International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 6 Issue 10|| October 2017 || PP. 12-19

Fabrication and Mechanical Properties of Al7075-SiC-TiC Hybrid Metal Matrix Composites

B. Ravi[1]
[1](*Assistant Professor, Department of Mechanical Engineering, SBIT, Khammam, Telangana, INDIA)*

ABSTRACT: *The world market for metal matrix based composites (MMCS) consumed 5.9 million kilograms of produce in 2014.It is expected to increase to 10 million in 2020 for a compounded annual growth rate of 7%. Various MMCs are found in many applications such as aerospace, space, electrical and automotive industries due to their good physical, mechanical and corrosion properties. But MMCs suffer from insufficient process stability, reliability and in-adequate economic efficiency. To overcome these problems, the hybrid metal matrix composites (HMMCs) were developed. The reinforcement materials in aluminum alloy improve the mechanical properties. In this work, the mechanical behavior of Aluminum Hybrid Metal Matrix Composites (HMMCs) has been investigated. Al7075 alloy was selected as matrix alloy and Silicon Carbide (SiC) and Titanium Carbide (TiC) were used as reinforcements for fabrication of HMMCs by liquid metallurgical technique (Stir Casting Technique). The mechanical properties such as yield strength, ultimate tensile strength, Brinell hardness and Impact strength were conducted for HMMCs specimen as per ASTM standard. The mechanical properties are increased for the combination of reinforcement TiC and SiC and impact strength was decreased.*

Keywords: *Composite, Hybrid, Mechanical, MMCs, SiC, TiC*

Date of Submission: 14-10-2017 Date of acceptance: 31-10-2017

I. INTRODUCTION

Since aluminium has lesser density than steel, good corrosion resistance, good mechanical and recycling properties, aluminium and its alloys have been widely used in various sectors such as automotive and aerospace. Aluminium metal matrix composites reinforced with ceramic particles are gaining wide popularity as high performance material because of their improved strength, high elastic modulus and increased wear resistance, their ability to exhibit superior strength-to-weight and strength- to-cost ratio over conventional base alloy [1,2]. Aluminum alloy based Metal matrix composite (MMC) is engineered combination of the metal (Matrix) and hard particle/ceramic (Reinforcement) to get tailored properties. MMC's are either in use or prototyping for the space shuttle, commercial airliners, electronic substrates, bicycles, automobiles, golf clubs, and a variety of other applications.

Like all composites, aluminum-matrix composites are not a single material but a family of materials whose stiffness, strength, density, thermal and electrical properties can be tailored. The matrix alloy, reinforcement material, volume and shape of the reinforcement, location of the reinforcement and fabrication method can all be varied to achieve required properties. The aim involved in designing metal matrix composite materials is to combine the desirable attributes of metals and ceramics. The addition of high strength, high modulus refractory particles to a ductile metal matrix produce a material whose mechanical properties are intermediate between the matrix alloy and the ceramic reinforcement. Metals have a useful combination of properties such as high strength, ductility and high temperature resistance, but sometimes have low stiffness, whereas ceramics are stiff and strong, though brittle [3]. By carefully controlling the relative amount and distribution of the ingredients of a composite as well as the processing conditions, these properties can be further improved. The correlation between tensile strength and indentation behavior in particle reinforced MMCs manufactured by powder metallurgy technique [4]. The microstructure of SiC reinforced aluminium alloys produced by molten metal method. It was shown that stability of SiC in the variety of manufacturing processes available for melt was found to be dependent on the matrix alloy involved [5]. Among discontinuous metal matrix composites, stir casting is generally accepted as a particularly promising route, currently practiced commercially. Its advantages lie in its simplicity, flexibility and applicability to large quantity production. It is also attractive because, in principle, it allows a conventional metal processing route to be used, and hence minimizes the final cost of the product. This liquid metallurgy technique is the most economical of all the available routes for metal matrix composite production [6], and allows very large sized components to be fabricated. The cost of preparing composites material using a casting method is about one-third to half that of competitive methods, and for high volume production, it is projected that the cost will fall to one-tenth [7].

