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Development of aluminum matrix composite with hybrid reinforcement using stir casting route

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Abstract. Aluminum matrix composite (AMCs) has widely utilized in various industries such as automotive, aerospace maritime, electronics components, sports equipment. AMCs is considered a potential materials due to their excellent mechanical and physical properties. The aim of this work is to investigate effect of the addition SiC and fly ash on mechanical properties of AMCs. In this study, AMCs is fabricated using stir casting method with SiC (8 wt%) and Fly ash (0 wt%, 4 wt%, 8 wt% and 12 wt%) as hybrid reinforcement. Aluminum alloy was heated above its melting temperature in the steel crucible and poured into steel mold at 700°C with a rotating speed of blade and mixing time are 350 rpm and 400 S, respectively. Mechanical properties of AMCs samples were characterized using tensile test, hardness test and impact test. Mechanical properties test reveals that AMCs with composition 12 wt% fly ash and 8 wt% SiC has maximum value in term of tensile test (15,859 kgf/mm²), impact test (10,22 Joule) and hardness test (57,15 BHN).

Keywords: Aluminium matrix composite, stir casting, fly ash

1. Introduction

Nowadays, development Metal Matrix Composites (MMCs) has been play important role in material innovations. Aluminium matrix composite (AMC) is classified as MMCs refer to aluminium alloy as matrix used. AMC has some potential properties for engineering structure application such as low density, stiffness, wear resistance, fatigue resistance, high thermal conductivity, high energy absorption and better stability at elevated temperature. Owing to this advantages, AMCs are utilized widely for various advanced applications such as automotive part aerospace, marine and nuclear industries. In weight reduction issue, automotive industries are being subjected to reducing strict of pollution and fuel consumption, AMCs have to be alternative material to change conventional materials [1, 2].

Ceramic particles generally used as reinforcement in AMCs fabrication. The addition of ceramics particles has significant contribution to increase hardness, stiffness and strength of composite [3, 4]. Silicon carbide and alumina are ceramic particles which has been ordinarily used as reinforced [5, 6]. AMCs reinforcement materials in term of particle shape can be divided into four categories; continuous fibers, short fibers, whiskers and particles. Continuous fibers is effective to strengthening in certain direction meanwhile reinforcement particles more attractive due low cost and flexibility.

Commonly fabrication of AMCs can be divided into two methods, solid state processing and liquid state processing. Stir casting can be classified as liquid state processing with some advantages such as lower cost, near net shape and mass production. AMCs Fabrication methods has important role to determine mechanical and physical properties of composite. Moreover, it is having also give contribution to determine of the interfacial bonding between reinforcement material and matrix.

AMCs Fabrication still faces several challenging issues to solve such as distribution of reinforcement and bonding of ceramic particles with aluminum alloy as matrix. At elevated temperature during casting process promotes chemical reaction which leads degradation of ceramic particles [7, 8]. After occurs degradation on ceramic particles, expectation mechanical properties of composite is difficult to obtain. Fly Ash is part of the remaining coal combustion consisting of amorphous fine particles and ash which is an inorganic material formed from mineral materials.

Stir casting is one of the routes to produce aluminum matrix composites in liquid conditions using a stirrer, which is carried out above the melting temperature of the metal. The advantage of the stir casting method is simple process, flexible and can be used for products in large quantities. Moreover, it is the most economical for producing aluminum matrix composites and allows to be used for large component fabrication processes. The main objective of this study is to analyze the effect of additional of SiC and fly ash as hybrid reinforcement in Aluminum matrix composite.

2. Materials and methods

In this study, fly ash was collected at surrounding area at one power plant in Tanjung Enim, South Sumatera, Indonesia. Fly ash particles in this work has irregular shape with 40 mesh size. Chemical composition was performed to investigate chemical component of fly ash. Fly ash consist of some ceramics component as can be seen on the Table 1.

Table 1. Chemical composition of fly ash.

components	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	TiO ₂	CaO	MgO	K ₂ O	others
Wt %	57.95	28.15	4.75	0.93	3.74	1.73	0.62	2.13

Homogen distribution of reinforce particles in aluminum matrix composite is critical issue which has responsible for mechanical and physical properties of AMCs. Processing parameters such as casting temperature, mixing speed and type of blade are some parameters should be considered [1]. In this work, Electric motor with control speed was utilized to generate carbon steel stirring blade. Furnace temperature to melt aluminum alloy was regulated using electric blower to adjust air flow in to burning chamber. The molten aluminum alloy was stirred until generate vortex, during molten aluminum alloy was stirred preheat fly ash was added slowly. Furthermore, at temperature 700°C molten aluminum alloy was poured into carbon steel mold.

