The Impact of Stirring Model on Aluminum Alloys ADC12's Microstructure and Mechanical Properties

by Syaharuddin Rasyid

The Impact of Stirring Model on Aluminum Alloys ADC12's Microstructure and Mechanical Properties

Syaharuddin Rasyid[1*], Ilyas Renreng[2], Hairul Arsyad[3], Muhammad Syahid[4]

(*) Corresponding author

Abstract - *Replacing automotive components made of iron alloys with aluminum alloys is one of the strategies to reduce vehicle weight and increase fuel efficiency in the automotive sector. Semi solid casting with stirring for microstructure and mechanical properties. This research aims to study the influence of mechanical agitation models on the aluminum alloy ADC12 to microstructure and mechanical properties. Using a metal mold, gravity casting was used as the research methodology. Mechanical stirrers (round rod stirrers, straight plate stirrers, and twist plate stirrers) were used to mix the aluminum ADC12 slurry for 60 seconds at a speed of 300 rpm. Additionally, the ADC12 aluminum slurry is poured into a metal mold at a temperature of 600^oC. Optical microscopy, scanning electron microscopy (SEM), secondary α-Al phase dendritic arm spacing, and Si eutectic phase were used to directly observe the microstructure features. The hardness test and tensile test were used to examine the mechanical properties.. The highest mechanical properties occur in the straight plate stirrer model followed by the twist plate model and the round rod stirrer model. When agitated with a straight plate stirrer, the aluminum alloys of ADC12 have mechanical parameters of 129.7 HB, 249.96 N/mm2 tensile strength, and 4.33 percent fracture strain.*

***Keywords**: stirrer model; ADC12, mechanical properties, semi-solid casting*

I. Introduction

Implementation of strategies for reducing vehicle weight is one of the efforts to improve fuel efficiency in the automotive field. Replacing automotive components made of iron alloys with aluminum alloys is one of the implementations of this strategy. Utilization of aluminum alloy for automotive component manufacturers is also followed by development in the field of process technology. Currently under development of a new process called semi-solid forming process. Manufacture of automotive products with the semi-solid process is very advantageous because of low cycle time, improved properties, extend tool life/dies and decrease product weight (Flemings [1]; Winterbottom [2]).

Molten metal that has been subjected to a shear force will differ from product to product when creating semi-solids. Among these variables are grain size, grain spreading, and globular shape perfection. The difference in the final product is influenced by the following variables: stirring speed, stirrer diameter, stirring material, starting and finishing stirring temperatures, heated mold, and stirring time (Antara [3]).

Industrial machinery frequently makes use of aluminum-silicon alloys (Al-Si) because of its exceptional qualities, including their light weight, strong thermal conductivity, good casting capabilities, and good welding properties (Chiang [4]). One type of Al-Si alloy is aluminum dies casting 12 (ADC12). In the two-phase liquid and very thin solid stages of the Al-Si phase diagram, the silicon element in the ADC12 alloy is very close to the eutectic point. The semi-solid casting method employing the aluminum alloy ADC12 has received extensive press coverage from numerous researchers (Wang [5], Hu [6-8]). None of them, however, mention semi-solid that has been stirred mechanically.

Mechanical stirrers have been used in the metal smelting industry to handle metal solutions together with other techniques including gas injection and the addition of fluxes. Different rotary impeller systems have been used for this purpose, however unlike other fields like chemical engineering, food processing, and biotechnology, the treatment of molten aluminum places severe restrictions on the design of the impeller.

There has been a lot of research on the impact of the stirrer model and stirrer parameters on liquid flow patterns (Ameur [9], Ameur [10], Su [1[illegible] Yamamoto [12]), but there hasn't been much done on the impact of stirrer models on the microstructure and mechanical properties of aluminum alloys. Stirring effectiveness affects inclusion removal, bubble injection, flux treatment efficiency, and degassing (Yamamoto [12]).

Numerous studies have been conducted on the impact of stirring settings on the microstructure and mechanical characteristics of aluminum and alloying metals (Fatchurrohman [13]; Ramakoteswara [14]; Ming [15]; Prasad [16]; Alhawari [17]; Wan [18]; Rasyid [19]; Rasyid [20]). However, in the literature that has been reported does not explain the shape or model of the agitator used. Mechanical stirrers can alter the mechanical characteristics and microstructure of ADC12 aluminum alloys from dendritic to non-dendritic (Rasyid [19]). The speed of the stirrer affects how well the ADC12 aluminum alloy's mechanical qualities work (Rasyid [20]). Mechanical stirrers can alter the mechanical characteristics and microstructure of ADC12 aluminum alloys from dendritic to non-dendritic (Rasyid [19]). The speed of the stirrer affects how well the ADC12 aluminum alloy's mechanical qualities work (Rasyid [20]).

In this investigation, experiments were carried out to investigate the effects of mechanical stirring models (round rods, straight plate, and twist plate) in the slurry preparation of ADC12 aluminum alloy on microstructure and mechanical characteristics.

