Estimation of Mechanical Characteristics of Aluminium-4032 Reinforced With Titanium Dioxide

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Abstract- *Now a days, the researchers are focused on light weight and high strength materials for substituting the existing heavy weight materials.*

This is compensated by using the metal matrix composites. Among the different metal matrix composites the AMC's are preferred due to their preferable mechanical and physical properties. In this scenario, some of the researchers are substituting the aluminium-4032 piston in place of cast iron pistons but it is limited to small I. C. Engines.

The present investigation is done on Aluminum-4032 reinforced with Titanium dioxide at various weight percentages (0, 1, 2 & 3 wt %) through stir casting route. Here the investigation focused on mechanical properties like tensile and compression strength, impact strength and hardness also were examined microstructure

I. INTRODUCTION

Composite materials are manmade materials consisting of two or more constituents which give superior properties than those of the individual components used alone. The constituents are having intimate contact with each other and recognizable interface between them which are not soluble in each other. As compared to metallic mixture, each and every material has its individual physical, chemical and mechanical properties. The two constituents are reinforcement or fortification and a matrix. The primary of interest of composite materials are their high strength and stiffness, low density when compared to bulk materials, which provides a less weight in the finished part, the reinforcing phases provide strength and stiffness. In almost all cases, the fortification is harder, stronger and stiffer than matrix.

Continuous fibers have long aspect proportions with preferred orientation and examples include in this composites are unidirectional, woven material and helical winding whereas discontinuous fibers have short aspect proportions with arbitrary orientation and examples include in this composites are chopped fibers and random mat. continuous fiber composites are continuously made into overlays by stacking single sheets of continuous fibers in various orientations to get the coveted strength and stiffness properties with fiber volumes as high as 60 to 70 %. Fibers produce high strength composites because of small diameter: they contain less defects (normally surface defects) compared to material produced in mass.

In general, smaller the diameter of the fiber has high strength and if go on decreasing the diameter size which increases the cost. Moreover, small diameter high strength fibers have greater flexibility and agreeable to manufacturing process such as waving or framing over radii. Commonly, fibers include glass, aramid and carbon,which may be continuous or discontinuous. The continuous phase is a matrix, may be a metal, polymer or ceramic.

Polymers have less strength and stiffness compared to metals and ceramics. Metals have intermediate strength and stiffness with high ductility whereas ceramics have high strength and stiffness with brittle. The matrix creates several tasks such as placing the fibers in proper orientation and protecting them from corrosion. In polymer and metal matrix composites which forms a strong bond between the fiber and the matrix, the matrix transmits loads from matrix to fibers through shear loading at the interface.

In ceramic matrix composites, the function is to increase the toughness rather than strength and stiffness, therefore it has low interfacial strength bond is helpful. The sort and amount of the support determine the final properties. High strength and modulus are obtained with continuous fiber composites. About 70% volume reinforcement can be added to form a composite. At higher rates, there is matrix too little to hold the fiber effectively.

II. MATERIAL SURVEY

Matrix Material:

Aluminum alloy 4032 is chosen as matrix material on account of its medium strength, low coefficient of thermal expansion, heat-treatable, good corrosion resistance and good flow characteristics. In aluminum alloy 4032, silicon is the major alloying element. Aluminum alloy 4032 broadly used in forged pistons, master brake cylinders, transmission valves, bushings for rack and pinion steering systems.

Composition	Weight percentage (%)
Al	76.73
Si	21.42
Ni	0.82
Cu	0.67
Fe	0.22
Ag	0.10
Mn	0.04

Aluminum alloy 4032 ingot

Reinforcement Choice:

Titanium dioxide (TiO_2):

Titanium dioxide (Tio2) is a bright white substance used primarily as a vivid colourant in a wide array of common products. It has a number of lesser known qualities that makes it an extremely useful and important ingredient to fight climate change . it depends on for its non-toxic, non reactive and luminious properties.

