# AA8011 Reinforced with Molebdenum Disulphide, Tungsten Disulphide and Nano Nickel Particles

Shiju T. Varghese and Robinson Smart



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# TUNGSTEN DISULPHIDE AND NANO NICKEL PARTICLES

**SHIJU VARGHESE T[1], D. S. ROBINSON SMART[2]**

[1]*Department of Mechanical Engineering, Karunya Institute of Technology and Sciences, Coimbatore, Tamil Nadu, India*

[2]*Professor, Department of Mechanical Engineering, Karunya Institute of Technology and Sciences, Coimbatore, Tamil Nadu, India*

***ABSTRACT***

The most predominant materials in modern industries are aluminium alloys. This is due to the fact that the aluminum has a unique combination of attractive properties. It would be very unusual to find pure aluminium chosen for fabrication because of their strength characteristics. Addition of alloying elements to aluminium is the principal method used to produce a selection of different materials that can be in a wide assortment of structural applications. In this research a Hybrid Metal Matrix Composite of Aluminium 8011 reinforced in alliance with Molybdenum sulphide, Titanium sulphide and Nickel by using stir casting method. The samples were casted by varying the proportions in weight percentage by stir casting route. The samples are subjected to micro structural characterization and analysis of mechanical properties**.**

***KEYWORDS: Aluminium Metal Matrix Composite, Al8011, Molybdenum sulphide, Tungsten disulphide & Nano- Hybrid Composite***

## I. INTRODUCTION

Metal Matrix Composites have emerged as advanced materials which exhibit higher stiffness, improved wear resistance, excellent wear strength to wear ratio and better high temperature performance compared to the micro composite and monolithic counterparts. MMCs are fast replacing conventional metallic alloys in major applications like aerospace, automobile, automobile, defense, marine, sports and recreation industries. For many researches the term MMC is often used for light metal matrix components. MMCs are basically metallic alloys reinforced with mostly ceramic materials like Aluminium, Magnesium and Titanium. Aluminium remains the most utilized metallic alloy as matrix material in the development of MMCs and the reason for this has been reported. [1].

Aluminium components are prepared by various methods such as powder metallurgy [2], vortex method [2], squeeze casting [2], stir casting [2], thermal spray deposition [3], laser surface alloying [3], and reactive process [4]. Stir casting is one of the suitable methods which are mostly used for preparing reinforced Aluminium matrix composites. The above stir casting can be divided under liquid stir casting and solid stir

casting. In this research work we followed liquid stir casting method.
Generally AMCs reinforced with particle tend to offer superior properties compared to unreinforced alloy. In this paper AA8011 reinforced with Mo $S_2$, $WS_2$, and Ni is synthesized through stir casting and materials are subjected to SEM analysis, to study the material characterization. The fabricated specimens were proposed to test for mechanical properties like hardness and tensile strength.
Aluminum metal matrix composite has a great role in replacing the conventional materials and it is clearly evident in the recent researches. S Magibalan et.al [5] describes the tribological behavior of Aluminium alloy AA8011 fabricated through liquid metallurgy route. It is observed that the applied load is the significant parameter followed by time and sliding velocity for the wear rate and coefficient of friction. Mechanical properties of aluminium 8011 reinforced with B4C and Al2O3 by stir casting method investigated by R Kandan et.al [6]. The mechanical properties like tensile strength, compressive strength and hardness can be increased by reinforcing AA8011 with Boron carbide and Aluminium oxide.
Dinesh C et.al [7] investigated the mechanical properties of different layered stacking sequence of glass / flax fiber Hybrid epoxy composite. K.K Padmanabhan and G Prabhu [8] experimented the cryogenic treatment of Al6063 and 8011 and NiCoW coating to improve Hardness and Wear. The cryogenic coolant has enhanced the hardenability of Aluminium alloys resulting in increased hardness of nearly 15%. The cryogenic coolant gas increased the wear resistance properties of Aluminium coated with NiCoW by nearly 25%. [8].
Palanisami Pugalenthi et.al [9] fabricated Al7075 composites with Silicon Carbide and Aluminium Oxide as reinforcements through stir casting. Four specimen were produced with different composition comprising SiC (3, 5,7and 9%) and Al2O, 2 weight % in all combinations. Mechanical properties like Ultimate Tensile Strength (UTS), Yield Strength (YS), Percentage of Elongation (POE) and Hardness were examined along with fractography studies. The micro structural characterization of the composites was also studied through micrograph obtained from the Scanning Electron Microscope (SEM). The test result revealed that the increase in weight % fractions of the reinforcement materials caused an increase in the Tensile strength, Yield Strength and Hardness of the Aluiminium composite, except for the % of elongation which is reduced with the addition of ceramic particles.
Michael Oluwatosin Bodunrin et.al [10] attempts to review the different combinations of reinforcing materials used in processing of Hybrid Aluminum Matrix Composites and wear performance of the materials. Z Yuan et.al [11] has recently reported the synthesis of Molybdenum Trioxide Nano flaxes by a simple and low cost hydrothermal method for gas sensing applications.

