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EFFECT OF MECHANICAL STIRRER AND POURING TEMPERATURE ON SEMI SOLID RHEOCASTING OF ADC12 AL ALLOY: MECHANICAL PROPERTIES AND MICROSTRUCTURE

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ABSTRACT

The aim of this research is to explore microstructure and mechanical properties in thesemi-solid casting process of aluminum alloy ADC12. The research method was done by gravity casting using ametal mold. The aluminum ADC12 slurry is stirred by a mechanical stirrer at 300 rpm for 60 seconds. Furthermore, the aluminum slurry of ADC12 is poured on a metal mold with a starting temperature of 580-680 ^oC. The microstructure characteristics were examined by direct observation using optical microscopy, scanning electron microscopy (SEM), secondary α-Al phase dendrite arm spacing, and Si eutectic phase were identified. The mechanical properties were investigatedby hardness test and tensile test. The results showed that mechanical stirring had an effect on the change of mechanical properties and microstructure of aluminum alloy of ADC12. The mechanical properties of ADC12 aluminum alloys increased after semi-solid casting using a stirring bar. The highest mechanical properties occur at the temperature of the casting 600 ^oC. The formation of microstructure from dendritic becomes non-dendritic (globular) after the aluminum alloy slurry of ADC12 is prepared by mechanical stirring.

Keywords: semi-solid, mechanical stirrer, ADC12 aluminum alloy.

INTRODUCTION

The processing of semi-solid metal (SSM) or thixoforming was a patented metal formation technology by Spencer in the early 1970s [1]. Currently, the thixoforming process has been widely used in manufacturing applications due to its ability to produce high-quality spare parts production. The cost of the thixoforming process is lower than that of conventional forming techniques such as casting or forging. Engine components such as engine mount suspension and steering knuckles for some car brands are some examples of this application [2, 3].

Already many different materials have been developed and used with the SSM process. The success of the SSM process is determined by a microstructure having a spherical solid density close to the broad transition region of solidus to liquidus [4]. These microstructures are called thixotropic properties in slurries, which means they have shear and time-dependent properties.

Various processes have been found for the production of semisolid metal slurries. The SSR process (semisolid rheocasting) [5] is one of the processes for obtaining ideal microstructure in semisolid formation. The ideal microstructure can be produced by short stirring during the first few percent of compaction through agitation combined with rapid heat extraction through the agitator. In this process, cold copper or rotating graphite rods are immersed in a melt held just above the liquid temperature. Soaring rotating rods create a high local cooling area and drop the bulk melting temperature below the liquid temperature. At the same time, it gives a strong convection in melting. This will result in the formation of high-density nuclei which are well distributed in melt and produce non-dendritic primary particles, which are substantially free of trapped fluid [6].

Aluminum-silicon alloys (Al-Si) are generally used in industrial machinery because of their superior properties such as; lightweight, good thermal conductivity, good casting properties, and good welding properties [7]. Aluminumdies casting 12 (ADC12) is one kind of Al-Si alloy. The silicon element in the ADC12 alloy is very close to the eutectic point in the Al-Si phase diagram and the two-phase liquid and very thin solid states. Despite the widely publicized semi-solid technique with aluminum alloy material, but research using anADC12 aluminum alloy with semi-solid technique is still very less.

In this study, experiments were performed to study the comparative effect of slurry preparation aluminum alloysADC12 are stirred and unstirred with a mechanical stirrer and pouring temperature on mechanical properties and microstructure.

EXPERIMENTAL METHOD

Material and Tools

The ADC12 aluminum alloys were used in this experiment that has compositions as listed in Table-1. The liquid temperature of this alloy is about 577 ^oC. The alloy is melted in a graphite container at 700 ^oC using a gas furnace. The tools used were a metal mold, a rounded T model, and heater device.

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Table-1. Composition of ADC12 aluminum alloys.

ADC12 Aluminum Alloys	Weight %											
	Si	Cu	Fe	Mn	Mg	Zn	Ti	Cr	Ni	Pb	Sn	Al
	9.55	2.01	0.91	0.16	0.22	1.31	0.03	0.02	0.14	0.11	0.02	85.49

The casting method

The sequence of experimental steps undertaken in this study was:

a. Metal molds are prepared and heated to a temperature of ± 300 °C;
b. the material of ADC12 Aluminum alloy was prepared (± 280 grams, according to mold volume);
c. The alloy material of aluminum ADC12 was melted;
d. The melted aluminum alloy of ADC12 was poured into a metal mold after the temperature reaches 580 °C;
e. Testing phase starts from point(a) to point (d); Re-testing 2 times;
f. Perform the same testing phase for casting temperature 600, 620, 640, 660, and 680 °C;
g. Re-testing point (a) to (f) after the aluminum alloy has been melted and stirred for 60 seconds (stirring temperature ± 5 °C above the pouring temperature) using a rounded model T over 300 rpm,
h. The specimens of casting result are cut into 5 parts (Size 10x12x160 mm)as the tensile specimen with size d_0 = 8 mm, and L_0 = 50 mm.

