EVALUATION OF MECHANICAL PROPERTIES OF ALUMINIUM REINFORCED WITH Al_2O_3 NANO PARTICLES- A REVIEW

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ABSTRACT: Aluminium based metal matrix nano composites (AMMNC$_s$) are a new generation of materials that have the potential of satisfying the recent demands of advanced engineering applications. Because of their excellent property of high strength to weight ratio, they are widely used in aerospace, aircrafts, automobile industries, structural applications and many other defence systems. Researchers have been observed that the addition of nano sized Al_2O_3 particles with aluminium metal matrix yields superior mechanical and physical properties and interfacial characteristics of nano composites. The Scanning electron microscope of the Al-MMNCs indicate that the reinforcing nanoparticles of Al_2O_3 are uniformly distributed in metal matrix. This paper attempts to review the fabrication methods and mechanical properties of Aluminium/Al_2O_3 based metal matrix nano composites.

KEYWORDS:- Aluminium metal matrix nano composite; microstructural study by SEM; nanoparticle reinforcement; mechanical properties;

INTRODUCTION

Metal matrix nano composites (MMNCs) are strong metal matrix that is reinforced with nano sized ceramics to improve is mechanical properties and other important properties such as high strength to weight ratio, wear resistance, damping capacity, high specific strength, high specific stiffness etc. metal matrix nano composites combine the properties of both metal matrix and nano ceramic that leads toward the superior properties than metal matrix, moreover the strength of metal matrix can be improved without sacrificing the ductility. Because of these superior characteristics of metal matrix nano composites have numerous applications in aerospace, military, aircraft, and automobile industry applications. A lot of research has been done on aluminium based metal matrix nano composites, because of its unique properties like good corrosion resistance, less wear, high strength to weight ratio , high damping capacity, ductility, availability, low cost and wide applications. Currently there are several methods are available in which mechanical alloying and casting method mostly preferred because of its simplicity and less cost. Fabrication methods can be broadly classified into two types first is liquid state processing and solid state processing. In liquid state processing, mechanical and electromagnetic stirring and ultrasonic based dispersion is uses for the proper distribution of nanoparticles that have some important 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. because of poor wettability of ceramic nanoparticle into molten metal will cause difficulty in uniform dispersion. This problem is mostly faced in more viscous alloy because ceramic nanoparticles having higher tendency to agglomeration and clustering. In solid state of processing mostly preferred method is powder metallurgy in which, the main drawback of liquid state of processing technique can be overcome that is non uniform dispersion of ceramic nanoparticles. But this uniform dispersion of nanoparticles makes it costly and lengthy process. Solid state processing routs is not mostly preferred because of the limitation in size and the complexity of components.

Alumina (Al_2O_3), boron carbide (B_4C), silica (SiO_2), silicon carbide (SIC), graphite(Gr), tungsten carbide (WC), titanium dioxide (TiO_2), carbon nano tubes (CBN), titanium carbide (TIC) etc. are ceramic nanoparticles that are used for the reinforcement in metal matrix to enhance the properties. But in recent study that has been done by the researchers, is found that alumina and silicon carbide nanoparticle are mostly utilize as compare to others. Conventional aluminium metal matrix reinforced with Sic and Al_2O_3 have shown its higher mechanical strength and stiffness but ductility and fracture toughness of the metal matrix nano composite decreases. Aluminium metal matrix reinforced with the alumina nanoparticle will leads to increase its characteristics that are high mechanical strength, higher creep resistance at higher temperature high fatigue life and good machinability that makes it suitable for the application of aerospace, aircraft, automobile and electronic industry. This paper aimed to review the fabrication method and mechanical property of aluminium metal matrix reinforced with Al_2O_3.

FABRICATION TECHNIQUE OF COMPOSITE

In last two decades it is found that the various fabrication techniques are powder metallurgy, spray deposition, electro plating, immersion plating and chemical vapour deposition comes under the solid state fabrication techniques and stir casting, ultrasonic stirring, melt infiltration, squeeze casting, melt oxidation process, mechanical alloying, spark plasma sintering, are comes under the solid state fabrication technique. The nanoparticles have tendency of agglomeration and clustering because of the electrostatic, high surface energy, adhesiveness due to the moisture present. Out of these fabrication techniques some are discussed below that are mostly preferred for the reinforcement of the ceramic nanoparticles into metal matrix –

