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A Comparative Study on the Properties of Al-7%Si-Rice Husk Ash and Al-7%Si-Bagasse Ash Composites Produced by Stir Casting

A. M. Usman[1]*, A. Raji[1], M. A. Hassan[1] and N. H. Waziri[1]
Mechanical Engineering Department, Modibbo Adama University of Technology, P. M. B. 2076, Yola, Adamawa State, Nigeria

--ABSTRACT--

The aim of this study was to compare the properties of composites produced from an aluminium alloyAl-7%Si as matrix and two agro wastes Rice Husk Ash (RHA) and Bagasse Ash (BA) as reinforcement. The total silica and alumina contents of the ashes obtained at 700°C were 98.24wt% and 88.24wt% for RHA and BA, respectively. Density and mechanical properties of the produced composites were determined. The results show that the composites produced with addition of BA with low density of 238.269kgm^{-3} have better density decreasing ability as BA decreases the density of the alloy by 19% compared with RHA with density of 397.114kgm^{-3}and 15% decrease. The results of mechanical properties show that RHA and BAimproved the mechanical properties upto 10.2% and 7.5% for UTS, respectively. Impact strength increased upto 84.8% and 52.7%, hardness upto 55.2% and 28.8% and fatigue strength upto 316.7% and 190.0% for RHA and BA, respectively. These results show better improvement in mechanical properties with RHA addition however, the statistical analysis results show that there is no significant difference among the pairs of some properties (UTS, Young modulus and fatigue strength) of the two composites and hence both could be used in similar applications where tensile and fatigue strength are of importance.

KEYWORDS**:** *Alumina, Bagasse ash, Comparison, Composites, Density, Propeties, Rice husk ash, Silica.*

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I. INTRODUCTION

Nigeria is blessed with a land mass of about 98million hectares, out of which only 30-40million hectares are presently under cultivation [1]. Every agricultural product leaves behind a significant quantity of wastes which is not being economically utilised and which contributes directly to environmental pollution through a variety of processes from cultivation, processing and disposing of waste, leaving behind average of 20 to 70% total waste with rice specifically having about 20% husk after milling etc [2]. The main characteristic of wastes from agricultural activities or agro-industrial processing is their large quantity and availability [3]. In general, agrictural waste disposal practices are dumping of wastes in bush, road side, water ways etc, and burning in open air. Sometime, the wastes and their ashes are scattered on the agricultural fields as fertilisers. However, these practices cause the release of CO_2 gas in burning and disposal, while methane and other gases are released from the rotten agricultural wastes. A new reuse process of these wastes has to be established because these wastes, their ashes and gases are environmental burdens [4]. The chemical composition of these agricultural wastes are found to vary from one sample to another due to the differences in the type of paddy, crop year, climate, property and constituent of the soil and geographical conditions [5]. Composite materials have an edge over monolithic materials because of their superior properties such as high specific strength and stiffness, increased wear resistance, enhanced temperature performance together with better thermal and mechanical fatigue and creep resistance. Metal matrix composites (MMCs) are one of the important innovations in the development of advanced materi- als. Among the various matrix materials available, aluminum and its alloys are widely used in the fabrication of MMCs and have reached the industrial production stage. The emphasis has been given on developing affordable Al-based MMCs with various hard and soft reinforcements (SiC, Al_2O_3, zircon, graphite, and mica) because of the likely possibilities of these combinations in forming highly desirable composites [6]. The need for metal matrix composites in engineering components for different structural applications has motivated the need to find a cost effective production methods for these composites. The addition of hard and stiff ceramic phase has been established to improve the modulus behaviour and strength properties in the metallic matrices [7, 8].

But this improvement could vary from one ceramic material to another depending on the physical and chemical properties of the ceramic material. These properties include hardness, stiffness, and their interaction between each other and to the matrix material. Hence different ceramic material could give different improvement to the properties of matrix material and the selection of reinforcing material depends on the basic requirements of the components during usage. Reinforcing aluminium metal with rice husk and bagasse ashes as a source of silica particulate will yield a material that displays combination of physical and mechanical properties of both the metal matrix and the silica and alumina from the ashes. In our previous work Usman et al. [9, 10] the silica and alumina potentials of rice husk ash and bagasse ash were determined while in other works [11, 12], the density and some mechanical properties of composites produced by reinforcing aluminium alloy with rice husk ash and bagasse ash, respectively were determined. The aim of present study is to utilise the abundant agro-industrial waste (rice husk and bagasse) in the north eastern region of Nigeria as reinforcement in aluminium matrix composites, determine and compare the properties of these composites and determine which ash has better density and mechanical properties improving ability. The economic utilisation of these agro-residue and scraps will not only enhance the energy problem of the country but will also provide alternative engineering material for composites and ceramics applications, provide source of income to farmers and masses thereby escalating rural developments and reducing environmental pollution.

