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STUDY OF BOTTOM ASH REINFORCED ALUMINUM METAL MATRIX COMPOSITE FOR AUTOMOTIVE PARTS

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Abstract. Low cost and light materials nowadays are the requirements for industry, especially automotive. An aluminum based metal matrix composite (MMC) with bottom ash reinforcement is developed as input and ideas for automotive industry, because of its properties are equivalent with metals, however this MMC is lighter, cheaper, and easy to get. The objective of the study is creating automotive parts using Al metal matrix with bottom ash reinforcement composite. Al-bottom ash composite is formed by HAS method then necessary machining added. The tests performed to the composite are tensile test, hardness test, corrosion and microstructure. The result shows the number of mechanical properties in general, mechanical properties increased about by 30% compared with properties of standard propeller found in market. The microstructure images support the other mechanical destructive testing that Al-bottom ash composite can be used as an alternative as automotive parts.

Keywords: aluminum-bottom ash; automotive parts; mechanical properties; metal matrix composite.

1. Introduction

In recent years, very many projects performed in Indonesian universities directed to the manufacture of electric cars. The high electric car project is performed by the college, which also conducting research on components, used in the electric car, in order to be able to produce their own spare parts and compete with the latest models. Metal matrix composite (MMC) is one of the solutions that can be developed, because the MMC demonstrates a strong, light-weight and corrosion-resistant properties. This type of composite is a widely developed composite matrix of metal, which is aluminum matrix composite (AMC). Currently AMCs are used in the automotive industry for pistons, disc brakes, gears etc. [2].

The advantages of AMCs include their light weight, they have high hardness, high specific modulus and good wear resistance. One of the most important electrical components of a car is a disc cradle [1]. The amplifier component must have a higher elastic modulus than the matrix component [2]. There must be a strong surface bonding between the amplifier and matrix components.

According to the research that has been done, the selected treatment process includes the stages of solution treatment at 540 °C for 4 hours, quenching and aging process. The parameters used are temperatures of 100 °C and 200 °C with aging time of 1, 10 and 24 hours; then the samples were tested. Resulting conclusions touched of the effect of aging temperature from 100 °C to 200 °C on metal matrix composites, which can improve mechanical properties especially tensile strength and hardness. While the aging time from 1 hour to 24 hours may decrease tensile strength even, when hardness increases.

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2. Methods

Aluminum matrix composite with ash coal base consists of aluminum (93.5%), ash coal base (4%), silica sand (2%) and Mg (0.5%).

Casting process. Tools of casting process are casting furnace, K-type thermocouple, mold of the disc footer, mold of the test specimen.

The stages of casting:

1. preparing a cast stove;
2. heating the furnace to a certain temperature after the aluminum material is inserted into the already hot stove;
3. when aluminum has melted at a temperature of 600 °C (measured by thermocouple), the silica sand is mixed to separate the dirt/crust from the aluminum material;
4. after cleaning the aluminum material from the dirt/crust, the coal ash and Mg ash are mixed alternately and stirred;
5. liquid aluminum is poured into a preheated mold.

T6 heat treatment process. Tool of T6 heat treatment process are heating furnace with brand SELECTA and ability of heating up to 1200 ºC, thermometer, three coolants of medium, namely SAE oil 10-40, pure water and brine.

The steps of the T6 heat treatment process:

1. solution heat treatment at 540 ºC
2. quenching media with salt water, pure water, and SAE oil 40
3. artificial aging process with temperature of 180ºC and time variation from 1.3 to 5 h.
4. cooling to room temperature.

Metallographic testing. Metalography testing is first done by cutting the sample in accordance with the size of the specimen, then mounting the specimen so easily to hold it. The surface of the part tested is then smoothed using abrasive papers from the roughest grid to the finest grid, so in the end we can get a shiny specimen. To clean the surface, we polished it by using alumina. Prior to testing, etching solutions were used to dissolve grain boundaries on the surface of the specimen so that they could be seen using a microscope. Furthermore, observation of microstructure was performed by using metallurgical microscope. The microscope is set with standard way and has representative parts allowing to process necessary data.