1:- POWDER METALLURGY METHOD

Powder metallurgy has become competitive with processes such as casting, forging and machining, particularly for relatively complex components of aircraft and aerospace etc. powder metallurgy process basically consists five operation in sequence that are powder production, blending, compaction, sintering and finishing operations. In the first step powder is formed by the various process such as atomization, reduction, electrolytic deposition mechanical pulverization and grinding etc. second step is blending that is simply mixing in air or in inert atmospheres(to avoid oxidation). Lubricants and additives may be added to improve their flow characteristics. Third step is compaction of metal powders to increase the density or to reduce porosity in this step powders are pressed into shape of dies to obtain required shape, density, and particle to particle contact. Fourth step is sintering in which the compact powder is heated in a controlled atmospheric condition to a temperature below the melting point, but sufficiently high to allow the bonding between the particles. Generally sintering temperature is 70% to 90% of the melting temperature of the alloys or metal. Sintering time vary for the different metal and alloys such it is for the iron and copper alloy is 10 minute and for the tungsten and tantalum it is around of 10 hours.

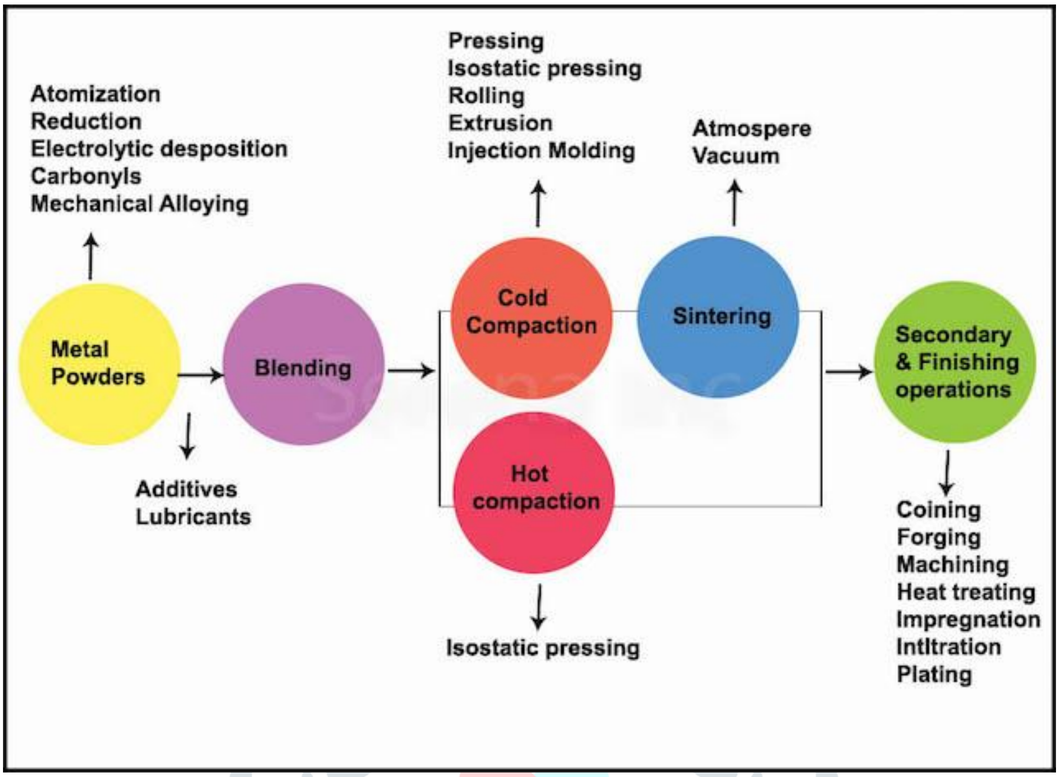

Fig:-1 flow chart of powder metallurgy process

2:- SPARK PLASMA STIRRING

The basic theory of spark plasma sintering process is based on the electrical spark discharge phenomenon where low voltage pulse current momentarily generates spark plasma in fine local areas between the particles at high energy. Spark plasma sintering is a new technique which takes only a few minutes to complete a sintering process compared to conventional sintering process that time consuming process.

This becomes possible because of the internal heating in case of spark plasma sintering as compare to external heating in case of conventional stirring. In conventional sintering usually a green compact needs to be prepared during the compaction before the sintering but in case of spark plasma sintering powder is directly fed into the graphite dies and the dies closed in suitable punch, but SPS is also completed in control atmospheric condition same as conventional sintering. This sintering process is capable of both conducting and non-conducting material.

