Fabrication, Reinforcement and Characterization of Metal Matrix Composites (MMCs) using Rice Husk Ash and Aluminium Alloy (A-356.2)

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Abstract— Fabrication and characterization of metal matrix composite of A-356.2 alloy reinforced with rice husk ash (RHA) particles are dealt in the present study. The metal matrix composites (MMCs) were prepared by addition of 2, 4, and 8 wt% RHA particulates through stir casting technique. The microstructure for characterization and mechanical properties of the fabricated composites were analyzed. The result reveals that the hardness of the aluminum alloy decreases with increase or in the increase in the weight fractions of RHA particles increases the ductility of the composites. The resultant composite product may be used as a replacement of raw aluminum alloy due to their stable hardness, strength, low cost, easy availability, light weight, low machine wear during processing etc. Various tests were also being performed for analyzing the properties. The study may provide a new era to the various products, parts and production themes given new opportunities.

Index Terms— *MMCs, RHA, Stir Casting, Fabrication, Reinforcement.*

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1 INTRODUCTION

TODAY'S world has been looking for the maximum optimization as possible in every field "and Engineering" is not an exception. In the quest for these developments, much affected is the environment. So the development of low cost metal matrix composites reinforced with eco-friendly material has been one of the major innovations in the field of materials to curtail environmental pollution. Aluminum alloy reinforced with particles offer superior mechanical properties compared with unreinforced alloys and hence reinforcements are candidates for engineering applications.

Among various reinforcements used like SiC, Al_2O_3 etc. rice husk ash [1-3] is one of the most inexpensive and low density reinforcement available in large quantities as solid waste byproduct. Approximately, 22 weighted percentage of paddy was received as husk during milling. Rice husks contain about 75 wt.% organic volatile matter and the balance 25 weighted percentage of this husk which is converted into ash during the firing process, is known as rice husk ash [4].

This RHA is a great threat to the environment, causing damage to the land and the surrounding area in which it is dumped. The need to protect environment is also a concern of this study to ensure the effective utilization of the agricultural waste.

Metal matrix composites (MMCs) possess significantly improved properties compared to unreinforced alloys. Hence composites with rice husk ash as reinforcement are likely to overcome the cost barrier for wide spread applications in advanced structural, aerospace, automotive, electronic, thermal management and wear applications and small engine applications. It is therefore expected that the incorporation of rice husk ash particles in aluminum alloy will promote yet another use of low cost waste byproduct and thereby, reducing the cost of aluminum products.

Nowadays the particulate reinforced aluminum matrix composites are gaining importance because of their low cost with advantage like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components. The present research is focused on the utilization of rice husk ash [5-6] in useful manner by dispersing it into aluminum to produce composites by stir casting method [7-10] and also reducing disposal and pollution problems of the husk.

2 OBJECTIVES

The main objective is gaining some valuable and beneficial performances or characteristics over the unreinforced composites. Some of them are:

- Processing of Aluminum alloy A-356.2 and Rice Husk Ash (RHA).
- To fabricate Metal Matrix Composites (MMCs) of aluminum alloy A-356.2 reinforced Rice Husk Ash.
- Analysis, study and characterization of different properties of treated Aluminum Matrix Composite.

3 LITERATURE REVIEW

Rice Metal-matrix composites (MMCs) begin with the concept of a metal matrix. A metal-matrix composite is a composite material with at least two constituent parts, one being a metal

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necessarily; the other material may be different metal or other materials such as ceramic or organic compound. When at least three materials are present, it is called Hybrid composite. MMCs have emerged as a class of materials capable of advanced structural, aerospace, automotive, electronic, thermal management, and wear applications. The performance advantage of metal matrix composites is their tailored mechanical, physical, and thermal properties that include low density, high specific strength, high specific modulus, high thermal conductivity, and high abrasion and wear resistance [11].

