Fabrication and Characterization of Basalt Powder Filled Aluminium Matrix Composite Material

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Abstract In these days composite materials have become very important material in the field of aerospace, automobile industries because of its heterogeneous composition and better properties such as low density, light weight, high fatigue strength, high specific modulus etc. This research paper contain the method of manufacturing of a metal matrix composite and testing of its mechanical properties such as tensile strength, flexural strength and impact strength by using the ASTM D3039, ASTM D 256 standards. In this research paper Aluminum 6061 is used as base metal with 2% of glass fiber as reinforcing agent and 2% of basalt dust powder as the filler material. The fabrication process of metal matrix composite is stir casting technique. During the fabrication process additives are added in proper quantities which are mixed by continuous stir casting method and specimen are prepared in specified shape and size by solidification of the molten materials. After testing the specimen it is obtained that Metal matrix composite Al6061+2% G +2% B.D.P have high tensile strength than Al6061/ ZrSiO4-10%, higher flexural strength than Al/SiC/Gr-MMCs with 5% graphene. Also the impact strength of Al6061+2% G +2% B.D.P is greater than Al+3%SiC+0.2%CNT.Thus from the experiment it is observed that the incorporation of basalt dust powder modifies the impact, flexural and tensile strength of aluminium metal matrix composite with glass fibre reinforcement.

Keywords —AL 6061, ASTM, Stir Casting, Basalt Dust Powder, e-glass fiber, MMC.

I. INTRODUCTION

The Progress of technology and material science has generated an awesome material called composite. Composite is a very advanced material which can be used for preparation of a lot of engineering material. Now a day composite material is replacing the traditional material rapidly because of its higher strength, higher stiffness, higher strength to weight ratio in comparison to traditional material. It has very small thermal expansion. Composite materials are basically made of two or more than two dissimilar components with reinforcing fibres or fillers and compactable matrix, which having different phases, insoluble in each other, and also is chemically inhomogeneous and physically distinct in nature. One or more than one discontinuous or dissimilar phases are combined in a continuous or similar phase to create a composite material. [1] The dissimilar discontinuous phase has generally higher wear resistant and stronger than similar or continuous phase. This discontinuous phase can be termed as reinforcement on the other hand the continuous phase can be termed as matrix. Generally matrixes are made of metal, ceramic or of polymer. The matrix of a metal is known as metal matrix composite (MMC). The matrix of polymer is known as polymer matrix composite. When the matrix is of a ceramic then this is known as ceramic matrix composite. It should be taken into consideration that metals and plastics are not considered as composite materials although it having many different impurities and filler materials. The very important and notable point is that the composite produced after combining their constituents form a specific material which having different properties from their constituents.

From many reports it is suggested that by mixing filler particle into the matrix many effect can be seen such as higher modulus, lower cost of the material with less impact toughness and strength.[2],[3] Basalt dust powder filled aluminium matrix composite is a composite which having very high wears resistance, toughness and strength. Basically basalt dust powder is wastage of marble industries or of construction places. Basalt is a hard material and also having very high wear resistant properties, hence it is very important can be used to modify hardness and wear resistant properties of various composites of aluminium. There are various components which have to bear a lot of erosion due to fast moving fluid such as wind turbine blade, propeller of ship, blades of helicopter and props of aeroplane etc. The

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erosion resistant properties of such parts can be increased to a high level by using a coating of basalt dust powder filled aluminium composite.

