[ICAMS: March 2017]
ISSN 2348 – 8034
Impact Factor- 4.022

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

EDS ANALYSIS AND MECHANICAL TESTING OF ALUMINA AND GRAPHITE PARTICULATE ALUMINIUM METAL MATRIX COMPOSITE

Naveen C R[*1], Dr. Thomas Pinto[2] & Kiran Holla[3]
[*1]Asstant Professor, Mechanical Engineering, Srinivas Institute of Technology, Mangaluru, India
[2]Professor, Mechanical Engineering, Srinivas Institute of Technology, Mangaluru, India
[3]Student, Mechanical Engineering, Srinivas Institute of Technology, Mangaluru, India

ABSTRACT

Development of hybrid metal matrix composites has become an important area of research interest in Materials Science. Hybrid Metal Matrix Composites (HMMCs) are highly attractive for large range of hi-tech engineering applications because of their useful properties. Stir casting is the most commonly used method for production of particulate reinforced cast HMMCs. A recently developed modification of stir casting has been used in the present investigation to produce aluminium matrix composites reinforced with alumina and graphite. Here Aluminium 2024 is used as a base metal and Al_2O_3 & Gr is a reinforced material. The preferred fabrication process is stir casting. Al 2024 material is fabricated with Al_2O_3 & Gr on various wt% of 0%, 5%, 10%, 15% of alumina oxide and 2.5% constant Graphite compositions. The fabricated materials were then subjected to mechanical properties such as hardness test, tensile test, SEM analysis and EDS Spectrum were evaluated. The mechanical property hardness and tensile is improved with the increase in weight percentage of Al_2O_3 particulates with various weight percentages in the aluminum matrix.

Keywords- *Composite, HMMCs, SEM, EDX, hardness, tensile strength.*

I. INTRODUCTION

Aluminium alloys are used in advanced applications because their combination of high strength, low density, durability, machinability, availability and cost is very attractive compared to competing materials. However, the scope of these properties can be extended by using aluminium matrix composite materials. Metal matrix composites consist of at least two chemically and physically distinct phases suitably distributed to provide properties not attainable with either of the individual phases. Metal matrix composites (MMCs) have been developed to respond the demand for lighter materials with high specific strength, stiffness and wear resistance. Aluminium is favoured as matrix material in MMCs because of its low density, easy fabrication and good engineering properties Metal-matrix composites (MMCs) have been developed to combine the good ductility and toughness of the metal matrix and the superior strength and stiffness of the ceramic reinforcement, and they have been used in some important engineering applications including automotive and aerospace. The reinforcement of metals can have many different objectives. The reinforcement of light metals opens up the possibility of application of these materials in areas where weight reduction has first priority. The precondition here is the improvement of the component properties Aluminium-based alloys are widely used as aerospace and automotive components, because of their high specific strength, stiffness and formability. However, both pure Al and Al alloys possess poor wear resistance. On the other hand, Al alloy matrix composites are known to offer better wear resistance and bulk mechanical properties.

II. LITERATURE REVIEW

Mohd Abdul Qudirkhan et al[1],The present work focuses on the fabrication of reinforced with 12 wt. % of B_4C particulates through ball milling. Ethanol (5 wt. %) has been used as a process control agent (PCA). In this work, mechanical alloying was used to synthesize aluminium matrix composite powder in a conventional ball mill under argon atmosphere with different milling time of 5, 10 and 15 hours. The ball to powder weight ratio was maintained at 10:1. Scanning electron microscopy (SEM) of the ball milled powder shows that addition of boron carbide particles accelerates the milling process. The Hardness of the composites was increased with increase in the milling time.

Md. Tanwir Alam et al[2], In the present study, the effect of silicon carbide on stir cast aluminium metal matrix composite is developed by varying SiC 10%, 20%, 30%, 40% and 50% by weight at stirring speed of 300 rpm. In the present scenario, crystallite size, lattice strain, lattice constant and interplaner distance, by x-ray diffraction (XRD) patternof aluminium metal matrix composites reinforced with silicon carbide particles produced by stir casting method at 680C and 900C pouring temperatures, are found and discussed. Compositions of aluminium alloy and aluminium-silicon carbide composites are found by energy dispersive spectroscopy (EDS) and scanning electron microscopy (SEM). It is found that as the crystallite size increases, lattice strain decreases and vice-versa.

