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Studying the mechanical properties of aluminum alloy reinforced with graphite and Al_2O_3 by stir casting process

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Abstract
Aluminum and its alloys are widely used in automobile and aerospace industries due to their excellent mechanical properties, low density, high corrosion resistance and wear and low thermal coefficient of expansion. With these excellent properties and relatively low production cost Aluminum and its alloys have variety of application in scientific and technological viewpoints.
The aim involved in present work is to the study of behavior of Aluminum 6063 with Graphite and small quantity of Alumina (AL_2O_3) composite made by stir casting technique. In this different percentage of reinforcement is used and Density test, Tensile test, Hardness test are performed on the samples obtained from stir casting process. SEM & EDS is also performed on samples to find out the reinforced material.
Tensile test is performed to measure the maximum elongation and reduction in area of metal matrix composites whereas hardness tester is employed to evaluate the bonding between the matrix and reinforced particles with constant load and constant time. SEM and EDS is performed to know the presence of reinforced Alumina particles in the metal matrix composite and elemental composition of samples respectively.

Keywords: Al6063, Reinforcement, Stir casting, SEM, Energy Dispersive Spectroscopy

1. Introduction
A composite material is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties. Therefore the new material formed may be preferred for many reasons such as they are light in weight, stronger, less expensive as compared to traditional materials.
Metal matrix composites (MMC) are made by dispersing a reinforcing material into a metal matrix. Like other composites, aluminum matrix composite are not a single material but a family of material whose stiffness, density thermal and electrical properties can be tailored. Therefore composites materials are high stiffness and high strength, low density, high temperature stability, high electrical and thermal conductivity, adjustable coefficient of thermal expansion, corrosion resistance, improved wear resistance etc. These properties can be attained with the proper choice of matrix and reinforcement.
Composite materials consist of matrix and reinforcement. Its main purpose is to transfer and distribute load to the reinforcement. This transfer of load depends on bonding which depends on type of matrix and reinforcement and fabrication technique. The matrix can be selected on the basis of oxidation and corrosion resistance or other properties. Generally Al, Ti, Ni, Cu, Mg, Pb, Fe, Ag, Zn, and Si are used as matrix material.
The choice of Graphite as reinforcement into Al 6063 is due to its unique properties of both metal and non-metal. It is flexible but not elastic, has a high thermal and electrical conductivity, and is highly refractory and chemically inert. Graphite has a low adsorption of X-rays and neutrons making it a particularly useful material in nuclear applications. Aluminum based metal matrix composites have been one of the key research areas in materials processing field in the last few decades. Most of the Research work has been dealing with aluminum matrix with Al_2O_3 & SiC reinforcement requiring the light weight in combination of high strength and high stiffness. This is because aluminum is lighter weight which is first requirement in most of the industries. In addition, impressive strength improvement and the thermal expansion coefficient of Al matrix composites can be adjusted by using Graphite in varying proportion. Al 6063 is casted with varying %age of Graphite (5%, 10%) and with small quantity of Alumina.

2. Experimental procedure
Preparation of Samples
Aluminum Alloy was melted in a crucible by heating in a muffle furnace at 850ºC for 2 hours and 30 minutes. The temperature of furnace was first raised above the liquidis temperature of aluminum near about 700ºC to melt the Aluminum alloy completely and then cooled down just below the liquidis to keep the slurry in semi-solid state. Manual stirring is carried out for about 6-7 minutes, after that the Alumina particles were added manually to the molten. In the final mixing process the furnace temperature was maintained at 750ºC. After stirring process the mixture was pour in the mould to get desired shape of specimen as shown in figure below. The presence of reinforcement through the specimen was inspected by cutting the casting at different locations and under microscopic examination. Same process was repeated for specimen of different compositions of Graphite-Alumina particles.

