

**INVESTIGAÇÃO TÉCNICA DO REFORÇO DE AREIA DO MAR PARA NOVOS
COMPÓSITOS AL6061-AREIA DO MAR: IDENTIFICAÇÃO DE DESEMPENHO E
PROPRIEDADES MECÂNICAS****TECHNICAL INVESTIGATION OF SEA SAND REINFORCEMENT FOR NOVEL AL6061-
SEA SAND COMPOSITES: IDENTIFICATION OF PERFORMANCE AND MECHANICAL
PROPERTIES**Akbar, Hammar Ilham¹; Surojo, Eko^{2*}; Ariawan, Dody³; Prabowo, Aditya Rio⁴^{1,2,3,4} Department of Mechanical Engineering, Universitas Sebelas Maret, Surakarta, Indonesia

* Corresponding author
e-mail: esurojo@ft.uns.ac.id

Received 12 June 2020; received in revised form 10 August 2020; accepted 01 September 2020

RESUMO

Materiais leves com baixo custo de produção foram desenvolvidos nos últimos anos. A adição de cerâmicas e partículas de óxidos como Al₂O₃, SiC e SiO₂ tem melhorado as propriedades mecânicas dos compósitos com matriz de alumínio (AMCs). Como solução, o uso de material de reforço natural continua a ser investigado. Este artigo investiga a areia do mar como um reforço alternativo aos AMCs. O Al 6061 foi usado como matriz e areia do mar como reforço. A fabricação do compósito foi realizada por rota de fundição sob agitação com variação de 0, 2, 4, 6% em peso da armadura. O compósito foi testado quanto à dureza e resistência à tração, o teste de dureza foi obtido de acordo com ASTM E-10, e o teste de tração foi conduzido de acordo com a norma JIS Z2201. A densidade do composto diminui linearmente com a adição do reforço de 2% em peso a 6% em peso, e o mesmo fenômeno é obtido na porosidade, a porosidade aumenta com a adição de partículas de areia do mar de 2% em peso a 6% em peso. O declínio na densidade devido à menor densidade das partículas de areia do mar em comparação com a matriz de alumínio. Quanto maior a partícula de areia do mar que se dispersa na matriz, menor a densidade do composto. O aumento da porosidade causou uma maior fração de reforço resultando em maior contato superficial entre a matriz e o reforço que promovem a porosidade. A dureza e a resistência à tração final dos AMCs aumentam com o aumento do conteúdo de partículas de areia do mar. A presença de um composto de óxido na areia do mar aumentou as propriedades mecânicas do composto. O aumento nas propriedades mecânicas indica que a partícula de areia do mar dispersa na matriz e a areia do mar podem ser usadas como material para fins de engenharia.

Palavras-chave: *alumínio, compósito, areia do mar, resistência a tração, dureza.***ABSTRACT**

Lightweight materials with low-cost production have been developed in recent years. The addition of ceramics and oxide particles such as Al₂O₃, SiC, and SiO₂ has been improving in the mechanical properties of aluminum matrix composites (AMCs). As a solution, the use of natural reinforcing material continues to investigate. This paper investigates sea sand as an alternative reinforcement to AMCs. The Al 6061 was used as the matrix and sea sand as reinforcement. The manufacturing of the composite was conducted by stir casting route with variation 0, 2, 4, 6 %wt of the reinforcement. The composite was tested in hardness and tensile strength, the hardness test was obtained according to ASTM E-10, and the tensile test was conducted according to JIS Z2201 standard. Composite density decreases linearly with the addition of the reinforcement from 2 %wt to 6%wt, and the same phenomenon is obtained in porosity, the porosity increases with the addition of sea sand particles from 2%wt to 6%wt. The decline in density due to the lower density of sea sand particles compared to the aluminum matrix. Higher the sea sand particle that disperses into the matrix resulted in a lower density of the composite. Increasing porosity caused a higher fraction of reinforcement resulting in wider surface contact between matrix and reinforcement that promote the porosity. The hardness and ultimate tensile strength of AMCs increase with increasing of sea sand particles content. The presence of an oxide compound on the sea sand increased the mechanical properties of the composite. Increasing in mechanical properties indicate the sea sand particle dispersed into the matrix and sea sand can be used as engineering purpose material.

Keywords: *aluminum, composite, sea sand, tensile strength, hardness.*

1. INTRODUCTION:

The industrial demand for reliable, lightweight, and eco-friendly materials has increased in recent years. This is related to the massive, environmentally friendly campaign (Akbar *et al.*, 2018; Zheng *et al.*, 2018; Radhika *et al.*, 2015). One of the materials that have the qualifications and continuously developed is aluminum matrix composites (AMC). AMC is a combination of several materials, with aluminum matrix and reinforcing materials, which are ceramic compounds, and its mechanical properties can be achieved with specific compositions (Nagaral *et al.*, 2017). The popular matrix used in AMC is Al 6061. In the commercial, Al 6061 is an aluminum alloy that can be improved in mechanical properties after heat treatment (Giofré *et al.*, 2017). The Al 6061 is commonly chosen as construction, automotive, aerospace, and marine application due to their characteristics such as intermediate strength, good corrosion resistance, and can be improved in mechanical properties (Gireesh *et al.*, 2018).

In the AMC manufacturing, ceramic particles such as Al₂O₃, SiO₂, SiC, TiO₂, and graphite are used as reinforcements (Bisane *et al.*, 2015). The addition of ceramic particles improved the mechanical properties of the composite (Bharat *et al.*, 2014). On the other hand, manufacturing AMC with ceramic material as reinforcement in AMC limits its application due to expensive production costs (Tiwari and Pradhan, 2017). As a solution, researchers innovate to utilizing organic and eco-friendly materials to reduce production costs (Patel *et al.*, 2017; Reddy and Srinivas, 2018). One of the potential materials that contain ceramic compounds, as mentioned, is sea sand.

