# An Investigation of Mechanical and Tribological Properties of Al6082 Hybrid Metal Matrix 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. Silicon nitrate ($Si_3N_4$) and Egg shell particles were used as reinforcement phases for the present study.The hybrid MMC was prepared with varying the $Si_3N_4$ particles weight ratio ranging from 1% to 2% and chicken eggshell were varied 3% to 5% fixed quantity 1% of magnesium.The various mechanical properties and wear analysis were investigated and compared with non-metal matrix alloy of Al6082.**

**Keywords: MMC, Al Matrix composite, tensile strength, compressive strength, stiffness.**

## I. INTRODUCTION

The term composite is utilized for describing materials which are semi-homogeneous and have unrivaled mechanical and physical properties than those of their segments. The framework of a composite can be a metal, fired or Polymer. Moreover, composites can be gathered based on the fortifications gave. Metal Matrix Composites: The matrix stage for a MMC is a metal regularly which is bendable. MMCs are fabricated with intends to have high solidarity to weight proportion, high protection from scraped area and erosion, protection from creep, great dimensional solidness and high temperature operability. MMCs are utilized in businesses like vehicle and aviation. Generally, aluminum is utilized as the metal Matrix. Clay Matrix Composites (CMCs): This class of composites contains artistic materials as lattice stage. CMCs are created primarily to improve the break sturdiness of fired materials. This makes the CMCs to be utilized in extraordinary situations of high temperature and stress state. The scattered stage assumes a significant job in forestalling the spread of breaks. This scattered stage can be strands, particles or stubbles.

Polymer Matrix Composites (PMCs): They contain polymer as the lattice stage and strands, for example, E-glass, carbon or aramid as the fortifying stage. The various assortments of PMC for the most part utilized are Glass Fiber-Reinforced Polymer (GFRP) composites, Carbon Fiber-Reinforced Polymer (CFRP) composites and aramid fiber-strengthened polymer composites. The most generally utilized polymers as matrix are vinyl esters and polyesters.

## II.LITERATURE SURVEY

**Surabhi Lata [1]**et.alwere 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. **Roussos G. Papagiannakis [2]** et.alwere studied hybrid Aluminium matrix composite was fabricated through stir casting route. Silicon nitrate ($Si_3N_4$)and graphite (Gr) particles were used as reinforcement phases for the present study. The hybrid MMC was prepared with varying the $Tio_2$ particles volume fraction ranging from 5% to 10%.and fixed quantity 3% of graphite. The average on reinforced particles size of $Tio_2$ 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.alwere 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 wearbehaviour of these composites were explored to a maximum extent and were reported by number ofresearch scholars for the past 25 years. In the present investigation, we have chosen aluminium as a matrix phase and titanium oxide as are inforcement phase. **Mohammad Faisal Ansari [4]**et.alwere 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 $TiO_2$ 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.alwere 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 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. **Mr. Azeem Dafedar[6]**et.al were experimentally, a composite material containing Aluminium (Al), Silicon nitrate ($Si_3N_4$)and Titanium Carbide (TiC) are mechanically manufactured by method of powder metallurgy which will be effective in aerospace application. 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. **Vyacheslav Syzrantsev[7]**et.alwere demonstrated a comparative study of the scope and surface properties of alumina (Al2O3) and Silicon nitrate ($Si_3N_4$)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 inthe 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. **B. Krause [8]**et.alwere studied, 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. **G.Baskaran[9]**et.alwere investigated the characterization of mechanical properties with production routes of powder metallurgy for aluminium matrix - TiC - $TiO_2$ composites.. Hardness test, wear resistance test, and density test are performed on the samples obtained by the powder metallurgy process. **K. Yoganandam[10]**et.alwere studied, Al6082 is chosen as matrix material and Titanium Oxide ($TiO_2$) particles as reinforcement. Aluminum-$TiO_2$ composites reinforced with various weight percentages (0, 3, 6 and 9 wt. %) were produced by semi-solid state compo casting route 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 $TiO_2$.