Fig 1: Mould and cast product after casting

Table 1: Composition of Samples

Sample no.	Aluminum (gm)	Graphite (gm)	Alumina (gm)	Remarks
1	503	0	0	Weight of sample = 427 gm
2	424	18	0	Graphite= 5%
3	402	36	0	Graphite= 10%
4	402	18	33	Graphite= 5% + Alumina= 5%
5	358	36	66	Graphite= 10% + Alumina= 10%

3. Results & discussion

3.1 Density Measurement Test

The table below shows the values of density obtained for the different wt % of reinforced samples. From the table it can be concluded that the density of composites vary due to the presence of porosity in the samples. The porosity is probably due to:

1. Increase in surface area in contact with air.
2. Gas entrapped during stirring.
3. Gas injection of particles introduces a quantity of gas into the melt.
4. Hydrogen evolution.
5. The pouring distance from the crucible to the mould
6. Shrinkage during solidification.

Table 2: results of density measurement test

Sample no	Sample Name	Density (gm/m^3)
1	Pure	2.679
2	Graphite= 5%	2.587
3	Graphite= 10%	2.582
4	Graphite= 5% + Alumina= 5%	2.591
5	Graphite= 10% + Alumina= 10%	2.602

3.2 Hardness Test

A Vickers Hardness Tester machine was used for hardness measurement. Firstly machining of samples was done to get a good surface finish and then different loads were applied on samples. Hardness test was carried out at room temperature and then the average values were utilized to calculate hardness number. The maximum testing height is 200mm. The result of Vickers hardness for pure sample that is without reinforcement (sample no. 1) and weight percentage of different samples with reinforced Graphite as 5%, 10% and Graphite 5% / Al_2O_3 5% and Graphite 10% / Al_2O_3 10%. It is evident that, as the percentage of particulates is increased, the hardness of the composite increases monotonically. It found that the hardness linearly increases with increasing volume percentage of Graphite and further goes on increasing with addition of Graphite/ Al_2O_3 mixture.

Table 3: Results of Hardness Test

Sample no.	Sample name	Hardness Vickers Hardness			Mean Hardness
		Trial 1	Trial 2	Trial 3	
1	Pure	52.1	53.4	51.9	52.4
2	Graphite= 5%	55	54	54	54.3
3	Graphite= 10%	56	57	59	57.3
4	Graphite= 5% + Alumina= 5%	70	68	71	69.6
5	Graphite= 10% + Alumina= 10%	68	73	75	72

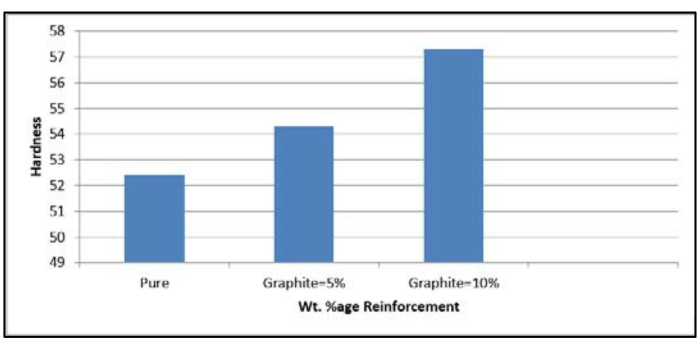


Fig 2: Comparison the hardness with wt. % variations of Graphite

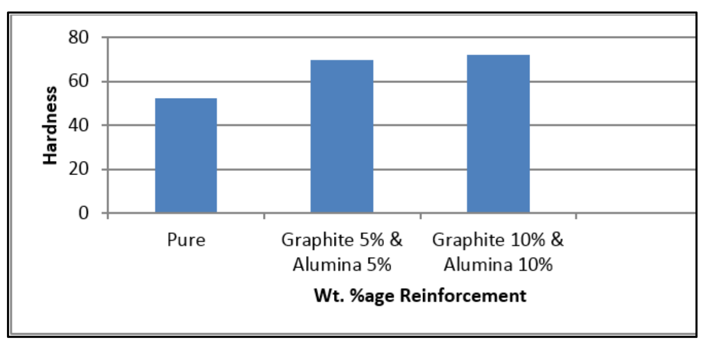


Fig 3: Comparison the Hardness with wt. % variation of combined Graphite & Alumina

