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Mechanical Properties Investigation Study of Hybrid Metal Matrix Nano Composites Reinforced with Steel Wires

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Abstract— *Light weight, low density with high mechanical properties and corrosion resistance, aluminum is the most important material and is commonly used for high performance application such as aerospace, military and especially automotive industries.A lot of research was undertaken to produce thin sectioned aluminum parts with improved mechanical properties .Thus, composite materials,particularly metal matrix composites, have taken aluminum's place due to the enhancement of mechanical properties of aluminum alloys by reinforcement.Graphene has recently attracted many researches due to its superior elastic modulus, high fatigue strength and low density.*

Composite materials ,particularly metal matrix composite, have taken aluminum place due to its enhancement of material properties of aluminum alloys by reinforcement, such as aluminum, graphene and steel wires. In the last few decades the global era has been shifted from matrix composites to the Metal Matrix Composites. Due to their diversified properties they are being used in different sectors including majors as in automobile, aerospace and defense. Some most important properties includes good mechanical properties, its low density and better corrosion properties as compared to conventional metals and alloys. The distribution of reinforcement particulates in the matrix and the morphology of secondary matrix phase act as the most enticing part for mechanical properties of Metal matrix composites. Its low relative cost of production and beguiling mechanical properties

make it a very attractive campaigner for the applications in both scientific and technological fields. Stir casting process appears a more wide and promising technique for production of metal matrix composite. This paper provides a literature review on MMCs and various effecting parameters like densities of reinforcements and metal matrices, stir speed, time of stirring, angle of stirrer and a wide range of research options which can be used and can be of vital importance for MMCs.

Keywords— *Composite materials, Alumina, MMC, Alloys*

I. Introduction

The history of the light metal industry, as that of many other industries in this century, is one of notable and ever accelerating expansion and development. There are few people today who are not familiar with at least some modern application of aluminium and its alloys. The part it plays in our everyday life is such that it is difficult to realise that a century ago the metal was still a comparative rmity. The excellent corrosion resistance of pure aluminium is largely due to its affinity for oxygen; this results in the production of a very thin but tenacious oxide film which covers the surface as soon as a freshly. Aluminium is a strongly electro-negative metal and possesses a strong affinity for oxygen; this is apparent fi·om the high heat of formation of its oxide. For this reason, although it is among the six most widely distributed metals on the surface of tbe earth, it was not isolated until well into the nineteenth century. Alumina (A~0) was known, however, in the eighteenth century, and the first unsuccessful attempts to isolate the metal were made by Sir Humphry Davy in 1807, when the isolation of the alkali metals had made a powerful reducing agent available. It was not, however, until 1825 that the Danish Worker, H.C

Oersted, succeeded in preparing aluminium powder by the reduction of anhydrous aluminium chloride with sodium amalgam; two years later, F. Wohler replaced the amalgam by potassium, and between 1827 and 1847 discovered and listed many of the chemical and physical properties.

However, many years passed before the metal could be produced commercially. The father of the light metal industry was probably the French scientist, Henri Sainte-Claire Deville, who in 1850 improved Wohler's method of preparation by replacing potassium by sodium, and by using the double chloride of sodium and aluminium as his source of the metal, thus making the production of aluminium a commercial proposition; the price of the metal, however, was still comparable with that of gold. The production of aluminium received a further impetus when Robert Bunsen and, following him, Deville, showed how the metal could be produced electrolytically from its ores. In 1885, the brothers Cowie produced the first aluminium alloys containing iron and copper, soon after which the invention of the dynamo made a cheaper supply of electricity available and resulted, in 1886, in Herault's and Hall's independent French and American patents for the electrolytic production of aluminium from alumina and molten cryolite (AIF3 NaF).

Thencefmth, the production of aluminium in Europe centred round the first factory in Neuhausen, while Hall's process was applied in the U.S.A. in Pittsburgh. Modem production of aluminium begins from the mineral bauxite, which contains approximately 25% of aluminium. This is converted to

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alumina by digestion with a solution of sodium hydroxide under pressure (the Bayer process), and the purified alumina produced is added to a molten mixture of cryolite and fluorspar. This mixture is electrolysed in a cell with carbon anodes and the molten mixture is tapped from the bottom of the cell.

