DEVELOPMENT AND CHARACTERIZATION OF AL / RICE HUSK ASH GREEN METAL MATRIX COMPOSITE

Manish Kumar singh[1], Kuldeep Kumar[1], Akash Rai[1], Vikas Kumar Yadav[1], SashiPrakash Dwivedi[1*]

[1]*Mechanical Engineering Department, Noida Institute of Engineering and Technology, India*

ABSTRACT

In This Investigation Exhaust Literature review of aluminum 6063 /RHA was carriedoutindividualeffect of RHA of al 6063 observed from the Result of Various researcher. It was find that material properties were improved. While cast density reduces.

Keywords:Aluminum6063, Rice husk , Hardness, Tensile Strength,*Toughness, Density, Porosity etc.*

I INTRODUCTION

Today's the word has been looking for the maximum optimization as possible in every field. Engineering is not an exception engineers are looking for creating the extreme best from the best during these developments some way or the other much affected is the environment. The development of low cost metal matrix composite reinforced with eco-friendly material has been one of the major innovation in the field of materials in the past few decades .Aluminum alloy reinforced with ceramic particles exhibit superior mechanical properties to unreinforced AL alloys and hence are candidate for engineering application.

Now the most of the research work carried out to develop composites using various recycled wastes, especially in developing composites using most environmentally friendly agro-waste (lignocellulosic materials) as reinforcing fillers .Among them rice husk (RHA) is an agriculture waste by product abundantly available. During milling of paddy about 78% of weight is received as rice, broken rice and brain. Rest 22% of the weight of paddy is received as husk. This husk is used as fuel in the rice mills to generate steam for the parboiling process. This husk contains about 75% of organic volatile matter and the balance 25% of the weight of this husk is converted into ash during the firing process, is known as rice husk ash (RHA). For every 1000 kgs of paddy milled, about 220 kgs (22%) of husk is produced , andwhen this husk is burnt in the boilers , about 55 kgs (25%) of RHA is generated .It is assumed that about 70 million tons of RHA is produced annually worldwide.

This RHA is great environment threat causing damages to the land and the surrounding area in which it is dumped. This ensures the researcher for effective utilization of this agriculture waste. Therefore the environment is protected from these waste .The recent research studies reportedthat RHA in turns contains around 85% - 90% amorphous silica. On thermal treatment the silica converts to crystobalite, which is a crystalline form of silica. However, under controlled burning condition, amorphous silica with high reactivity, ultra –fine size and large surface area is produced. This micro silica can be a source for preparing advanced materials like Sic, Si3N4, elemental Si and Mg2si.

The present research is focused to utilize the rice husk by dispersing it into the aluminum to produce matrix composites through stir cast route on thelines of .The various weight fraction of rice husk particles are considered in the study. Experiments have been conducted to assess the mechanical behavior of the rice husk ash ceramic composite .Further microscopic studies were conducted to establish the wear mechanism and transition from one mechanism to another using the scanning electron microscope (SEM).

II LITERATURE REVIEW

DHADSANADHEP et al. [2008] fabricated powder metallurgy by in-situ reaction to form alumina during fabrication. Starting materials were mixture of aluminum, copper, and silica powders. Silica is in form of rice husk ash. The mixture was cold compacted, and sintered at 650°C for 1 h. Hot forging was carried out to further consolidate the sintered billet, followed by 10-h heat treatment at temperatures between 590 to 650°C. Phase analysis by XRD confirmed that in-situ reaction between silica and aluminum powders occurred during heat treatment at temperatures above 590°C. The products of reaction were silicon and gamma-alumina. Microstructure investigation showed that the reacted areas were the previous locations of silica powder. In some areas remaining silica was found amid reaction products. Hardness of the fabricated composite made of Al-4wt .% Cu and 5, 10 and 15vol% silica are 16, 23, and 30 HRA, respectively.[1]