Titanium dioxide has been widely used in paints, sunscreens, cosemitics and foods since its successful commercialization as white pigment. Since reported on the photocatalytic activity of TiO_2 water splitting under ultraviolet light,intensive and extensive investigation has been attracted to its number of applications in photocatalysis and photovoltaics.

These applications range from energy and environment to health, clearly demonstrating that (Tio2) will surely play a more important role in serving human society and deserve more efforts in advancing its applications.

Synthetic amorphous titanium dioxide:

- Sol-Gel method
- Hydrothermal / solvothermal method
- Microemulsion and Micelle Methods

Sol-Gel Method:

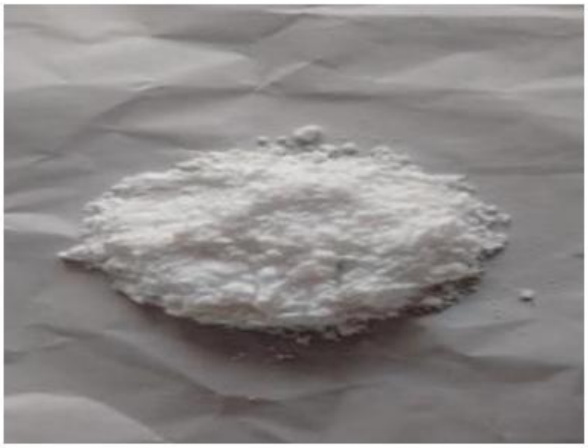
In a typical sol-gel process, monomers which are usually inorganic metal salts or metal organic compounds such as metal alkoxides, will be converted into a colloidal solution (sol, which is formed from the hydrolysis and polymerization reactions of the monomers) that acts as the precursor for an integrated network of either particles or network polymers.

Hydrothemal/Solvothermal Method: Hydrothermal and solve thermal process are generally carried out in Teflon-lined stainless steel autoclaves at Temperature usually above the boiling temperature of the solvent to create a high pressure. Often, the temperature and pressure will be above the critical point of the solvents , leading to the formation of supercritical fluids. Generally solvothermal methods techniques employ water as solvent while solvothermal process use nonaqueous solvent

Microemulsion and Micelle Method: Microemulsion and micelle methods have been widely used in preparing TiO2 crystals. Microemulsion are thermodynamically stable dispersions of oil, water, and amphiphilic surfactants (frequently in combination with co-surfactants), Where the surfactants are used to stabilize small droplets of one liquid that immiscible with the second liquid but can dissolve.

Properties of TiO_2:

Properties	Values
Tensile strength	14 MPa
Melting point	1843^{0}c
Boiling point	2972^{0}c
Density	3.78 g/cm^3
Thermal conductivity	8.4 W/m^{0}c
Compressive strength	82MPa
Poison's ratio	0.3
Modulus of elasticity	177Gpa



Titanium nano powder

Properties of Aluminum Alloy 4032:

- Machinability: Machinability of aluminum amalgam 4032 is assessing as fair to good. Use of lubricating oils during machining is recommended.
- Welding: This amalgam is weldable and utilization of inert-gas arc welding is the recommended method. Gas welding should be avoided.
- Forming: This is a forging amalgam and forming is done by hot die forging.
- Forging: Aluminum amalgam 4032 is a forging amalgam and hot die forging is done at temperature range of 510 to 371^{0}C.
- Heat Treatment: In this amalgam, solution heat treatment is done at 950^{0}F for 1 to 12 hours based on the thickness of the section. Cold water quench.
- Hot Working: The identical comments as for “forging” is applied to hot working.
- Cold Working: This amalgam is basically a hot forged, cannot be cold worked.
- Annealing: Annealing of this amalgam can be done at 413^{0}C (775^{0}F) for certain amount of time through heating, followed by controlled cooling manner at rate of 50^{0}F (10^{0}C) per hour to 400^{0}F (204^{0}C) then air cool.
- Aging: The amalgam may be aged (T6 temper) by first solution heating at 950^{0}F and cold water quenching, followed by a 340^{0}F heating for 10 hours and air cooling.