The mechanical properties of Al 6061-TiB_2 in-situ composites fabricated by liquid metallurgy route using Al 6061 as the matrix material and Al-10% Ti and Al-3% B as reinforcements. The developed in-situ composites exhibited considerable improvement in the mechanical properties as compared to the base metal [8]. The mechanical properties of aluminum metal matrix are improved by adding reinforcement of SiC [9]. The microstructural behavior of aluminum with SiC (grit size 60) by varying mass fractions of 5%, 10%, 15%, and 20%. They observed that there is a uniform distribution of silicon carbide in aluminum metal matrix [10]. Al6061 reinforced with TiB_2 particles by stir casting method. Experiments were conducted by varying weight fraction of TiB_2 (0%, 4%, 8% and 12%), while keeping all other parameters constant. This study revealed that the addition of TiB2 improves the wear resistance of aluminium composites. The results showed that increase in the mechanical properties, such as wear resistance and hardness were caused by the percentage of TiB_2 present in the samples [11]. The hardness of metal matrix composite increases with increase in reinforcement content and the wear rate of the Al6061-SiC composite decreased with increasing SiC content [12]. Reinforcement of SiC and TiB_2 with aluminium matrix forms a hybrid metal matrix composite. The addition of TiB_2 to metal matrix composites has been observed to exponentially enhance stifness, hardness and wear resistance [13].

The aim of the present investigation is to evaluate the mechanical properties of Al7075 alloy, discontinuously reinforced with two different types of particles such as SiC and TiC. The stir casting method is chosen for the manufacturing of hybrid metal matrix composites. The mechanical properties are increased for the combination of reinforcement TiC and SiC and impact strength was decreased.

II. EXPERIMENTAL DETAIL

2.1. Experimental Details

The proposed AL7075-5%SiC+5%TiCMMC was produced by modified stir casting process. AA7075 alloy was used as a matrix SiC and TiC with a size of 1µ was used as reinforcement during stir casting process. The chemical composition and the mechanical the mechanical properties of AA7075 are given Tables 1 and Table 2 respectively.

Table 1. Chemical composition of Aluminium alloy (AA7075)

S. No.	Sample Identification	Cu %	Mg%	Si%	Mn%	Fe%	Zn%	Cr%	Sn%	Al%
01	Al 7075 Sample	1.52	2.20	0.227	0.009	0.157	5.94	0.19	0.005	Bal

Table 2. Ultimate Tensile Strength and Yield Strength of AA7075

S. No.	Property	Units	Value
01	Ultimate Tensile Strength	N/mm^2	116
02	Yield Stress	N/mm^2	94

A batch of 550 grams of aluminum alloy was melted in clay graphite crucible. It was then melted in a resistance Induction furnace to the desired temperature of 660^0C. In the meantime SiC and TiC particulates of size 1µ wereheated in another crucible to a temperature of 150^0C to remove moisture and the die was preheated to a temperature of 400^0C. The mixtures of preheated SiC and TiC particles were added at a constant feed rate into the vortex. The mixture was stirred continuously by using manual hand stirring for about 10-15 minutes at speed of 250 rpm. The melt temperature was maintained at 800^0C during addition of the particles. The molten metal was then poured into the preheated die to cast plates of 300mmx300mmx16mm size. The AMMCs having different weight percentages (5 and 10) of SiC and TiC were fabricated by same procedure. The manufactured MMCs are shown in Figures.