Hardness testing. Tests were performed by using the Rockwell method. First, the surfaces of specimens were leveled off. Then the tool for the Rockwell hardness test was prepared, in particularly the diamond indentor with angle at tip of 120^{o}. Then it was touched onto the specimen surface with force of 150 kgF and held for 30 seconds. After that, the hydraulic valve is opened to restore the load to its original position.

Tensile testing. Specimen was prepared in accordance with JIS Z2201. The specimen was gripped by the upper and lower chucks. The button “Start” is used for automatical testing. The generated plot “stress – strain” is directly analyzed.

4. Results and analysis

Hardness testing. Figure 1 shows increasing in hardness value after T6 heat treatment. The highest increase in hardness corresponds to artificial aging for one hour in comparison with other considered cases. It can be concluded that the one-hour time of the treatment is the most optimal artificial aging time to increase material hardness.

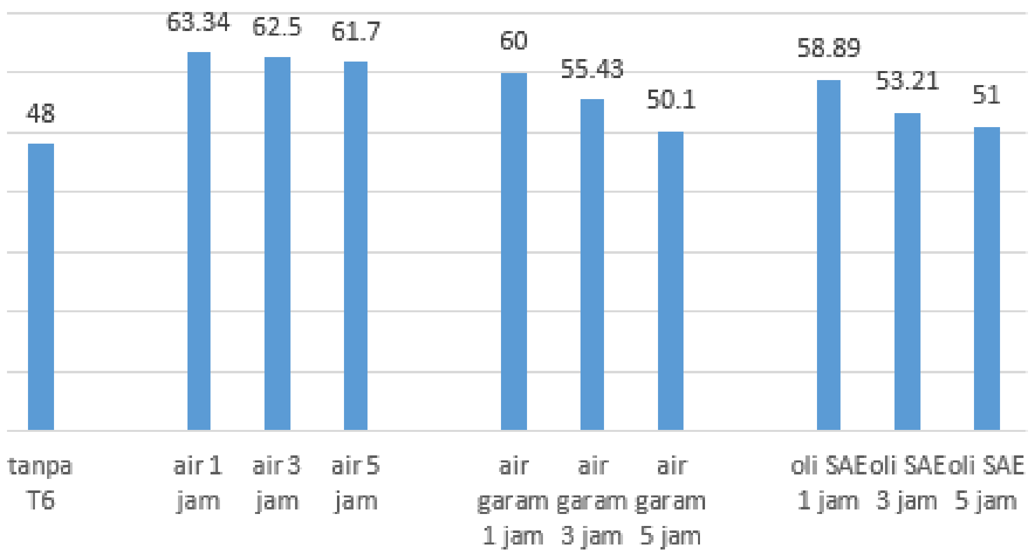

Fig. 1. Results of hardness tests.

Similar results were obtained for the cooling medium. The cooling medium with pure water is the best cooling medium for T6 heat treatment process, proved by its relatively close hardness values at each of the time cases, and the hardness value in the case of cooling by pure water is higher than for other cooling media. This proves Basuki's theory [4] about pure water cooling medium. The highest hardness value (63.34 HRc) was obtained for pure water cooling at artificial aging time for one hour.

Tensile testing. From Fig. 2 it can be concluded that T6 heat treatment has an effect on the increasing of strength value. The highest increase of the tensile strength can be seen predominantly in the artificial aging for one hour. While at comparison of cooling media, cooling by using pure water demonstrates the highest value compared with other cooling media. So, the case of cooling with pure water and artificial aging time of one hour is the most optimal decision.

