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Research Article

Influence of Rice Husk Ash-Yttrium Oxide Addition on the Mechanical Properties Behavior of Aluminum Alloy Matrix Hybrid Composites

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Abstract

The present study deals with the wear behavior of Aluminum 4032 alloy as a matrix reinforced with rice husk ash (RHA) and yttrium oxide (Y2O3) hybrid composite. The Aluminum 4032 matrix alloy was prepared from used minibus scrap pistons. The rice husk ash (RHA) was prepared from burning the rice husk at 700 °C followed by heat treatment at 1100 °C for 2hrs and then characterized by X-ray florescence and X-ray diffraction. The Al-Mg alloy-(RHA-Y2O3) hybrid composites were prepared using two-step stir casting process by adding RHA: Y2O3 in weight ratios 4:0, 3:1, 2:2, 1:3 and 0:4 to Al 4032 alloy such that the total reinforcement is 10wt%. Dry sliding wear, coefficient of friction, hardness, apparent density, percentage of porosity were examined. The prepared hybrid composites were characterized using optical micrograph, SEM and X-ray diffraction. The results showed that the hardness, apparent density and porosity increased with increasing volume fraction of Y2O3, while apparent density decreased with increasing percentage of RHA. The addition of RHA particles increased hardness and lower the wear rate and friction coefficient. The results showed that the wear rate of the hybrid composites increased with increasing of the applied load. Coefficient of friction varies inversely with increasing both applied load and volume fraction of RHA. The Al-Mg alloy-RHA and Al-Mg alloy-(RHA-Y2O3)[3:1] composites have minimum wear rate, while Al-Mg alloy-RHA composite has lower friction coefficient.

Keywords: *Aluminium hybrid composites, Rice husk ash, yttrium Oxide, Stir Casting, Wear behavior*

1. Introduction

The increasing demand for lighter weight and fuel efficient materials is the major factor which is motivating the researchers for the development of more advanced metal matrix composite materials. (Prasad and Ramachandra, 2013) . Aluminum based Metal Matrix composites (MMC) have received increasing attention in recent decades as engineering materials due to their enhanced high strength, hardness and wear resistance over conventional Al alloy (Sharma *et al*., 2015), (Admile *et al*., 2014).

Hybridization is a process of incorporating two or more reinforcements in order to yield better stiffness, strength, high strength to weight ratio and other mechanical properties (Dhanabal *et al*., 2015). Stir casting is currently practiced commercially to produce metal matrix composites where the reinforcing phases are distributed into molten matrix by mechanical Stirring. Stir casting is suitable for manufacturing composites with up to 30% volume fractions of reinforcement(Subramani *et al*., 2014). The advantages of stir casting lie in its simplicity, flexibility and applicability to large quantity production (Mathurand Barnawal, 2013).

Millions of tons of rice husks generated per year as by-product of rice milling process. Rice husk can contribute about 20% of its weight to rice husk ash (RHA) (Usman *et al*., 2014) . It would be beneficial to the environment to recycle and to effectively utilized this agricultural waste in order to protect the environment (Saravanan and Kumar, 2013)(Subrahmanyam *et al*., 2015) studied the microstructure and mechanical properties of AlSi10Mg/RHA/ fly ash hybrid composites and found that the hardness of the composites increased with increasing wt % of RHA and decreased with increasing wt% of fly ash. Double stir casting process was used by (Prasad *et al*., 2014) to prepare Al/ RHA/ SiC hybrid composites and found that the hardness and porosity of the hybrid composite increased with increasing reinforcement wt % but the density decreased. (Shridhara *et al*., 2015) used stir casting to prepare Al-4.5% Cu/ bamboo leaf ash/ graphite hybrid composites and found an increase in hardness, tensile strength, and wear resistance with increasing the bamboo leaf ash and graphite content .

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The wear characteristics of Al/ graphite/SiC hybrid composites was studied by (Suresha and Sridhara,2010) and found that hybrid composites exhibit better mechanical properties and wear characteristics. The dry sliding wear behavior of A356.4/RHA /SiC hybrid composites was studied by (Prasad and Shoba, 2014) and found that hybrid composites exhibit better wear resistance when compared with unreinforced Al-alloy. (Kumar *et al*., 2014) prepared Al 6063 / Al2O3/graphite composites by stir casting and found that Al 6063-6% Al2O3-1%graphite composite exhibit better wear resistance when compared with Al 6063- 6% Al2O3.

The influence of RHA: SiC weight ratios on the mechanical behavior of Al-Mg-Si alloy matrix hybrid composites was studied by (Alaneme and Adewale, 2013) using two-steps stir casting method. The results showed that the composites have good casting quality with less than 2.5 % porosity. The tensile, yield, and specific strength for all composites decrease with increase in the weight proportion of RHA in the RHA-SiC reinforcement.

The coefficient of friction and the wear rate of the hybrid Composites (Al-Mg-Si)/ Alumina/ RHA was studied by (Alaneme and Olubambi, 2013) and found the coefficient of friction and the wear rate of the composites increase with increase in RHA wt %. (Boopathi *et al*., 2013) showed that the density of the 2024 Al/ SiC/ fly ash hybrid composites decreased and the hardness was increased in comparison with unreinforced Al-alloy.(Prasad and Krishna, 2011) studied the mechanical properties of A356.2 / (RHA) composite by vortex method. They found the addition of RHA particles reduces the density of composite but increasing some of their mechanical properties.

