this work, Aluminum matrix composite (AMC) was fabricated with help of a stir casting process. Stir casting route is method of melting the material with continuous mixing using a blade and directly pouring the melt into the cavity mold. Stirring process is conducted during the process to avoid agglomeration reinforcement particles. It is also necessary factor to improve homogeneous distribution of reinforcement particles in matrix [13].

Stir casting were performed with parameter process mixing speed, mixing time and mixing temperature for 350 rpm, 5 minute, 660°C respectively. Aluminum alloy was melted in the crucible that heated to melting temperature. Fly ash was added externally in a fixed proportion (4, 8 and 12 wt%) into aluminum alloy melt. Magnesium alloy with 2.5wt% was added to aluminum alloy composite to increase wettability between aluminum alloy and reinforcement particle. Table 1 shows aluminum alloys composition was used as a matrix in this work with fly ash as reinforcement particles.

Table 1 Chemical composition of Aaluminium alloy (wt%)

Element	Fe	Mn	Cu	Zn	Pb	Al
wt%	0.424	0.649	0.345	0.286	0.033	balance

Mechanical properties of AMC cast part was characterized using Brinnel Hardness Testing Machine using JIZ Z2243 standard for measuring hardness value. The ability of AMC specimens to absorb energy until fracture were measured using impact test base on JIZ Z2202 standard. Moreover, tensile strength of AMC specimen was investigated using Universal Testing Machines based on JIS Z 2201 standard. Scanning electron microscopy (SEM) was used to study the surface morphology cast part of AMC.

3. Results and Discussions

Reinforcement particle distribution is main factor to determine performance of mechanical and physical properties of AMC [13]. Impact test was performed to investigate of toughness properties of aluminum matrix composite. Toughness properties in term of mechanical definition is the ability of a material to absorb energy up to fracture. Figure 1 shows impact test results of AMC cast part for various weight percentage of fly ash. The addition of fly ash has effect to influence impact properties of AMC. Maximum hardness value (11.879 Joule) was obtain in composition 8wt% of fly ash.

On the other hand, composition 4wt% and 12wt% were not significant to change impact properties compare to specimens without fly ash content.

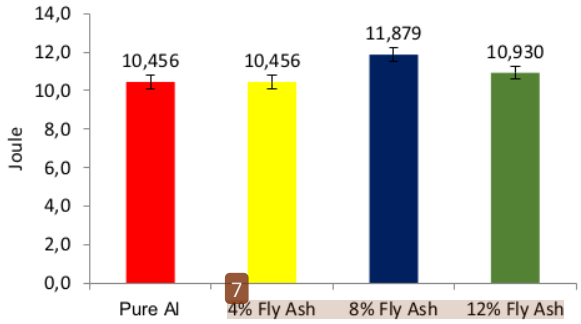

Figure 1 Impact test results of aluminium matrix composite for various percentage of fly ash

Figure 2 shows Effect of various percentage fly ash on the tensile strength of the Aluminum matrix composite. Compare to aluminum alloy without reinforcement particles, the addition of reinforcement particles into aluminum alloy can improve tensile strength of AMC. The tensile strength tends to increase with the addition of fly ash percentage from 4 wt% to 8 wt%. The maximum tensile strength value (11.879 kgf/mm2) was achieved at 8 wt% and minimum tensile strength at 12 wt% (13.443 kgf/mm2). The reduction of tensile strength value after 8 wt% fly ashes due to excessive of reinforcement particles in AMC which is refer to in term of the ability matrix to bond reinforcement particles.

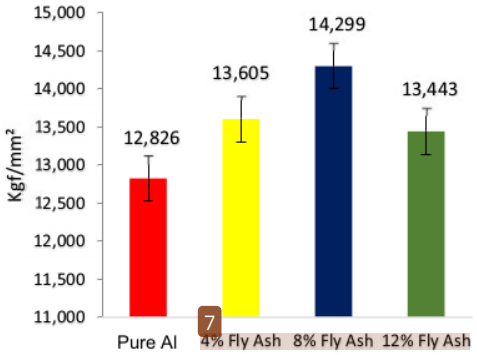

Figure 2 Effect of various percentage fly ash on tensile strength of Aluminum matrix composite

Density measurement of aluminum matrix composite samples were conducted using Archimedes method. Figure 3 shows density result of aluminum matrix composite with various percentage of additional of fly ash. Maximum density value was obtained in fly ash composition 8 wt% on the other hand minimum density value of AMC in composition 4 wt% for 2.716 g/cm^3 and 2.684 g/cm^3, respectively. The additional of fly ash content more than 8 wt% has play important role to reduce density value of AMC. The occurrence of porosity on the AMC specimen is believe to be main factor to reduce density value.