II. PROPERTIES OF ALUMINIUM

It can be called as 'Magical' metal or the 'Miracuos' metal because of its chemical and physical properties, as well as for the broad range of mechanical characteristics that can be achieved with modern aluminium alloys.Aluminium has exepectionally broad range of abilities, properties, physical, chemical, mechanical characteristics, which are manifested through an extensive number of alloys.Briefly on aluminium;

Very low specific weight, About 1/3 of iron. It can be easily shaped, rolled, drawn, extruded, welded and therefore it is th ideal metal for construction. Its modulus of elasticity is (70.000Mpa) is 3 times lower than iron. Under load condition, an aluminium structure has 3 times greater elastic elongation than iron. Aluminium and most of its alloys range from resistant to very resist again various forms of corrosion. Due to its close chemical affinity with oxygen , the metals physical surface is permanently covered with a layer aluminium oxide, which is a very effective way of preventing further corrosion.
The three main properties on which the application of aluminium is based are its low density of approximately 2.7, the high mechanical strength achieved by suitable alloying and heat treatments, and the relatively higb corrosion resistance of the pure metal. Other valuable properties include its high thermal and electrical conductance, its reflectivity, its high ductility and resultant low working cost, its magnetic neutrality, high scrap-value, and the non-poisonous and colourless nature of its corrosion products which facilitates its use in the chemical and food-processing industries. Still further valuable features are obtained by various treatments of the metal; these will be considered when the applications of aluminium and its finishes are considered.

A. TYPES OF ALUMINIUM

1.AL 1100- Excellent weldability

2.AL2011- Poor weldability III.AL3003- Excellent weldability IV.AL5052- Good weldability

3.AL6061- Good weldability VI.AL6063-Good weldability VII.AL7075-Poor weldability

B. SELECTION OF ALUMINIUM GRADE

Aluuminium comes in many different shapes and grades the type of aluminum grade we choose ultimately depends on how we intend to use the metal. So that we separate the characteristics of each grade from most important to least important.

C. ALUMINIUM 6061

6061 is a precipitation-hardened aluminium alloy, containing magnesium and silicon as its major alloying elements. Originally called "Alloy61S", it was developed in 1935. It has good mechanical properties, exhibits good weldability, and is very commonly extruded.

D. PROPERTIES OF ALUMINIUM - 6061

1) PHYSICAL PROPERTIES

Density :2.70gm/cm3

2) MECHANICAL PROPERTIES

Young's modulus :68.9GPa
Tensile strength :124-290MPa
Elongation at break :12-25%

3) THERMAL PROPERTIES

Melting temperature :585 *C
Thermal conductivity :151-202W/(m*K

E. STIR CASTING

In stir casting we use stirrer to agitate the molten metal matrix. The stirrer is generally made up of a material which can withstand at a higher melting temperature than the matrix temperature. Generally graphite stirrer is used in stir casting. The stirrer is consisting of mainly two components cylindrical rod and impeller. The one end of rod is connected to impeller and other end is connected to shaft of the motor. The stirrer is generally held in vertical position and is rotated by a motor at various speeds.

The resultant molten metal is then poured in die for casting. Stir casting is suitable for manufacturing composites with up to 30% volume fractions of reinforcement.A

major concern in associated with the stir casting is segregation of reinforcement particles due to various process parameters and material properties result in the non-homogeneous metal distribution. The various process parameters are like wetting condition of metal particles, relative density, settling velocity etc. The distribution

of particle in the molten metal matrix is also affected by the velocity of stirrer, angle of stirrer, vortices cone etc. In this method first the matrix metal is heated above its liquid temperature so that it is completely in molten state. After it is cooled down to temperature between liquid and solidus state means it is in a semi-solid state. Then preheated reinforcement particles are added to molten matrix and again heated to fully liquid state so that they mixed thoroughly each other

F. FACTORS AFFECTING PROCESS

Information collected through various research papers show the following factors which affect the stir casting process the most. They are

- Speed of stirring
- Time duration of stirring
- Stirring temperature

1) SPEED OF STIRRING

It is reported by several authors that uniform distribution of the reinforcement particles is necessary for the improvement in the properties of the particulate MMCs like hardness, toughness, tensile strength etc. The low rpm of the stirrer applies less shearing force on the matrix metal and

(dispersed phase) to distribute uniformly throughout the matrix . Moreover the dispersed phase has the tendency to agglomerate and form clusters. This happens due to the absence of the required force to resist it. At higher speeds of the stirrer the shear force applied on the matrix metal is higher which creates the passage for

the dispersed phase to move inside through the vortex created by stirring. The energy supplied by high speed rotation of the stirrer is strong enough to disperse the particles of the dispersed phase which causes uniform distribution of the dispersed phase into the matrix . It was also founded out by the researchers that on increased stirrer speeds there is chance for the gas particles to move inside the matrix and increase the porosity.

2) TIME DURATION OF STIRRING

It plays a very important role in uniform distribution of dispersed phase into the matrix. Less time duration of stirring causes the clustering of the particles of reinforcement . It is also seen that some portions of the matrix were found without inclusions of the reinforcement particles.