## II. MATERIAL

Aluminium 8011 alloy is a wrought alloy in which aluminium is the predominant metal. The following table1 shows the chemical composition of aluminium 8011alloy.Apart from iron, aluminium is the next mostly used metal in the industrial world. This is due to the fact aluminum has a unique combination of attractive properties such as its low weight, corrosion resistance and easy maintainability. The given below table shows the chemical composition of aluminium 8011 alloy. The mechanical properties of the alloy were given in table 2

Table 1. Chemical composition of AA 8011 aluminum alloy

| Si | Fe | Cu | Mg | Mn | Cr | Zn | Ti | Al |
|---|---|---|---|---|---|---|---|---|
| 0.6% | 0.7% | 0.25% | 0.9% | 0.15% | 0.2% | 0.25% | 0.15% | Remaining |

Table 2. Mechanical Properties of AA 8011 aluminum alloy

| | |
|---|---|
| Tensile Strength M Pa | 134 |
| Density Kg/m3 | 2.71 |
| Hardness BHN | 33.5 |
| Impact Strength J | 54 |

## III. REINFORCEMENT ELEMENTS

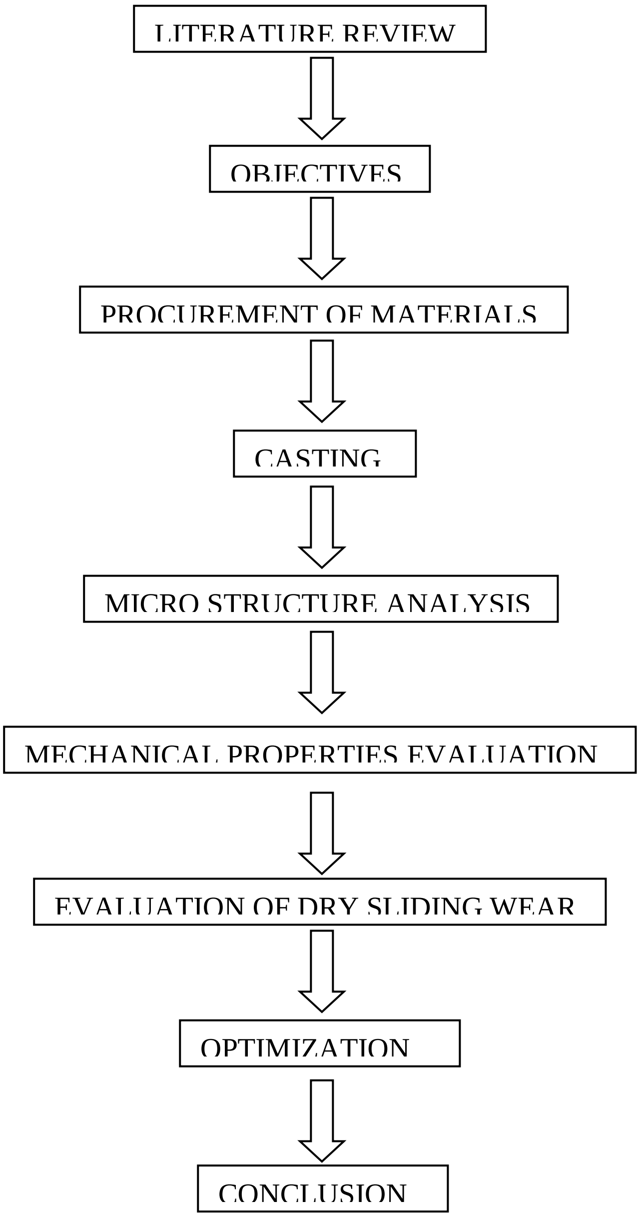
Metal Matrix Composite (MMC) of Aluminium alloy AA8011 with the addition of varying weight percentage of micro particles of Molybdenum Disulphide, Tungsten Disulphide and Nickel Nano Particles. The properties were tested under the laboratory conditions. Variations in the properties are taken into a consideration.

