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Applied Sciences for Sustainable Earth,
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Makassar, Indonesia • 18–19 November 2023

Editors • Vilia Darma Paramita, Abdul Kadir Muhammad,
Naksit Panyoyai and Ahmad Sabirin Bin Zoolfakar



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Vilia Darma Paramita

Abdul Kadir Muhammad

Ujung Pandang State Polytechnic, Makassar, Indonesia

Naksit Panyoyai

Chiang Mai Rajabhat University, Chiang Mai, Thailand

Ahmad Sabirin Bin Zoofakar

MARA University of Technology, Selangor, Malaysia

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Editors

Vilia Darma Paramita

Ujung Pandang State Polytechnic
Chemical Engineering
Perintis Kemerdekaan Km.10, Tamalanrea
Makassar, 90245
Indonesia

Email: viliadarma@poliupg.ac.id

Abdul Kadir Muhammad

Ujung Pandang State Polytechnic
Center for Research and Community Service
Perintis Kemerdekaan Km.10, Tamalanrea
Makassar, 90245
Indonesia

Email: kadir.muhammad@poliupg.ac.id

Naksit Panyoyai

Chiang Mai Rajabhat University
Agricultural Technology
202 Changpuak Rd, Tambon Chang Phueak, Mae-Rim District
Chiang Mai, 50330
Thailand

Email: naksit_pan@cmru.ac.th

Ahmad Sabirin Bin Zoofakar

MARA University of Technology
Electrical Engineering
Jalan Ilmu 1/1
Selangor, 40450
Malaysia

Email: ahmad074@uitm.edu.my

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RESEARCH ARTICLE | JULY 10 2024

Characterization of Al-Si aluminum alloy stir casting results with the addition of Mg and SiC elements


Nur Wahyuni ; Muhammad Arsyad; Yan Kondo


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
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Characterization of Al-Si Aluminum Alloy Stir Casting Results with the Addition of Mg and SiC Elements

Nur Wahyuni^{1, 2, a)}, Muhammad Arsyad^{1, 2)}, and Yan Kondo^{1, 2)}

¹ Department of Mechanical Engineering, Politeknik Negeri Ujung Pandang, Makassar 90245, Indonesia

² Center for Material And Manufacturing, Department Of Mechanical Engineering, Politeknik Negeri Ujung Pandang, Makassar 90245, Indonesia.

^{a)} Corresponding author: nurwahyuni@poliupg.ac.id

Abstract. This research represents an advancement of the preceding study, specifically examining the Impact of SiC Addition on Resistance, Wear, and Hardness through Stir Casting of Aluminum Matrix Composites. Within this investigation, the identical casting technique, the Stir Casting Method, was employed, with a focus on Al-Si aluminum alloy incorporating SiC and Mg reinforcement. The composition of the raw materials mixture (Al-Si aluminum alloy) was 60%, while the adhesive materials mixture comprised 40%, consisting of 20% SiC and 20% Mg. The pour temperature utilized in melting the raw and adhesive materials in furnaces was set at 600°C and 700°C. Subsequently, the molten specimen samples were poured into mold patterns and further processed for hardness and impact tests. Impact test results were obtained for specimen samples with a 60% Al-Si alloy, combined with a mixture of 20% SiC and 20% Mg adhesives at a cast temperature of 600°C, yielding an Impact Energy of 68.60 J and Impact Strength of 0.85 J/m. Meanwhile, specimen samples at a cast temperature of 700°C exhibited an Impact Energy of -95.40 J and Impact Strength of -1.19 J. Hardness test results for specimen samples of the 60% Al-Si alloy, combined with a mixture of 20% SiC and 20% Mg adhesives at a cast temperature of 600°C, showed an average hardness of 65 kgf/mm. On the other hand, specimen samples at a cast temperature of 700°C displayed an average hardness of 50 kgf/mm.

INTRODUCTION

This study aims to determine the characterization of the hardness and impact strength of Al-Si aluminum alloy plus SiC and Mg reinforcement using the Stir Casting casting method, namely 60% Al-Si aluminum alloy and 40% adhesive mixture, respectively 20% SiC and 20% Mg with cast temperatures (pour temperature) in furnaces are 600°C and 700°C.

The use of SiC, Mg, and a combination of the two as adhesive mixtures in various casting methods from several previous studies showed results that had a positive impact on its mechanical properties. The addition of SiC to a certain degree is proven to improve mechanical properties while the toughness of composite fractures will be reduced with the addition of SiC [1].

The aluminum alloy treatment process can significantly improve environmental performance in terms of manufacturing systems [2]. The casting process with Stir Casting can reduce porosity. Porosity will increase with increasing mass amount of weight SiC [3]. The implementation of Stir Casting casting on hybrid composites results in better properties that can be optimized and can be implemented in industry for large-scale applications [4].