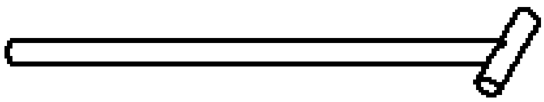

Figure-1. The rounded model T.

The mechanical and microstructure analysis

The mechanical properties of the foundry are investigated experimentally, including the nature of hardness and tensile properties. Hardness is evaluated by Brinnel hardness tester, where steel ball indenter is used at 300 N load for 15 s. Tensile properties are checked at room temperature using a universal screw driven type screw machine with a capacity of 100 kN. The test specimens were designed based on ASTM B557. Characteristics of microstructures are examined by optical microscopy (MO), a scanning electron micrograph (SEM) and energy dispersive X-ray spectroscopy (EDX). The secondary dendritic arm spacing of the alpha-Al (SDAS) phase and the size of the eutectic base phase Si were measured using image analysis.

RESULTS AND DISCUSSIONS

The mechanical properties of ADC12 aluminum alloys such as the hardness, the tensile strength, and also the microstructure properties can be explained as follows.

Hardness properties

In Figure-2, the results of the aluminum hardness test of ADC12 in semi-solid casting process (Rheocasting) with the preparation of slurry before and after stirring using a mechanical stirrer. The hardness of aluminum alloys ADC12 after stirring is higher than before stirring. The highest hardness occurred at 600 °C of pouring temperature of 87.9 HB, and lowest at 680 °C at 76.7 HB. This indicates that the preparation of ADC12 slurry with mechanical stirring results in an increase in the hardness value of the material. Decreasing SDAS will increase the hardness value. It is accordance with Hall–Petch relationship, the smaller grain size will increase obstacle of dislocation movement that increases the mechanical properties.

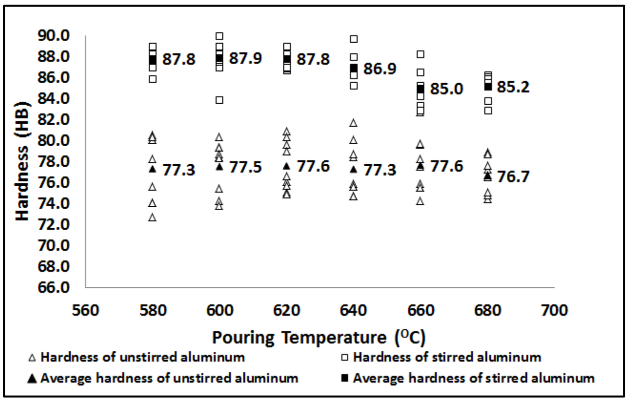

Figure-2. The hardness of ADC12 aluminum alloys at semi-solid casting.

Tensile strength

Figure-3 shows the results of the aluminum ADC12 tensile test in a semi-solid casting process (Rheocasting) with slurry preparation without and with stirring using a mechanical stirrer. The tensile stress of aluminum alloy ADC12 in semi-solid casting with mechanical stirring has a tensile stress value greater than before stirring. The highest tensile stress with stirring occurs at a temperature of 600 °C of 235 N/mm^2 and the lowest tension occurs at a temperature of 680 °C at 224 N/mm^2.

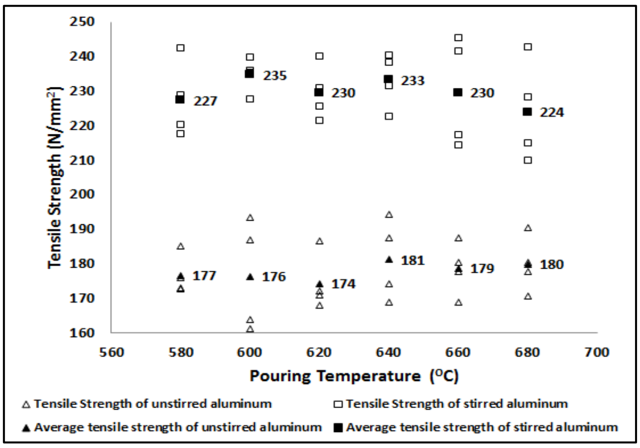

Figure-3. The tensile strength of ADC12 aluminum alloy at semi-solid casting.