As the owner of 5.9 million km² sea area and 95,161 km coastline, which is the second-longest in the world (Lasabuda, 2013), Indonesia has abundant natural resources of sea sand. Oxide minerals such as SiO₂, Al₂O₃, ZnO, MgO, and TiO₂, which are found on the south coast of Java and Aceh province, allowed the sea sand as one of the high-tech materials (Alimi *et al.*, 2016; Jalil *et al.*, 2017). Utilizing sea sand particles as reinforcement in aluminum composite materials has not been investigated. Generally, sea sand is used as a substitute for aggregate in concrete. Previous research shows that concrete with sea sand combined with fiber-reinforced polymer (FRP) has been studied by Dong *et al.* (2019). The results state that the presence of sea sand

as an aggregate in concrete results the concrete is improving strength, but tend to be a brittle fracture.

Manufacturing aluminum matrix composites with stir casting is a common process. This method is the easiest and has a significant production capability. Behind its simplicity, the stir casting also has deficiencies in particle distribution or homogeneity. Homogeneity of aluminum matrix composites is strongly influenced by several factors, including a fraction of reinforcing particles, stirring speed, and particle treatment. The fraction of particles affects the mechanical properties of aluminum matrix composites. The addition of bamboo leaf ash to aluminum matrix composite has a positive effect. The mechanical properties of the composites increase with the addition bamboo leaf ash from 0 to 4% wt, then decrease when bamboo leaf ash content increase to 6% wt (Dhanesh *et al.*, 2020). The mechanical properties of the Al₂O₃/3Y-TZP composite increase with the increasing content of micro-alumina. The Vickers hardness dropped from 12.6 GPa to 8.9 GPa with the particle addition from 20 vol% to 50 vol%. The flexural strength increases significantly from 547.1 MPa at 0 vol% to 633.3 MPa at 20 vol% (Zhang *et al.*, 2015).

Previous research shows the addition of ceramic and oxide particles such as SiC (Hall *et al.*, 1994), red mud particle (Chinta *et al.*, 2018) resulted in increasing the mechanical strength of aluminum matrix composites. This study aims to determine the addition of sea sand particles as an aluminum matrix composite reinforcement to its mechanical properties.

1.2. Literature review

The manufacturing of AMC with alternative reinforcement has been investigated before. Reinforcement from various industrial, agricultural, and natural material wastes such as fly ash, red mud, rice husk ash, and sugar bagasse ash has been studied and improved the mechanical properties of AMC. Except to improve the mechanical properties of AMC, this innovation also has an impact on reducing production costs and increasing the value of raw materials into materials for engineering purposes (Patel *et al.*, 2017).

Hybrid composite rice husk-SiC-Al 6061 has been successfully produced (Sarkar *et al.*, 2018). Hybrid composites have porosity less than 2.86%. The composite hardness decreases with

an increasing quantity of rice husk ash. The tensile strength of hybrid composites is lower than Al composites with SiC. However, the tensile strength of hybrid composites at 110 MPa remains higher than the matrix. Investigation of mechanical properties and tribology of Al-SiC-Rice Husk Ash (RHA) hybrid composites with powder metallurgy fabrication showed excellent results (Shaikh *et al.*, 2019). Hybrid composites have a lower density of up to 9% when reinforcement is increased, and porosity increases from 3.7% in pure Al to 11% in Al-10%wt SiC-15%wt RHA. Composite hardness increased to 19% with the best SiC and RHA compositions of 10%wt, respectively. Al-10%wt SiC-10%wt RHA showed better wear resistance with a 33% increase compared to pure Al.

The addition of bagasse ash to Al 5056/SiC hybrid composites decreases the wear rate of the composites. The wear rate falls with increasing Si, which effectively blocks the movement of dislocation (Harish *et al.*, 2019). Another natural material used as reinforcement in AMCs is coconut shell ash (CSA). Studies of the effect of adding CSA to Al 6082/CSA/ZrO₂ hybrid composite has been investigated (Kumar *et al.*, 2018). Composite hardness decrease when 10 %wt CSA is added, the highest hardness and tensile strength is achieved in the composition of 8%wt ZrO₂ reinforcement and 2 %wt CSA. The decrease in composite hardness is due to the lubrication properties of CSA particles. The highest flexural strength is achieved at 2 %wt ZrO₂ and 8%wt CSA. The hardness and tensile strength of Al6061/CSA/SiC composite increased up to the addition of 8%wt CSA and compressive strength increased until the addition of CSA 6% wt. Friction resistance is increased when CSA particles are added to Al6061-SiC composites (Satheesh and Pugazhivadivu, 2019).

In addition to materials from industrial and agricultural waste, other natural based materials that have the potential to be used as reinforcement in AMC is sea sand. Sea sand has been investigated for its effect on the strength of concrete. The use of sea sand as an aggregate in concrete increases its strength (Xiao *et al.*, 2017; Zhang *et al.*, 2019). Chemical analysis shows that sea sand contains compounds such as Fe₂O₃, SiO₂, Al₂O₃, and MgO (Carranza-Edwards *et al.*, 2009) that can improve the mechanical properties of AMC.

Increasing reinforcing volume fraction increased the strength but decreased the plasticity of the composite (Raj and Thakur, 2019; Razzaq *et al.*, 2017; Song, 2009; Viswanaatha *et al.*, 2013). Figure 1 shows the comparison of the volume fraction of reinforcing particles on aluminum composites. Higher ceramic particles added increased the agglomeration in the matrix (Das *et al.*, 2014). The agglomeration caused composite porosity (Podymova and Karabutov, 2017). Agglomeration of 14 %vol SiC nanoparticles in aluminum composites is shown in Figure 2. The Figure 3 shows the surface fracture of a SiC/Al composite with various SiC volume fractions. Observation of the fracture shows the characteristics of ductile fractures with the presence of dimple on the surface fracture of the specimen (Song, 2009).

The effect of the weight fraction of ash in the aluminum hybrid composite linearly increased with the addition of ash. The maximum tensile strength, impact strength, and compressive strength are achieved on the addition of 6% wt ash. The maximum hardness of the hybrid composite is found in the addition of 4% wt of ash (Vijaybabu *et al.*, 2019). The study of mechanical characterization of aluminum E-waste composite has resulted in the tensile, yield, and compressive strength increases by addition fly ash with a constant amount of e-glass fiber. The toughness of the composite is decreased with an increasing fraction of the fly ash ((Patel *et al.*, 2017).