PRASAD et al. [2010]. The metal matrix composites (MMC's) were prepared by addition of 2, 4 and 8wt% RHA particulates through stir casting technique. Scanning electron microscope equipped with energy dispersive X-ray analyzer is used for micro structural characterization and the presence of silicon particles in the composites .Mechanical properties

like density and hardness were measured for the composites. As the percentage of RHA particles increases, the density of the composites decreases and there is slight increase in the hardness were observed.[2]

Luangvaranunt et al.[2010] The starting powders were aluminum, copper, and rice husk ash silica. Processing was by sintering at 650_C for 3.6 k s, hot forging of sintered billet at600_C under 660 MPa pressure, followed by heat treatment. Hot forging of sintered billet induced plastic deformation of the matrix as well as fractured the porous silica, thus created ultimate contact between the two phases. The following heat treatment produced alumina, which was there enforcement phase, by chemical reaction between fractured rice husk ash silica and aluminum matrix. The fabricated composite contained y-and k -alumina, and elemental silicon in matrix of aluminum solid solution. Addition of copper facilitated sintering by formation of liquid phase, as well as yielding a matrix material which can be strengthened by precipitation hardening. Maximum hardness obtained was 44 HRA, for composite material using 15 vol % rice hush ash silica. Peak hardness of the matrix was in range of 130–136 HV, after aging for 28.8 to 43.2 k.[3]

Ferraro et al.[2012] Rice husk ash (RHA) is one of the promising pozzolanic materials that can be blended with Portland cement for the production of durable concrete and the reduction of the environmental impact of the cement industry. Commercially available RHA contains 3% or more graphitic carbon which determines the dark pigmentation of the material. Recent studies have led to the production of carbon neutral rice ash named OWRHA (Off-White Rice Husk Ash), with no graphitic carbon, no crystalline SiO2 and toxic metals, so legitimately considered environmental friendly. This paper presents the results of an experimental investigation on the strength, porosity, corrosion resistance and thermal conductivity of white concrete blended with OWRHA. The results show that the compression strength of the concrete increases with replacement level of OWRHA, while the porosity decreases. Accelerated corrosion tests demonstrate that the use of OWRHA increases the corrosion resistance at all levels of replacement. The results on mortal samples showed that also thermal conductivity and density decrease with the increase in OWRHA and with age. With the intention of reducing the carbon footprint in the cement industry, this study evidences encouraging results for the use of OWRHA in sustainable construction.[4]

Rama Krishna et al.[2012] The RHA particles were added into the matrix melt by creating a vortex with the help of a mechanical stirrer and the melt temperature was maintained between 800 and 850 ±C. Dry sliding wear experiments were performed in a pin on disc wear equipment against a chromium steel disc at 30 ±C. Scanning electron microscopy is used tostudy the wear characteristics of the unreinforced Al alloy and the A356.2/RHA composites. From the experiments it is observed that the composites exhibit higher hardness and resistance to wear as compared to unreinforced Al alloy.[5]

Kusbiantoro et al. [2012] The development of fly ash and microwave incinerated rice husk ash (MIRHA) blend as the source materialforgeopolymer concrete was studied through the observation of the hardened specimen strength. Compressive and bonding strength of the specimen indicate the significance of curing temperature inthe activation of MIRHA particles. The elevated temperature is presenting a suitable condition for rapiddissolution of silicate monomer and oligomer from MIRHA surfaces, which supports the formation ofsupersaturatedaluminosilicate solution in geopolymer system. It contributes to the refinement of poresstructure via the increasing geopolymer gel growth, as observed in the consistent compressive strengthdevelopment of ambient-cured specimen to the oven-cured specimen. Densification of geopolymerframework appears to be the main contributor to the increasing bonding capacity of geopolymer binder.[6]

