Mechanical properties of Nano Al-SiC- GNP Metal matrix composites Fabricated by Stir Casting Method

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Abstract: *This project is aimed to process characterization of the conventional hardness and microstructure of Al-Sic nanocomposites with grapheme flakes. It is planned to use various combinations with weight percentage of grapheme and Sic and to produce the Aluminum matrix composites by friction stir casting. The mixtures are to be mixed with nano Aluminum (70%) by weight percentages of adding nano Sic (28%, 26%, 24%, 22%), Graphene nano particles (GNP) (2%, 4%, 6%, 8%) followed by Friction stir processing to make a rigid form. graphene and SiC nano particles predominantly are homogeneously distributed on the grain boundaries of Al matrix and SiC nano particles are distributed between GNP. Lot of work has been carried on synthesis of Al–Sic-Graphene composites for various engineering applications. Graphene has endowed with excellent physical and mechanical properties such as Tensile strength, elastic modulus and thermal conductivity and has got attention in the field of electronics, automobile industries, aerospace projects and other engineering applications. The prepared compacts must undergo microstructure evaluation by Metallurgical microscope and also find the Conventional hardness.*

Key words: *Aluminium nano particles, SiC Nano particles, Graphene Nano particles, Stir casting, Microstructure, Hardness test.*

1: INTRODUCTION

A. Radha et al [5] Nowadays, Aluminium Matrix Composites (AMCs) find application in various fields like Automobiles, Aeronautical etc., due to its light weight and high strength. Also, nano particles are used as reinforcement in AMCs due to the fact that it can serve as a very good reinforcing agent and adds more stiffness. Aluminium Alloy (AA) is mixed with nano particles like graphene as reinforcement to prepare AMCs. Reinforcement of graphene with the matrix metal leads to enhancement in mechanical properties without any considerable increase in weight of the material. In this study, samples of AA6061 reinforced with constant wt% of Silicon Carbide (SiCp) (10% of AA) and varying wt % of graphene (0%, 0.3%, 0.5%, and 0.7%) were fabricated by Stir Casting technique. The specimens were undergone through various tests like tensile, flexural, hardness, impact and wear and Microstructure analysis. The optical and SEM images shows that uniformly distributed in AMCs. The overall test results are revealed that the addition of graphene helped to improve the mechanical properties significantly when compared to reinforced Aluminium with SiCp.

Chi-Hoon Jeon et al [1] Graphene/Al MMC were successfully fabricated by FSP. In the fabrication process the graphene reinforcement was applied in the form of GO/water colloid for a safer and simpler manufacturing process. The results of Raman spectroscopy suggest that graphene reinforcements were successfully mixed into the aluminum matrix by the intense stirring and mixing of materials during FSP. The experimental result shows that the thermal conductivity of the graphene/Al MMC was increased by more than 15% in comparison with that of the aluminium matrix. The increased thermal conductivity of the MMC suggests that the GO in the colloid was effectively reduced into highly conductive RGO during FSP. As shown by quasi-static tensile testing, FSP and GO reinforcement both improve the ductility of the fabricated MMC. This simple but effective process suggested in the present study for fabricating graphene/Al MMC with enhanced thermal conductivity may provide benefits in the development of compact and light-weight heat exchangers.

Xiang Zeng et al [2] In the present study, hybrid composites consisting of a hypoeutectic aluminum-silicon (Al-Si) matrix with 10 wt.% silicon carbide (SiCp) and varying reduced graphene oxide (RGO) composition (0.3-0.7 wt.%) were fabricated by a combination of a solution-mixing and powder metallurgy route. The solution mixing and PM route proved to be effective for the fabrication of HAMCs(hybrid aluminum-matrix composites) consisting of an Al matrix with a uniform distribution of RGO.

Meysam Tabandeh,et al[3] This work has been made on using graphene as a reinforcement in metal matrix nanocomposites due to its extraordinary high strength and high modulus, metal-matrix graphene nanocomposites still exhibit large scatters in experimentally measured physical and mechanical properties. Existing theoretical models on the effects of graphene on mechanical properties including tribological behavior will also be discussed and compared with experimental observations. Potential future research directions in the area of graphene-reinforced MMNC will be outlined.

