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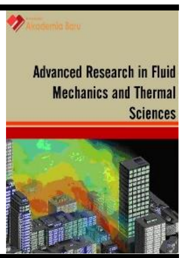

Effect of Burning Temperature on Rice Husk Silica as Reinforcement of Recycled Aluminium Chip AA7075

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ABSTRACT

Aluminium recycling is now a well-known technique used in material manufacturing because it consumes less energy and is environmentally friendly. This paper presents the effect of burning temperature on rice husk silica as reinforcement of recycled Aluminium chip AA7075 on physical properties and hardness. Rice husk silica was prepared without any chemical treatments which are original rice husk (O), rice husk ash burned at 700°C (RHA) and calcination of rice husk ash burned at 1000°C (CRHA). Recycled Aluminium chip AA7075 reinforced with rice husk silica i.e., 2.5 wt.%, 5 wt.%, 7.5 wt.%, 10 wt.% and 12.5 wt.% were prepared. Analyses of silica were conducted by using x-ray diffraction (XRD) and x-ray fluorescence (XRF) test. Silica remains to be in amorphous phases for original rice husk and rice husk ash at 700°C. However, at a burning temperature of 1000°C, silica was observed in semi crystalline phase. Porosity and water absorption of composite of metal matrix increased with an increasing the composition of rice husk silica. The hardness of composite of metal matrix improved with increasing rice husk silica, while the hardness of chip AA7075/O and chip AA7075/CRHA decreased with increasing rice husk silica. Based on investigation to Aluminium reinforced rice husk at different burning temperatures, amorphous phase of silica burned at 700°C shows good potential to improve the hardness of material by appropriate composition of rice husk silica.

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1. Introduction

Aluminium is a nonferrous metal contained heavily metals in the world [1]. The third element in earth's crust which is most abundant found in bauxite. The process of primary Aluminium to produces alumina is includes grinding, digestion, filtration, precipitation and calcination phases. Recycling Aluminium scrap obtained as secondary Aluminium. As energy consumption in Aluminium mining

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and melting is high, exchanging part of Aluminium through recycling of industrial waste such as Aluminium chips promises low manufacturing costs, does not harm the environment and saves primary Aluminium resources, the current industrial societies objectives are thus fulfilled [2,3].

Development of composites using various reused wastes primarily in the development of composites using the most environmentally friendly agro-wastes as reinforcing fillers such as bamboo leaf and fly ash are currently gotten worldwide [4,5]. The recycling of agricultural waste encouraged the sustainability awareness due to the reduction of greenhouse gas emission and indirectly produced a sustainable product [6]. Rice husk (RH) is one of agro-waste materials produced by the rice production industry that generated large amounts of rice husk during paddy production from the agricultural fields. The burning of rice husk has specific benefits, changing rice husk from a valueless to valuable materials such as silica were its produced higher percentage of silica than other biomass fuels, were its was an excellent source of silica that can replace other conventional silica sources [7,8]. The usage of rice husk ash increased the compressive strength [9] According to Boateng *et al.*, and Ismail et al., amorphous silica was detected in rice husk ash below 800°C, while crystallization of silica overtakes after this temperature [10,11].

The objective of this study was to determine the effect of burning temperature of rice husk can improve physical properties and hardness to composite of metal matrix, so it can transform industrial waste into beneficial industrial material.

2. Experimental Material and Procedure

2.1 Composite of Metal Matrix Material

In the current experimental works, Aluminium block AA7075 was used as a metal matrix material with the chemical element composition in weight percentage as listed in Table 1. A natural resource which is rice husk (RH) was obtained from rice industry company, Nano Siltech Sdn. Bhd. Three parameters of rice husk were used as reinforcing agent which is original rice husk (O), rice husk ash burned at 700°C (RHA), and rice husk ash from 700°C then undergo burning process at second time at 1000°C (CRHA) which known as calcination process. The chemical composition (wt.%) of each reinforcing agent is shown in Table 2, Table 3 and Table 4. The characterization of rice husk ash was carried out using x-ray fluorescence analysis (XRF analysis).

