# Experimental Study of Aluminum Composite Material by the Percentage Variation of Volcanic Ash Reinforcement

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Keywords: Aluminum composite, volcanic ash, percentage of reinforcement, stir casting, material testing.

Abstract: This research is using the volcanic ash from the eruption of Mount Kelud as material composite reinforcement. Information about large amounts of Silica (SiO2) on Mount Kelud volcanic ash and its abundant amounts in Yogyakarta after the eruption, were the reason for choosing this material as reinforcement in the making of aluminum metal composite. This composite is using the recycled aluminum material as their matrix. Stir casting method used during the experiment. 1%, 3%, 5% of volcanic ash used with 300 rpm stirring rotation and 4 minutes stirring rotation. Microstructure testing, hardness testing, impact testing and tensile testing were carried out to determined changes in material characteristic. The result showed that the addition of 1% volcanic ash reinforcement gives the highest hardness and toughness number to aluminum composite material, but the lowest ductility value. The highest aluminum composite material ductility value reached in the addition of 3% volcanic ash reinforcement.



## 1 INTRODUCTION

Aluminum material is widely used because it has several advantages, including formability and tensile strength which can be improved through cold working processes or a heat treatment process (Callister, 2007)) . In the aluminum industry, it is usually combined with other elements to get better product characteristic. Composite is a material that composed from a combination of two or more types of material which are differentially macro in shape and composition(Waddoups and Halpin, 1974). It is produces new material which is very different from the basic material. Al-Si-Cu-Mg is the aluminum composites that quite widely used in the industrial world because of their pour ability and good mechanical characteristic in heat treatment conditions (Runxia et al., 2010). The Stir casting method is the process of casting by melting the metal until it boils and then stirring continuously until a vortex is formed (Hashim et al., 1999). The reinforcement (in the form of powder) is mixed gradually through the edges of the formed vortex (Ajiriyanto, 2010).

Bhushan and Kumar (Bhushan and Kumar, 2011) have conducted research on the the distribution effect of SiC particles on Al-7075 with the stir casting method and maintained temperature in the range of 750 to 800o C. This experiment result shows that the 5 to 15% SiC reinforcement added will increase the 10.48% hardness value. In stirring with a rotation of 500 rpm, metallographic result shows a uniform distribution of granule structure with clearly visible granule boundaries. This study took the stir casting method from Bhushan and Kumar experiment by using the volcanic ash as a reinforcement material. The stir casting method are suggested to reduce the porosity in material composite (Wilastari et al., 2011).

Volcanic ash often referred to volcanic sand or pyroclastic fall. It is a falling volcanic material that sprayed into the air during an eruption, consisting of large to fine-sized rocks. The volcanic ash that usedon this experiment coming from the eruption of Mount Kelud. Mount Kelud erupted on February 13th 2014 and sent wind-erupted volcanic ash in the form of fine material falling in Yogyakarta. The result from European Satelite Agency shows the chemical analysis of Kelud volcanic ash which contains minimum of 55.05% silica (SiO2) (Guidebook et al., 2000). This



Mulyanti, J., Sukamto, ., Arviyanto, N., Anggraini, S. and Biddinika, M.
Experimental Study of Aluminum Composite Material by the Percentage Variation of Volcanic Ash Reinforcement.
DOI: 10.5220/0009879501340138
In *Proceedings of the 2nd International Conference on Applied Science, Engineering and Social Sciences (ICASESS 2019)*, pages 134-138
ISBN: 978-989-758-452-7

information and abundant amount of Kelud volcanic ash are the reason for choosing this material as reinforcement for Aluminum metal composite.

Few research on Mt. Kelud volcanic ash utilization has been done particularly on the agriculutre and building material (concrete and brick) (Bahri, 2015), (Saputra, 2011). The chemical characteristic of Indonesia volcanic ash has been research with SEM-EDS test. This research obtained Si content of the three types of volcanic ash ranges 45-60% and elements of Al ranges 14-20% (Latif et al., 2016). The research on the field of metal composite material just has been done in this research. The volcanic ash contain mineral and silica that never change into time. This material expected to improve the aluminum composites characteristic, such as tensile strength, hardness and toughness value.