Abhishek Sharma Et al[4] Fabricating high wear resistance Al matrix composite without sacrificing its ductility and thermal properties is a critical issue in the designing of Al-based composites. In present study, a detailed wear mechanism of Al-SiC surface composite modified by the impregnation of Graphene, Graphite & carbon Nanotubes through friction stir processing (FSP) is documented. The results revealed that with SiC and graphene nanoplatelets (GNP) reinforcements the friction coefficient and specific wear rate decreased by ~ 34% and ~ 50 % as compared to as-received Al6061 alloy respectively. On the other hand, combination of SiC and carbon Nanotubes (CNT) reinforcements severely deteriorates the wear resistance of the composite. The layered structure, large specific surface area and the wrinkled morphology of the graphene flakes are the primary reasons for the increased wear resistance. The exfoliation of GNP to few layered graphene (FLG) under the effect of plastic flow stresses during FSP also contributes significantly to the improvement of surface properties. The abrasion is identified as the dominant wear mechanism in the Al-SiC-Graphite & Al-SiC-GNP hybrid composite. Whereas, delamination due to adhesion with the counter surface is the leading mechanism in the Al-SiC-CNT hybrid composite. Various characterization strategies such as micro structural characterization through SEM, interfacial study through TEM and phase analysis through XRD corroborate the results. Finally, GNP is identified as the best reinforcement among the carbon family for improvement in wear resistance of Al6061-SiC

2. METHODS OF SYNTHESIS OF NANO MATERIALS: -

There are a wide variety of techniques for producing Nanoparticles. These essentially fall into three categories: condensation from a vapor, chemical synthesis, and solid-state processes such as milling. Particles can then be coated, with hydrophilic (water-loving) or hydrophobic (water-hating) substances, for example: depending on the desired application.

(a) Vapor condensation: - This approach is used to make metallic and metal oxide ceramic Nanoparticles. It involves evaporation of a solid metal followed by rapid condensation to form Nano sized clusters that settle in the form of a powder. Various approaches to vaporizing the metal can be used and variation of the medium into which the vapor is released affects the nature and size of the particles. Inert gases are used to avoid oxidation when creating metal Nanoparticles, whereas a reactive oxygen atmosphere is used to produce metal oxide ceramic Nanoparticles. The main advantage of this approach is low contamination levels. Final particle size is controlled by variation of parameters such as temperature, gas environment and evaporation rate.

(b) **Chemical synthesis: -** The most widely used chemical synthesis technique consists essentially of growing Nanoparticles in a liquid medium composed of various reactants. This is typified by the Bayer villager oxidation approach and is also used to create quantum dots (Nanoparticles in which quantum mechanical properties are the key to their useful behavior). Chemical techniques are generally better than vapor condensation techniques for controlling the final shape of the particles. The ultimate size of Nanoparticles might be dictated, as with vapor condensation approaches, by stopping the process when the desired size is reached, or by choosing chemicals that form particles that are stable, stop growing, at a certain size. The approaches are generally low-cost and high-volume but contamination from the precursor chemicals can be a problem. This can interfere with one of the common uses of nanoparticles, sintering, to create surface coatings.

(c) Solid state process:

Solid-state processes grinding or milling can be used to create Nanoparticles. The milling material, milling time and atmospheric medium affect resultant Nano particle properties. The approach can be used to produce Nanoparticles from materials that don't readily lend themselves to the two previous techniques. Contamination from the milling material can be an issue.

3. CLASSIFICATION OF SYNTHESES ROUTES: -

However, the most popular way of classifying the synthesis routes is based on how the Nanostructures are built, and such an approach leads to two routes, namely,

1. Top down approach / Nano fabrication
2. Bottom up approach / Nano assembly

3.1 Top-down approach/ Nano fabrication: -

The top-down approach to Nanotechnology is that in which large objects are made to small by miniaturization. Techniques that remove atoms from a structure (such as wet & dry etching) and those that add atoms to a structure (such as oxidation, diffusion and electroplating) in a controlled way are the foundations of this approach. The top-down approach to reaching the Nano scale is best exemplified by the development of integrated circuit in which lateral feature size of components such as transistors, contacts and metals interconnect have gradually decreased from several microns and are approaching to a size <100 nm. There are many methods, which fall under top-down/Nano fabrication. The important methods are described below.