AMCs specimens were prepared through machining process for tensile, hardness and impact strength. Universal testing machine BH-3CF RAT-30 30tf was conducted to investigate tensile strength refers to the JIS Z 2201 standard. Meanwhile impact strength was investigate using Charpy Impact testing machine based on JIS Z 2202 Standard.

3. Results and discussion

Figure 1 shows the AMCs specimen for tensile test and impact test that fabricated using stir casting after through machining process.



Figure 1. Tensile and impact test sample with composition 4 wt% Fly ash and 8 wt% SiC

Tensile strength is important properties that considered primary properties for engineering design. Figure 2 shows tensile strength result of AMCs specimen with various composition. Maximum tensile strength value (15.859 kgf/mm²) was obtained in composition 12 wt% fly ash and 8 wt% SiC, meanwhile minimum tensile strengths in AMCs Specimen without composition of fly ash.

The increasing of amount of fly ash percentage has contribution to enhance tensile strength value of AMCs. On the other hand, the increasing of fly ash has effect to decrease elongation of AMCs. The addition of fly ash percentage with existence of SiC has effect to reduce ductility of AMCs as shown measurement of elongation as shown on Figure 3.

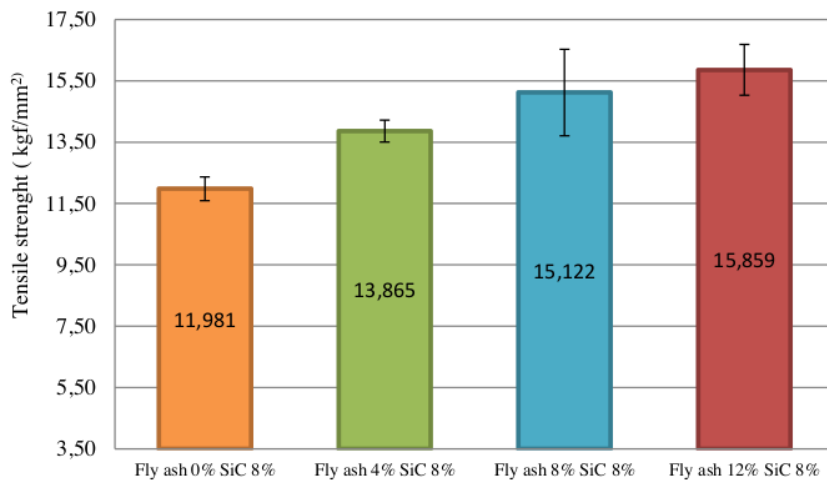


Figure 2. Tensile strength of AMCs with 8 wt% SiC and various weight percentage of fly ash content

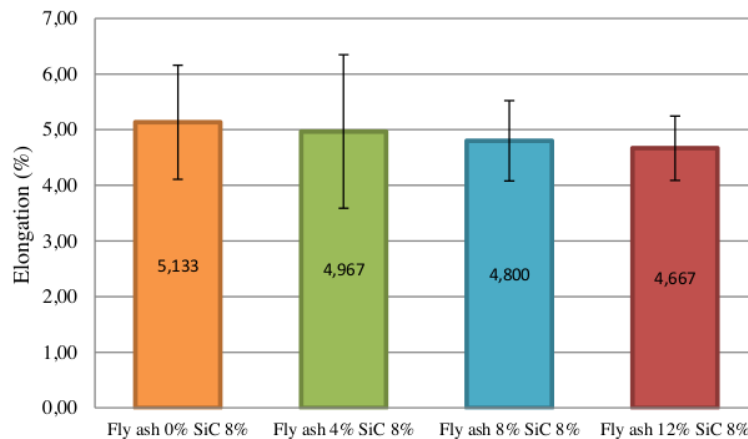


Figure 3. Elongation of AMCs with 8wt% SiC and various weight percentage of fly ash content

The impact tests for AMCs sample were conducted using Charphy test. Impact tests result show that AMCs obtain maximum value on the composition 12 wt% fly ash and 8 wt% SiC in the other word that the sample absorb more energy than other composition.

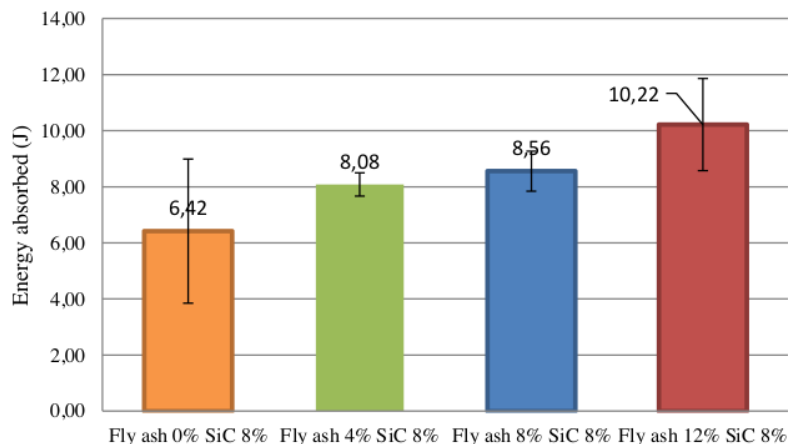


Figure 4 Energy absorbed of AMCs with 8wt% SiC and various weight percentage of fly ash content