Manjunath et al[3], In this project a hybrid composites of Al6061hexa boron nitride-graphite and chemosphere will be created and the different mechanical and physical properties of the composites are discovered and compared with the properties of the reinforced Al6061 alloy. Al6061 is selected as the base metal matrix. Boron nitride, graphite and cenosphere are selected as the reinforcement. Boron nitride and graphites is maintained at constant of 2% and 6% weight for all the composition and varying cenosphere from 2% weight to 6% weight in the increments of 2% weight. The composites will be developed by stir casting method hardness test, and density test will be conducted. The bonding between matrix and reinforcements of different compositions will be found out by using SEM Analysis.

Gheorghe IACOB et. al[4], The paper presents the results of experimental research in production of Al/Al2O3/Gr powder composites using mechanical alloying. Obtaining of these composites by conventional methods is difficult because the resulting products have low mechanical properties due to the structural unhomogeneity of the obtained material. The resulted samples then been characterized by SEM and EDS analysis. Experiments indicate that this method is appropriate for obtaining composites with better homogeneity.

Senthil kumar et al[5], The present investigation to produce aluminum-magnesium matrix composites reinforced with silicon carbide. Here Aluminium 5083 is used as a base metal and SiC is a reinforced material. The preferred fabrication process is stir casting. Aluminum 5083 material is fabricated with SiC on various wt% compositions. The fabricated materials were then subjected to mechanical properties such as hardness; SEM analysis and EDS Spectrum were evaluated. The metallurgical test such as phase segmentation test is also evaluated. The mechanical property hardness is improved with the increase in weight percentage of SiC particulates with various weight percentages in the aluminum matrix.

III. MATERIAL PROPERTIES

Aluminium 2024

Aluminum alloy 2024 is an aluminum alloy, with copper as the primary alloying element. It is used in applications requiring high strength to weight ratio, as well as good fatigue resistance. It is weld able only through friction welding, and has average machinability. Due to poor corrosion resistance, it is often clad with aluminum or Al-1Zn for protection, although this may reduce the fatigue strength. 2024 is widely used in aircraft structures,especially wing and fuselage structures under tension.

Table 1: Composition of composite

Materials	Weight %
Aluminium (Al)	93.3%
Copper (Cu)	4.3%
Manganese (Mn)	0.4%
Magnesium (Mg)	1.3%
Iron (Fe)	0.4%
Silicon (Si)	0.3%

Aluminium Oxide

Aluminium oxide or alumina is a chemical compound of aluminium and oxygen with the chemical formula Al_2O_3. It is the most commonly occurring of several aluminium oxides, and specifically identified as aluminium oxide. It is commonly called alumina, It occurs naturally in its crystalline polymorphic phase α-Al_2O_3 as the mineral corundum, varieties of which form the precious gemstones ruby and sapphire. Al_2O_3 is significant in its use to produce aluminium metal, as an abrasive owing to its hardness, and as a refractory material owing to its high melting point of 2072C.

Graphite

Graphite is one of two naturally occurring crystalline forms of the sixth element, carbon, the other being diamond. It is a soft greyish black mineral with a metallic lustre. A graphite crystal is made up of loosely stacked one atom thick grapheme layers much like a deck of cards. These layers can slide around giving graphite its lubricity. Graphite is an excellent conductor of heat and electricity and is relatively inert being unaffected by most chemicals. It maintains its properties even at extreme temperatures in excess of 3500°C, which makes it invaluable to the industry. It is a good dry lubricant and hence reduces wear and abrasion.

IV. EXPERIMENTAL PROCEDURE

The details of the experiments carried out on Al 2024 alloy subjected to refinement and with heat treatment has been highlighted under the following headings.

- Preparation of reinforcement
- Melting and Stir casting

Aluminium oxide and graphite are sieved to a fine grain size of maximum 37µm. Al 2024 bars were machined according to the size of the crucible without adding any coolant.

