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An Investigation and FEA Analysis Effect of $CaCO_3$ and SiC Particles of Aluminium based Composites

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Abstract: Among automobile manufacturers, in recent times, a paramount importance has been given to less fuel consumption of the vehicles by utilizing lightweight and high strength materials. Metal matrix composites (MMCs) have been used commercially in the automotive market for nearly twenty years. Metal Matrix Composites (MMCs) have very light weight, high strength, stiffness and exhibit greater resistance to corrosion, oxidation, and wear. Tensile and compressive strength is an especially important property of Aluminium matrix composites which is essential for automotive application. In this study hybrid Aluminium matrix composite was fabricated through crucible casting route. Calcium carbonate and silicon carbide were used as reinforcement phases for the present study. The hybrid MMC was prepared with varying the $CaCO_3$ and SiC particles weight ratio ranging from 2.5% to 5% and silicon carbide was varied 2.5% to 5%. The various mechanical properties were investigated and compared with non-metal matrix alloy of Al6061. According to the FEA analysis we have found minimum deformation, stress and strain occurs Ratio 3 AL6061+ $CaCO_3$ 5% +SiC 5% is very low value compare than other ratio. So we concluded regarding deformation and vibration character ratio 3 AL6061+ $CaCO_3$ 5% +SiC 5% is better than others.
Keywords: Aluminum metal matrix composites, Sand Casting, Reinforcement, Calcium Carbonate

I. INTRODUCTION

Surabhi Lata [1] et.al were investigated the mechanical properties of aluminium reinforced with titanium dioxide particles which is fabricated through casting process. A comparative study has been conducted by varying the percentage of the reinforcement in the base metal matrix. The composite was casted and the samples were prepared, by simple turning and milling processes, for performing various mechanical tests. The reinforcement i.e. Silicon nitrate (Si3N4) weight percent of 5 %, 10 % and 15% resulted in increasing ultimate tensile strength, impact strength, average hardness and density with increasing concentration of titanium dioxide particles, while the compressive strength decreases with increase in the concentration of titanium dioxide reinforcement. Hence, it can be concluded that as the percentage of titanium dioxide increases the properties show enhancement due to the development of strong bonding between the particles of reinforcement and the base matrix and also due to the wettability property of the reinforcement in the base metal matrix.

Roussos G. Papagiannakis [2] et.al were studied hybrid Aluminium matrix composite was fabricated through stir casting route. Silicon nitrate (Si3N4) and graphite (Gr) particles were used as reinforcement phases for the present study. The hybrid MMC was prepared with varying the Tio2 particles volume fraction ranging from 5% to 10%.and fixed quantity 3% of graphite. The average on reinforced particles size of Tio2 and graphite are 25 microns and 45 microns respectively. The stirring process was carried out at 200 rev/min for 15 min. The microstructure and mechanical properties are investigated on prepared MMCs.

Ganesh Khandoori [3] et.al were analyzed these composites initially replaced Cast Iron and Bronze alloys but owing to their poor wear and seizure resistance, they were subjected to many experiments and the wear behaviour of these composites were explored to a maximum extent and were reported by number of research scholars for the past 25 years. In the present investigation, we have chosen aluminium as a matrix phase and titanium oxide as a reinforcement phase. The aim of our project is 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.

Mohammad Faisal Ansari [4] et.al were investigated AMC attracts much attention due to their lightness, high thermal conductivity, and moderate casting temperature, corrosion resistance. Engine pistons, engine blocks and other automotive and aircraft parts operating under severe friction conditions are fabricated from reinforced aluminum matrix composites. The pure Aluminium was reinforced with TiO2 particles 5% by wt., 10% by wt., 15% by wt. The composites were characterized by XRD, TGA, Wear, Compressive, Tensile, Hardness and Impact tests were carried out in order to identify mechanical properties.

Vikram Kumar S. Jain [5] et.al were investigated microstructure, microhardness and wear properties was systematically investigated. Micro structural studies revealed a fine equiaxed grain structure in the stir zone due to the dynamic recrystallization. The first pass surface composite sample results in agglomeration of particles toward the advancing side due to insufficient materials flow and strain. The second pass was carried out by changing advancing and retreating side of composite plate processed by the first pass. The results showed that marginal change in grain size was observed with homogeneous microstructure when compared to first-pass surface composite. Microhardness was carried out across the cross sections of the surface composites to obtain hardness profile. The tribological performance was assessed using a pin-on-disk tribometer. The result reveals that surface composites processed by the second pass show better hardness and wear resistance when compared to as-received aluminum. The wear mechanism shows a transition from adhesive wear in surface composites to the combination of abrasive and delamination wear in as-received aluminum.