Hardness properties of AMCs was characterized using Brinell hardness tester type BH-3CF with Indenter ball (5 mm). The load (500 kgf) was subjected to the AMCs sample refer to JIS B 7724 standard. Brinell method is chosen due to more accurate to analyses heterogenic material such as metal matrix composite. Distribution of reinforcement materials is problem encountered in fabrication metal matrix composite. It always occurs due to the density different between matrix alloys and reinforcement materials.

The position of reinforcement particles in matrix composite are determined by during mixing, after mixing and after solidification. Hardness measurement result revealed that hardness value of AMCs sample increase with the additional of fly ash percentage. Maximum hardness value (57.15 BHN) was obtained in composition 12 wt% fly ash and 8 wt% SiC. Otherwise, minimum hardness value (50.61 BHN) was obtained in composition 8 wt% SiC

without fly ash content. The increasing of hardness value is determined by the additional of fly ash percentage with has some ceramic components with high hardness value. When hardness test was carry out, indenter ball was resisted by reinforcement materials.

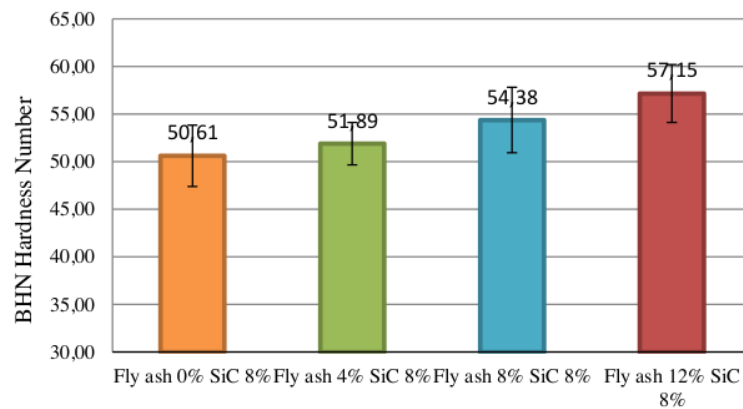


Figure 5 Hardness test result of AMCs with 8wt% SiC and various weight percentage of fly ash content

The Ideal casting process for fabrication aluminum matrix composite if **distribution of reinforcement particles** uniformly dispersed **throughout the matrix**. Distribution of reinforcement particles is complicated problem there are many factors to determine as previous discuss. Moreover, not only from processing variables but also from size, shape and physical properties of reinforcement particle and matrix have strong contribution. To investigate microstructure of AMCs and distribution of reinforcement particles.

Optical microscope was utilized to analyzed morphology of AMCs as shown on the Figure 6. Based on the optical microscope investigation that reinforcement particles have been found particles dispersed on the surface of AMCs.

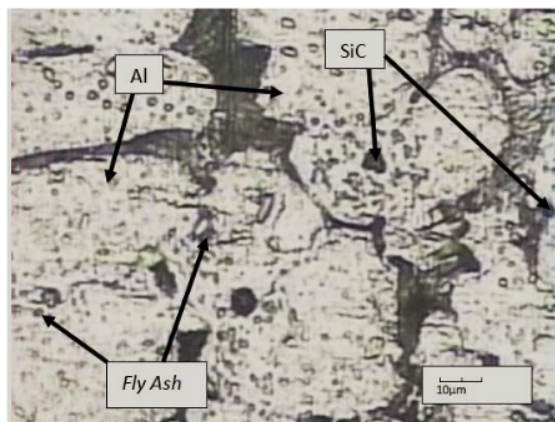


Figure 6 Microstructure aluminum matrix composite with 4 wt% fly ash and 8% SiC

4. Conclusions

Fabrication of Aluminum matrix composite with hybrid reinforced (SiC + fly ash) using stir casting method was successfully performed. In this study the addition of various fly ash (0, 4, 8 and 12 wt %) has contribution to improve mechanical properties of AMCs such as tensile

strength, energy absorption and hardness. On the other hand, Elongation of AMCs tend to decrease with the additional of percentage of fly ash. Maximum value is obtain for tensile test, impact and hardness AMCs composition with 12 wt% fly ash and 8 wt% SiC are 15,859 kgf/mm², 10,22 Joule and 57,15BHN, respectively.

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