Singla et al. [2013] Metal composites possess significantly improved properties including high tensile strength, toughness, hardness, low density and good wear resistance compared to alloys or any other metal. There has been an increasing interest in composites containing low density and low cost reinforcements. Among various reinforced materials used, fly ash is one of the most inexpensive and low density reinforcement available in large quantities as waste product during combustion of coal in thermal power plants as well as in the brick factory and rice mill. Hence, composites with fly ash with Al 7075 as reinforcement are likely to overcome the cost barrier as well as the different physical and mechanical properties for widely used in the automotive and space craft applications.[7]

Sasakul et al. [2013] studied the effects of ground rice husk–bark ash (GRBA) on compressive strength, chloride diffusion coefficient,chloride binding capacity, and steel corrosion of concrete exposed to a marine site for 5 years werereported and discussed. The GRBA was used as a pozzolanic material to replace Type I Portland cemented 0%, 15%, 25%, 35%, and 50% by weight of the binder. Concrete cube specimens of 200 mmwere cast, andsteel bars were embedded in concrete. Concrete specimens were exposed to a tidal zone of seawater inthe Gulf of Thailand. After 5-year exposure, the specimens were tested for compressive strength, acid soluble and water soluble chlorides and corrosion of embedded steel bar. The results showed that during5-year exposure, GRBA concretes gained strength faster than Type I Portland cement concretes and nostrength loss was found in GRBA concrete. The findings also indicated that the durability of concrete in terms of chloride diffusion coefficient, chloride binding capacity, and resistance to corrosion of embedded steel could be considerably improved by utilizing GRBA as high as 35%.[8]

Saravanan et al. [2013] studied and indicated the possibilities of reinforcing aluminium alloy (AlSi10Mg) with locally available inexpensive rice husk ash for developing a new material. A rice husk ash particle of 3, 6, 9 & 12 % by weight were used to develop metal matrix composites using a liquid metallurgy route. The surface morphology was studied using scanning electron microscope for analyze the distribution of RHA particles. The mechanical properties such as tensile strength, compressive strength, hardness and percentage elongations are studied for reinforced RHA composites. The results reveal that the percentage reinforcement of RHA will increase ultimate tensile strength, compressive strength and harness of the composite. [9]

Olumbai et al. [2013]fabricatd characteristics and mechanical behavior of Al-Mg-Si alloy matrixcomposites reinforced with alumina (Al2O3) and rice husk ash (RHA, an agro-waste) wasinvestigated. This was aimed at assessing the viability of developing high performance AL matrix composites at reduced cost. Al2O3 particulates added with 0, 2, 3, and 4 wt% RHAwere utilized to prepare 10 wt% of the reinforcing phase with Al-Mg-Si alloy as matrix using two-step stir casting method. Density measurement, estimated percent porosity, tensile testing, micro-hardness measurement, optical microscopy, and SEM examination were used to characterize the composites produced. The results show that the less dense AL-Mg-Si/RHA/Al2O3 hybrid composites have estimated percent porosity levels as low as the single Al2O3 reinforced grade (<2.3% porosity). The hardness of the hybrid composites decreases slightly with increase in RHA content with a maximum reduction of less than11% observed for the Al-4 wt% RHA-6wt% Al2O3 composition (in comparison with theAl-10 wt% Al2O3 single reinforced composition). Tensile strength reductions of 8% and 13%,and specific strengths which were 3.56% and 7.7% lower were respectively observed forth 3 wt.% and 4 wt.% RHA containing hybrid composites. The specific strength, percent elongation and fracture toughness of the 2 wt% RHA containing hybrid composite was however, higher than that of the single Al2O3 reinforced and other hybrid composite compositions worked on. RHA thus has great promise to serve as a complementing reinforcement for the development of low cost-high performance aluminum hybrid composites. [10]