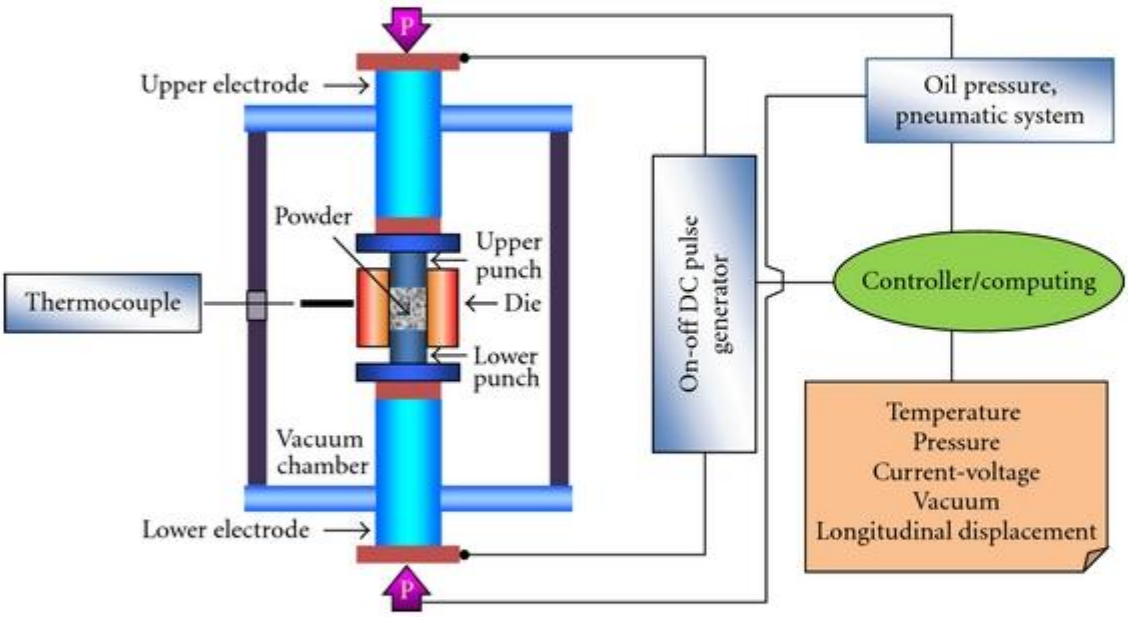

Fig:-3 schematic diagram of spark plasma sintering

3:- STIR CASTING METHOD

Stir casting is mostly preferred method for the reinforcement of ceramic particles into the metal matrix. In this process the ceramics nanoparticles mixed with the molten metal by mechanical stirring process. After the uniformly mixing of ceramics particles this liquid of composite material is casted by conventional casting method. Stir casting is an economical process for the fabrication of aluminium matrix composites. From the microstructural characterization, it is concluded that the shorter stirring period is required for ceramic incorporation to achieve metal/ceramic bonding at the interface. High temperature for stirring also leads to improved ceramic incorporation.