II. MATERIALS AND METHODS

2.1 Materials and Preparation

The materials used were rice husk, bagasse and aluminium scraps. The rice husk and bagasse were prepared, the ashes were produced and their chemical compositions were determined according to procedure reported in earlier studies [9, 10]. The results of the chemical composition of RHA and BA at 700^{o}C are given in Table 1 while the preparation of the scraps and its elemental analysis was determined as reported in earlier work [11, 12] and the results are shown in Table 2.

Table 1: Percentage chemical composition of rice husk and bagasse ashes burnt at 700^{o}C

Ashes	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	Others	LOI
RHA	97.095	1.135	0.316	0.073	0.825	0.146	0.181	0.092	Balance	0.965
BA	77.286	10.951	3.660	2.088	1.489	0.487	3.159	0.381	Balance	3.277

Table 2: Elemental percentage composition of synthesized aluminium alloy

Si	Mn	Fe	Cu	Zn	Mg	Cr	Ti	Al
6.70	0.80	1.50	3.20	0.50	0.35	0.10	0.10	Bal

2.2 Composites Production and Analysis

The Al-RHA and Al-BA composites were produced according to procedure reported in earlier works [11, 12].Test samples and the density and mechanical properties of the composites viz UTS, Young modulus, impact strength, hardness and fatigue strength were then determined according to the methods reported in literatures [11, 12]. Using SPSS statistical tool software, T-test among the means of the different properties of composites of rice husk ash and bagasse ash was carried out.

III. RESULTS AND DISCUSSIONS

3.1 Result of the Study

The result of the density and mechanical properties of the composites produce with RHA and BA as reinforcement are given in Figures 1- 6 while Table 3 shows the two tailed T-test result for paired samples of the properties of the produced composites.