Sharma et al.[2014] :found that Despite all these good qualities, it has low wear resistance. But some applications entail high hardness and tensile strength, high modulus of elasticity than the conventional aluminumalloy with good tribological properties. Keeping in view the enhancement of mechanical as well as tribological properties with reduction in weight, the aluminum alloy is reinforced with a second phase which is hard and brittle, and the newly formed material has better mechanical and tribological properties. The paper reviews the various manufacturing processes of aluminum matrix composites, and it was found that the mechanical and tribological properties of the single reinforcement composites are better as compared to pure aluminum and its alloys irrespective of the aluminummatrix composites manufacturing process. Further, it was found that most of the hybrid composites exhibit better mechanical and tribological properties as compared to single reinforcement composites .[11]

Usman et al. [2014]: used total silica and alumina contents of the ashes obtained at 700oC 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-3and 15% decrease. The results of mechanical properties show that RHA and BAimproved the mechanical properties up to 10.2% and 7.5% for UTS, respectively. Impact strength increased up to 84.8% and 52.7%, hardness up to 55.2% and 28.8% and fatigue strength up to 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.[12]

Adewale et al.[2014] prepared metal matrix composite with the aid of scanning electron microscopy. The results show that the effect of RHA/SiC weight ratio on the corrosion behavior of the composites in 3.5%NaCl solution was not consistent for the different weight percent of reinforcement (5,7.5, and 10 wt%) used in developing the Al–Mg–Si based composites. It was evident that formost cases the use of hybrid reinforcement of RHA and SiC resulted in improved corrosion resistance of the composites in 3.5% NaCl solution. Preferential dissolution of the moreAnodic Al–Mg–Si alloy matrix around the Al–Mg–Si matrix/RHA/SiC particle interfaces was identified as the primary corrosion mechanism. The coefficient of friction and consequently the wear resistance of the hybrid composites were comparable to that of the Al–Mg–Si alloy matrix reinforced with only SiC. [13]

Aigbodion et al.[2014]. Showed the result of the tests and analysis carried out, revealed that addition of rice husk ash as reinforcement increases hardness values with a decrease in density and impact energy, as the weight fraction of rice husk ash increased in the alloy. The strength increased up to a maximum of 15 wt% addition of the reinforcement. The microstructure revealed the distribution of the rice husk ash particle in the ductile metal matrix. However, an increase in strength and hardness values occurs because the highly dispersed phase severely restricts the movement of dislocation through the metal lattice. This study has showed that abundant rice husk can be used in the production of metal matrix composites for engineering applications.[14]

Alanemea et al.[2015] studied the corrosion and wear behavior of rice husk ash Alumina reinforced and alumina as reinforcements has been investigated .Alumina added with 2,3, and 4wt.% RHA were utilized to prepare 10wt.% of their reinforcing phase with AL-Mg Si alloy as matrix using double stir casting process open circuit corrosion potential (OCP) and potential dynamic polarizationmeasurements were used to study the corrosion behavior while coefficient of friction was used to assess the wear behavior. The corrosion and wear behavior of Al-Mg-Si matrix composite containing 0:10, 2:8,3:7 and 4.6wt,% RHA and alumina as reinforcement was investigated and finally concluded that the corrosion resistance of the single reinforced Al-Mg-Si / 10 wt.% Al2O3 composites were superior to that of the hybrid composite in 3.5% NaCl solution, the corrosion rates increased along with the coefficient of friction and consequently , the wear rate of the composite were observed to increase with increase In RHA weight %. [15]

Saravanan et al.[2015] studied the effect of Mechanical properties on rice husk ash (RHA) reinforced with alumina as it reinforcement .A rice husk particle of 3, 6, 9 & 12 % by weight were used to develop metal matrix composite using a liquid metallurgy route. The surface morphology was studied using scanning electron microscope (SCM) for analyze the distribution of RHA and derived the conclusion that the tensile strength increased with an increase in the weight percentage of rice husk ash (RHA) due to the RHA particles act as barriers to the dislocations when taking up the load applied.[16]