A. Mechanical alloying: -

This process is commonly used to produce Nano structured materials is mechanical alloying. There are two basic versions of this process. The first, more specifically called mechanical attrition, is a process where high-energy ball milling is used to grind and refine the structure to produce highly mixed, ultrafine powders.

Grain sizes of the material are partially dependent on time, where extended milling times result in more uniform grain sizes. The second version, reaction milling, involves in-situ solid-state chemical reactions between precursor materials while they are mixed and milled. Producing large quantities of nano structured material is one advantage of the mechanical alloying process. More over various types of Nano materials, such as metals, ceramics inter metallic and composites, can be produced using these straight forward processes. However, contamination from the milling hardware and environment, non-uniform particle sizes due to short milling times, and non-homogeneous chemical composition due to incomplete milling reactions are problems for mechanical alloying processes. One way to lessen the effects of environmental contamination is to perform the process in the presence of liquid nitrogen, which is also referred to as cryogenic milling.

B. Lithography

Lithography (or patterning) refers to the series of steps that establish the shapes, dimensions, and location of the various components of the integrated circuit (IC). The current progress in IC design, with the decreased dimensions (miniaturization) of the chip and increased density of transistors, is possible only if smaller areas on the wafer surface can be patterned. This is primarily the function of lithography. Thus, the success of modern IC design is due largely to lithography. This can be summarized in the process goals:

1. Create a pattern with the dimensions established by the circuit design.
2. Place the pattern correctly with respect to the crystal orientation and other existing patterns.

After the pattern is created, either the defined part of the wafer surface is removed (trench creation) or left behind (island creation) or new material is deposited. Lithography is also used to expose certain parts of the wafer surface for doping (either with a hard mark for thermal diffusion or with a soft mask for ion implantation). The correct placement of the circuit pattern involves alignment or registration of various masks. An IC wafer fabrication process can require forty or more patterning steps. Alignment of these individual steps is critical to form a working IC.

Techniques of lithography:

a. Photo lithography, b. E-beam lithography.
c. X-Ray lithography. d. Interference lithography. f. Scanning probe.

3.2 Bottom -up approach/ Nano assembly:-The alternate to the top-down approach is known as the bottom-up approach, first predicted by Feynman. This is the purview of chemistry and colloidal science and includes macromolecular synthesis, dendrimers, inclusion chemistry, surfactant mediates nanoparticles synthesis and micro emulsion approaches. The important methods, which come under Bottom -up approach/Nano assembly, are described below.

A. Chemical precipitation: -

This represents a wet chemical method capable of rapid production of large quantities of materials. It offers the possibility of incorporation and dispersing the additive or catalytic components on a particular support during synthesis. In this method the kinetics of nucleation and particle growth in homogeneous solutions can be adjusted by the controlled release of the anions and cautions. Careful control of the kinetics of the precipitation can result in monodisperse nanoparticles. It is essential to control the factors that determine the precipitation process, such as the pH and the concentration of the reactants and ions. Organic molecules are used to control the release of the reagents and ions in the solution during the precipitation process. The particle size is influenced by the reactant concentration, pH and temperature. By engineering these factors, nanoparticles with narrow size distributions can be produced.

B. Hydrothermal method:

Hydrothermal synthesis is typically carried out in a pressurized vessel called an autoclave with the reaction in aqueous solution. The temperature in the autoclave can be raised above the boiling point of water, reaching the pressure of vapor saturation. Hydrothermal synthesis is widely used for the preparation of metal oxide nanoparticles which can easily be obtained through hydrothermal treatment of peptized precipitates of a metal precursor with water. The hydrothermal method can be useful to control grain size, particle morphology, crystalline phase and surface chemistry through regulation of the solution composition, reaction temperature, pressure, solvent properties, additives and aging time.