3.3 Tensile Strength Test

Tensile strength test was done to determine the mechanical behavior of composites and matrix alloy. The composite and matrix alloy rods were machined to tensile specimens with a diameter of 14mm and gauge length of 30mm. Ultimate tensile strength (UTS) is the maximum stress that a material can withstand while being stretched or pulled before failing or breaking. It is also known as tensile strength or ultimate strength. Some materials breaks sharply while others experience some plastic deformation and possibly necking before fracture. However, it is dependent on other factors, such as the preparation of the specimen, the presence or otherwise of surface defects, and the temperature of the test environment and material. The table shown below shows the reinforcement of Graphite as 5%, 10% in two samples and another two samples of Graphite 5% with Alumina 5% & Graphite 10% with Alumina 10%, with all these increase in reinforcements the ultimate tensile strength of metal matrix composite goes on increasing.

Table 4: Ultimate tensile strength & Elongation values

Sample no.	Alloy	T.S (N/mm^2)	Elongation %
1	Pure	126	9.85
2	Graphite= 5%	132.979	3.55
3	Graphite= 10%	138.269	3.07
4	Graphite= 5% + Alumina= 5%	145.817	4.13
5	Graphite= 10% + Alumina= 10%	149.146	4.03

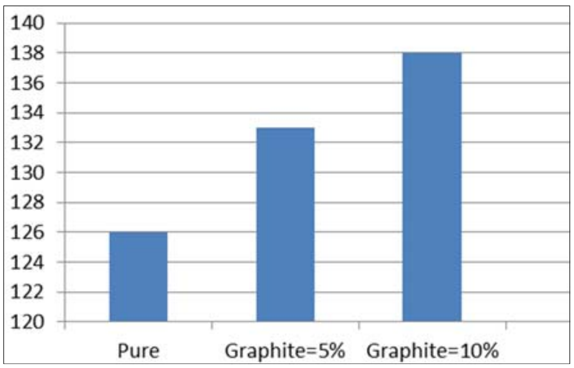


Fig 4: Comparison of the Ultimate Tensile Strength with wt. % variation of Graphite

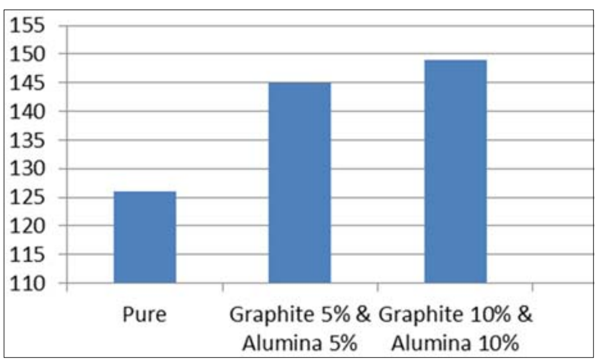


Fig 5: Comparison of the Ultimate Tensile Strength with wt. % variation of Graphite & Alumina mixture

Length Elongation Comparison

The below results on elongation are shown with reinforced Graphite as 5%, 10% in two samples and another two samples reinforced Graphite 5% with Alumina 5% & Graphite 10% with Alumina 10%, which shows that the elongation decreases with increase in %age of reinforced particles