Siva Prasad et al. [2015].Studied the Production and Mechanical Properties of RHA Composites by vortex method .The ash was obtained by burning rice husk and was thoroughly washed with water to remove the dust and dried at room temperature for 1 day. Then It was heated to 200 ° C for 1 h in order to remove the moisture and organic matter. It was then heated to 600° C for 12 h to remove the carbonaceous material. The silica-rich ash, thus obtained, was used as a filler material for the preparation of composite. Here A356.2 alloy with the theoretic density of 2760 kg/m3 is used as the matrix material and RHA is used as the reinforcement having wt. %(4, 6 and 8) and observedthat the hardness along with ultimate tensile strength increases and the density decreases with the increase in the RHA wt%. [17]

Aigbodion et al. [2015] studied the Development of Al-Si-Fe/Rice husk ash particulate composites synthesis by double stir casting method. The specimens were produced by keeping the percentage of iron and silicon constant and varying the rice husk particle (reinforced particles) in the range of 5-20%. And concluded that with the addition of rice husk ash particles to Al-Si-Fe alloy increases the yield strength, ultimate tensile strength and hardness values up to a maximum values of 79.98, 106.12 Nmm2 and 67 HRB respectively at 15% rice husk ash addition. [18]

Adewale et al.[2015] studied the influence of rice husk ash (RHA) and silicon carbide (SiC) weight ratio on the mechanical behavior of Al-Mg-Si alloy matrix hybrid composites was investigated. RHA and SiC mixed in weight ratios 0:1, 1:3, 1:1, 3:1, and 1:0 were utilized to prepare 5, 7.5 and 10 wt% of the reinforcing phase with Al-Mg-Si alloy as matrix using two-step stir casting method. Density measurement, estimated percent porosity, tensile properties, fracture toughness, and SEM examination were used to characterize the composites produced. The results show that the composites were of good casting quality as the estimated porosity values were less than 2.5 % in all grades produced. For the three weight percent worked on, the tensile-, yield-, and specific strength decreases with increase in the weight proportion of RHA in the RHA-SiC reinforcement. However, the results show that the composites with composition of 1:3 weight ratio RHA: SiC (25% RHA: 75% SiC) offers comparable specific strength values with the single SiC reinforced Al composite grades. The strain to fractures was invariant to the weight ratio of RHA/SiC for all weight percent but the composite compositions Containing RHA had improved fracture toughness compared with the single SiC reinforced Al compositegrades. [19]

III MATERIALS AND METHODS

3.1 Selection of matrix material

Aluminium 6063 is considered as matrix metal and its physical, mechanicalthermal, electrical and chemical properties are given below

Table 1 Properties of Aluminium

Density	2.6g/cm^3
Youngs modulus	68.3GPa
Tensile strength	145-186MPa
Elongation	18-33%
Poisson’s ratio	0.3
Melting temperature	615^{0}C
Thermal conductivity	201-218W/m*K
Linear Thermal expansion coefficient	2.34*10^{-5}K^{-1}
Specific Heat capacity	900J/Kg*K
Volume resistivity	30-35nOhm*m

Table 5.2 Chemical Composition

Silicon	0.25%
Copper	0.10%
Manganese	0.10%
Iron	0.35%
Magnesium	0.45%
Chromium	0.10%
Zinc	0.10
Other element	0.05%

Fig 5.1 Al 6063 Rod

5.2 Selection of Reinforcement

Reinforcement are the material which are embedded in metal matrix. It is used to change the Physical Properties such as wear resistance, friction coefficient, or thermal conductivity .it can be continuous or discontinuous. Rice Husk ash is used as reinforcement material to improve the property of Composite