Table 1
Chemical element composition of AA7075 alloy (mass fraction, wt.%) [12]

Al	Zn	Cu	Si	Cr	Others
87.18	9.49	2.59	0.31	0.28	0.15

Table 2
Chemical composition of original rice husk, O (wt %)

SiO_2	SO_3	Fe_2O_3	Others
67.1	7.0	0.8	25.1

Table 3
Chemical composition of rice husk ash at 700°C, RHA (wt %)

SiO_2	C	K_2O	P_2O_5	CaO	MgO	SO_3	Cl	Fe_2O_3	Al_2O_3
87.23	0.11	4.77	3.58	1.74	1.23	0.61	0.15	0.23	0.35

Table 4
Chemical composition of rice husk ash at 1000°C, CRHA (wt %)

SiO_2	K_2O	P_2O_5	CaO	MgO	SO_3	Cl	Fe_2O_3	Al_2O_3	Others
94.17	2.39	0.87	0.62	0.39	0.23	0.02	0.17	0.97	0.17

2.2 Preparation of Chips AA7075

High speed milling machine, Mazak Nexus 410A-II was used to produce Aluminium chip. The parameters of milled Aluminium chip as follows in Table 5.

Table 5
The parameters of milled Aluminium chip

Feed rate	1100 mm/min
Depth cut	1 mm
Cutting velocity	345 m/min

Then, ultrasonic bath apparatus, FRITSCH – ultrasonic cleaner Labarette 17 was used to clean the milled Aluminium chip with duration of 1 hour using an acetone solution to remove oil, grease and any impurities. Lastly, the milled Aluminium chip is drying using drying oven at 75°C temperature in 1 hour to remove the remaining acetone solution from the Aluminium chip [12-16].

2.3 Preparation of Rice Husk Ash

High impact mill was used to prepare rice husk silica in smaller particle size. Rice husk silica was put in porcelain jar contained ball mill under wet milling cycles for 10 minutes. Next, vibrator type apparatus was used to separate the 63µm particle size for 30 minutes with amplitude of 1.

2.4 Mixing, Compaction and Sintering Process

The Aluminium chips were mixed with original rice husk (O), rice husk ash burned at 700°C (RHA) and calcination rice husk ash burned at 1000°C (CRHA), and then poured into the mold to compact the sample using press machine were the compaction load is 9 tons with compaction of holding time in 20 minutes [17,18]. The composition of mixing process of rice husk silica and Aluminium chip is shown in Table 6. Then, the samples were sintered according to sintering profile shown in Figure 1 [12].

2.5 Physical Test and Hardness Test

The physical test consists of density, porosity and water absorption of composite of metal matrixes is measured with Archimedes Principle which is using an electronic balance, Mettler Toledo German. The analysis testing was conducted followed by standard ASTM B328 for density and ASTM B962-17 for porosity.

Hardness test was conducted using Vickers method followed by standard ASTM E-384. Vikers hardness test machine equipped with a diamond indenter to measure the hardness. The measurements were performed with eight indenters to take the average.

Table 6
Composition of rice husk silica and Aluminium chip (MMC) sample

Reinforcement	Composition
None	100 wt.% chip AA7075
Original rice husk (O)	97.5 wt.% Chip AA7075 + 2.5 wt.% of O
	95.0 wt.% Chip AA7075 + 5.0 wt.% of O
	92.5 wt.% Chip AA7075 + 7.5 wt.% of O
	90.0 wt.% Chip AA7075 + 10.0 wt.% of O
	87.5 wt.% Chip AA7075 + 12.5 wt.% of O
Rice husk ash at 700°C (RHA)	97.5 wt.% Chip AA7075 + 2.5 wt.% of RHA
	95.0 wt.% Chip AA7075 + 5.0 wt.% of RHA
	92.5 wt.% Chip AA7075 + 7.5 wt.% of RHA
	90.0 wt.% Chip AA7075 + 10.0 wt.% of RHA
	87.5 wt.% Chip AA7075 + 12.5 wt.% of RHA
Calcination rice husk ash at 1000°C (CRHA)	97.5 wt.% Chip AA7075 + 2.5 wt.% of CRHA
	95.0 wt.% Chip AA7075 + 5.0 wt.% of CRHA
	92.5 wt.% Chip AA7075 + 7.5 wt.% of CRHA
	90.0 wt.% Chip AA7075 + 10.0 wt.% of CRHA
	87.5 wt.% Chip AA7075 + 12.5 wt.% of CRHA

