Evaluation in Mechanical Properties of Aluminium Matrix Reinforced with Titanium Dioxide (TiO_2) Composite via Stir Casting - A Review

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Abstract— In this present scenario metals are used for the variety of application's in Automobile Industries, Aerospace Industries, Marine applications, Infrastructure and other daily utilities. So in the current demands of advanced engineering applications Aluminium based nano composites are the new generation of metals. Researchers have been observing that the addition of nano sized titanium dioxide (tio2) particles with aluminium metal matrix leads towards superior mechanical properties, physical properties and interfacial characteristics of nano composities. The image of scanning electron microscope of aluminium metal matrix nano composites indicate that the nano Titanium dioxide (Tio2) reinforcing particles are uniformly distributed in the metal matix. This paper tries to review the fabrication techniques and mechanical properties of aluminium/tio2 based metal matrix composites.

Key words: Aluminium Metal Matrix Nano Composite, Fabrication Technique, Scanning Electron Microscope, Mechanical Properties Metalmatrix Composite, Titanium Oxide (TiO_2)

I. Introduction

There is a tremendous demand for advanced engineering materials with high strength, light weight, and increased resistance to wear in aerospace, civil and sliding components of automobile sectors. This leads to the development of aluminium matrix composites (AMCs). Aluminium is principally reinforced with hard phases such as SiC, TiC, TiB2 and Al2O3 and soft phases like graphite (Gr) and MoS2.Aluminium metal matrix composite filled with nano particles featuring physical and mechanical properties very different from conventional metal. The nano particles can improve the base material in terms of Tensile strength, compressive strength, hardness, wear resistance, damping properties, porosity, corrosion resistance and mechanical properties. The Exploitation of reinforcement of nano particles on metal matrix depends on the type of primary and secondary processing, matrix composition, size, volume fraction, morphology of reinforcement and heat treatment. Among all the investigated nano particles reinforcement with Titanium dioxide was found to be most effective in enhancing the strength properties of Auminium when incorporated via ingot metallurgy process. Fabrication methods can be broadly classified into Two types, solid state processing and liquid state processing. In liquid state processing mechanical and electromagnetic stirring and ultrasonic based dispersion is uses for the proper distribution of nano particle that have some advantages than solid state of processing that are high productivity, flexibility, easy to control on matrix structure and better bonding between matrix and particles etc. In solid state of processing mostly preferred method is powder metallurgy in which, the main drawback of liquid state processing technique can be overcome that is non-uniform dispersion of nano particles but this uniform dispersion of nano particles makes it costly and lengthy process.

A. *Fabrication Technique:*

Processing of Aluminium metal matrix nano composite (Al-MMNC's) are classified into two

1) Solid state
2) Liquid state

1) Solid state: In solid state Diffusion Bonding, Electroplating, Powder Metallurgy, Spray Deposition, Immersion Plating, etc.
2) Liquid state: In Liquid state processing includes Stir Casting, Squeeze Casting, Melt Infiltration, Compo Casting and Melt Oxidation processing etc.

But Powder Metallurgy, Stir Casting , High Energy Ball Milling, Squeeze Casting, Mechanical Alloying , Spark Plasma, Ultra sonic cavitation based solidification and Laser Deposition mostly used. The nano particles have tendency of agglomeration and clustering because of electrostatic, high surface energy, adhesiveness due to the moisture present. Out of these fabrication technique some are discuss below that are mostly prefer for reinforcement of ceramic nano particles on metal matrix.

1) *Spark plasma sintering*

In spark plasma sintering the release of electrical energy through a porous powder and then breakdown of surface film take place. The basic theory of spark plasma sintering process is based on the generation electrical spark. Low voltage pulse current momentarily generates spark plasma in fine local areas between the particles at high energy. Spark plasma is advanced technique which takes less time to complete sintering process comparison to the conventional sintering process. In conventional sintering usually a green compact needs to be prepared during the compaction before the process but in the spark plasma sintering it is not necessary to green compaction in this process directly fed in to the graphite dies and dies closed in suitable punch. When spark discharge generate in the gap between the particles of a material, a local high temperature state appears. This cause vaporization and melting of the surface of the powder particles takes place in spark plasma sintering. Constricted shape or necks are formed around the contact between the particles.