Fig 5.2 Rice Husk

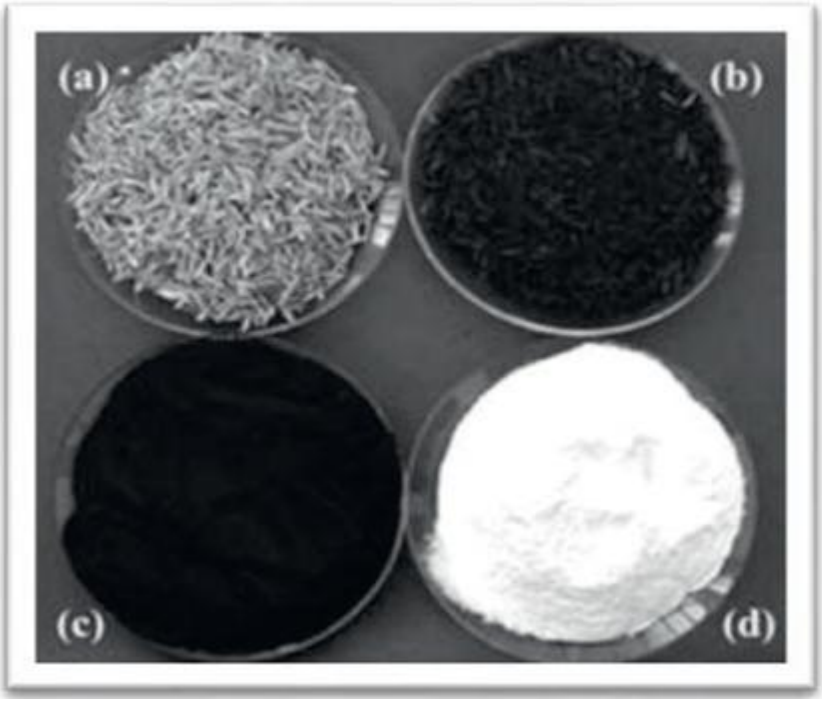

Fig 5.3 (a) Raw Rice Husk (b) Carbonize Rice Husk Ash (c) Grounded Carbonized Rice Husk Ash and (d) Combusted Rice Husk Ash (Grayish White)

Table5.3 Physical properties of RHA

Sr. No	Particulares	Properties
1	Colour	Gray
2	Shape Texture	Irregular
3	Mineralogy	Non crystalline
4	Particle size	< 45microne
5	Odour	Odourless
6	Appearance	Very fine

Table 5.4 Chemical Properties Of RHA

SR. NO	PARTICULARS	PROPORTION
1	Slicon dioxide	86.94%
2	Aluminium oxide	0.2%
3	Calcium oxide	0.3-2.25%
4	Magnesium oxide	0.2-0.6%
5	Sodium Oxide	0.1-0.8%
6	Potassium Oxide	2.15-2.30%

5.3 Mechanical Properties

5.3.1Tensile strength is a measurement of the force required to pull something such as rope, wire or a structural beam to the point where it breaks. The tensile strength of a material is the maximum amount of tensile stress that it can take before failure, for example breaking. The most common testing machine used in tensile testing is the universal testing machine.

5.3.2 Hardness represents the resistance of material surface to abrasion, scratching and cutting, hardness after gives clear indication of strength. In all hardness tests, a define force is mechanically applied on the piece, varies in size and shape for different tests. Common indentors are made of hardened steel or diamond. Rockwell hardness tester presents direct

reading of hardness number on a dial provided with the m/c. principally this testing is similar to Brinell hardness testing. It differs only in diameter and material of the indentor and the applied force. Although there are many scales having different combinations of load and size of indentor but commonly 'C' scale is used and hardness is presented as HRC

5.3.3 Toughness is the ability of a material to absorb energy and plastically deform without fracturing. One definition of material toughness is the amount of energy per unit volume that a material can absorb before rupturing. It is also defined as a material's resistance to fracture when stressedThe toughness of a material can be measured using a small specimen of that material. A typical testing machine uses a pendulum to strike a notched specimen of defined cross-section and deform it. The height from which the pendulum fell, minus the height to which it rose after deforming the specimen, multiplied by the weight of the pendulum is a measure of the energy absorbed by the specimen as it was deformed during the impact with the pendulum. The Charpy and Izod notched impact strength tests are typical ASTM tests used to determine toughness.