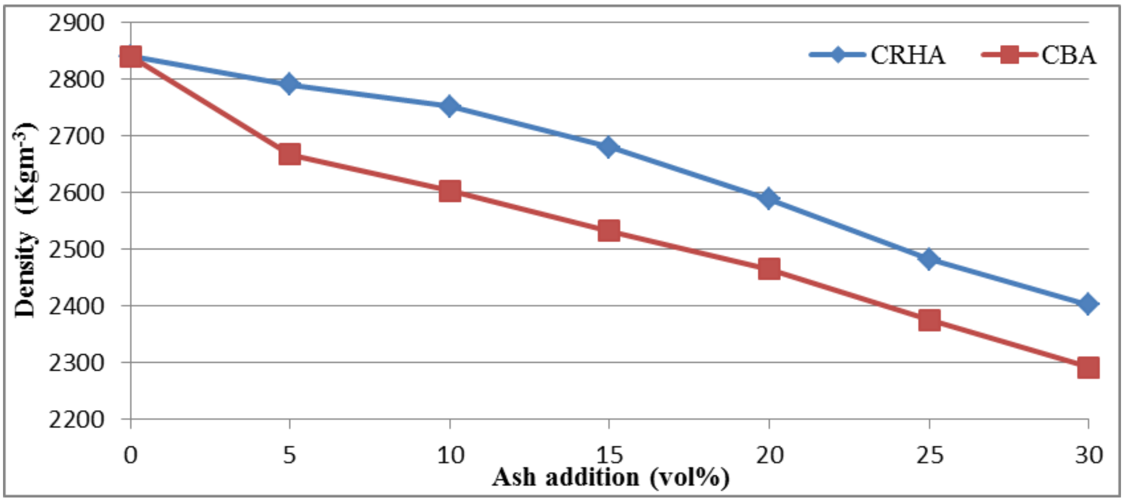

Figure 1: Variation of density with percentage ash addition

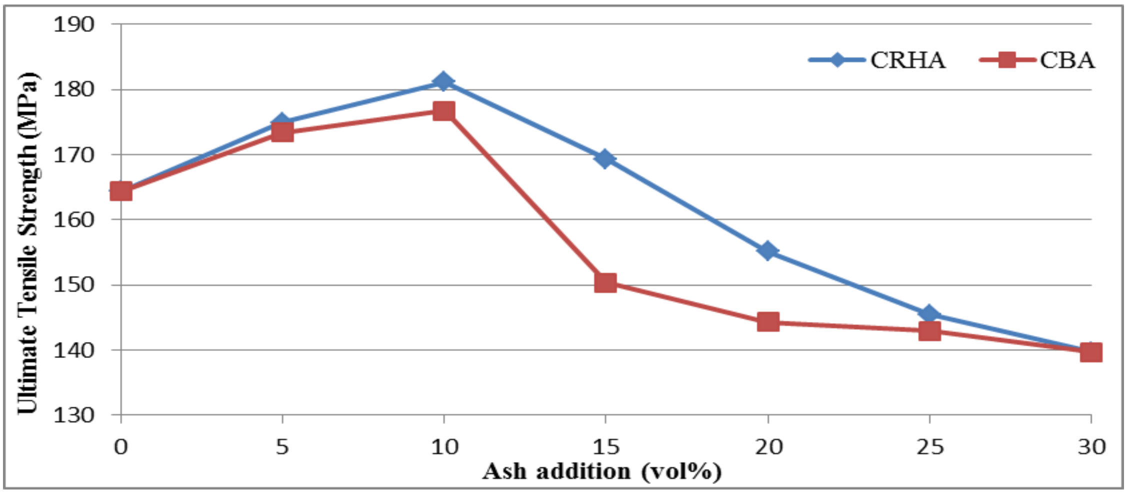

Figure 2: Variation of tensile strength with percentage ash addition

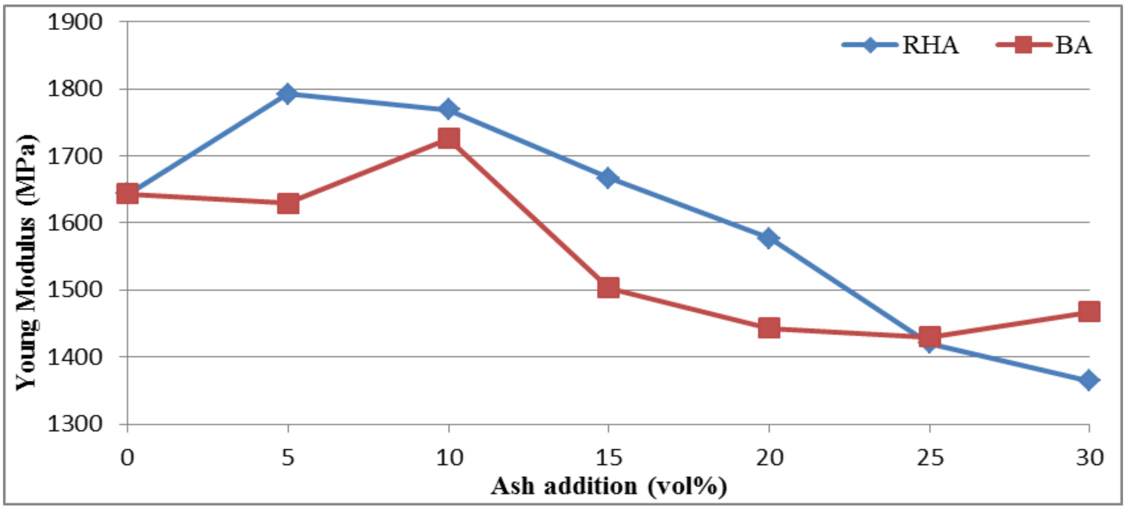

Figure 3: Variation of Young modulus with percentage ash addition

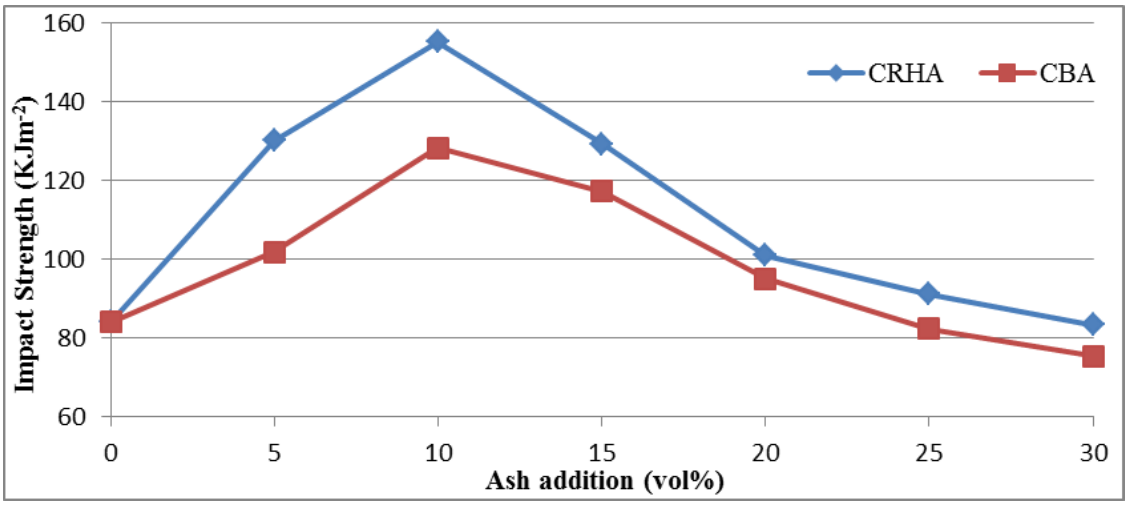

Figure 3: Variation of Impact strength with percentage ash addition

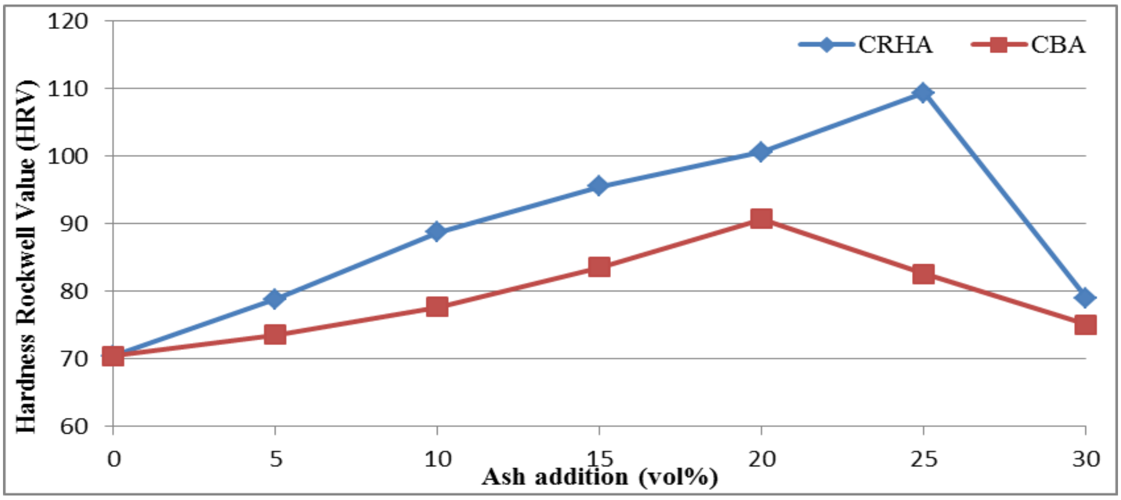

Figure 4: Variation of HRV value with percentage ash addition

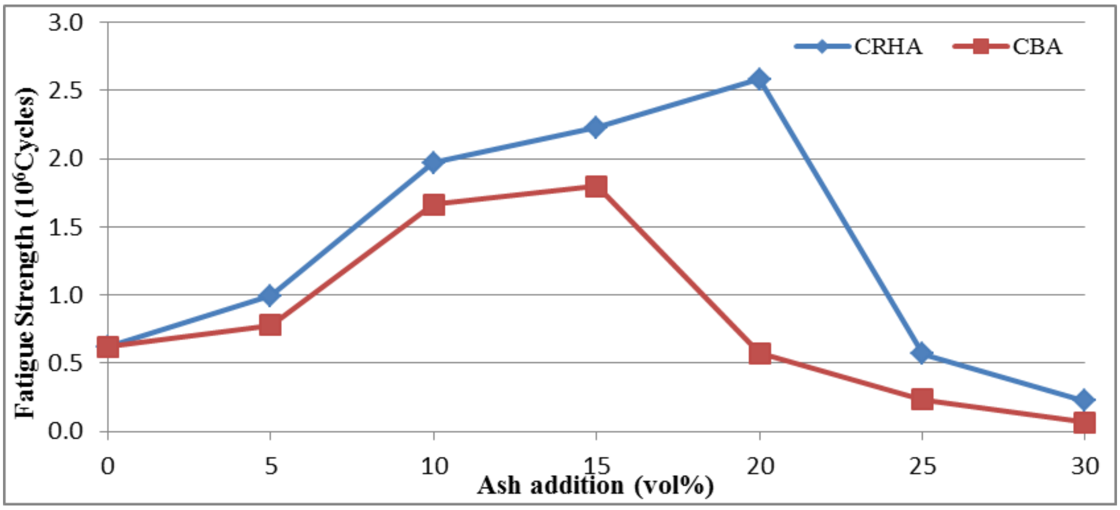

Figure 5: Variation of fatigue strength with percentage ash addition

Table 4: Result of two tailed T-Test of the data for the produced composites

Properties	Mean		T-Value	Significance	Remark
	Al-RHA	Al-BA			
Density	2648.22	2539.54	5.679	0.001	S
UTS	161.45	155.96	1.541	0.174	NS
Young modulus	1605.00	1548.87	1.460	0.195	NS
Impact Strength	110.57	97.73	3.164	0.019	S
Hardness	88.95	79.11	3.025	0.023	S
Fatigue Strength	$1.31x10^6$	$8.19x10^5$	2.190	0.071	NS

IV. DISCUSSION OF RESULTS

From the results of the density given in Figure 1, it can be deduced that the density of the produced composites decreases with the percentage volumes of RHA and BA addition which implies that the percentage decrease will rise by the percentage ash. The decrease in densities was from the addition of hard, stiff and low density reinforcement material with densities of 397.114kgm^{-3} and 238.269kgm^{-3} for RHA and BA, respectively which leads to the replacement of soft and high density matrix material (i.e. the synthesized aluminium alloy) with density of 2840.242kgm^{-3} in the composites thereby giving the composites overall decrease in densities with addition of the ashes up to 15% and 19% of the control sample at 30vol% RHA and BA, respectively. Comparing the densities and the percentage density decrease of CBA with that of CRHA, CBA give higher decrease in