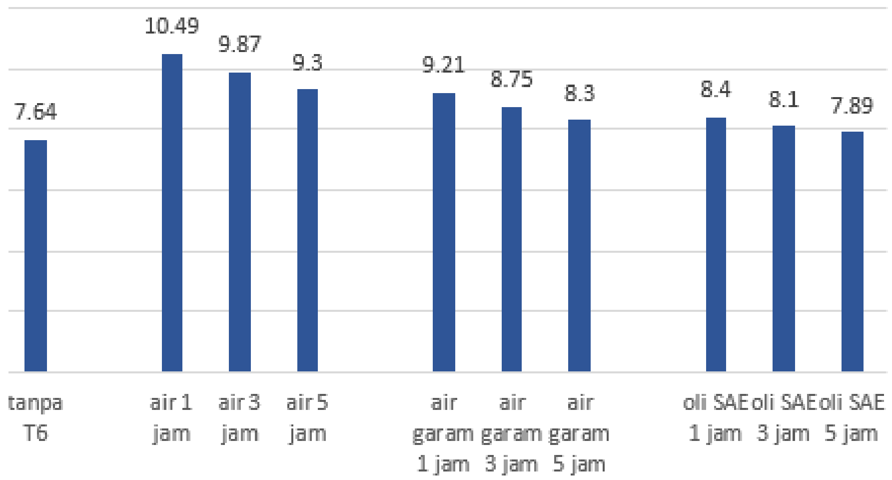

Fig. 2. Results of tensile tests.

In this tensile strength test, the highest tensile strength value (10.49 kgF/mm^2) was obtained for water cooling media with at artificial aging time of 1 hour. In a whole, there is coincidence of the behavior of mechanical properties: strength and hardness increase according to the theory of Dieter [5]. At increasing the strength, the hardness of a material also increases, accompanied by the decrease of its ductility.

Microstructure testing. Figures 3 – 6 present specimen microstructures for different cases of quenching medium and holding time. The calculated number of grains (*G*) and mean diameter of grains (D_m) are obtained by direct measurements in the figures.

Table 1 presents results for the tested microstructures on the disc cradle with estimation of the effect of aging time (1, 3, and 5 hours) and the cooling medium/quenching (brine, pure water and SAE 10-40 oil) on number of grains and the mean diameter of the granules on aluminum-ash coal base. In particular, we obtained the following results for holding time of 5 hours: (i) at the water cooling medium, the number of grains G = 5.47 and the mean diameter of the granules D_m = 55 μm; (ii) at the brine cooling medium, the number of grains G = 5.02 and the mean diameter of the granules D_m = 65 μm, (iii) at the SAE 10-40 hydraulic oil cooling medium, the number of grains G = 7.58 and the mean diameter of the granules D_m = 27 μm. In the case without T6 heat treatment, the number of grains G = 3.90 and the mean diameter of the granules D_m = 90 μm.

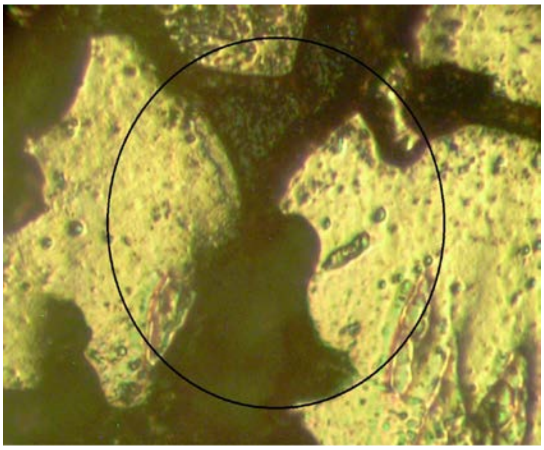

Fig. 3. Specimen microstructure for water is the quenching medium and holding time – 1 h; number of grains, G = 4.85, mean diameter of grains, D_m = 65 μm.