According to D. Siva Prasad and Dr. A. Rama Krishna (2011), the reduced weight and improved strength and stiffness of the MMCs are achieved with various monolithic matrix materials [11]. In recent years there has been an incredible interest in composites containing low density and low cost reinforcements. Among various reinforcements used like SiC, Al2O3 etc., rice husk ash [12-14] is one of the most inexpensive and low density reinforcement available in large quantities as solid waste by product.

In this thesis, our main approach to make a composite that enhances the various physical properties rather than normal metal alloy. Our interest is mainly to make a metal matrix composite made of A-356.2 alloy and RHA. It should also be noted that, Aluminum based matrices also have the advantage that they are the cheapest among other competing matrix materials (Copper, Titanium, Magnesium) for metal matrix composites (MMCs) development; and also are amenable to processing using techniques [31]. Also it conventionally suited for the production of metals and alloys [16-17]. According to Z. Mišković, I. bobić, S. tripković, A. rac, and A. vencl (2006) A-356 alloy or its similar alloy is used as a matrix for obtaining composites [15-16], which have an enhanced wear resistance, favourable mechanical properties at room temperature and enhanced mechanical properties at elevated temperatures. A356 solidifies in a wide enough temperature interval between the solidus and liquidus temperatures.

Here, A-356.2 alloy was used so as to evaluate the effect of added particle strengthener on the structure and mechanical properties of the composite without modification effects. The results of preliminary mechanical tests on the obtained composite were compared with the known values of mechanical properties of a commercial modified heat treated A356.2 alloy [17].

Aluminium matrix composites (AMCs) are noted for their unique combination of mechanical, physical and chemical properties which are scarcely attainable with the use of monolithic materials [18-20]. This has made AMCs a strong competitor to steel and other relevant alloy for use in a wide range of engineering applications [21]. AMCs are currently applied in the design of components for automobiles, aircrafts, marine structures and facilities, defensive assemblies, sports and recreation among many others [22-24]. Other notable advantages of AMCs are the relatively low cost of processing and its amenability to production utilizing processing techniques applied for the production of conventional monolithic metallic alloys [25, 26]. Currently, the design of high performance aluminium based composites like A-356.2 and RHA, MMC which significantly reduced cost is receiving much attention from materials researchers [27, 28].

In the present work, an attempt is made to utilize the abundantly available RHA as reinforcement in MMC's to improve the mechanical properties of the material. Here, rice husk ash is used as a filler material of the MMCs. Among others filler material like coconut shell ash, bamboo leaf ash, groundnut shell ash RHA have the advantages of low densities and processing cost compared with other filler material's processing cost [29, 30]. The use of hybrid reinforcements utilizing A-356 or its similar alloy and agro waste ashes as a means of improving the properties of AMCs has attracted interest recently with very encouraging results obtained [31].

Our overall approach is to developed and fabricated something unique from the traditional metal or similar types of aluminium alloy. After completing the experimental work, the resulting composite not only just a unique composite but it also enhances the physical properties. The resulting composite have been used for vast and advanced applications with low cost production and also this type of composite is much more sustainable due to environmental impact rather than normal aluminium alloy.

4 FABRICATION PROCESS

4.1 Total Overview of Fabrication

Rice Husk Ash (RHA) was mainly used as reinforcement and Aluminium A-356 was used as matrix in this study. This metal alloy mainly purchased from Khulna. Rice husk is collected from rural area of Khulna, Bangladesh. The methodology has been showed in step by step below.

4.1.1 Fabrication process of Rice Husk

In the present study, rice husk was procured from local sources in Khulna and was thoroughly washed with water to remove the dust and dried. In order to sustain for further operations, the Rice husk is usually dried at room temperature. Here no chemical properties are normally changed. Only dust and other unnecessary substances are removed for further actions. [32]

4.1.2 Fabrication process of Rice Husk Ash (RHA)

Initially, washed dry rice husk is taken to graphite crucible. By proper arrangement of furnace and graphite crucible, washed rice husk was then heated up to 200° C for one hour. This operation removes the moisture and organic matter. During this operation, the color of the husk changed from yellowish to black because of carring of organic matter.