## III. OBJECTIVES

**Objectives of Present Work**

The requirement of composite material has gained popularity in these days due to their various properties like low density, good wear resistance, good tensile strength and good surface finish. Silicon nitrate is one of the least expensive and low density reinforcement available in huge quantities as solid waste by-product in ceramic plant. The Hardness strength will also be taken into consideration. For the achievement of the above, an experimental set up is prepared where all the necessary inputs will be made. In this work a composite is developed by adding Silicon nitrate, Egg shell & magnesiumin Aluminum metal by mass ratio with various percentages. The composite has to be prepared by crucible casting technique and has to be analyzed various mechanical properties.

## IV.EXPERIMENTAL PLAN


**Figure 1. Black Diagram of Proposed work**

## V. MATERIALS AND METHODS

**Aluminum-6082**

Al 6082 has a good surface finishes; 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.

**Chemical Composition of Aluminum6082**

**Table 1. typical chemical composition for aluminum alloy 6082**

| Element | Percentage (%) | |
|---|---|---|
| | minimum | maximum |
| Si | 0.70 | 1.30 |
| Fe | 0.0 | 0.50 |
| Cu | 0.0 | 0.10 |
| Mn | 0.40 | 1.00 |
| Mg | 0.60 | 1.20 |

| | | |
|---|---|---|
| Zn | 0.0 | 0.20 |
| Ti | 0.0 | 0.10 |
| Cr | 0.0 | 0.25 |
| Al | - | Bal |

**Al 6082 Aluminum Mechanical Properties**

**Table 2. Al6082 Mechanical Properties**

| | |
|---|---|
| Density | 2.70g/cm$^3$ |
| Melting Point | 555$^o$c |
| Modulus of Elasticity | 70 gpa |
| Thermal conductivity | 180 W/m.K |
| Thermal Expansion | 24 x10-6 /K |
| Electrical resistivity | 0.038 x10-6 Ω .m |

## VI. CASTING PROCESS

The aluminum metal matrix composite materials are the combination of two or more constituents in which one is matrix and other is filler materials (reinforcements). Aluminum metal matrix may be laminated, fibers or particulates composites. These materials are usually processed through powder metallurgy route, liquid cast metal technology or by using special manufacturing process. The processing of discontinuous particulate metal matrix material involves two major processes (1) powder metallurgy route (2) liquid cast metal technology. The powder metallurgy process has its own limitation such as processing cost and size of the components. Therefore only the casting method is to be considered as the most optimum and economical route for processing of aluminum composite materials. For alloy development aluminum 6082 rod and Alumina oxide average particles size 200µm were purchased from local market. The aluminum rod was melted in a graphite crucible and alloyed with required quantity of reinforcements.

### Casting

In this venture we have utilized sand shape throwing for produce the prerequisite size. Sand throwing, otherwise called sand shaped throwing, is a metal throwing process described by utilizing sand as the form material. It is moderately modest and adequately stubborn in any event, for steel foundry use. A reasonable holding operator (typically mud) is blended or happens with the sand. The blend is soaked with water to create quality and pliancy of the dirt and to make the total appropriate for trim. The expression "sand throwing" can likewise allude to a throwing created by means of the sand throwing process. Sand castings are created in specific processing plants called foundries. Over 70% of every metal throwing are delivered by means of a sand throwing process.

