Synthesis and Characterisation of Aluminium 2024 and Graphene Metal Matrix Composites by Powder Metallurgy Means

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Abstract

Powder Metallurgy is a term covering a wide range of methods in which materials or powders are made from metal powders. It is a highly developed and reliable method of manufacturing ferrous and non ferrous parts.This work involves the development of metal matrix composite materials by combining the desirable attributes of metals and reinforcements. Here aluminum of 2024 issued as metal matrix composite with graphene as reinforced material. 0.25%, 0.5%, 0.75%, 1% of graphene are added to the metal to form composite. This matrix composite has superior qualities compared to other matrixes. They have applications in several demanding fields like automobile, aerospace, defense, sports, electronics, bio-medical and other industrial purposes. Composite materials possess improved physical and mechanical properties e.g. lower density, low coefficient of thermal expansion, good corrosion resistance, high tensile strength, high stiffness, and high hardness and wear resistance. This AMMC's can be fabricated in powder metallurgy set up with little effort and at low cost. Tensile, Impact, flexural and hardness tests are performed to study the mechanical properties.

Keywords- *powder metallurgy, fabrication, Composites, metal matrix composites.*

I. INTRODUCTION

Metal matrix composites (MMCs) these days are used in many applications and are highly preferred over monolithic materials, since the conventional monolithic materials have limitations in achieving good combination of strength, stiffness, toughness and density etc. And thus to overcome these shortcomings and to meet the ever increasing demand of modern day technology, composites are most promising materials of recent interest. Metal matrix composites (MMCs) possess significantly improved properties like high specific strength and good wear resistance compared to unreinforced alloys. There has been an increasing interest in composites with low density but high specific properties. Now a days the particulate reinforced aluminium matrix composite are gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components. Recently, there has been interest to develop AMMCs based on the use of Aluminium Alloy; Aluminium Alloy is conventionally applied for the design of medium strength window and door profiles and other architectural design works. The choice of Aluminium Alloy is informed by its local availability and lower cost of processing. Many techniques were developed for producing particulate reinforced MMCs, such as powder metallurgy and squeeze casting. The particulate composite can be prepared by mixing aluminium and graphene as reinforcement. Powder metallurgy is preferred as it has flexibility to produce compositions not possible by other methods. Among the entire processes powder metallurgy is the only process which produces very little scrap. The only problem with this technique is it is not useful for low melting powder such as zinc, tin and cadmium as they show thermal difficulties during sintering operations. Mechanical properties of composites are affected by the size, shape and volume fraction of the reinforcement matrix material and reaction at the interface.

A. Metal Matrix Composites

A Metal Matrix Composite (MMC) is a composite material in which one constituent is a metal or alloy forming at least one percolating network, while the other constituent is embedded in this metal matrix and usually serves as reinforcement. The reinforcement in MMC could be particulate, fibres or whiskers. Reinforcements are usually done to improve the properties of the base metal like strength, stiffness, conductivity, etc., as well as lower weight and thermal coefficient of expansion. Thus MMC serve as potential substitutes for conventional metals, alloys, and polymers in various applications due to their superior properties over the unreinforced alloys.

B. Matrix

Aluminium alloys are preferred engineering material for automobile and aerospace 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 aluminium alloys that are available Al 2024 is considered for this development. Al 2024 alloy is primarily composed of copper as the alloying agent of the aluminium, as well as higher levels of

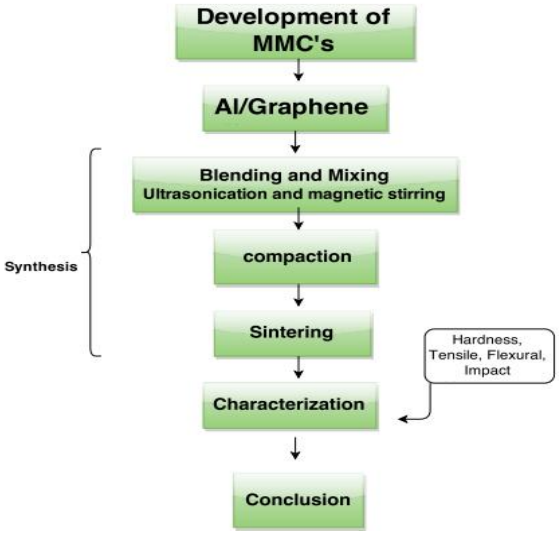
magnesium and manganese etc. Composition of aluminium 2024 goes as 4.3-4.5% copper,0.5-0.6% manganese,1.3-1.5% magnesium and small amounts of silicon, zinc, nickel, chromium, led and bismuth. This alloy of aluminium is as hard as many steels while still retaining the lightweight qualities of aluminium. Due to these properties this alloy of aluminium is used for highly stressed structural parts. Thus it is used commercially for wide range of applications like aircraft fittings, gears and shafts, missile parts etc.