CALCULATION FOR MATERIAL WEIGHTS:

In this aluminium metal matrix composites are prepared with four different weight percentage of reinforcement i.e. 0, 1, 2 and 3wt% of TiO_2. Also hear five different distractive mechanical tastings and microscopic study carried out for evaluating the mechanical properties and microstructure. So that for preparing the specimens, the calculations done with respective length of the casted rod for each test, mass of the aluminium taken for each casting and weight percentage of silicon dioxide in grams.

S.No	TEST	Diameter (mm)	Length (mm)
1	Tensile Test	16	100
2	Compression Test	16	45
3	Izod Test	16	80
4	Charpy Test	16	60
5	Hardness	16	25
Total		16 mm	310

So that, from the bellow equation the mass of AL4032 required,

Mass = Volume X Density

Volume = $\frac{\pi}{4} D^2 X\ L$

Density = 3780 Kg/M^3

Mass = $\frac{\pi}{4}0.016^2 X\ 0.4$

Mass = 0.21714 Kg or 217.14 Grams

Adding other allowances take mass of aluminium 4032 is 300 grams for each casting

EXPERIMENTAL WORK

The stir casting method also known as liquid state technique is utilized for manufacturing of metal matrix composites. Here stir casting method is done with by using designed open hearth furnace. In this technique disseminate stage is assorted with molten metal with the help of motor stirrer. The liquid composite material is then cast by using traditional casting techniques (permanent mould casting).

Stir casting process:

Initially took 300 grams of pure aluminum-4032 are melted up to liquefy point. Then by adding necessity quantity of reinforcement for 300 grams of pure aluminium-4032 is 3 grams for 1 Wt% and stirred continuously. Allow some time to obtain the super heat.

After the stirring molten metal with TiO_2 is poured in to the mould to form required shapes.

After pouring the molten metal in to the die allow some time to cool down or solidification. Fettling the molded rods from the die

Machining of tensile specimens:

As shown in the above figures the tensile specimens are prepared according to ASTM standard E-8 that is sub size. Here tensile specimens are machined in required shapes by using CNC cutting machine.

specimen for tensile test

Machining of compression test specimens:

As shown in the above figures the compression specimens are prepared according to ASTM standard E-9 that is medium with length 39mm, diameter 13mm and L/D ratio is 3. Here compression specimens are machined in required shapes by using lathe machine

Machining of charpy test specimens:

As shown in the above figures the charpy specimens are prepared according to ASTM standard E-23 that is v-notch with length 55 mm, width 10 mm, thickness 10 mm, notch depth 2 mm. Here charpy specimens are machined in required shapes by using shaper machine

Machining of izod test specimens:

As shown in the above figures the izod specimens are prepared according to ASTM standard E-23 that is v-notch with length 75 mm, width 10 mm, thickness 10 mm, notch depth 2 mm. Here izod specimens are machined in required shapes by using shaper machine.

Machining of hardness test specimens:

QAs shown in the above figures the hardness specimens are prepared according to ASTM standard E18. Here hardness specimens are machined in required shapes by using shaper machine.

Mechanical Properties:

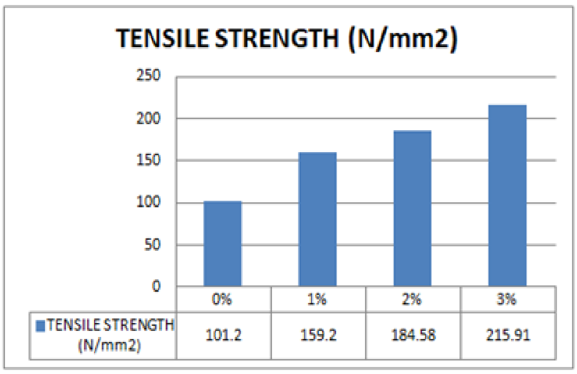
To evaluate the mechanical properties like ultimate tensile strength, ultimate compressive load, impact strength and hardness test we performed some mechanical tests. These are, Tensile Test, Compression Test, Impact (IZOD-V) Test, Impact (CHRPY-V) Test and Hardness (Brinell) Tests.