C. Sol-gel method:

It is possible to synthesize complex composition materials, to form higher purity products through the use of high purity reagents. The sol-gel process allows obtaining high quality films up to micron thickness, difficult to obtain using the physical deposition techniques. Moreover, it is possible to synthesize complex composition materials and to provide coatings over complex geometries. The starting materials used in the preparation of the sol are usually inorganic metal salts or metal organic compounds, which by hydrolysis and poly condensation reactions from the sol. When the sol is cast into a mold, a wet gel will form. By drying and heat-treatment, the gel is converted into dense ceramic or glass materials. If the liquid in a wet gel is removed under a supercritical condition, a highly porous and extremely low-density aerogel material is obtained. As the viscosity of a sol is adjusted into a suitable viscosity range, ceramic fibers can be drawn from the sol. Ultra-fine and uniform ceramic powders are formed by precipitation, spray pyrolysis, or emulsion techniques.

D. Thin film Growth:

Two categories of thin film growth methods are normally used to produce nanomaterials, nanostructures, hetero structures, and quantum well structures. These are:

a) Physical vapor deposition (PVD): -

It is a technique used to deposit thin films of various materials on to various surfaces (e.g., of semiconductor wafers) by physical means, as compared to chemical vapor deposition. PVD involves condensation from the vapor phase. The PVD process is composed of three mainsteps: -

(a) Generating a vapor phase by evaporation or sublimation of the material.
(b) Transporting the material from the source to the substrate.
(c) Formation of the particle or film by nucleation and growth.

Different techniques have been used to evaporate the source such as electron beam, thermal energy, sputtering, cathodicarc plasma, and pulsed laser.

b) Chemical vapor deposition (CVD): -

It is a chemical process often used in the semiconductor industry for the deposition of thin films of various materials. In a typical CVD process the substrate is exposed to one or more volatile precursors, which react or decompose on the substrate surface to produce the desired deposit. In CVD, the vaporized precursors are introduced into a CVD reactor and absorb on to a substance held at an elevated temperature. These absorbed molecules will either thermally decompose or react with other gases/vapors to form crystals.

The CVD process consists of three steps:
(a) Mass transport of reactants to the growth surface through a boundary layer by diffusion.
(b) Chemical reactions on the growth surface.
(c) Removal of the gas-phase reaction byproducts from the growth surface.

Nucleation in the gas phase is homogeneous; whereas nucleation on the substrate is heterogeneous. Catalysts, usually transition metal particles such as Fe, Ni, and Co, are also used in the CVD process.

4. SYNTHESIS PROCESS PARAMETERS

a).St*i*rrer Design: It is very important parameter in stir casting process which is required for vortex formation. The blade angle and number of blades decides the flow pattern of the liquid metal. The stirrer is immersed till two third depth of molten metal. All these are required for uniform distribution of reinforcement in liquid metal, perfect interface bonding and to avoid clustering.

b). Stirrer speed: Stirring speed is an important parameter to promote binding between matrix and reinforcement i.e. wet ability. Stirring speed decides formation of vortex which is responsible for dispersion of particulates in liquid metal. In our project stirring speed is 300 rpm.

c).Stirring temperature: Aluminium melts around 650°C, at this temperature semisolid stage of melt is present. Particle distribution depends on change in viscosity. The viscosity of matrix is mainly influenced by the processing temperature. The viscosity of liquid is decreased by increasing processing temperature with increasing holding time for stirring which also promote binding between matrix and reinforcement. Good wet ability is obtained by keeping temperature at 800°C.

d).Stirring time: As stirring promote uniform distribution of reinforcement partials and interface bond between matrix and reinforcement, stirring time plays a vital role in stir casting method. Less stirring leads to non-uniform distribution of particles and excess stirring forms clustering of particles at some places. Stirring time is 5 minutes in our case.