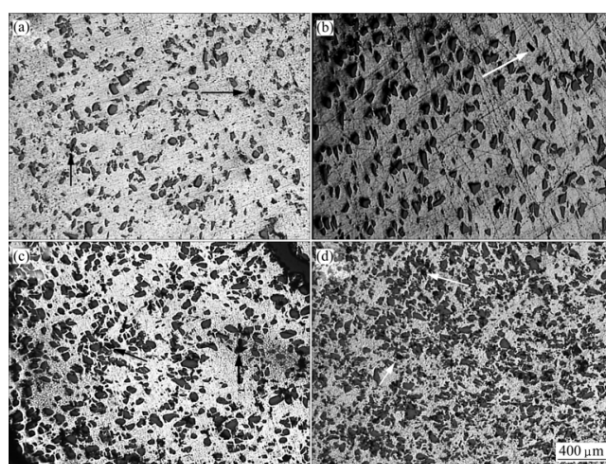


Figure 1. Optical observation of SiC various fractions in SiC/Al composite: (a) 8%vol (b) 12%vol (c) 16%vol (d) 20%vol (Song, 2009)

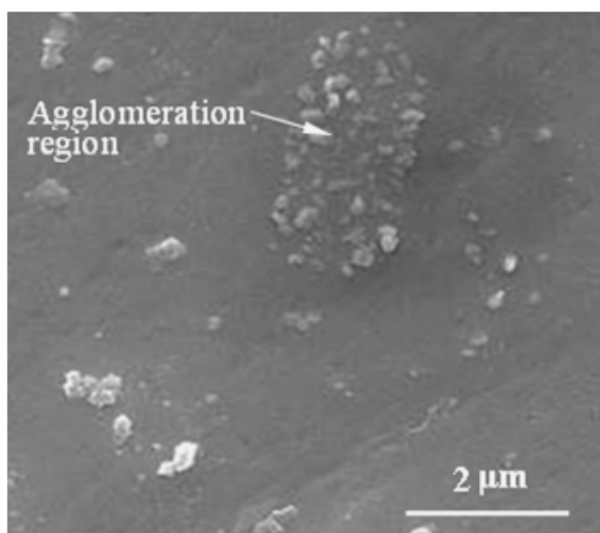


Figure 2. The agglomeration of 14%vol nanoparticles in Al composite (Xiong *et al.*, 2011)

Effect of various alumina nanofibre content on the alumina toughened zirconia composite resulted in increasing microhardness by 14% at the addition of 5% wt the alumina nanofibre, and the highest fracture toughness is reached at the addition of 1% wt of alumina fiber (Leonov, 2019). Addition ZrB₂ particle increasing mechanical properties of AA6063-ZrB₂ composite. Maximum tensile strength is achieved in addition to 10% wt of reinforcement. The hardness of the composite is increased from 52 HV to 63 HV with the addition ZrB₂ particle from 0 to 10% wt (Mohanavel *et al.*, 2018).

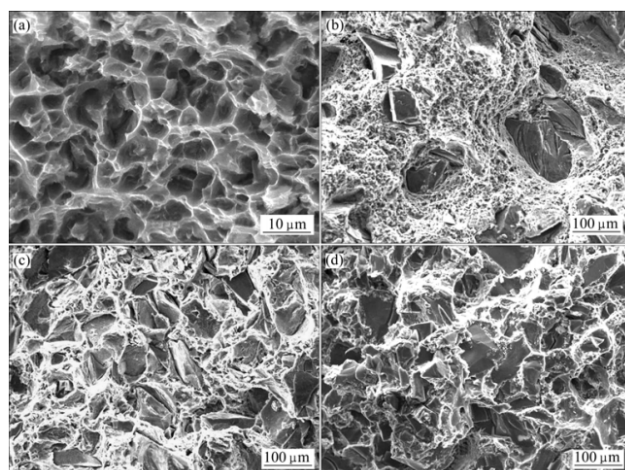


Figure 3. SEM observation of various SiC volume fractions in SiC/Al composite: (a) 8% (b) 12% (c) 16% (d) 20% (Song, 2009)

Addition of silicon nitride from 2% wt to 10% wt with 2% wt increasing on the aluminum

metal matrix composite affected increasing in hardness and ultimate tensile strength of composite with an addition 8% wt reinforcement. The composite hardness increases from 44.8 to 54.4 BHN, and the tensile strength increases from 127.1 to 178.5 MPa (Rao and Mohan, 2020). The optimum of SiO₂ addition on the aluminum composite was achieved in 20% wt. In addition, 20% of wt has an optimum intersection between hardness and ductility curve of the composite (Pattnayak *et al.*, 2018). Increasing the content of TiC ceramic particle resulted in an increase in hardness. The hardness escalated with increasing from 0% wt to 12% wt of TiC particle (Sharma *et al.*, 2020)

On the manufacturing of aluminum matrix composite, stir casting is the simplest and most effective method. On the other hand, the stir casting method has limitations, such as (1) Dispersed reinforcement is limited (usually is under 30% vol). (2) The distribution of reinforcement is not perfectly homogeneous. (3) Forming a local cluster of reinforcement (agglomeration) (Thomas *et al.*, 2014). In the stir casting, the high shear force is needed to dispersed reinforcement into the matrix, but the vortex that resulted from stirring process can increase the porosity and decreasing properties of the composite (Zhang *et al.*, 2019)

One limitation of in the aluminum matrix composite manufacturing is wettability. Wettability in aluminum matrix composite plays a crucial role in the final properties of the composite. Wettability can be defined as the ability of a molten metal to disperse on the solid surface, which represents a contact angle between the liquid and solid (Hashim *et al.*, 2001). The wetting behavior is affected by many factors, the thermodynamics characteristics, atmosphere, roughness of the reinforcement, crystallography, impurities, surface oxidation, and oxide film (Sangghaleh and Halali, 2009). Wettability can be improved with several approaches (Hashim *et al.*, 2001):