Fig. 1 Stir Casting Set-up used for fabrication of Composite Plates (AA 7075-5%SiC+5%TiC)

Fig. 2 SiC powder and TiC powders added to molten AA7075

Fig. 3 HMMC of AA7075 with 5% SiC and 5% TiC

Table 3. Process Parameters

S. No	Specifications	Units	Value
01.	Capacity of Furnace	Kg	100
02.	Frequency Range	Hz	1000
03.	Input Voltage	Kw	250
04.	Diameter of Crucible	Mm	230
05.	Length of Crucible	Mm	270
06.	Pre Heating Temp of Die	°C	150
07.	Volume of die	mm^3	300x300x16
08.	Pre Heating Temp of Powder	°C	50

2.2. Hardness Test

To evaluate the hardness of the composites, the Brinell hardness was conducted. The micro hardness of polished samples was measured at different locations using the Brinell hardness at a load of 1000 gram for 10 sec.

Table 4. Hardness and Impact Test

S. No.	Test	Units	Value
01.	Hardness	BHN	229
02.	Izod	Joules	40
03.	Charpy	Joules	22

2.3. Evaluation of Mechanical Properties of HMMCs

2.3.1. Tensile Test

The tensile tests were used to assess the mechanical behavior of cast the composites and the matrix alloy. The tensile specimens were prepared from the cast MMCs as per ASTM E08 standard. The dimensions of the specimens are shown in Figure 4. The Ultimate Tensile Strength (UTS) was estimated using a computerized universal testing machine (TUE-C-1000). Three specimens prepared from each HMMC and base alloy as shown in Figure 4 were tested and the average value of tensile strength was estimated.