3) STIRRING TEMPERATURE

It is also one of the most prominent parameters which affect the stir casting process. On increasing the temperature of the matrix metal the viscosity decreases and the distribution of the particles is affected. The chemical reaction between reinforcement particles and metal matrix is accelerated on increasing the temperature of the melt.

Fig -1 stircasting machine

Fig -2 furnace

Fig- 3 temperature reading

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SAMPLE INGREDIENT

Fig – 5 grapheme and steel wires

III. GRAPHENE OXIDE AND PROPERTIES

Graphene oxide (GO) is the oxidized analogy of graphene. GO is recognized as the only intermediate for obtaining the latter in large scale,since the English chemist, sir Brodie first reported about the oxidation of graphite centuries ago. About thirty years ago, the term graphene was officially claimed to define a single atom-thin carbon layer of graphite , which structurally comprises sp2 hybridized carbon atoms

arranged in a honeycomb lattice, rendering itself large surface area and some promising properties in terms of mechanical, electrical, and others. Despite being the best known with these properties, it remains to be found limited success in practical applications, mostly due to difficulties in the formation of desired large-scale highly organized structures. Thus, GO as one promising precursor is the highlight of research and industry in the last decades, because it is readily exfoliated from bulk graphite oxide in both laboratory and industry lines. This bottom-down strategy of chemical way features the upmost flexibility and effectiveness arousing the greatest interest in its practical applications.

Now we are clear that GO is a non-stoichiometric chemical compound of carbon, oxygen, and hydrogen in variable ratio which largely depends in part on the processing methodologies. And it possesses abundant oxygen functional groups that are introduced to the flat carbon grid during chemical exfoliation, evidenced as oxygen epoxide groups (bridging oxygen atoms), carbonyl (C=O), hydroxyl (-OH), phenol, and even organosulfate groups (impurity of Sulphur). In other word, defects of various kinds are brought into the naturally intact graphene structure, identified as on-plane functionalization defects, in-plane lattice defects (vacancy defects and hole defects) which are then semi-randomly distributed in GO's σ-framework of the hexagonal lattice. Such a defect-rich structure leads to a unique set of properties of GO and render GO of scalability of consequent applications via post treatments , e.g. chemically-derived graphene-like materials, functionalized graphene-based polymer composites, sensors, photovoltaics, membranes and purification materials. On the detailed structure of GO, it however remains ambiguous and literature reports are still sometimes in argument

Fig - 6 graphene powder

IV. WORKING PROCEDURE

Required quantity of RM (AL) can be purchased. Required quantity=750grm/sample

Total sample = 6 sample Total amount of RM = 4.5 kg

Based on the stircasting machine,furnace capacity,raw material can be cutted into small pieces by using RM cutter.

The cutted raw material intiay headed by using pre-heater.The pre-heater all pieces are allowed into stircasting machine furnace for melting purpose.

During melting the temperature can be maintained by the furnace is 900 c- 1000c.After 30-45 minutes the material will

[1] 3	S[2]	[3] %	[4]	graphene+1mm steel wire+750grm of AL 6061
[5] 4	S[6]	[7] %	[8]	graphene+1 .5mm steel wire+750grm of AL 6061
[9] 5	S[10]	[11] %	[12]	graphene+1mm steel wire+750grm of AL 6061
[13] 6	S[14]	[15] %	[16]	graphene+1 .5mm steel wire+750grm of AL 6061

be melted.

After melting the different ratio of grapheme and stee wires are added into furnace By uing stirrer the amont of molden metal ,grapheme and steel wires are mixed the rotationa speed maintained by the stirrer in 400-450 RPM.The stiring time 2 to 3 minutes

The mixed state of the molden metal will be pured into cylindrical die (dia 25mm,length-300mm) After pured the material will be solitified.

After solidified the excess material can be removed by lathe oberation (facing
,turning).

S1 - w/o graphene+1mm steel wire+750grm of AL 6061
S2 - w/o graphene+1.5mm steel wire+750grm of AL 6061

V..TESTING PROCEDURE

Hardness test

Brinell hardness test as per ASTM size of material can be cutted by using NC. The cutted pieces can be used for testing purpose

Micro scopic test

As per ASTM size the maerial can be cutted into a small pieces.Due to fine finished required for microscopic test the cutted small pieces are allowed into the Grinding process.