1. Addition of alloying elements
2. Coating of the reinforcement
3. Treatment on the reinforcement

The addition of alloying elements is the simplest method for improving wettability. The common is the addition of magnesium. Magnesium can be improved the wettability because magnesium has lower surface tension compared to aluminum, and magnesium can reduce the interfacial energy and forming new compounds on the interface of the reinforcement

(Hashim *et al.*, 2001). Effect of addition Mg on the wettability of SiC-Al showed that contact angel between Al and SiC decreases with increasing process temperature. The process temperature from no-wetting to wetting is decreased with the increasing content of Mg (Liu and Lin, 2017). However increasing of Mg addition more than 1% wt on the molten aluminum resulted in increasing viscosity of molten metal and more difficult to achieved a homogeneous distribution of particles (Bihari and Singh, 2017)

2. MATERIALS AND METHODS

Al 6061 was used as a matrix in the manufacture of Al 6061-sea sand composites. Sea sand particles were obtained from Samas beach, Yogyakarta, Indonesia. Before processed, the sea sand particle washed with alcohol to obtain impurities free on sea sand particles. After that, the sea sand was crushed to get a 200 mesh size using a ball milling process. The result of the ball milling process on sea sand has shown in Figure 4.

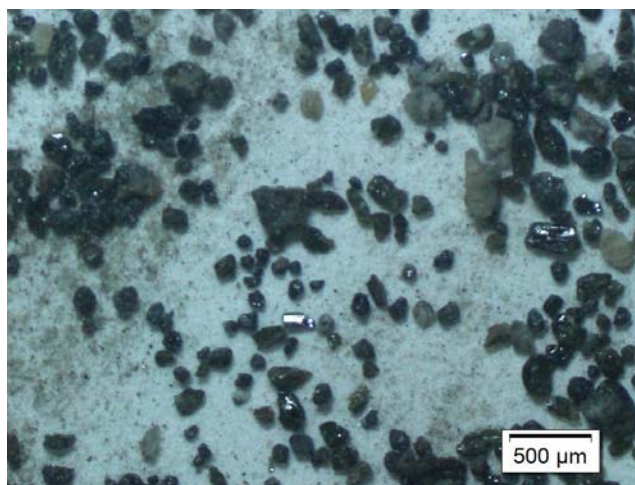


Figure 4. Sea sand particles after ball mill.

Stir casting technique has been used for composite manufacturing. The calculated Al 6061 was heated in the furnace, and the temperature was controlled at 800 °C with accuracy $\pm 25^\circ\text{C}$. Vortex flow was generated with a 45° four-blade impeller, which had been coated with 200 μm TiO₂ ceramics. The dimension of the impeller, as shown in Figure 5. The stirring condition was set at 720-750°C for 5 minutes and of 400 rpm. After first stirring, the 1 %wt of Mg was added as a wetting agent into the mixture, then continued stirring for 5 minutes. The composite mixture was poured into 130 x 130 x 60 mm permanent mold that has been heated at 700 °C, with pouring

temperature has controlled at 750 °C. The stir casting equipment is shown in Figure 6.

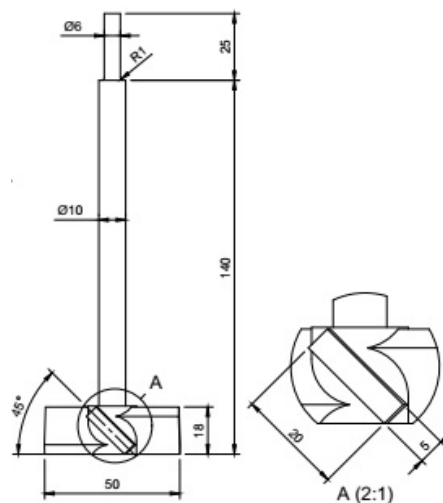


Figure 5. Impellers dimension.

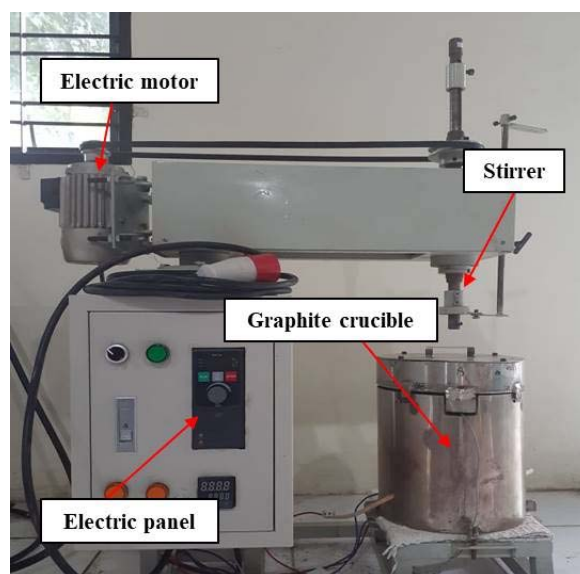


Figure 6. Stir casting equipment.

The prepared composite was mechanical and physical characterization by density, hardness, and tensile tests. The density and porosity were calculated by Archimedes's method. The hardness composite was measured using O.M.A.G AFRI ITALY MOD 100 MR, according to ASTM E-10, with a 2.5 mm steel ball indenter and 62.5 kg load. The hardness Brinell of the composite was calculated using Eq.1. Where P symbolize the load was used, D diameter of indenter and d symbolize the width of indentation diameter on the specimen. The

hardness value reported is an average of 9 readings taken at variously located of the specimen.

$$\text{BHN} = \frac{2P}{(\pi D)(D - \sqrt{D^2 - d^2})} \quad (\text{Eq.1})$$

The tensile strength test was measured using SUNPOC WEW-300D Hydraulic Universal Testing Machine according to JIS Z2201 standard with 6 mm specimen thickness. The dimension of the tensile test specimen has shown in Figure 7.