Mr. Azeem Dafedar [6] et.al were experimentally, a composite material containing Aluminium (Al), Silicon nitrate (Si3N4) and Titanium Carbide (TiC) are mechanically manufactured by method of powder metallurgy which will be effective in aerospace application. The composites will be tested by using different percentage composition of materials. The process will start by mixing Aluminium matrix with Titanium Oxide and titanium Carbide reinforced with different percentage composition and the results will be compared with the values of pure Aluminium. The phase composition and morphology of material will be evaluated from hardness test. The microstructure of specimens will be revealed to investigate on continuous distribution of TiO2 and TiC in the metal matrix, which will be responsible for enhancement of tensile strength of the material. This feature is very likely and due to addition of Titanium Carbide (TiC) and Titanium Oxide (TiO2) in Aluminium (Al) matrix, there will be a good interface bonding of uniformly dispersed submicron size of reinforced materials. Good stiffness, high strength to weight ratio, good thermal properties which are very beneficial for aerospace applications are emphasized in the current paper.

Vyacheslav Syzrantsev [7] et.al were demonstrated a comparative study of the scope and surface properties of alumina (Al2O3) and Silicon nitrate (Si3N4) nanoparticles, synthesized using different methods, was carried out using Fourier-transform infrared spectroscopy (FTIR), ultraviolet-Vis diffuse reflection spectroscopy (UV-Vis DRS), and Raman spectroscopy, as well as X-ray diffraction methods. It is shown that the differences in the synthesis methods can change the surface properties of the nanoparticles, while maintaining the phase composition of the material. The nanoparticles of each material are shown to exhibit unexpected properties. In particular, the special luminescence characteristics of TiO2, a photon- energy shift from the rutile region into that region typical for the anatase, and a significant difference in the Lewis center concentration values for the alumina -phase were observed. This variation in the properties indicates the necessity to involve a wider range of analysis techniques and the importance of precisely characterizing the surface properties. To identify those nanoparticle functional properties that determine their interactions with other materials, a comprehensive study of their phase compositions and surface properties must be completed.

B. Krause [8] et.al were stududied, we compared different analytical techniques for NM analysis. Regarding possible adverse health effects, ionic and particulate NM effects have to be taken into account. As NMs behave quite differently in physiological media, special attention was paid to techniques which are able to determine the biosolubility and complexation behavior of NMs. Representative NMs of similar size were selected: aluminum (Al0) and aluminum oxide (Al2O3), to compare the behavior of metal and metal oxides. In addition, titanium dioxide (TiO2) was investigated. Characterization techniques such as dynamic light scattering (DLS) and nanoparticle tracking analysis (NTA) were evaluated with respect to their suitability for fast characterization of nanoparticle dispersions regarding a particle's hydrodynamic diameter and size distribution. By application of inductively coupled plasma mass spectrometry in the single particle mode (SP-ICP-MS), individual nanoparticles were quantified and characterized regarding their size. SP-ICP-MS measurements were correlated with the information gained using other characterization techniques, i.e. transmission electron microscopy (TEM) and small angle X- ray scattering (SAXS). The particle surface as an important descriptor of NMs was analyzed by X- ray diffraction (XRD). NM impurities and their co localization with biomolecules were determined by ion beam microscopy (IBM) and confocal Raman microscopy (CRM). We conclude advantages and disadvantages of the different techniques applied and suggest options for their complementation. Thus, this paper may serve as a practical guide to particle characterization techniques.

G.Baskaran [9] et.al were investigated the characterization of mechanical properties with production routes of powder metallurgy for aluminium matrix - TiC - TiO2 composites. Aluminium matrix is reinforced with much smaller particles of TiC- TiO2 submicron range is one of the key factors in producing high performance composites, which yields improved mechanical properties. Reinforcements with different percentages are used. A uniform distribution of the TiC- TiO2 reinforcement phase in the Al matrix can be obtained by high-energy ball milling of Al- TiC- TiO2 blends. Hardness test, wear resistance test, and density test are performed on the samples obtained by the powder metallurgy process. Powder metallurgy methods are becoming more common for the production of Al – TiC - TiO2 composites. Hardness test is performed to evaluate the interfacial bonding between the particles and matrix by intending the hardness with the constant load and constant time.
K. Yoganandam [10] et.al were stududied, Al6082 is chosen as matrix material and Titanium Oxide (TiO2) particles as reinforcement. Aluminum- TiO2 composites reinforced with various weight percentages (0, 3, 6 and 9 wt. %) were produced by semi-solid state compo casting route. The microstructure of fabricated composites and monolithic alloys were examined by Optical Microscope (OP). Hardness and Ultimate Tensile Strength (UTS) of the produced composites were investigated. The test results show that the mechanical behaviors of the fabricated composites are enhanced by increasing the Titanium Oxide content. The UTS and hardness of the produced composite enhanced with the addition of higher percentage of TiO2.