Table 2: Composition of composite

Sl No	Al 2024 % By Grams	Al_2O_3 % by grams	Gr % by grams
1	100	0	0
2	92.5	5	2.5
3	87.5	10	2.5
4	82.5	15	2.5

Now days with the modern development need of developments of advanced engineering materials for various engineering applications goes on increasing. The simplest and the most cost effective method of liquid state fabrication is stir casting. So, for fabrication process stir casting process is used. A stir casting setup consists of preheated, electric furnace with stirrer assembly. Three-phase electrical resistance type 10 KW capacity furnace is used. The temperature range of the furnace is 1000° C. The temperature range of pre-heater is about 800°C.The melting range of aluminium in 700°C - 800°C.

Preheated alumina and Graphite particles was added into the vortex slowly and steadily while continuing stirring to ensure the complete dispersion of reinforced particles it also promotes wettability. The addition of alumina and Graphite will be added on the %wt of the Aluminium alloy 2024.The molten alloy was stirred at 200 rpm for up to 3 minutes. Die is preheated to avoid porosity and scale formation on the samples due to sudden cooling. The molten metal was poured into the preheated die after the removal of slag. Addition of Magnesium enhances the wetability. However increase the content above 1.5wt. % increases viscosity of slurry and hence uniform particle distribution will be difficult. 22mm dia and 300mm length were prepared.

ISSN 2348 – 8034
Impact Factor- 4.022

Figure 1: Stir casting apparatus & Composite material

V. TESTING PROCEDURES

Scanning electron microscopy and EDS

Scanning Electron Microscopy (SEM): high vacuum, high resolution to evaluate surface structure. Environmental scanning electron microscopy can also be performed on hydrated samples.

Energy Dispersive Spectroscopy (EDS): provides elemental information about the composition of the structure of the surface of a sample. Performed in conjunction with SEM. Elements with atomic numbers down to carbon can be viewed with EDS. Energy Dispersive X-Ray Analysis (EDX), referred to as EDS or EDAX, is an x-ray technique used to identify the elemental composition of materials.

Figure 2: SEM & EDSTesting

Hardness Test

Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However, the term hardness may also refer to resistance to bending, scratching, abrasion or cutting. The specimen or the area or location must be selected and polished so as to give a reliable indication of the properties of the material. The specimen was placed on the anvil so that the surface is normal to the direction of applied load. Load (100 kgf) with a ¼ inch diameter steel ball indenter and wait for 30 seconds duration, to ensure the complete acting of the load on the specimen by the indenter. Remove the load after 30 seconds, measure the indentation by using a travelling microscope and find out the RHN using formula.

ISSN 2348 – 8034
Impact Factor- 4.022

Figure 3: Rockwell hardness tester

Tensile Test

Test specimens were prepared according to ASTM standards, specimen diameter of 12.5 mm and 60 mm gauge length was used. The specimen was loaded in computerized universal testing machine. Tests were conducted on composites of different combinations of reinforcing materials and ultimate tensile strength was measured. Simultaneous readings of load and elongation were taken at uniform intervals of load.

Figure 4: UTM Machine and samples

VI. RESULTS & DISCUSSION

Scanning electron microscopy (SEM)

Scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS) were used in order to examine the morphological changes of certain phases in the microstructure of Al2O3 & Gr particles in aluminium matrix. The SEM and EDS micrographs of aluminium and Al-Al_2O_3-Gr composites with Al_2O_3 contents 0%, 5%, 10%, 15% and keeping 2.5% Gr constant have been shown in the Fig.

In this study, the irregular shapes of most of the particles in the composite were found. The particles of the filler material are found randomly oriented and at most of the places at 10%Al2O3, they are embodied and closely packed into the matrix which improved the mechanical properties. Scanning electron images of HMMCs revealed that the typical microstructure of the AMMCs composites shows low porosity levels and better distribution of the Al2O3 & Gr. The importance of the matrix strength on the mechanical properties of the composites is confirmed by the influence of the presence of the Al_2O_3 &Gr. The agglomeration tendency was also observed in the composite. The SEM and EDS analysis of composites show the presence of the dispersed phase, i.e. alumina & graphite is homogeneously distributed in the matrix phase of aluminum and on the surface of the composites. There are some white particles which predicted the presence of aluminum oxides (Al_2O_3) and graphite, formed during polishing with atmospheric oxygen and pores in the grain boundaries are clearly visible during the investigation.