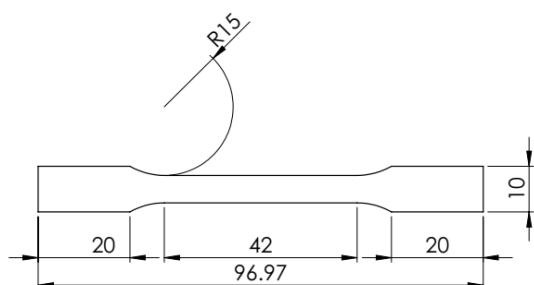


Figure 7. Tensile specimen dimension (mm).

3. RESULTS AND DISCUSSION:

3.1 Density and porosity

The theoretical, experimental density and porosity of the Al 6061-Sea sand composite are determined based on the rule of the mixture as follows Equation 2 (Kannan and Ramanujam, 2017).

$$\rho_{\text{theoretical}} = \rho_m \phi_m + \rho_r \phi_r \quad (\text{Eq.2})$$

Where ϕ_m and ϕ_r symbolize the weight fraction of the matrix and reinforcement, while ρ_m and ρ_r symbolize the density of the matrix and reinforcement, the experimental density was calculated adopting the Archimedes principle. Calculation of porosity of composites can obtain using Equation 3.

$$\text{Porosity} = \frac{(\text{Theoretical density} - \text{Experimental density})}{\text{Theoretical density}} \times 100\% \quad (\text{Eq.3})$$

The density and porosity of Al6061-sea

sand composites are shown in Figure 8 and Figure 9. The density of composite Al 6061-sea sand with a 2 %wt particle is 2.69 g/cm³. Composite density is decreased to 2.67 g/cm³ at the addition of 4%wt and 6 %wt of sea sand, respectively. This is due to the lower sea sand reinforcement density, which is 2.5-2.6 g/cm³ (Di *et al.*, 2019; Hilman *et al.* 2014), resulting in the composite density decreases with increasing reinforcement weight fraction. On the other hand, composite porosity increases with increasing reinforcement of sea sand reinforcement. The higher porosity caused by the increase in the surface of the sand sea in contact with molten aluminum, the higher the contact surface, resulted in a higher chance of porosity (Garg *et al.*, 2019).

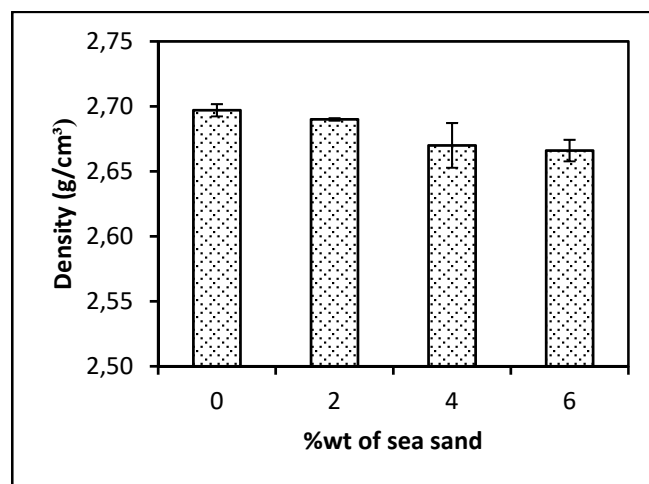


Figure 8. The density of the Al6061-sea sand composite.

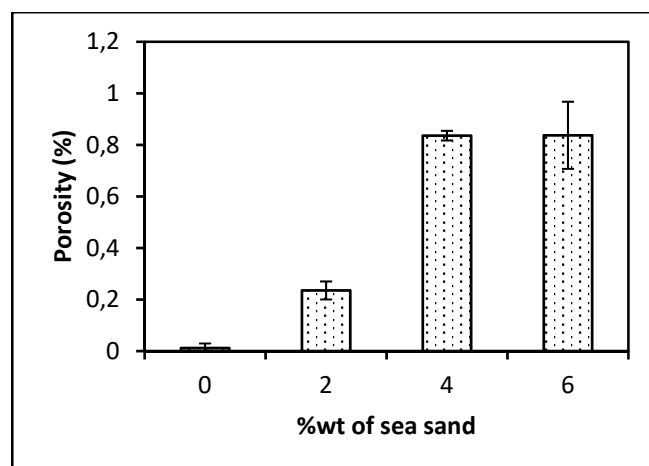


Figure 9. The porosity of the Al6061-sea sand composite.

3.2 Hardness

The hardness test of the composite is shown in Figure 10. The highest hardness is obtained in addition to 6 %wt sea sand with 119 BHN. The lowest hardness is captured in the acquisition of 2 %wt reinforcement with 107.93 BHN. Composite hardness increases with an increasing fraction of sea sand. The hardness of ceramic compounds that contain in sea sand affects the hardness of composites. Higher sea sand particles dispersed in the composite results increasing the hardness of the composite (Zhou and Xu, 1997). The dispersion of sea sand particles on the matrix causes slip disruption that limiting dislocation (Rozhbiany and Jalal, 2019). Also, ceramic compounds that contain in sea sand also increase the hardness of composites (Kumar *et al.*, 2013).