Fig. 1. Placing rice husk in graphite crucible

Fig. 2. Heated rice husk at 200 °C

Fig. 3. Black RHA after heated at 200°C

After heated rice husk at 200°C, then the ash again heated up to 600°C to 800°C for 6 hours, in order to remove the carbonaceous material [38]. In this operation, the rice husk is completely burnt in the presence of oxygen. For obtaining desired properties the ash is further heated in the electrical furnace at 750°C for 12 hours. Here, the rice husk ash is used as a filler material. After finalized this operation and after cooling the ash's colour is completely changed from black to gray or slightly greyish white.

Fig. 4. RHA heated at 600°C

Fig. 5. Cooling of ash

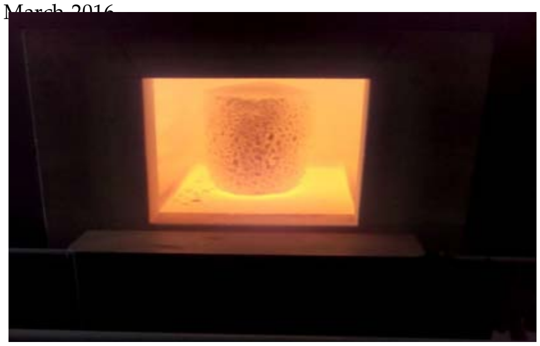

Fig. 6. RHA heated in electrical furnace

Fig. 7. Different states of RHA

4.2 Experimental specimen preparation

4.2.1 Preparation of Aluminium alloy (A-356.2)

Initially, A-356.2 Al alloy was charged into the graphite crucible. At first the aluminium alloy is heated to about 750 ºC till the entire alloy in the crucible was melted. After the molten metal was fully melted, it stirred manually in order to remove porosity, bubbles inside of aluminium alloy. The stirrer made up of stainless steel was lowered into the melt slowly to stir the molten metal [33].

Fig. 8. Preparation of Aluminium alloy (A-356.2)

4.2.2 Mixing of Rice Husk Ash (RHA) with Aluminium alloy (A-356.2)

In another crucible the reinforcement particles (RHA) were preheated to 800°C for 1 hour before incorporation into the melt. The preheated RHA particles were added into the molten metal at a constant rate during the stirring time. The stirring was continued for another 5 min even after the completion of particle feeding. Constant stir is necessary in order to uniform mixture [33].

4.2.3 Analyzing specimen preparation

For analyzing different composition of composites mainly prepared by RHA and A-356.2 are given below:
Specimen 1: Aluminium alloy A-356.2 fabricated with 2 percentages of RHA
Specimen 2: Aluminium alloy A-356.2 fabricated with 4 percentages of RHA
Specimen 3: Aluminium alloy A-356.2 fabricated with 8 percentages of RHA

4.2.4 Preparation of sand mold and pouring of mixture into the mold

The sand mold is mainly prepared by green sand which is also known as molding sand. The mold mainly prepared with the help of drag and cope. Here the molding pattern can be made by some standard specimen. In order to obtain uniform solidification, the mold was also preheated to 500ºC in C.D. Oven about 30 minutes. The mixture was poured slowly into the mold. Using this process 2, 4, and 8% by weight RHA particle-reinforced composites were produced. The casted MMC samples were examined for different destructive and non-destructive test for further actions.

4.3 Specimen Preparation for testing

After molding and cooling process has been completed the mold was broken to find the desired work piece. For testing these work piece for different purpose different machining process is necessary. Some of them are:

- Turning operation has been completed with the help of lathe machine for turning cylindrical work piece.
- Shaper operation is required to shaping of rectangular or square bar.
- Threading operation is required for cutting of thread in cylindrical work piece.
- Cutting V-notch with the help of triangular file.