II. RESEARCH IMPORTANCE

Nesic S. (Computation of localized erosion-corrosion in disturbed two-phase flow) [4] examined that erosion rate is over predicted by Finnie's model and it present a formula in term of critical velocity. Bitter's (A study of erosion phenomena part 1 and part 2) [5-6] erosion model suggests that there are two mechanisms for erosion. First one is due to continuous deformation during collision and second one is due to cutting action of free particles. Conclusion is that cutting action take place for small impact angle and at these places hard materials are used to minimise erosion. Also there are many other erosion models which are suggested by Laitone (Erosion prediction near a stagnation point resulting from aerodynamically entrained solid particles) [7], Bourgoyne (Experimental study of erosion in diverter systems due to sand production) [8], Salama and Venkatesh (Evaluation of erosion velocity limitations of offshore gas wells) [9], Mc Laury (A model to predict solid particle erosion in oil field geometries) [10], Chase et al (A model for the effect of velocity on erosion of N80 steel tubing due to the normal impingement of solid particles)[11], Jordan (Erosion in multiphase production of oil and gas) [12], Svedeman and Arnold (Criteria for sizing Multiphase flow lines for erosive/corrosive services) [13]. Also Shirazi and Mc Laury (Erosion modeling of elbows in multiphase flow) [14] have presented a model showing idea on multiphase erosion in elbows. From the various research paper the some facts are obtained such as:

1. For mechanical and wear characteristic there are many research effort on the topic of particulate filled composite and fibre reinforced composite. However particulates and fibres both in polymer can give a synergism of improve performance which are not adequately addressed so far. Also the potential use of solid industrial wastes as particulate filler in composite has been rarely considered.
2. Although there is a number of reports available for utilisation and disposal of many solid industrial wastes but there is no report on industrial waste like basalt dust powder in existing literatures.
3. There are a number of investigators who have proposed number of model for predication of erosion behaviour of metal matrix composite material but no one have considered the erodent temperature as influencing parameter to erosion rate. So there are no specific theoretical models which are based on kinetic and thermal energy of the erodent.

The objective of this paper is to develop aluminium metal matrix composite with glass fibre as reinforcement and basalt dust powder as adhesive and characterized the mechanical and corrosion resistance properties of developed composite. Specimen is developed to predict strength, erosion and corrosion resistance properties of the developed composite.

III. MATERIAL

III.I. ALUMINIUM METAL

The most probably aluminium alloy of 6000 series is Al 6061. It is heat treated and extruded alloy which having capability from medium to high strength. It has tremendous corrosion resistance and excellent weldability but its strength is reduced in the zone of weld.

Table:1 The chemical composition of aluminium alloy 6061 can be given as:

Elements	% of Elements
Magnesium (Mg)	0.80 - 1.20
Copper (Cu)	0.15 - 0.40
Silicon (Si)	0.40 - 0.80
Iron (Fe)	0.0 - 0.70
Titanium (Ti)	0.0 - 0.15
Manganese (Mn) 0.0 - 0.15	0.0 - 0.15
Zinc (Zn)	0.0 - 0.25
Chromium (Cr)	0.04 - 0.35
Other	0.0 - 0.05
Aluminium (Al)	Balance

III.I.I. The properties of 6061 aluminium can be given as:

1. It has very good toughness.
2. It has medium to high strength.
3. It has very good corrosion resistance properties in the atmospheric condition.
4. It has excellent surface finish.
5. It has very good corrosion resistance properties against sea water.
6. It has excellent workability.
7. It has excellent brazability and weldability.
8. It has good availability.

III.I.II Physical and mechanical properties of aluminium 6061 can be given as:

1. Its melting point is near about 580^0C.
2. Its density is 2.7 g/cm^3.
3. Its poissons ratio is 0.33.
4. Its modulus of elasticity is 70-80 GPa.

III.I.III. Electrical properties:

The electrical resistivity of Al 6061 is about 3.7×10^{-6} Ω.cm to 4.0×10^{-6} Ω.cm.

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III.I.IV Thermal properties:

The thermal conductivity of Al 6061 is 173 W/m.K and its thermal coefficient of expansion is 23.5×10^{-6}m/m.^{0}C in the temperature range from 20^0C to 100^0C.