5.3.4 Density A material's density is defined as its mass per unit volume. It is, essentially, a measurement of how tightly matter is crammed together. The principle of density was discovered by the Greek scientist Archimedes.

5.3.5 Porosity is a phenomenon that occurs in materials, especially castings, as they change state from liquid to solid during the manufacturing process. It has the form of surface and core imperfections which either effects the surface finish or as a leak path for gases and liquids.

5.4 Experimental Set-UP

Stir Casting method is a liquid metallurgy technique in which the second phase materials (reinforcements) are introduced into the molten matrix and allowing the mixture to solidify. Here, the critical thing is to create good wetting between the reinforcements and the moltenaluminium or aluminium alloy, this is the simplest and most commercially used technique and known avortex technique or stir-casting technique.

In case of some molten metal like aluminum, inert gas such as nitrogen and argon can also be used to remove hydrogen, this method involveintroducing bubbled inert gas into the liquid aluminum. The hydrogen is drawn to the inert gas bubbles, then carried up through the aluminum and released on the surface. In recent development, the composite is stirred whilethe molds are filled by pouring the melt through the bottom of the crucible

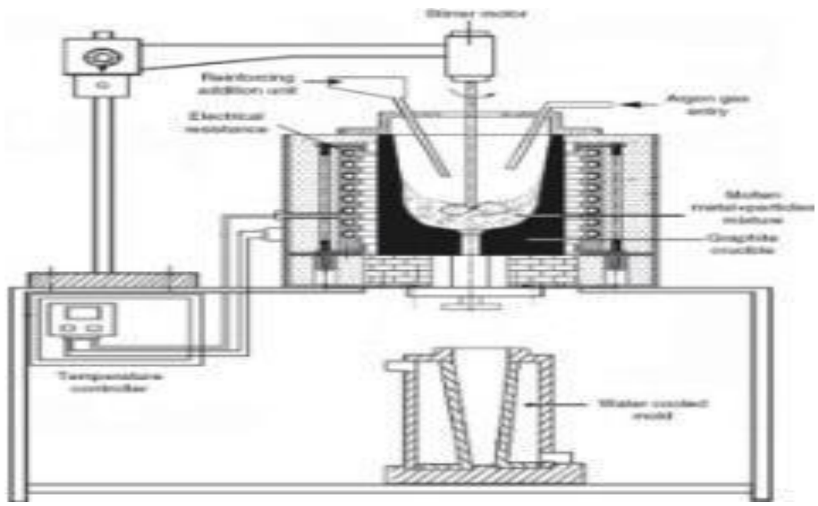

Fig 5.4 Stir Casting Setup

VI CONCLUSIONS

a. From The review Following Conclusions Can be drawn.
b. Mechanical properties were improved after adding RHA in aluminium .
c. Density and cast reduces**.**

REFERENCES

[1] Rong Chen, Guoding Zhang, Casting defects and properties of cast A356 aluminium alloy reinforced with SiC particles, Composites Science and Technology, 47 (1) (1993) 51–56.

[2] W.D. Griffiths, D.G. McCartney, The effect of electromagnetic stirring during solidification on the structure of Al-Si alloys, Materials Science and Engineering: A, 216 (1–2) (1996) 47–60.

[3] W.D. Griffiths, D.G. McCartney, The effect of electromagnetic stirring on macrostructure and macrosegregation in the aluminium alloy 7150, Materials Science and Engineering: A, 222(2) (1997) 140–148.

[4] SuchetaNagarajan, B. Dutta and M.K. Surappa, The effect of SiC particles on the size and morphology of eutectic silicon in cast A356/SiCp composites, Composites Science and Technology, 59 (6) (1999) 897–902.