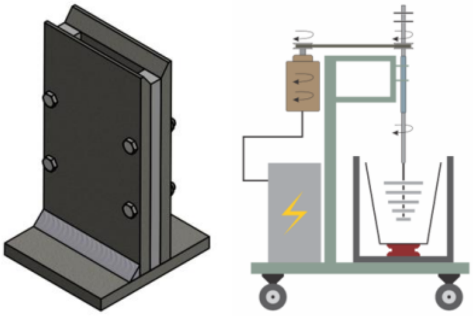
II. Experimental Design

II.1. Material Preparation

Commercial aluminum alloys (ADC12) are chosen in this study since the automobile sector has made extensive use of them. The chemical composition of the aluminum alloys ADC12 is Si 9.55; Cu 2.01; Fe 0.91; Mn 0.16; Mg 0.22; Zn 1.31; Ti 0.03; Cr 0.02; Ni 0.14; Pb 0.11; Sn 0.02; Al 85.49 (wt.%).

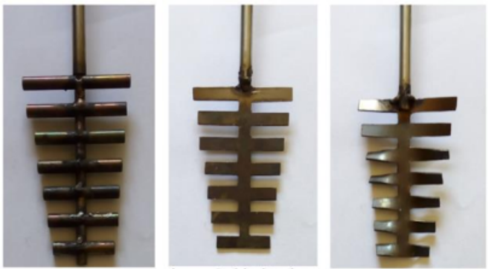
II.2. Preparation of Semi-Solid Rheocasting Slurry and Tensile Test Specimen

A temperature of around 300 oC is used to prepare and heat metal molds (Figure 1.a). ADC12, an aluminum alloy material, is manufactured (around 280 grams, based on die volume). Using a gas fuel furnace, the aluminum alloy ADC12 is melted to a temperature of 650 °C (Figure 1.b). Aluminum fluid and metal mold temperatures were measured with thermocouple gauges and infrared temperature sensors, respectively. The aluminum alloy liquid or slurry of ADC12 is swirled for 60 seconds at 300 rpm using several mechanical stirring models at 610 °C (Figure 2). The liquid or ADC12 aluminum alloy is poured into the metal mold at a temperature of 600 °C. The foundry specimen (Figure 3) is split into five (5) sections (10 x 10 x 160 mm in size). The 10 x 10 x 160 mm specimens were formed into tensile specimens of size d_0 = 8 mm, and L_0 = 50 mm (Figure 4).



a. Metal Mold b. Gas fuel furnace

Fig. 1. Metal mold and gas fuel furnace.



a. Round rod stirrer. b. Straight plate stirrer. c. Twist plate stirrer.

Fig 2. Mechanical stirrer models.

Fig. 3. Specimens cast results.

Fig. 4. Tensile specimens.

II.3. Mechanical Testing and Microstructure Analysis

Experimental research is done on the foundry's mechanical characteristics, including the type of hardness and tensile characteristics. The Brinnel hardness tester uses a steel ball indenter and an 1840 N load for 5 seconds to determine the degree of hardness. Using a 100 kN capacity universal screw driven type screw machine, the tensile characteristics are examined at room temperature. The test specimens were created using ASTM B557 as a guide. Optical microscopy (MO), scanning electron microscopy (SEM), and energy dispersive X-ray spectroscopy are used to evaluate the characteristics of microstructures (EDX). Using image analysis, the size of the eutectic base phase Si and the grain size of the α-al phase were determined.

II.4. Microstructure Analysis

On identical rheocast samples, microstructural analyses were performed utilizing image analysis methods and typical metallographic procedures. A linear intercept approach was used to calculate the average dendritic arm spacing (DAS) and main particle size. The following equation (Suery [21]) was used to calculate the shape factor (SF) of the particles:

$$SF = \frac{4.\pi.A}{P^2} \qquad (1)$$

The letters P and A, respectively, stand for a particle's perimeter and surface area. While an endlessly long needle-like particle would have a value of 0, a completely spherical particle would have a value of unity.. On the agglomerates, microstructural investigations were also carried out. Similar techniques were used to measure the features' size and form factors. According to the agglomeration-disagglomeration theory (Flemings [1] and Fan [22]), primary particle sintering causes agglomerates to form. The pseudo-particle/pseudo-cluster concept was not able to account for the findings of this study because it was intended to explain the formation, growth, and separation of primary particles from crucible walls under mild temperature gradients (Falak [23]; Niroumand [24]), not the development of semisolid microstructures. In a semisolid processed slurry, the growth circumstances and evolutionary paths are quite different. In reality, rather than forming on the stirrer surface, it appears that the majority of the solid particles are created close to the stirrer, where significant undercooling has been caused by the effects of highly localized cooling.