Generally Al alloy 6061 is available in the form of bar, tube, rod and pipe. The application of this aluminium alloy is very wide which includes:

1. Marine fittings
2. Aerospace and aircraft components
3. Bicycle frames
4. Transport
5. Brake components
6. Drive shafts
7. Valves
8. Camera lenses
9. Couplings

III.II. *GLASS FIBRE*

The material glass fibres have very fine fibres of the glass. The glass fibre is basically a reinforced plastic. The glass fibre is generally woven into fabric, randomly arranged or flattened into sheet form. It is obtained like Pele's hair naturally. It is worked as reinforcing agent for manufacturing of many products such as for manufacturing of light weight and very strong fibre reinforced polymer composite which is called fiberglass or glass reinforced plastic. In this paper work glass fibre have 2% according to volume. Fibreglass is strong, light weight and less brittle in nature. The very important properties of fibre glass are its property to get moulded into any complex shapes. This is the property due to which it is used for in manufacturing of boats, roofing, bathtubs, aircraft and many other things. There are various natural minerals and chemicals which are used as raw material for manufacturing of glass fibre. The major contents are limestone, soda ash and silica sand. The other contents may be borax, alumina, nepheline syenite, feldspar, kaolin clay and magnesite etc.

III.II.I. Types of fibreglass:

On the basis of raw material used and their proportions used for manufacturing the fibreglass are classified as follows:

1. A-glass: This glass is also called alkali glass and it is very resistant against the chemicals. It is used for manufacturing of process equipment and window glass.
2. C-glass: This glass is also known as chemical glass and it has excellent resistance against chemical impact.
3. E-glass: It has excellent insulation against electricity and it is also known as electrical glass.
4. AE-glass: It is alkali resistant glass.
5. S-glass: It has very good mechanical properties and it is also known as structural glass.

Table:2 Among these types of the glass fibre the most usable type is e-glass. The mechanical properties of the e-glass fibre can be given as:

Property	Minimum Value (S.I)	Units (S.I)
Poisson's Ratio	0.21	-
Shear Modulus	30	GPa
Tensile Strength	1950	MPa
Young's Modulus	72	GPa

The fibre glass is found in various forms such as:

Fibreglass cloth: It is found in various forms like glass filament yarns and glass fibre yarns. It is very smooth. It is used in fire curtains and in other material for heat shields.

Fibreglass tape: It is used for thermal insulation. It is made of glass fibre yarns. It is used for wrapping hot pipelines, vessels etc.

Fibreglass rope: It is made of by wrapping glass fibre yarns. It is used in purpose of packing.

There are various properties which make it very useful for manufacturing of composite materials. These are:

Electrical properties: Even at low thickness fibre glass has excellent electric insulation properties.

Mechanical strength: The specific resistance of fibre glass is greater than steel. To make high performance fibre glass can be used very frequently.

Dimensional stability: It has very low sensitivity against variation of hygrometry and temperature. Its coefficient of linear expansion is very low.

Non-rotting: It is not affected by the rodent's action and hence it has non rotting property. It is also non effective against insect's action.

Incombustibility: It is a mineral material hence it is incombustible. Flame cannot be supported or propagated by it. During heating it does not emit any toxic product or smoke.

Thermal conductivity: Its thermal conductivity is very low hence it is very useful for manufacturing buildings.

Dielectric permeability: Due to its dielectric permeability it is very useful for electromagnetic windows.

III.III. BASALT DUST POWDER

Basalt is a dark volcanic rock which is very hard and dense and it is composed of pyroxene, plagioclase and olivine and

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it have a glassy appearance. It also contain small amount of iron- titanium oxide, iron oxide, quartz, nepheline, hornblende, orthopyroxene etc. It is used in manufacturing and can be converted into various forms such as in fine, superfine and ultra-fine fibers. In this paper work 2% of basalt dust powder is used according to the volume.

Basalt has a wide range of application. It is generally crushed and used as aggregate in manufacturing of buildings and other construction purpose. The crushed form of basalt is generally use for concrete aggregate, railroad ballast, road base, filter stone in drain fields, asphalt pavement aggregate and at many other places.

In this paper many experiment carried out by mixing the basalt dust powder with aluminium matrix to improve the mechanical properties of the composite with glass fibre as reinforcement. The manufacturing of composite is done by stir casting method. The mechanical properties of the composite are found by the process of flexural test, tensile test, Izod impact test method and vickers hardness test method. The result obtained from these test shows that the mechanical properties of composite are improved by blending the basalt dust powder in the aluminium composite.