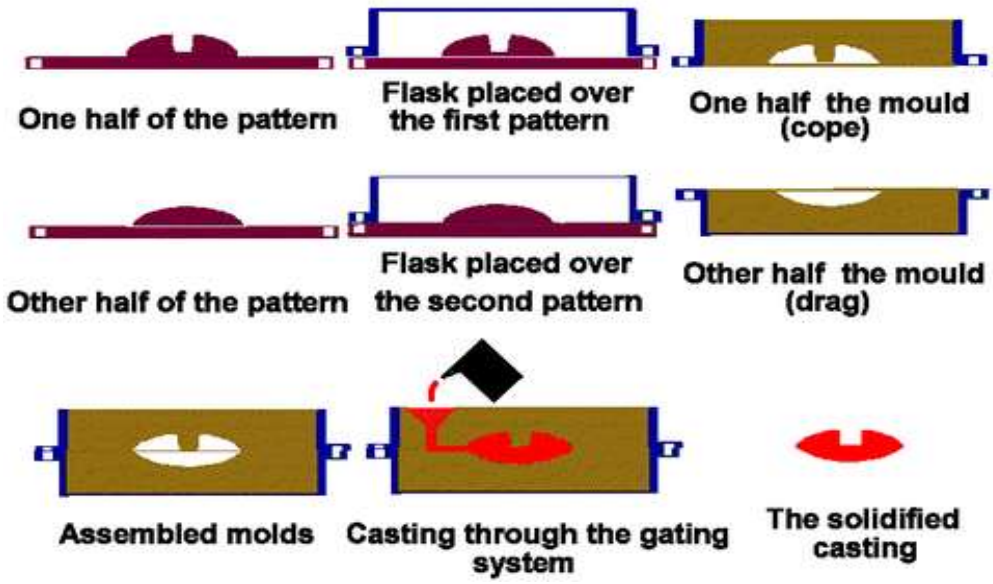
### Basic process

**There are six steps in this process:**

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.

**STEPS**




## VII. MATERIAL REQUIREMENT FOR CRUCIBLE CASTING

**Cylindrical Specimen** size-2.5cm dia-&Length-30cm
**Rectangular Specimen:**10x3.5x1.6 Cm
Volume-3.14/4*$25^2$*320*percentage of composite*density*percentage of excess of material

**CALCULATION FOR ALL RATIO:**
Volume= $\pi/4\ d^2$ *L
= $\pi$/4*$3.5^2$*23---vol 221.28

Plate: L*B*H(cm)
=10* 1.5*1.5=22.5
221.28 +22.5=243.78
Al=243.78 *2.7=658g+20% Extra-131.6(Density-4.23 g/$cm^3$)
Totai Al 6082-800gram
Titanium di oxide (Density-4.23 g/$cm^3$)-Mass Basis Ratio

**MIXING RATIO**
Sample1: :Al6082+100%
Sample2: : Al6082 + $Si_3N_4$-1%+ Es-3%+Mg-1%
Sample3: : Al6082 + $Si_3N_4$-2%+ Es-5%+Mg-1%

**Table 3. Mixing Ratio**

| Ratio | AL 6082 grams | $Si_3N_4$ | EGG SHELL ESp | Mg 1% |
|---|---|---|---|---|
| 0 | 800 | 0 | 0 | 0 |
| I | 800 | 1%-8g | 3%-24g | 1%-8g |
| II | 800 | 2%-16g | 5%-40g | 1%-8g |

## VIII. MECHANICAL TEST

### ROCKWELL HARDNESS TEST

Rockwell Hardness frameworks utilize an immediate readout machine deciding the hardness number dependent on the profundity of infiltration of either a precious stone point or a steel ball. Profound infiltration demonstrated a material having a low Rockwell Hardness number. 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 an unmistakable light or "minor" load and an unequivocal overwhelming or "Major" load. The ball penetrators are tosses that are made to hold 1/16" or 1/8" breadth solidified steel balls. Additionally accessible are ¼" and ½" ball penetrators for the testing of gentler materials.