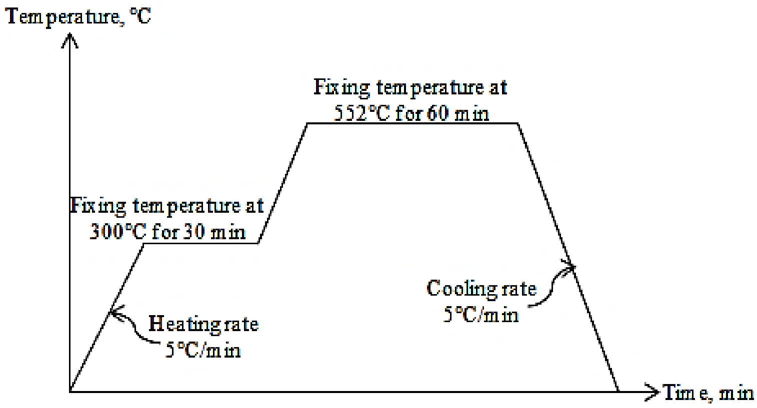

Fig. 1. Sintering profile [12]

3. Results and Discussion

3.1 X-ray Diffraction Analysis

The rice husk silica was characterized by using XRD testing. Original rice husk and rice husk ash at 700°C remains in amorphous phases, while crystallization peaks were formed in calcination rice husk ash at 1000°C as shown in Figure 2.

The formation peaks of Cristobalite, Tridymite and Quartz as major content indicate CRHA has start to formed crystalline phase as shown in Figure 3. According to Ismail et al. and D.R. Lee, the peaks were very narrow and intense at higher burning temperature (above 1100°C) which is reflecting higher crystallinity [11,19]. However, contamination occur while burning process of rice husk ash as Al_2O_3 increased as shown in XRF data and the formation of Corundum peaks appeared in XRD graph analysis.

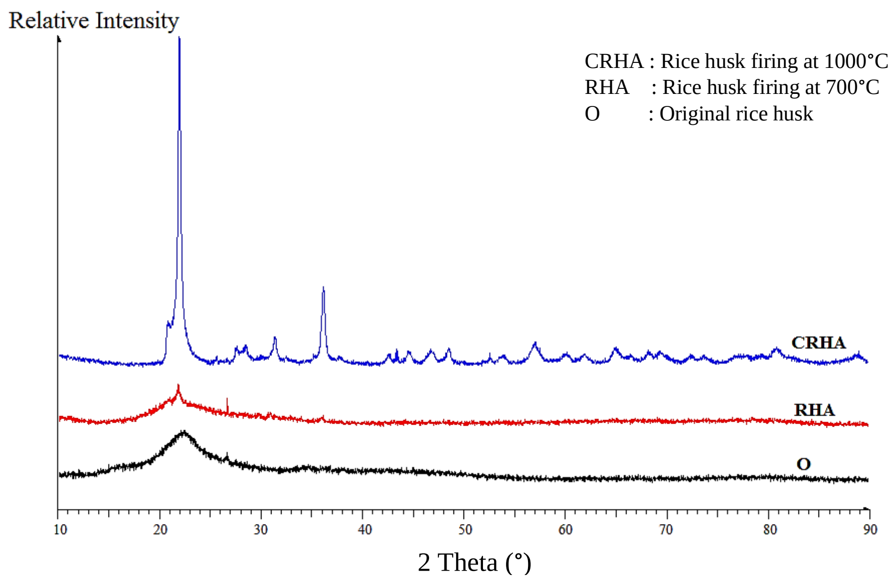

Fig. 2. XRD patterns of rice husk at original, burning at 700°C, and burning at 1000°C