4.4 Specimen testing

4.4.1 Hardness testing (Brinell Hardness Test)

The Brinell tester usually consists of a hand-operated hydraulic press, designed to force a ball indenter into the test specimen. Standard procedure requires that the test be made of a ball of 5 mm diameter under a load of 3000 kg for ferrous metals, or 500 kg for non-ferrous metal. For ferrous metals the loaded ball is pressed into the test specimen for at least 10 seconds; for non-ferrous metals the time is 30 seconds. The diameter of the impression produced is measured by means of a microscope containing an ocular scale, usually graduated in tenths of a millimeter, permitting estimates to the nearest 0.05 mm.

The Brinell hardness number is the ratio of the load in kilograms to the impressed area in square millimeters, and is calculated from the following formula: $BHN = \frac{[illegible]}{[illegible]}$
Where, L = test load, kg
D = diameter of ball, mm
D = diameter of impression, mm [34]

4.4.2 Impact testing

The toughness of a material can be calculated with the help of an impact tester. Generally, notch type specimens are used for impact tests. Two general types of notches are used in bending impact tests, the keyhole notch and the V notch. Here Izod specimen is placed in the vise so that one end is free and is therefore a cantilever beam.

The ordinary impact machine has a swing pendulum of fixed weight which is raised to a standard height depending upon the type of specimen tested. At that height, with reference to the vise, the pendulum has a definite amount of potential energy. When the pendulum is released, the energy is converted to kinetic energy until it strikes the specimen. The charpy specimen will be hit behind the V notch [35].

4.4.3 Tensile testing

Tensile test is performed to determine certain mechanical properties. A specifically prepared sample is placed in the heads of the testing machine and an axial load is placed on the sample through a hydraulic or mechanical loading system. The force is indicated on a calibrated dial. If the original cross sectional area of the specimen is known, the stress developed at any load may be calculated [36].

4.4.3.1 Elongation testing

The elongation test can be determined by fitting together of fractured parts of the specimens. After that, measure the distance between the fractured parts of the specimen.
Elongation (percent) = $\frac{[illegible]}{[illegible]} * 100$
Where, L_f = Final gauge length
L_o = Original gauge length [37]

4.4.3.2 Reduction in area testing

The reduction in area can be determined from the broken halves of the tensile specimen by measuring the minimum cross sectional area by using the following formula: Reduction in area (percent) = $\frac{[illegible]}{[illegible]} * 100$
Where, A_o = Original cross-section area
A_f = Final cross-sectional area [37]

4.4.4 Compresive testing

Compressive test is usually performed to determine and observe how much stress a composite material or alloy can sustain. It calculates the amount of forces that the specimen can sustain without fracture or deform. This test usually performed by compressive tester and usually results the compressive force before deform as KN (kilo-newton).

5 RESULT AND COMPARISON

5.1 Results of tensile stress of composites

In the experimental work piece, it has been found that the tensile stress is decreased due to the increased percentage of RHA in aluminum alloy.

The effects of loading on tensile stress of different composites can be showed by the following table:

TABLE 1
Tensile Stresses of different composites

Experimental Specimen	Tensile Stress (σ)
Specimen 1	174.6 MPa
Specimen 2	239.36 MPa
Specimen 3	277.66 MPa

5.2 Results of hardness of composites

The hardness of different composite material has a great impact on its mechanical properties. In our experimental work piece, it has been found that the hardness of different work piece is decreased due to the increased percentage of RHA in aluminium alloy. Thus, the mixing of RHA which act as a filler material increases of the ductility of different composites which decreases the hardness of composites.
The effects of loading on hardness of different composites can be showed by the following table:

TABLE 2
Hardness of different composites

Experimental Specimen	Hardness number (BHN)
Specimen 1	76.78
Specimen 2	82.45
Specimen 3	84.44

5.3 Results of absorbed energy of composites in impact test

Impact test identifies how much energy a material can absorb. Our specimens are mainly made of aluminum alloy, which has low hardness and high ductility. For this reason, for calculating absorbed energy the pendulum set to the low position for observing accurate values.
The absorbed energy of different composites can be showed by the following table:

TABLE 3
Absorbed energy of different composites in impact test

Experimental Specimen	Absorbed energy
Specimen 1	1.0 Kg-m
Specimen 2	1.2 kg-m
Specimen 3	1.3 kg-m

5.4 Results of compressive stresses of composites

In the experimental work piece, it has been found that the compressive stress is decreased due to the increased percentage of RHA in aluminium alloy.