The effects of Y2O3 on microstructure, mechanical properties, and resistance to corrosive wear of Al/ Y2O3 composite were studied by (Bouaeshi and Li, 2007) .They found refinement of the composite microstructure with the increase in yttria content and a new phase, Al3Y, is formed. The hardness, strength and wear rate are improved by adding Y2O3 .

There are a limited literatures on the use of synthetic/agro waste hybrid reinforcements for aluminum alloy composites such as SiC/RHA (Alaneme and Adewale, 2013), Alumina/ RHA (Alaneme and Olubambi, 2013), SiC/ fly ash (Boopathi *et al*., 2013). Thus, the aim of this work is to use stir casting to prepare Alunimum/ RHA/ Y2O3 hybrid composites. Dry sliding wear, coefficient of friction, hardness, apparent density, percentage of porosity were studied. The hybrid composites were characterized usingoptical micrograph, SEM and X-ray diffraction.

2. Materials and Methods

2.1 Materials

The source of aluminum alloy is a used car pistons taken from mini bus and were bought from local market. The chemical analysis of used pistons Al-alloy was done using spectrometer type (ARL 3460, USA) as shown in Table 1. According to the Aluminum Association Standard (ASM, 1992) this aluminum alloy is 4032Alloy.

Table 1 Chemical Composition of Al-Alloy KIA Mini Bus Piston (ASM, 1992)

Elements	Cr	Zn	Ni	Fe	Mg	Cu	Si	Al
Standard Alloy	0.1 max	0.25 max	0.5-1.3	1.0 max	0.8-1.3	0.5-1.3	11-13.5	Bal.
Actual Alloy	0.01	0.08	0.5	0.5	0.8	1.19	12.5	Bal.

2.2 Preparation of Master Aluminum Alloy

The used mini bus pistons were cut into small pieces and then cleaned and then melted in alumina crucible(14cm height and 7 cm diameter) using gas fired furnace equipped with a stainless steel electrical stirrer with a controlled speed of 600 -750 rpm. The stirrer is a three rounded blades with 5mm diameter and 8cm long. The furnace temperature is controlled by K-type thermocouple. First the furnace was kept at 750 °C for 30 minutes to allow complete melting of the alloy. About 1wt % aluminum chloride (AlCl3-6H2O) and 1wt % sodium hydroxide were added to the aluminum melt to reduce the porosity. The molten Al-alloy was poured into a cylindrical carbon steel mold. These ingots will be considered as the master Al-alloy that will be used as the matrix for aluminum composite materials.

2.3 Preparation of RHA

The rice husk was obtained from local Iraqi mill. The rice husk was first washed with tap water several times in a steel container and then was manually removed from the steel container. The washed rice husk was then sun dried for 24 hours and then was ignited with kerosene in a perforated cylindrical steel container (d= 75 cm and h= 20 cm) and left to burn completely and the ashes removed 12 hours. The ash was then milled and sieved to 125 micron and then heat treated in an electrical box furnace at 1100 °C for 2 hours with a heating rate of 7˚C/ min to remove carbonaceous materials. The rice husk ash has a grayish white color after heat treatment at 1100 °C.

2.4 Al-Mg Alloy/ RHA-Y2O3 Composite Preparation

The Al-Mg alloy /RHA-Y2O3 hybrid composite was prepared by melting 440 gm of master Al-alloy; 50 gm (Y2O3 + RHA) powder with different ratios ; and 10gm of magnesium (flake) as shown in Table 2. The yttrium oxide (Y2O3) powder (Fixanal company, Germany) used with purity 99% , particle size less than 53 micron. A 440 gm of Al- Master alloy was melted in a gas fired furnace at 750 °C for 30 minutes to get a homogenous melt and then the temperature was reduced to 675 °C and 10 gm of magnesium flake (99% purity, BDH chemicals Ltd, England) was added to improve the wettability of the molten aluminum alloy (Prasad and Krishna, 2011) . The magnesium was wrapped in Al –foil and then dropped in the molten alloy with hand stirring for 3 minutes. This new Al-alloy will be called Al- Mg alloy and will be used as the matrix for composite material. The Y2O3 and RHA were first preheated to 350 ºC to remove the moisture. After reducing the temperature of the molten Al-alloy to about 630 °C, the preheated Y2O3 and RHA were added the molten alloy in two batches. The first powder batches was added to the Al-alloy melt and then hand stirred for 3 minutes, then the melt with the powder was heated to about 630-640 ºC . The second powder patch was added to the Al-alloy melt and stirred manually for 3-4 minutes and then the temperature dropped to about 590 °C (Alaneme and Adewale, 2013) . The temperature was then increased to about 780 °C and the molten alloy was stirred using stainless steel mixer at speed 600 -750 rpm for 4-5 minutes .

After complete mixing the temperature was reduced to 760 °C and the molten alloy composite was poured into a preheated carbon steel cylindrical mold (d= 15mm , h=160 mm) to 350 °C. The Al-Mg alloy/RHA-Y2O3 composite ingot was cooled to room temperature and was then taken out of the mold. The composite ingot was cut into samples for hardness, microstructure and wear test.