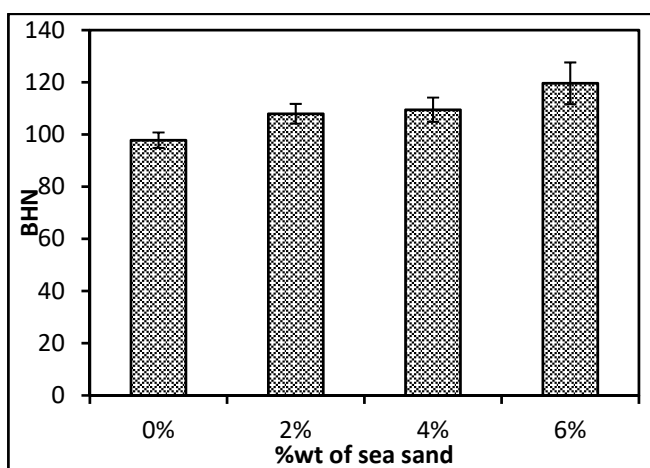


Figure 10. The hardness of the Al6061-sea sand composite

3.3 Tensile strength

The tensile strength of the Al6061-sea sand composite is shown in Figure 11. The UTS increases with an increasing fraction of sea sand. The highest tensile strength is achieved at 6% wt sea sand with 119 MPa, while the lowest tensile strength obtains at 2% wt sea sand with 98 MPa. Increased tensile strength is associated with ceramic compounds (Al_2O_3 , SiO_2 , Fe_2O_3) that contain in sea sand (Dhaneswara *et al.*, 2017). Previous research states that in composites, there are several strengthening mechanisms, including grain refinement, particle reinforcement, and reinforcement due to thermal differences (Kannan and Ramanujam, 2017). In Al6061-Sea sand composites, the strengthening mechanism that occurs is the mechanism of particle strengthening. This phenomenon is related to the

limited movement of dislocation due to the presence of sea sand particles. This is in accordance with the Orowan's mechanism (Srivastava and Chaudhari, 2018; Tang *et al.*, 2018).

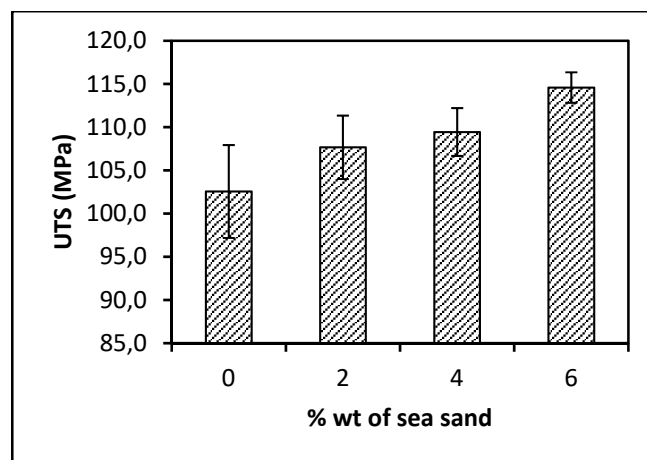


Figure 11. UTS of the Al6061-sea sand composite

4. CONCLUSIONS

In this study, Al 6061 composites with sea sand reinforcement were produced by the stir casting method. The findings of this work can be summarized:

1. Aluminum composite with sea sand reinforcement has been successfully produced by the stir casting method. The physical and mechanical properties of a composite depend on the amount of reinforcement added into the matrix.
2. Composite density decreases with increasing fraction sea sand, while porosity increases with an increasing fraction of sea sand.
3. The hardness and UTS of the composite increased due to an increasing fraction of sea sand. This phenomenon occurred due to ceramics compounds in sea sand, which gives a strengthening effect on composites.

Based on experiments, the sea sand can be used as an alternative reinforcement on aluminum composites, while also increasing the raw materials into materials for engineering purposes.

5. ACKNOWLEDGMENTS

This research was funded by the Republic of Indonesia Ministry of Research and Technology (National Research and Innovation Agency). Through research program for Ph.D. dissertation, contract No. 111/UN27.21/HK/2020.

6. REFERENCES

- 1 Akbar, H. I.; Surojo, E.; Ariawan, D. (2018). Effect of quenching agent on dimension stability of Al 6061-Al₂O₃ composite. *MATEC Web of Conferences*, 159.
- 2 Alimi, M.; Putri, S. E. (2016). Analisis Kandungan Mineral Pasir Pantai Losari Kota Makassar Menggunakan XRF dan XRD. *Jurnal Chemica*, 17(2), 19–23. (in Indonesian)
- 3 Bharath, V.; Nagaral, M.; Auradi, V.; Kori, S. A. (2014). Preparation of 6061Al-Al₂O₃ MMC's by Stir Casting and Evaluation of Mechanical and Wear Properties. *Procedia Materials Science*, 6, 1658–1667.
- 4 Bihari, B.; Singh, A. K. (2017). An Overview on Different Processing Parameters in Particulate Reinforced Metal Matrix Composite Fabricated by Stir Casting Process. *International Journal of Engineering Research and Applications*, 7(1), 42–48.
- 5 Bisane, V. P.; Sable, Y. S.; Dhobe, M.M.; Sonawane, P. M. (2015). Recent development and challenges in processing of ceramic reinforced Al matrix composite through stir casting: A Review. *International Journal of Engineering Research and Applied Science*, 21(10), 11–16.
- 6 Carranza-Edwards, A.; Kasper-Zubillaga, J. J.; Rosales-Hoz, L.; Morales-de la Garza, E. A.; Lozano-Santa Cruz, R. (2009). Beach sand composition and provenance in a sector of the southwestern Mexican Pacific. *Revista Mexicana de Ciencias Geológicas*, 26(2), 433–447.
- 7 Chinta, N. D.; Selvaraj, N.; Mahesh, V. (2018). Mechanical characterization of aluminium-Red mud metal matrix composites. *Materials Today: Proceedings*, 5, 26911–26917.
- 8 Das, D. K.; Mishra, P. C.; Singh, S.; Pattanaik, S. (2014). Fabrication and heat treatment of ceramic-reinforced aluminium matrix composites- A review. *International Journal of Mechanical and Materials Engineering*, 9(1), 1–15
- 9 Dhanesh, S.; Kumar, K. S.; Yohannan, L.; Fayiz, N. K. M.; Sajith, E. (2020). Materials Today : Proceedings Aluminium metal matrix composites reinforced with non - conventional materials: A review. *Materials Today: Proceedings*.
- 10 Dhaneswara, D.; Syahrial, A. Z.; Ayman, M. T. (2017). Mechanical Properties of Nano SiC-Reinforced Aluminum A356 with Sr Modifier Fabricated by Stir Casting Method. *Procedia Engineering*, 216, 43–50.
- 11 Di, W. U.; Yan, Q.; Wang, Y. J.; Gan, X. Q.; Dong, Z. H.; Wang, J. B.; Chen, J. J. (2019). Micro-analysis of Marine Sand from Zhoushan Seas. *IOP Conference Series: Earth and Environmental Science*, 304(3).
- 12 Dong, Z.; Wu, G.; Zhu, H. (2019). Mechanical properties of seawater sea-sand concrete reinforced with discrete BFRP-Needles. *Construction and Building Materials*, 206, 432–441.
- 13 Garg, P.; Jamwal, A.; Kumar, D.; Sadasivuni, K. K.; Hussain, C. M.; Gupta, P. (2019). Advance research progresses in aluminium matrix composites: manufacturing and applications. *Journal of Materials Research and Technology*, 8(5), 4924–4939.
- 14 Giofré, D.; Junge, T.; Curtin, W. A.; Ceriotti, M. (2017). Ab initio modelling of the early stages of precipitation in Al-6000 alloys. *Acta Materialia*, 140, 240–249.
- 15 Gireesh, C. H.; Durga Prasad, K.; Ramji, K. (2018). Experimental Investigation on Mechanical Properties of an Al6061 Hybrid Metal Matrix Composite. *Journal of Composites Science*, 2(3), 49.
- 16 Hall, J. N.; Jones, J. W. (1994). Particle size, volume fraction, and matrix strength effects on fatigue behavior and particle fracture in 2124 aluminum-SiCp composites. *Materials Science and Engineering A*, 183, 69–80.
- 17 Harish, T. M.; Mathai, S.; Cherian, J.; Mathew, K. M.; Thomas, T.; Prasad, K. V.