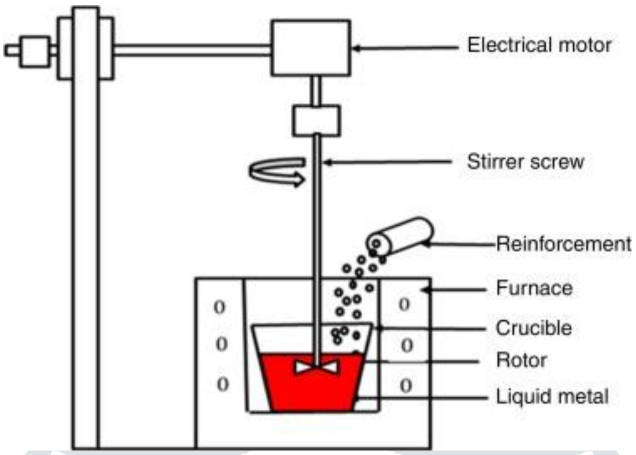

Fig:-3 schematic diagram of stir casting process

LITERATURE REVIEW

Bharath v. in this work an attempt has been made to synthesize metal matrix composite of aluminium alloy and ceramic alumina nanoparticles by using liquid processing route in particular stir casting method. Ceramic nanoparticles reinforced by varying percentage 6% to 12% by weight in step of in step of 3%. For each composite, ceramic nanoparticles preheated to the 200^0c to increase the wettability of the nanoparticles. Then microstructural characteristics of composites are investigated by SEM photograph that is taken by the scanning electron microscope and after that mechanical properties determined before the reinforcement and after the reinforcement and it is found that Al_2O_3 nanoparticles are distributed uniformly in aluminium alloy, wear rate decreases after the reinforcement of nanoparticles , and weight loss is maximum at the maximum percentage of reinforcement(12% ceramic nanoparticles) ,mechanical properties improves but ductility decreases as compare to aluminium alloy without reinforcement.

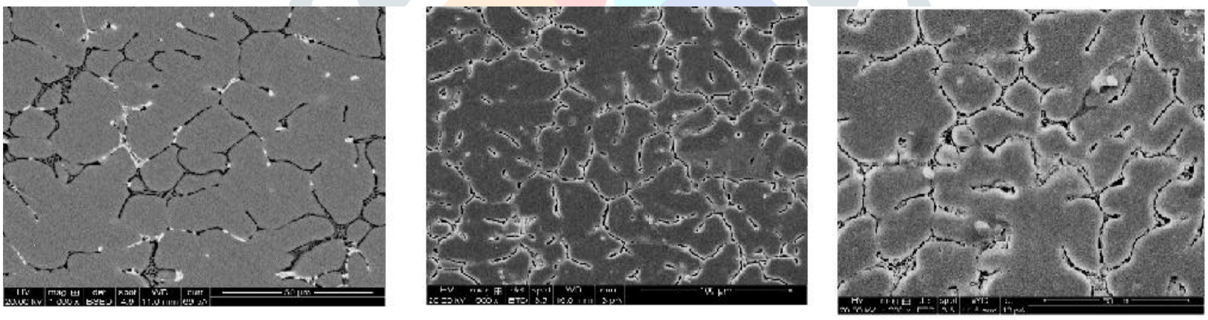

Fig:-4 SEM photographs of aluminium alloy and with Al_2O_3 particulate with 6% of Al_2O_3, with 9% Al_2O_3 and with 12% Al_2O_3.

M. Karbalaei Akbari In this work he uses a novel approach for the reinforcement of the Al_2O_3 particles with aluminium to avoid the agglomeration and clustering of the nanoparticles in composite matrix. Al_2O_3 nanoparticles were separately milled with Al and Cu powder at different milling duration and then reinforced into aluminium alloy and then effect of milling process and milling duration on composite material was investigated by determining the mechanical properties of composites. It is found that due to the uniformly distribution of the nanoparticles, this composite material shows enhanced mechanical properties than that of pure Al_2O_3 nanoparticle reinforced composite.

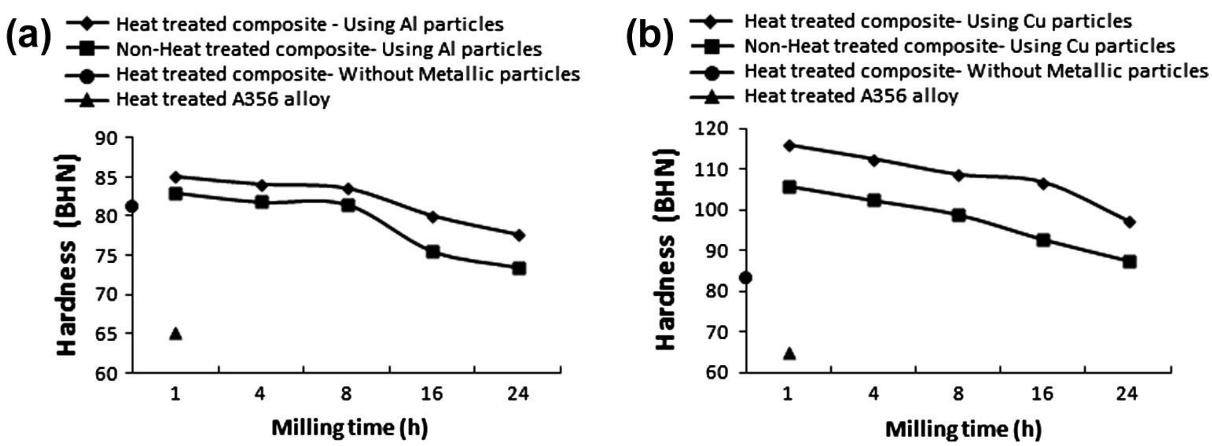

Fig5:-variation of hardness of (a) Al_2O_3-Al and (b) Al_2O_3 –Cu reinforced composite

A.Fathy in this work, Effect of Mg content on microstructure and mechanical properties of Al–Al2O3 (10%) composite. magnesium mixed with the aluminium powder by varying wt. percentage 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.