III. Results and Discussion

III.1. Microstructure Analysis

Figure 5-7 compares the surface microstructure of a product made of the aluminum alloy ADC12 that was agitated using several 200X magnification mixer models. Figures 5-7 demonstrate the non-dendritic microstructure that was produced after 60 seconds of agitation below the liquid temperature using a round rod stirrer model (Figure 5), a straight plate stirrer model (Figure 6), and a twist plate stirrer model (Figure 7). By utilizing the stirrer's convection and powerful cooling capabilities, non-dendritic morphology can be achieved.

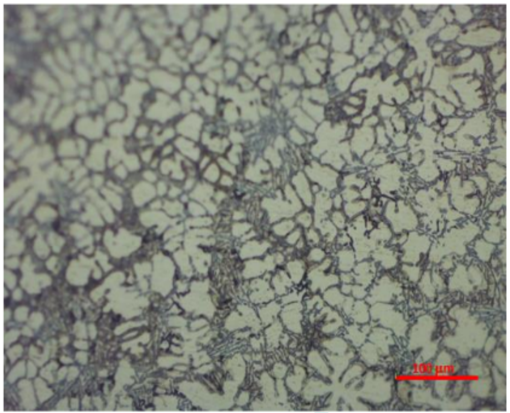


Fig. 5. Photograph of semi-solid casting ADC12 aluminum alloy structure using a round rod stirrer model.

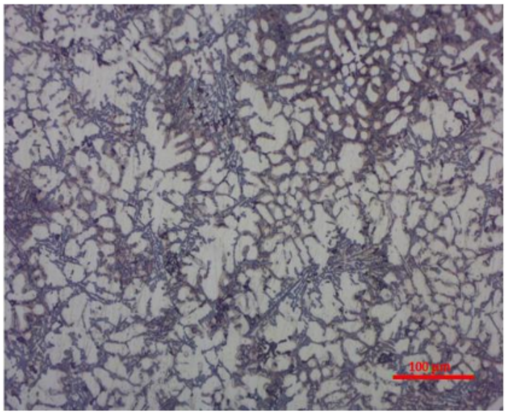


Fig. 6. Photograph of semi-solid ADC12 aluminum alloy microstructure using a straight plate stirrer model.

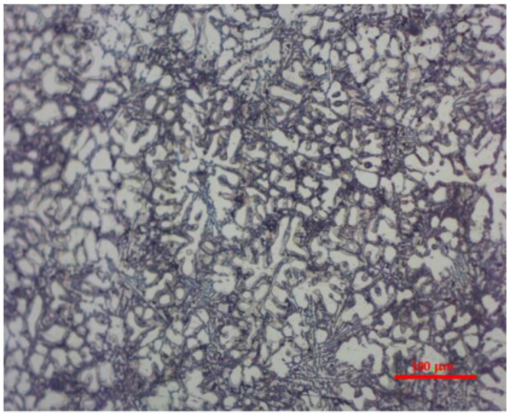


Fig. 7. Photograph of semi-solid ADC12 aluminum alloy microstructure using a twist plate stirrer model.

Figure 8 depicts the grain size of the ADC12 aluminum alloy using different stirrer model changes. Aluminum alloy ADC12 stirred with a straight plate stirrer model had a grain size value that was less than that of the same alloy stirred with a round rod stirrer model and a twist plate mixer model. Where the straight plate stirrer model produces a flow zone in very heavy and turbulent metal liquids with a very strong shift when compared with other stirrer models (round rod stirrer model and twist plate mixer model). The results of this study are reinforced by research conducted by Yamamoto [12], that the strength and direction of the release flow are influenced by the torsional angle. The release flow strength decreases as the twist angle increases, and the impeller blade's surface and the distance between neighboring blade gaps both have an impact on the flow's direction.

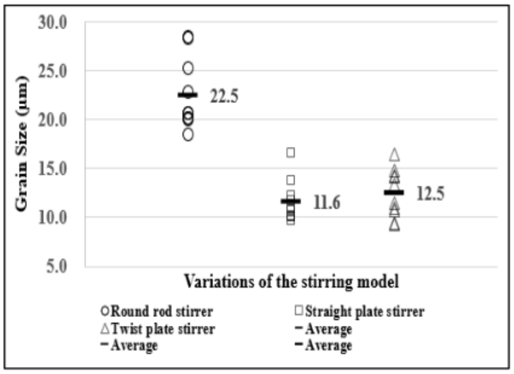


Fig. 8. Graph of the relationship between grain size and aluminum alloy stirring model of ADC12 at semi-solid casting.

The stirrer models with the largest grain sizes are round rods measuring 22.5 m, and the stirrer models with the smallest grain sizes are straight plates at 11.6 m. This result was confirmed by Rasyid [19]. He reported that the value of the ADC12 aluminum alloy grain size was stirred with straight plate stirrer of 9-13 µm.

In order to increase the mechanical properties of the ADC12 aluminum alloy, it can be assumed that the preparation of aluminum slurry with alterations in the stirrer model impacts the distance of the secondary dendrite arm. The churning force prevents dendrite formation and increases solidification, which results in smaller grains.