### IMPACT TEST

Izod Impact testing quality testing is an American standard Testing Metals (ASTM) standard strategy for deciding effect quality. An indented test is commonly used to decide sway quality. Effect is a significant wonder in overseeing the life of a structure. On account of airplane, effect can occur by the winged creature hitting the plane while it is cruising, during take - off and arriving there is sway by the trash present on the runway an arm held at a particular tallness (consistent potential vitality) is discharged. The arm hits the example and breaks it. From the vitality consumed by the example, its effect quality is resolved. The North American standard for Izod Impact testing is ASTM D256. The outcomes are communicated in vitality lost per unit of thickness, (for example, ft-lb/in or J/cm) at the indent. Then again, the outcomes might be accounted for as vitality lost per unit cross-sectional zone at the score ($J/m^2$ or $ft\text{-}lb/in^2$). In Europe, ISO 180 strategies are utilized and results depend just on the cross-sectional zone at the score ($J/m^2$). The elements of a standard example for ASTM D256 are 4 x 12.7 x 3.2 mm (2.5" x 0.5" x 1/8").

### 6.3 TENSILE TEST& ELONGATION

Friction prepared joints are assessed for their mechanical attributes through tractable testing. A tensile test helps deciding tensile properties, for example, rigidity, yield quality, level of prolongation, and level of decrease in region and modulus of flexibility. The welding parameters were randomly picked inside the range accessible in the machine. The joints were made with irregular parameters and assess elasticity and consume off. At that point the joints were made and assess the mechanical and metallurgical attributes. The friction welded examples were set up according to the ASTM norms. The test was completed in an all inclusive testing machine (UTM) 40 tones FIE make.

**Elongation**

Deformation in continuum mechanics is that the transformation of a body from a reference configuration to a current configuration. A configuration may be a set containing the positions of all particles of the body. Contrary to the common definition of deformation, which means distortion or change in shape, the continuum mechanics definition includes rigid body motions where shape changes don't happen A deformation could also be caused by external loads, body forces (such as gravity or electromagnetic forces), or temperature changes within the body. Strain may be a description of deformation in terms of relative displacement of particles within the body.
Different equivalent choices could also be made for the expression of a strain field counting on whether it's defined with reference to the initial or the ultimate configuration of the body and on whether the metric tensor or its dual is taken into account. During a continuous body, a deformation field results from a stress field induced by applied forces or is thanks to changes within the temperature field inside the body. The relation between stresses and induced strains is expressed by constitutive equations, e.g., Hooke's law for linear elastic materials. Deformations which are recovered after the strain field has been removed are called elastic deformations. During this case, the continuum completely recovers its original configuration.

**COMPRESSION TEST**

Compression test is any test during which a fabric encounters contradicting powers that push internal upon the example from inverse sides or is in any case packed, "crushed", squashed, or leveled. Reason for Compression Tests: The objective of a pressure test is to work out the conduct or reaction of a fabric while it encounters a compressive burden by estimating principal factors, for example, strain, stress, and twisting.

## IX. RESULTS AND DISCUSIONS

**HARDNESS VALUE**

**Table 4. Hardness value**

| S.No | COMPOSITION | HRB |
|---|---|---|
| $R_1$ | Al6082-100% | 76 |
| $R_2$ | Al6082 + $Si_3N_4$-1%+ Es-3%+Mg-1% | 89 |
| $R_3$ | Al6082 + $Si_3N_4$-2%+ Es-5%+Mg-1% | 87 |