## 2 METHODOLOGY

This experimental study was conducted to determine the physical and mechanical characteristic of Aluminum metal composite material with volcanic ash reinforcement by the stir casting process (Bhandare and Sonawane, 2013).

### 2.1 Material Preparation

The main material used in this study was recycled aluminum bars, with 80% aluminum and Kelud volcanic ash.

Figure 1: Aluminum bars and mount Kelud volcanic ash.

### 2.2 The Making of Composite Material

1. Smelting Process
   This smelting process used the smelting furnace with the LPG fuel. Heat the crucible then put the aluminum until its melt.
2. Mixing process
   Mixing Process is the mixture process of aluminum composite matrix with the volcanic ash as reinforcement, strain the volcanic ash with smooth sieve, then heat to 600°C nearly the molten aluminum temperature. The little amount of volcanic ash was put gradually into the molten aluminum. This mixture done with the stir casting method, by the 300 rpm stirring speed and 4 minutes stirring time. This mixing process was done with three variation of volcanic ash reinforment percentage (1%, 3%, and 5%). The percentage of volcanic ash was have to be under 5% to avoid mixture clotted.

Figure 2: Stir Casting furnace

Figure 3: Material Mixing Process

3. Pouring & Dismantling Process
   Pouring process used crucibles ladel, molding pattern with gating system, green sand, and molding frame. Pour the molten aluminum on 650oC temperature. The molding dismantling process took after 15 minutes.

Figure 4: Material Casting Process and Casting Results

# 3 RESULT AND DISCUSSION

## 3.1 Composition Test Result

The result obtained from Spectrometer at the Engineering Materials Laboratory, Department of Mechanical and Industrial Engineering, Faculty of Engineering, Gajah Mada University. From the table above, we can see that the raw material of aluminum contains 13,3651% of Zn element. It means, the raw material itself was Al-Zn alloy. From the results of the composition test, it can be seen that the silica content addition does not addded Si composition to the composite material. A large percentage of Zn (Zinc) element will affect the nature of the composite material. The higher content of Zn (Zinc) in the composite soften the granule of the matrix but it will increase the composite brittleness (E8, 1992). The addition of 5% volcanic ash reinforcement decreased Al content until 78.35%.

| Specimens | Original | 1%, 300rpm, 4' | 3%, 300rpm, 4' | 5%, 300rpm, 4' |
|---|---|---|---|---|
| Element | (%) | (%) | (%) | (%) |
| Si | 2.3387 | 2.2714 | 2.5118 | 2.1722 |
| Fe | 0.7118 | 0.873 | 0.8989 | 3.9102 |
| Cu | 1.0887 | 0.9892 | 1.134 | 2.2344 |
| Mn | 0.2397 | 0.2845 | 0.2591 | 0.2495 |
| Mg | 0.0034 | 0.0008 | 0.0006 | 0.001 |
| Cr | 0.0133 | 0.0152 | 0.0145 | 0.015 |
| Ni | 0.0551 | 0.0526 | 0.0563 | 0.0558 |
| Zn | 13.3651 | 11.9488 | 13.0086 | 12.3766 |
| Pb | 0.6139 | 0.7124 | 0.5995 | 0.6499 |
| Sn | 0.0259 | 0.0239 | 0.0261 | 0.0321 |
| Al | 81.5 | 82.81 | 81.71 | 78.35 |

Figure 5: Composition Testing Result.

## 3.2 Microstructure Testing Result

The microcrostructure testing in this experiment using 200x magnifition. The size and granule form observation method are using in the discussion of this microstructure result. Planimetri method is used to observe the granule size, which a circle with the certain size made on the microscope photograph.

The amount of granule on the circle, measured with the formula :

$$n_{eq} = \frac{n_c}{2} + n_i \quad (1)$$

$n_i$ = the amount of granule on the circle $n_c$ = the amount of granule cut in circles

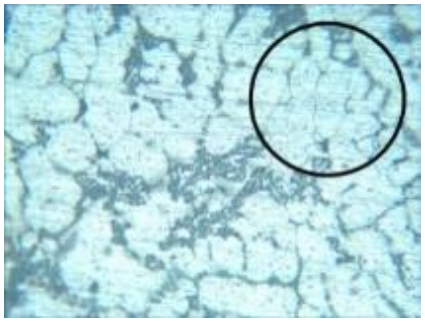

Figure 6: 1% of volcanic ash (Amount of granules = 12)