Figure 9 shows the Shape factor (SF) ADC12 aluminum alloy with a stirrer model variation. Shape factor (SF), the largest occurred on straight plate stirrer model of 0.56, followed by a twist plate stirrer model 0.53, and 0.26 round rod stirrer models. Inversely correlated with grain size is the value of the form factor. This shows that the fundamental particle shapes are significantly influenced by the variation model of churning at liquidus temperature.

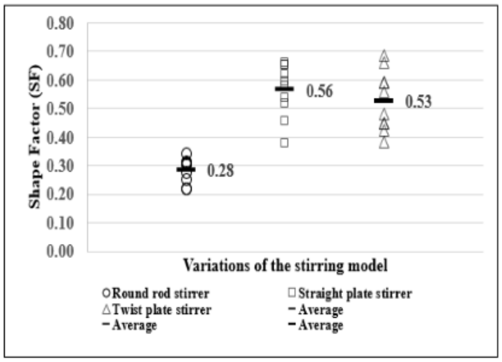


Fig. 9. Graph of the relationship between the shape factor (SF) and the aluminum alloy stirring model ADC12 in semi-solid casting.

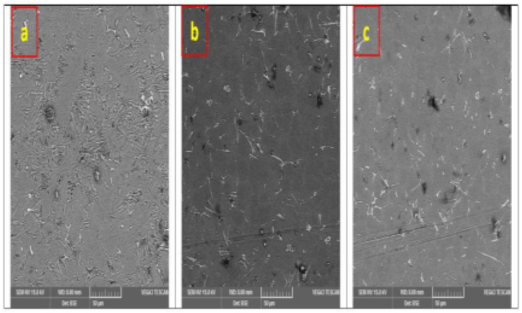


Fig. 10. SEM aluminum alloy semi-solid casting with a variety of stirrer models: round rod stirrer (a), straight plate stirrer (b), and twist plate stirrer (c).

Figure 10 displays a SEM picture of the aluminum alloy ADC12's surface following three stirring models (500X magnification). Figure 10.a generally shows a short silicon-eutectic element between aluminum matrices. The silicon-eutectic element looks short, smooth, and blends with the aluminum matrix (Fig. 10.b and 10.c). This shows that the straight plate stirrer model and the twist plate stirrer model have a significant influence in uniting the silicon and aluminum elements so that the mechanical properties of the ADC12 aluminum alloy are higher than the round rod stirrers.

Figure 11 depicts the backscattered EDS of an aluminum alloy ADC12, and Table 2 provides the pertinent elemental analysis. Position 1 shows the matrix α-Al, Position 2 shows the grey phases are Al-Si eutectic, and Position 3 shows the white phases are CuAl2-Mg (position 3).

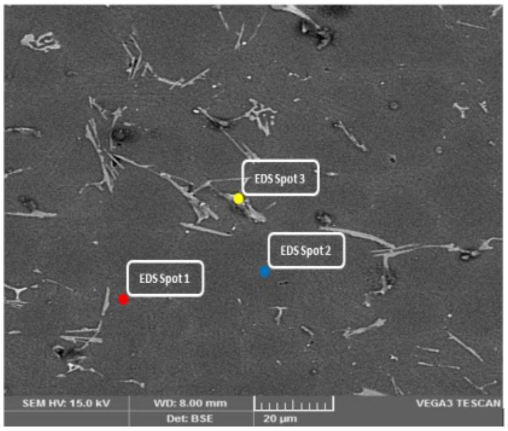


Fig. 11. Photo of the microstructure of EDS aluminum alloy ADC12 using straight plate stirrer model.

TABLE I
THE ALUMINUM ALLOY STRUCTURE IN ADC12 AT THE POSITION DEPICTED IN FIGURE 15'S ELEMENTAL COMPOSITION

Position	Types of structure that may be formed	Si	Cu	Mg	Al
1	Si-eutectic	22.14	0.93	0.43	71.54
2	Matrix α-Al	1.62	0.83	0.27	97.28
3	$CuAl_2$-Mg	1.47	3.16	0.44	94.92

III.2. Hardness Properties

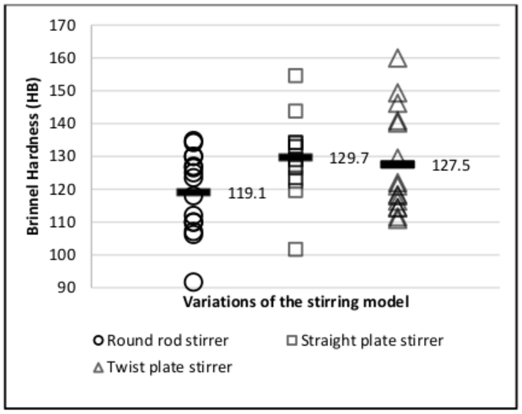


Fig. 12. Graph of the relationship between hardness value and ADC12 aluminum alloy stirring model on semi-solid casting.