5. EXPERIMENTAL SETUP AND PROCEDURE:

The process of stir casting starts with placing empty crucible in the furnace. The heater temperature is then gradually increased up to 800°C. Aluminum alloy is cleaned to remove dust particles, weighed and charged in the crucible for melting. Required quantities of reinforcement powder and magnesium powder are weighed on the weighing machine. Reinforcements are heated for 45 minutes at a temperature of 500°C. When matrix was in the semisolid stage condition at 650°C, 1 % by weight of pure magnesium powder is used as wetting agent. After five minutes the scum powder is added which forms a scum layer of impurity on liquid surface which to be removed.

Heater temperature is then gradually increased to 800°C. At this heater temperature stirring is started and continued for five minutes. Stirring rpm is gradually increased from 0 to 300 RPM with the help of speed controller. Preheated reinforcements are added during five minutes of stirring. Reinforcements are poured manually with the help of conical hopper. The flow rate of reinforcements measured is 0.5 gram per second. Stirrer rpm is then gradually lowered to the zero. Then molten composite slurry is poured in the metallic mold without giving time for reinforcement to settle down at crucible bottom. Mold is preheated at 500°C temperature for one hour before pouring the molten slurry in the mold. This is necessary to maintain slurry in molten condition throughout the pouring. While pouring the slurry in mould the flow of the slurry is kept uniform to avoid trapping of gas, also distance between crucible and mold plays a vital role in quality of casting.

Fig5.1: -Aluminum Nano powder

Fig5.2: -Silicon carbide Nano powder

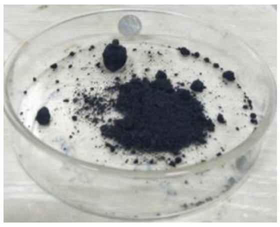

Fig5.3: -Graphene Nano powder

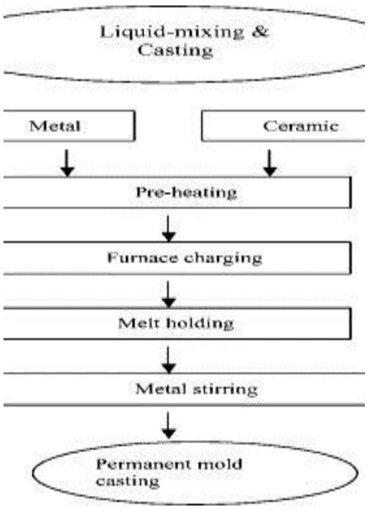

Fig5.4: Steps in stir casting

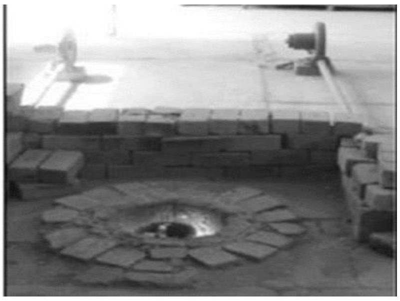

Fig5.5: Melting of powders in furnace

Fig5.6: - Sample Test Piece for Rockwell Hardness Test

PROCEDURE:

1. Melting temperature is 700 degree centigrade
2. Stir speed is 600-800 rpm
3. Diameter of the workpiece is 20mm
4. Length of workpiece is 150mm Finishing operations

1. Excess material is removed by using lath machine.
2. Grinding the surface of work pieces for smoothness by using the grinding machine.
3. Polish the workpieces for mirror surface by using emery paper.
4. Cutting the workpieces into small pieces in required sizes.
5. These pieces are used for doing different tests.

Fig5.7: - Work pieces before finishing

Fig5.8: - Work pieces after finishing

6. RESULTS & DISCUSSION:

(a) Observations during Rockwell Hardness Test

S.No	Composition (%)	Trail-1	Trail-2	Trail-3	Average
1	70-28-02	86	82	95	88
2	70-26-04	88	78	91	86
3	70-24-06	75	89	90	85
4	70-22-08	64	69	88	74

Table 6.1 Observations during Rockwell Hardness test

(B). Microstructure of Work pieces

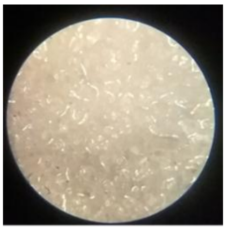

Fig: 6.2. Composition of Al-Sic-Gnp (70-28-02)