The material used in paper work having following composition. This material is named as A_1 material.

A_1 Al6061+2% Glass Fibre +2% Basalt dust Powder

IV. MANUFACTURING TECHNIQUE

STIR CASTING:

This is most cost effective and simplest liquid state method which is used for manufacturing of composite materials. In this method a mechanical stirrer is used for mixing dispersed phases with molten matrix metal. Basically stir casting is most frequently and economically used method for manufacturing of the aluminium matrix composite. There are various parameters which affect the mechanical properties and microstructure of composites. In this study glass fibre is used as reinforcement with various percentage of micron size basalt dust powder used for fabrication of composite. In this method casting temperature is approximately 680^0C to 850^0C and the period of stirring is about 2 to 6 minutes. Then the composite is moulded in specified shape and size for testing of mechanical properties of the composite materials. A setup of stir casting is shown in figure.

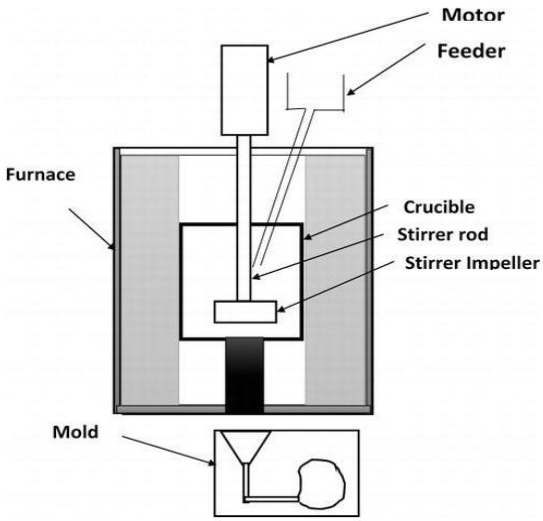

Figure:1. Process of stir casting.

V. MECHANICAL CHARACTERIZATION

V.I. TENSILE TEST

In the present work, this test is performed in the universal testing machine Instron 1195 at a crosshead speed of 10 mm/min and the results are used to calculate the tensile strength of composite samples.

Figure: 2. Loading arrangement of specimen on Universal tensile testing machine.

The tensile test is generally performed on flat specimens. The dimension of the specimen is 150 mm ×10 mm × 4 mm and a uniaxial load is applied through both the ends. The ASTM standard test method for tensile properties of fiber resin composites has the designation D 3039.

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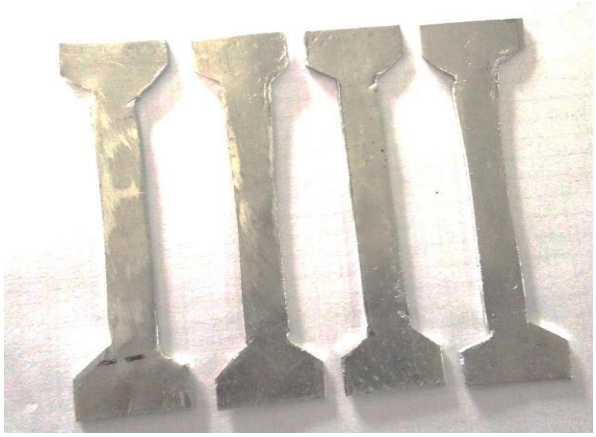

Figure: 3. Specimen for tensile test.

V.II. FLEXURAL TEST

The maximum tensile stress is the flexural strength of composite which the material can bear while bending before going to the breaking point. At universal testing machine Instron 1195 the three point bending test is conducted over the all composite samples.