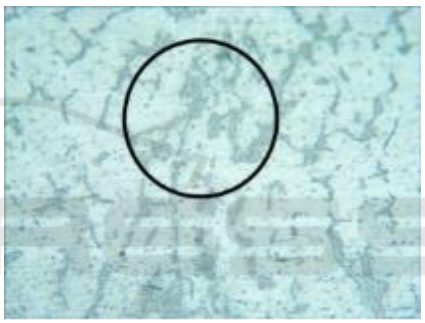

Figure 7: 3% of volcanic ash (Amount of granules = 6)

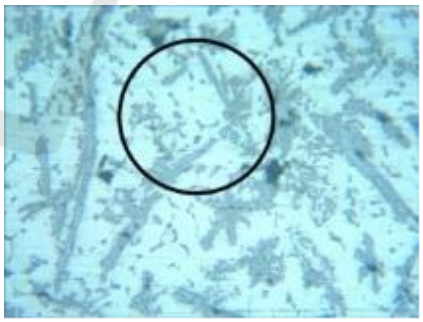

Figure 8: 5% of volcanic ash (Amount of granules = 4)

The number of granule affects the material mechanical characteristic. The more number of granule, the higher value of material hardness and toughness.

## 3.3 Hardness Testing Result

| No. | Specimens | Point 1 | Point 2 | Point 3 | Average |
|---|---|---|---|---|---|
| | | Hardness ($HR_C$) | | | |
| 1 | Volcanic ash: 1% n : 300rpm t : 4 minute | 29 | 27 | 27 | 27.67 |
| 2 | Volcanic ash: 3% n : 300rpm t : 4 minute | 27,5 | 24 | 25.5 | 25.67 |
| 3 | Volcanic ash: 5% n : 300rpm t : 4 minute | 24,5 | 26.5 | 26 | 25.67 |

Figure 9: Hardness Testing Result.

This hardness test uses Rockwell scale C (HRC) hardness method. The highest hardness value was obtained on aluminum composites with 1% volcanic ash reinforcement of 27.67 HRC. The addition of reinforcement with a percentage of 3% and 5% reduces the hardness of the composite. Another research shows that the SiC added will increase the hardness value. This contary results shows from the existance of Silicone Carbida as reinforcement addition (Nugroho et al., 2014).

The microstructure test calculation result shows that the highest amount of granule were obtained from 1% volcanic ash reinforcement which reach 12 granule. The amount of granule on 3% volcanic ash reinforcement addition is 6 and on 5% volcanic ash reinforcement is 4 granule. The higher addition amount of granule, addition the higher material hardness value. On contrary, the fewer amount of granule, the lower material hardness value.

## 3.4 Impact Test Result

| No. | Specimens | A ($mm^2$) | U ($Joule/mm^2$) | E (Joule) |
|---|---|---|---|---|
| 1 | Volcanic ash: 1% n : 300rpm t : 4 minute | 80 | 1.49 | 119.5 |
| 2 | Volcanic ash: 3% n : 300rpm t : 4 minute | 80 | 1.41 | 113.1 |
| 3 | Volcanic ash: 3% n : 300rpm t : 4 minute | 80 | 1.44 | 115.3 |

Figure 10: Impact Testing Result.

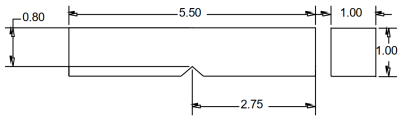


Figure 11: Impact Testing Result.

The result on the Figure 10 shows that absorbed energy to break the specimen are not much different among others. The calculation shows that the highest value from 1% volcanic ash reinforcement addition is equal to 119.5 Joules, while the lowest of 3% volcanic ash reinforcement addition is equal to 113.1 Joule.

The microstructure testing shows that 1% of volcanic ash reinforcement have the highest amount of granule and the highest energy to break the specimen. Therefore higher volcanic ash reinforcement will decrease the thoughness value.