Figure 12 displays the outcomes of the ADC12 aluminum hardness test conducted using a range of mechanical stirring models during a semi-solid casting process. The hardness of aluminum alloy ADC12 varies; the straight plate stirrer has the highest hardness at 129.7 HB, followed by the twist plate stirrer at 127.5 HB and the round bad stirrer at 119.1 HB. This suggests that the agitator model has an effect on the hardness properties of the aluminum alloy of ADC12. This suggests that the agitator model affects the aluminum alloy ADC12's hardness characteristics. The agitation process affects grain size and shapes factor. This is reinforced by the grain size (Figure 8) and the shape factor (SF) (Figure 9) from the measurement of the microstructure of the aluminum alloys ADC12.

Above all, the hardness value using the straight plate stirrer models was higher than the other stirrer models for small grain size and shape factor is greater. Figure 13 shows the correlation between grain size and hardness of the three samples of the agitator model. The decline of grain size will increase the value of violence. Smaller grain size will increase the resistance to dislocation movement, increasing mechanical characteristics, according to the Hall-Petch relationship. Similarly, the shape factor (SF) of the microstructure of the aluminum alloys of ADC12 stirred with straight plate stirrer was higher when compared with other stirrer models (Figure 9).

Yim [25] provided confirmation of this outcome. The hardness values of the various rheocast magnesium alloys determined by hardness testing are compared with those anticipated by the empirical, according to the report. Semi-solid casting possesses superior mechanical qualities than those of traditional casting, according to research by Bochao et al. [26].

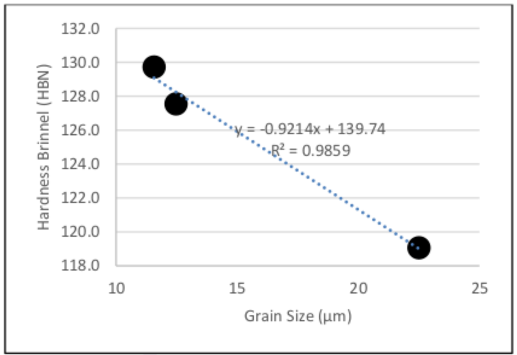


Fig. 13. Graph of the relationship between grain size and hardness of aluminum alloy ADC12 at semi-solid casting.

III.3. Tensile Strength Properties

ADC12 aluminum alloy tension at semi-solid casting with a variety of mechanical stirrer models, with a straight plate stirrer having a larger tensile stress value than other variations of stirring model, is shown in Figure 14 as the results of tensile testing. The highest drag occurs in the straight plate stirrer model of 249.96 N/mm^2 and the lowest tensile stresses in the 205.73 N/mm^2 round rod stirrer model and the twist stirrer model have tensile stress between the straight plate stirrer and round rod stirrer model of 235.51 N/mm^2. The rise in fracture strain is also a result of the tensile phenomena of the aluminum alloy ADC12 in the semi-solid casting process with the adjustment of the agitator model, as illustrated in figure

15. This makes it possible to produce the ADC12 aluminum alloy through the forming process. This is reinforced by grain size (Figure 7), shape factor (SF) (Figure 8), and finer Si-eutectic (Figure 10) from the measurement of the microstructure of aluminum alloys ADC12. The rise in fracture strain is also a result of the tensile phenomena of the aluminum alloy ADC12 in the semi-solid casting process with the adjustment of the agitator model, as illustrated in figure 15. This makes it possible to produce the ADC12 aluminum alloy through the forming process.

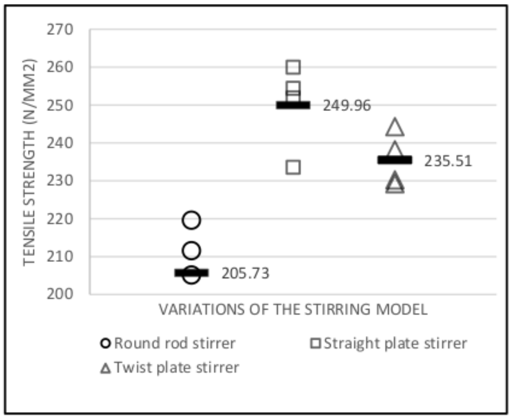


Fig. 14. Tensile stress and aluminum alloy mixer model of ADC12 on semi-solid casting relationship graph.

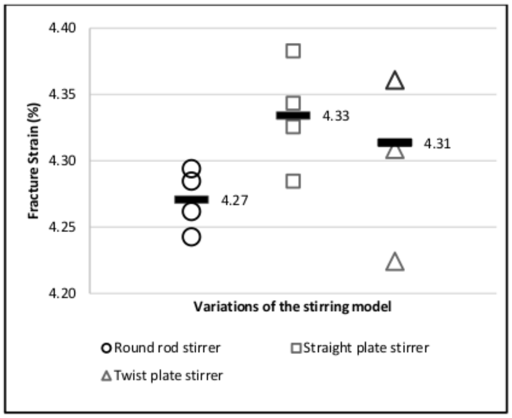


Fig. 15. Relationship between the fracture strain and the semi-solid casting's ADC12 aluminum alloy mixer model.