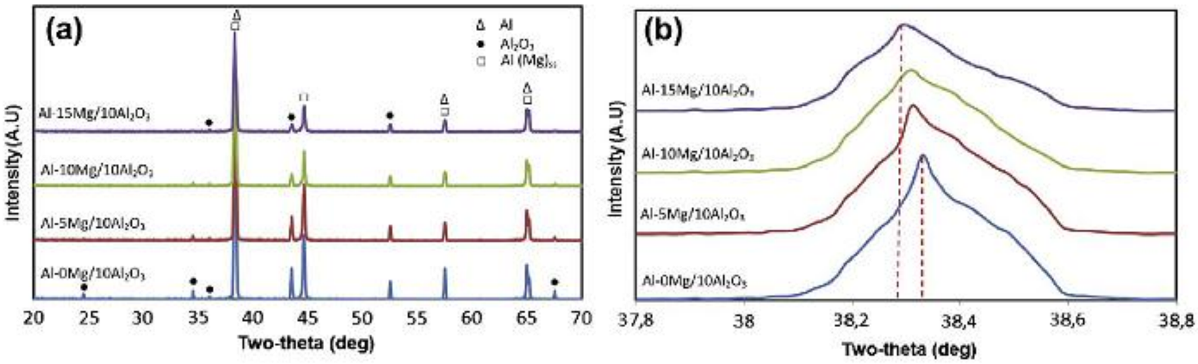

Fig:-6 X-ray diffraction patterns of Al–x Mg/10Al_2O_3 powder mixture milled for 20 hours.

X-ray diffraction patterns of Al–x Mg/10 Al_2O_3 (x = 0, 5, 10 and15 wt. %) powder mixtures after 20 h milling are presented in fig. For Al/Al_2O_3 and Al–Mg/Al_2O_3 powder mixtures characteristics.

V.sridhar in this work he presents the synthesis and mechanical properties of the magnesium reinforced with nano alumina powders with the varying percentage of alumina by volume in three amounts of .35%, .7% and 1.4%. Powder metallurgy technique is used for the reinforcement of ceramic alumina nanoparticles with the magnesium metal matrix with sintering temperature of 600-620^{0}C Upto investigate the microstructural properties XRD technique uses and SEM photograph is used to compare the various compositions of nano alumina to magnesium. With the increase in amounts of nano-alumina in composite material shows significantly increase in density, in XRD graph it is found that intensity increases with increase in amount of alumina nanoparticle with pure magnesium, by viewing the SEM images it can be considered that the nanoparticles of alumina distributed uniformly in magnesium metal matrix and hardness of composite material increases progressively with increase in amount of reinforcement.

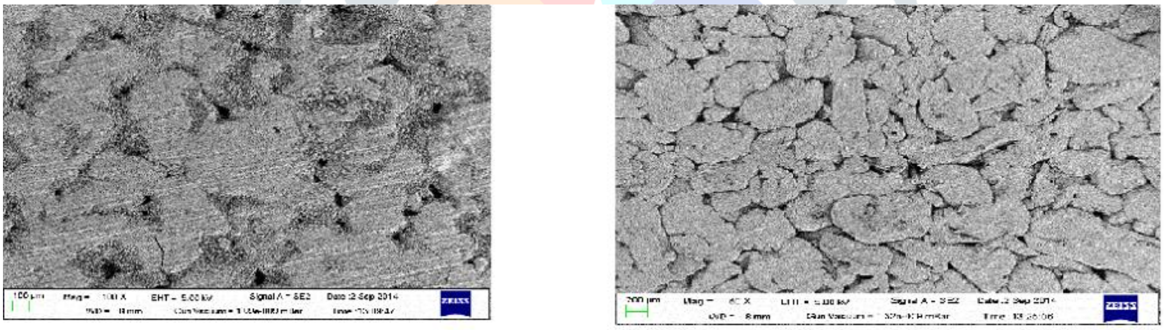

Fig:-7 (a) pure Mg (b) Mg+0.35% Al_2O_3

B.N. sarada In this work, attempts were made to produce aluminium hybrid metal matrix composite (LM 25+ Activated Carbon+ Mica) by stir casting method and then comparison is made with the conventional composites (LM25+ Activated Carbon) and (LM25+Mica) separately. And specimens were tested for hardness test by using Brinnel Hardness Tester and wear properties using Abrasive belt wear testing machine.

