ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 5, Issue 4, April 2020

Experimental Evaluation of Mechanical Behavior of Al6061-TiO_2-Gr Hybrid Composite Using Stir Casting Technique

[1] Shruthi H.M, [2] Doddaswamy. V
[1] PG student, Dept. of Mechanical Engineering PESCE Mandya
[2] Assistant Professor, Dept. of Mechanical Engineering PESCE Mandya

***Abstract:*--** **Metal Matrix Composites (MMCs) have many beneficial characteristics like light weight, high strength, stiffness and exhibit greater resistance to corrosion, oxidation, and wear. The effect of TiO2 and graphite particulates on mechanical strength of the Aluminium based composites processed through stir casting technique was investigated. Titanium Oxide (TiO2) and graphite (Gr) particles were used as reinforcement phases for the present study. The hybrid MMCs was prepared with varying volume proportions of TiO2 particles for 4%, 8% and 12% and 3% constant volume of graphite. The average particles size of TiO2 and graphite are 44 microns and 149 microns respectively. The stir casting process was carried out. The microstructure and mechanical properties are investigated on prepared hybrid MMCs.**

Index Terms:- Hybrid MMCs, Stir Casting, Aluminium, Titanium Dioxide, Graphite.

1. INTRODUCTION

Normally, conventional alloy materials have some problems in achieving a good combination of mechanical properties such as strength, hardness, toughness, stiffness, density and other inevitable mechanical properties. To overcome this limitation, composite materials are developed. If more than two materials present in a composite, then it is known as a hybrid composite. This research is an attempt to test and analyze the mechanical properties of hybrid metal matrix composites. Hybrid metal matrix composites are used in braking systems, piston rods, piston pins, pistons, frames, valve spring caps, brake discs, disc brake caliper, brake pads, etc. They have also found application in aerospace, military and civil fields.

A survey by Ajith kumar.R, Chandan singh [1] have written a review on the enhancement of mechanical properties of aluminium 6061 metal matrix composite and observed that as the percentage of reinforcement increased the mechanical properties are improved.

G.Sivakaruna and Dr. P.Suresh Babu[2] have written a review on the effects of reinforcement on Aluminium metal matrix composites and observed that as the percentage of reinforcement increased the mechanical properties are improved.

Gowrishankar T P[3], et. al., reviewed the manufacturing methods and mechanical properties of various aluminium matrix composites. By selecting suitable values of process parameters such as stirring speed, pouring temperature, etc. good quality composites can be made. By using graphite, friction can be reduced and also the machinability can be improved.

Dr. G Elango1, K Balaji [4] have written a review on the investigation on Mechanical Properties of Gr+ TiO_2reinforced Composite made by stir casting method and observed that by adding reinforcement the tensile properties reduced but the hardness increased.

G.S. Kataiah[5] concluded that in the case of cast Al 6061 alloy/ TiO_2 particulate composites the mechanical properties improved significantly. It was found that by increasing TiO_2 the hardness, tensile strength and Impact strength can be improved.

Himanshu Kala et al [6] have written a review on the tribological aspects and mechanical properties of Al matrix composites made by stir casting method and observed that by adding graphite the tensile properties improved but the hardness decreased.

Niranjan K N[7] reported about the preparation and characterization of Al6061 hybrid composite. The decrease in hardness of hybrid composite is likely because of poor wetting characteristics of Al 6061 on graphite. It was

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 5, Issue 4, April 2020

observed that the compressive strength increased as the SiC and graphite content increased.

M. Meignanamoorthy and M. Ravichandran[8] have first prepared the hybrid MMC's by varying TiO_2 percentage and fixing the graphite percentage and then fixed the TiO_2 percentage and varied the graphite percentage. To fabricate the hybrid MMC's, authors followed powder metallurgy process and observed that by adding the reinforcement into the matrix the mechanical properties will be decreased.

1. SELECTION OF MATERIALS

Aluminium and its alloys are the most widely used matrix material for the development of Metal Matrix Composites (MMCs). This is mainly due to the broad spectrum of unique properties it offers at relatively low processing cost. Some of the attractive property combinations of Al based matrix composites are: high specific stiffness and strength, thermal conductivity, and low thermal expansion. TiO_2 (rutile) is a soft solid powder. Graphite is a soft grayish-black substance. The average particles size of TiO_2 and graphite are 44 microns and 149 microns respectively. The composition of Al 6061 is given in table 2.1 and material properties are given in table 2.2.