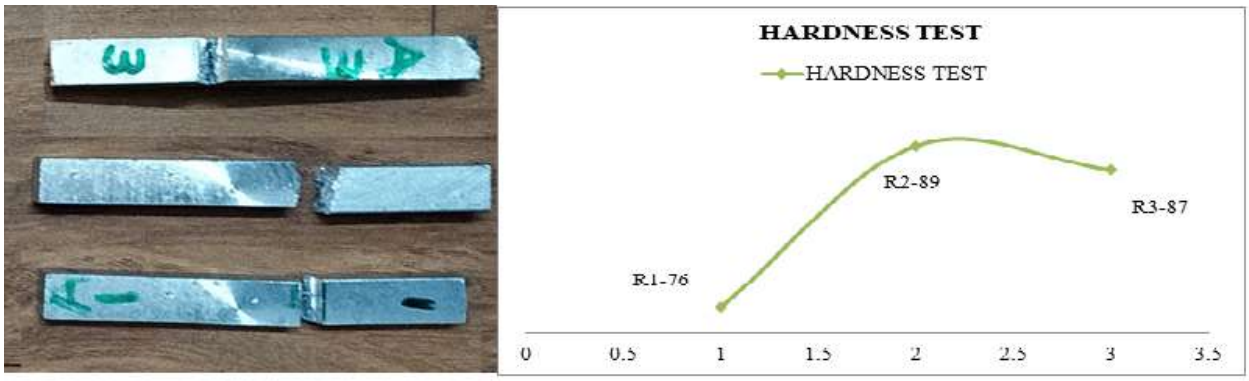



**Figure 2(a). After Hardness Strength Specimen Image**
**(b)** Hardness Strength

**TENSILE STRENGTH VALUES**

**Table 5. Tensile Strength**

| sample | Dia (mm) | CSA (mm2) | YL (kN) | YS ($N/mm^2$ | TL (kN) | TS ($N/mm^2$ | IGL (mm ) | FGL (mm) | %E | FD | %R A |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $A_1$ | 15.78 | 195.65 | 14.57 | 74.47 | 17.46 | 89.24 | 50.00 | 51.24 | 2.48 | 15.06 | 8.92 |
| $A_2$ | 15.96 | 200.14 | 15.06 | 75.25 | 19.56 | 97.73 | 50.00 | 51.06 | 2.12 | 15.24 | 8.82 |
| $A_3$ | 16.02 | 201.65 | 15.92 | 78.95 | 20.57 | 102.01 | 50.00 | 51.34 | 2.68 | 15.41 | 7.47 |

**IMPACT STRENGTH VALUES**

**Table:6 Impact value**

| S.No | COMPOSITION | Impact Strength (Joules) |
|---|---|---|
| $R_1$ | Al6082-100% | 10 |
| $R_2$ | Al6082 + $Si_3N_4$-1%+ Es-3%+Mg-1% | 6 |
| $R_3$ | Al6082 + $Si_3N_4$-2%+ Es-5%+Mg-1% | 3 |