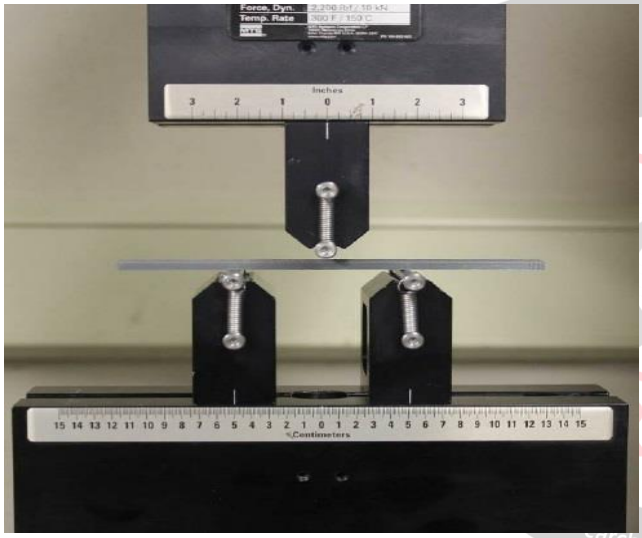

Figure: 4. Loading arrangement for flexural test.

The dimensions of every sample are 60mm × 10mm × 4mm. For this test a span length of 40mm with cross head speed 10mm/min is maintained. For flexural strength the test is repeated three times for every composite type and we considered the mean value as result. The flexural strength can be calculated by the following formula:

Flexural strength= $3PL/ (2bt^2)$

Figure: 5. Specimen for flexural test.

V.III. IMPACT STRENGTH

The impact test is carried out to know the shock absorbing capability of material which is subjected to suddenly applied load or shock load. Low velocity impact test are done on the composite samples.

Figure: 6. Impact testing machine.

Using impact tester this test is carried out as per ASTM D 256. Specimens with a V notch are used for the test. According to ASTM D 256 the standard size of the specimen is 64mm × 12.7mm ×3.2mm which is used for this test. Here we put the depth of the notch is 10mm.

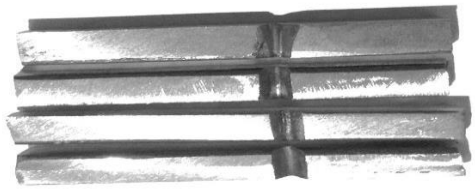

Figure: 7. Specimen for impact test.

VI. RESULT AND DISCUSSION

VI.I. TENSILE TEST

Tensile test is done for measuring the tensile strength of the material. This test is done on the material having 2% of glass fibre and 2% of basalt dust powder. The ultimate tensile strength of the material is 171MPa.

VI.II. FLEXURAL TEST

Flexural strength as increasing the percentage of this particulate filler, the flexural strength starts increasing. Basically it depends on the shape, size and type of the particulate filler material. The flexural strength of the specimen is obtained 262MPa.

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VI.III. IMPACT TEST

The mechanical property due to which materials absorb and dissipate energies under the action of impact or shock loading is called the impact strength of the material and it was observed 13.8J

VII. CONCLUSION

This experiment and analytical analysis on basalt dust powder filled aluminium metal matrix composite shows following specific conclusion:

1. Industrial wastage such as basalt dust powder can be gainfully used for fabrication of metal matrix composite.
2. Incorporation of basalt dust powder modifies the impact, flexural and tensile strength of aluminium metal matrix composite with glass fibre reinforcement.
3. Tensile strength of the Al6061+2% Glass Fibre +2% Basalt dust Powder is 81.91% greater than Al6061/ ZrSiO4-10%. [15].
4. Al6061+2% Glass Fibre +2% Basalt dust Powder have 13.91% greater flexural strength obtained than the Al/SiC/Gr-MMCs. highly effective strength obtained due to the combination of basalt dust powder.[16]
5. The Al+3%SiC+0.2%CNT have 38% low impact strength than the Al6061+2% Glass Fibre +2% Basalt dust Powder due the the presence of silicon carbide.[17]
6. Several wear mechanism can be seen microscopically which explain the way through which aluminium metal matrix composite respond to erosion. Micro ploughing in the matrix, stripping, transverse shearing and fibrillation of fibre can be predominant damage mechanism. Also fibre matrix deboning, fracture and fibre pulling occurs in glass fibre based composite.

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