According to Tahamtan [31], shrinkage porosities were seen in the tensile fracture side views of gravity-cast A356 samples while the tensile fracture course of rheocast A356 inclined to shear eutectic phase.

The results of the aluminum alloy ADC12's fracture tests on semi-solid casting are shown in Figure 15. Fracture strain on straight plate stirrer models higher than other mixer models. However, differences in fracture strain are not too great. It can be concluded that the variation model of the stirrer does not significantly influence the fracture strain.

IV. Conclusion

Following a study of the mechanical characteristics and microstructure of aluminum alloys ADC12 created utilizing semi-solid casting technology and a variety of mechanical stirring models, the findings can be combined as follows. After semi-solid casting with a few mechanical stirrer types, aluminum alloys ADC12 have different mechanical properties. The highest mechanical properties occur in the straight plate stirrer model followed by the twist plate stirrer model and the round rod stirrer model. The straight plate stirrer type produces aluminum alloys of ADC12 with mechanical parameters of 129.7 HB, 249.96 N/mm^2 tensile strength, and 4.33 percent strain. When compared to previous stirrer models, these mechanical qualities are supported by smaller particle size values and a higher form factor (SF).

ACKNOWLEDGMENTS

The principal author and a lecturer from Hasanuddin University's mechanical engineering department can work together to finish this article. We appreciate the research facilities provided by the Hasanuddin University Geology Department, Ujung Pandang State Polytechnic, and the Department of Mechanical Engineering.

REFERENCES

[1] M. C. Flemings, "Behavior of metal alloys in the semisolid state," *Metallurgical Transactions A*, vol. 22, no. 5, pp. 957-981, 1991/05/01 1991.
[2] W. Winterbottom, "Semi-solid forming applications: high volume automotive products," *Metallurgical Science Tecnology*, vol. 18, no. 2, 2000.
[3] I. Antara, S. Tabuchi, K. Suzuki, S. Kamado, and Y. Kojima, "Refining Nuclei and Distributing Spherical Primary Crystals in Billets for Semi-Solid Casting," *Advances In Technology Of Materials Materials Processing Journal*, vol. 6, no. 1, pp. 87-94, 2004.
[4] K.-T. Chiang, N.-M. Liu, and T.-C. Tsai, "Modeling and analysis of the effects of processing parameters on the performance characteristics in the high pressure die casting process of Al–SI alloys," *The International Journal of Advanced Manufacturing Technology*, vol. 41, no. 11-12, pp. 1076-1084, 2009.
[5] S. Wang, Z. Ji, S. Sugiyama, and M. Hu, "Segregation behavior of ADC12 alloy differential support formed by near-liquidus squeeze casting," *Materials Design*, vol. 65, pp. 591-599, 2015.
[6] Z.-h. Hu *et al.*, "Primary phase evolution of rheo-processed ADC12 aluminum alloy," *Transactions of Nonferrous Metals Society of China*, vol. 26, no. 1, pp. 19-27, 2016.
[7] Z.-H. Hu *et al.*, "Dry wear behavior of rheo-casting Al–16Si–4Cu–0.5 Mg alloy," *Transactions of Nonferrous Metals Society of China*, vol. 26, no. 11, pp. 2818-2829, 2016.
[8] Z.-h. Hu *et al.*, "Microstructure evolution and mechanical properties of rheo-processed ADC12 alloy," *Transactions of Nonferrous Metals Society of China*, vol. 26, no. 12, pp. 3070-3080, 2016.
[9] H. Ameur and M. Bouzit, "Power consumption for stirring shear thinning fluids by two-blade impeller," *Energy*, vol. 50, pp. 326-332, 2013.
[10] H. Ameur, "Energy efficiency of different impellers in stirred tank reactors," *Energy*, vol. 93, pp. 1980-1988, 2015.

[11] T. Su, F. Yang, M. Li, and K. Wu, "Characterization on the hydrodynamics of a covering-plate Rushton impeller," *Chinese journal of chemical engineering,* vol. 26, no. 6, pp. 1392-1400, 2018.

[12] T. Yamamoto, A. Suzuki, S. V. Komarov, and Y. Ishiwata, "Investigation of impeller design and flow structures in mechanical stirring of molten aluminum," *Journal of Materials Processing Technology,* vol. 261, pp. 164-172, 2018.

[13] N. Fatchurrohman, S. Sulaiman, S. Sapuan, M. Ariffin, and B. Baharuddin, "Analysis of a metal matrix composites automotive component," *International Journal of Automotive Mechanical Engineering,* vol. 11, p. 2531, 2015.