II. CHOICE OF MATERIAL

A. Aluminum-6061

Al 6061 has a good surface finish; high corrosion resistance is readily suited to welding and can be easily anodized. Most commonly available as T6 temper, in the T4 condition it has good formability.

Density	2.70g/cm^3
Melting Point	652ºc
Modulus of Elasticity	68.9 gpa
Thermal conductivity	167 W/m.K
Thermal Expansion	24 x10-6 /K
Electrical resistivity	3.99 x10-6 Ω .m

Table-1 Mechanical properties of Aluminium 6061

B. Calcium Carbonate

Calcium carbonate is a chemical compound that is used for shells of marine organisms, snails, and eggshells. It is also commonly found in limestone. With the chemical formula of CaCO3, the compound appears to have a white chalky consistency that is also odorless. This compound's structure is trigonal making the main shapes dipyramids, rhombohedron, and scalenohedron. Though the compound is soluble in dilute acids, its solubility in water is quite poor. The compound comes in three different mineral types; calcite, aragonite, and vaterite. These minerals can be found in places that limestone, chalk, travertine, and marble settle for these rocks are all, for the most part, calcium carbonates. Depending on the addends, calcium carbonate releases and makes different products. An example of a chemical reaction is when the compound reacts with acids, it releases carbon dioxide. Another example is that the compound will form calcium bicarbonate when mixed with water saturated with carbon dioxide. The compound was also found in outer space and specifically in Mars. The discovery of calcium carbonate showed evidence that there was indeed water present in Mars.

C. Silicon Carbide

Silicon carbide (SiC) ceramic materials has high temperature strength, high temperature oxidation resistance, good wear resistance, good thermal stability, small thermal expansion coefficient, high thermal conductivity, high hardness, thermal shock resistance, chemical resistance and other excellent features. In automobile, machinery, chemical industry, environmental protection, space technology, electronic information, energy and other fields, SiC material have increasingly widespread application, it has become an irreplaceable structural ceramics in many industries with excellent performance.

Silicon carbide (SiC) is a generic name for a material produced by numerous process routes that result in a host of different external and internal microstructures and, as a consequence, a broad range of properties. The thermal, mechanical, chemical, and electronic properties of SiC make possible a substantial number and variety of applications. The primary driving forces for the interest in SiC for electronic applications are for high-power, high-frequency, and high-temperature devices resistant to radiation damage and for substrates for Group IIIB nitride thin films and optoelectronic and microelectronic devices.

SiC is suitable for these applications primarily because of its wide bandgap, excellent thermal conductivity, good electrical conductivity, and moderately close match in atomic arrangement and distances among atoms on the basal planes with those of AlN and selected AlGaN alloys. Basic device structures including p–n junctions and Schottky contacts, as well as more complex SiC devices including metal–semiconductor field effect transistors (MESFETs), junction FETs, metal–oxide–semiconductor FETs (MOSFETs), and thyristors have been developed and are being introduced commercially.

III. PREPERATION OF CASTING

In this project we have used sand mold casting for produce the requirement size. Sand casting, also known as sand molded casting, is a metal casting process characterized by using sand as the mold material. It is relatively cheap and sufficiently refractory even for steel foundry use. A suitable bonding agent (usually clay) is mixed or occurs with the sand. The mixture is moistened with water to develop strength and plasticity of the clay and to make the aggregate suitable for molding. The term "sand casting" can also refer to a casting produced via the sand casting process. Sand castings are produced in specialized factories called foundries. Over 70% of all metal castings are produced via a sand casting process.

A. 6 basic steps

1) Place a pattern in sand to create a mold.
2) Incorporate the pattern and sand in a gating system.
3) Remove the pattern.
4) Fill the mold cavity with molten metal.
5) Allow the metal to cool.
6) Break away the sand mold and remove the casting.