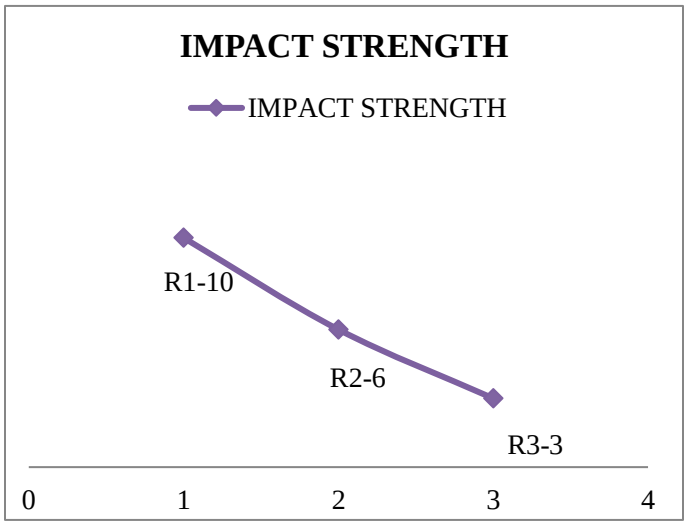



**Figure 3 (a). After Impact Strength Specimen Image (b) Impact strength**

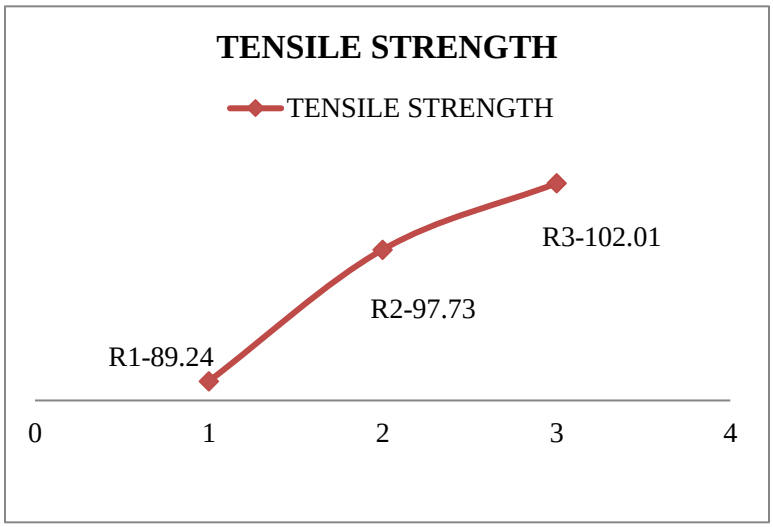



**Figure 4 (a). After Tensile Strength Specimen Image (b) Tensile strength**

**ELONGATION**

Sample 1 Composite 1-**2.68 mm**

Sample 2 Composite 2-:**2.48 mm**

Sample 3 Composite 3-**2.41 mm**

**COMPRESSIVE STRENGTH VALUES**

**Table: 7 Compression Strength**

| S.No | COMPOSITION | Compression Strength N/mm$^2$ |
|---|---|---|
| $R_1$ | Al6082-100% | 252.47 |
| $R_2$ | Al6082 + $Si_3N_4$-1%+ Es-3%+Mg-1% | 290.67 |
| $R_3$ | Al6082 + $Si_3N_4$-2%+ Es-5%+Mg-1% | 311.40 |

**WEAR TEST**

A tribometer is an instrument that measures tribological quantities, like coefficient of friction, friction force, and wear volume, between two surfaces in touch . A tribo tester is that the general name given to a machine or device wont to perform tests and simulations of wear and tear, friction and lubrication which are the topic of the study of tribology. Often tribo testers are extremely specific in their function and are fabricated by manufacturers who desire to check and analyze the long-term performance of their products. An example is that of orthopedic implant manufactures who have spent considerable sums of cash to develop tribo testers that accurately reproduce the motions and forces that occur in human hip joints in order that they will perform accelerated wear tests of their products.