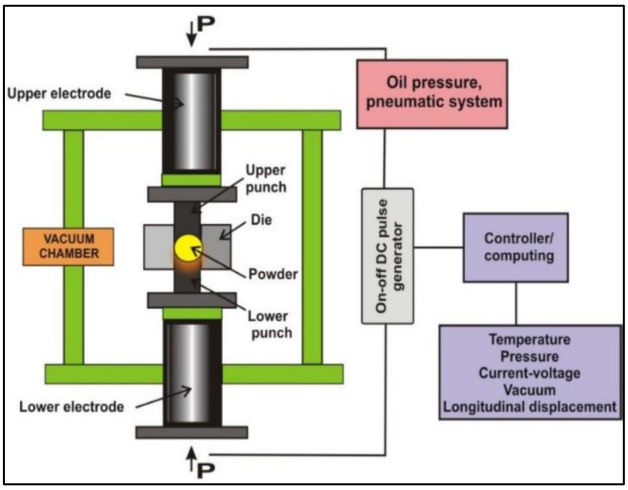


Fig. 1: schematic dia. Of spark plasma

2) Stir Casting

Conventional stir casting process has been employed for producing discontinuous metal matrix nano composite. The major problem of this process is to obtain proper mixing of nano particle with the liquid metal and to obtain homogenous dispersion of particles. But this method is mostly used because of their simplicity, low cast and less time consuming process. From micro structural characterization, it is concluded that the shorter stirring period is required for ceramic incorporation to achieve metal/ceramic bonding at the interface.

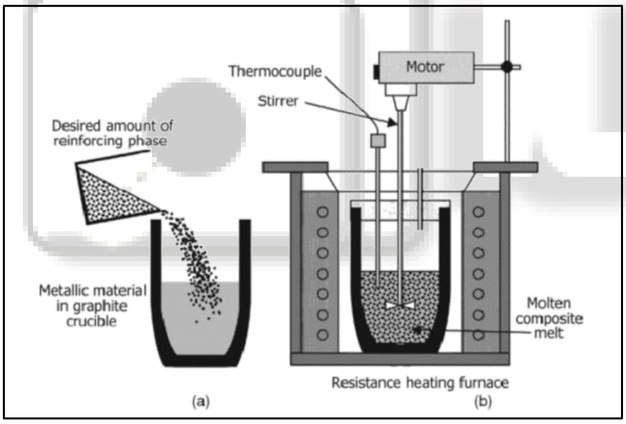


Fig. 2: schematic dia. of stir casting

3) Powder Metallurgy

Powder metallurgy has a great advantages comparison to the other processes such as casting, forging, and machining particularly for complex part made of high strength and hard alloy. Powder metallurgy has a 5 step blending, compacting, sintering, finishing. First step to form a powder by the various process such as reduction, atomization, electrolytic deposition, mechanical pulverization and grinding etc. second step is blending, blending is a process of mixing of the powder of metal in an inert gas atmosphere to avoid oxidation. Lubricants and additives can be added to improve their flow characteristics. Third step is compaction of metal powder that is a process of reducing the porosity and increasing the density by the help dies for required shape and size of the metal powder. Fourth step is sintering in which compact powder is heated to a temperature below the melting point temperature in controlled atmospheric condition but temperature must be sufficient to allow bonding between the particles. Generally sintering is done at a .7 to .9 of their melting point temperature. Sintering is done for the improving the mechanical strength.

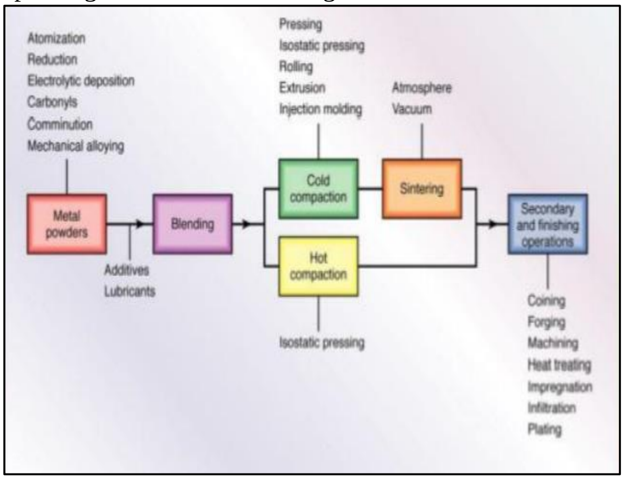


Fig. 3: Schematic dia. powder metallurgy process

II. LITERATURE REVIEW

A. Antony Vasantha Kumar

C.Antony Vasantha Kumar Have done the natural mineral rutile (TiO_2) was reinforced to Al−15%SiC composites through powder metallurgy process. Inclusion of rutile increases the density and microhardness of the hybrid composites. The density and microhardness show remarkable improvement with the mass fraction of TiO_2 (rutile).