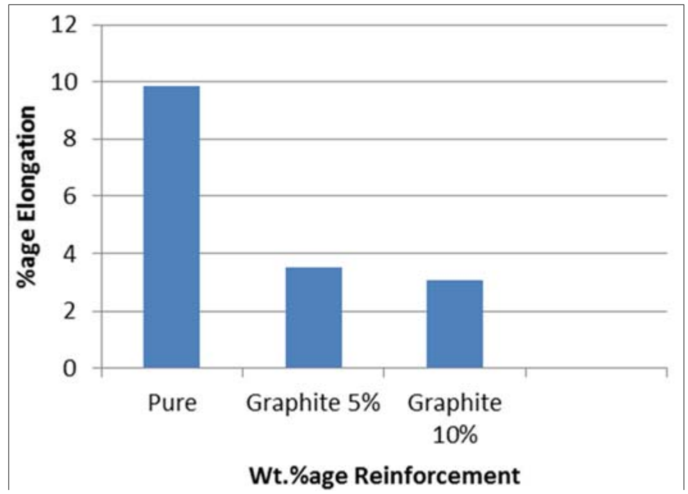


Fig 6: Comparison the Elongation with wt. % variation of Graphite

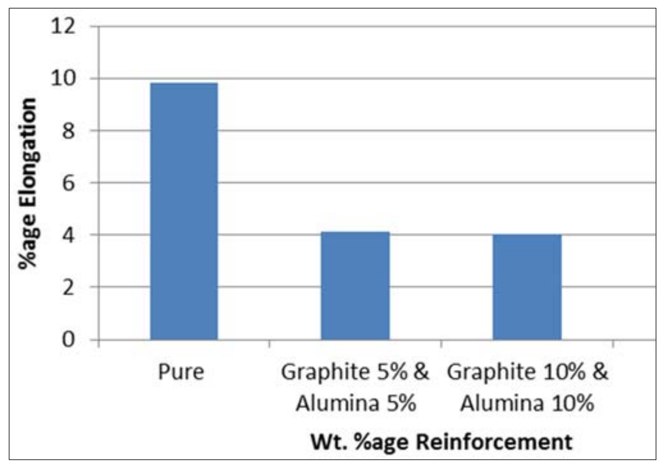
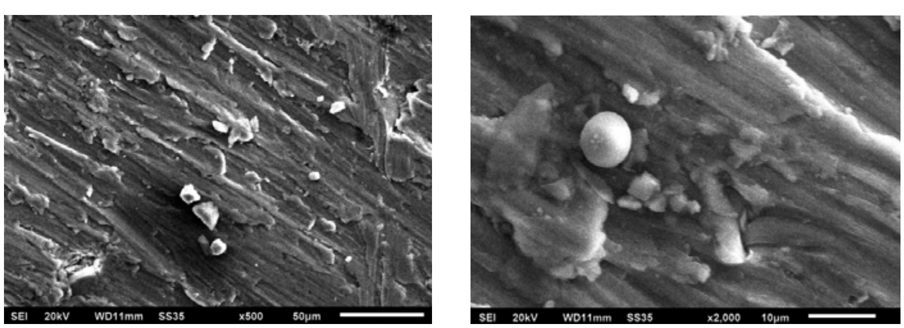


Fig 7: Comparison the Elongation with wt. % variation of Graphite & Alumina mixture

As shown in above graphs it is clearly seen that as the wt of graphite & alumina increases elongation decreases. This is due to decrease in ductility because of increase in tensile strength.