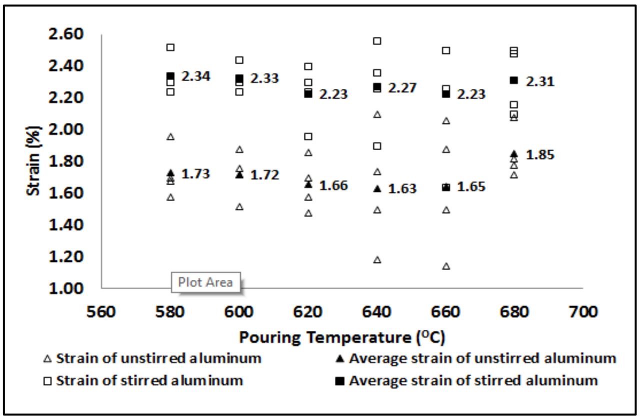

Figure-4. The tensile strain of ADC12 aluminum alloy at semi-solid casting.

Increased tensile stresses of aluminum alloys of ADC12 in the semi-solid casting process are also followed by an increase in tensile strain as shown in Figure-4. This allows the ADC12 aluminum alloy to be manufactured by the forming process.

Microstructure

Figure-5 shows the comparison of surface microstructure of aluminum alloy products ADC12 unstirred and stirred slurry aluminum. Figure-5 (a) a silicone element (black in color) is elongated by a matrix of aluminum that forms dendrites of uniformly dispersed widths and Figure-5 (b) the dendritic structure of aluminum has been transformed into a globular structure.

The formation of this globular structure takes place through the cutting mechanism of the dendritic arm due to the stirring force. In the early stages of growth, dendritic pieces will develop into dendrites. However, with increasing time and continuous shear force given during freezing, the dendrite will turn into a rosette. Next, because the cooling rate is relatively slow and the shear strain rate is relatively high then the rosette form turns into globular. The cutoff mechanism of dendrites can also be through the melting of dendritic arm roots due to temperature disturbances during stirring [2, 8]. This is in accordance with the results of previous studies for aluminum alloys ADC12 with different stirring methods [9-13].

Figure-6 shows the secondary dendrite arm spacing (SDAS) of aluminum alloy products ADC12 unstirred and stirred slurry aluminum. SDAS from unstirred aluminum alloys ADC12 is higher than the stirred SDAS aluminum alloy of ADC12. SDAS aluminum alloys ADC12 unstirred is 19 - 29 μm and stirred is 9 - 19 μm. It can be assumed that the preparation of aluminum slurry with stirring affects secondary dendritic arm spacing so that the mechanical properties of aluminum alloys of ADC12 increase. When the molten aluminum alloy was poured into the mold, nucleus growth occurs in the melt, and then that makes dendrite formation. The stirrer force interferes with the growth of dendrites and increases the level of solidification causing the smaller SDAS. This is in accordance with the results of previous studies on ADC12 materials [14-16].

Figure-7 shows an SEM image of the aluminum alloy surface of ADC12 before and after stirring 1000X magnification. Figure-6 (a) generally looks silicone-eutectic element in the form of a longitudinal line between the aluminum matrix and Figure-6 (b) visible element of silicone-eutectic short-shaped due to stirring.

Figure-8 shows the backscattered EDS of as-cast ADC12 aluminum alloys and the corresponding elemental analysis is provided in Table-2. The α-Al matrix can be seen (position 4), and it is clear that the grey phases are Al-Si eutectic (position 1 and 3), and the white phases are $CuAl_2$ (position 5).

This experiment can also be performed to calculate the power consumption for the casting process as well as was done by Nur *et al* [19]. They have analyzed the use of power consumption in the turning process of aluminum alloys.