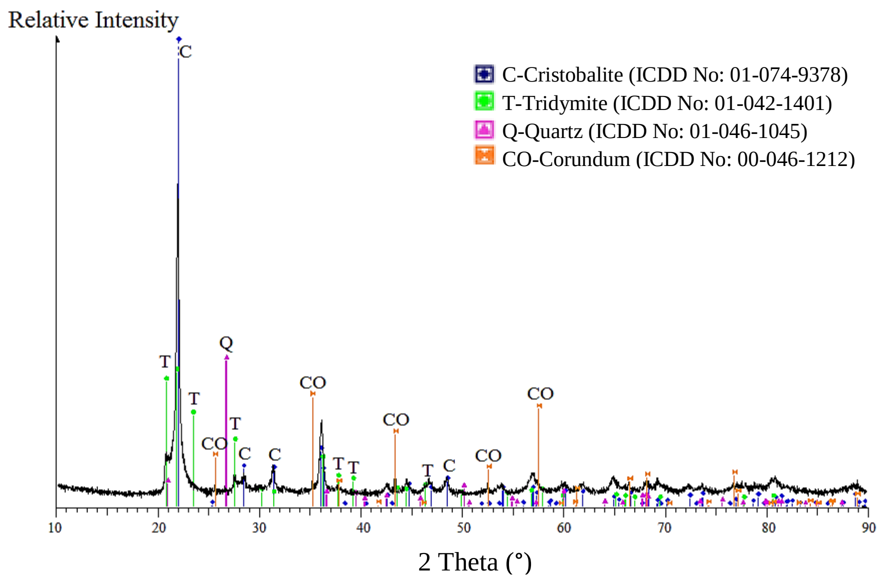

Fig. 3. Crystalline phase obtained at 1000°C burning rice husk ash

3.2 Physical Properties

In Figure 4, the density of composite of metal matrixs improved quickly by raising the composition of rice husk silica up to 5 wt.% for recycled Aluminium chip reinforced amorphous silica. However, the density of composite of metal matrix was decreased after it was reinforced for more than 5 wt % of rice husk silica. The effect between original and rice husk burning at 700°C shows the same trend line of graph. Recycled Aluminium chip reinforce semi crystalline shows that the density increase up to 10 wt.% and decrease at 12.5 wt.% of rice husk silica.

Apparent porosity and water absorption shows the increment percentage. It can be relate to the chemical composition of rice husk silica, there is carbon content, whereby its affected the process of compaction and sintering of metal matrix samples.