C. Reinforcement

Graphene Nano-Powder is the reinforcement used. Generally metal matrix composites use three types of reinforcements: particulate, fibrous, and continuous. Particulate reinforcements consist of powders such as silicon carbide, that are used in metal matrices. Fibrous reinforcements include silicon carbide fibres dispersed in an aluminium alloy matrix. Continuous reinforcements include filament-wound, carbon fibre, magnesium composites, or woven carbon fibre cloth reinforced aluminium alloys. Here this reinforcement comes under particulate reinforcement. Graphene is selected because of its unique property i.e., this is the only form of carbon (or solid material) where every atom is available for chemical reaction from two sides thus resulting in ease of combining with it matrix and also in general improvement of mechanical tensile strength.

II. EXPERIMENTAL PLAN

The experimental plan is shown in the flow chart and we planned to prepare 20 samples of graphene reinforced aluminium initially. The composition of graphene is 0.25%,0.5%,0.75%, 1% by wt. We use ASTM standard dies to fabricate the samples for tensile, hardness, impact, and flexural test. Then the green compacts obtained are sintered at 600°c in conventional furnace. The tests like tensile strength, flexural strength, impact strength and hardness are carried out to study on basic mechanical properties.



III. PROBLEM STATEMENT

Mechanical properties have high importance and needed to be studied for successful functioning of a component. Many properties of a material are to be studied to specify the most effective use of the developed material. There are many cases where tensile strength of a material is the most important factor required. Impact strength of a part is very important in many applications. More importantly these days, it involves the perplexing problem of product safety and liability.

IV. MATERIALS

The materials used in the present study were Aluminium alloy 2024 (Al2024) which served as matrix and graphene powder which was used as reinforcement. The composition of Al 2024 is shown in table.

component	%wt
al	90.7-94.7
cr	Max 0.1
cu	3.8-4.9
fe	Max 0.5
mg	1.2-1.8
mn	0.3-0.9
si	Max 0.5
ti	Max 0.15
zn	Max 0.25

Al 2024 Chemical composition

V. COMPOSITE FABRICATION

Aluminium reinforced MMC is prepared by powder metallurgy means. In this study, Al-2024 is used as metal matrix composite with different wt % of graphene. The quantity of Al 2024 is 18 grams and graphene particles required to produce composites are 0.25 % , 0.5 % , 0.75 % and 1% by weight .The

process for fabrication of MMC remains same even though composition of MMC changes.
First the metal matrix composite and graphene are weighed based on our requirement.Graphene is mixed blended with acetone and then kept in ultrasonic liquid processor for about 1 hour till it is equally dispersed in the solvent. Then 18 grams of aluminium 2024 is added to the solution and kept in ultrasonic liquid processor for about 30 minutes. Later the obtained solution is kept undisturbed for about 3 hours on magnetic stirrer which allows proper distribution of particles.After 3 hours of time mixture will be in a semi solid state then it is kept in hot air oven for about 24 hrs to obtain dry mixture of Al2024 and grapheme.. After 24hours powder is taken and preheated to about 300^{o} C before compaction is done. The powder after heating is placed in a die and 20 ton weight is applied using universal testing machine. The sample is removed from the die and specimen is obtained.

