ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology
Vol. 2, Issue 4, April 2015

Production and testing of Al-Fe_2O_3 particulate composite

Trishul M.A[1], Virupaxayya Hiremath[2], Shreyas P[3]

Assistant Professor, Mechanical Engineering Department, PMCE, (Anna University), Hosur, India[1]

M.Tech Student(Research Scholar), Advanced Machinery Design, MSRUAS, Bengaluru, India[2]

Assistant Professor, Mechanical Engineering Department,

CMRIT, (Visvesvaraya Technological University), Bengaluru, India[3]

Abstract: In a world where there is ever increasing demand for new materials, composite materials find the topmost spot. Knowledge of history and basic physical properties of these materials enables a better understanding of why they are used in specific applications. Composite materials find use in various fields like spacecrafts, construction, automobile etc.
The present day needs focus on cheaper and flexible materials which perform at stringent conditions of high temperature and pressure, in highly corrosive environment, with higher strength but low weight, with wear resistance and longer durability. Over recent decades many new composites have been developed, some with very valuable properties. By carefully choosing the reinforcement, the matrix, and the manufacturing process that bring them together, engineers can tailor the properties to meet specific requirements.
With this project an attempt has been made to study the mechanical properties of aluminum-iron oxide composite. I.e., taking aluminium 6061 as base metal and adding iron oxide in different proportions. Aluminum and iron oxide are compounded by gravity die cast process. Gravity die casting process is one of the most versatile and economic method to prepare a composite material. The materials prepared are subjected to various tests like tensile, micro structure, hardness, compression and systematically analyzed to study the behavior and variation of properties with respect to their composition. The results obtained from the tests have been documented in detail.

Keywords: Metal Matrix Composites, Al 6061, Hardness Testing.

1. INTRODUCTION

Composite materials are engineered materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct on a macroscopic level with in the finished structure.
Fibers or particles embedded in **matrix** of another material are the best example of modern day composite materials, which are mostly structural. Laminates are composite material where different layers of materials give them the specific character of a composite material having a specific function to perform. Fabrics have no matrix to fall back on, but in them, fibers of different compositions combine to give them a specific character. Reinforcing materials generally withstand maximum load and serve the desirable properties[1]. Further, though composite types are often distinguishable from one another, no clear determination can be really made. To facilitate definition, the accent is often shifted to the levels at which differentiation take place viz., **microscopic** or **macroscopic**. In **matrix**-based structural composites, the matrix serves two paramount purposes viz., binding the reinforcement phases in place and deforming to distribute the stresses among the constituent reinforcement materials under an applied force. The demands on matrices are many. They may need to temperature variations, be conductors or resistors of electricity, have moisture sensitivity etc. This may offer weight advantages, ease of handling and other merits which may also become applicable depending on the purpose for which matrices are chosen.
Solids that accommodate stress to incorporate other constituents provide strong bonds for the reinforcing phase are potential matrix materials. A few inorganic materials, polymers and metals have found applications as matrix materials in the designing of structural composites, with commendable success. These materials remain elastic till failure occurs and show decreased failure strain, when loaded in tension and compression. Composites cannot be made from constituents with divergent linear expansion characteristics[2]. The interface is the area of contact between the reinforcement and the matrix materials. In some cases, the region is a distinct added phase. Whenever there is **interphase**, there has to be two interphases between each side of the interphase and its **adjoint constituent**. Some composites provide interphases when surfaces dissimilar constituents interact with each other. Choice of fabrication method depends on matrix properties and the effect of matrix on properties of reinforcements. One of the prime considerations in the selection and fabrication of composites is that the constituents should be chemically inert non-reactive. Significant examples include the use of reinforcing mud walls in houses with bamboo shoots, glued laminated wood by Egyptians (1500BC), and laminated metals in forging swords (1800AD). In the 20th century, modern composites were used in the 1930's

 DOI 10.17148/IARJSET.2015.2405

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
Vol. 2, Issue 4, April 2015

where glass fibers reinforced resins. Boats and aircrafts were built out of these glass composites, commonly called Fiber Glass. Since the 1970's application of the composites has widely increased due to the development of new fibers such as carbon, boron, and aramids, and new composite system with matrices made of metal and ceramics.