Table 2.1: chemical composition of Al 6061

6061 Aluminum Alloy Composition by Weight %								
Mg	**Si**	**Cu**	**Fe**	**Mn**	**Zn**	**Ti**	**Cr**	**Al**
1.2	0.2	0.3	0.5	0.1	0.12	0.14	0.3	balance

Table 2.2: Material property of Al6061, TiO_2 and Gr

Material	Density (g/cc)	Poisson's ratio	Elastic Modulus (GPa)	Melting point (°C)
Al6061	2.7	0.33	68.9	582-652
TiO_2	4.23	0.27-0.29	230-288	1,843
Gr	2.75	0.17-0.23	4.1-27.6	3500°C

2. STIR CASTING

In conventional stir casting method, reinforcement is mixed into the molten metal by mechanical stirring. Mechanical stirring is the most important step in casting process, which decides the uniform distribution of reinforcing particles in molten matrix materials. After the mechanical mixing, the molten metal is directly transferred to a shaped mould prior to complete solidification. The essential thing is to create the good wetting between particulate reinforcement and aluminum melt. The distribution of the reinforcement in the final solid depends on the wetting condition of the reinforcement with the melt, relative density; rate of solidification etc. Distribution of reinforcement depends on the geometry of the stirrer, melt temperature and the position of the stirrer in the melt.

Fig 3.1: specimens after casting

3.1 PREPARATION OF AL 6061, TiO2 AND Gr COMPOSITE

The stir casting setup was prepared initially. The Al 6061 with 0%, 4%, 8%, 12% of TiO_2 powder and 3% graphite composite specimens were prepared by stir casting technique where Al6061 is the base material and TiO_2 and Gr is the reinforcement materials.

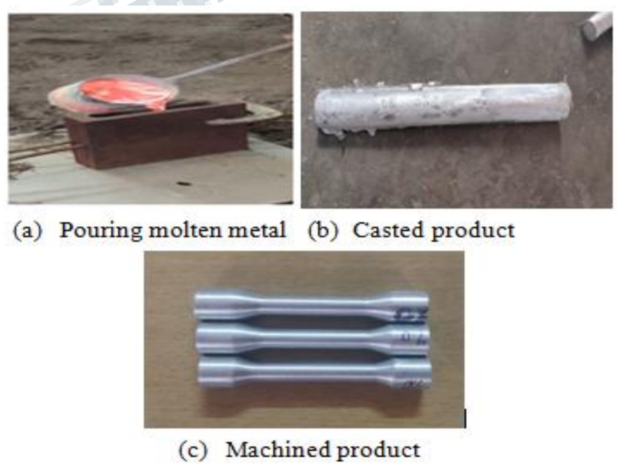


Fig 3.2: stir casting process

Step 1: Melting of base metal Al 6061 in furnace. In meanwhile preheat the reinforcement material i.e. titanium dioxide and graphite around 1000°C. [13]

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 5, Issue 4, April 2020

Step 2: Add the preheated reinforcement titanium reinforcement powder in a suitable proportion and stir it for at least 20 min[13] to get uniform distribution of titanium dioxide and graphite powder in the molten aluminum.
Step 3: After stirring add the scum powder which removes the slag and flux which is present in molten metal.
Step 4: Pouring of molten metal mixture into the mould and solidification.
The compositions followed during the specimen preparation are shown in table 3.1. After casting, the specimen is cut as per ASTM E8 standard and finished by grinding process.

Table 3.1: compositions of metal matrix composites

Samples	Compositions
1	Al6061
2	Al6061+4%TiO_2+3%Gr
3	Al6061+8%TiO_2+3%Gr
4	Al6061+12%TiO_2+3%Gr

4. EXPERIMENTAL DETAILS

Various tests were conducted on fabricated MMCs samples to analyze the casting performance characteristics of hybrid MMC's. Mechanical properties such as tensile strength and hardness are determined on fabricated MMCs in addition to this densities and porosities are determined. The tensile test was carried out at room temperature on tensometer. Brinell hardness test was carried out on a hydraulic Brinell Hardness test machine of capacity 2500Kg utilizing 10mm diameter of high carbon steel ball and also microstructure of hybrid MMC's were analysed.

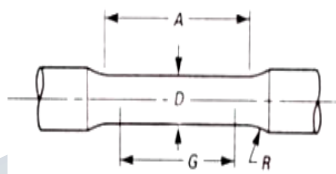
4.1 DENSITY AND POROSITY

The theoretical density was calculated by the rule of mixture, actual density was measured by Archimedes principle and porosity of the composites were obtained by theoretical and actual densities.