density of 2292.21kgm^{-3} which is 19% decrease from that of the control sample (2840.242kgm^{-3}). Hence, BA with low density of 238.27kgm^{-3} has better density decreasing ability as compared with RHA with higher density of 397.11kgm^{-3}. The result of decrease in density with RHA and BA addition conforms to the result reported in literatures [7, 13 -17]. From the result in Figure 2, the UTS of produced composites by addition of rice husk ash and bagasse ash increases with increase in RHA and BA addition up to 10vol% after which it decreases steeply with addition of RHA and BA to 30vol% RHA and BA. The UTS of the composites improved up to 10.2% and 7.5% for sample with RHA and BA, respectively over that of the control sample and up to 15vol% RHA and 10vol% BA the composites have better UTS as compared to that of the control sample. From Figure 3, the Young's moduli of the produced composites by adding RHA and BA as reinforcements follow approximately the same trend as the ultimate tensile strength. Below 10% ash there are less reinforcement and more ductile matrix which isolate the reinforcing particulates from each other, thereby maintaining or increasing the ductility of the composites. Less reinforcement in the matrix increase the adhesive force between the matrix and the reinforcement by isolating the reinforcing particulates. This shows that increase in ash percentage above 10% in the alloy introduce more reinforcements in the matrix and thereby more site for crack initiation and hence decreases the load bearing capacity of the composites thereby reducing the tensile strength [15]. The improvement in UTS and Young modulus of the composites with BA is lower as compared to that with RHA. These could be attributed to higher unwanted constituents (Fe_2O_3, Na_2O, K_2O, and MgO etc.) in BA as low or absence of these impurities are needed in the reinforcement material and their high quantity could adversely affect the ultimate tensile strength and Young modulus of the composites. The results and the trend support the results reported in some previous studies [6, 13, 14, 16 – 19].