Introduced over 50 years ago, composites are fiber-reinforced plastics used in a variety of applications and industries. They also provide good design flexibility and high dielectric strength, and usually require lower tooling costs. Because of these advantages, composites are being used in a growing number of industries, such as recreational boating applications. Their tremendous strength-to-weight and design flexibility make them ideal in structural components for the transportation industry. High-strength lightweight premium composite materials such as carbon fiber and epoxies are being used for Aerospace applications and in high performance sporting goods.

Composite's superior electrical insulating properties also make them ideal for appliances, tools and machinery. Tanks and pipes constructed with corrosion-resistant composites offer extended service life over those made with metals. One of composite's main advantages is how their components glass fiber and resin matrix complement each other. While thin glass fibers are quite strong, they are also susceptible to damage. Certain plastics are relatively weak, yet extremely versatile and tough. Combining these two components together, however, results in a material that is more useful than either separately. With the right fiber, resin and manufacturing process, designers today can tailor composites to meet final product requirements that could not be met by using other materials.

2. ALUMINIUM 6061

Aluminum alloys are used in advanced applications because their combination of high strength, low density, durability, machinability, availability and cost is very attractive compared to competing materials. However, the scope of these properties can be extended by using aluminum matrix composite materials.

Aluminum alloys are preferred engineering material for automobile, aerospace and mineral processing industries for various high performing components that are being used for varieties of applications owing to their lower weight, excellent thermal conductivity properties. Among several series of aluminum alloys, heat treatable Al6061 and Al7075 are much explored, among them Al6061 alloy are highly corrosion resistant and are of excellent extricable in nature and exhibits moderate strength and finds much applications in the fields of construction (building and high way), automotive and marine applications. Aluminum alloy 7075 possesses very high strength, higher toughness and are preferred in aerospace and automobile sector. The composites formed out of aluminum alloys are of wide interest owing to their high strength, fracture toughness, wear resistance and stiffness. Further these composites are of superior in nature[3] for elevated temperature application when reinforced with ceramic particle. The matrix material used in the present investigation is aluminum 6061 alloy. Alloy 6061 is one of the most widely used alloys in the 6000 series. This standard structural alloy, one of the most versatile of the heat-treatable alloys, is popular for medium to high strength requirements and has good toughness characteristics. Applications range from transportation components to machinery and equipment applications to recreation products and consumer durables.

Alloy 6061 has excellent corrosion resistance to atmospheric conditions and good corrosion to sea water. This alloy also offers good finishing characteristics and responds well to anodizing. This alloy is easily welded and joined by various commercial methods. Since 6061 is a heat-treatable alloy, strength in its T6 condition can be reduced in the weld region. Selection of an appropriate filler alloy will depend upon the desired weld characteristics.

ELEMENT	WEIGHT (%)
Si	0.80
Fe	0.70
Cu	0.40
Mn	0.15
Mg	1.2
Cr	0.35
Zn	0.25
Ti	0.15
Al	96

Table 2.1 Chemical Composition of Al 6061

Aluminum 6061 is a precipitation hardening aluminum alloy, containing magnesium and silicon as its major alloying elements. It has good mechanical properties and exhibits good weldability. It is one of the most common alloys of aluminum for general purpose use. The very high strength alloys always contains additions of copper to improve their resistance to stress corrosion cracking [SCC]. The strength properties that are developed are relatively insensitive to rate of cooling from high temperature and they possess a wide range for solution treatment. Improvements in resistance to stress corrosion cracking have come through control of both composition and heat treatment procedures. With respect to composition, it is well known that both tensile strength and susceptibility to cracking increase as the Mg content is raised and it is therefore necessary to seek a compromise when selecting aluminum alloy for a particular application.