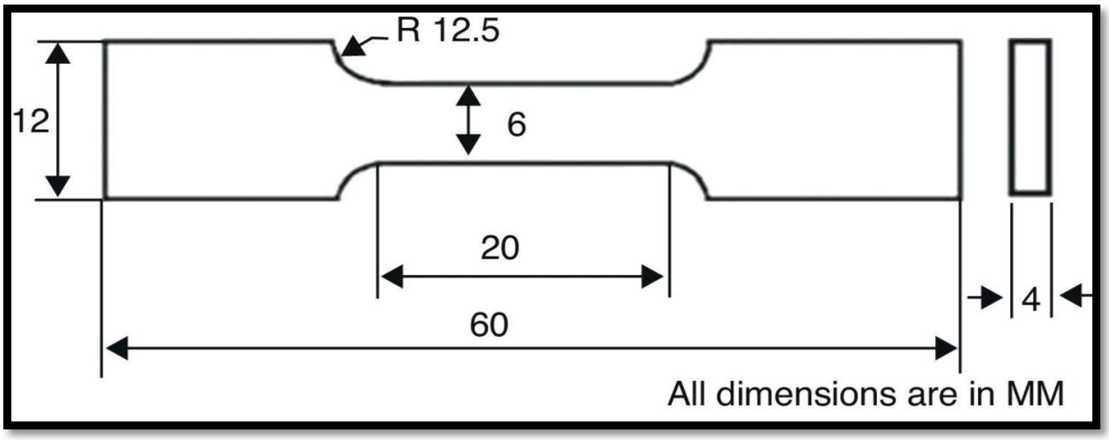

Fig. 4 Dimensions of Tensile Specimen of AA7075-SiC and TiC

Fig. 5 Tensile Specimens of AA7075-SiC and TiC composites before fracture

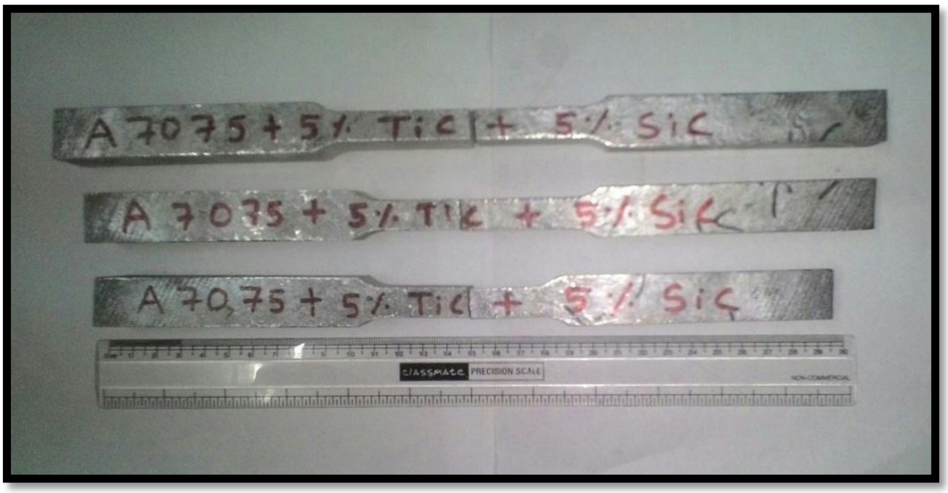

Fig. 6 Tensile Specimens of AA7075-SiC and TiC composites after fracture

The amount of energy absorbed by the specimen when subjected to sudden dynamic load was measured using an impact test. The specimen was prepared as per IS: 1757 standards as shown in Figure 7 In this work, the Charpy and Izod impact test was used.

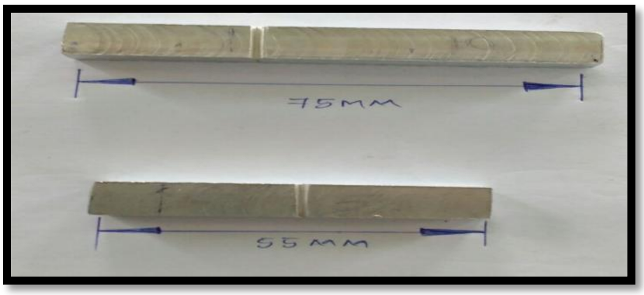

Fig. 7 Impact test Specimens of AA7075-SiC and TiC composites before fracture

III. RESULTS AND DISCUSSION

3.1. Characterization of AA 7075- 5%SiC+5%TiC HMMC

Aluminum reinforced with SiC and TiC particulate composites are successfully fabricated by a modified stir casting process. The addition of flux has improved the wettability of SiC particles with molten aluminum and fabricated the incorporation of SiC particle in the Al matrix. The flux reacts with the melted surface of SiCparticle and produces Ti layers around the surface of SiC particles. This reaction is exothermic in nature and heat is evolved in the vicinity of SiC particle-melt interface which enhances the incorporation of particles into the melt [14].

3.1.1. Evaluation of Mechanical Properties

The estimated mechanical properties of AMMCs are presented in Table 4.1.

Table 3.5. Mechanical Properties of Produced AA7075 with SiC and TiC

Test Samples	UTS (N/mm^2)	Hardness (BHN)	Yield Stress (N/mm^2)	Impact Strength (Joules)
AA7075	320	95	310	2.31
AA7075+SiC	330	140	319	2.62
AA7075+TiC	345	195	328	3.34
AA7075+SiC+TiC	368	229	351	4.2

3.1.1.1. Hardness Test

The mechanical properties of matrix alloy AA7075 is improved upon SiC and TiC incorporation. From table 4.1, it is observed that the microhardness of MMCs is increased when the amount of reinforcement particulates increases. Addition of reinforcement particles in the matrix increases the surface area of the reinforcement. The presence of such hard surface area of particles offers more resistance to plastic deformation which leads to increase in the hardness of composites. It is reported [15] that the presence of hard ceramic phase in the soft ductile matrix reduces the ductility of composites due to reduction of ductile metal content which significantly increases the hardness value.

