Effect of quenching agent on dimension stability of Al 6061-Al_2O_3 composite

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Abstract. Al 6061-Al_2O_3 composite is a lightweight materials that can be used as an alternative material in automotive parts. T6 heat treatment is generally used on aluminium alloy series 6xxx . On T6 heat treatment process, material heated to temperature for obtaining a single phase of α, quenched and then continued by artificial ageing. Quenching is critical step because distortion can be occur in material. The aim of this research is to investigated effect of quenching agent and electroless coating treatment of Al_2O_3 in distortion at Al 6061-Al_2O_3 composite . The distortion was measured by dimensional change in the specimen. Coordinate Measuring Machine (CMM) was used to measured distortion based on coordinate change. Lower distortion are occur on 10E and 10N specimens. Electroless coating process on the reinforcement is more effective to obtain lower distortion on Al 6061-Al_2O_3 composite. The severity (H) of quenchant influenced distortion on specimen. Higher H value produce higher distortion on Al 6061-Al_2O_3 composite.

1 Introduction

Environmental problem encourage the development of lightweight materials. Lightweight materials can be used to reduce fuel consumption and overcome environmental issue. Composite is one of solution for that issue.

Aluminium metal matrix composite (AAMc) are widely used in aerospace, ground and water public transportation. AAMc demand are increased due to their strength to weight ratio, corrosion resistance, high thermal capacity [1]. One of AAMc is Al 6061-Al_2O_3 composite. This AAMc with particle reinforcement materials is widely used as structure and automotive parts. Boeing have been applied Aluminium 6xxx in their structural parts [2].

The mechanical properties of composite materials with aluminium matrix can be increased by using heat treatment in general. Heat treatment is the treatment consist of two different heat treatment that are solution heat treatment and precipitation hardening [3]. Solution heat treatment is carried out by heating Al alloy to a temperature that produce single phase of α and then quenching to room temperature. Heat treatment with various of quenching agent affected mechanical properties of AA6060 material [4]. Quenching rate must be fast to obtain maximum strength of material. On the other hand, quenching rate must be slow to avoid the distortion [5].

Tianbin et al [6] reported that heat treatment in addition changed mechanical properties, can caused distortion in material. Higher heating temperature can cause distortion effect on material [7]. The distortion in quenching is caused by inhomogeneity of cooling rate [8] and material thickness [9].

At the present, many of quenching agent are used in heat treatment, such as water, oil and salt solution. Water was widely employed as quenching agent with beneficially cheap and high cooling rate until 300°C. With addition of 5-10% salt, the solution can be increased cooling rate until 500°C on steel [9]. Compared with water, oil caused dangerous smoke and expensive, but oil has lower cooling rate than water [10]. Higher cooling rate tends to distortion occurred. High cooling rate resulted high residual in stress that lead the crack, instability in machining and dimensioning [11].

In heat treatment, different quenching agent can be produce different mechanical properties and distortion of materials. The distortion could change the dimension of the material, thus eliminate the used value of materials. Therefore, it is important to know for investigated effect of quenching agent and electroless coating treatment on distortion of Al 6061-Al_2O_3 composite.

2 Materials and Methodology

Aluminium alloy 6061 and Al_2O_3 powder with size <1μm was used in this research. The properties of Al_2O_3 powder is shown in Table 1. Al 6061-Al_2O_3 composites were manufactured by stir casting method as shown in Figure 1. and then followed by T6 heat treatment process. Stir casting is general method on manufacturing metal matrix composite because it has low cost, flexible, and large quantity production [12].

Table 1. Properties of Al_2O_3 particle

Chemical composition	
Al_2O_3 (%)	99.6
Na_2O (%)	0.3
SiO_2 (%)	0.02
Fe_2O_3 (%)	0.02
Physical composition	
Ave. Grain Dia μ	50
Specific Gravity	3.92