B. Steps

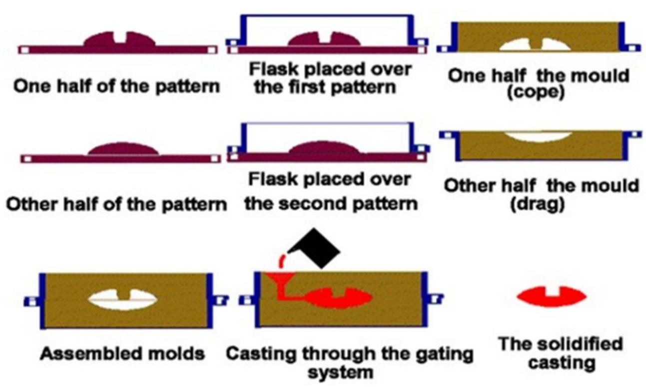

Fig-1 Sand casting pattern

IV. REQUIREMENT ANDCALCULATION OF SPECIMEN

A. Material Requirement

1) Cylindrical Specimen size-2.5cm dia-&Length-30cm
2) Rectangular Specimen:10x3.5x1.6 Cm
3) Volume-3.14/4*252*320*percentage of composite*density*percentage of excess of material

B. Model Calculation

1) Volume = π/4 d 2 *L
   = π/4*3.52*23---vol 221.28
2) Plate: L*B*H(cm)
   =10* 1.5*1.5=22.5 221.28 +22.5=243.78
3) Al=243.78 *2.7=658g+20% Extra-131.6 (Density-4.23 g/cm3)
4) Total Al 6061-800 gram

V. EXPLORATORY WORK

A. *Rockwell Hardness*

1) Rockwell Hardness frameworks utilize an immediate readout machine deciding the hardness number dependent on the profundity of entrance of either a jewel point or a steel ball. Profound entrance showed a material having a low Rockwell Hardness number.
2) However, a low entrance shows a material having a high Rockwell Hardness number. The Rockwell Hardness number depends on the distinction in the profundity to which a penetrator is driven by a positive light or "minor" load and a clear substantial or "Major" load.
3) The ball penetrators are hurls that are made to hold 1/16" or 1/8" distance across solidified steel balls. Additionally accessible are ¼" and ½" ball penetrators for the testing of milder materials.
4) There are two kinds of blacksmith's irons that are utilized on the Rockwell hardness analyzers. The level faceplate models are utilized for level examples. The "V" type iron blocks hold round examples immovably.
5) Test squares or alignment squares are level steel or metal squares, which have been tried and set apart with the scale and Rockwell number. They ought to be utilized to check the exactness and adjustment of the analyzer as often as possible.

B. *Impact Test*

Izod impact strength testing is an ASTM standard method of determining impact strength. A notched sample is generally used to determine impact strength. Impact is a very important phenomenon in governing the life of a structure. In the case of aircraft, impact can take place by the bird hitting the plane while it is cruising, during take - off and landing there is impact by the debris present on the runway an arm held at a specific height (constant potential energy) is released. The arm hits the sample and breaks it. From the energy absorbed by the sample, its impact strength is determined. The North American standard for Izod Impact testing is ASTM D256. The results are expressed in energy lost per unit of thickness (such as ft-lb/in or J/cm) at the notch. Alternatively, the results may be reported as energy lost per unit cross-sectional area at the notch (J/m^2 or ft-lb/in^2). In Europe, ISO 180 methods are used and results are based only on the cross-sectional area at the notch (J/m^2). The dimensions of a standard specimen for ASTM D256 are 4 x 12.7 x 3.2 mm (2.5" x 0.5" x 1/8"). The most common specimen thickness is 3.2 mm (0.125"), but the width can vary between 3.0 and 12.7 mm (0.118" and 0.500").The Izod impact test differs from the Charpy impact test in that the sample is held in a cantilevered beam configuration as opposed to a three point bending configuration.

C. *Tensile Test*

Friction processed joints are evaluated for their mechanical characteristics through tensile testing. A tensile test helps determining tensile properties such as tensile strength, yield strength, percentage of elongation, and percentage of reduction in area and modulus of elasticity. The welding parameters were randomly chosen within the range available in the machine. The joints were made with random parameters and evaluate tensile strength and burn off. Then the joints were made and evaluate the mechanical and metallurgical characteristics. The friction welded specimens were prepared as per the ASTM standards. The test was carried out in a universal testing machine (UTM) 40 tones FIE make.