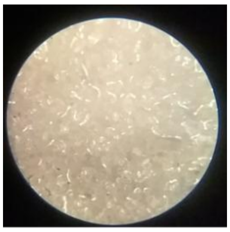

Fig: 6.3. Composition of Al-Sic-Gnp (70-26-04)

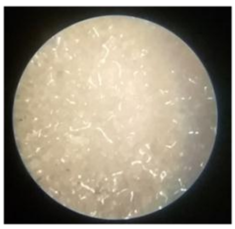

Fig: 6.4. Composition of Al-Sic-Gnp (70-24-06)

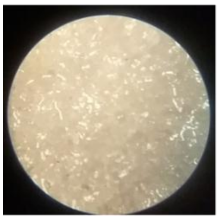

Fig: 6.5. Composition of Al-Sic-Gnp (70-22-08)

6. CONCLUSION:

1. The Sic & Graphene are the most effective strengthening particulates, for higher strength, hardness & grain size reduction.
2. As it is also noted that Addition of these composites to the aluminium results in the increase of hardness number for a material which reduces the weight of the material and possess high thermal and electrical conductivity of the material.
3. So, the percentage of aluminum is kept constant as 70%, silicon is decreasingly added from 28% and the graphene is increased from 02%.
4. Finally, we conclude that a lot of work has been carried on synthesis of Al –Sic –graphene composites for various engineering applications.
5.Then the prepared compacts must undergo microstructure evolution by Metallurgical microscope and find the hardness by Rockwell Hardness Test Experiments.
6. By this project we conclude that the hardness number 88 is the highest value for the sample 1 having the composition of 70%-28%-02% (Al-Sic-Gnp).

REFERENCES

[1]. Chi-hoon jeon, yong-ha jeong, jeong-jin seo, huynh ngoc tien, sung-tae hong#, young-jin yum, seung-hyun hur, and kwang-jin lee, "Material Properties Of Graphene/Aluminum Metal Matrix Composites Fabricated by Friction Stir Processing" international journal of precision engineering and manufacturing vol. 15, no. 6, pp. 1235-1239 june 2014 / 1235.

[2]. Xiang Zeng, Jingang Yu, Dingfa Fu, Hui Zhang, Jie Teng, "Wear characteristics of hybrid aluminum-matrix composites reinforced with welldispersed reduced graphene oxide nanosheets and silicon carbide particulates" PII: S0042-207X(18)30770-X, DOI: 10.1016/j. vacuum. 2018.06.033 Reference: VAC 8053.

[3]. Meysam Tabandeh-Khorshid, P. Ajay Kumap, Emad Omrani, Chngsoo Kim, Pradeep Rohatgi, "Synthesis, characterization, and properties of graphene reinforced metal-matrix Nanocomposites" PII: S1359-8368(19)30640-7 DOI: doi.org/10.1016/j. compositesb. 2019.107664, Reference: JCOMB 107664.

[4]. Abhishek Sharma, Damanapeta Narsimhachary, Vyas Mani Sharma, Baidehish Sahoo, Jinu Paul, "Surface modification of Al6061-SiC surface composite through impregnation of graphene, graphite & carbon nanotubes via FSP: A tribological study" PII: S0257-8972 (19) 30360-3 DOI: https://doi.org/ 10.1016/j.surfcoat.2019.04.001
Reference: SCT 24496.

[5]. A.Radha, K. R.Vijayakumar, "An investigation of mechanical and wear properties of AA6061 reinforced with silicon carbide and graphene nano particles-Particulate composites" Materials Today: Proceedings 3 (2016) 2247–2253

[6]. Charles Chikwendu Okpala.Nanocomposites – An Overview Department of Industrial /Production Engineering, Nnamdi Azikiwe University, P.M.B. 5025 Awka, Anambra State,Nigeria.