2.5 Hardness Test

Hardness test samples of the hybrid composites were prepared according to ASTM E384 standard (ASM, 2000) . The hardness samples of Al-master alloy and Al-Mg alloy / RHA- Y2O3 hybrid composites are cylindrical in shape with diameter 12 mm and height 10mm. Hardness tests were performed by taking the average of 5 readings for each sample using micro-Vickers hardness machine (Model: HVS-1000, USA) with a load 490 gm for 20 seconds. After the force is removed, both diagonals are measured and the average is used to calculate the HV according to (ASM, 2000):

$$Hv=1854.4(P/d^2) \quad (1)$$

Table 2 Al - Mg Alloy / RHA - Y2O3 Composite

Sample No.	Composition
1	Al-Master Alloy
Al-Mg Alloy + RHA / Y2O3	
2	Al-Mg Alloy + 10% RHA + 0% Y2O3
3	Al-Mg Alloy + 7.5% RHA + 2.5% Y2O3
4	Al-Mg Alloy + 5% RHA + 5% Y2O3
5	Al-Mg Alloy + 2.5% RHA + 7.5% Y2O3
6	Al-Mg Alloy + 0% RHA + 10% Y2O3

2.6 Wear Tests

A pin-on-disc wear test apparatus (Model: ED-201, India) was used to measure the dry sliding wear of Al-alloy (master alloy), Al-Mg alloy / RHA- Y2O3 composites. Wear tests pecimens were prepared according to ASTM G99-95 standard (ASM, 2000) and the wear tests were conducted for 15 minutes at different loads: 5, 10, 15 and 20 N at room temperature using sliding speed 480 rpm . The steel disc hardness was used (62 HRC), with 60mm track diameter. Test samples were cleaned with alcohol before and after each test. After wear test for a fixed time period, the specimen was removed, cleaned with alcohol, dried and weighed. The wear rates were determined using the weight loss method according to the following equation (Prasad *et al*., 2013):

$$WR = \Delta m / 2\pi rnt \quad (2)$$

Where :-

WR :- Wear rate (gm/cm)
Where : Δm is the difference in mass (gm) before and after the wear experiment, r =The radius of the specimen to the center of the disc (cm).
n = Disk speed in rpm
t = Sliding time (min.)

Table 3 Chemical composition of RHA

Elements	wt%
SiO2	91
C	4.7
CaO	2.54
Fe2O3	0.65
Na2O	0.58
MgO	0.25
K2O	0.123
Others	<0.1

2.7 Apparent Density and Porosity Measurements

The apparent density and porosity were calculated according to Archimedes principle under ASTM C373-88. The weight of the specimen was measured using digital balance type Sartorius (Model: BL 210 S, Germany manufacture) with accuracy of ± 0.1mg.

2.8 Characterization

The microstructure of the Al-alloy casting (master alloy) and the composites were examined using optical microscope (Model: MT 71000, Meiji techno Co. Ltd., Japan with a digital camera (canon, Japan). The specimens were ground, polished and then etched using Keller's reagent (95 ml water, 2.5 ml HNO_3, 1.5 ml HCl, 1.0 ml HF) for 15 minutes (Alaneme *et al*., 2015).

The diffractrometer type Shimadzu (Model: XRD-6000,Japan , Cu target , 40 Kv and 30 mA, wave length 1.54060 A°,) was used to characterized the samples . The scanning process is done with speed of 5°/min. The diffraction angle ranged from 10° to 80°. The X-Ray Florescence type Spectro/Ametek, (Model: XEPOS, Germany) was used to determine the elements and oxides amount in the RHA.

SEM apparatus (model: Viga-3, Belgium) was used to characterize the morphologies of the samples.

3. Results and Discussion

3.1 Rice Husk Ash Characterization

The chemical composition and X-ray diffraction of the rice husk ash treated at 1100 °C for 2 hrs are shown in Table 3 and Figure 1 respectively . The main element in the ash are silicon, while the major oxide in rice husk ash is the silica with purity (91%) along with small amounts of other inorganic oxides Table 3. The chemical composition analysis also revealed small amount of CaO, Fe_2O_3, Na_2O, MgO, K_2O and traces of Al_2O_3, MnO and TiO_2 oxide were detected. Only silica and carbon peaks were observed in the X-ray diffraction patterns as shown in Figure 1. Silica initially exists in the amorphous form in the rice husk but after heat treatment of the rice husk ash at 1100 °C for 2 hrs the porous and amorphous phase will change to crystalline structure. This is in agreement with work of Ramezanianpour *et al*., (2009) [68]. Rice husk ash begins to transform from purely amorphous to crystalline at temperature above 500 °C.

3.2 Microstructure of Al-Mg Alloy Composites

Figure 2a shows the microstructure of Al-master alloy prepared from Mini Bus Piston. The microstructure includes a mixture of primary aluminum and primary silicon in addition to eutectic phase. The microstructure of Al-Mg alloy-RHA composite shows coarsening of the microstructure due to addition of RHA as shown in Figure 2b. The grain size of the composite increases with increasing of ash content and this is attributed to the coarse nature of RHA ash. Good interfacial bonding between Al matrix and RHA due to increased wettability caused by Mg addition. The microstructure of Al-Mg alloy-Y_2O_3 composite, Figure2c, shows aluminum dendrites and Y rich eutectic phase. The reinforcement particles become more uniform with fine arm dendrite spacing.