The effects of loading on tensile stress of different composites can be showed by the following table:

TABLE 4
Compressive stresses of different composites

Experimental Specimen	Compressive Stress (σ_C)
Specimen 1	232.64 MPa
Specimen 2	261 MPa
Specimen 3	267.9 MPa

5.5 Results on elongation of composites during tension

In the experimental work piece, it has been found that during tension operation the elongation of different composites increased due to the increased percentage of RHA in aluminum alloy.
The effects of loading on tensile stress of different composites can be showed by the following table:

TABLE 5
Elongation of different composites

Experimental Specimen	Elongation Percentage
Specimen 1	3.37%
Specimen 2	2.33%
Specimen 3	2.01%

5.6 Results on reduction in area of composites during tension

In the experimental work piece, it has been found that during tension operation the cross sectional area of different composites increased due to the increased percentage of RHA in aluminum alloy. Here area is measured by the cross sectional area of the ruptured surface due to tensile force.
The effects of loading on tensile stress of different composites can be showed by the following table:

TABLE 6
Area reduction of different composites in tension

Experimental Specimen	Reduction in area
Specimen 1	20.03%
Specimen 2	23.46%
Specimen 3	29.51%

5.7 Variation of properties between standard and fabricated A-356.2

5.7.1 Hardness Properties

Hardness is one of the major mechanical properties of a material, metal, or composite. Hardness is the measurements of how resistant solid matter is to various kinds of permanent shape change when a compressive load is applied or deformation. Microscopic hardness is generally characterized by strong intermolecular bonds, but the behavior of solid material under force. Usually it is measured by indentation. Generally used indentation ball is of diameter 10 mm. but the used indenter was of 5 mm. Standard casted A-356.2 have a balanced hardness property. The standard BHN no. for A-356.2 is 75 [39].

Here different specimen hardness calculation can be showed as calculated as follows:

Hardness for specimen 1: BHN_1 = 76.78
Hardness for specimen 2: BHN_2 = 82.45
Hardness for specimen 3: BHN_3 = 84.44

The comparison of tensile stress between standard specimen and different specimens can be showed by a graph:

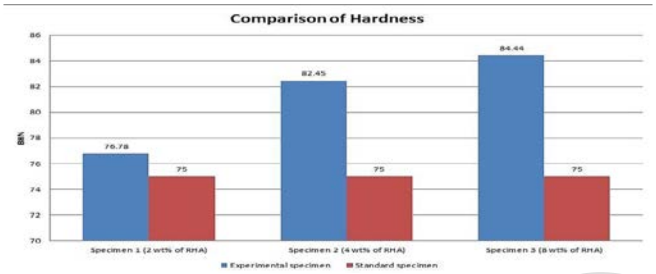

Fig. 9. *Comparison of different specimen's hardness with standards*

5.7.2 Tensile Properties

Standard casted aluminium alloy A-356.2 has a good tensile property. It has been found that standard tensile stress of aluminium A-356.2 is almost 230 MPa [39].

Here different specimens stress calculation can be showed as calculated as follows:

Tensile stress for specimen 1: σ_1 = 174.6 MPa
Tensile stress for specimen 2: σ_2 = 239.36 MPa
Tensile stress for specimen 3: σ_3 = 277.66 MPa

The comparison of tensile stress between standard specimen and different specimens can be showed by a graph:

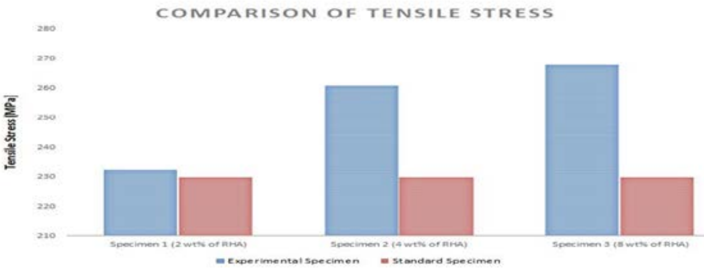

Fig. 10. *Comparison of different specimen's tensile strength with standards*

5.7.3 Compressive Properties

Compressive property defines how much compressive force a work piece can sustain without damage the work piece. It has been found that, compressive strength of aluminium alloy A-356.2 is around 234 to 245 [40].