Tensile behavior of AL 4032-TiO_2 (0, 1, 2 and 3 Wt %):

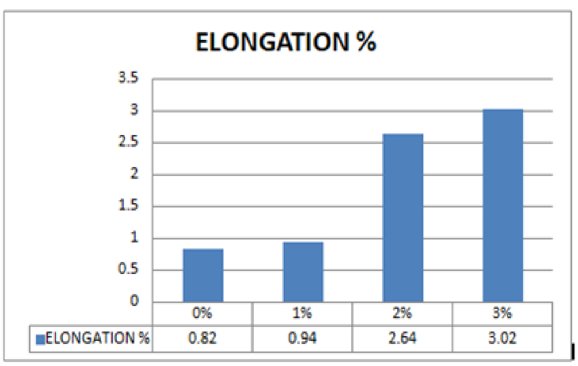
The tensile behavior of AL 4032-TiO_2 (0, 1, 2, and 3 Wt %.) is evaluated as cast and after ECAP. The ultimate tensile strength of Al 4032- reinforced with 0.5Wt% TiO_2

after ECAP is much higher than the before ECAP. Similarly, the ultimate breaking load is grater for AL 4032- reinforced with 0.25 Wt% TiO_2 after ECAP sample among the all samples.

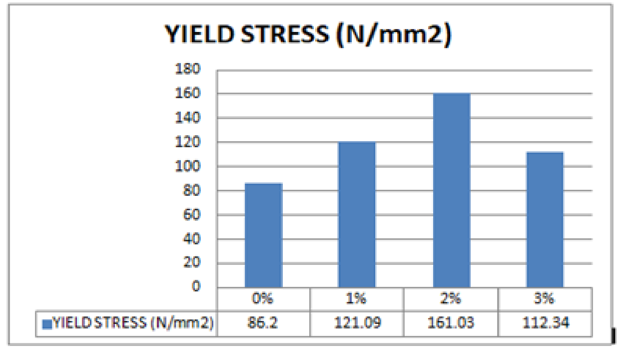
COMPOSITION	TENSILE STRENGTH (N/mm^2)	ELONGATION %	YIELD STRESS (N/mm^2)
Al 4032+0% TiO_2	101.2	0.82	86.2
Al 4032+1% TiO_2	159.20	0.94	121.09
Al 4032+2% TiO_2	184.58	2.64	161.03
Al 4032+3% TiO_2	215.91	3.02	112.34