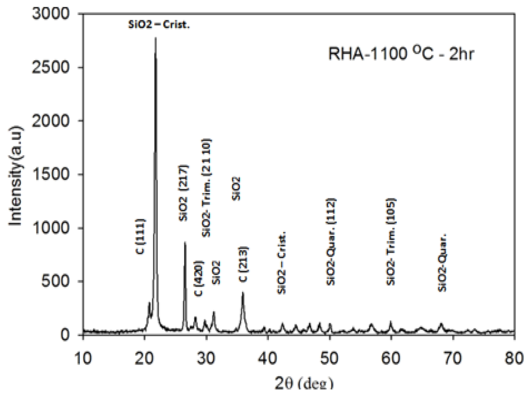
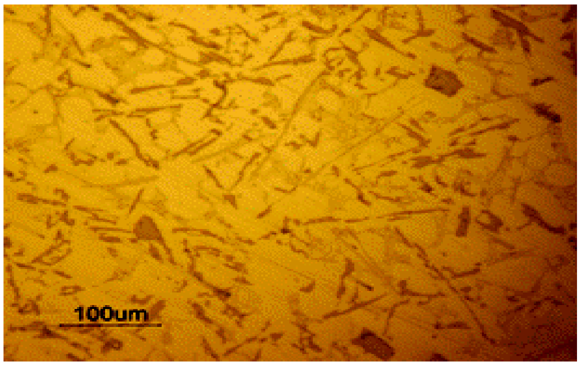
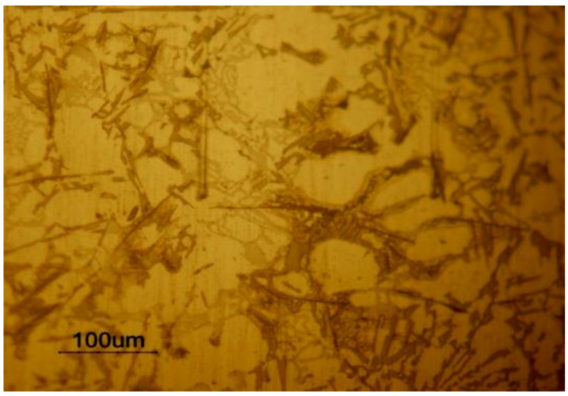


Figure 1 XRD of Heat Treated RHA

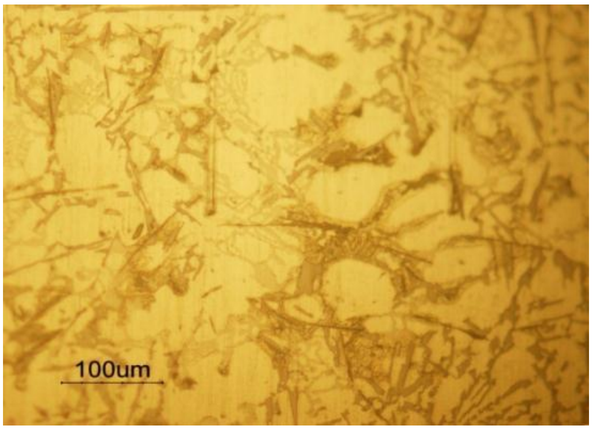
Figure 2d shows the microstructure of Al-Mg alloy-(RHA-Y_2O_3)[2:2] hybrid composite with finer dendrites when compared with Al-Mg alloy-RHA This is due to yttria addition, which agglomerate between the dendrites. In general, the ash is uniformly distributed in the matrix in spite of some regional clusters of it. In composite casting the reinforcement particles may become non homogeneously distributed in spite of homogeneous state of suspension in slurry. During liquid matrix alloy solidification, the reinforcement particles will migrate towards or away from the freezing front, while the particle near freezing front may engulfed or ejected (Hashim *et al*., 1999).



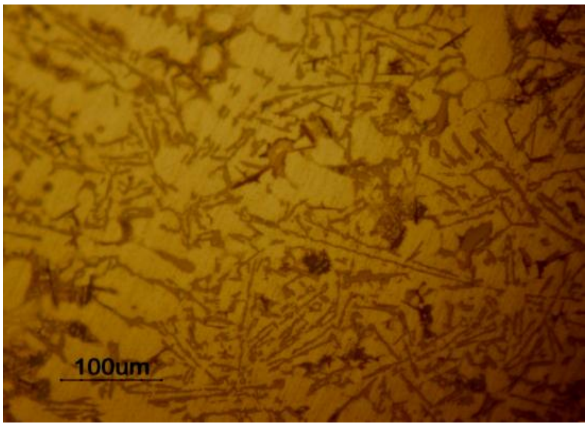
(a)Al-Master Alloy



(b) Al-Mg Alloy-RHA



(c) Al-Mg Alloy-Y2O3



(d) Al-Mg Alloy-(RHA-Y2O3)[2:2]

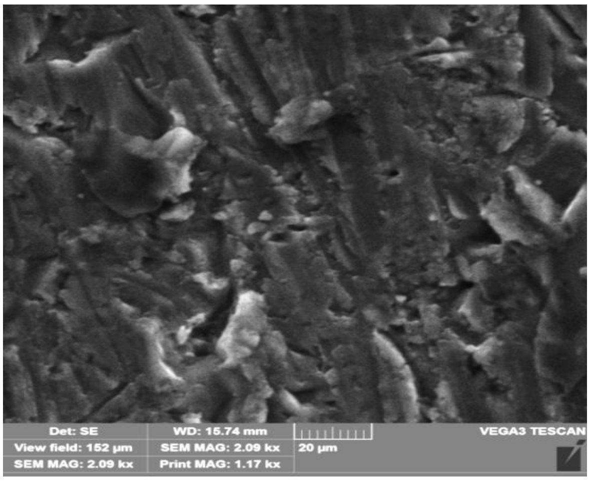
Figure 2 Microstructure (a) Al-Master Alloy; (b) Al-Mg Alloy-RHA Composite ; (c) Al-Mg Alloy-Y2O3Composite ;(d) Al-Mg Alloy-[RHA-Y2O3]2:2] HybridComposite