Here different specimens' compressive strength calculation can be showed as calculated as follows:

Compressive strength for specimen 1: σ_c = 239.64 MPa
Compressive strength for specimen 2: σ_c = 261 MPa
Compressive strength for specimen 3: σ_c = 267.9 MPa

The comparison of compressive stress between standard specimen and different specimens can be showed by a graph:

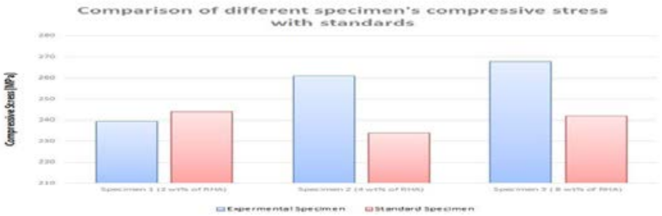

Fig. 11. *Comparison of compressive strength with standards*

5.7.4 Elongation Properties

Elongation of a work piece defines how much length increases in a work piece during tension. It has been found that due to increase in percentage of RHA in aluminium alloy, ductility increases. And due to increase of ductility, elongation percentage of different specimen increases. Standard aluminium alloy A-356.2 has elongation percentage around 2 [39].

Here different specimens' elongation percentage is calculated as follows:

Elongation percentage for specimen 1: 3.37%
Elongation percentage for specimen 2: 2.33%
Elongation percentage for specimen 3: 2.01%

The comparison of tensile stress between standard specimen and different specimens can be showed by a graph:

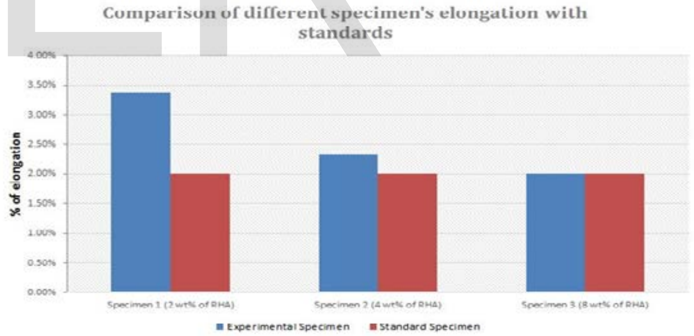

Fig. 12. . *Comparison of different specimen's elongation with standards*

6 CONCLUSION

Rice husk ash particles were successfully incorporated in A 356.2 alloy by using stir casting techniques. Microstructure analysis shows the uniform distribution of rice husk ash particles in the aluminum alloy. The microstructure revealed good interfacial bond between matrix and rice husk ash particles. The hardness of A356.2/ RHA composites increases with increase in rice husk ash contents. The ultimate strength increases with increase in rice husk ash content. The compressive strength of A356.2/RHA composites also increases with the increase in rice husk content. The elongation increases with the increase in rice husk ash content. The toughness measured by impact test increases in rice husk ash content. Rice husk ash, the agricultural waste generated from milling paddy can be successfully used as a reinforcing material to produce Metal Matrix Composites (MMCs) components in aluminum matrix. Thus the use of RHA for the production of composites can turn agricultural waste into industrial wealth and inevitably solve the problem of storage and disposal of RHA. Incorporation of rice husk ash particles in aluminum matrix can lead to the production of low cost aluminum composites with improved hardness and strength. These composites can find application where lightweight materials are required with good stiffness and strength.

REFERENCES

[1] P.Rohatgi, “Cast aluminum-matrix composites for automotive applications,” JOM Journal of the Minerals, Metals and Materials Society, Vol. 43(4), page 10-15, 1997.