[7].Kamaal Haider, Md.Azad Alam, Amit Redhewal,Vishal Saxena. Investigation of Mechanical Properties of Aluminium Based Metal Matrix Composites Reinforced with Sic & Al2O3 et al. Int. Journal of Engineering Research and Applications ISSN: 2248-9622, Vol. 5, Issue 9, (Part - 2) September 2015,pp.63-69

[8]. Manjunath Naik H R, Manjunath L H, Puneeth N. Synthesizes and Characterization of Al 6061-Graphene-Silicon Carbide Hybrid Composites by Powder Metallurgy Route. International Journal of Advances in Scientific Research and Engineering (injure) E-ISSN: 2454-8006 Vol. 3. Special Issue 1,August-2017.

[9]. M. Ramezani, T. Neitzert. Mechanical milling of aluminum powder using planetary ball milling process. Mechanical milling of aluminum powder using planetary ball milling process, Journal of Achievements in Materials and Manufacturing Engineering 55/2 (2012)790-798.

[10]. R.S. Rana, Rajesh Purohit, V.K. Soni, S. Das. Characterization of Mechanical Properties and Microstructure of Aluminum Alloy-Sic Composites. Materials Today: Proceedings Volume 2, Issues4–5.

[11]. S.Vijayakumar, M. Soundarrajan, P. Palanisamy, K. Pasupathi. Studies on Mechanical Properties of Al-Sic Metal Matrix Composite. SSRG International Journal of Material Science and Engineering (SSRG-IJMSE) volume 2 Issue6 November to December 2016 ISSN:2394.

[12]. Ternopol, Z, Kyzas, G.Z, Bikiaris, D.N. Recent advances in nanocomposite materials of graphene derivatives with polysaccharides. Division of Chemical Technology, Department of Chemistry, Aristotle University of Thessaloniki, Thessaloniki, GR-541 24, Greece MaterialsVolume 8, Issue 2, 2015, Pages652-683.

[13].Vijaylaxmee Mishra, Richa Sharma, Nakuleshawar Dut Jasuja, Deepak Kumar Gupta. A Review on Green Synthesis of Nanoparticles and Evaluation of

Antimicrobial Activity. Department of Biotechnology and AlliedSciences.

[14]. Sable, A.D., Deshmukh, S.D., "Preparation of MMCs By Stir CastingMethod" IJMET, pp.3,(2012)

[15].Aqida,S.N.,Ghazali,M.I.,Hashim.J.,"The Effects of Stirring Speed and Reinforcement Particles on Porosity Formation in Cast MMC"pp.

[16].RajeshKumar,ParshuramM.,"Preparation of Aluminum Matrix Composite by Using Stir Casting Method" IJEAT, Vol-3,(2013)

[17].J.Hashim,L.Looney, "Metal matrix composites: production by the stir casting method" IJEAT(1999)

[18]. Shubham Mathur, Alok Barnawal, "Effect of Process Parameter of Stir Castingon Metal Matrix Composites"IJSR.

[19].ClyneTW, Withers PJ, "An introduction to metal matrix composites", 1st edition. Cambridge: Cambridge University Press.

[20].Srinivasulu. Dorasila, M.Venkata Sai, M.Hemanth Sai , Venkatesh, D.Moshea, V.Arun Kumar – " Fabrication And Testing Mechanical Behaviour Of Jute Fibre And Aluminium Composite Materials" International Research Journal of Engineering and Technology (IRJET)- e-ISSN: 2395-0056, p-ISSN: 2395-0072, Volume: 07, Issue: 05 | May 2020 , Pages 7086 - 7096.

[21].Redankamma Yenumula, Srinivasulu Dorasila, SCV Ramana Murthy Naidy, Rambabu Kalpukuri – "Experimental Investigation of Mechanical Properties of pure Al-Sic Metal Matrix Composite by Stir Casting Method" *International Journal of Engineering Trends and Technology (IJETT)- ISSN:2231-5381 Volume 59, Issue 3 - May 2018. pg, 148-154.*

[22].Srinivasulu Dorasila, Dr.Ch.Srinivas Rao and Dr.D.Lingaraju -"An Experimental Investigation On Design and Development of Rotational Arc welding Machine and parametric study on process variables" *International Journal of Science, Engineering and Technology Research(IJSETR)- April/2016.*