4.2 TENSILE TEST

Fig 4.1: Tensometer

The tensile test is conducted by tensometer as shown in figure 4.1. Tensile specimen is machined as per ASTM E8 standard as shown in figure 4.2.



Where,
D= gauge diameter=9mm
G=gauge length=36mm
R=fillet radius=8mm
A=reduced section=45mm

Fig 4.2: Tensile specimen

Both the ends of the specimen is fixed into a Tensometer. In the test one end is fixed and another end is stretched. Specimen is stretched slowly in tension until it breaks shown in figure 4.3, while the load and the distance across the gauge length are continuously monitored. The result is a stress strain plot of the material.

Fig 4.3: Tensile specimen broken

4.3 HARDNESS TEST

Hardness is a measure of the resistance to localized plastic deformation induced by either mechanical indentation or abrasion. In this work Brinell hardness test is conducted using Brinell hardness testing machine as shown in figure 4.4.

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 5, Issue 4, April 2020

Fig 4.4: Brinell hardness testing machine

Brinell hardness number is observed and obtained by using a perfectly shaped spherical steel ball of 10 mm. this is forced to be pressed against the test specimens surface using a force of 500kg (for aluminium) for 30 sec[7] to measure the indentation which is done by the steel ball. To measure the indentation, we use graduate low power Microscope.

$$\mathrm{BHN} = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

Where, P=test load in kilograms
D=diameter of ball in mm
d=diameter of read impression in mm

4.4 SEM (Scanning Electron Microscope)

SEM image is obtained by using scanning electron microscope which is having the resolution of 30nm at 30KV and maximum field of view is 0.08micrometer. tungsten heated cathode electron gun is used in this microscope. The electrons interact with atoms in the sample, producing various signals that contain information about the surface topography and composition of the sample.

4.5 ENERGY DISPERSIVE SPECTROSCOPY

EDX or EDS is energy dispersive X-ray spectroscopy. It is a characterization technique that provides elemental composition of various constituent elements in a material. The abscissa of the EDX spectrum indicates the ionization energy and ordinate indicates the counts. Higher the counts of a particular element, higher will be its presence at that point or area of interest.

5. RESULT AND DISCUSSION

This work presents the result for selected hybrid MMC's in accordance with the design and methodology. The work is carried out for different weight percentage of TiO_2 and fixing 3% of graphite. The data of tensile test and hardness test result has been analysed in addition to this microstructure, density and porosity data is analysed.

5.1 DENSITY AND POROSITY RESULTS

The theoretical and actual density values are increasing while adding reinforcement into the matrix which is given in the table 5.1.

Table 5.1: Density of composite materials

Sl no	Hybrid composite	Theoretical Density g/cm³	Experimental density g/cm³	Porosity %
1	Al 6061	2.7	2.675	0.925
2	Al 6061 + 4%TiO_2 + 3%Gr	2.7471	2.664	3.02
3	Al 6061 + 8%TiO_2 + 3%Gr	2.8083	2.667	5.03
4	Al 6061 + 12%TiO_2 + 3%Gr	2.8695	2.685	6.42

It can be observed from the table 5.1 that the densities of composites are higher than that of their base matrix. Further, the density increases with the percentage of reinforcement content increased in the composites. The increase in the amount of reinforcement during stir casting, the porosity of the composites was also increased because of pore nucleation at the reinforcement particulate surfaces. This increases the generation more gas bubbles and decreases the liquid metal flow in the composites.

5.2 TENSILE TEST RESULT

Tensile test has been performed on tensometer, to examine the composite specimens to find important mechanical properties of Al 6061 hybrid metal matrix composites.

Table 5.2: Tensile test results

Samples	Compositions	UTS (N/mm^2)
1	Al6061	175.133

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 5, Issue 4, April 2020

2	Al6061+4%TiO_2+3%Gr	160.066
3	Al6061+8%TiO_2+3%Gr	138.3
4	Al6061+12%TiO_2+3%Gr	98.566

Table 5.2 shows the effect of reinforcement on the ultimate tensile strength was investigated and the results are plotted.