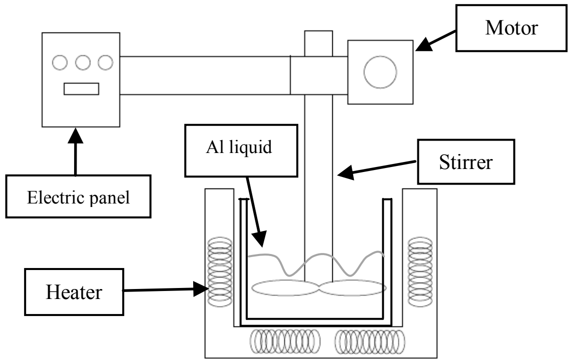

Fig. 1. Stir casting equipment

Al 6061 ingot was melted at a temperature of 700-750° C, then Al_2O_3 was added with a weight fraction as shown in Table 2. This experiment using Al_2O_3 particles with electroless coating and without electroless coating. Particles of Al_2O_3 were electroless coated in order to increase their wetting ability in liquid aluminium [13]. The electroless coating process of Al_2O_3 was conducted with 40 ml of 65% HNO_3 solution, 0.1 gram of Mg fine powder, and 0.5 gram of fine Al powder.

Table 2. Specimen tabulation

Specimen	**Weight fraction of Al_2O_3 (%)**	**Treatment of Al_2O_3**
0X	0	—
10N	10	Without electroless coating
10E	10	Electroless coating

Stirring casting of Al 6061-Al_2O_3 composite was carried out at 500 rpm and 700-720°C and then poured into the mould. The heat treatment of T6 in Al 6061-Al_2O_3 composite was conducted with solution heat treatment at 540° for 6 hours, then quenched on various quenching agent (water, oil, and salt solution 10%) and followed by artificial ageing treatment at 200° C for 4 hours.

Dimensional stability of Al 6061-Al_2O_3 composite specimen was measured by CMM Mitutoyo Bright-STRATO 707 with 5 point measurement method as shown in Figure 2. The Al 6061 matrix and Al_2O_3 interface bonding was examined using SEM JEOL JSM6510LA.

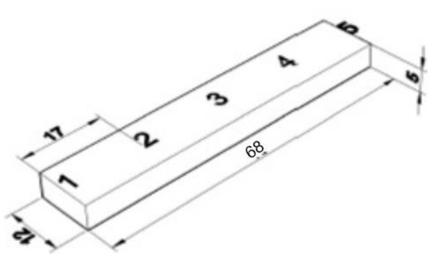

Fig.2. Specimen test

3 Result and discussion

In this research the difference between the highest and the lowest deflection was defined as distortion, an example deflection on 10N with brine quenching as shown in Figure 3. Distortion on various quenching agent was shown in Figure 4.

The specimen without reinforcement had the biggest distortion. It decreased by addition of 10% Al_2O_3 ceramics. The electroess coating process on Al_2O_3 ceramics also affected distortion. It produce the lowest distortion.

The distortion also affected by quenching agent. Higher cooling rate of quenchant produce higher distortion. Brine with highest cooling rate produce highest distortion. The lowest distortion was obtained by using oil quenching.

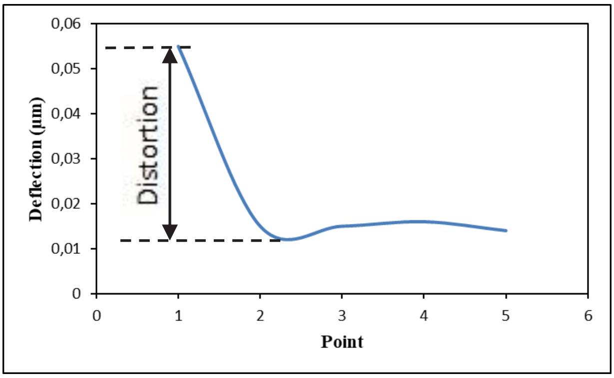

Fig. 3. Deflection on 10N brine quenching agent.

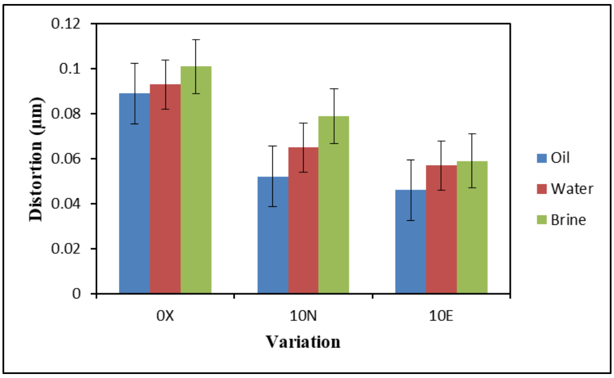

Fig. 4. Distortion of Al 6061-Al_2O_3 composite.