Research conducted by Hammada [5] showed that the results of orthotropic metal strength plus SiC reinforcement were obtained very well at a 15% SiC composition of 59.333 N and an impact strength value of 344802.86 Joules / M. Similarly, previous on the addition of SiC to aluminum matrix composites (AMC) showed an increase in the highest matrix hardness value at a pour temperature of 738 ° C, which is 596.89 HBW 10/3000/15 [6].

Pavitra et al [7] showed the addition of SiC reinforcement in the aluminum matrix increases the hardness and tensile strength of the ultimate gradually. The improvement in mechanical properties was found to be directly proportional to the weight % of SiC particles added. The best results have been obtained for composites reinforced with 15% SiC particle weight fraction, the maximum hardness achieved is 47HV &; the maximum highest tensile strength is 130 MPa.

Syamsul Hadi [8] showed that the addition of 0.5% Mg can increase the tensile strength of brake linings and drum castings due to the formation of Mg₂Si deposits, which can cover the empty space in the alloy structure, causing the structure to become tighter and more homogeneous, but has decreased with an increase of 1% Mg.

Yushi Chen [9] showed that a rise in mold temperature contributes to an increase in particle size and alloy density and a decrease in dislocation density. Rapid coarsening and then normal growth of particles during solution treatment are observed, and a long rod-like Zn₂Zr₃ phase occurs.

Ning Fang [10] showed to develop aluminum-silicon based alloys with improved performance by introducing high pressure. Al-7Si-3Cu-0.4 Mg alloy made under 5 GPa shows the highest compressive strength of 863.6 MPa and microhardness of 214.3 HV after aging.

Therefore, this study aimed to determine the characterization of the hardness and impact strength of Al-Si aluminium alloy plus SiC and Mg reinforcement using the Stir Casting casting method, namely 60% Al-Si aluminium alloy and 40% adhesive mixture, respectively 20% SiC and 20% Mg with cast temperatures (pour temperature) in furnaces were 600°C and 700°C.

RESEARCH METHODS

The stages in this research are described in the flowchart as follows:

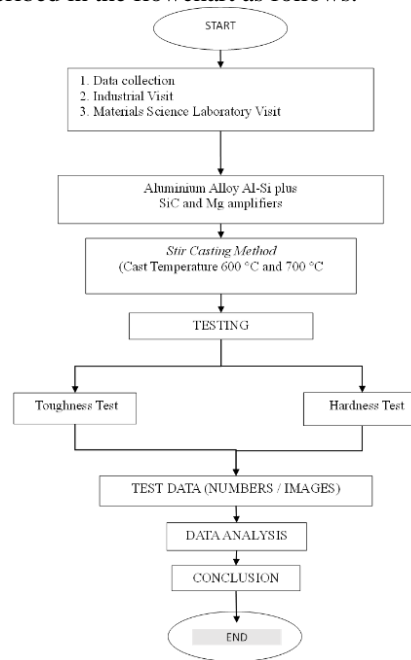


FIGURE 1. Flow Chart Research

Stir Casting

Stir casting is like a casting process by adding a pure metal (usually Al) with a composite, by melting the pure metal, then the melted pure metal is stirred continuously until it forms a vortex, then the composite (in the form of powder) is mixed little by little through the edge of the vortex that has been formed.

Impact Testing (Toughness Test)

In the testing procedure, the specimen was initially positioned horizontally, and both ends were carefully supported on an anvil. The notch was precisely located in the middle, oriented with the direction of impact from behind the notch. Subsequently, the amount of impact energy in joules could be observed directly from the scale of the testing

machine. These sequential steps ensured a systematic and controlled approach to assessing the specimen's response to impact forces during testing.

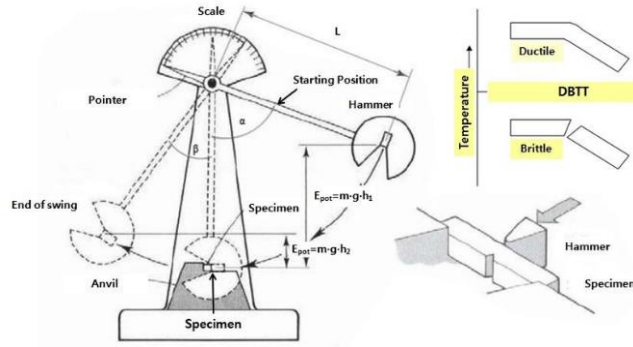


FIGURE 2. Impact Testing

Hardness Test

In the testing procedure, the following steps were undertaken: First, the specimen surface was meticulously cleaned and sanded until it was flat and smooth, ensuring it could be adequately rested with the test surface in a horizontal position. Subsequently, the Rocwell hardness tester was calibrated to ensure accurate measurements. The hardness test itself involved pressing the indenter onto the specimen surface for a duration of 10-30 seconds. These steps were meticulously followed to maintain precision and reliability in the hardness testing process.