[5] E.J. Zoqui, M. Paes and E. Es-Sadiqi, Macro- and microstructure analysis of SSM A356 produced by electromagnetic stirring, Journal of Materials Processing Technology, 120 (2002) 365–373.

[6] Zheng LIU, Wei-min MAO and Zheng-duo ZHAO, Effect of pouring temperature on semi-solid slurry of A356 Al alloy prepared by weak electromagnetic stirring, Transactions of Nonferrous Metals Society of China, 16 (1) (2006) 71–76.

[7] T.P.D. Rajan, R.M. Pillai, B.C. Pai, K.G. Satyanarayana and P.K. Rohatgi, Fabrication and characterisation of Al–7Si–0.35Mg/fly ash metal matrix composites processed by different stir casting routes, Composites Science and Technology, 67 (2007) 3369–3377.

[8] Dehong Lu, Yehua Jiang, Guisheng Guan, Rongfeng Zhou, Zhenhua Li and Rong Zhou, Refinement of primary Si in hypereutectic Al–Si alloy by electromagnetic stirring, Journal of Materials Processing Technology, 189 (2007) 13–18.

[9] C.G. Kang, J.W. Bae and B.M. Kim, The grain size control of A356 aluminum alloy by horizontal electromagnetic stirring for rheology forging, Journal of Materials Processing Technology, 187–188 (2007) 344–348.

[10]Jiangbo Cheng, BinshiXu, Xiubing Liang, Yixiong Wu and Zhengjun Liu, Effect of electromagnetic stirring on the microstructure and wear behavior of iron-based composite coatings, Journal of University of Science and Technology Beijing, Mineral, Metallurgy, Material, 15 (4) (2008) 451–456.

[11]Arda Cetin and Ali Kalkanli, Effect of solidification rate on spatial distribution of SiC particles in A356 alloy composites, journal of materials processing technology, 205 (2008) 1–8.

[12]N. Barman, P. Kumar and P. Dutta, Studies on transport phenomena during solidification of an aluminum alloy in the presence of linear electromagnetic stirring, Journal of Materials Processing Technology 209 (2009) 5912–5923.

[13]K. Abedi and M. Emamy, The effect of Fe, Mn and Sr on the microstructure and tensile properties of A356–10% SiC composite, Materials Science and Engineering: A, 527 (16–17) (2010) 3733–3740.

[14]C. Mapelli, A. Gruttadauria and M. Peroni, Application of electromagnetic stirring for the homogenization of aluminium billet cast in a semi-continuous machine, Journal of Materials Processing Technology 210 (2010) 306–314.

[15]AleksandarVencl, IlijaBobi, SaioaArostegui, BiljanaBobi, AleksandarMarinkovi and MiroslavBabi, Structural, mechanical and tribological properties of A356 aluminium alloy reinforced with Al2O3, SiC and SiC + graphite particles, Journal of Alloys and Compounds, 506 (2) (2010) 631–639.

[16]Wang Jing, Li Peijie, MiGuangbao and ZhongYuexian, Microstructural evolution caused by electromagnetic stirring in superheated AlSi7Mg alloys, Journal of Materials Processing Technology, 210 (2010) 1652–1659.

[17]Lei Yao, HaiHao ,Song-weigu, Han-wei dong and Xing-guozhang, Effects of electromagnetic stirring on microstructure and mechanical properties of super light Mg-Li-Al-Zn alloy, Transactions of Nonferrous Metals Society of China, 20 (2) (2010) 388–392.

[18] D. Sohrabi Baba Heidary and F. Akhlaghi, Theoretical and experimental study on settling of SiC particles in composite slurries of aluminum A356/SiC, ActaMaterialia, 59 (11) (2011) 4556–4568.

[19]D. Cree and M. Pugh, Dry wear and friction properties of an A356/SiC foam interpenetrating phase composite, Wear, 272 (2011) 88– 96.