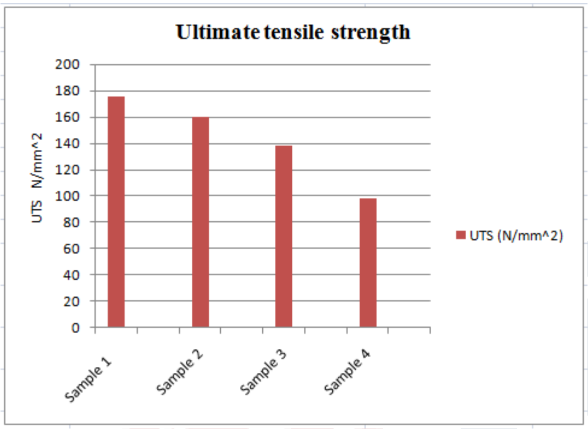


Fig 5.1: Ultimate tensile strength graph

From the figure 5.1 it is clear that the trend of ultimate tensile strength decreases with increase of reinforced TiO_2 and Gr weight percent in Al-matrix. The ultimate strength decreases due to the bonding between TiO_2, Gr and Al6061 is poor.

5.3 HARDNESS TEST RESULT

Table 5.3 : Brinell hardness result

Samples	Compositions	BHN
1	Al6061	24
2	Al6061+4%TiO_2+3%Gr	22
3	Al6061+8%TiO_2+3%Gr	21
4	Al6061+12%TiO_2+3%Gr	16

Table 5.3 shows the effect of reinforcement on the Brinell hardness number. The hardness of unreinforced alloy is higher but when increases in the reinforcement, the Brinell hardness number decreases Hence, the hardness of the hybrid MMC's decreases with increase in reinforcement.

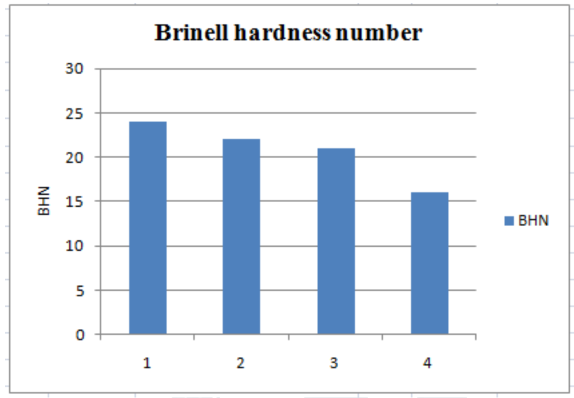
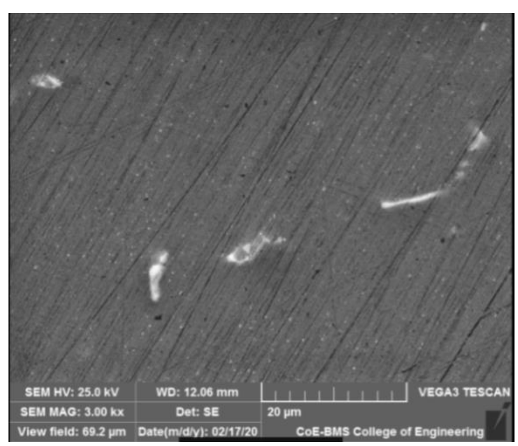


Fig 5.2 : **Hardness result**

Figure 5.2 shows the decrement in the Brinell hardness number by increasing the reinforcement into the matrix. This is due to improper mixing of TiO_2, Gr and Al6061.

5.4 SEM RESULTS

From the SEM images, it is noticed that the distributions of reinforcement in the matrix alloy. The SEM also shows the increased filler contents in the composites. It is also evident from the image that minor degree of porosity is discovered. It is reported that higher hardness is always associated with lower porosity of metal matrix composites. Further, it is revealed that there is a improper bonding between the matrix and the reinforcement material.



ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 5, Issue 4, April 2020

Fig 5.3: Al6061

The Figure 5.3 shows the distribution of Al 6061 without adding any reinforcement into the sample.

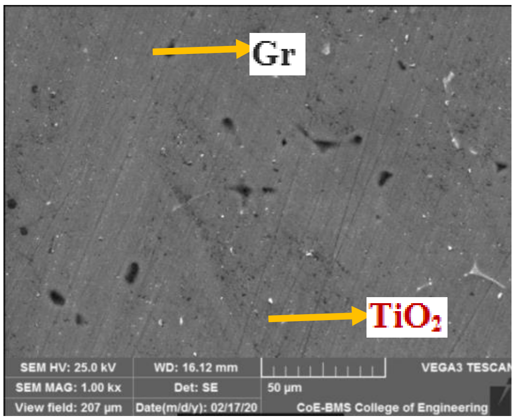


Fig 5.4: Al6061+4%TiO_2+Gr

The Figure 5.4 shows that the clear distribution of Aluminum 6061 with 4% weight composition of reinforced TiO_2 and 3% graphite.