Molybdenum features high density and melting point and is immune to heat and wear as like other refractory metals. Molybdenum enhances the strength, hardenability, weldabilty, toughness, and elevated temperature strength and corrosion resistance. The addition of improves resistance to both corrosion and creep deformation at high temperature in nickel based alloys. Molybdenum disulphide, $MoS_2$ excels as a lubricating material due to its layered structure and low coefficient of friction. The shear strength of $MoS_2$ increases being the coefficient of friction increases. At ambient conditions, the coefficient of friction for $MoS_2$ was determined to be 0.150, with corresponding estimated shear strength of 56.0 MPa.[12]. $MoS_2$ used as a solid-film lubricant has been shown to have high load- carrying capacity at high pressures [13] ; to maintain low coefficients of friction over a wide range of sliding velocities [14].

Tungsten disulphide is an inorganic compound composed of tungsten and sulphur with the formula $WS_2$. $WS_2$ adopts a layered structure similar, or isotopic with $MoS_2$, instead with W atoms situated in trigonal prismatic coordination sphere owing to this layered structure, $WS_2$ forms inorganic nanotubes, which were discovered after heating a thin sample of $WS_2$ in 1992.[15] $WS_2$ nanotubes have been investigated as reinforcing agents to improve the mechanical properties of polymeric Nano composites. From the literature review it is noted that, $WS_2$ nanotubes reinforced biodegradable polymeric Nano composites of polypropylene fumarate (PPF) showed significant increases within the Young's modulus, compression yield strength, flexural modulus and flexural yield strength, compared to single- and multi-walled carbon nanotubes reinforced PPF Nano composites, suggesting that $WS_2$ nanotubes may be better reinforcing agents than carbon nanotubes.[16] Nickel is added to aluminium alloys to improve hardness and strength at elevated temperatures and to reduce the coefficient of expansion. [17]

## IV. METHODOLOGY

The master alloy used for the experiments was AA8011. The alloying elements added are W $S_2$, Mo $S_2$ and Ni on different mass combinations. This alloy was casted using stir casting technique. The test specimens were cut out from the casting using wire cut EDM to perform various studies. Figure shows the entire methodology of the work.



## V. EXPERIMENTATION

The stir casting technique was adopted to reinforce the elements in the AA8011 alloy. Stir casting may be a sort of casting process during which a mechanical stirrer is introduced to make vortex to combine reinforcement within the matrix material. It is a suitable process for production of metal matrix composites due to its cost effectiveness, applicability to mass production, simplicity, almost net shaping and easier control of composite structure.

Table 3. Process Parameters for Stir Casting

| PROCESS PARAMETER | VALUE |
|---|---|
| Crucible Furnace | Electric muffle furnace |
| Melting Temperature | 650 $^{0}$c |
| Stirring Speed | 200 rpm |
| Stirring Time | 5 min |
| Max. Temperature of furnace | 870 $^{0}$c |
| Preheating Temperature | 500 $^{0}$c |

Four combinations of reinforcement are fabricated with aluminium metal matrix and the reinforcement particles having an average size of 40-80nm. The different weight percentages of elements are listed in the Table 3. In liquid metal stir casting, the AA8011 was placed in the crucible and melted by using electrical resistance furnace and it was maintained at 850$^{0c}$ to convert it to molten form.

Table 4. Alloy compositions of castings

| SAMPLE | AL 8011 | Mo S2 | W S2 | NICKEL |
|---|---|---|---|---|
| COMPOSITE 1 | 88% | 2% | 6% | 4% |
| COMPOSITE 2 | 85% | 3% | 8% | 4% |
| COMPOSITE 3 | 82% | 4% | 10% | 4% |
| COMPOSITE 4 | 79% | 5% | 12% | 4% |

## VI. TESTS PERFORMED

- Tensile test
- Micro Hardness test
- Impact test
- Microstructure

Before commencing the experiments, the samples were machined to the particular size according to the ASTM standards. Tested samples are being encountered microstructure testing scanning electron microscope. The distribution of the reinforcement over the matrix was explored with the scanning electron microscopic analysis along with the elemental analysis on the composite.

