International Journal of Production Technology and Management (IJPTM)
Volume 10, Issue 2, July-December, 2019, pp. 16–25, Article ID: IJPTM_10_02_003
Available online at
http://www.iaeme.com/ijptm/issues.asp?JType=IJPTM&VType=10&IType=2
Journal Impact Factor (2019): 7.2150 (Calculated by GISI) www.jifactor.com
ISSN Print: 0976- 6383 and ISSN Online: 0976 – 6391

A STUDY ON WEAR AND MICROSTRUCTURE PROPERTIES OF AA7075 REINFORCED WITH SIC MMC BY STIR CASTING TECHNIQUE

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ABSTRACT

Metal matrix composites of aluminum alloy reinforced with nano silicon carbide reinforcement are useful in highly stressed parts of an aircraft, automobile and many industrial sectors because of their higher strength, good resistance to fatigue and corrosion. AA7075 reinforced with many particulates in developing various MMC's have been revealed significant wear resistance of MMC's research work. In this work, AA7075 metal matrix is chosen and it is reinforced with 500nm(0.5micron) silicon carbide powder as a reinforcement. The MMC's samples have been prepared by low cost stir cast method. The silicon carbide was increased incrementally from 2% to 8% wt. fractions. Wear behavior of these specimens were observed using Pin and Disc experimental setup and the results shows improved wear resistance as the percentage of the reinforcement material increased. This work also contains EDX analysis of tested samples and from the EDX analysis it is ensured that along with major compositions of metal matrix are combined with the reinforced material.

Key words: 500nmSiC, AA7075, MMC's, and wear resistance, impact load and EDX analysis.

Cite this Article: Anil Kumar S Kallimani, N Chikkanna, Suresha P and Thirthaprasad P, A Study on Wear and Microstructure Properties of AA7075 Reinforced with SiC MMC by Stir Casting Technique, *International Journal of Production Technology and Management (IJPTM)*, 10(2), 2019, pp. 16–25.
http://www.iaeme.com/ijptm/issues.asp?JType=IJPTM&VType=10&IType=2

1. INTRODUCTION

Research work shows that MMCs offer many advantages with respect to the unreinforced alloys, they do have certain limitations, because of the micron length scale of the reinforcement, like low ductility and low toughness in comparison with unreinforced matrix [1], excessive wear damage of the counter-material in tribological application [2] and extremely high tool wear during machining [3, 4].

To solve the issues which are existing in MMC's and to have materials with improved tensile strength, hardness, with good ductility and fracture toughness properties both at room and high temperatures, the length scale of reinforcing has been decreased to enhance better properties and the research work id tending towards reducing the reinforcement sizes to nanometric levels (less than100 nm) to develop metal matrix nano composites (MMNCs).

1.1. Particle Reinforced Aluminium Matrix Composites (PAMCs)

These AMC's generally contain ceramic particles with equiaxed configuration. the aspect ratio is less than 5. Ceramic particles are generally oxides, carbides and borides (Al2O3 or SiC or TiB2) and used as a volume fraction up to 30% and are used as a weight fraction up to 15% that are used for structural and wear resistance purposes. In general, these are developed by solid state (Powder Metallurgy processing) or liquid state (stir casting, infiltration) processes. Particle reinforced Aluminium matrix composites are less expensive compared to continuous fibre reinforced Aluminium matrix composites. Mechanical properties of PAMCs are inferior compared to whisker/short fibre/continuous fibre reinforced AMCs but far superior compared to unreinforced aluminium alloys. These composites are isotropic in nature and can be subjected to a variety of secondary forming operations including extrusion, rolling and forging. Present work describes preparation specimens of AA7075 reinforced with (500nm) silicon carbide particles by stir casting method. various fabrication processes are being used for aluminum matrix composites like squeeze casting, vacuum casting, stir casting, in situ casting, powder metallurgy and compo casting [2].but, stir casting method founds to be a simple, convenient and economical [3]. MMC materials commonly exhibits a lesser wear rate than the metal alloys. This is mainly due to the enhanced strength of the composites due to reinforcement of the particles into the matrices. The particles exhibit load-bearing properties in the composite materials and this makes improved wear resistance of the composites as compared with the unreinforced alloys. Stir casting is commonly used liquid-based technique employed for MMNCs production, due to its simplicity and cost effectiveness. The reinforcing phase is usually added to the matrix and distributed in the molten state by applying mechanical stirring through an impeller. Due to the low wettability of nanoparticles within the molten metal, their tendency to agglomerate, and the differences in density between particles and matrix, it is usually difficult to obtain a homogeneous distribution of the nano-reinforcement. This results in clustering of nanoparticles. Moreover, due to the air entrapment induced by the rotating stirrer, a high porosity content can characterize the composite and, furthermore, undesired chemical reactions at the matrix/reinforcement interface may occur. Stir casting. Stir casting is one of the most widespread liquid-based technique employed for MMNCs production, due to its simplicity and cost effectiveness; moreover, it is suited to be applied to large volumes of metal [4–6].