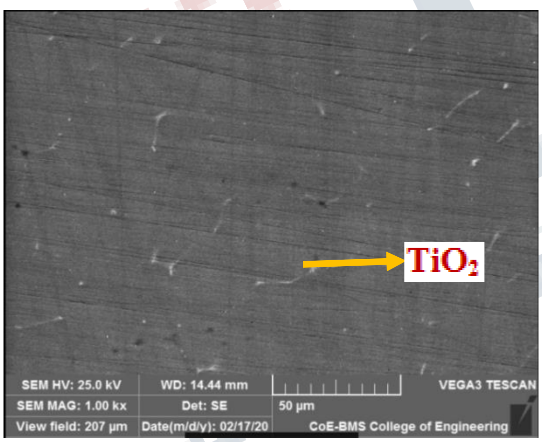


Fig 5.5: Al6061+8%TiO_2+Gr

The Figure 5.5 shows that the clear distribution of Aluminum 6061 with 8% weight composition of reinforced TiO_2 and but the distribution of graphite particles is not present.

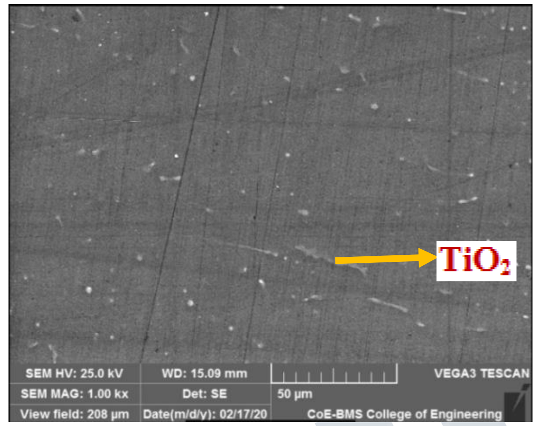


Fig 5.6: Al6061+12%TiO_2+Gr

The Figure 5.6 shows that the distribution of Aluminum 6061 with 12% weight composition of reinforced TiO_2 and but the distribution of graphite particles is not present.

5.4 ENERGY DISPERSIVE SPECTROSCOPY RESULTS

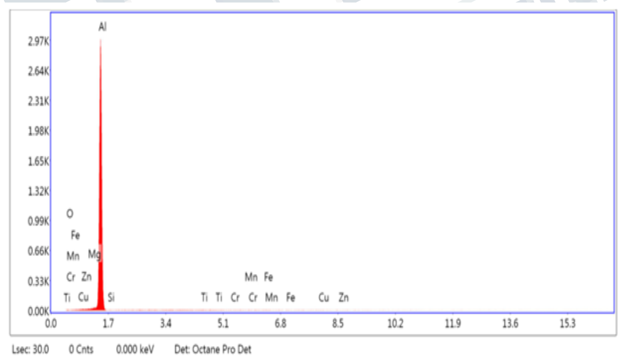


Fig 5.7: EDAX result of Al6061/TiO_2+Gr

Energy dispersive spectroscopy analysis of the hybrid metal matrix composite is shown in Figure 5.7. It is clear that oxygen peak is observed in the EDS analysis. The EDS analysis confirms that TiO_2 particles are present within the composites. But carbon peak is not observed in EDS analysis. This confirms that Graphite particles is not present in the composites. Therefore, these SEM structures are evidence of partial incorporation of hybrid metal matrix composites.

6 CONCLUSION

As per the work conducted in the present study the mechanical and morphological structure of Al 6061 with different percentage of TiO_2 processed by stir casting technique, following conclusions were made. Unreinforced Al6061 exhibits good hardness behavior as compared to hybrid composite materials. Al 6061 reinforced with TiO_2 and Gr are fabricated, the TiO_2 uniform distribution with Al 6061 has confirmed by SEM images but the distribution of graphite is not present in the composites.

The ultimate tensile strength and hardness of the hybrid metal matrix composites is decreased by adding the reinforcement to the Al 6061 and hence the material properties are reduced.

REFERENCES

[1] Ajith kumar.R , Chandan singh M: "Enhancement of mechanical properties of aluminium 6061 metal matrix composite" , International Journal of Pure and Applied Mathematics Volume 119 No. 15 2018, 2063-2078.

[2] G.Sivakaruna and Dr. P.Suresh Babu, "A survey on effects of reinforcement on Aluminium metal matrix composites", International Journal of Mechanical Engineering and Technology (IJMET), volume no.8, pp.112–131, 2017.