D. *Compressive Test*

A compression test is any test in which a material experiences opposing forces that push inward upon the specimen from opposite sides or is otherwise compressed, “squashed”, crushed, or flattened. Purpose of Compression Tests: The goal of a compression test is to determine the behavior or response of a material while it experiences a compressive load by measuring fundamental variables, such as, strain, stress, and deformation

VI. RESULTS

A. *Rockwell Hardness*

S.No	Material	HRB
R1	Al6061-100%	35
R2	AL6061+ $CaCO_3$ 2.5% +SiC 2.5%	88
R3	AL6061+ $CaCO_3$ 5% +SiC 5%	60

Table-2 Hardness Test Result

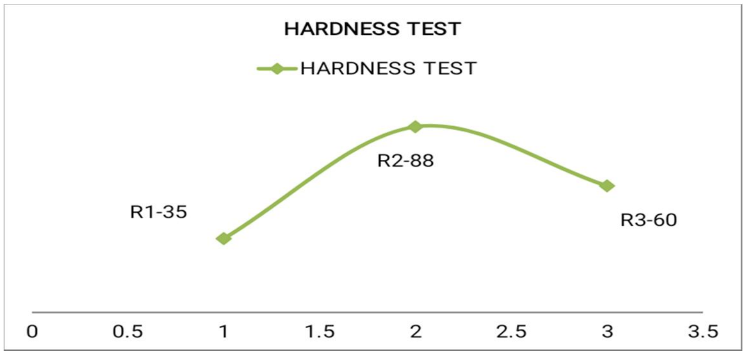

Chart-1. Hardness Test

B. *Impact Test*

S.NO	COMPOSITION	Impact Strength (Joules)
R1	Al6061-100%	8
R2	AL6061+ CaCO3 2.5% +SiC 2.5%	6
R3	AL6061+ CaCO3 5% +SiC 5%	4

Table-3 Impact Test Result

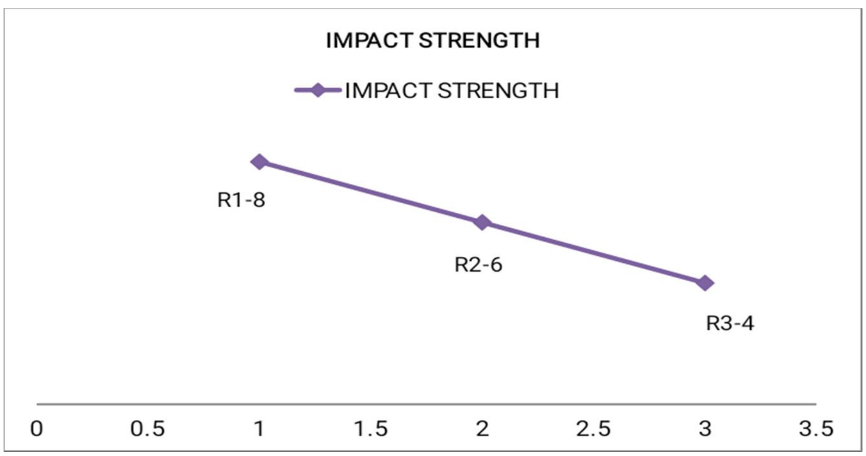

Chart-2. Impact Test

C. *Tensile Test*

sample	Dia (mm)	CSA (mm^2)	YL (kN)	YS (N/mm^2	TL (kN)	TS (N/mm 2	IGL (mm)	FGL (mm)	%E	FD	%RA
A1	15.86	197.64	14.28	72.25	21.06	106.56	50.00	50.29	0.58	15.39	5.84
A2	15.97	200.39	15.89	79.30	21.49	107.24	50.00	50.47	0.94	15.49	5.92
A3	16.04	202.15	17.46	86.37	23.48	116.15	50.00	50.24	0.48	15.76	3.46

Table-4 Tensile Test Result

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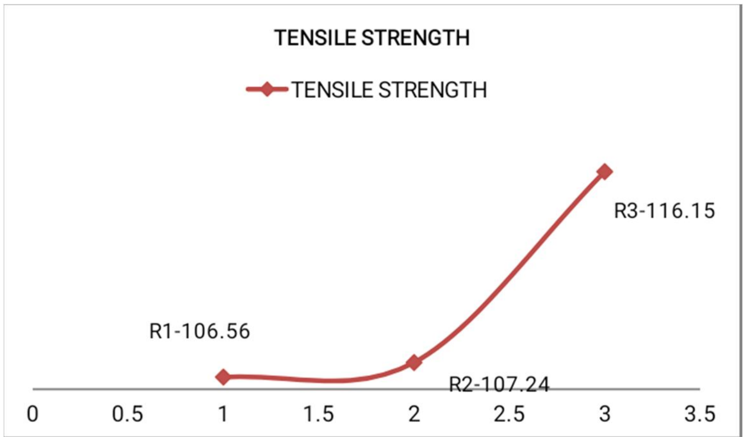