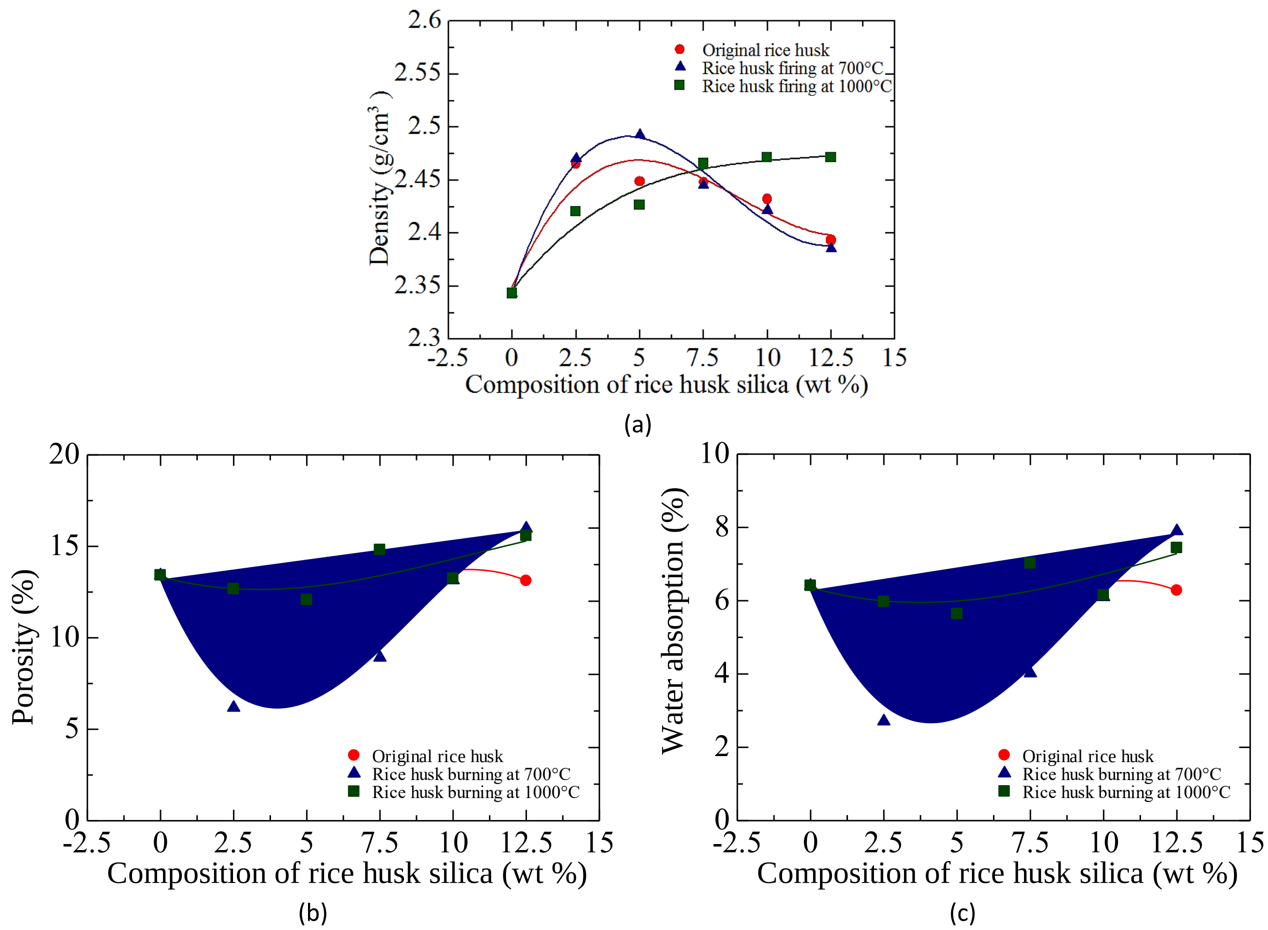

Fig. 4. Physical properties of metal matrix reinforce; (a) original rice husk; (b) untreated rice husk ash at 700°C; (c) calcination untreated rice husk ash at 1000°C

3.3 Microhardness

Figure 5 illustrates the relationship of hardness between various composition and different type of rice husk silica. The hardness of metal matrix of fully AA7075 recycled Aluminium chip is 53.49 Hv. It has been found that the hardness of amorphous silica for rice husk burned at 700°C increases with increasing composition of rice husk ash content, where the hardness of composite of metal matrix had enhanced. The highest hardness for original rice husk parameter were 58.37 Hv at 2.5 wt.% of rice husk silica and the hardness shows decreasing with increasing in composition of rice husk silica. The hardness of rice husk ash burned at 700°C sample has increase at increasing in composition of rice husk silica reach 69.53 Hv at 10 wt.% and for calcination rice husk ash burned at 1000°C, the hardness reaches 64.70 Hv at 7.5 wt.% of rice husk. It shows that the hardness of composite of metal matrix was relying to composition of rice husk silica. It also shows that rice husk ash burned at 700°C improved the hardness of composite of metal matrix higher than original rice husk and calcination rice husk ash burned at 1000°C. However, Saravanan et al., and Tiwari et al., reported that the composition of rice husk silica that increased to more than 10 wt % was seen decreasing the hardness of material because of inadequate bonding between metal matrix and reinforced agent [7,20].