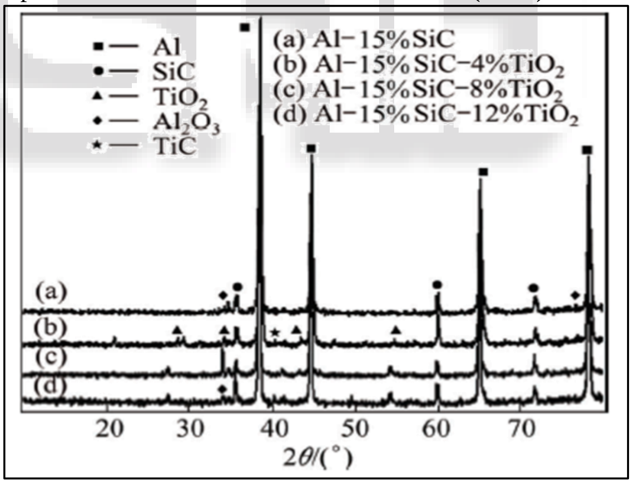


Fig. 3: XRD patterns of wear debris collected from wornsurface of proposed composites

B. Amal E. Nassar, Eman E. Nassar

In this research work Amale and Nassar have done the pure aluminum Nano composite reinforced with Nano titanium dioxide was produced by powder metallurgy route. Measurements of tensile strength, hardness, and density showed that the porosity and the tensile strength of composites increased with an increase in volume fraction of nanoparticles; however ductility of aluminum was decreased. Wear test revealed that composites offer superior wear resistance compared to alloy.

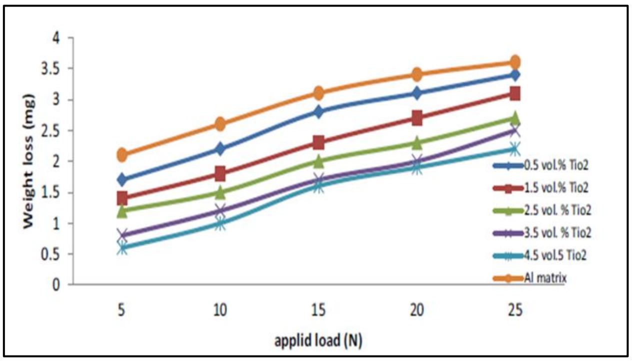
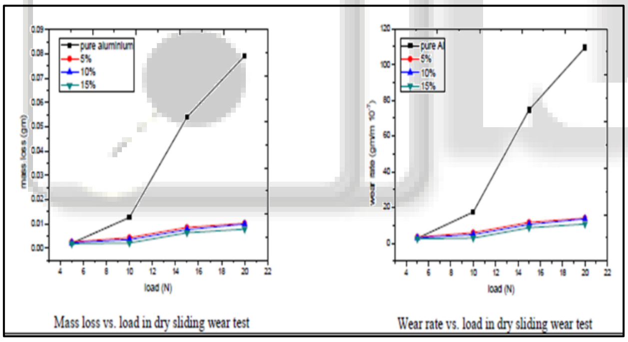


Fig. 4: Effects of applied load on wear resistance.

C. *Ganesh and Chandraveer Singh*

In the present investigation mr. Ganesh and Chandraveer have chosen aluminium as a matrix phase and titanium oxide as a reinforcement phase. The aim of their project is to investigate the wear behaviour of aluminium metal matrix on different amount of reinforcement. The titanium oxide, 5%, 10%, and 15% weight of aluminium was used to make three different specimen. Among all the fabrication process we choose stir casting because stir casting process are simplest and cheapest. Magnesium (4% by weight) was added in molten aluminium to improve the wettability. After fabrication; the composites have been characterized for their wear behaviour to see the suitability as a wear resistant material. Wear test was performed as a function of sliding distance, applied load, sliding velocity with the help of Pin-On-Disc wear test machine.