Chart-3. Tensile Test

D. Compressive Test

S.No	COMPOSITION	Compression Strength N/mm^2
R1	Al6061-100%	333.22
R2	AL6061+ CaCO3 2.5% +SiC 2.5%	333.97
R3	AL6061+ CaCO3 5% +SiC5%	371.97

Table-5 Compressive Test Result

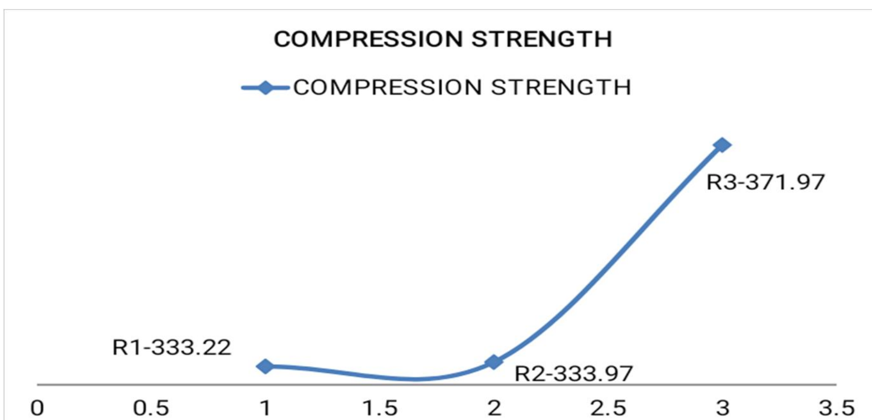

Chart-4. Compressive Test

VII. MODELING AND ANALYSIS

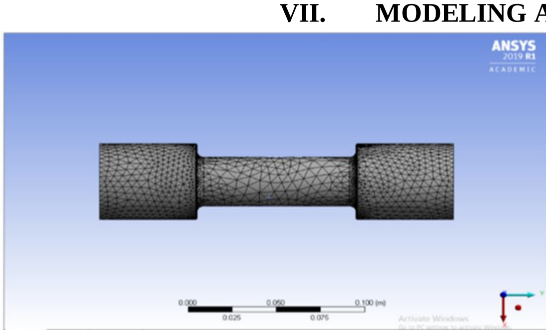

Fig-2 Geometric Modal

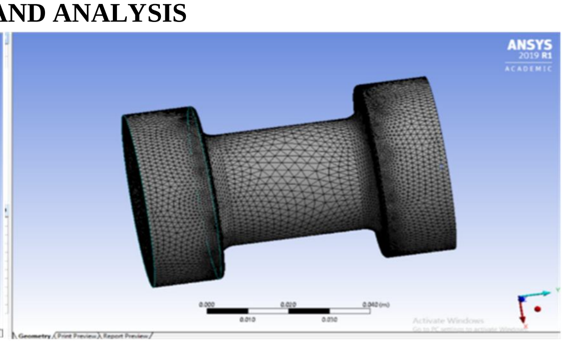

Fig-3 Mesh Modal

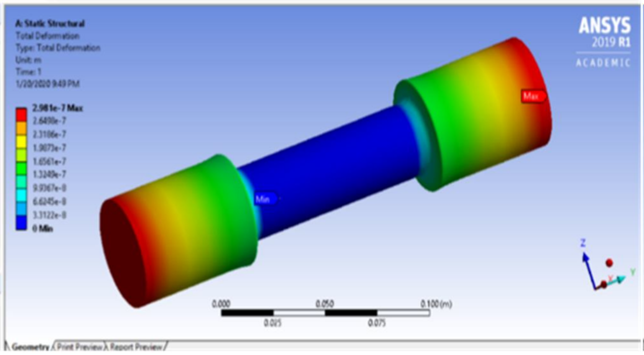

Fig-4 Total Deformation (Ratio-1)