## VI. (i) TENSILE TEST

To determine the behavior of the samples while an axial stretching load is applied, the ultimate tensile strength was measured using Servo hydraulic universal testing machine. Testing of the specimens was in the parallel direction of the applied load providing controlled uniformly increasing tension force, applied to the specimen. Fig.1expresses a relationship between loads applied to a specimens and the deformation of the material, caused by the load. The initial straight line of the curve characterizes proportional relationship between the stress and the deformation. The point where the stress causes sudden deformation without any increase in the force is called yield limit. When the load increase, the specimen continues to undergo plastic deformation and at a certain stress value its cross-section decreases due to necking and stress reaches the maximum value, which is called ultimate tensile strength. The amount of force applied to the sample and the elongation of the sample are measured throughout the test. Fig 2 & 3 shows the variations in Tensile strength and percentage of elongations in various compositions.

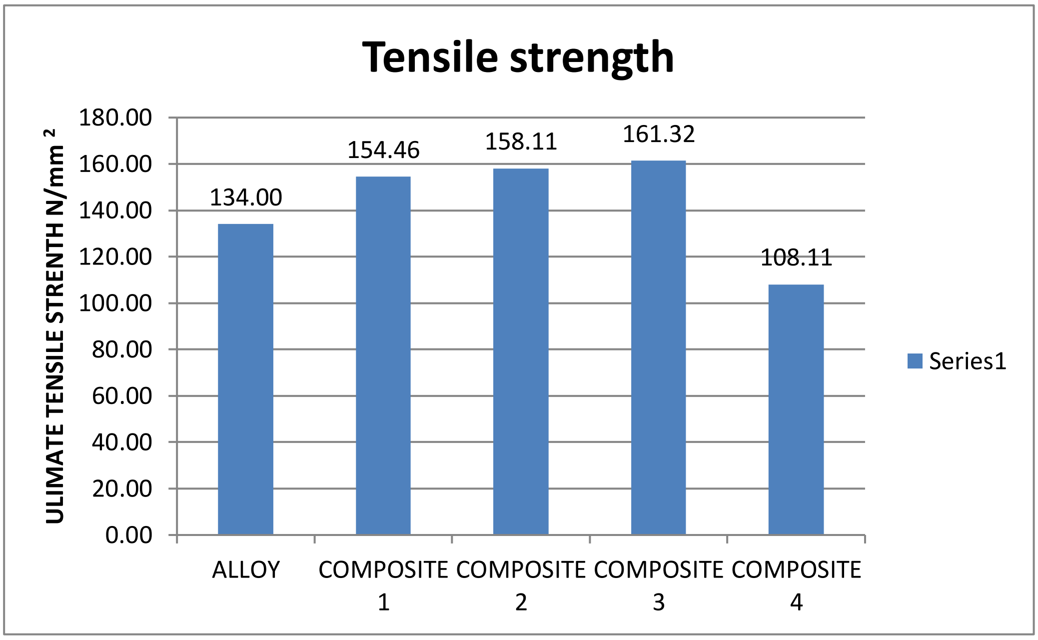
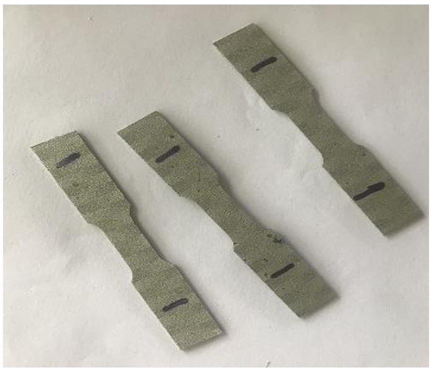
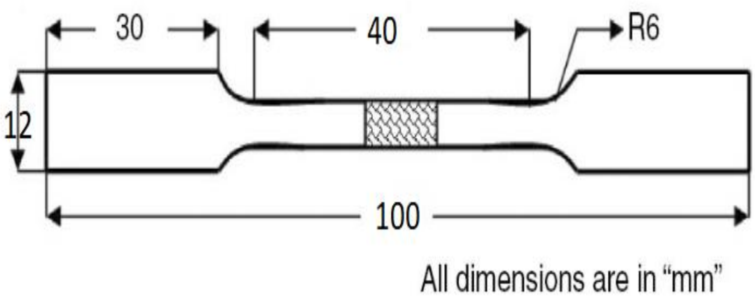