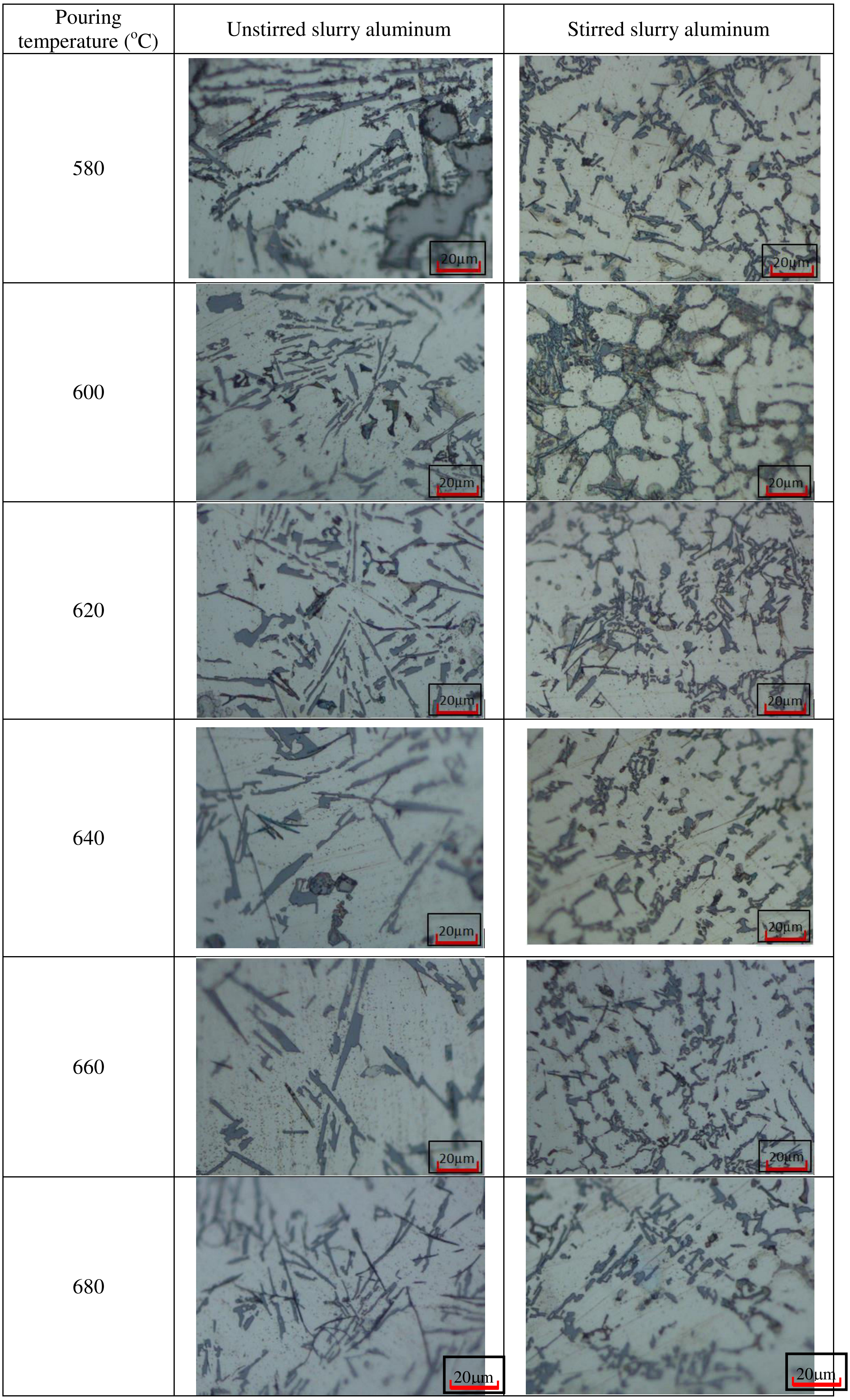

Figure-5. The microstructure of aluminum alloys ADC12 in semi-solid casting (200X magnification).

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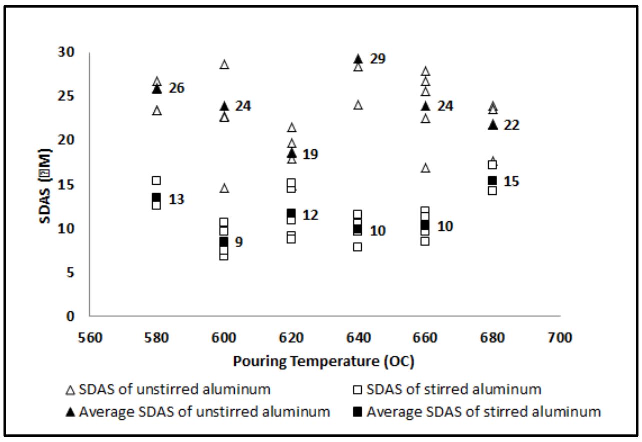

Figure-6. Secondary arm spacing (SDAS) ofADC12 aluminum alloy atsemi-solid casting.