3.3 SEM of Composites

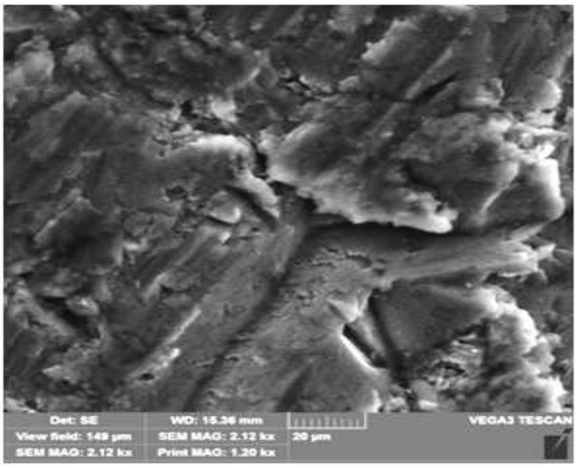
Figure 3 shows SEM micrographs of Al-Mg alloy-RHA composite and Al-Mg alloy- Y2O3 composite. A uniform distribution of the reinforcement's particles without discontinuities can be observed along with good bonding between matrix material and the reinforcements. The SEM micrographs showed small voids for Al-Mg alloy-Y2O3 composite and this is in agreement with the measured porosity 7.63% in this composites.

3.4 X-Ray Characterization

X-ray diffraction of Al-master alloy which was prepared by melting and casting of used mini bus pistons shows three distinct peaks of Al, Si and FeAl2 phases as shown in Figures 4. The major phase is aluminum, and the other minor phases represented by Al8Fe2Si, Al2CuMg and MgAl2O4.



(a) Al-Mg Alloy-RHA



(b) Al-Mg Alloy-Y2O3

Figure 3 SEM Micrographs of Composites, (a) Al-Mg Alloy-RHA ;(b) Al-Mg Alloy-Y2O3

The X-ray pattern for Al-Mg alloy-RHA ,Figure 5 , shows two distinct peaks represented by Al and Si phases and the major phase is aluminum. In Al-Mg alloy-RHA some minor distinct peaks such as SiO2 , C , Al8Fe2Si and Mg2Al4Si5O18 phases are also present. Figure 6 shows the XRD for Al-Mg alloy-Y2O3. The major phases are aluminum, and the other minor phases represented by Al8Fe2Si, Al2CuMg and MgAl2O4. X-ray pattern for Al-Mg alloy-Y2O3, Figures 6, shows Al3Y, Al2Y4O9 and Al4MgY phases. The other phases such as Al3Mg2, Mg2Zn3, Fe3Si and Al8Si6Mg3Fe are belong to the Al-Mg matrix alloy. The yttrium solubility in aluminum is less than 0.1% and the addition of Y2O3 to Al-Mg alloy matrix leads to the formation of intermetallic compound such as Al3Y phase which is thermodynamically stable below 1253 K. This is in agreement with the work of (Bouaeshi and Li 2007).

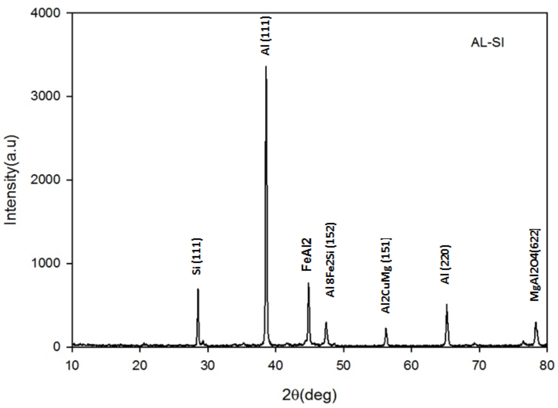


Figure 4 XRD of Al-Master Alloy

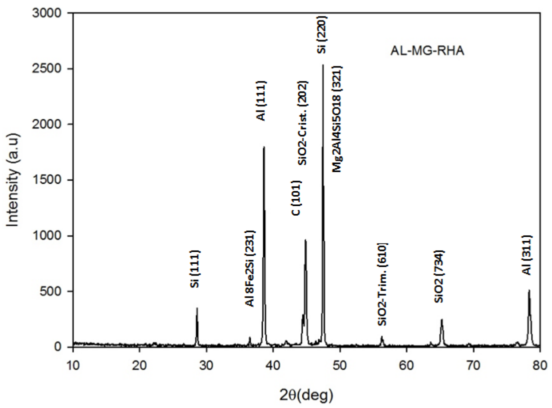


Figure 5 XRD of Al-Mg Alloy-RHA Composite

3.5 Hardnessof Hybrid Composites

The hardness of the hybrid composites samples was measured by micro-Vickers hardness using 490 gm load for 20 second duration time. The variation of hardness with different filler contents is shown in Figure 7. The hardness is 33 for Al-master alloy, 42.4 for Al-Mg alloy-RHA composite and 52.23 for Al-Mg alloy-Y2O3 composite. The hardness values for Al-Mg alloy-(RHA-Y2O3) hybrid composites are between 43-47.3 for different reinforcement ratio of RHA:Y2O3 and the highest value was at weight ratio (1:3) of RHA:Y2O3. The hardness of Al-Mg alloy-(RHA-Y2O3) hybrid composites increases with increase the weight of Y2O3 and the maximum hardness was 52.23 for Al-Mg alloy -Y2O3 composite.