3. IRON OXIDE

Iron(III) oxide or ferric oxide is the inorganic compound with the formula Fe_2O_3. It is one of the three main oxides of iron, the other two being iron(II) oxide (FeO), which is rare, and iron(II,III) oxide (Fe_3O_4), which also occurs naturally as the mineral magnetite. As the mineral known as hematite, Fe_2O_3 is the main source

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
Vol. 2, Issue 4, April 2015

of the iron for the steel industry[4]. Fe_2O_3 is ferromagnetic, dark red, and readily attacked by acids. Rust is often called iron(III) oxide, and to some extent this label is useful, because rust shares several properties and has a similar composition. To a chemist, rust is considered an ill-defined material, described as hydrated ferric oxide.

4. COMPOSITE PREPARATION

The gravity die casting process allows obtaining high quality castings, being associated to several advantages with respect to other foundry processes. The steps involved in die casting are

1. Melting
2. Degassing
3. Impregnation of **Fe_2O_3** particulates and stirring
4. Pouring
5. Solidification

4.1 Melting

Melting is carried out in electric resistance furnace. Calculated amount of Al ingots are charged in to graphite crucible under a cover of flux in order to minimize the oxidation of molten metal. Temperature of about 800˚C is set in the furnace.

Fig 4.1 Electric Furnace

4.2 Impregnation of Fe_2O_3 particulates and stirring

Pre-determined weight percentage of Fe_2O_3 particulates (grain size of 75µm) is pre-heated to 1560˚c and then impregnated in the molten metal which is stirred continuously by using mechanical stirrer. The stirring time was maintained at 3-5 min. The dispersion of the preheated Fe_2O_3 particulates was achieved in accordance with the vortex method.

4.3 Degassing

This step is essential in order to remove adsorbed gasses, water and/or hydroxides. Hexachloroethane (C_2Cl_6) in tablets form is used for degassing the molten metal. These are chlorine based tablets, which are held below the melt surface until complete reaction occurs with the molten aluminium.

Fig 4.2 Degassing Process

4.4 Pouring

After the uniform distribution of Fe_2O_3 particles in the molten Aluminium alloy, it is then poured into the die cast mould through pouring basin by gravity.

Fig 4.3 Pouring

Fig 4.4 Cast Al-Fe_2O_3 Composites of different compositions

4.5 Die Dimension

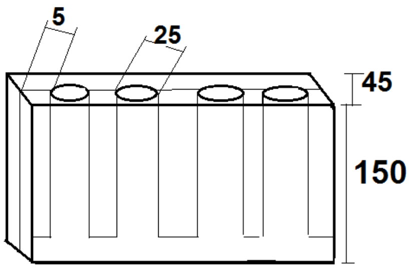


Fig 4.5 Die Dimensions

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
Vol. 2, Issue 4, April 2015

5. SPECIMEN PREPARATION FOR TESTING

5.1 Finishing the surface to be analyzed using emery sheets

For rough grinding process of metallic specimens sequential silicon carbide (SiC) abrasive paper is the most efficient and economical. A typical abrasive grinding procedure would consist of 120 or 240 grit Sic paper followed by decreasing the size of the SiC paper (320, 400, and 600 grit)[5]. Finer papers are also available for continued abrasive paper grinding (800 and 1200 grit). In addition to the correct sequence and abrasive size selection, the grinding parameters such as grinding direction, load and speed can affect the specimen flatness and the depth of damage. The basic idea is to remove all of the previous specimen damage before continuing to the next step while maintaining planar specimens.

5.2 Polishing the specimen

It is done by using smooth emery sheet. The specimens were polished on a buffing machine. The polishing material was surfaced with soft cloth. To avoid friction marks, cold distilled water was added intermittently. It was finally lapped on a soft cloth.

5.3 Etching

The purpose of etching is to optically enhance micro structural features such as grain size and phase features. Etching selectively alters these micro structural features based on composition, stress, or crystal structure. The most common technique for etching is selective chemical etching. In chemical etching the surface of the specimen was rubbed with cotton dipped in dilute HCL which is an etchant[6]. After etching, the surface of the specimens was washed with clean distilled water. The specimens were dried.