[3] Gowrishankar T P, Manjunath L, Jegadeeswaran N "The Properties of an Aluminum Metal Matrix Composite - A review", International Journal of Advances in Scientific Research and Engineering (IJASRE), volume no.3, 2017.

[4] Dr. G Elango1, K Balaji2, R M Kingsley Solomon3, R Vallal Peruman: "Investigation on Mechanical Properties of Gr+Tio2reinforced Composite", IJIRT , Volume 5 Issue 11, ISSN: 2349-6002.

[5] G.S. Kataiah, Dr.D.P.Girish "The mechanical properties of aluminium 6061 - TiO2 composites" International Journal of Innovative Research and Development (Special Issue) volume no.5, 2016.

[6] Himanshu Kala, K.K.S Mer, Sandeep Kumar, "A Review on Mechanical and Tribological Behaviors of Stir Cast Aluminium Matrix Composites", Science direct, pp.1951-1960, 2014. International Journal of Pure and Applied Mathematics Special Issue 2077.

[7] Niranjan K N, Shivaraj B N, Sunil kumar M, Deepak A R, "Study of Mechanical Properties on Aluminium 6061 hybrid composite by stir casting method" International Research Journal of Engineering and Technology (IRJET), volume no.4, 2017.

[8]Manickam Ravichandran, Meiyanathan Meignanamoorthy and Sundaram Dineshkumar: " Microstructure and Properties of Hot Extruded Al-TiO2 Powder Metallurgic Composites", ISSN:1662-7482, Vol. 852, pp 130-13.

[9]Ganesh Khandoori, Dr. K.K.S Mer and Chandraveer Singh, "Sliding behaviour of Aluminium metal matrix composite reinforced with Titanium oxide" International Journal of Recent Scientific Research, volume no.6, pp.4197-4203, 2015.

[10] G.Baskaran, I.Daniel Lawrence, C.Ramesh Kannan, B.Stalin, "Characterization of Aluminium Based Metal Matrix Composite Reinforced with TiC and TiO2" International Journal of Applied Engineering Research, volume no.10, pp.51, 2015.

[11] Maninder Singh, Khushdeep Goyal, Deepak Kumar Goyal, "Fabrication and Performance of Aluminium Based Metal Matrix Composites with SiO2 and TiO2 as Reinforced Particles", Universal Journal of Mechanical Engineering, pp.142-146, 2015. International Journal of Pure and Applied Mathematics Special Issue 2076.

[12] Padmavathi.K.R,Dr.R.Ramakrishnan, "Tribological behaviour of Aluminium Hybrid Metal Matrix Composite", Elsevier publications, pp.660-667, 2014.

[13] Roussos G. Papagiannakis: "Fabrication of hybrid (Al+Tio2+Gr) metal matrix composites-An Experimental Study" , Rev. Téc. Ing. Univ. Zulia. Vol. 37, Nº 2, 33 - 36, 2014.

[14] M.Meignanamoorthy and M.Ravichandran: "Experimental Investigations on Mechanical Properties of Hot Extruded Al -TiO2 - Gr Hybrid Composites", International Journal Of Core Engineering & Management (IJCEM) Volume 1, Issue 12, March 2015 128.

[15]Ganesh Khandoori, Dr. K.K.S Mer and Chandraveer Singh, "Sliding behaviour of Aluminium metal matrix composite reinforced with Titanium oxide" International Journal of Recent Scientific Research, volume no.6, pp.4197-4203, 2015.

[16]S.Hanish anand, Praveen Kumar, Muthu Karthikeyan: " Fabrication and hardness testing in aluminium 6061-matrix titanium aluminide composite formed in situ from aluminium, titanium dioxide and sodium hexafluoroaluminate", International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE) ISSN: 0976-1353 Volume 21 Issue 3 – April 2016.

[17]M.Ravichandran, A.Naveen Sait, V. Anandakrishnan: “Hot upset forging studies on Al-2.5%TiO_2-C hybrid powder metallurgy composite”, transactions of pmai, vol. 40 (2), december 2014.

[18] T. Dileep, P. N. S. Srinivas: “ Enhancement of mechanical, microscopic and tribological properties of hybrid metal matrix composite reinforced with alumina, graphite and silicon carbide”, International Journal of Latest Engineering Research and Applications (IJLERA) ISSN: 2455-7137 Volume – 01, Issue – 04, July – 2016, PP – 41-49.