From the impact strength test result in Figure 3, the impact strength of the composites increase from 84.020Jm^{-2} for the control sample to 155.244Jm^{-2} and 128.262Jm^{-2} at 10% ash for both RHA and BA composites, respectively. This improvement is about 84.8% and 52.7% of that of the control sample, respectively. The composites have better impact strength compared to the control sample at up to 25vol% RHA and 20vol% BA with values of 91.080Jm^{-2} and 95.092Jm^{-2} respectively for CRHA and CBA. Literature reviewed does not give adequate information on the impact strength of composites used for production of automobile parts to enable comparison. However, the results show that there is a significant improvement in the impact strength of the produced composites as compared with the unreinforced Aluminium alloy. The improvement in impact strength of the composites with BA is lower as compared to that with RHA. This could be attributed to higher unwanted constituents in BA as earlier mentioned, the presence of which could adversely affect the impact strength of the composites. From the result shown in figure 4, the hardness of the composites produced with RHA and BA increases approximately linearly from 70.467HRV for the control sample to 109HRV at 25vol% RHA and 90.767HRV at 20vol% BA and decreases to 79.033HRV at 30vol% RHA and 75.067HRV at 30vol% BA. Hence all the composites have higher HRV value than the control specimen and thus higher hardness. As can be observed in Figures 4, the hardness value increases up to 25vol% and 20vol% of reinforcement and beyond this reinforcement the hardness trend started decreasing. This improvement is up to 55.2% and 28.8% over that of the control sample for RHA and BA composites, respectively.