VI. TESTS CONDUCTED ON THE SPECIMEN

A. Tensile Test

The tensile test is one of the most widely used of the mechanical tests.A tensile test of a material is performed on ductile materials to determine tensile properties such as :
1)Limit of proportionality
2)yield point
3)Maximum tensile strength
4)Breaking strength
5)Percentage elongation
6)Percentage reduction in area
7)Modulus of elasticity

The material to be tested is also known as a specimen,is machined to standardised dimensions.The specimen is elongated by the moving cross head,load cell and extensometer measure the magnitude of applied load and elongation.The specimen to be tested is fastened to the two end jaws of the Instron.Now the load is applied gradually on the specimen by the means of the movable cross head till the specimen fractures.During the tests the magnitude of the load is measured by the load measuring unit.A strain guage or extensometer is used to measure the elongation of the specimen between the guage marks when the load is applied.Then the different values of load and elongation at different intervals are recorded and tabulated.

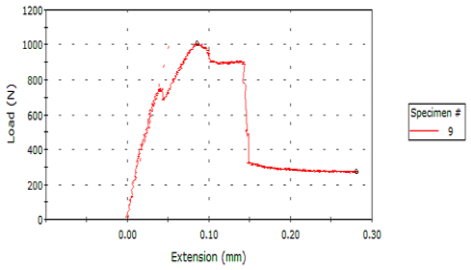
1) Result

Table:

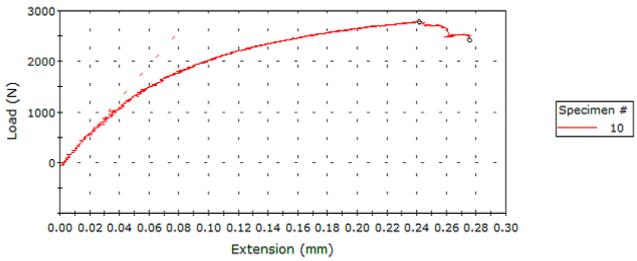
Composition of specimen(%)	Elongation at break(standard)(mm)
Pure aluminium2024	0.22471
0.25%graphene	0.13231
0.5%graphene	0.00000
0.75%graphene	0.16152
1%graphene	0.12296
Maximum	0.22471
Mean	0.12832
minimum	0.00000

2) Computer Generated Graphs

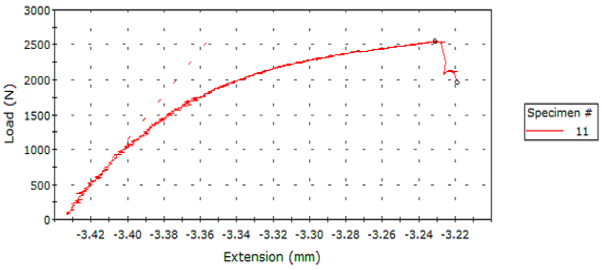
Graph 1 (pure aluminium 2024)



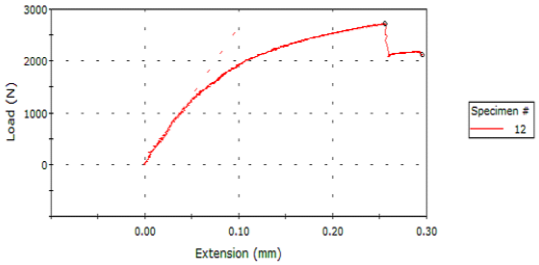
Graph2(al2024 with 0.25% graphene)



graph3(al2024 with 0,5%graphene)



Graph4(al2024 with 0.75% graphene)



B. Hardness Test Results

In this test, resistance to indentation is measured. Rockwell hardness test is carried out to find the hardness of the samples.

6.2.1 results:

6.2.2 table:

Composition of graphene in the sample(%)	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average hardness value
No gr	67.1	59.3	64.2	62.5	59.4	62.57
0.25	56.3	55	58.5	51.5	55.6	55.38
0.5	52.8	53.1	49.8	52.5	52.1	52.06
0.75	56.0	54.5	54.1	53.9	54.7	54.64
1	53.5	57.0	55.2	58.6	55.1	55.88

Average hardness value:56.106

C. Impact Test

The Izod impact test is performed to determine the amount of energy absorbed by material during fracture. The test samples are prepared based on ASTM E23-12c standard. The test will be carried. The charpy impact test also known as the charpy v notch test is a standardized high strain rate test which determines the amount of energy absorbed by a material during fracture.The absorbed energy is a measure of a given material's notch toughness and act as a tool to study temperature dependent ductile-brittle transition.