The reinforcing phase is usually added to the matrix and distributed in the molten state by applying mechanical stirring through an impeller. MgO, Al2O3, ZrO 2 and SiC nanoparticles as well as CNTs are used for aluminum and magnesium matrices by stir casting method [1, 2, 7–10]. The molten alloy together with the dispersed particles may be used for sand casting or permanent mold casting. Due to the low wettability of nanoparticles within the molten alloy, their tendency to agglomerate, and the differences in density between particles and matrix, it is usually difficult to obtain a homogeneous distribution of the nano-reinforcement. This results in clustering of nanoparticles [1, 2, 4, 11–13]. Moreover, due to the air entrapment induced by the rotating stirrer, a high porosity content can characterize the composite and, furthermore, undesired chemical reactions at the matrix/reinforcement interface may occur

2. MATERIALS AND METHODS

2.1. Materials

AA7075 (AlZn5.5MgCu) alloy, with zinc, Magnesium and copper are the major alloying elements. It is strong, and provides high UTS comparable to many steels and it has higher fatigue strength and better machinability, but it has less corrosion resistance compared to other aluminum alloys. Its relatively high cost compared other alloys which restricts its use to applications. But with T173 and T7351 condition it shows high stress corrosion resistance and becomes AA7075 a better choice over 2024, 2014 and 2017 in the many critical usages. The properties of AA7075 alloy is improved by reinforcing with micro, submicron and nano sized ceramic particles. In the present examination, Tempered Aluminum AA7075 with Untempered condition was selected as a base matrix material with submicron sized silicon carbide as filler added to an extent of 2%, 4%, 6%, and 8 wt.%. Properties of AA7075 and (SiC) are displayed in Table 1. The Blocks of Al 7075-T6 were provided by Sara Metal & Alloys, peenya, Bengaluru, India and the submicron silicon carbide powder with size 500 nm was provided by Reinste Nano Ventures Pvt.Ltd. New Delhi. Chemical composition of Al 7075 alloy is shown in Table 2. Figure 1. Shows the raw material procured for sample preparation.

Figure 1 AA7075 Ingots and 500nm Silicon Carbide Powder

Table 1 Properties of initial materials (as said by suppliers).

Material	Melting Point (°C)	Thermal Conductivity W/mk	Density g/cm^2	Modulus of Elasticity (GPa)	Co-eff. of thermal expansion (/°C)
AA7075-O	635	173	2.81	71.7	25.2X10^{-6}
SiC	1650	120	3.10	410	4.0X10^{-6}

2.2. Sample Preparation

The commercial Al-zn alloy blocks were heated at metling temperature with optimum care and standard procedure was followed to obtain the cast composites prepared by using the stir casting . The particles were preheated before being introduced into the vortex and stirring of the molten composite were accomplished for 10 minutes at 400 rpm stirrer speed. Pouring temperatures adopted were 477^0C. The moulds of 22mm dia. X 210mm length cast composites of Al7075-SiC were obtained. Testing specimens were machined according to the American Society of Testing Methods (ASTM) Standards. Machined specimens of MMC's were undergone for wear test, Impact test. The samples of these MMC's were also checked for microstructure observations.