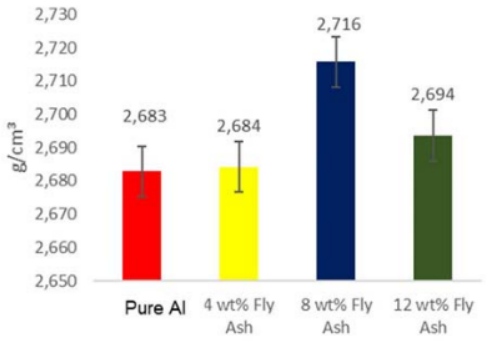

Figure 3 density of Aluminium matrix composite with various percentage of fly ash

The porosity percentage in the specimen causes the material to be light and not dense. When tensile testing is carried out, porosity will form a large hole so that crack propagation occurs which causes a break in the specimen. This phenomenon makes the value of tensile strength in addition 4 and 12% become brittle.

The addition of 8 wt% fly ash has a maximum tensile strength value due to the bond between matrix and amplifier is still optimum. The value of high tensile strength at the addition of 8 wt% fly ashes can also be seen from the density value. The density value at the addition of 8% fly ash also has the highest value compared to pure aluminum and aluminum with the addition of 4 and 12% fly ash. Maximum density value is obtained at the addition of 8% of fly ash as an indication low porosity level compare to the other sample.

The presence of porosity in aluminum matrix composite detriment to mechanical properties especially tensile strength. Porosity in a material under tensile load is a significant contribution to accelerating crack propagation in the material. The occurrence of porosities on stir casting product due to chemical reaction between reinforcement particle (fly ash) and aluminum alloy [14]. Moreover, stirring process also give contribution for bubbles formation during stirring was conducted.

Morphology surface of aluminum matrix composite was investigated using scanning electron microscopic. Fracture surface morphology of sample in cross section area was observed using SEM analysis to determine fracture mode of material. Figure 4 shows SEM analysis for surface morphology of AMC cross section. SEM observation revealed that brittle fracture mode was observed which is indicating the material tend to brittle. Moreover, formation some dimples also was founded in the morphology AMC. Furthermore, analysis SEM shows the existence of porosities occur in some places in the surface which has significant contribution to detriment mechanical properties of AMC.

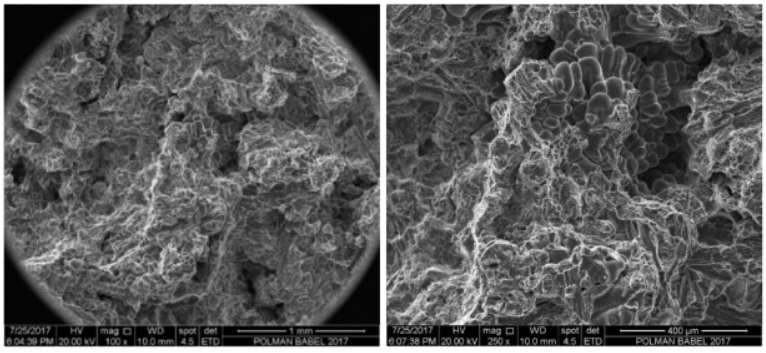

Figure 4 SEM images analysis of aluminum matrix composites

Mechanical properties test comprising to tensile, impact and density test revealed that the maximum value were obtained for fly ash composition 8 wt%. At This composition alumunim alloy as matrix and fly ash as reinforcment phasing in best condition to generate optimum value of mechanical properties.

4. Conclusion

Fabrication of aluminum matrix composite with fly ash as reinforcement particles was successfully fabricated through stir casting method. The addition of fly ash percentage has play important role to determine mechanical properties of AMC. The composition 8 wt% of fly ash content shows maximum value in term impact, tensile and density measurement. SEM analysis indicates the composites indicates the distribution of the fly ash components throughout the aluminum matrix. Furthermore, there are some porosities were observed in cross section area. Porosity is believing to be detrimental factor to reduce mechanical properties of AMC product. It was supported by density results which is the AMC specimen with higher value of density has maximum value of impact and tensile test. The addition of fly ash into aluminum alloy melt has effect to reduce ductility of composite base on surface morphology of specimen.

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