[2] M.K.Surappa, Sadhana, “Aluminium matrix composites: Challenges and opportunities,” Journal of Materials Science, Vol. 28(1), page 319-334, 2003.

[3] S.Das, T.K.Dan., S.V.Prasad., and P.K.Rohatgi., “Aluminium alloy-rice husk ash particle composites,” Journal of Materials Science Letters, Vol. 5(5), page 562-564, 1986.

[4] V.P.Della., I.Kühn., and D.Hotza, “Rice husk ash as an alternate source for active silica production,” Materials Letters, Vol. 57(4), page 818-821,2002.

[5] S.Chandrasekhar., K.G.Satyanarayana., P.N.Pramada., P.Raghavan and T.N.Gupta., “Review processing, properties and applications of reactive silica from rice husk - an overview,” Journal of Materials Science, Vol. 38(15), page 3159-3168, 2003.

[6] A.M.Davidson., and D.Regener., “A comparison of aluminium-based metal-matrix composites reinforced with coated and uncoated particulate silicon carbide,” Composites Science and Technology, Vol. 60(6), page 865-869, 2000.

[7] H.Zhang., X.Zhao., X.Ding., H.Lei., X.Chen., and Z.Wang, “A study on the consecutive preparation of d-xylose and pure superfine silica from rice husk,” Bioresource Technology, Vol. 101(4), page 1263-1267, 2010.

[8] D.S.Prasad., and A.R.Krishna., “Tribological Properties of A356.2/RHA Composites”, Journal of Material Science and Technology, Vol. 28(4), page 367-372, 2012.

[9] M.K.Surappa., “Dry sliding wear of fly ash particle reinforced A356 Al composites,” Wear, Vol. 265(3), page 349-360, 2008.

[10] R.Ipek., “Adhesive wear behaviour of B_4C and SiC reinforced 4147 Al matrix composites (Al/B4C–Al/SiC),” Journal of Materials Processing Technology, Vol. 162, page 71-75, 2005.

[11] D. Siva Prasad and Dr. A. Rama Krishna, “Production and Mechanical Properties of A356.2 /RHA Composites”, International Journal of Advanced Science and Technology, Vol. 33, page 51-53, August, 2011.

[12] Sathy Chandrasekhar, P. N. Pramada, Jisha Majeed, “Effect of calcination temperature and heating rate on the optical properties and reactivity of rice husk ash”, J Mater Science, Vol. 41, page 7926-7933, 2006.

[13] P. Mishra, A. Chakraverty, H. D. Banerjee, “Production and purification of silicon by calcium reduction of rice-husk white ash”, Journal of Materials Science, Vol. 20, page 4387-4391, 1985.

[14] Ubolluk Rattanasak, Prinya Chindaprasirt, Prasert Suwanvitaya, “Development of high volume rice husk ash alumino silicate composites”, International Journal of Minerals, Metallurgy and Materials Vol. 17, Number 5, Page 654, October 2010.

[15] Z. MIŠKOVIĆ, I. BOBIĆ, S. TRIPKOVIĆ, A. RAC, A. VENCL, “The Structure and Mechanical Properties of an Aluminium A356 Alloy Base Composite With Al_2O_3Particle Additions”, Tribology in industry, Vol. 28, No. 3&4, page 23, 2006.

[16] N. Natarajan, S. Vijayarangan, I. Rajendran, “Wear behaviour of A356/25SiCpaluminium matrix composites sliding against automobile friction material”, IJSER, page 812-822, 2006.

[17] Ljevački priručnik, Zagreb, “Development of rice husk”, IJSR page 467, 1984.

[18] Kenneth Kanayo Alaneme, Peter Apata Olubambi, “Corrosion and wear behaviour of rice husk ash Alumina reinforced Al-Mg-Si alloy matrix hybrid composites”, j mater res technol., Vol. 2(2), page. 188-189, 2013.