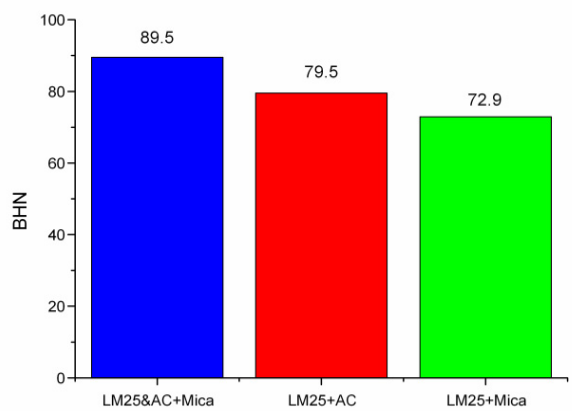

Fig 8:-brinell hardness test result

From the result of hardness testing graph is plotted for aluminium hybrid metal matrix composite (LM 25+ Activated Carbon+ Mica) and conventional composites (LM25+ Activated Carbon) and (LM25+Mica), it is found that hybrid composite material showing maximum hardness as compare to conventional composite. From the abrasive wear testing it is found that the Abrasive action is in the direction of sliding but the wear debris are finer and smoother for hybrid composite than conventional composites.

G.G. sozhamannam:- in this work Sic(silicon carbide) nanoparticle reinforced with the aluminium metal matrix at the different temperature and different holding time by using the stir casting method. Because by changing the temperature and holding time distribution of nanoparticles in composite matrix changes and then make a comparision in mechanical properties of the different specimen. The distribution is examined by microstructure analysis, hardness distribution and density distribution. From the microstructure analysis it is found that there is increase in particles clustering corresponding to an increase in processing temperature and also the clustering tendency is more in the higher holding time than in the low holding time. The ultimate strength of composite increases when processing temperature increases from 700-800^{0}C and then decreases from 800-900^{0}C.it can be seen in graph plotted below. From the microstructural analysis it is found that, the particles distributed uniformly at the processing time of 750-800^{0}C and particles agglomerations takes place at the temperature of 700,850 and 900^{0}C. This is happens because of the change in viscosity of the metal matrix of the aluminium with the change in temperature.

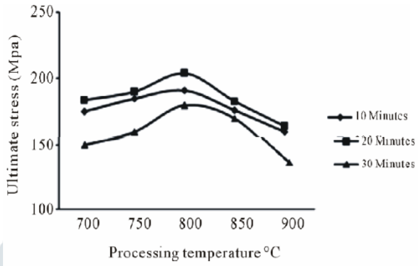

Fig:-9 effect of processing parameter on tensile strength of Al/Sic.

M.Ramchandra :- in this work zirconium oxide(n-ZrO_2) is used to produce aluminium nano composite material. nano particles are produced by using solution combustion technique. These nanoparticles reinforced into aluminium metal matrix by varying the percentage. Powder-metallurgy technique uses for the reinforcement. And then specimen are prepared for conducting hardness testing and microstructural analysis of composite material. Microstructural analysis reveals the uniform distribution of the nanoparticles with small agglomeration and it also reveals the good interfacial bonding between the n-ZrO_2 nanoparticles and aluminium metal matrix. SEM images of the composite material shown below:-