- V; Ravi, V. C. (2019). Development of aluminium 5056/SiC/bagasse ash hybrid composites using stir casting method. *Materials Today: Proceedings*, 27(3), 2635-2639.
- 18 Hilman, P. M; Suprpto, S. J; Sunuhadi, D. N; Tampubolon, A; Wahyuningsih, R; Widhyatna, D; Pardiarto, B; Gunradi, R; Franklin, F; Yudawinata, K; Sutisna, D. T; Dinarsih, D; Sukaesih.; Yuningsih, E.T; Candra.; Oktaviani, P; Rahmawati, R; Ulfa, R. M; Sukmayana, I; Ostman, I. (2014). Pasir besi di Indonesia: Geologi, Eksplorasi dan Pemanfaatannya, Pusat Sumber Daya Geologi, Bandung. (in Indonesian).
- 19 Hashim, J.; Looney, L.; Hashmi, M. S. J. (2001). The wettability of SiC particles by molten aluminium alloy. *Journal of Materials Processing Technology*, 119(1-3), 324-328.
- 20 Jalil, Z.; Rahwanto, A.; Mustanir.; Akhyar.; Handoko, E. (2017). Magnetic behavior of natural magnetite (Fe₃O₄) extracted from beach sand obtained by mechanical alloying method. *AIP Conference Proceedings*, 1862(July 2017), 8-12.
- 21 Kannan, C; Ramanujam, R. (2017). Comparative study on the mechanical and microstructural characterisation of AA 7075 nano and hybrid nanocomposites produced by stir and squeeze casting. *Journal of Advanced Research*, 8(4), 309-319.
- 22 Kumar, A; Lal, S; Kumar, S. (2013). Fabrication and characterization of A359/Al₂O₃ metal matrix composite using electromagnetic stir casting method. *Journal of Materials Research and Technology*, 2(3), 250-254.
- 23 Kumar, K. R.; Pridhar, T.; Sree Balaji, V. S. S. (2018). Mechanical properties and characterization of zirconium oxide (ZrO₂) and coconut shell ash (CSA) reinforced aluminium (Al 6082) matrix hybrid composite. *Journal of Alloys and Compounds*, 765, 171-179.
- 24 Lasabuda, R. (2013). Development in Coastal and Ocean in Archipelago Perspective of The Republic of Indonesia. *Jurnal Ilmiah Platax*, 1, 92-101. (in Indonesian)
- 25 Leonov, A. (2019). Effect of Alumina Nanofibers Content on the Microstructure and Properties of ATZ Composites Fabricated by Spark Plasma Sintering. *Materials Today: Proceedings*, 11, 66-71.
- 26 Liu, Z. X.; Lin, W. S. (2017). The effect of Mg on the wetting behavior of SiC-Al system. *Materials Science Forum*, 893 MSF, 132-135.
- 27 Mohanavel, V.; Kumar, S. S.; Sathish, T.; Anand, K. T. (2018). Effect of ZrB₂ content on mechanical and microstructural characterization of AA6063 aluminum matrix composites. *Materials Today: Proceedings*, 5(5), 13601-13605.
- 28 Nagaral, M; Shivananda, B. K; Auradi, V; Parashivamurthy, K. I; Kori, S. A. (2017). Mechanical Behavior of Al6061-Al₂O₃ and Al6061-Graphite Composites. *Materials Today: Proceedings*, 4(10), 10978-10986.
- 29 Patel, S; Rana, R. S; Singh, S. K. (2017). Study on mechanical properties of environment friendly Aluminium E-waste Composite with Fly ash and E-glass fiber. *Materials Today: Proceedings*, 4(2), 3441-3450.
- 30 Pattnayak, A.; Madhu, N.; Panda, A. S.; Sahoo, M. K. (2018). A Comparative study on mechanical properties of Al-SiO₂ composites fabricated using rice husk silica in crystalline and amorphous form as reinforcement. *Materials Today: Proceedings*, 5(2), 8184-8192.
- 31 Podymova, N. B; Karabutov, A. A. (2017). Combined effects of reinforcement fraction and porosity on ultrasonic velocity in SiC particulate aluminum alloy matrix composites. *Composites Part B: Engineering*, 113, 138-143.
- 32 Radhika, N.; Balaji, T.V.; and Palaniappan, S. (2015). Studies On Mechanical Properties And Tribological Behaviour Of LM25/SiC/Al₂O₃ Composites. *Journal of Engineering Science and Technology*, 10, 134-144.
- 33 Raj, R; Thakur, D. G. (2019). Effect of particle size and volume fraction on the strengthening mechanisms of boron carbide reinforced aluminum metal matrix composites. *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, 233(4), 1345-1356.
- 34 Rao, P. S. R.; Mohan, C. B. (2020). *Materials Today: Proceedings Study on*