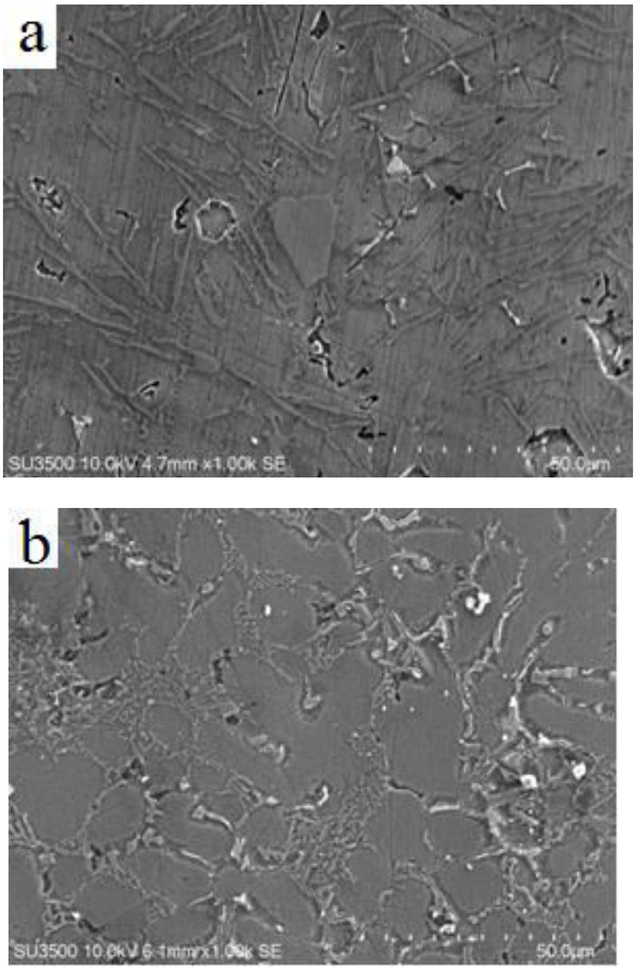

Figure-7. SEM micrograph aluminum alloys ADC12, (a) Unstirred slurry aluminum, (b) Stirred slurry aluminum, (1000X magnification) at pouring temperature 600 °C.

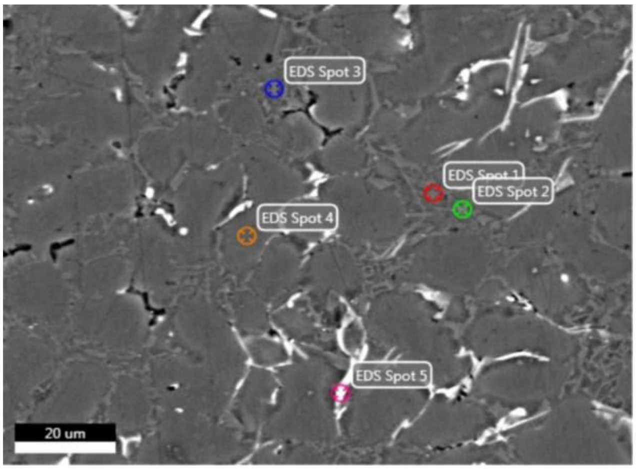

Figure-8. EDS micrograph aluminum alloys ADC12 (Stirred slurry aluminum) at pouring temperature 600 °C.

Figure-8 shows the backscattered EDS micrograph aluminum alloys ADC12 (Stirred slurry aluminum) at pouring temperature 600 °C.

Table-2. The elemental compositionof the structure in the aluminum alloy ADC12 at the position shown in Figure-7.

Position	Types of structure that may be formed	Si	Cu	Mg	Al
1	Si-eutectic	27.14	0.93	0.43	71.54
2	Al-Si-Mg	19.17	1.18	0.47	79.17
3	Si-eutectic	24.33	1.08	0.50	74.08
4	Matrix α-Al	1.62	0.83	0.27	97.28
5	CuAl2	1.47	3.16	0.44	94.92

CONCLUSIONS

The mechanical properties of ADC12 aluminum alloys made with semi-solid casting technology (Rheocasting) using mechanical stirrers have been studied, and the results obtained can be synergized as follows. The mechanical properties of aluminum alloys of ADC12 increase after semi-solid casting using stirring rods. The highest mechanical properties occur at the temperature of 600 °C.There is a change of microstructure from dendritic to non-dendritic (globular) after the aluminum alloy slurry ADC12 is prepared by mechanical stirring.

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