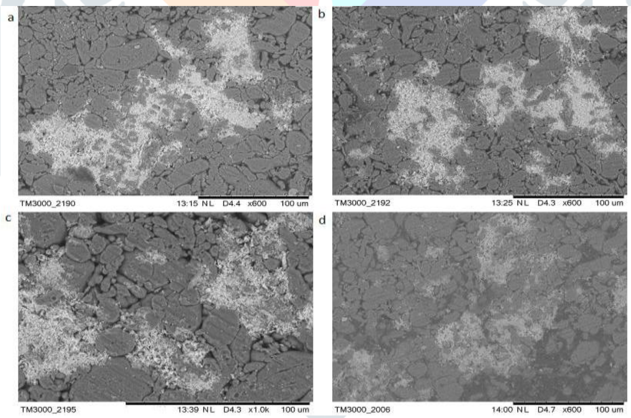

Fig10:- SEM micrograph of (a)1% ZrO_2(b) 2% ZrO_2(c)3% ZrO_2(d)4% ZrO_2

From the above study it is found that the hardness of the composite material due to the reinforcement of the n-ZrO_2 nanoparticle increases as the percentage of nano particle increases and the microstructure of nano composites reveals near uniform distribution of n-ZrO_2 particles with slight agglomeration.

J.H. Shin:- In this work titanium oxide (TiO_2) reinforced with ultrafine-grained aluminium alloy by using conventional milling and hot pressing fabrication technique. Owing to the characteristics of the TiO_2 particles, the interface structure is found to be clean and clear without any micro pores and contaminations. It is found after the performing mechanical testing on specimen of the composite material that the hardness, elastic modulus, and is increases as the volume percentage of TiO_2 increase. SEM images of the composite insures the uniform distribution of the Tio_2 nanoparticles on aluminium metal matrix.

Yong yang :- In this work ,ultrasonic dispersion method is used for an inexpensive fabrication of bulk lightweight MMNCs with reproducible microstructures and superior properties by use of ultrasonic nonlinear effects, namely transient cavitation and acoustic streaming, to achieve uniform dispersion of nano-sized Sic particles in molten aluminium alloy. And then Microstructural study was carried out with the help of optical microscope, Scanning electron microscope and XPS. From the micro level study it is found that the Sic nanoparticles uniformly distributed with slight clustering that is shown below and some of the particles oxidised and formation of SiO_2 take place. After the analysing the composite material it is found that the strength of composite increases 50% with the addition of 2% of Sic nanoparticles with the aluminium alloy.

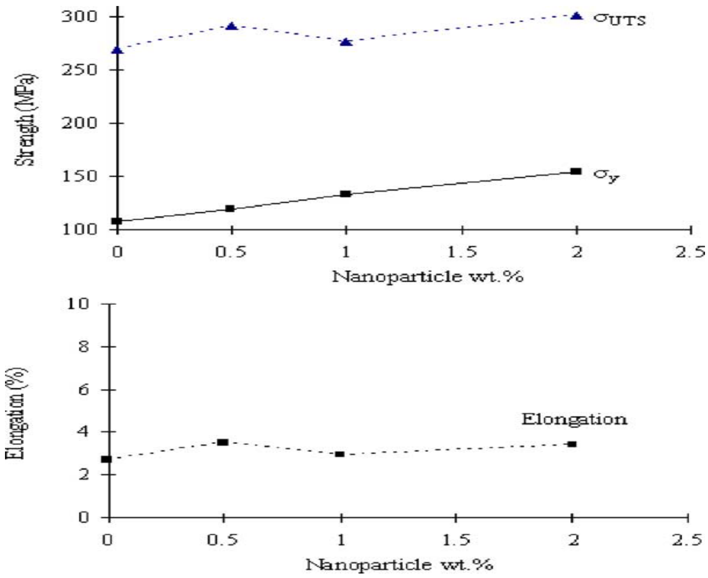

Fig 11 :- change in tensile strength and elongation of composite with increase in percentage of Sic nanoparticles

CONCLUSION: -

This paper presents various fabrication techniques and mechanical behaviours of metal matrix nano composites reinforced with the ceramic nanoparticles. It is showing that the ceramic nanoparticles reinforced metal matrix have improved mechanical properties than the unreinforced metal matrix or alloys. As the percentage of reinforcement of ceramic nanoparticles increases in metal matrix its strength, hardness, wear resistance, fatigue strength and creep strength at high temperature of metal matrix nano composite increases. Microstructural evaluation of the composite material is done by the scanning electron microscope that shows that particulates are uniformly distributed in the metal matrix with slight agglomeration which is depends upon the process that is follow for the fabrication of composite. Due to the nanoparticles reinforcement porosity of the composite increases but within acceptable limits. Most commonly techniques which followed for the fabrication are stir casting technique, powder metallurgy, spark plasma sintering and ultrasonic assisted casting can be used for the high sensitive parts.

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