Fig 2. Details of Tensile Test






Tensile Test Specimen

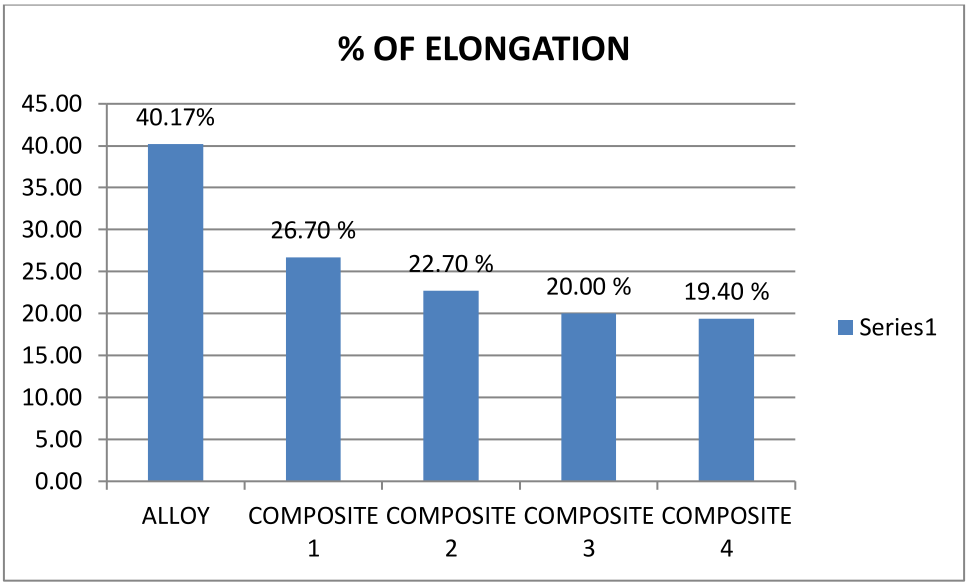



Fig 3. Elongation under Tensile Load

## VII. (ii) MICRO HARDNESS TEST

Micro hardness Testing is conducted to work out the material’s hardness or resistance to penetration when test samples are very small or thin, or when small regions during a composite sample or plating are to be measured. It can provide precise and detailed information about surface features of materials that have a fine microstructure, are multi-phase, non-homogeneous or susceptible to cracking. The micro Vickers hardness test is used in this study to examine the hardness by Appling load of 0.5kg for 20 seconds with a ball intender of 0.5mm diameter. The averages of the hardness values were considered as hardness number and given in figure 4.

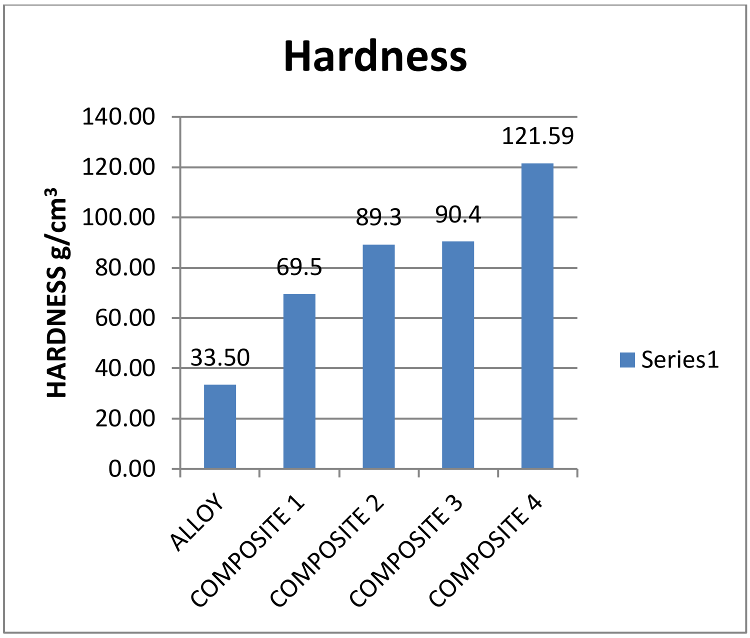
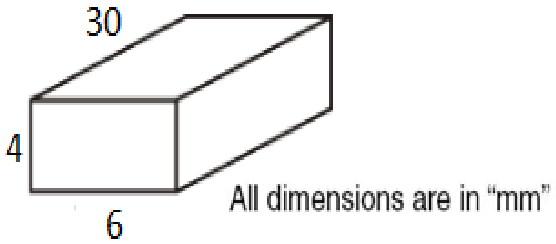



Fig. 4. Details of Hardness Test




Hardness Test Specimen

## VII. (iii) IMPACT TEST

Impact testing is used to determine material behavior at higher deformation speeds and also energy absorbed by a material during fracture. The amount of energy observed during the applied impact load on the composite specimens were shown in Fig. 5, from this figure it was noted that the amount of impact energy for the pure and hybrid aluminium composite specimens was decreased gradually. The amount of impact energy observed by the pure and hybrid aluminium composite specimens during the Izod impact test was found in the range of 54, 53, 51, 49 and 51 Joules correspondingly. The maximum impact energy of 54 Joules was found at pure aluminium8011 composite.