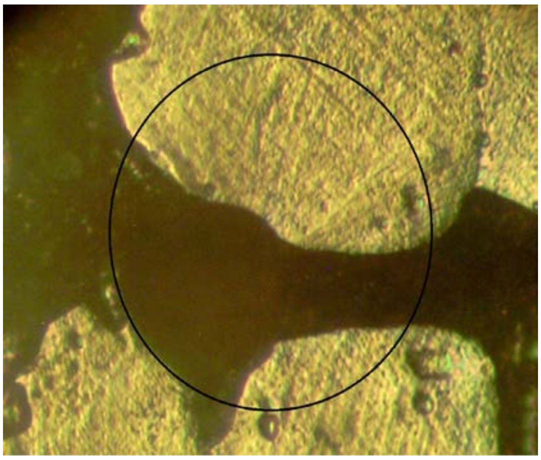

Fig. 4. Specimen microstructure for salt water is the quenching medium and holding time – 1h; number of grains, G = 3.37, mean diameter of grains, D_m = 0.105 μm.

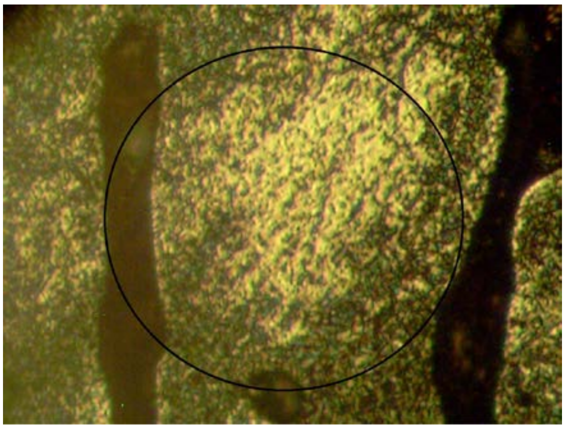

Fig. 5. Specimen microstructure for SAE Oil is the quenching medium and holding time – 1h; number of grains, G = 6.52, mean diameter of grains, D_m = 30 μm.

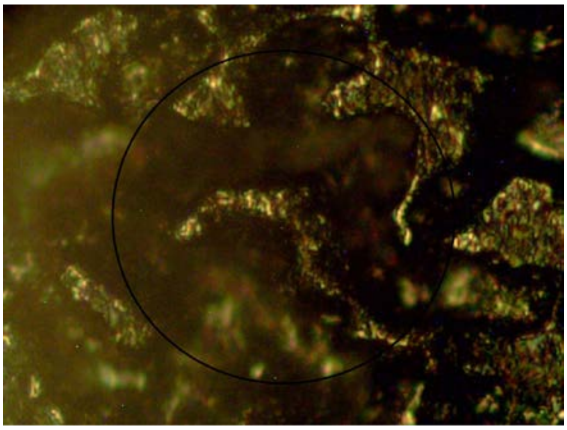

Fig. 6. Specimen microstructure without treatment; number of grains, G = 3.90, mean diameter of grains, D_m = 90 μm.

Table 1. Grain size for various cases of quenching medium and holding time.

Quenching medium	Holding time (hours)		
	1	3	5
Pure Water	G = 4.85; D_m = 65 μm	G = 4.95; D_m = 65 μm	G = 5.47; D_m = 55 μm
Salt water	G = 3.37; D_m = 0.105 μm	G = 4.25; D_m = 75 μm	G = 5.02; D_m = 65 μm
Oil SAE 10-40	G = 6.52; D_m = 30 μm	G = 6.90; D_m = 30 μm	G = 7.58; D_m = 27 μm
Without treatment	G = 3.90; D_m = 90 μm		

5. Conclusion

In the grain growth in the structure of the disk holder component, there is a process without T6 heat treatment, leading to the number of grains G = 3.90 and obtaining the mean diameter of D_m = 90 μm.

Moreover, the following results for holding time of 5 hours were obtained:

1. at the water cooling medium, the number of grains G = 5.47 and the mean diameter of the granules D_m = 55 μm;
2. at the brine cooling medium, the number of grains G = 5.02 and the mean diameter of the granules D_m = 65 μm,

3. at the SAE 10-40 hydraulic oil cooling medium, the number of grains G = 7.58 and the mean diameter of the granules D_m = 27 μm.

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