The addition of RHA reinforcement to the Al-Mg matrix alloy will increase the percentage of hard and brittle phase of ceramic body in the matrix alloy and that will increase the dislocation density at the particles-matrix interfaces as reported by (Aigbodion, 2012). The addition of Y2O3 as reinforcement will increase the hardness mainly due to the formation of intermetallic compound such as Al3Y in addition to the refinement of microstructure. The increment in hardness of samples can be attributed to residual atoms of yttrium in the matrix, where the solubility of it is very low in aluminum. These residual yttrium atom can lead to solution-hardening of the aluminum alloy (Bouaeshi and Li, 2007) .

3.6 Apparent Density and Porosity of Al-Mg Alloy-(RHA-Y2O3)

In the present research work, the density and porosity of Al-Mg alloy-(RHA-Y2O3) hybrid composites were measured using archimedes principle (Prasad *et al.*, 2014) as shown in Table 4. The measured density is 2.613 gm/cm^3 for Al-master alloy, 2.512 gm/cm^3 for Al-Mg alloy –RHA composite , 2.674 gm/cm^3 for Al-Mg alloy-Y2O3 composite and between 2.65-2.726 gm/cm^3 for different reinforcement ratio of RHA-Y2O3. The highest measured density is 2.726 gm/cm^3 at weight ratio of (1:3) of RHA-Y2O3.The measured density of Al-Mg alloy-(RHA-Y2O3) hybrid composites increases with increasing weight of Y2O3.

The measured porosity , Figure 8 and Table 4 , is 2.5% for Al-master alloy, 3.6 % for Al-Mg alloy-RHA composite , 7.63% for Al-Mg alloy -Y2O3 composite which is the highest , and between 1.04-3.4 % for different reinforcement ratio RHA:Y2O3 of Al-Mg alloy-(RHA-Y2O3).

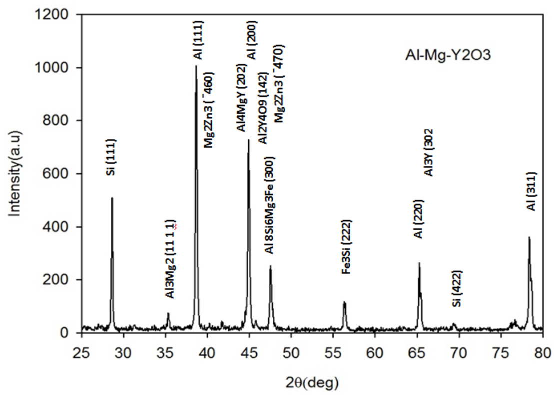


Figure 6 XRD of Al-Mg Alloy- Y2O3 Composite

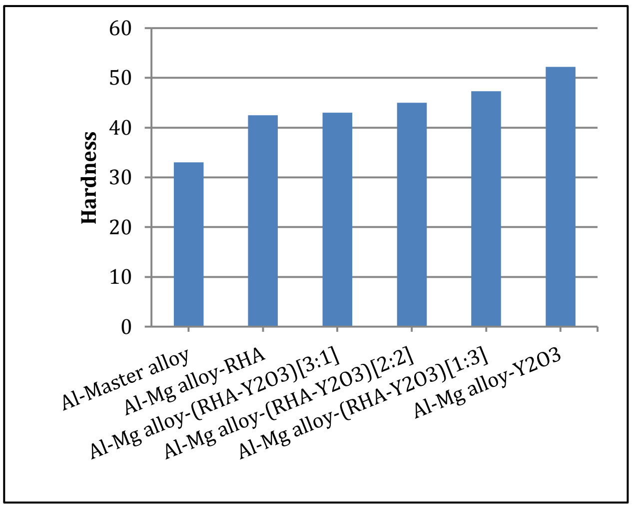


Figure 7 Hardness of Al-Master Alloy, Al-Mg Alloy-(RHA-Y2O3) Hybrid Composites

The increment in porosity attributed to hydrogen evolution and gas entrapment during stir casting and during solidification. The air bubbles entering the slurry by air envelope of the reinforcement particles (Prasad *et al.*, 2014). Composite casting have higher volume fraction of nonmetal solid suspension and the potential for nucleation of these bubbles is enormous. It has been observed that the porosity in composites increases almost linearly with increasing particle content. These results are in agreement with work of (Hashim*et al.*, 1999).

3.7 Wear Rate

Figures 9-10 and Table 5 show the variation of wear rate with the normal loads (5N, 10N, 15N, 20N) at 480 rpm for the hybrid composites. The results , Figure 9 revealed the wear rates increase with increasing normal load for Al-master alloy and Al-Mg alloy/ RHA-Y2O3 composites and this can be attributed to the increase in friction between the mating surfaces and that will generate more heat which causes localized welding that leading to shearing of welded interfaces(Sharma *et al.*, 2015).

For Al-Mg alloy-RHA and Al-Mg alloy- Y2O3 composites, Figure 10, the wear rate is lower than Al-master alloy and this is due to the hardness of reinforcement's particles in the matrix. These results are consistent with the trends reported by other investigators Prasad and Krishna, (2012).