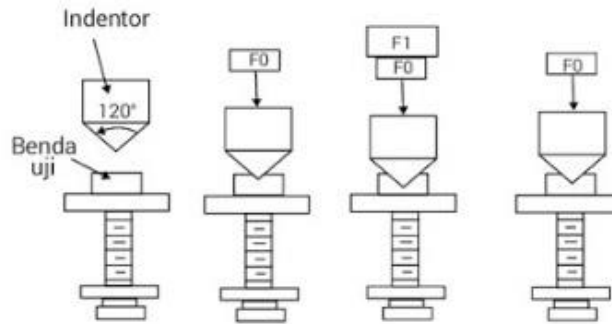


FIGURE 3. Hardness Testing

RESULTS AND DISCUSSION

The data presented in Table 1 illustrates the results of the stress test. ΔE (Impact Energy) is derived through the calculation of the reduction in the final angle cosine from the initial angle cosine, multiplied by the product of the pendulum weight and the cross-sectional area. I_s (Impact Strength) is determined by dividing ΔE (Impact Energy) by A_n (Cross-sectional area).

TABLE 1. The stress test result data.

Pour Temperature	A_n (mm ²)	Stress test results			
		α (°)	β (°)	ΔE (J)	I_s (J/m)
600°C	70	110	80	68.60	0.85
700°C	80	125	90	-95.40	-1.19

The data from Table 1 indicates that, under a cast temperature of 600°C, the Al-Si aluminum alloy specimen samples with 60% composition and a 40% adhesive mixture (comprising 20% SiC and 20% Mg) exhibit an impact energy (ΔE) of 68.60 J. This value is obtained by employing the formula $\Delta E = W l (\cos \beta - \cos \alpha)$, with specified pendulum weight (W) and pendulum arm (l), effective cross-sectional area (A_n) of 70 mm², an initial angle (α) of 110°, and a final angle (β) of 80°. The resulting Impact Force (IS) is 0.85 J/m, calculated using the formula: $Is = \Delta E/A$.

Similarly, at a cast temperature of 700°C, the Al-Si aluminum alloy specimen samples with 60% composition and a 40% adhesive mixture (comprising 20% SiC and 20% Mg) show an impact energy (ΔE) of -95.40 J. This is determined using the formula $\Delta E = W l (\cos \beta - \cos \alpha)$, with the same set pendulum weight (W) and pendulum arm (l), an effective cross-sectional area (A_n) of 80 mm², an initial angle (α) of 125°, and a final angle (β) of 90°. The corresponding Impact Force (IS) is -1.19 J/m, calculated by the formula: $Is = \Delta E/A$.

This indicates that the incorporation of SiC and Mg reinforcement components, coupled with a substantial proportion of the mixture, has a significant influence on the levels of impact energy and impact strength. The use of higher cast temperatures (pour temperatures) leads to a decrease in impact strength and impact energy. Table 1 illustrates that specimen samples at a cast temperature of 600°C exhibit higher impact energy and impact strength in comparison to those at 700°C.

This observation aligns with the findings of research conducted by Sijo et al [9], which asserts that the addition of adhesive elements, particularly SiC to a certain extent, is validated for enhancing mechanical properties, albeit at the cost of reduced toughness in composite fractures. A similar trend was corroborated by Nur Wahyuni et al. [6], who reported an augmentation in the highest matrix hardness value with the addition of SiC to aluminum matrix composites (AMC) at a pour temperature of 738 °C. Mechanical properties, however, were observed to decline above the temperature threshold of 738 °C.

TABLE 2. The hardness test result data.

Pour Temperature	Part		
	1 kgf/mm	2 kgf/mm	3 kgf/mm
600°C	65	65	65
700°C	50	50	50

Based on Table 2 provided above reveals a more uniform distribution of hardness across each section of the specimen. Specifically, at a cast temperature of 600°C, the Al-Si aluminum alloy specimen samples with 60% composition and a 40% adhesive mixture (comprising 20% SiC and 20% Mg) exhibit an average uniform hardness of 65 kgf/mm. This is notably higher compared to the specimen samples at a cast temperature of 700°C, where the average uniform hardness is recorded as 50 kgf/mm.

CONCLUSIONS

1. Impact Strength of specimens made from Al-Si alloy with a mixture composition of SiC 20% and Mg 20% at a pour temperature of 600°C, obtained 68,60 J of Impact Energy and 0,85 J/m of Impact Force. Impact Strength of specimens made from Al-Si alloy with a mixture composition of SiC 20% and Mg 20% at a pour temperature of 700°C, obtained -95,40 J of Impact Energy and -1,19 J/m of Impact Force.
2. Average Hardness Value of specimens made from Al-Si alloy with a mixture composition of 20% SiC and 20% Mg at a pour temperature of 600°C, obtained 65 kgf/mm and Hardness of specimens made from Al-Si alloy with a mixture composition of SiC 20% and Mg 20% at a pour temperature of 700°C, obtained 50 kgf/mm.

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