D. *B.Stalin, S.Arivukkarasan and C.Selva Ganesan*

In this work B.Stalin, S.Arivukkarasan and C.Selva had made three different samples Aluminium which are fabricated and the following inferences are made. It has been inferred that the tensile strength of sample 1 is marginally higher than other two samples because of its Aluminium content. But, the sample 3 has higher tensile strength (157.1 MPa) than sample 2 (148.48 MPa). It has been noted that the flexural strength of sample 1 is higher than other two samples. Considering the results of the impact test, the impact value of sample 1 (3 J) is lower than the impact value of sample 2 (4 J) and sample 3 (4 J). Also, the Brinell hardness of sample 2 (61.5) is marginally lower than that of sample 3 (61.8), but higher than that of sample 1 (56.4)

Sample 1	Aluminium alloy
Sample 2	Aluminium alloy—92%, Titanium dioxide —3% , Boron carbide—5%
Sample 3	Aluminium alloy—92%, Titanium dioxide —5%, Boron carbide—3%

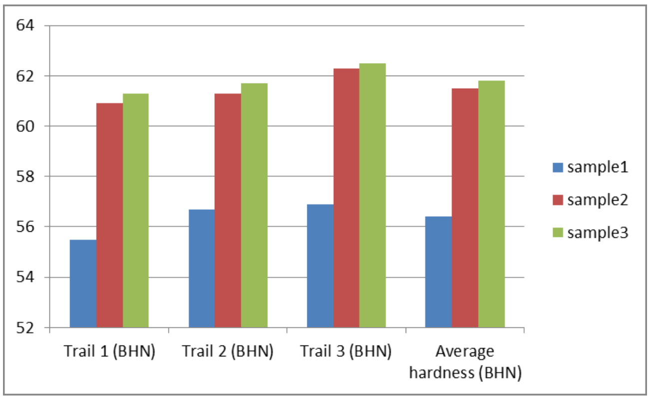


Fig. 5: Comparison of Hardness values

E. *M. Ramchandra*

In this work aluminum metal matrix reinforced by the zirconium dioxide nano particles, zirconium dioxide nano particles produced by the solution combustion method. Urea is used as the fuel for solution combustion method and nano particles reinforced with different percentage of weight in to the aluminum by using the powder metallurgy process.

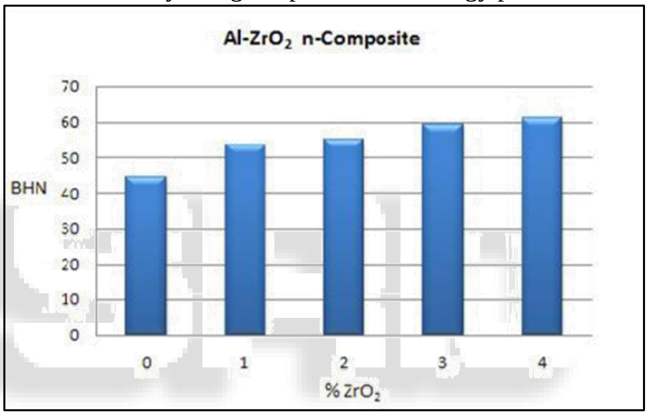


Fig. 6: Hardness (BHN) value of Al-Zro2 composite

The prepared specimen is tested for the hardness test and microstructure characterization. The metal matrix nano composite are tested for wear resistance by using the disc wear technique. Reinforcement of n-Zro2 particles in aluminum metal matrix improved the hardness and the wear resistance.