[14] V. RamakoteswaraRao, N. Ramanaiah, M. S. Rao, M. Sarcar, and G. Kartheek, "Optimisation of process parameters for minimum volumetric wear rate on AA7075-TiC metal matrix composite," *International Journal of Automotive Mechanical Engineering,* vol. 13, no. 3, pp. 3669-3680, 2016.

[15] M.-f. Qi, Y.-l. Kang, and G.-m. Zhu, "Microstructure and properties of rheo-HPDC Al-8Si alloy prepared by air-cooled stirring rod process," *Transactions of Nonferrous Metals Society of China,* vol. 27, no. 9, pp. 1939-1946, 2017.

[16] K. V. Prasad and K. Jayadevan, "Simulation of stirring in stir casting," *Procedia technology,* vol. 24, pp. 356-363, 2016.

[17] K. Alhawari, M. Omar, M. Ghazali, M. Salleh, and M. Mohammed, "Microstructural evolution during semisolid processing of Al–Si–Cu alloy with different Mg contents," *Transactions of Nonferrous Metals Society of China,* vol. 27, no. 7, pp. 1483-1497, 2017.

[18] B. Wan, W. Chen, M. Mao, Z. Fu, and D. Zhu, "Numerical simulation of a stirring purifying technology for aluminum melt," *Journal of Materials Processing Technology,* vol. 251, pp. 330-342, 2018.

[19] S. Rasyid, E. Arif, H. Arsyad, and M. Syahid, "Effect of mechanical stirrer and pouring temperature on semi solid rheocasting of ADC12 Al Alloy: Mechanical properties and microstructure," *ARPN Journal of Engineering Applied Science,* vol. 13, no. 6, pp. 2032-2037, 2018.

[20] S. Rasyid, E. Arif, H. Arsyad, and M. Syahid, "Effects of stirring parameters on the rheocast microstructure and mechanical properties of aluminum alloy ADC12," in *MATEC Web of Conferences*, 2018, vol. 197, p. 12004: EDP Sciences.

[21] D. H. Kirkwood, M. Suéry, P. Kapranos, H. V. Atkinson, and K. P. Young, *Semi-solid processing of alloys*. Springer, 2010.

[22] Z. Fan, "Semisolid metal processing," *International materials reviews,* vol. 47, no. 2, pp. 49-85, 2002.

[23] P. Falak and B. Niroumand, "Rheocasting of an Al–Si alloy," *Scripta Materialia,* vol. 53, no. 1, pp. 53-57, 2005/07/01/ 2005.

[24] B. Niroumand and K. Xia, "3D study of the structure of primary crystals in a rheocast Al–Cu alloy," *Materials Science and Engineering: A,* vol. 283, no. 1, pp. 70-75, 2000/05/15/ 2000.

[25] C. D. Yim and K. S. Shin, "Changes in microstructure and hardness of rheocast AZ91HP magnesium alloy with stirring conditions," *Materials Science and Engineering: A,* vol. 395, no. 1, pp. 226-232, 2005/03/25/ 2005.

[26] L. BoChao, P. YoungKoo, and D. HongSheng, "Effects of rheocasting and heat treatment on microstructure and mechanical properties of A356 alloy," *Materials Science and Engineering: A,* vol. 528, no. 3, pp. 986-995, 2011/01/25/ 2011.

[27] J. W. Bae, S. M. Lee, and C. G. Kang, "Forging Process of Wrought Aluminum Alloy with Controlled Solid Fraction by Electromagnetic Stirring," *Solid State Phenomena,* vol. 141-143, pp. 277-282, 2008.

[28] I. Polmear, *Light alloys: from traditional alloys to nanocrystals*. Elsevier, 2005.

[29] I. Polmear, D. StJohn, J.-F. Nie, and M. Qian, *Light alloys: metallurgy of the light metals.* Butterworth-Heinemann, 2017.

[30] U. Curle, "Semi-solid near-net shape rheocasting of heat treatable wrought aluminum alloys," *Transactions of Nonferrous Metals Society of China,* vol. 20, no. 9, pp. 1719-1724, 2010.

[31] S. Tahamtan, A. F. Boostani, and H. Nazemi, "Mechanical properties and fracture behavior of thixoformed, rheocast and gravity-cast A356 alloy," *Journal of Alloys and Compounds,* vol. 468, no. 1, pp. 107-114, 2009/01/22/ 2009.

AUTHORS' INFORMATION

[1]Department of Mechanical Engineering, State Polytechnic of Ujung Pandang
[2,3,4]Department of Mechanical Engineering, Hasanuddin University
Email: [1]syaharuddinrasyid@poliupg.ac.id, [2]ilyas.renreng@gmail.com, [3]arsyadhairul@yahoo.com, [4]syahid.arsjad@gmail.com

Syaharuddin Rasyid was born in Sungguminasa on January 5th. Completed his Bachelor's degree in 1994 at the Department of Mechanical Engineering, Hasanuddin University, Makassar, Indonesia. Masters Education (Mechanical Construction) at Hasanuddin University Postgraduate Program in Mechanical Engineering in 2004. Doctoral education (Materials And Metallurgy) at Hasanuddin University Mechanical Engineering Doctoral Study Program in 2019. Currently he is conducting research on the characteristics of aluminum alloys with semi-solid casting techniques and engineering design of appropriate technology. Previous research on the characteristics of steel materials with heat treatment techniques.