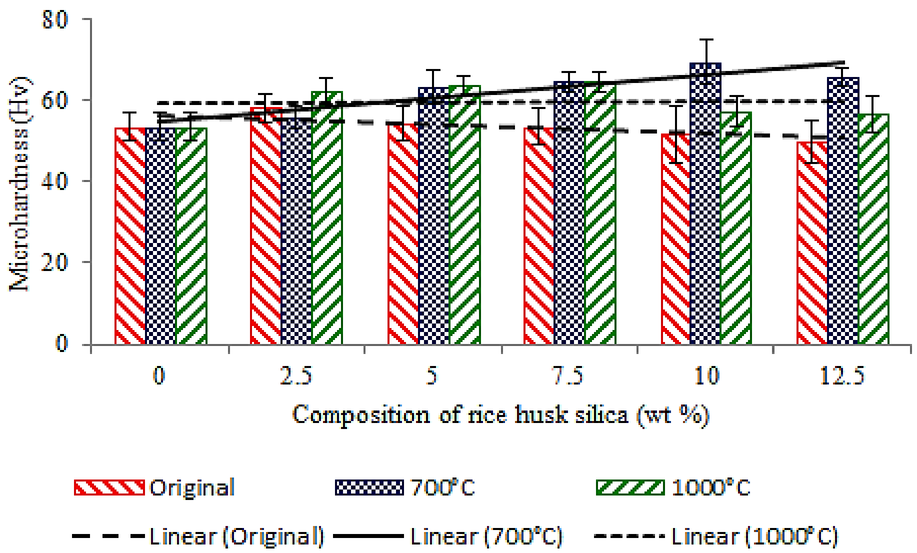

Fig. 5. Microhardness (Hv) with the increasing of different RHA (wt.%)

4. Conclusions

Rice husk can also be used in the manufacturing of composite metal matrix as a valuable reinforcing additive. It is one of the excellent sources of silica and can replace other conventional silica source. Using rice husk ash for composites manufacturing can make agricultural waste's industrial wastes into industrial wealth. This also solves the problem of rice husk storage and disposal.

The hardness of composite of metal matrix was increased at increasing composition of rice husk silica. The composite of metal matrix for fully chip AA7075 has improved from 53.49 Hv to 58.37 Hv for original rice husk, 69.53 Hv for rice husk ash burned at 700°C and 64.70 Hv for calcination rice husk ash burned at 1000°C. Improvement in physical properties can be well attributed to generating better material. When the percentage of rice husk silica increases above a certain limit (12% above) its effect was minimized due to poor wettability with Aluminium chips. Finally, it was concluded that amorphous rice husk ash burned at 700°C has the best potential to be an excellent reinforcing agent compared to others.

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References

[1] Sheasby, Peter G., and Robert Pinner. *The surface treatment and finishing of aluminium and its alloys*. Vol. 2. ASM International, 2001.

[2] Gronostajski, J. Z., H. Marciniak, A. Matuszak, and M. Samuel. "Aluminium–ferro-chromium composites produced by recycling of chips." *Journal of Materials Processing Technology* 119, no. 1-3 (2001): 251-256. https://doi.org/10.1016/S0924-0136(01)00966-9

[3] Fogagnolo, J. B., E. M. Ruiz-Navas, M. A. Simón, and M. A. Martinez. "Recycling of aluminium alloy and aluminium matrix composite chips by pressing and hot extrusion." *Journal of Materials Processing Technology* 143-144 (2003): 792-795. https://doi.org/10.1016/S0924-0136(03)00380-7

[4] Lindroos, V. K., and M. J. Talvitie. "Recent advances in metal matrix composites." *Journal of Materials Processing Technology* 53, no. 1-2 (1995): 273-284. https://doi.org/10.1016/0924-0136(95)01985-N