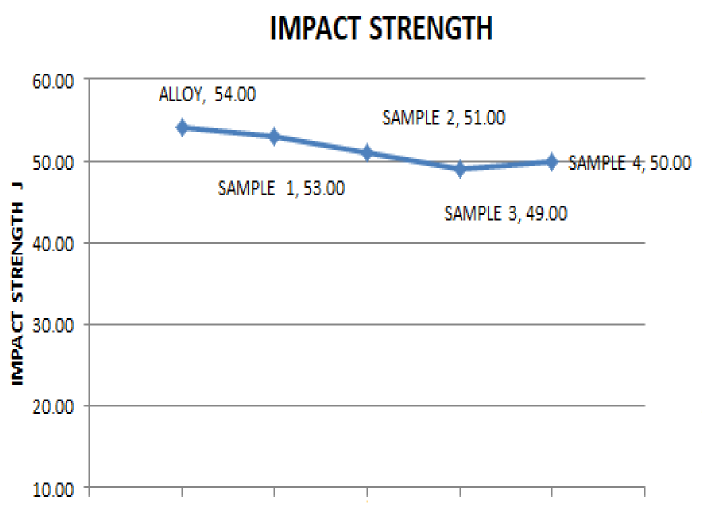
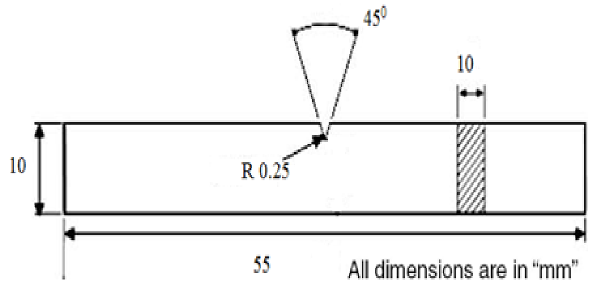