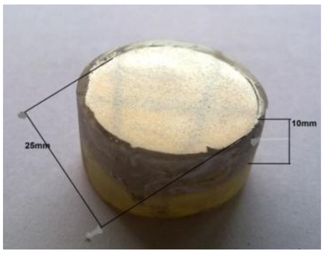


Fig 5.1 Etched Specimen

6. TESTS CONDUCTED

6.1 Hardness Test

Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However, the term hardness may also refer to resistance to bending, scratching, abrasion or cutting. Hardness is not an intrinsic material property dictated by precise definitions in terms of fundamental units of mass, length and time. A hardness property value is the result of a defined measurement procedure.

The usual method to achieve a hardness value is to measure the depth or area of an indentation left by an indenter of a specific shape, with a specific force applied for a specific time. There are three principal standard test methods for expressing the relationship between hardness and the size of the impression, these being Brinell, Vickers, and Rockwell. For practical and calibration reasons, each of these methods is divided into a range of scales, defined by a combination of applied load and indenter geometry.

Brinell Hardness Test was carried out on the composite.

6.2 Tensile Test

A tensile test is probably the most fundamental type of mechanical test that can be perform on a material. Tensile tests are simple, relatively inexpensive and fully standardized. Tensometer is used for ascertaining the strength and deformation of all kinds of materials, such as aluminum, steel and other materials such as composites in the form of rods, sheets, wires, tubes, chains etc. computer control operating system will enhance the performance of the machine, uniform and accurate control of the testing. It is usually loaded with a sample between two grips that are adjusted automatically to apply force to the specimen.

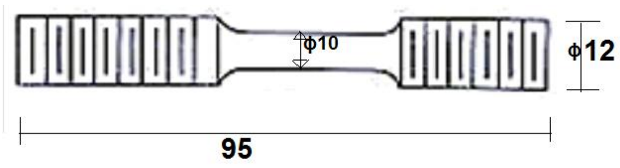


Fig 6.2 Tensile test specimen

6.3 Compression Test

Compression test is the measure of capacity of a material or structure to withstand axially directed pushing forces. When the limit of compressive strength is reached, materials are crushed. Compressive strength is often measured on a universal testing machine; these range from very small table top systems to ones with over 53 MN capacity. Measurements of compressive strength are affected by the specific test method and conditions of measurement. Compressive strengths are usually reported in relationship to a specific technical standard.

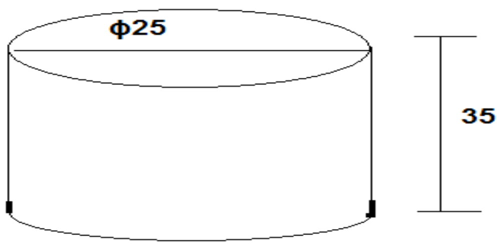


Fig 6.2 Compression Test Specimen

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
Vol. 2, Issue 4, April 2015

7. RESULTS AND CONCLUSIONS

In brinell hardness testing machine for ductile materials the load applied of 1500kg is chosen. The Brinell harness number is calculated by using the following formula,

$$BHN = \frac{2F}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

Where, F= Force applied in N
D= Diameter of indenter in mm
d = Diameter of indentation