4. Results of SEM

1: 5% graphite mixed with aluminum alloy



500X **2000X**

Fig 8: Microscopic view of 5% of Graphite reinforced in Al-Alloy

2: 10% Graphite mixed with Aluminum alloy

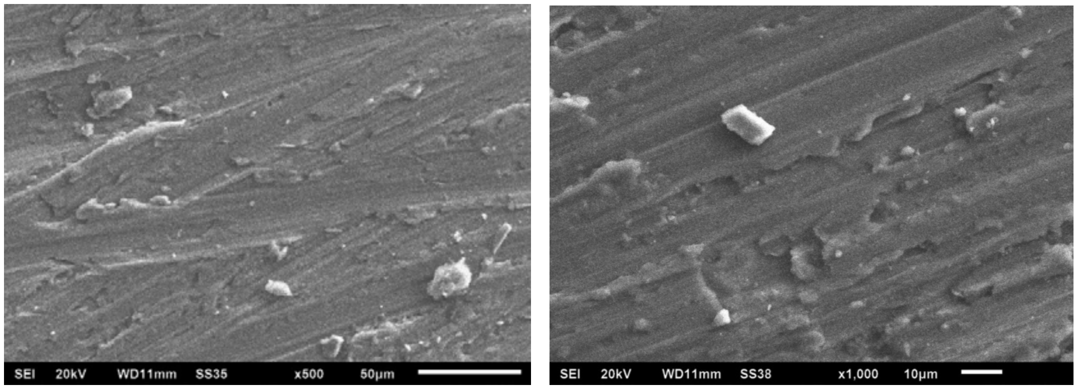


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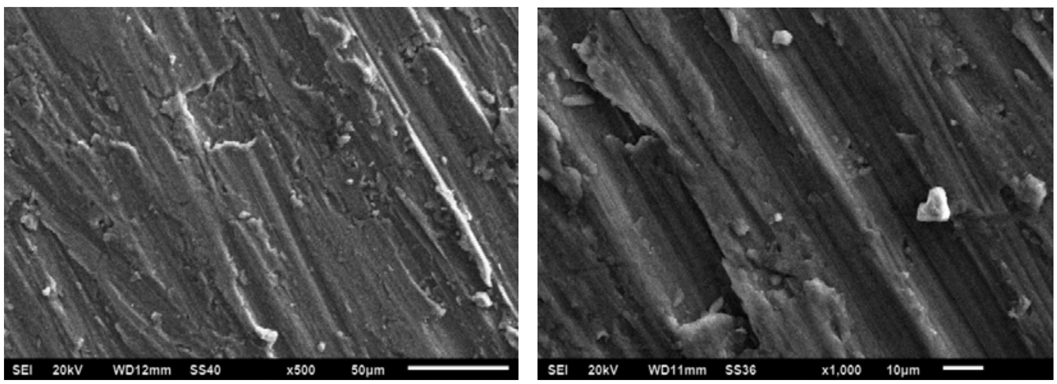
Fig 9: 5.14 Microscopic view of 10% of Graphite reinforced in Al-Alloy

3: 5% Graphite & 5% Alumina mixed with Aluminum alloy



500X **1000X**

Fig 10: Microscopic view of 5% Graphite & 5% Alumina reinforced in Al-Alloy

4: 10% Graphite & 10% Alumina mixed with Aluminum alloy

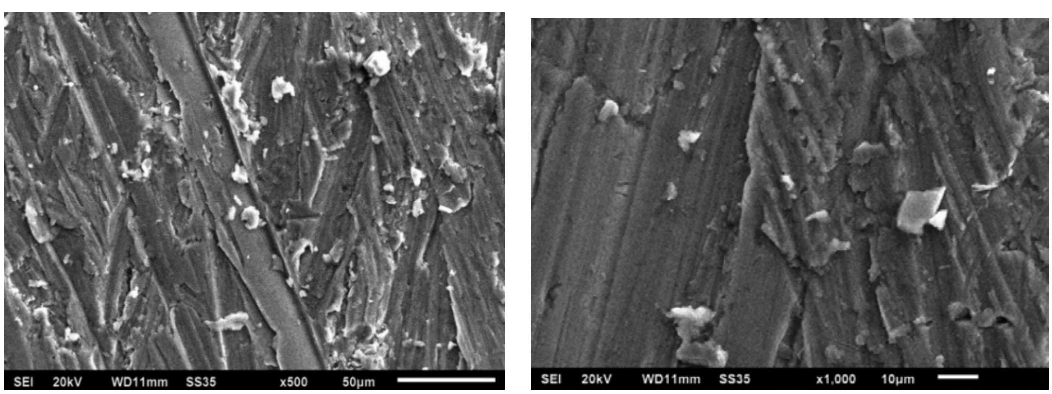


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Fig 11: Microscopic view of 10% Graphite & 10% Alumina reinforced in Al-Alloy

The above figures represent the microphotographs of Al-Graphite and Alumina matrix composites which are examined under Scanning Electron Microscope (SEM). From figures it can be observed that, the distributions of reinforcements in the respective matrix are fairly uniform. Further these figures reveal the homogeneity of the cast composites. The microphotograph also clearly revels the increased filler contents in the composites.