Figure 4 shows that the effect the quenching agent on distortion have similar trend. The quenching process with brine medium in all variation has the largest distortion, followed by water and oil quenching medium. That phenomenon was related to severity quenching coefficient (H) of quenching agent. It because brine has the highest severity quenching coefficient (H) with 2.0-2.2. Water has 1.0-1.1 of H value, and oil has 0.30-0.35 of H value [9,14]. The characteristic of water quenching produce non-uniform geometry and high temperature gradient on specimen, which generated the residual stress and the distortion [5].

Al_2O_3 particle affected distortion of the specimen. Specimen of Al 6061-10% Al_2O_3 have lower distortion than specimen without Al_2O_3. The Addition of ceramics particles (e.g Al_2O_3) on the metal matrix composite can decrease thermal conductivity [15]. The electroless coating treatment on Al_2O_3 can affected the distortion of specimen. Specimen with electroless coating process had lower distortion result than specimen without electroless coating process. Al_2O_3 with electroless coating has higher wettability in Al matrix than Al_2O_3 without electroless coating. Therefore, electroless coating that was applied on Al_2O_3 able to increase interface bonding caused the oxide film is formed to despotition the metal film so the wettability increased.

The specimen without electroless coating process formed agglomeration of Al_2O_3 reinforcement. The agglomeration of Al_2O_3 reinforcement on specimen was shown in Figure 5a is caused by weak interface bonding between Al matrix and Al_2O_3. The weak interface bond is an obstacle to achieving the desired properties of the composite [16] . The agglommeration did not occur on specimen with electroless coating process as shown in Figure 5b

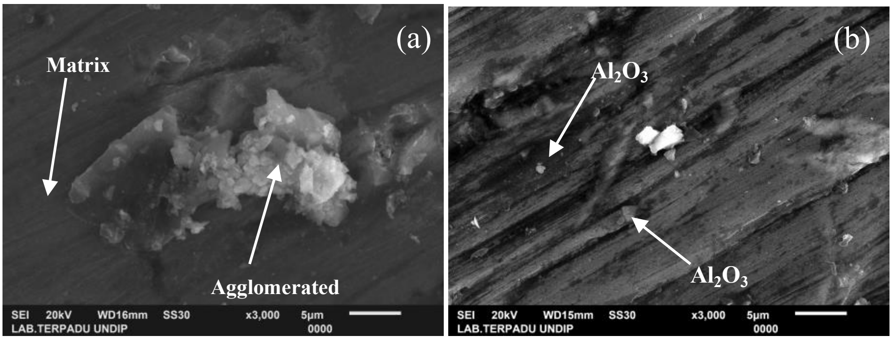

Fig. 5. SEM image (a) non-electroless coating specimen; (b) electroless coating specimen

The agglomeration of reinforcement can generate bigger distortions. That phenomenon was due to the fact that the agglomeration of reinforcement have lower interface bonding strength between matrix and reinforcement. It show that main problem in Al 6061-Al_2O_3 composite is wettability of Al to Al_2O_3 ceramics. Moreover, the agglomeration reinforcement increase opportunities to obtain bigger porosity on the composite material.

The addition of reactive Mg to HNO_3 at electroless coating process will produce Al_2O_3 with $MgAl_2O_4$ spinel phase that have higher wettability [17]. Moreover, the addition of Mg at electroless coating process increase the capillarity of penetration to the passive layer of oxide and also facilitate the interface bonding formation. It produces Al 6061-Al_2O_3 composite with good interface bonding. The good bonding interface between Al 6061 and ceramics Al_2O_3 could increase the heat capacity of composite, so it reduce distortion in quenching process.

4 Conclusion

Increasing of H value of quenching agent produce higher distortion on the specimen. Addition of Al_2O_3 reinforcement decrease the distortion on the specimen. Application of electroless coating on the Al_2O_3 reinforcement more effectively decrease distortion on Al 6061-Al_2O_3 composite.

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