The maximum value of Ultimate Tensile Strength occurred at 3% of Tio_2



The maximum value of Elongation occurred at 3% of Tio_2

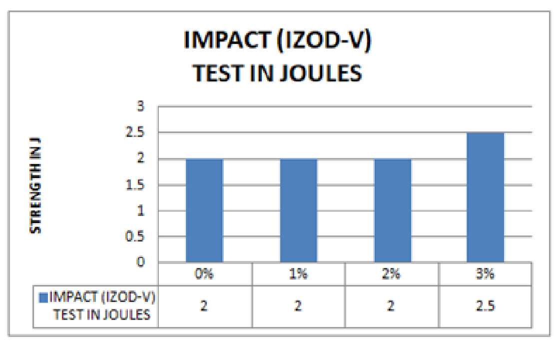


The maximum value of Yield Stress occurred after ECAP at 2%of Tio_2

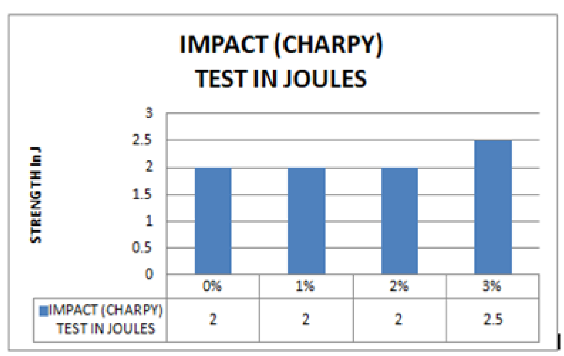
Impact strength of AL 4032-TiO_2 (0, 1, 2 and 3 Wt %).

The impact strength of AL 4032-TiO_2 (0, 1, 2 and 3 Wt %.) were evaluated. In both the cases the breaking loads

COMPOSITION	IMPACT (IZOD-V) TEST IN JOULES	IMPACT (CHARPY) TEST IN JOULES
Al 4032+0% TiO_2	2	2
Al 4032+1% TiO_2	2	2
Al 4032+2% TiO_2	2	2
Al 4032+3% TiO_2	2.5	2.5



The value of Impact (Izod-V) occurred is same in all composition

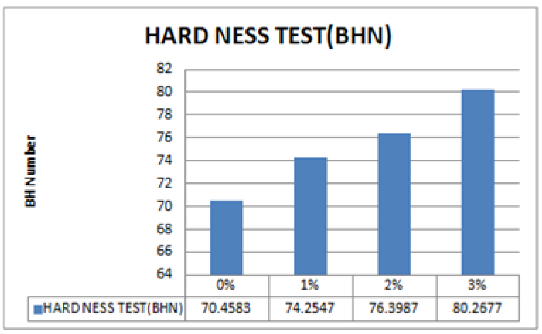


The maximum value of Impact (Charpy) occurred is same in all composition

Hardness (Brinell) test of AL 4032-TiO_2 (0, 1, 2, and 3 Wt %).

The hardness of the AL 4032-TiO_2 (0, 1, 2, and 3 Wt %.) were evaluated as. The Brinell hardness number (HB) is maximum for AL 4032- reinforced with 3 Wt% TiO_2

Composition	HARD NESS TEST(BHN)
Al 4032+0% TiO_2	70.4583
Al 4032+1% TiO_2	74.2547
Al 4032+2% TiO_2	76.3987
Al 4032+3% TiO_2	80.2677



The maximum value of Hardness occurred at 3%of T io2

III. CONCLUSIONS

Al 4032-TiO_2 based metal matrix composites upto 3 wt% were successfully fabricated by stir casting technique. From above experimental the following conclusions were drawn.

- Addition of TiO_2 in Al 4032 improves the tensile strength compared to unreinforced composites. Also Al 4032 reinforced with TiO_2 at 1, 2 wt% has high tensile strength compared to Al 4032 reinforced with TiO_2 at 3% wt.
- Addition of TiO_2 in Al 4032 improves the compression strength compared to unreinforced composites. Also Al 4032 reinforced with TiO_2 at 1, 2 wt% has high compression strength compared to Al 4032 reinforced with TiO_2 at 3% wt.
- Addition of TiO_2 in Al 4032 improves the Rockwell and Vickers hardness compared to unreinforced composites. Also Al 4032 reinforced with TiO_2 at 1, 2 wt% has Rockwell and Vickers hardness compared to Al 4032 reinforced with TiO_2 at 3% wt.
- Addition of TiO_2 in Al 4032 there is no change in the impact strength viz., izod, charpy compared to unreinforced composites.
- Agglomeration and non uniform distribution of TiO_2 particles in Al 4032 were perceived in the microstructure at 3wt%.

From the above results, the TiO_2 reinforced Al 4032 has better tensile strength, compression strength and hardness than unreinforced alloy.

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