Table 2 Chemical compositions of AA7075 aluminium alloy in Wt%. (as said by supplier).

AA7075	**Al**	**Cr**	**Cu**	**Fe**	**Mg**	**Mn**	**Si**	**Ti**	**Zn**
	87.1-91.4	0.18-0.28	1.2	Max 0.5	2.1-2.9	Max 0.3	Max 0.4	Max 0.2	5.1-6.1

3. EXPERIMENTAL PROCEDURE

For the preparation of cast samples and their testing, following machines and equipment's are used.1. Weighing Machine 2. Crucible (Graphite) 3. Furnace 4. Mould (Mild Steel) 5.Stirrer 6.Ultrasonic Probe (For ultrasonic stir casting) 7.Cutting Grinder 8.Pin and disc wear testing machine

3.1. Stir Casting Process

Stir casting setup, crucible furnace, graphite mold used and casted products are shown in below figure 2.

Figure 2 a. Stir Casting Set Up b. Casting moulds c. cast samples

Stir casting setup consists of the induction furnace, stirrer. The stirrer is made up of the mild steel that is connected to the radial drilling machine. Speed can be varied from 80rpm-800rpm by using steel shaft. The stirrer has of nine blades and crucible is a mild steel coated with graphite and it has capacity of 5kg which is placed in the furnace. 3kg of Al alloy in ingots were melted in the induction furnace at 700^oC to attain liquid form and sage was taken out by the adding the flux powder and gas was cleared out by introducing the tablet after the Al-7075 in completely in the molten state. The reinforcement is pre-heated on the surface of the furnace to remove of the O_2 moisture to achieve the good wettability of the reinforcements the stir setup was Readily available for next process. The stirrer will be depending 1 1/4 of its body stirring will be started up to 500 rpm and the vortex will create in sides the crucible. The mixture of reinforcement like SiC by 2%, 4%, 6% & 8% were added with spoon at the rate of 10-20gr/min in to the metal. The speed is controlled with the speed meter and temperature is closely monitor at the stage of reinforcement adding in the composites after complete addition of the reinforcement removed the stir and the glass well be removed by molten metal and melt poured in to the pre-heated mould allows it in to solidified in the atmospheric air this will be rappelled for 2%,4%, 6% &8% SiC. Cast samples were machined as per the drawing shown in the figure3.