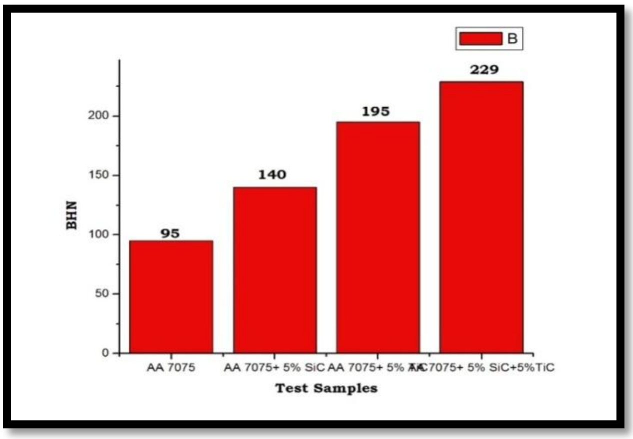

Fig. 8 Graphical representation of Hardness

3.1.1.2. Tensile Test

Table 4.1 shows the value of ultimate tensile strength, yield strength and percentage of elongation of MMCs. It can be inferred that SiC and TiC particles are very effective in improving the tensile strength of composites from 150 MPa to 155 MPa. It may be due to the strengthening mechanism of the reinforcement [16]. The addition of SiC and TiC particles in the matrix induces much strength to matrix alloy by offering more resistance to tensile stresses. The thermal mismatch between the matrix and the reinforcement causes higher dislocation density in the matrix and load bearing capacity of the hard particles which subsequently increase the composite strength [17].