- mechanical performance of silicon nitride reinforced aluminium metal matrix composites. *Materials Today: Proceedings*.
- 35 Razzaq, A. M; Majid, D. L; Ishak, M. R; Basheer, U. M. (2017). Effect of fly ash addition on the physical and mechanical properties of AA6063 alloy reinforcement. *Metals*, 7(11), 1–15.
 - 36 Reddy, B. R; Srinivas, C. (2018). Fabrication and Characterization of Silicon Carbide and Fly Ash Reinforced Aluminium Metal Matrix Hybrid Composites. *Materials Today: Proceedings*, 5(2), 8374–8381.
 - 37 Rozhbiany, F. A. R; Jalal, S. R. (2019). Reinforcement and processing on the machinability and mechanical properties of aluminum matrix composites. *Journal of Materials Research and Technology*, 8(5), 4766–4777.
 - 38 Sangghaleh, A.; Halali, M. (2009). Effect of magnesium addition on the wetting of alumina by aluminium. *Applied Surface Science*, 255(19), 8202–8206.
 - 39 Sarkar, S; Bhirangi, A; Mathew, J; Oyyaravelu, R; Kuppan, P; Balan, A. S. S. (2018). Fabrication characteristics and mechanical behavior of Rice Husk Ash-Silicon Carbide reinforced Al-6061 alloy matrix hybrid composite. *Materials Today: Proceedings*, 5(5), 12706–12718.
 - 40 Satheesh, M; Pugazhvadivu, M. (2019). Investigation on physical and mechanical properties of Al6061-Silicon Carbide (SiC)/Coconut shell ash (CSA) hybrid composites. *Physica B: Condensed Matter*, 572(August), 70–75.
 - 41 Shaikh, M. B. N; Arif, S; Aziz, T; Waseem, A; Shaikh, M. A. N; Ali, M. (2019). Microstructural, mechanical, and tribological behaviour of powder metallurgy processed SiC and RHA reinforced Al-based composites. *Surfaces and Interfaces*, 15 (December 2018), 166–179.
 - 42 Sharma, P.; Prakash, S.; Sharma, R.; Dabra, V.; Sharma, N. (2020). Materials Today: Proceedings Microstructural and mechanical behavior of aluminium alloy reinforced with TiC. *Materials Today: Proceedings*, 25, 934–937.
 - 43 Song, M. (2009). Effects of volume fraction of SiC particles on mechanical properties of SiC/Al composites. *Transactions of Nonferrous Metals Society of China (English Edition)*, 19(6), 1400–1404.
 - 44 Srivastava, N; Chaudhari, G. P. (2018). Microstructural evolution and mechanical behavior of ultrasonically synthesized Al6061-nano alumina composites. *Materials Science and Engineering A*, 724(December 2017), 199–207.
 - 45 Tang, X. C; Meng, L. Y; Zhan, J. M; Jian, W. R; Li, W. H; Yao, X. H; Han, Y. L. (2018). Strengthening effects of encapsulating graphene in SiC particle-reinforced Al-matrix composites. *Computational Materials Science*, 153 (April), 275–281.
 - 46 Thomas, A. T.; Parameshwaran, R.; Muthukrishnan, A.; Kumaran, M. A. (2014). Development of Feeding and Stirring Mechanisms for Stir Casting of Aluminium Matrix Composites. *Procedia Materials Science*, 5, 1182–1191.
 - 47 Tiwari, S; Pradhan, M. K. (2017). Effect of rice husk ash on properties of aluminium alloys: A review. *Materials Today: Proceedings*, 4(2), 486–495.
 - 48 Vijaybabu, G.; Raju, K. P.; Raju, V. V. M. K.; Sunilkumar, K. (2019). Studies on effect of ash in aluminium hybrid metal matrix composites. *Materials Today: Proceedings*, 18, 2132–2136.
 - 49 Viswanatha, B.M.; Kumar, M.P.; Basavarajappa, S.; and Kiran, T.S. (2013). A356/SiCp/Gr Metal Matrix Composites. *Journal of Engineering Science and Technology*, 8, 754–763.
 - 50 Xiao, J; Qiang, C; Nanni, A; Zhang, K. (2017). Use of sea-sand and seawater in concrete construction: Current status and future opportunities. *Construction and Building Materials*, 155, 1101–1111.
 - 51 Xiong, B; Xu, Z; Yan, Q; Lu, B; Cai, C. (2011). Effects of SiC volume fraction and aluminum particulate size on interfacial reactions in SiC nanoparticulate reinforced aluminum matrix composites. *Journal of Alloys and Compounds*, 509(4), 1187–1191.

- 52 Zhang, F.; Li, L.; Wang, E. (2015). Effect of micro-alumina content on mechanical properties of Al₂O₃/3Y-TZP composites. *Ceramics International*, 41(9), 12417–12425.
- 53 Zhang, Q; Xiao, J; Liao, Q; Duan, Z. (2019). Structural behavior of seawater sea-sand concrete shear wall reinforced with GFRP bars. *Engineering Structures*, 189(March), 458–470.
- 54 Zhang, W. Y.; Du, Y. H.; Zhang, P. (2019). Vortex-free stir casting of Al-1.5 wt% Si-SiC composite. *Journal of Alloys and Compounds*, 787, 206–215.
- 55 Zheng, K; Politis, D. J; Wang, L; Lin, J. (2018). A review on forming techniques for manufacturing lightweight complex—shaped aluminium panel components. *International Journal of Lightweight Materials and Manufacture*, 1(2), 55–80.
- 56 Zhou, W; Xu, Z. M. (1997). Casting of SiC reinforced metal matrix composites. *Journal of Materials Processing Technology*, 63(1–3), 358–363.