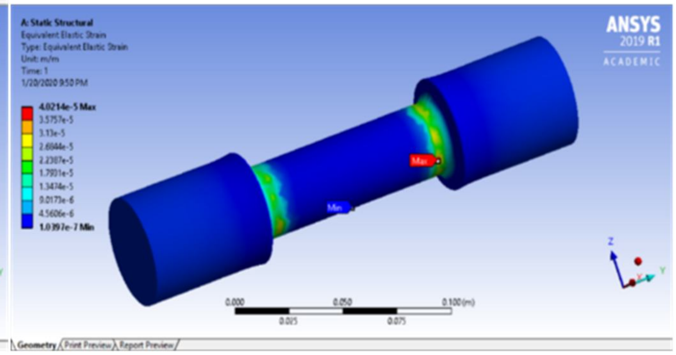

Fig-5 Equivalent Elastic Strain (Ratio-1)

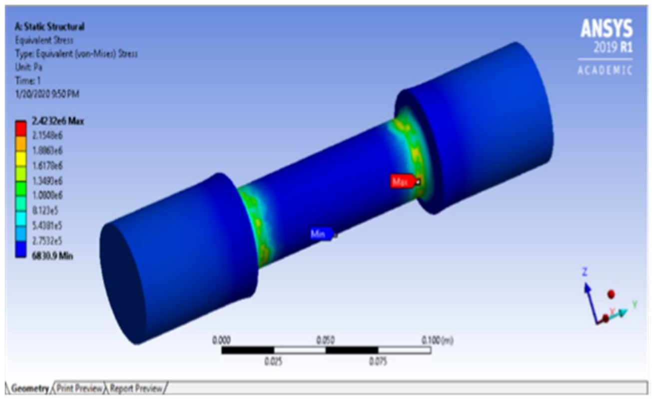

Fig-6 Equivalent Stress (Ratio-1)

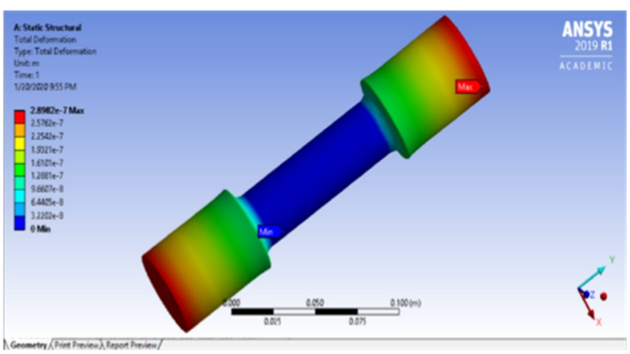

Fig-7 Total Deformation (Ratio-2)

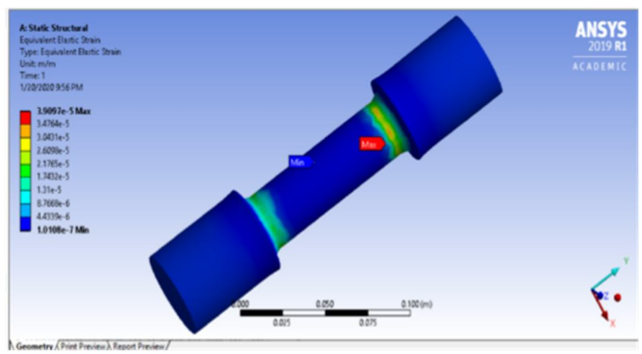

Fig-8 Equivalent Elastic Strain (Ratio-2)

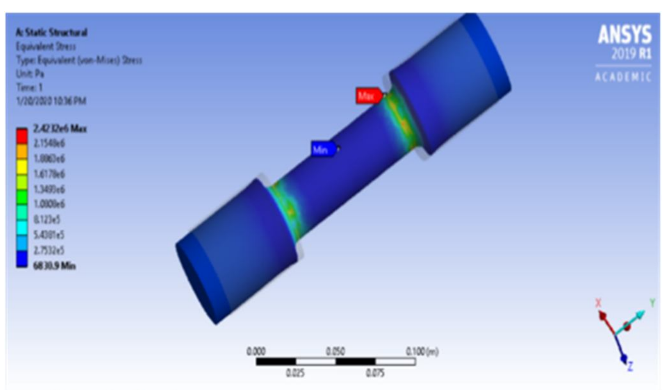

Fig-9 Equivalent Stress (Ratio-2)