For Al-Mg alloy-RHA composite, the presence of the graphite layer (as confirmed by XRD) which acted as a solid lubricant will lower the wear rate as compared with Al-Mg alloy-Y2O3 composite. This is in agreement with results of (Kumar *et al.*, 2014) .

The presence of more graphite in Al-Mg alloy-(RHA-Y2O3)[3:1] composite ,Table 5 , will give lower the wear rate compared with both Al-Mg alloy-(RHA-Y2O3)[2:2] and Al-Mg alloy-(RHA-Y2O3)[1:3] hybrid composites.

Table 4 Density and Porosity of Al-Master Alloy and Al-Mg Alloy-(RHA-Y2O3) Hybrid Composites

	Composition	Theoretical Density (gm/cm^3)	Measured Density (gm/cm^3)	Porosity (%)
1	Al -Master Alloy	2.68	2.613	2.5
2	Al-Mg Alloy-RHA	2.606	2.512	3.6
3	Al-Mg Alloy-(RHA-Y2O3) [3:1] Hybrid	2.678	2.65	1.04
4	Al-Mg Alloy-(RHA-Y2O3) [2:2] Hybrid	2.75	2.66	3.27
5	Al-Mg Alloy-(RHA-Y2O3) [1:3] Hybrid	2.822	2.726	3.4
6	Al-Mg Alloy-Y2O3	2.895	2.674	7.63

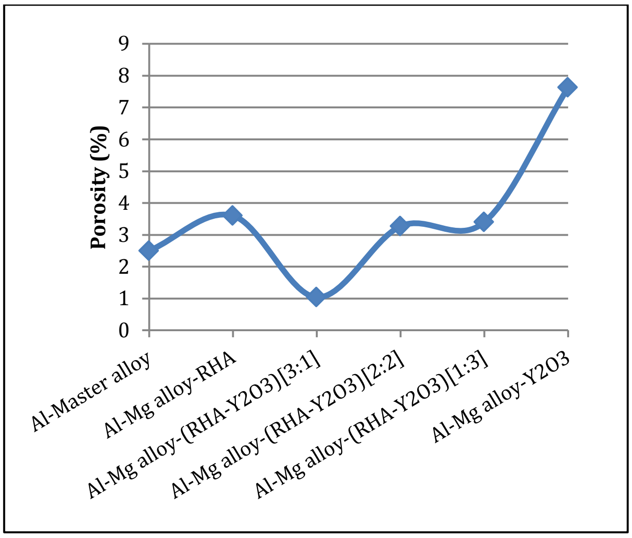


Figure 8 Porosity of Al-Master Alloy and Al-Mg Alloy (RHA-Y2O3) Hybrid Composites

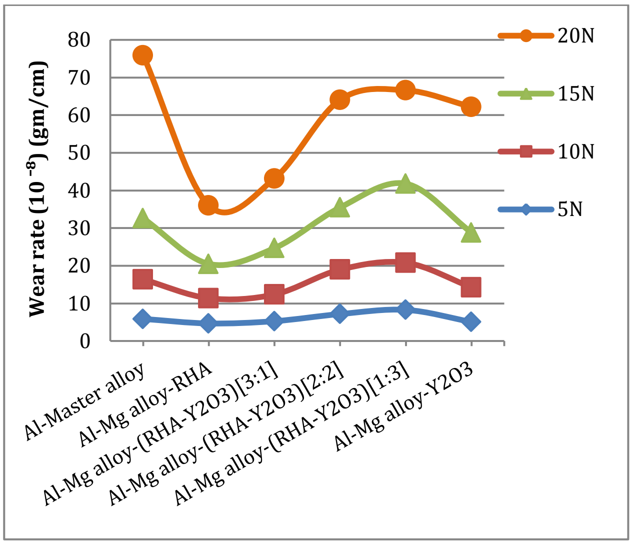


Figure 9 Variation of wear rate with applied loads for hybrid composites

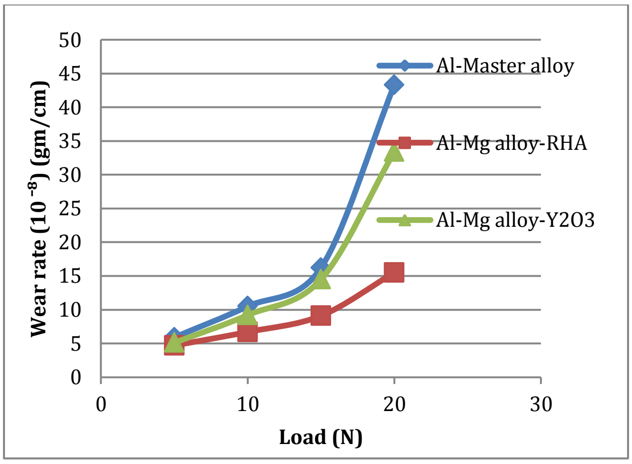


Figure 10 Wear Rate of Al-Master Alloy and Al-Mg Alloy-RHA/Y2O3 Composites

Table 5 Wear Rate of Al-Master Alloy and Al-Mg Alloy Composites

Sample	Hybrid Composite	Wear Rate (10^{-8})(gm/cm)			
		5N	10N	15N	20N
1	Al-Master Alloy	5.9	10.5	16.2	43.3
2	Al-Mg Alloy-RHA	4.7	6.7	9.1	15.5
3	Al-Mg Alloy-(RHA-Y2O3)[3:1]	5.3	7.1	12.3	18.5
4	Al-Mg Alloy-(RHA-Y2O3)[2:2]	7.2	11.8	16.5	28.6
5	Al-Mg Alloy-(RHA-Y2O3)[1:3]	8.3	12.5	21	24.8
6	Al-Mg Alloy-Y2O3	5.1	9.2	14.5	33.4