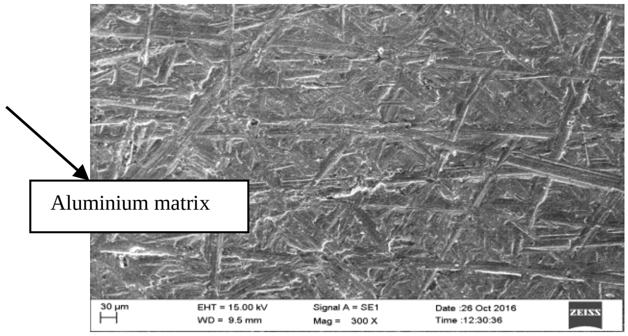


Fig 5: SEM image of Al2024

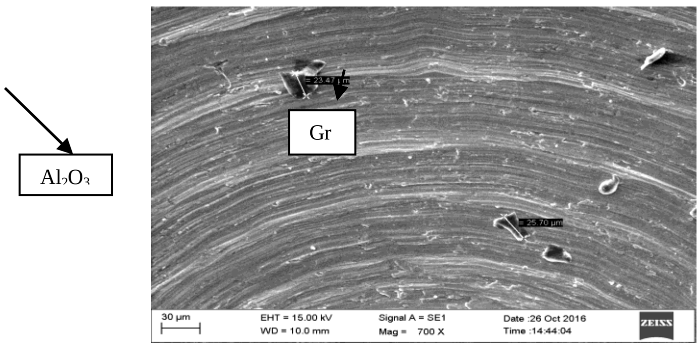


Fig 6: SEM image of 5%Al_2O_3

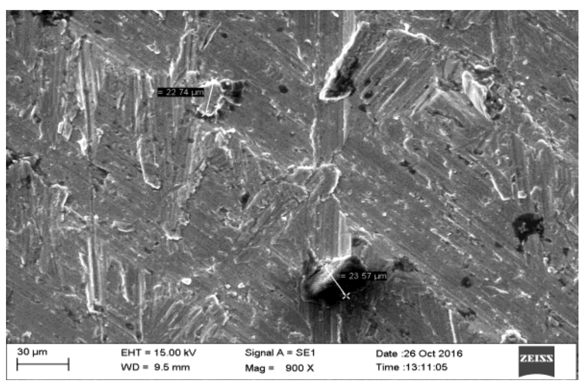


Fig 7: SEM image of 10%Al_2O_3

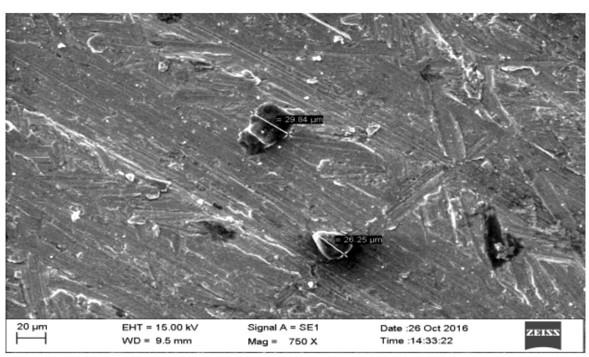


Fig 8: SEM image of 15%Al_2O_3

ISSN 2348 – 8034
Impact Factor- 4.022

Energy Dispersive X-ray Spectroscopy (EDX)

Elemental analysis was carried out in an EDX system attached to scanning electron microscope to investigate the chemical composition of composite. The EDX diffractograms for the same are shown in fig. all the EDX graphs are taken after performing. From the images it is clear that all the elements which are added in the mixture are present, as their peaks are clearly visible.

The EDS spectrum respectively at the marked location at particle matrix interface of $Al/Al_2O_3/Gr$ composite processed by stir casting process. The figure shows a wider interfacial reaction zone and the formation of Al, Mg, Cu and Carbon is evident from the EDS spectra. The infiltration of matrix alloy into the particle is also observed, which may be attributed mainly to the cracked particles and to a lesser extent to interfacial reaction. Figure shows the Colour SEM micrographs of Al/with different wt% Al_2O_3/Gr. From this colour SEM micrograph, the matrix element Aluminium and Reinforcement alumina and graphite can be easily viewed.