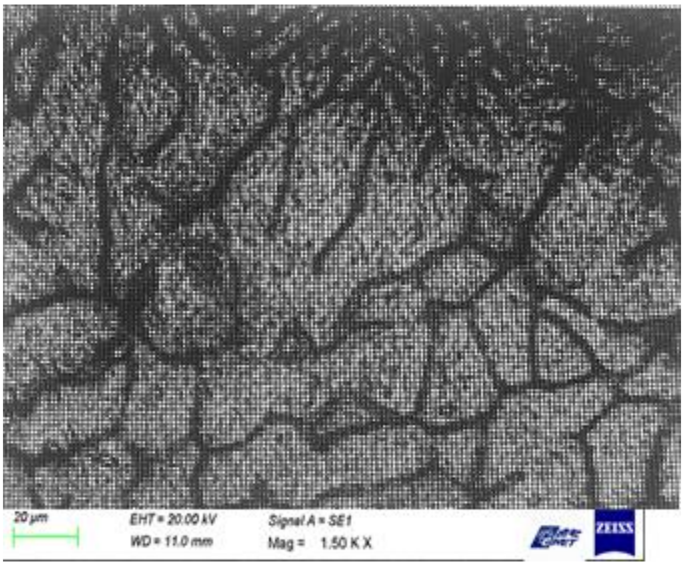

Fig.5. Details of Impact Test




Impact Test Specimen

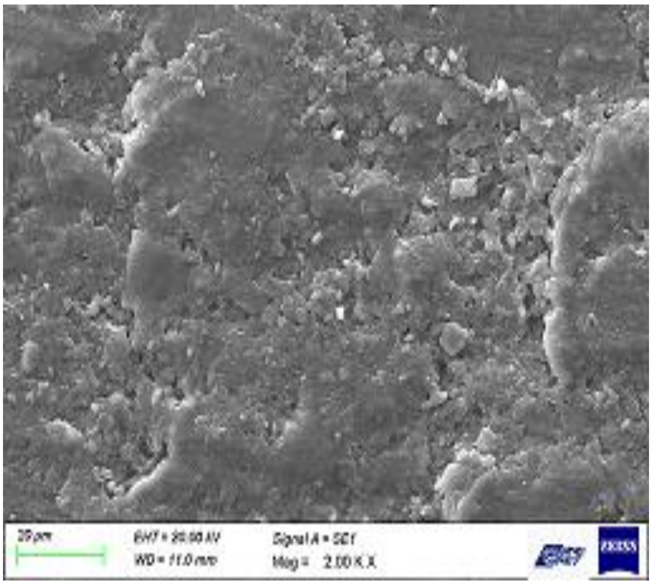
## VII. (iv) MICROSTRUCTURE

The microstructure of the composite is studied using SEM which provides the formation details of compound and presence of any defects. It can be used to identify the phases present, soundness of the casting. Mechanical properties strongly depends on the microstructural features such as shape, grain size etc. The SEM results have provided a fundamental understanding of the surface structure of each sample. It seems that the amounts of voids present in composites are reduced compared to the aluminum alloy. In order for a semi-quantitative element results, energy-dispersive x-ray spectroscopy (EDAX or EDS) was conducted at the location of interest. The spectrum peaks and EDX results were presented in figure. The fig. 7 shows the spectrum analysis of the composite which also confirms the presence of aluminium, mole

