Casting and Welding of Aluminium Matrix Composite Materials Reinforced by SiC Particles

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Abstract. Aluminium casting is often done, but for the casting of composite materials base on aluminium is very rare. The purpose of this research is make composite material based on aluminium reinforced by SiC particles by casting. This research method use three different casting molds that are permanent cast, ceramic (chamotte sand / Al2O3-SiO2) molds and sand molds. The best casting product that has a small porosity is the AlMg10Si make of permanent molding. The small porosity effect causes the AlMg10Si material to become harder. The oxy-acetylene welding results show that the AlMg10Si + composite material reinforced by 15% SiC particles, has a fine discontinuity when the liquid penetrant test, which means that very small cracks occur, and potholes result from casting. This composite material has enormous energy to break is 0.94 Joule at impact test.

1. Introduction

Industry of aluminum (Al) is produced by casting and forming process. Product of aluminum casting many use in many household appliances and automotive components such as cast wheel, piston, engine block and at aerospace components. The alloy composition and selection of fabrication processes greatly affect the physical and mechanical properties of aluminum alloys [1]. Fatigue failure is caused by cracking in aluminum alloys, this is a serious problem. Cracks are caused by a combination of rotational and concentration stress interacting with regions on weak material [2]. There is often a fracture form of transgranular cleavage (usually a material with Body Center Cubic structure (BCC), when tested at low temperatures. Occasionally, intercrystalline fractures occur and not often accompanied by significant deformations. This type of fracture is usually caused by a brittle second precipitation phase around the grain boundary [3].

To ‘repair’ aluminum, many research make composite material with aluminum matrix is called Aluminum Matrix Composites (AMC). AMC with reinforcement Silicon Carbide (SiC) powder has good development prospects, based on its excellent properties, such as hardness and high strength, good machine, low density, easy-to-reach base material, with economical price and compete with material other. AMC is widely used in the field of automotive, aviation, and defense industries as a combat vehicle material that requires high performance. AMC can be applied in aircraft engines, and applications in the automotive industry [4].
The manufacturing process of AMC by casting has several disadvantages such as the difficulty of mixing SiC particles into liquid aluminum because SiC particles are difficult to wet the surface by liquid aluminum. Another problem is the tendency of SiC particles to settle at the base of the aluminum liquid matrix. This causes the SiC distribution is not uniform and will affect the mechanical properties of the resulting AMC, so that the desired mechanical properties of the material can not be achieved. Several studies were conducted to overcome the problem of casting SiC aluminum casting with one of the methods used is stir casting technique using high rotation stirring and by preheating ceramic particles to be wetted by liquid matrix before mixing into matrix. The main purpose is to obtain a uniform ceramic particle distribution [5, 6]. Mechanical stirring is necessary to improve wettability. Stirring under perfect liquid conditions results in booster particles floating on the surface of the liquid matrix. Stirring under semi solid conditions may aid the unification of matrix and reinforcement, but must be reheated until the pouring temperature [7]. Another research have suggested of Al-Si-Mg alloy that is strengthened by silicon carbide particles has the potential to have excellent mechanical properties with light weight [8].

Prantasi, et al, 2009 [9] from her research stated that bending test results, on this composite material (AlSi10Mg matrix and reinforcement SiC), included in the brittle material. The result of fatigue test shows that the biggest SiC addition influences material toughness not fatigue quickly so that in general this composite material made by this casting, the data values can be used for alternative material of brittle aluminum alloy for ship material, but can not be used as a substitute for steel. Another result show that permanent mold casting more better than sand mold casting and add of SiC give effect of product of aluminum Metal Matrix Cast Composite (AMMCC) in casting process not only to permanent mold casting but also to sand mold casting [10].

Therefore, this research aims to find out how the cast results by using three different types of molds.

2. Methods

The cast materials used were AlSi and AlMg10Si, then compared by casting results with using three molds: (1) permanent mold of cast iron (Figure 1), (2) sand mold (Figure 2), and (3) ceramic mold (chamotte sand/Al₂O₃-SiO₂) (Figure. 3). For molding the sand is given a mixture of water in the mold made process, while for ceramic mold is given a mixture of water glass in the mold. The best of mold cast and the best of cast material obtained from porosity test and hardness test, use for cast molds for composite materials with AlSi or AlMg10Si matrix with 15% SiC particle reinforcement. The composite material of cast result was welding by oxy-acetylene, liquid penetrant test and impact test.