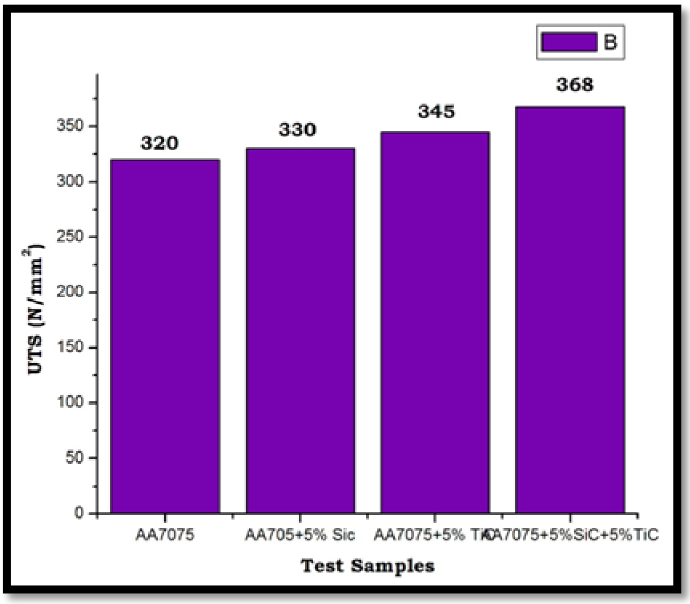

Fig. 9 Graphical representation of Ultimate Tensile Strength

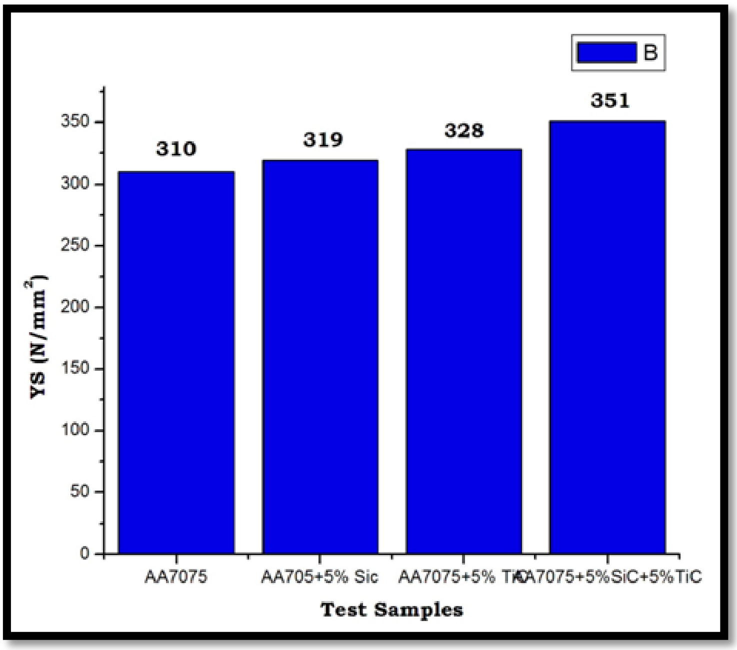

Fig. 10 Graphical representation of Yield stress

3.1.1.3. Impact strength of the composites

The impact strength of the AA7075 SiC and TiC composites are shown in figure 4.4. It is observed that the toughness is decreased by increasing the weight percentage of the SiC and TiC particles in the composite. This is due to the addition of SiC and TiC in various percentages with aluminum, the brittleness of the material also increased. Because of high brittleness, the impact strength of the material is decreased.

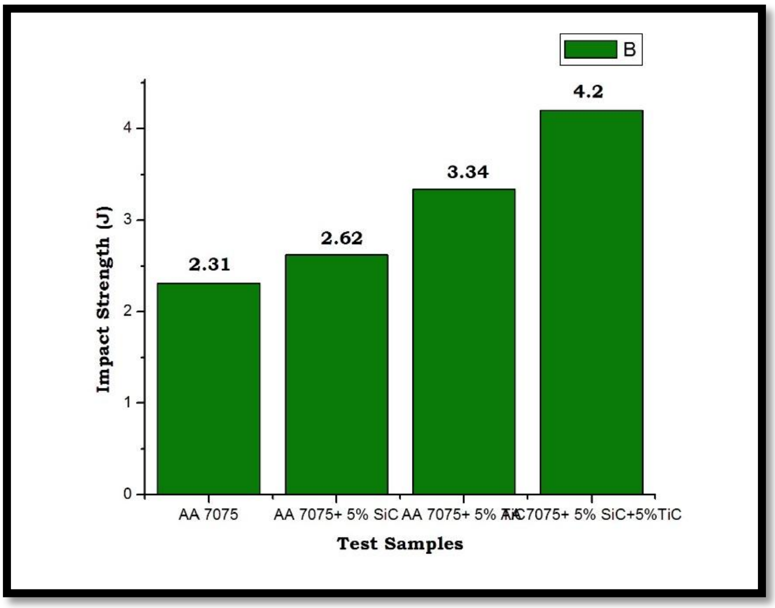

Fig. 11 Graphical representation of Impact strength

IV. CONCLUSIONS

From the results and analysis of the investigation the following conclusions were drawn on the mechanical behavior of as-cast MMCs (AA7075+SiC+TiC).

1. From the liquid metallurgy techniques Al7075 base alloy, Al7075+SiC+TiCMMCs composites were prepared successfully.
2. The hardness of as cast Al7075-5%TiC+5%SiC MMCs is increased by and 39 % when compared with AL7075 base alloy.
3. The ultimate tensile strength of as-cast Al7075 base alloy, Al7075- 5%TiC+5%SiC MMCs was 129and 155 MPa respectively. This shows an improvement of 32% when compared with as-cast Al7075 base alloy.
4. The yield strength of as-cast Al7075 base alloy, Al7075-5%TiC+5%SiC MMHCs were 104 and 116 MPa respectively this shows an improvement of 10.5% when compared with base alloy.
5. As the reinforcement content increases the tensile strength, yield strength and compressive strength increases up to 5%TiC reinforcement and decreases at 5 wt% SiC reinforcement in as cast and heat treated MMCs and MMHCs.
6. From the investigation it was concluded that, composites containing 5wt% Titanium carbide and 5 wt% Silicon Carbide reinforcements exhibited superior mechanical properties.