## 3.5 Tensile Test Result

| Specimens | F (N) | $L_1$ (mm) | ΔL (mm) | σ (MPa) | ε | E (MPa) |
|---|---|---|---|---|---|---|
| Volcanic ash: 1% n : 300rpm t : 4 minute | 7573.3<br>5846.8<br>5689.8 | 36.6<br>36.8<br>36.7 | 1<br>1.2<br>1.1 | 102.4 | 0.031 | 3362.32 |
| Volcanic ash: 3% n : 300rpm t : 4 minute | 9653<br>6317.6<br>6631.6 | 36.6<br>36.6<br>36.7 | 1<br>1<br>1.1 | 121.2 | 0.029 | 4198.44 |
| Volcanic ash: 5% n : 300rpm t : 4 minute | 8515.1<br>7730.3<br>6160.7 | 36.7<br>36.6<br>36.6 | 1.1<br>1<br>1 | 120.1 | 0.029 | 4128.33 |

Figure 12: Tensile Testing Result.

The test was carried out with a Servopulser machine using 4 tons load. With data spesimens are: L0=35.6mm, D=8.9mm, A=62.18mm2. The test founded that the highest average tensile on 3% volcanic ash reinforcement addition was 121.2 MPa and the smallest was 1% volcanic ash reinforcement addition was 102.4 MPa. The tensile value increases with the addition of volcanic ash reinforcement. The microstructure test and granule amout calculation shows the amount of granule on the 3% and 5% volcanic ash reinforcement added has less granule from 1% of volcanic ash reinforcement added. It means the less amount of granule, the higher tensile strength.



# 4 CONCLUSIONS

This research result shows that the composition of raw material is known as Al-Zn alloy. The addition of volcanic ash reinforcement does not add Silica elements to the composite material significantly. The addition of 1% volcanic ash reinforcement produces the highest hardness and toughness of aluminum composite material and provides the lowest tensile strength value. The addition of 3% and 5% volcanic ash reinforcement decreases the hardness and toughness of aluminum composites, but its increases the tensile strength.

# ACKNOWLEDGEMENTS

Thanks to the team of PT. Kereta Api Indonesia who collaborate in this research.

# REFERENCES

Ajiriyanto, M. K. (2010). Fabrikasi komposit al/al2o3 (p) coated dengan metode stir casting dan karakterisasinya= fabrication of composite al/al2o3 (p) coated using stir casting method and its characteristics.

Bhandare, R. G. and Sonawane, P. M. (2013). Preparation of aluminium matrix composite by using stir casting method. *International Journal of Engineering and Advanced Technology (IJEAT)*, 3(3):61–65.

Bhushan, R. K. and Kumar, S. (2011). Influence of sic particles distribution and their weight percentage on 7075 al alloy. *Journal of materials engineering and performance*, 20(2):317–323.

Callister, W. D. (2007). An introduction to materials science and engineering. *John Wiley and Sons Inc*.

Guidebook, E., Sriwana, T., and Sitorus, K. (2000). Crater lakes of java: Dieng, kelud and ijen.

Hashim, J., Looney, L., and Hashmi, M. (1999). Metal matrix composites: production by the stir casting method. *Journal of materials processing technology*, 92:1–7.

Latif, D. O., Rifa'i, A., and Suryolelono, K. B. (2016). Chemical characteristics of volcanic ash in indonesia for soil stabilization: Morphology and mineral content. *International Journal*, 11(26):2606–2610.

Nugroho, S. et al. (2014). Pengaruh komposisi mg dan sic terhadap sifat kekerasan komposit alsi-sic yang dibuat dengan proses semi solid stir casting. *Prosiding SNATIF*, pages 165–172.

Runxia, L., Yujin, C., Xiaoguang, Y., Yingdong, Q., and Rongde, L. (2010). Effects of cd and sn on double-peak age-hardening behaviors of al-si-cu-mg cast alloys. *Research & Development*, 7(1):1–5.

Waddoups, M. and Halpin, J. (1974). The fracture and fatigue of composite structures. *Computers & Structures*, 4(3):659–673.

Wilastari, S., Bayuseno, A., and Nugroho, S. (2011). Pengaruh variasi kecepatan putar dalam metode stir casting terhadap sifat kekerasan al-sic untuk aplikasi blok rem kereta api. *Majalah Ilmiah Gema Maritim*, 13(1):1–7.