From the results in Figure 4, the improvement in hardness of the composites with RHA is higher as compared to that with BA which could be attributed to similar reasons advanced for UTS and impact strength. These results and the trend agree with results reported by many authors [7, 13 – 14, 18 -24]. From Figures 5, the number of cycles at which the composites failed increases with the ashes addition from 0.620×10^6 for the control sample to 2.582×10^6 at 20vol% RHA and decrease to 0.224×10^6 at 30vol% RHA while it increases to 1.797×10^6 at 15vol% BA and decrease to 0.066×10^6 at 30vol% BA. This implies that the fatigue strength of the composites increases with increase in ash addition up to 20% for RHA and 15% for BA and decreases with further addition up to 30%. The improvement in the fatigue strength is up to maximum of 259.7% and 190% over that of the control sample for RHA and BA, respectively. Hence the particulate reinforced composites show improved fatigue behaviour compared to unreinforced alloy at up to 20vol% RHA and 15vol% BA and such improvement is attributed to the higher stiffness reinforcement material in the composites. The improvement in fatigue strength of the composites with RHA is higher as compared to that with BA which could be attributed to higher unwanted constituents of up to 11.264wt% in BA as mentioned earlier. For a given matrix material, the stress concentration in a composite where the matrix is surrounded by high stiffness reinforcement particles, is lower than in the unreinforced alloy. Since more of the load is being carried by the high stiffness reinforcement particles in the composite, therefore the matrix material in the composites will be subjected to lower stress than similar matrix material in the unreinforced alloy [25]. Hence there is a decrease in the number of cycles after the reinforcement addition above 20% and 15% for RHA and BA, respectively.

From Table 3, the results of the statistical analysis (T-test) for the variation among the pairs of means of the density and mechanical properties of the produced composites with RHA and BA, show that there is a significant difference among the means of density, impact and hardness properties of the composites ($P < 0.05$) while tensile strength, Young modulus and fatigue strength t-test results show that, there is no significant difference among the means ($P > 0.05$).

V. CONCLUSIONS

The following conclusions were made from the results and the discussion:

[1] Rice husk and bagasse ashes were successfully incorporated into aluminium alloy as reinforcement at a temperature of 800 ± 20^{o}C.
[2] Incorporating rice husk and bagasse ashes into the aluminium alloy reduces its density and improves its mechanical properties.
[3] RHA and BA decrease the density of the matrix Al-7%Si alloy by 15% and 19%, respectively.
[4] RHA and BA increase the ultimate tensile strength of Al-6.7Si alloy by 10.2% and 7.5% of the control sample both at 10vol%, respectively.
[5] The impact strength of Al-6.7Si alloy increases up to 84.8% and 52.7% of the control sample with RHA and BA addition, respectively.
[6] RHA and BA improved the hardness of the matrix Al-7%Si alloy by 55.2% and 28.8%, respectively.
[7] RHA and BA improved the fatigue strength of matrix Al-6.7Si alloy by 316.5% and 190.0%, respectively.
[8] RHA show better improvement in mechanical properties of Al-7%Si alloy as compared to BA however, BA show better reduction in density.
[9] The result of Analysis of variance (T-test) among different pairs of properties showed that there is significant difference among the means of the properties of the composites with RHA and BA addition ($P < 0.05$) except for UTS, Young modulus and fatigue strength which show insignificant difference ($P > 0.05$).

VI. RECOMMENDATIONS

[1] The use of Al-RHA and Al-BA composites should be encouraged for production of engineering components.
[2] Other methods of production such as powder metallurgy, die casting etc. should be used to produce Al-RHA and Al-BA composites.
[3] Other test such as wear test, heat and electric conductivity test and the load and the cycles for fatigue test should be varied to fully characterise and compare the properties of the composite.

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