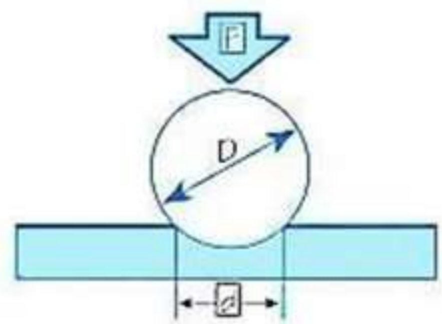
After Grinding process the material can be allowed into the microscopic test.

VI. HARDNESS TEST

Hardness is a measure of the resistance to localized plastic deformation induced by either mechanical indentation or abrasion. Some materials (e.g. metals) are harder than others (e.g. plastics, wood).The ability of a material to resist permanent indentation is known as hardness. It is an empirical test, rather than material property. In order to define different hardness values for the same piece of material, there are several types of hardness tests. The outcome of each test should have a label identifying the method used, as it is dependent on it. There is no intrinsic significance of hardness value or number, hence it cannot be used directly like tensile test value.

The value is only useful for comparing different treatments or materials. Testing is widely employed for process control and inspection, and the outcome is used in estimating mechanical properties like tensile strength. It is usually done using testing machines fitted with an indenter that is enforced into test matter over a period of time. The indentor's shape varies by the hardness test type, and includes pyramid, ball and cone shapes. Each machine also makes use of different load or force application system, while recording a hardness value in kg-force as per the individual scales.

During this test, an accurately controlled force is maintained when an indenter, generally a carbide ball, is forced into the test model for a specific period of time. Upon removal, it leaves an encircling indentation, the measurement of which is taken to calculate material hardness as per the formula



$$HB = \frac{2F}{\pi D(D - \sqrt{D - d})}$$

BEFORE HARDNESS TEST

Fig -7

AFTER HARDNESS TEST

Fig - 8

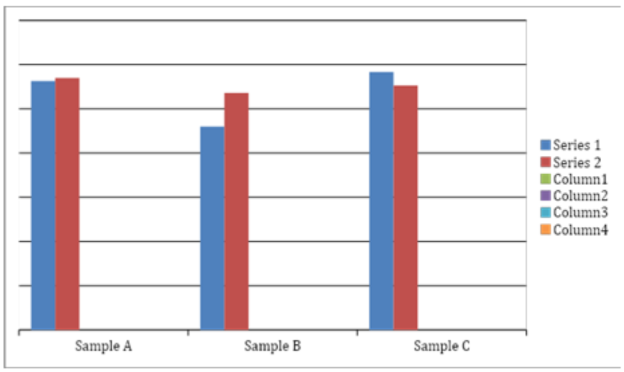
BRINELLHARDNESS TEST

VII. COMPARISON TABLE

Table -2

S.NO	SAMPE	ADDED GRAPHENE%	ADDED STEEL WIRES	OBSERVED VALUES IN HBW(10/500)			AVERAGE VALUES IN HBW(10/500)
1	S1	NILL	1mm	56	57	56	56.3
2	S2	NILL	1.5mm	57	58	56	57
3	S3	1	1mm	47	45	46	46
4	S4	1	1.5mm	57	50	54	53.6
5	S5	2	1mm	62	56	57	58.3
6	S6	2	1.5mm	58	51	57	55.3

GRAPHICAL REPRESENTATION



Sample A=S1&S2Sample B=S3&S4Sample C=S5&S6

A. RESULT OBTAINED BY HARDNESS TEST;

Sample 5(2% grapheme,1mm steel wire) which gives better test result((58.3HBW (10/500)) when compared to other 5 samples as per the, graphical representation.

VIII. MICROSCOPIC TEST

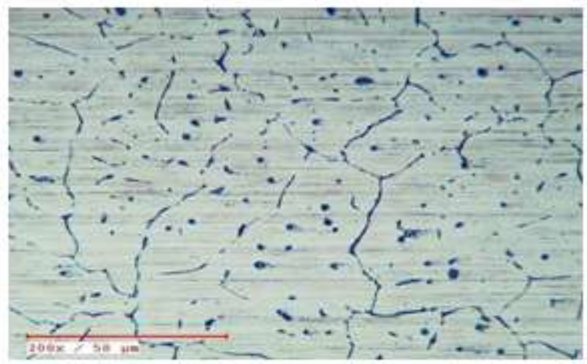
A. THE MICROSCOPIC EXAMINATION PROCESS

A carefully prepared specimen and magnification are needed for microscopic examination. Proper preparation of the specimen and the material's surface requires that a rigid step-by-step process be followed. The first step is carefully selecting a small sample of the material to undergo microstructure analysis with consideration given to location and orientation. This step is followed by sectioning, mounting, grinding, polishing and etching to reveal accurate microstructure and content.