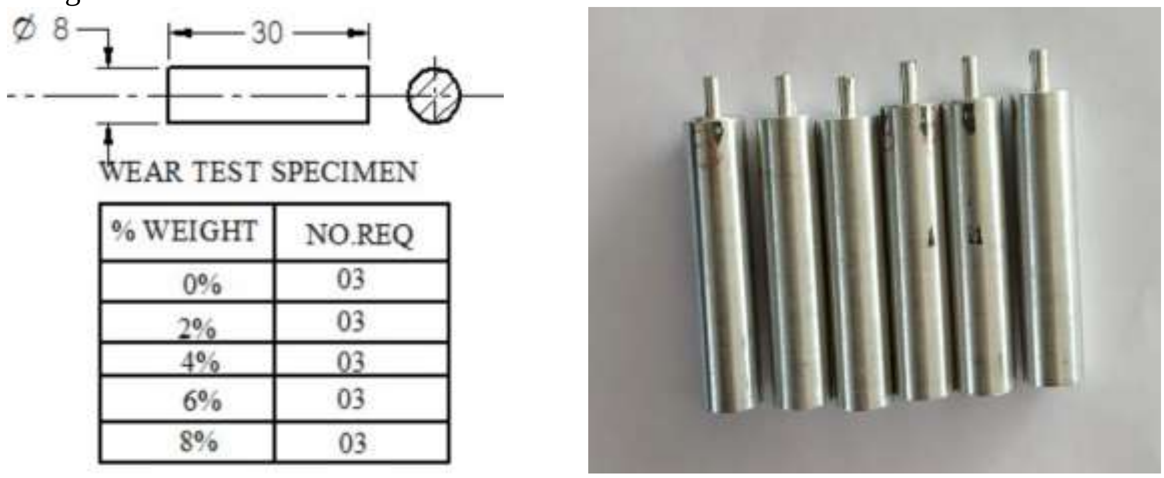

Figure 3 Specimen size & fabricated Specimens

3.2. Wear and Friction Testing

In a pin-on-disc wear test set up, a pin is installed vertically such that it's bottom surface comes in contact with the flat rotating disc. when the disc starts revolutions, a circular wear path is defined by the machine. here rotating disc or a pin can act as specimen, either of the two can act as a counter face. Iterations were condcuted by varying the load and velocity of pin sliding on the disc. The varying load of about 1kg and 1.5kg with respect to variation of speed about 350 rpm, 500 rpm and 650 rpm by maintaining the time interval as constant 30 minutes respectively. The weight loss due to wear on the sample surface are determined in microns. The test was conducted at SJMIT Research Centre Chitra Durga, Karnataka. The pin and disc wear test set up is shown in the figure 4.

Figure 4 Wear Testing Machine

4. RESULTS AND DISCUSSIONS

4.1. Morphological and Compositional Analysis

The microstructure images of the SiC particles are shown in Fig. 5 b–f. As can be seen from the Fig. 1a, shows the surface of the pure cast AA7075. Whereas, the SiC particles have seen in Fig5b.& f which show 2%wt sic particles at a lower magnification. plates like morphology is seen in the Figures. 5d & 5e. Figure 5f. shows the SEM image of AA7075 with 8%SiC, Due to the low wettability and high surface energy the particles formed cluster and agglomeration. EDS spectra are shown in Figs. 6, 7 and 8, respectively. The recorded EDS spectra confirm the presence of reinforcing materials as the related peaks were clearly observed in the EDS spectra.

EDAX is useful for the finding out of the morphology of a reinforced particles and the presence, distribution of elements within the matrix. EDAX analysis shows that there is a presence of major amounts of the elements Al and Mg, Cu, Fe,Cr, Mn along with SiC. EDAX is shown in figure 6. for AA7075 + 8% SiC.