[19] Christy TV, Murugan N, Kumar S. A, “Comparative study on the microstructures and mechanical properties of Al 6061 alloy and the MMC Al 6061/TiB2/12”. JMMCE, page 57-65, 2010.

[20] KK Alaneme, “Influence of thermo-mechanical treatment onthe tensile behaviour and CNT evaluated fracture toughnessof Borax premixed SiCp reinforced aluminium (6063) composites”, IJMME, Vol. 7, page 96-100, 2012.

[21] Rohatgi P, Schultz B., “Light weight metal matrix composites-stretching the boundaries of metals”, Mater Matt, Vol. 2, page 16-9, 2007.

[22] Macke A, Schultz BF, Rohatgi P., “Metal matrix composites offer the automotive industry an opportunity to reduce vehicle weight, improve performance”, Adv. Mater Processes, page 19-23, 2012.

[23] KK Alaneme, AO Aluko, “Fracture toughness (K1C) and tensile properties of as- cast and age-hardened aluminium(6063) silicon carbide particulate composites”, Sci Iran Trans A, page 992-996, 2012.

[24] Miracle DB., “Metal matrix composites”, Science to technological significance. Compos Sci Technol, page 2526-2540, 2005.

[25] MK Surappa, Sadhana, “Aluminium matrix composites: challenges and opportunities”, page 281-282, 319-334, 2003.

[26] M Adiamak, “Selected properties of aluminium alloy based composites reinforced with intermetallic particles”, JAMME, Vol. 14, page 43-47, 2006.

[27] H Zuhailawati, P Samayamutthirian, CH Mohd Haizu, “Fabrication of low cost aluminium matrix composite reinforced with silica sand” J Phys Sci, Vol. 18, page 47-55, 2007.

[28] Maleque MA, Atiqah A, Talib RJ, Zahurin H., "New natural fibre reinforced aluminium composite for automotive brake pad", IJMME Vol. 7, page 166-170, 2012.

[29] Mahendra KV, Radhakrisna A., "Characterization of stir cast Al-Cu-(fly ash+SiC) hybrid metal matrix composites." J Comp Mater, page 989-1005, 2010. And mater res technol, page 188-194, 2013.

[30] Madakson PB, Yawas DS, Apasi A., "Characterization of coconut shell ash for potential utilization in metal matrix composites for automotive applications", IJEST, Vol. 4, page 1190–1198, 2012.

[31] K.K. Alaneme, T.M. Adewale, "Influence of Rice Husk Ash-Silicon Carbide Weight Ratios on the Mechanical behavior of Al-Mg-Si Alloy Matrix Hybrid Composites", Tribology in Industry, Vol. 35, No. 2, 2013.

[32] D. Siva Prasad, "Production and Mechanical Properties of A356.2 /RHA Composites", International Journal of Engineering Science and Technology, Vol. 2, page 7603-7608, 2010.

[33] Peter Apata Olubambi and Kenneth Kanayo Alaneme, "Corrosion and wear behaviour of rice husk ash - Alumina reinforced Al-Mg-Si alloy matrix hybrid composites".

[34] Introduction to physical metallurgy by Sidney H Avner, Second edition; Tata McGraw Hill Education Private limited; page 26.

[35] Introduction to physical metallurgy by Sidney H Avner, Second edition; Tata McGraw Hill Education Private limited; page 42, 43.

[36] Introduction to physical metallurgy by Sidney H Avner, Second edition; Tata McGraw Hill Education Private limited; page 37, 38.

[37] Introduction to physical metallurgy by Sidney H Avner, Second edition; Tata McGraw Hill Education Private limited; page 41.

[38] S. Das, T. K. Dan, S. V. Prasad, P. K. Rohatgi, "Aluminium alloy-rice husk ash particle composites", journal of Materials Science Letters, page 562-564, 1986.

[39] Handbook of A356.2 ALUMINIUM CASTING ALLOY, Hadleigh Castings, Aluminium technology.

[40] Handbook of aluminium, Alcan Prime alloys, AA 354, A356, A356.2; C355 Foundry Ingot; page 6.