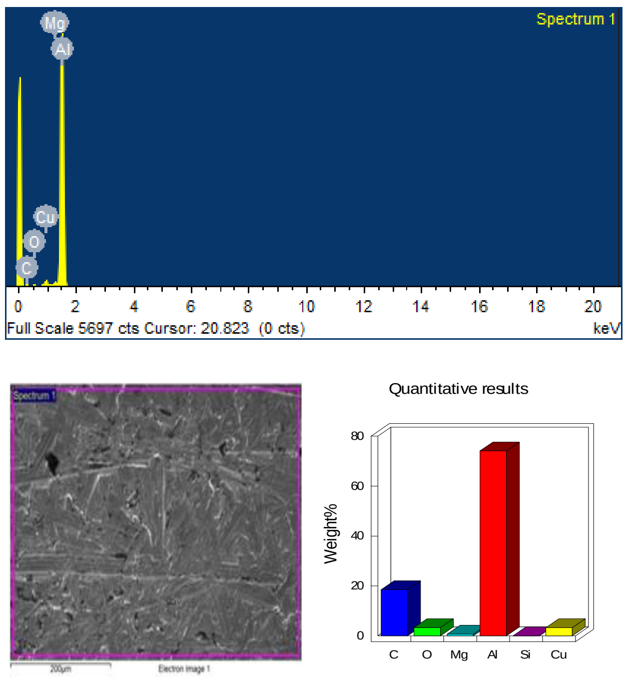
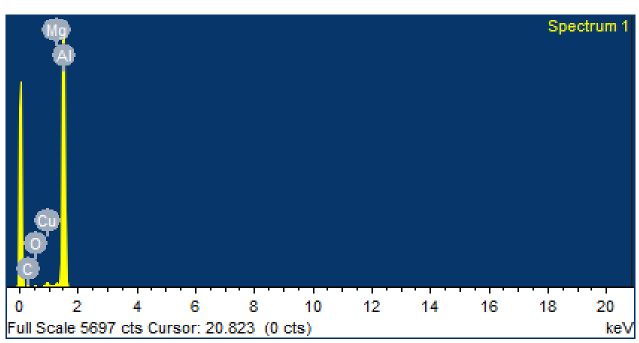


Fig 9: EDS spectrum analysis of Al2024

Figure 9 show the EDS spectrum respectively at the marked location at particle matrix interface of Al2024 material. In this case, the interface is very smooth and EDS spectra shows both the presence of aluminium, silicon, magnesium and copper phase at the interface. The image it is clear that all the elements which are added in the mixture are present, as their peaks are clearly visible.



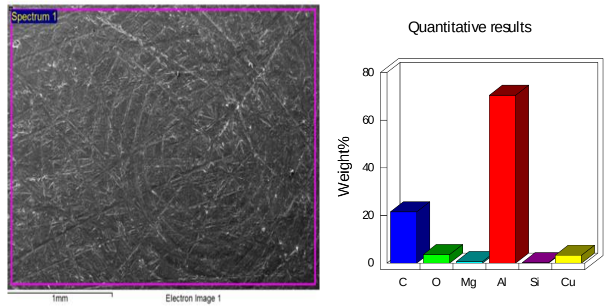


Fig 10: EDS spectrum of Al2024/5% Al_2O_3/2.5%Gr

Figure 10 show the EDS spectrum respectively at the marked location at particle matrix interface of Al2024/5%Al_2O_3/2.5%Gr composite. In the case, the interface is very smooth and EDS spectra shows both the presence of aluminium, carbon, silicon, magnesium and copper phase at the interface. Electron image focused on 200µm as shown in figure.