Ilyas Renreng, an Indonesian professor in the Hasanuddin university's Mechanical Engineering department, was born in Makassar on September 14, 1957. He holds a PhD degree from Indonesia's Brawijaya University in Malang. His research focuses on the production of materials.

Hairul Arsyad, an associate professor in the mechanical engineering department of Hasanuddin University in Indonesia, was born in Makassar on March 22, 1975. He graduated from Brawijaya College in Malang, Indonesia, with a doctorate. His research encompasses the production of materials.

Muhammad Syahid, who was born in Makassar on July 7, 1977, is an associate professor at Hasanuddin University in Indonesia's Mechanical Engineering department. He holds a doctorate from the Indonesian University in Jakarta, Indonesia. He focuses on materials in his study.

The Impact of Stirring Model on Aluminum Alloys ADC12's Microstructure and Mechanical Properties

ORIGINALITY REPORT

22%	16%	16%	8%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to International Islamic University Malaysia Student Paper	5%
2	www.arpnjournals.org Internet Source	4%
3	Syaharuddin Rasyid, Effendy Arif, Hairul Arsyad, Muhammad Syahid. "Effects of stirring parameters on the rheocast microstructure and mechanical properties of aluminum alloy ADC12", MATEC Web of Conferences, 2018 Publication	3%
4	www.researchgate.net Internet Source	2%
5	M. Reisi, B. Niroumand. "Effects of stirring parameters on rheocast structure of Al–7.1wt.%Si alloy", Journal of Alloys and Compounds, 2009 Publication	1%

6	S Rasyid, I Renreng, H Arsyad, M Syahid. "Optimization of Pouring Temperatures and Stirrer Speed Parameters on a Semi-Solid Slurry of ADC12 Al Alloy Prepared by Mechanical Stirring", IOP Conference Series: Materials Science and Engineering, 2019 Publication	1 %
7	Syaharuddin Rasyid, Ilyas Renreng, Effendy Arif, Hairul Arsyad, Muhammad Syahid. "Optimization of stirring parameters on the rheocast microstructure and mechanical properties of aluminum alloy ADC12", IOP Conference Series: Materials Science and Engineering, 2019 Publication	1 %
8	Takuya Yamamoto, Aire Suzuki, Sergey V. Komarov, Yasuo Ishiwata. "Investigation of impeller design and flow structures in mechanical stirring of molten aluminum", Journal of Materials Processing Technology, 2018 Publication	1 %
9	"High Performance Structural Materials", Springer Nature, 2018 Publication	<1 %
10	C.D. Yim, K.S. Shin. "Changes in microstructure and hardness of rheocast AZ91HP magnesium alloy with stirring	<1 %

	conditions", Materials Science and Engineering: A, 2005 Publication	
11	link.springer.com Internet Source	<1 %
12	orbi.uliege.be Internet Source	<1 %
13	"Light Metals 2014", Springer Science and Business Media LLC, 2016 Publication	<1 %
14	Submitted to Universiti Teknologi Malaysia Student Paper	<1 %
15	www.mdpi.com Internet Source	<1 %
16	Amir Bolouri, Chung-Gil Kang. "Thixoforging of Wrought Aluminum Thin Plates with Microchannels", Metallurgical and Materials Transactions A, 2014 Publication	<1 %
17	snp2m.poliupg.ac.id Internet Source	<1 %
18	Zhao-hua HU, Xiang PENG, Guo-hua WU, Da-qiang CHENG, Wen-cai LIU, Liang ZHANG, Wen-jiang DING. "Microstructure evolution and mechanical properties of rheo-processed	<1 %

	ADC12 alloy", Transactions of Nonferrous Metals Society of China, 2016 Publication	
19	1library.net Internet Source	<1 %
20	www.arpnjournals.com Internet Source	<1 %
21	Chauke, Levy, Hein MÃ¶ller, Ulyate Andries Curle, and Gonasagren Govender. "Industrial Heat Treatment of R-HPDC A356 Automotive Brake Callipers", Solid State Phenomena, 2012. Publication	<1 %
22	K. Yamamoto, M. Takahashi, Y. Kamikubo, Y. Sugiura, S. Iwasawa, T. Nakata, S. Kamado. "Effect of Mg content on age-hardening response, tensile properties, and microstructures of a T5-treated thixo-cast hypoeutectic Al–Si alloy", Materials Science and Engineering: A, 2020 Publication	<1 %
23	constellation.uqac.ca Internet Source	<1 %
24	doczz.cz Internet Source	<1 %
25	downloads.hindawi.com Internet Source	<1 %

26	shellbuckling.com Internet Source	<1 %

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		