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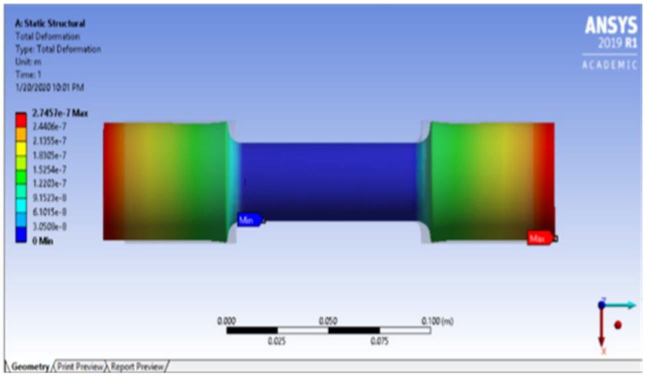

Fig-10 Total Deformation (Ratio-3)

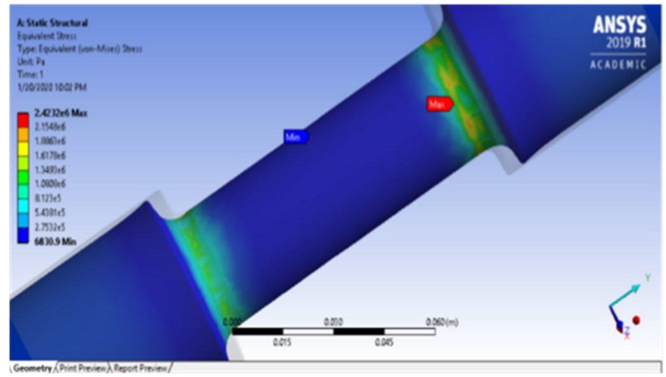

Fig-11 Equivalent Elastic Strain (Ratio-3)

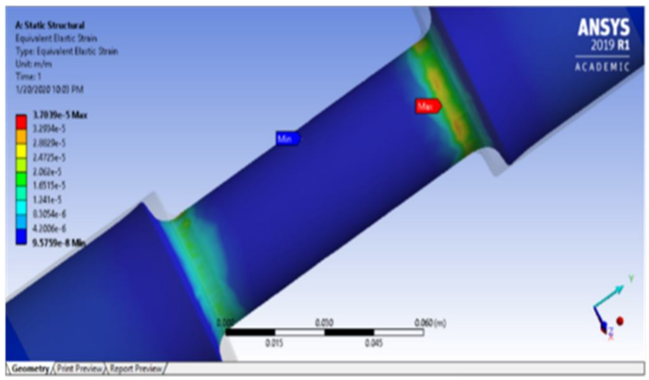

Fig-12 Equivalent Stress (Ratio-3)

A. *Result Summary*

Material Composition		Deformation (m)	Strain	Stress(Pa)
Al6061-100%	Maxi	2.981*E-7	4.021*E-5	2.423*E6
	Mini	0	1.0397*E-7	6830.9
AL6061+ CaCO3 2.5% +SiC 2.5%	Maxi	2.898*E-7	3.909*E-5	2.423*E6
	Mini	0	1.108*E-7	6830.9
AL6061+ CaCO3 5% +SiC 5%	Maxi	2.745*E-7	3.7039*E-5	2.423*E6
	Mini	0	9.5759*E-8	6830.9

Table-6 Result summary of specimen

VIII. CONCLUSION

It is found that the calcium carbonate and silicon carbide (CaCO3 & SiC) have been successfully incorporated in Al6061 matrix alloy through crucible casting technique. Composite materials especially Aluminum 6061 and calcium carbonate and silicon carbide composites having good mechanical properties compared with the conventional materials. It is used in various industrial applications these materials having light weight along with high hardness. From the investigation the mechanical property of Al 6061 metal matrix were analyzed finally tensile and compressive strength enhanced. In the Ratio-3 (AL6061+ CaCO3 5% +SiC 5%) is superior tensile and compressive strength compared than others. And hardness strength obtained maximum at ratio-2 (AL6061+ CaCO3 2.5% +SiC 2.5%). But impact strength shows higher in the ratio-1 Al 6061-100%. Due to agglеromation of the reinforcement reduces the impact strength of the metal matrix Al6061 alloy. According to the FEA analysis we have found minimum deformation, stress and strain occurs Ratio 3 AL6061+ CaCO3 5% +SiC 5% is very low value compare than other ratio. So we concluded regarding deformation and vibration character ratio 3 AL6061+ CaCO3 5% +SiC 5% is better than others.

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