[5] Ibrahim, I.A., Mohamed, F.A., and Lavernia E.J. "Particulate reinforced metal matrix composites — a review." *Journal of Materials Science* 26, no. 5 (1991): 1137-1156. https://doi.org/10.1007/BF00544448
[6] Aziz, Annis Nazirah Abdul, and Roszilah Hamid. "Mechanical Properties and Impact Resistance of Hybrid Kenaf and Coir Fibre Reinforced Concrete." *Journal of Advanced earch in Applied Mechanics* 47, no. 1 (2018): 1-10.
[7] Srikant Tiwari and Pradhan, M.K. "Effect of rice husk ash on properties of aluminium alloys: A review." *Materialstoday: Proceedings* 4, no. 2 (2017): 486-495. https://doi.org/10.1016/j.matpr.2017.01.049
[8] Armesto, L., Bahillo, A., Kati Veijonen, Cabanillas, A., and Otero, J. "Combustion behaviour of rice husk in a bubbling fluidised bed." *Biomass and Bioenergy* 23, no. 3 (2002): 171-179. https://doi.org/10.1016/S0961-9534(02)00046-6
[9] Kamolchanok Kueaket and Danupon Tonnayopas. "Enhanced Properties of Palm Oil Boiler Clinker Concrete with Sang Yod Rice Husk Ash." *Journal of Advanced Research in Applied Mechanics* 51, no. 1 (2018): 10-19.
[10] Boateng, A.A., and Skeete, D.A. "Incineration of rice hull for use as a cementitious material: the guyana experience." *Cement and Concrete Research* 20, no. 5 (1990): 795-802. https://doi.org/10.1016/0008-8846(90)90013-N
[11] Ismail, N.A.A., Azham Azmi, M., Ahmad, S., and Taib, H. "Effect of Rice Husk Firing Temperature on Synthesis of Silica (SiO_2)." *International Conference on X-Rays & Related Technique in Research & Industry* (2014): 183-184.
[12] Mohd Joharudin, N.F., Abdul Latif, N., Mustapa, M.S., Mansor, M.N., Siswanto, W.A., Murugesan, J., and Yusof F. "Effect of amorphous silica by rice husk ash on physical properties and microstructures of recycled aluminium chip AA7075." *Materialwissenschaft und Werkstofftechnik* 50, no. 3 (2019): 283-288. https://doi.org/10.1002/mawe.201800229
[13] Mustapa, M.S., Mahdi, A.S., Lajis, M.A., and Rashid M.W.A. "Physical properties of recycling milled aluminium chip (AA6061) for various sintering temperature." *International Journal of Mechanical and Industrial Technology* 3, no. 2 (2016): 33-40.
[14] Ab Kadir, Muhammad Irfan, Mohammad Sukri Mustapa, Noradila Abdul Latif, and Ahmed Sahib Mahdi. "Microstructural analysis and mechanical properties of direct recycling aluminium chips AA6061/Al powder fabricated by uniaxial cold compaction technique." *Procedia Engineering* 184 (2017): 687-694. https://doi.org/10.1016/j.proeng.2017.04.141
[15] Mahdi, Ahmed Sahib, Mohd Sukri Mustapa, Noradila Abdul Latif, Muhammad Irfan Ab Kadir, and Mohd Arif Samsi. "Heat treatment for an recycling aluminum AA6061 using milling process at various holding aging time." *International Journal of Engineering and Technology (IJET)* 8, no. 6 (2017): 2582-2587. https://doi.org/10.21817/ijet/2016/v8i6/160806213
[16] Mustapa, Mohammad Sukri, Noradila Abdul Latif, Mohd Joharudin, Nurul Farahin, Shahruddin Mahzan, Mohd Idrus Mohd Masirin, and Norashikin Abdul Hamid. "The Effect of Heat Treatment on Compression Strength of Recycled AA6061 Aluminium Chips." In *Materials Science Forum*, vol. 934, pp. 124-128. Trans Tech Publications Ltd, 2018. https://doi.org/10.4028/www.scientific.net/MSF.934.124
[17] Mahdi, Ahmed Sahib, Mohammad Sukri Mustapa, Mohd Amri Lajis, Abd Rashid, and Mohd Warikh. "Effect of holding time on mechanical properties of recycling aluminium alloy AA6061 through ball mill process." *International Journal of Mechanical Engineering and Technology (IJMET)* 6, no. 9 (2015): 133-142.
[18] Mahdi, Ahmed Sahib, Mohammad Sukri Mustapa, Mohd Amri Lajis, Abd Rashid, and Mohd Warikh. "Effect of compaction pressure on physical properties of milled aluminium chip (AA6061)." *International Journal of Science and Research (IJSR)* 4, no. 9 (2015): 1759-1764.
[19] Lee, D.R. "Characterisation and the diagenetic transformation of non and micro-crystalline silica minerals." *Department of Earth and Ocean Science, University of Liverpool* (2005): 1-20.
[20] Saravanan, S.D., and Senthil Kumar, M. "Effect of Mechanical Properties on Rice Husk Ash Reinforced Aluminium Alloy (AlSi10Mg) Matrix Composites." *Procedia Engineering* 64 (2013): 1505-1513. https://doi.org/10.1016/j.proeng.2013.09.232