3.8 Coefficient of Friction (COF)

The coefficient of friction of unreinforced Al-master alloy and Al-Mg alloy composites were studied at applied loads 5N,10N, 15N and 20N with varying weight percentage of particle reinforcement as shown in Figures 11-12 . The maximum coefficient of friction is 0.86 for Al-master alloy and 0.9 for Al-Mg Alloy-Y2O3. Initially, the COF is higher at low load (5 N) due to interlocking of surfaces and higher frictional force required to slide the surface over one another. When the wear process continued at higher load the contact surfaces become smoother as a result of abrasion and a transfer film formed(Anilkumar*et al*., 2014) . In general, at 5N Al-master alloy possess higher coefficient of friction when compared with Al-Mg alloy composites due to absence of tribo layer formation and increase contacting area between metal to metal (Sharma *et al*., 2015) . The reinforcement particles act as load bearing members when the applied load increases and this will decrease the contact area between rotating disk and specimen surfaces. Furthermore, the reinforcement particles will restrict the flow of metal during sliding. These reasons lead to decrease the coefficient of friction of composites. This is in agreement with the work of (Singh *et al*., 2016) who reported that the temperature rise is higher in aluminum matrix alloys when compared with their composites irrespective of surface conditions and applied force. With increase in the applied load, the temperature at specimen interface increases and leads to softening the materials and plastic flow of materials. The Al-Mg alloy-RHA composites possess the lowest coefficient offriction at 5N load . This can be attributed to the graphite layer that smeared at the sliding surface and acted as a solid lubricant (Kumar *et al*., 2014). In general, the COF decreases with increasing the applied load except for Al-Mg alloy-(RHA- Y2O3) [3:1] and Al-Mg alloy-(RHA-Y2O3) [2:2] hybrid composite at 15N and this can be attributed to the tribofilm formation at the interface between the contact surfaces (Suresh and Kumar, 2013).

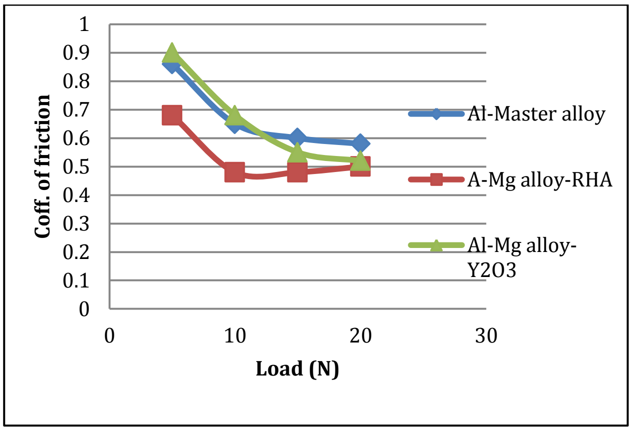


Figure 11 COF of Al-Master Alloy, Al-Mg Alloy-RHA and Al-Mg Alloy-Y2O3 Composites

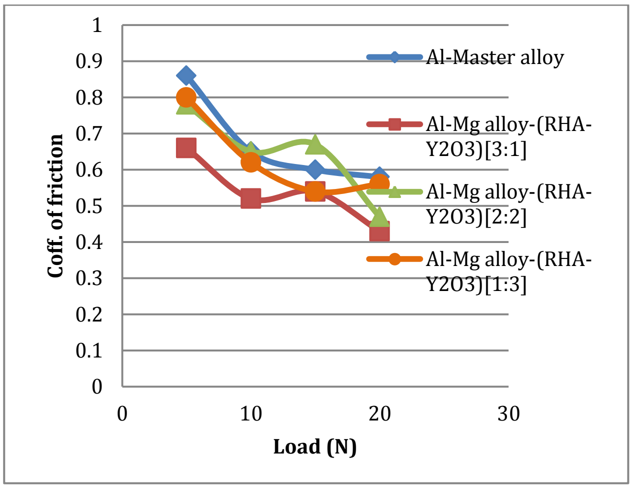


Figure 12 COF of Al-Master Alloy, Al-Mg Alloy-(RHA-Y2O3) Hybrid Composite

Conclusions

Based on the results, rice husk ash with 91% purity silica was prepared from rice husks by heat treatment at 1100 °C and 2hrs. Aluminum 4032 alloy can be prepared from used KIA minibus pistons which was used as a matrix to prepare hybrid composites with rice husk ash (RHA) and yttrium oxide (Y2O3) as reinforcing phases using two steps stir casting .The hardness of the composites is higher than their matrix alloy due to the reinforcement particles. The hardness increases with increasing Y2O3 ratio in the reinforcing phase (RHA:Y2O3) to reach higher value at 10%Y2O3. Al-Mg alloy-10%RHA composite has lower wear rate for Al-Mg alloy composite. The Coefficient of friction (COF) varies inversely with increasing both applied load and volume fraction of RHA. Porosity increases with addition of the reinforcing phase (RHA:Y2O3) .The maximum porosity occurs at 10% Y2O3 and minimum value at (RHA-Y2O3)[3:1] hybrid composites. Addition of Y2O3 caused refinement in the microstructure of the matrix and new phase, Al3Y, is formed.

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