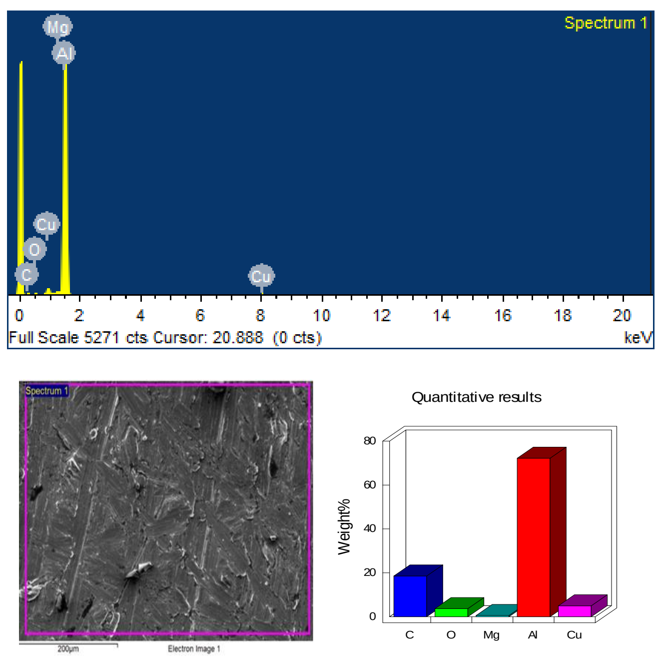


Fig 11: EDS spectrum of Al2024/10% Al_2O_3/2.5%Gr

Figure 11 show the EDS spectrum respectively at the marked location at particle matrix interface of Al2024/10%Al_2O_3/2.5%Gr composite. In this case, the interface is very smooth and EDS spectra shows both the presence of aluminium, carbon, silicon, magnesium and copper phase at the interface. Electron image focused on 200µm as shown in figure.

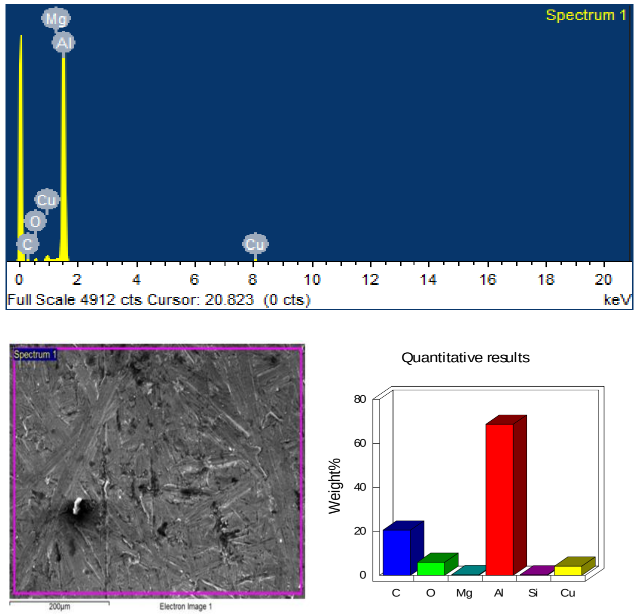


Fig 12: EDS spectrum of Al2024/15% Al_2O_3/2.5%Gr

Figure 12 show the EDS spectrum respectively at the marked location at particle matrix interface of Al2024/10%Al_2O_3/2.5%Gr composite. In this case, the interface is very smooth and EDS spectra shows both the presence of aluminium, carbon, silicon, magnesium and copper phase at the interface. Electron image focused on 200µm as shown in figure.

Hardness

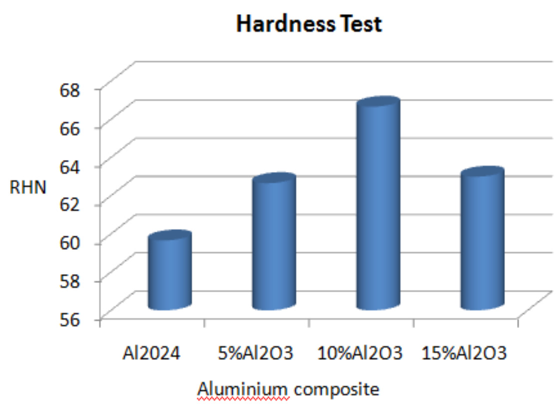


Figure 13: Composition v/s RHN value

Hardness property is influenced by % increasing of alumina, so the hardness vary drastically. The negligible variation in the hardness is due to the kept constant graphite percentage. better hardness and the maximum hardness of 66RHN in A20241+10%Al_2O_3+2.5%Gr. It's an increase hardness compared to cast Al2024.