Energy Dispersive Spectroscopy (EDS)

EDS analysis usually involves the generation of an X-ray spectrum from the entire scan area of the SEM. The image of polished specimen and corresponding X-ray spectra was generated form the entire scan area. The Y-axis shows the counts and the X-axis shows the energy level of those counts.

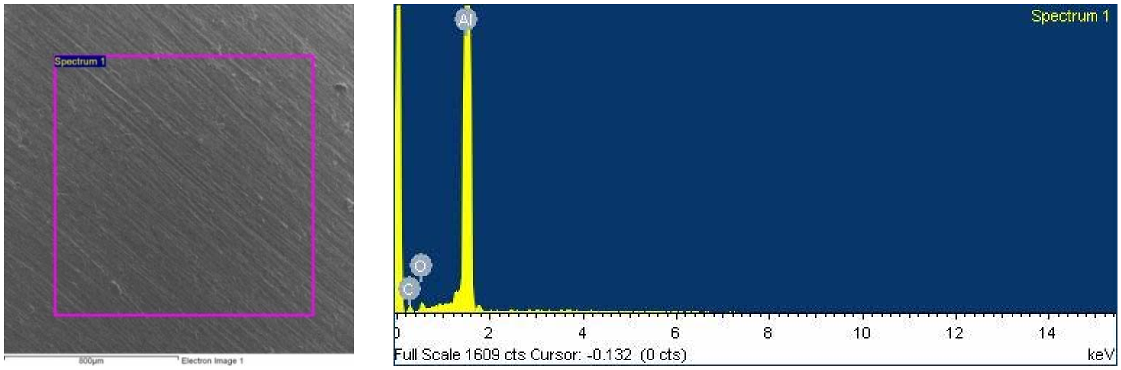

Fig 12: EDS structure showing spectra for 5% Graphite in Al-Alloy

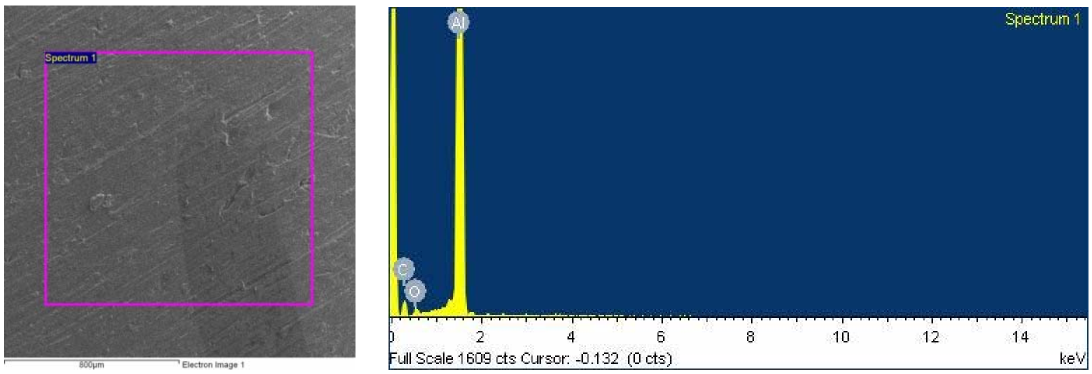

Fig 13: EDS structure showing spectra for 10% Graphite in Al-Alloy

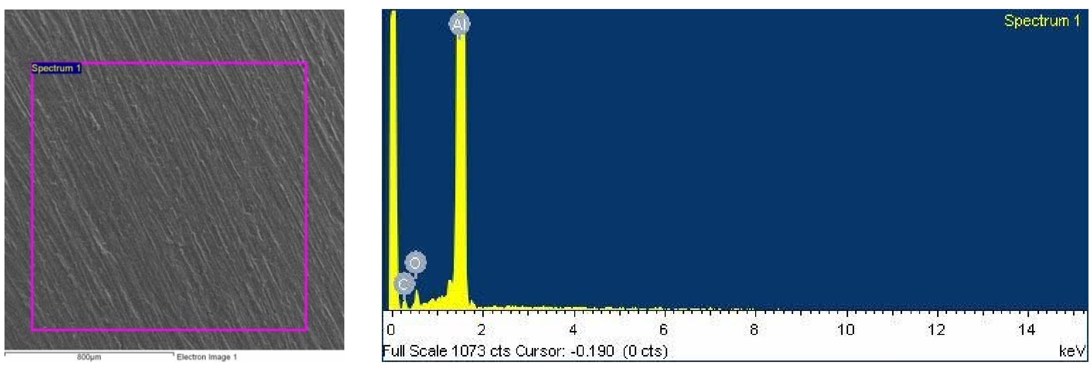

Fig 14: EDS structure showing spectra for 5% Graphite & 5% Alumina in Al-Alloy

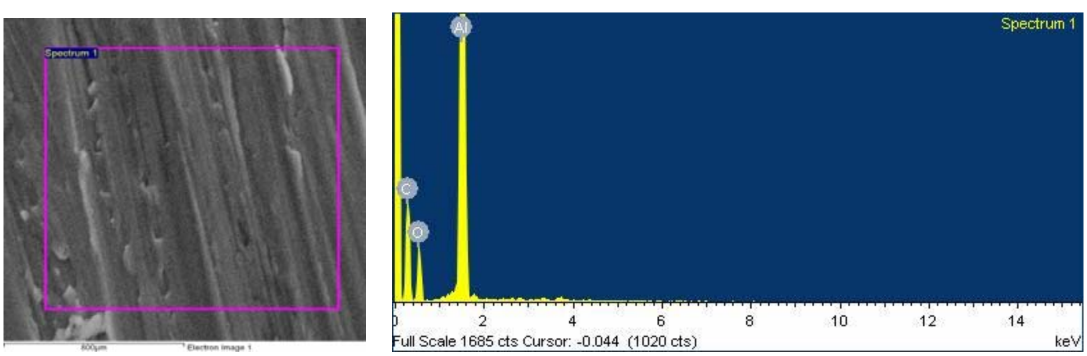

Fig 15: EDS structure showing spectra for 10% Graphite & 10% Alumina in Al-Alloy

5. Conclusions

The conclusions drawn from the present investigation are as follows:

1. The results confirmed that stir formed Al 6063 with Alumina/Graphite reinforced composites is clearly superior to base Al alloy in the comparison of tensile strength, Hardness test as well as density.
2. Dispersion of Alumina/Graphite particles in aluminum matrix improves the hardness of the matrix material.
3. It is found that elongation tends to decrease with increasing particles wt. percentage, which confirms that Graphite and Alumina addition increases brittleness.
4. Aluminum matrix composites have been successfully fabricated by stir casting technique with fairly uniform

distribution of Alumina/Graphite particles.
5. It appears from this study that UTS and Yield strength trend starts increases with increase in weight percentage of Alumina & Graphite in the matrix.
6. The Hardness increases after addition of SiC, Al2O3 particles in the matrix. SEM results showed the presence Alumina/Graphite particles in alloy matrix. This clearly shows that the reinforced Alumina/Graphite particles have dispersed uniformly throughout in the MMC thus strengthening the resulting composite.
7. Stir casting process, stirrer design and position, stirring speed and time, particle preheating temperature etc. are the important process parameters.

6. Scope of future work
1. This can be further extended by varying stirring speed and geometrical angle of stirrer.
2. More results can be obtained by varying reinforced particle size.
3. Heat treatment can also be done to improve properties
4. By varying the %age composition of reinforced particle more improved results can be obtained

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