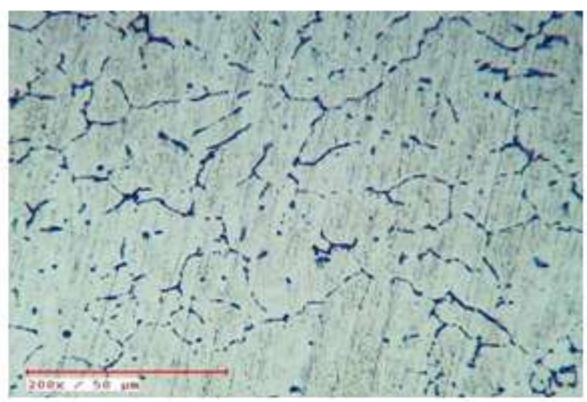
Detailed viewing of samples is done with a metallurgical microscope that has a system of lenses (objectives and eyepiece) so that different magnifications can be achieved, for example 50X up to 1000X. Scanning Electron Microscopes (SEMs) are capable of much higher magnifications and are utilized for highly detailed microstructural study.

B. BEFORE MICROSCOPIC TEST

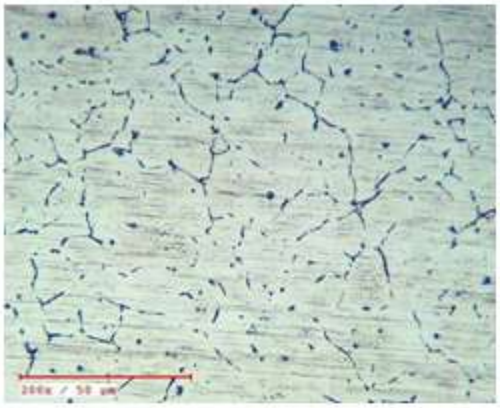
IX. MICROSCOPIC TEST RESULT



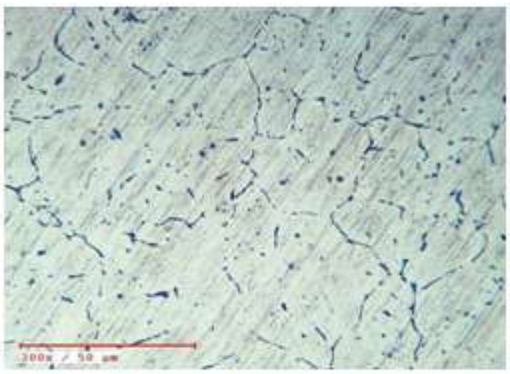
Sample1 (without grapheme, 1mm steel wire)



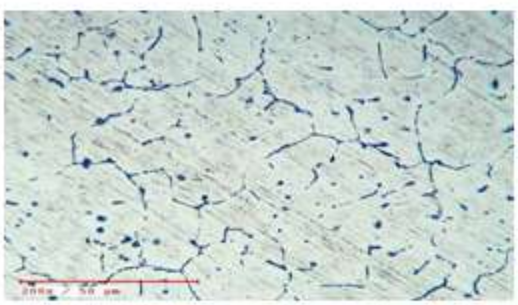
Sampe2 (without grapheme 1.5mm steel wire)



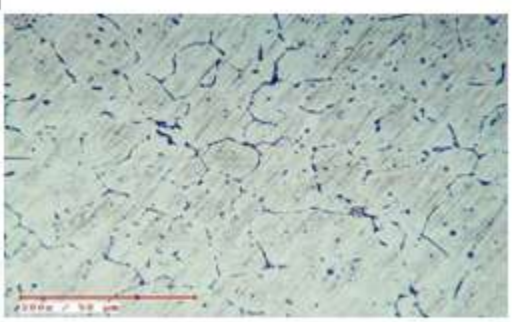
Sample3 (graphene1%, 1mm steel wire)



Sample4(graphene1%, 1.5 mm steel wire)



Sample5 (graphene2%, 1mm steel wire)



Sample6 (graphene2%, 1.5 mm steel wire)

X.CONCLUSION

Due to their attractive mechanical properties, aluminum metal matrix composite has been an important engineering material for industry. Therefore,researchers have given close attention to reinforcement materials. It can be clearly understood that the type and amount of reinforcements directly determine the mechanical properties of composite material. However, the incorporation of reinforcement still is the major concern. Particularly the

wettability and formation of porosity has to be evaluated. Stir casting method emerges as the best means of introducing particles into aluminum matrix. With its enhanced properties, the use of graphene as reinforcement for aluminum alloys appears to have the potential to produce higher toughness with minimum additions compare to ceramic particle additions.

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