Figure 1. Permanent mold of cast iron.
3. Results and discussion

Figure 4 shows the smallest porosity percentage obtained from permanent mold of 1% for AlSi and AlMg10Si. Results from ceramic mold are 1.66% for AlSi and 1.33% for AlMg10Si. The highest porosity was obtained from the cast by using sand molds of 2.5% for AlSi and 2.33% for AlMg10Si.

Figure 5 shows the greatest hardness value obtained from a permanent mold of 135.63 HVN for AlSi and 169 HVN for AlMg10Si. While the cast results from ceramic mold of 132.3 HVN for AlSi and 165.76 HVN for AlMg10Si. The smallest hardness values were obtained from the cast by using sand molds of 132.5 HVN for AlSi and 155.36 HVN for AlMg10Si.
It appears that AlMg10Si obtained from permanent mold casting results has the smallest porosity percentage meaning that the cast results was more compact, solid and homogeneous, thus having the highest hardness value. Visible from observation using Scanning Electron Microscopy (SEM) magnification 2000 x (figure 6). While Figure 7 shows the results of AlMg10Si cast from sand mold that look more coarse, porosity high and not homogeneous. While the function of Mg is to bind AlSi to be more compact and protect from dirt when casting.

Furthermore, since AlMg10Si is the best result for porosity test and its hardness test, AlMg10Si is used as a matrix to make composite material with 15% SiC reinforcing by casting. Results of oxy-acetylene welding then performed liquid penetrant test, each result is shown in Figure 7 for AlSi, Figure 8 for AlMg10Si and Figure 9 for AlMg10Si + 15% SiC. While complete data result of liquid penetrant test in table 1. Table 2 shows data of impact test. Energy for break declared with Ekpm (Joule) and impact strength expressed in Joule/mm$^2$ unit. Shows that composite material AlMg10Si + 15% SiC has highest a great energy to break was 0.94 Joule when impact test. This condition is closely related when composite material AlMg10Si + 15% SiC has a smooth discontinuity when liquid penetrant test.

![Average Value of Hardness AlSi and AlMg10Si](image)

**Figure 5.** Average value of hardness AlSi and AlMg10Si.

![Figure 6. SM images of AlMg10Si (permanent mold).](image)

![Figure 7. SEM images of AlMg10Si (sand mold).](image)
Figure 8. Liquid penetrant test of AlSi.

Figure 9. Liquid penetrant test of AlMg10Si.

Figure 10. Liquid penetrant test of AlMg10Si +15%SiC.

Table 1. Data of Liquid penetrant test.

| No | Part Item | Type of Indication | Size of Discontinuity (mm) | Result |
|----|-----------|--------------------|-----------------------------|--------|
|    |           | Rounded            | 2,2,6,3                     | -      |
| 1  | 1         | Rounded            | 2,2,6,3                     | -      |
| 2  | 2         | Rounded            | 4,2,5                       | γ      |
| 3  | 3         | Rounded            | 3,1,1                       | γ      |

Accepted  | Repaired
-         | γ
The results of this penetrant when compared with another research conducted by T Endramawan and A Sifa [11], showed that material mild steel 98.71% Fe and 0.212% C which is welded use SMAW butt joint with filler used LB 5218 electrode diameter 3.2 mm and result show the discontinuity of porosity on the surface of the welded and inclusion on sub material used ultrasonic test, all indication on dye penetrant or ultrasonic test if there were rejected of result of welded that there must be gouging on part which rejected and then re-welding. While the preliminary study of the fluid mechanics of liquid penetrant testing showed that is shown to be strongly dependent on defect geometry and penetrant application procedure. The effect of slight fluid elasticity is shown to be negligible [12]. Furthermore, to application of the composite material welding material to be used for electric furnaces [13].

4. Conclusions
This study about casting using three different molds and welding. The best results was AlMg10Si with permanent mold, which has the smallest porosity and the greatest hardness value. Composite material AlMg10Si + 15% SiC shows smooth discontinuity when liquid penetrant test, so having high energy a break when impact test.

The important of continuitas of this result is how to joint with welding between aluminium alloy and Aluminu m Matrix Composites (AMC).

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