F. *A.Fathy*

In this work, Effect of Mg content on microstructure and mechanical properties of Al–Al2O3 (10%) composite. magnesium mixed with the aluminum powder by varying wt.% of 0% to 20% with step size of 5% during milling and then characteristic of composite was investigated. The results show that with the increment of Mg to 15% of wt. the crystallite sizes of 20 h milled powders diminish from 44 to 26 nm and lattice strains increased from 0.22% to 0.32% caused by Mg atomic penetration into the substitution sites of the Al lattice. With up to 15% of wt. Mg (for 20 h milled composites) hardness increases from 120 to230 HV caused by the increment of the Mg concentration

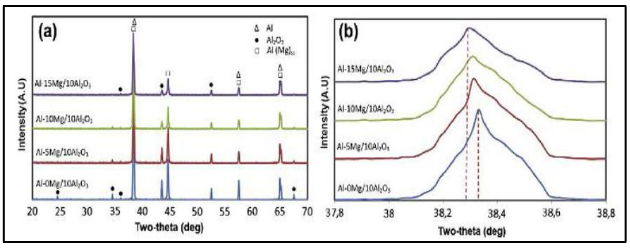


Fig. 7: X-ray diffraction patterns of Al–x Mg/10Al2O3 powder mixture milled for 20 hours

G. J. Safari

J. Safari present the study of milling time on microstructure and mechanical properties of Al and Al -10% weight of magnesium matrix with the reinforcement with the 5% weight of AL2O3 nano particles the mechanical properties are investigated. Steady state situation was occurred in Al-10Mg/5 Al2O3 in 20 hour but in the Al/5Al2O3 this situation was not occurred this due to the solution of Mg in to Al matrix. nano composite after 20 h, due to solution of Mg in to Al matrix. For the binary Al-Mg matrix up to 10 h lattice strain increased to about .4 and .66% for Al and Mg matrix with average crystalline size 34 nm.

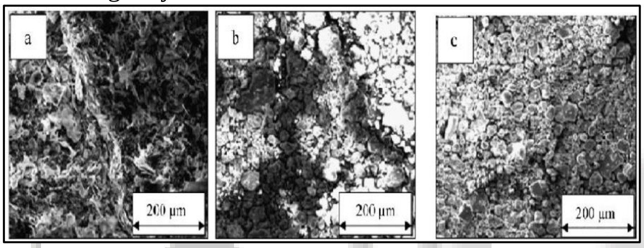


Fig. 8: SEM micrograph of AL-10Mg/5Al2O3 powder milled for different times (a) 2 h , (b) 5 h, (c) 10 h

H. G. Siva Kumar

In this work synthesized nano sic particles reinforced in to the Ti-6Al-4V alloy with different mass fraction 0, 5%, 10% and 15% by the powder metallurgy process. The effect of reinforcement of sic particles on the mechanical properties such as hardness and compressive strength of the alloy of titanium are determined. The optimum density 93.33% was obtained at the compaction pressure of 6.035 Mpa. The effect of reinforcement of nano sic particles in Ti64 alloy matrix composite on the phase formation are observed by the X-ray diffraction. After testing mechanical properties it shows that the compressive strength and hardness of Ti64 alloy improved by reinforcement of sic nano particles.

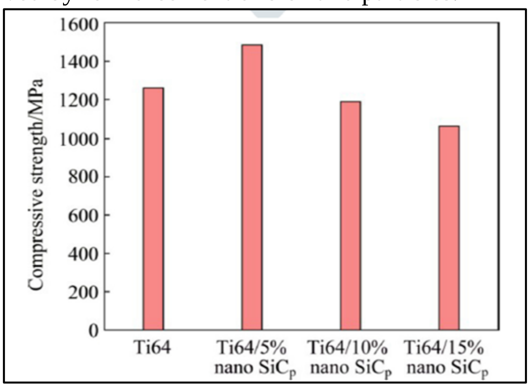


Fig. 9: compressive strength of Ti64 alloy and Ti64alloy/sic nano particles.

III. Conclusion

The whole work done by the researchers, they used various methods for the fabrication and the reinforcement of nano particles on metal matrix. Mostly used fabrication methods are stir casting, spark plasma, ultra-sonic assisted casting, powder metallurgy but stir casting most suitable due to their simplicity and low cost. Nano particles addition results in a significant improvement in, ultimate tensile and yield strength of composites. Hard Nano particles protect the surface, so the wear resistance is enhanced. It was found that the addition of nanoparticles to the matrix alloy increases the hardness as the nano TiO_2 particles act as obstacles for the dislocation motion. Through the reinforcement of nano particles on metal matrix the mechanical properties of composite metal matrix nano composite such tensile strength, hardness, compressive strength, wear resistance are improved comparison to the conventional metal matrix.

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