Indenter Diameter (ball type): D= 5 mm

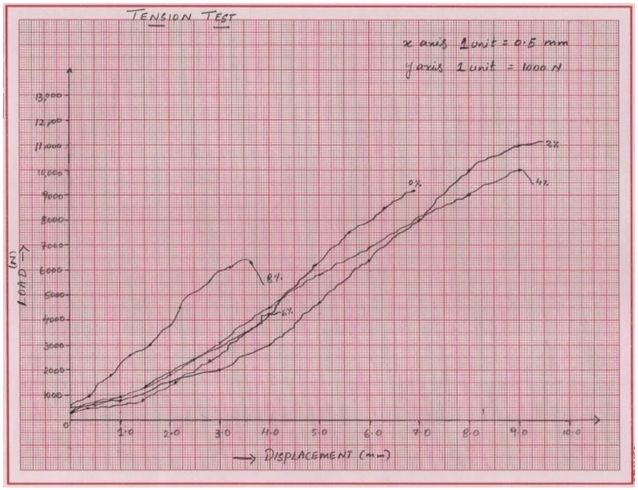
Load: F= 250 Kg

Serial No.	Specimen Composition	Impressio Diameter (mm)	BHN Value
1	0% of Fe_2O_3	3.0	69.0
2	2% of Fe_2O_3	3.1	64.6
3	4% of Fe_2O_3	3.2	60.5
4	6% of Fe_2O_3	3.3	58.6
5	8% of Fe_2O_3	3.3	58.6

Table 7.1 Hardness Test Results

It can be easily observed from the above table that the hardness value decreases with increase in the % of Fe_2O_3. This can be attributed to the fact that due to the inclusion of Fe_2O_3 there will be imperfections created in the matrix of the metal causing the hardness value to reduce.

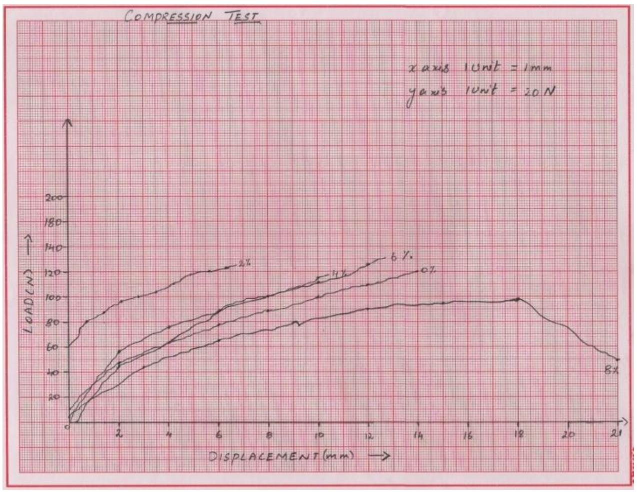
Fig 7.1 Tensile test specimen of 2% of Fe_2O_3



Graph 7.1 Tensile strength comparison of different compositions

From graph, it is seen that the yield strength value increases till the iron oxide is added in the ratio 2%, after this further addition of iron oxide causes the reduction of yield strength.

Fig 7.2 Compression test specimen of 4% of Fe_2O_3



Graph 7.2 Compression Strength comparison of different compositions

From compression test graph, it is seen that the yield strength value increases till the iron oxide is added in the ratio 2%, after this further addition of iron oxide causes the reduction of yield strength.

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology
Vol. 2, Issue 4, April 2015

From the testing results of microstructure, hardness, tensile and compression it is observed that the aluminium 6061 with 2% of iron oxide give better results compared to mixing of other ratios in their properties.

REFERENCES

[1] I. Dutta, et. al., "A theoretical and experimental study of aluminum alloy 6061-SiC metal matrix composite to identify the operative mechanism for accelerated aging", Volume 112, June 1989, Pages 67–77.

[2] R.J. Arsenault, et. al., "Microstructure of fiber and particulate SiC in 6061 Al composites", Volume 17, Issue 1, January 1983, Pages 67–71.

[3] G.M. Owolabi, et. al., "Dynamic shear band formation in Aluminum 6061-T6 and Aluminum 6061-T6/Al_2O_3 composites", Volume 457, Issues 1–2, 25 May 2007, Pages 114–119.

[4] David L. McDanels, "Analysis of stress-strain, fracture, and ductility behavior of aluminum matrix composites containing discontinuous silicon carbide reinforcement", June 1985, Volume 16, Issue 6, pp 1105-1115.

[5] John M. Papazian, "Effects of SiC whiskers and particles on precipitation in aluminum matrix composites", December 1988, Volume 19, Issue 12, pp 2945-2953.

[6] H. Ribes, et. al., "Microscopic examination of the interface region in 6061-Al/SiC composites reinforced with as-received and oxidized SiC particles", September 1990, Volume 21, Issue 9, pp 2489-2496.