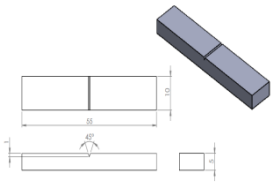


figure of specimen

6.3.1 results:

6.3.2 table:

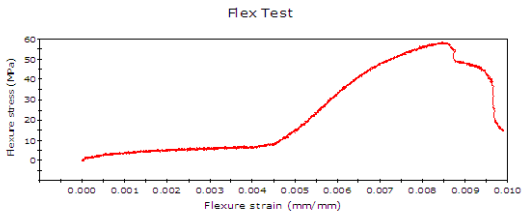
Composition(%)	Charpy value(J/cm^2)	Izod value (J/cm^2)
Pure	11.7714	3.5428
0.25	11.4285	3.4289
0.5	10.8571	2.8571
0.75	10.2857	2.2857
1	9.1428	1.7141

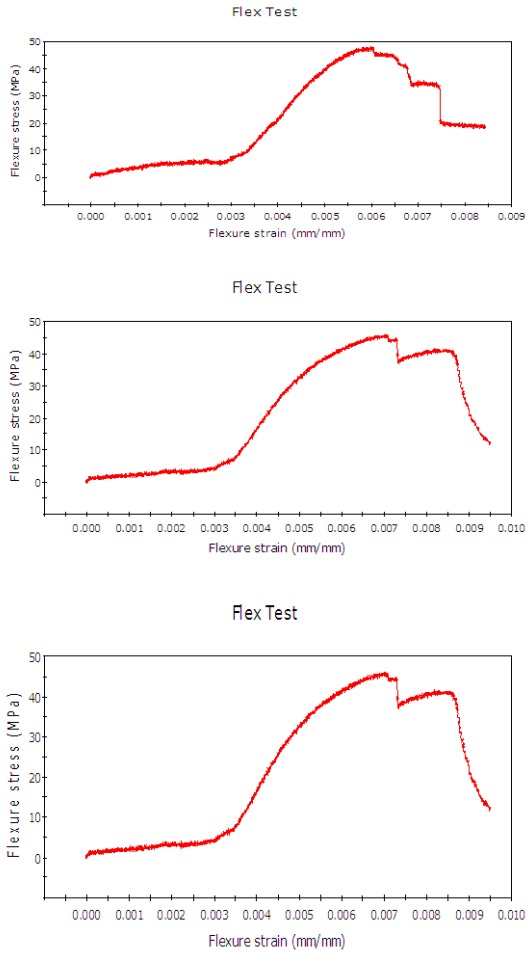
D. Flexural Test

The flexural test method measures behaviour of materials subjected to simple beam loading.It is also called a transverse beam test. Flexural strength is defined as the maximum stress in outermost .

Graph1	Pure al2024
Graph2	0.25%gr
Graph3	0.5%gr
Graph4	0.75%gr
Graph5	1%gr

6.4.1 Computer generated graphs:





6.4.2 results:

6.4.3 Table:

Composition of specimen(%)	Maximum load(N)	Flexural stress(mpa)
Pure al	409.90	43.03
0.25%gr	480.44	44.75
0.5%gr	459.26	48.72
0.75%gr	456.40	52.11
1%gr	437.97	52.98

VII. CONCLUSION

We can conclude that in Hardness test maximum Hardness is shown by pure Al2024 sample of 62.57 HRC and minimum hardness is shown by 0.5% graphene sample.

In Impact test the pure Al2024 sample shows the maximum impact strength of 11.7714J/cm^2 incharpy test and 3.5428J/cm^2 in izod test sample. In Flexural test maximum load of 480.44 N and max flexural stress of 52.98674MPa was sustained by 0.25 composition sample of Al2024 and graphene sample.

In tensile test maximum tensile strain of 0.60025 was shown by 0.75 wt % sample and the maximum load at breaking strength and at breaking strength was shown by 0.5 composition sample of 0.96 and maximum tensile stress at break is shown by 0.75 wt% sample.thus 0.75% grapheme sample is having high tensile strength.

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