Tensile

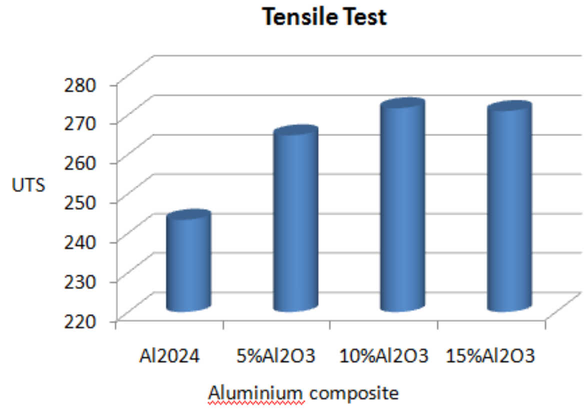


Figure 14: Ultimate tensile strength v/s composition

Tensile test has been conducted on the specimens. A tensometer is a device used to evaluate Young's modulus (how much it stretches under strain) of a material. The tensometer is usually loaded with a sample between two grips that are adjusted manually to apply force to the specimen. From the graph it is observed that 10% Al_2O_3 has better tensile strength.

VII. CONCLUSION

Al/Al_2O_3/Gr composites were produced by stir cast route with different weight percentage of reinforcement and the mechanical properties such as SEM analysis, EDS spectrum, hardness and tensile strength property evaluated.

1) The die is preheated to avoid the scale formation and reduce the porosity of the samples.
2) The phase and the volume fraction of hybrid metal matrix composite are viewed by using the Metallurgical Image Analysis System. The volume of Al_2O_3 is increased by increasing the wt % of Al_2O_3.
3) Elemental analysis was carried out in an EDX system attached to scanning electron microscope to investigate the chemical composition of composite. From the images it is clear that all the elements which are added in the mixture are present, as their peaks are clearly visible.
4) Rockwell hardness number (RHN) increase drastically because of increasing the wt % of Al_2O_3. reinforcement. Graphite is a good dry lubricant and hence reduces wear and abrasion.
5) Ultimate tensile strength (UTS) varies drastically because of increasing wt % of Al_2O_3. Reinforcement.

VIII. ACKNOWLEDGMENTS

The authors gratefully acknowledge the support and guidance of Prof. Dr. Thomas Pinto, M.Tech., Ph.d., Department of Mechanical Engineering, Srinivas Institute of Technology, Mangaluru and Prof. Dr. S.S. Sharma, M.Tech., Ph.d., Department of Mechanical Engineering, Manipal Institute of Technology, Manipal. G. Balakrishnan, Saravana foundry, Bangaluru.

REFERENCES

1) *Mohd abdul qadirkhan, "Fabrication and testing of Al-Cu-B4C composite by mechanical alloying", IJIRSET, Vol 4, Issue 9, 2015, ISSN: 23476710.*
2) *Md. Tanwir alam, "X-Ray diffraction analysis and microstructural examination of Al-SiC composite fabricated by stir casting technique", IJSTM, Vol 4, Issue 01, 2015, ISSN: 23941537.*
3) *Manjunath, "Fabrication of hBN-Gr cenosphere-Al6061 MMC and its charactirazation by stir casting method", IJTRE, Vol 3, Issue 10, 2016, ISSN: 23474718*

4) *Gheorghe IACOB, "Obtaining and charactirazation of Al/Al2O3/Gr composites by mechanical alloying", UPB Sci Bull, Vol 74, Issue 5, 2012, ISSN: 1454 2331*
5) *Senthil Kumar.T.S, "Evaluation of hardness test of silicon carbide particulated aluminium metal matrix composites", Vol 3, Issue 9, pg 74-84, 2015, ISSN: 2320 7345.*
6) *L. Krishnamurthy, B.K. Sridhara, D. Abdul Budan.;"Comparative study on the machinability aspects of aluminium silicon carbide and aluminum-graphite-silicon carbide hybrid composites" International Journal of Machining and Machinability of Materials 2011 - Vol. 10, No.1/2 pp. 137 -152.*
7) *G. Rajaram, S.Kumaran.; "Studies on high temperature wear and its mechanism of Al–Si/graphite composite under dry sliding conditions." Tribology International 43 (2010) 2152–2158.*
8) *V.L. Kingston, John Prabhakar,; " A study on mechanical and machinability characteristic of HMMCs", IJERA (March 2014), ISSN: 2248-9622.*
9) *Manna A. and Bhattacharyya B.; "Investigation for optimal parametric combination for achieving better surface finish during turning of AlSiC-MMC", International journal of Advance Manufacturing Technology, Vol. 23, (2004), pp. 658665*