REFERENCES

[1] Lakshmi S, Lu L, Gupta M. In situ preparation of TiB2 reinforced Al based composites. *J Mater Process Tech. 73(1-3)*, 1998, 160–6.
[2] Natarajan S, Naraynasamy R, Kumaresh Babu SP, Dinesh G, Anil kumar B, Sivaprasad K. Sliding wear behavior of Al 6063/TiB2 in situ composites at elevated temperatures. *Materials and Design. 30(7)*, 2009, 2521–31.
[3] S. Skolianos. *Mater. Sci. Eng. A210*, 1990, 72–82.
[4] Shen, Y.L., Williams, J.J., Piotrowski, G., Chawla, N. and Guo, Y.L. "Correlation between tensile and indentation behavior of particle reinforced metal matrix composites: a numerical and experimental study," *Acta Materialia, 49(16)*, 2001, 3219-3229.
[5] Llyod, D.J., Lagace, H., Mcleod, A. and Morris, P.L. "Microstructural aspects of aluminium silicon carbide particulate composites produced by a casting method", *Materials Science and Engineering, 107*, 1989, 73-80.
[6] M.K. Surappa. *J. Mater. Proc. Tech. 63*, 1997, 325–333.
[7] D.M. Skibo, D.M. Schuster, L. Jolla, Process for preparation of composite materials containing nonmetallic particles in a metallic matrix, and composite materials made by, *US Patent No. 4 786 467*, 1988.
[8] Ramesh CS, Pramod S, Keshavamurthy R. A study on microstructure and mechanical properties of Al 6061-TiB2 in-situ composites. *Materials Science and Engineering A. 528*, 2011, 4125–32.
[9] Jayashree PK, Gowri Shankar MC, Kini A, Sharma SS, Shetty R. "Review on Effect of Silicon Carbide (SiC) on Stir Cast Aluminium Metal Matrix Composites". *Inter-national Journal of Current engineering and Technology. 3(3)*, 2013, 1061–71.
[10] Neelima Devi C, Selvaraj N, Mahesh V. Micro structural aspects of Aluminium Silicon Carbide Metal Matrix Composite. *International Journal of Applied Sciences and Engineering Research. 2*, 2012, 250–4.
[11] Suresh S, ShenbagaVinayag Moorthi N. Process development in stir casting and investigation on microstructures and wear behavior of TiB2 on Al6061 MMC. *International Conference on Design and Manufacturing (IConDM2013). 64*, 2013, 1183–90.
[12] Prashant SN, Nagaral M, Auradi V. Preparation and evaluation of mechanical and wear properties of Al 6061reinforced with graphite and sic particulate metal matrix composites. *International Journal of Mechanical Engineering and Robotics Research. 3*, 2012, 106–12.

[13] Munro RG. Material Properties of Titanium Diboride. *Journal of Research of National Institute of Standards and Technology. 105(5),* 2000, 709–20.
[14] Kennedy, A.R and Brampton, B. "The reactive wetting and incorporation of B4C particles into molted aluminum", *Scr. Mater. 44(7),* 2001, 1077-1082.
[15] Ramesh, C.S., Keshavamurthy, R., Chennabasappa, B.H., and Abrar Ahmad. "Microstructure and mechanical properties of Ni-P coated Si3N4 reinforced Al6061 composites", *Mater. Sci. Eng., A 502(2),* 2009, 99-106.
[16] Feng, A.H., Xiao, B.L. and Ma, Z.Y. "Effect of microstructure evolution on mechanical properties of friction stir welded AA2009S/SiCp composite", *Compos. Sci. Technol., 68(9),* 2008, 2141-2148.
[17] Toptan, F., Karaaslan, A., Cigdem, A.M. and Kerti, I. "Processing and microstructural characterization of AA 1070 and AA 6063 matrix B4Cp reinforced composites", *Mater. Des., 31(1),* 2010, S87-S91

International Journal of Engineering Science Invention (IJESI) is UGC approved Journal with Sl. No. 3822, Journal no. 43302.

B. Ravi. "Fabrication and Mechanical Properties of Al7075-SiC-TiC Hybrid Metal Matrix Composites." International Journal of Engineering Science Invention(IJESI), vol. 6, no. 10, 2017, pp. 12–19.