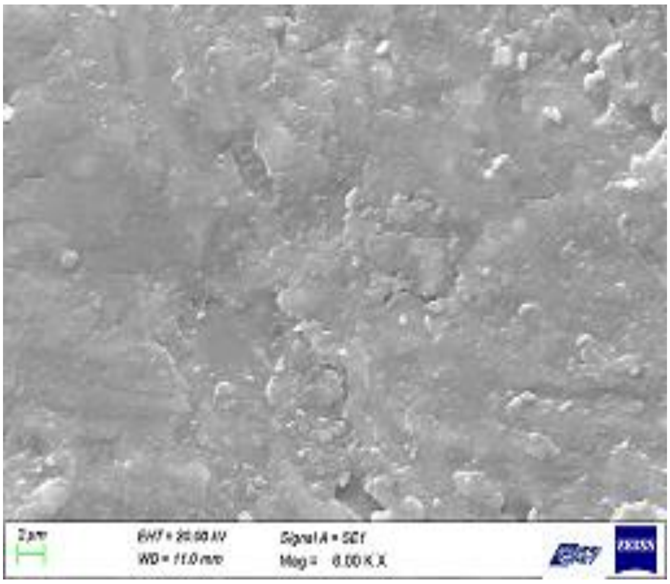



ALLOY

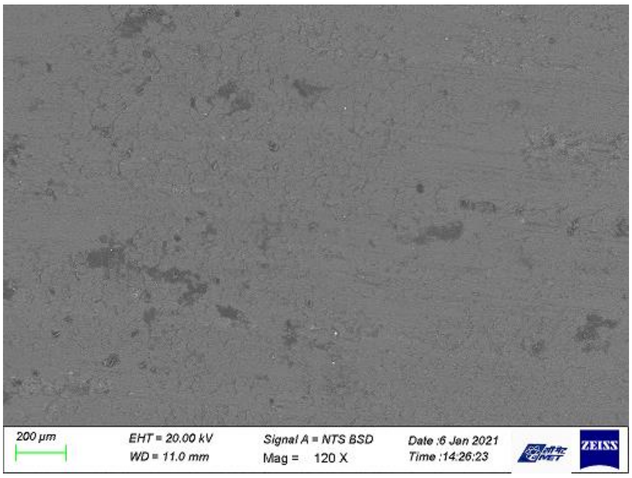

COMPOSITE 1



COMPOSITE 2



COMPOSITE 3




COMPOSITE 4

Fig.6 SEM images of composites

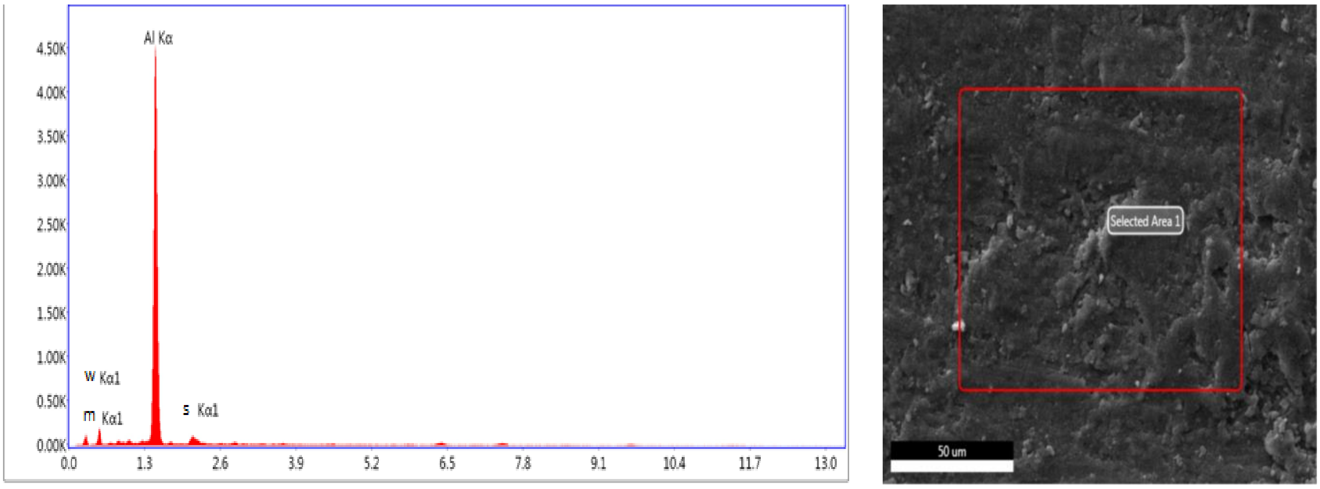



Fig 7. Spectrum Analysis of composite

## VII. (v) DENSITY

It is a measure of mass per volume. Density gives an insight into materials, like their purity, concentration of components and composition. Density measuring equipment works based on the Archimedes principle. The weight of the specimen is measured both dry and wet conditions.

$$D = [\ W_d / (\ W_d - W_w\ )\ ] \times D_w,$$

where Dw = density of water, Wd (Dry Weight), Ww (Wet Weight)

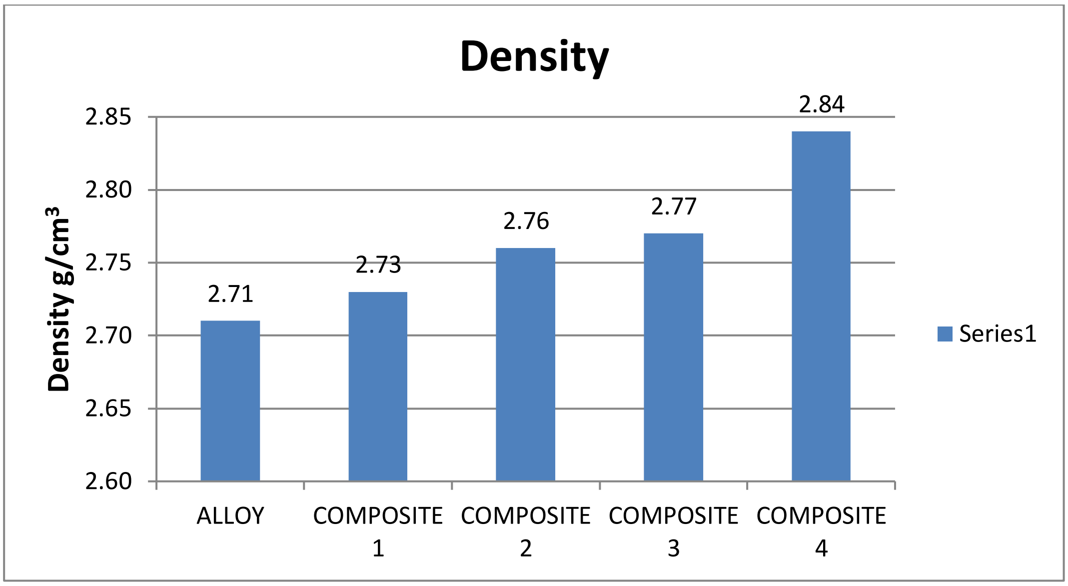



Fig.6. variations in density

## VIII. CONCLUSION

In this research, knowing the advantages of mechanical alloying, aluminum metal matrix composite with molybdenum disulphide, tungsten disulphide and nickel Nano particles produced by using stir casting method. The mechanical properties of composite depend on the size of reinforcing elements, manufacturing method and experimental setup. The hybrid composite samples were subjected to mechanical and micro structural characterization. The investigation after the number of tests conducted concluded that the strength and hardness of composite increases with the introduction of reinforcements in comparison to the pure base matrix. The rate of increase in hardness and ultimate tensile strength for the composites increased as the concentration of molybdenum and tungsten increased while the impact energy decreased in similar manner. This composite can constructively serve as the promising material for aerospace, automobile, manufacturing and architectural industries.

**CONCLUSIONS**

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