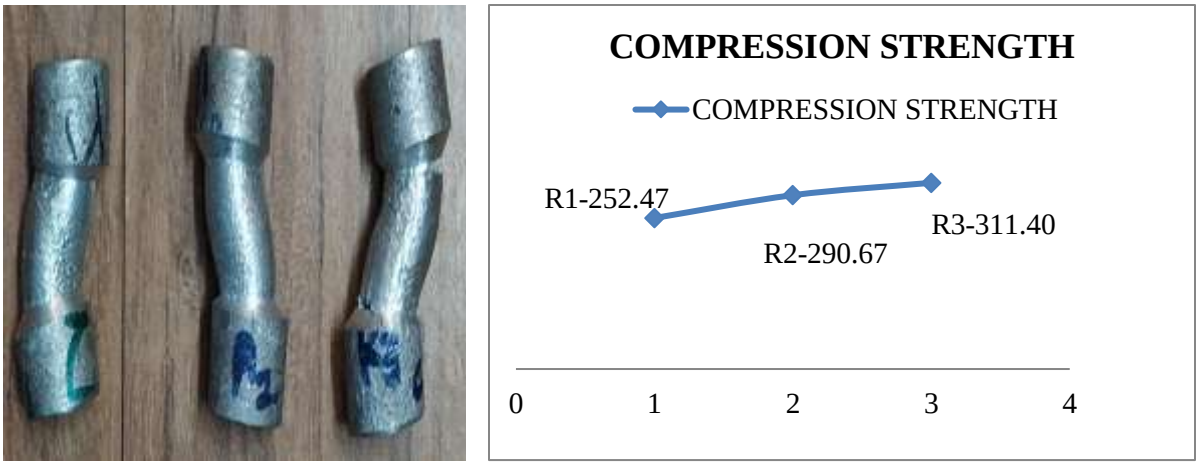



**Figure 5 (a). After Compression Strength Specimen Image (b) Compression strength**

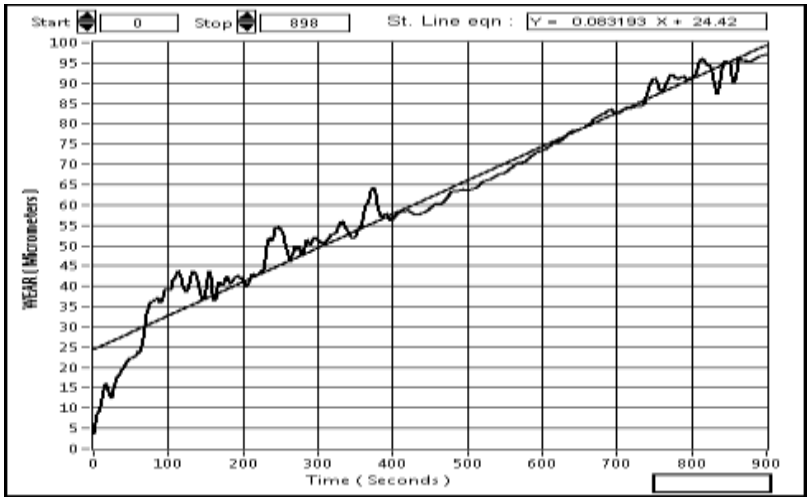



**Figure 6. Wear Test Analyses**

**Table 8. Weight of Testing Specimen Before and After**

| S.NO | RATIO | BEFORE WEIGHT | AFTER WEIGHT | DIFFERENCE |
|---|---|---|---|---|
| Sample1 | Al6082-100% | 6.5979 | 6.5821 | 0.016 |
| Sample 2 | Al6082 + $Si_3N_4$-1%+ Es-3%+Mg-1% | 6.0077 | 5.9944 | 0.013 |
| Sample 3 | Al6082 + $Si_3N_4$-2%+ Es-5%+Mg-1% | 6.0712 | 6.0575 | 0.014 |

According to the wear test have found the wear rate the Ratio 2Al6082 + $Si_3N_4$-1%+ Es-3%+Mg-1% is very low wear rate occurred during this investigation due to base on the reinforcement contribution

**Table 9. Specification**

| Load | Duration (Minutes) | Diameter (mm) | Speed (RPM) |
|---|---|---|---|
| 20N | 15 | 60 | 400 |

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## X. CONCLUSION

It is found that the silicon nitrate and chicken eggshell ($Si_3N_4$&ES) have been successfully incorporated in Al6082 matrix alloy through crucible casting technique. Composite materials especially Aluminum 6082 and silicon nitrate, Egg shell& magnesium 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 6082 metal matrix were analyzed finally tensile and compressive strength enhanced. In the Ratio-3 (Al6082 + $Si_3N_4$-2%+ Es-5%+Mg-1%) is superior tensile and compressive strength compared than others.And hardness strength obtained maximum at ratio-2 (Al6082 + $Si_3N_4$-1%+ Es-3%+Mg-1%).But impact strength shows higher in the ratio-1 Al 6082-100%. Due to aggle romation of the reinforcement reduces the impact strength of the metal matrix Al6082 alloy. According to the wear test have found the wear rate the Ratio 2Al6082 + $Si_3N_4$-1%+ Es-3%+Mg-1% is very low wear rate occurred during this investigation due to base on the reinforcement contribution.

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