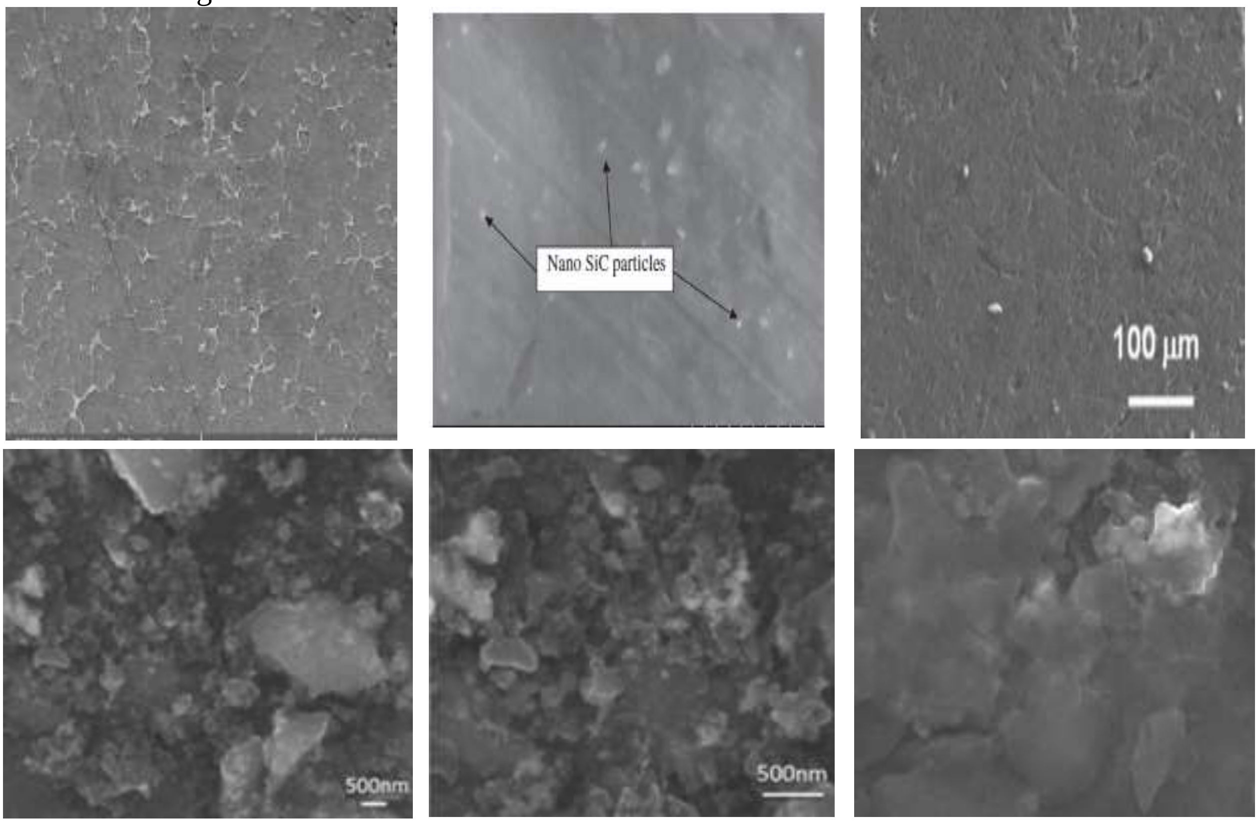

Figure 5 SEM Images of (a) AA7075 and (b)-(f) 2%,4%,6%,8%wt SiC reinforced Samples

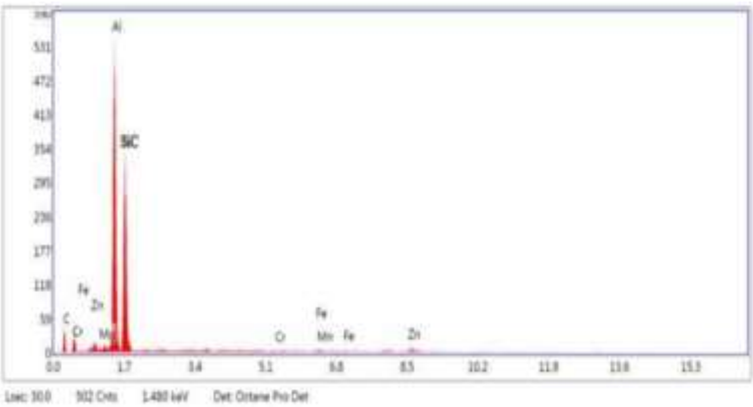

Figure 6 EDX Analysis of AA7075+8%SiC

4.2. Wear Test

Wear experiments were conducted using a pin-on-disc machine. Pins with 8mm in diameter machined from cast Al+SiC were slide against hardened and ground EN 31 steel discs. The disc with 165.0mm diameter and 8.0mm thickness, at room and elevated temperature, nominally dry conditions. Wear was measured in micrometers using a linear variable differential transducer or weight loss method using 0.0001gm balance and the frictional force was measured using load cell. The experiment conducted at the room temperature 27.2oC, with relative humidity 28%. 500rpm speed maintained with track diameter of 100mm and time period of 5minutes. Both wear and friction were simultaneously recorded during the experiments. 4 samples of each wt% fractions were tested and the recorded observations for each wt.% are listed below.

Table 3 wt. Loss and frictional force for AA7075 and SiC Reinforced specimens

AA7075	**Load (Kg) L**	**Wear-Weight Loss in grams(g)**			**Frictional Force (N)**
Trail No		**Wt. before**	**Wt. after**	**Difference**	
1	1	4.3286	4.3265	0.0021	3.6
2	2	4.3253	4.3233	0.0020	2.2
3	3	4.5612	4.5599	0.0013	3.3
4	4	4.2434	4.2411	0.0023	3.2
AA7075+2% SiC	Load (Kg) L	Wear-Weight Loss in grams(g)			Frictional Force (N)
Trail No		Wt. before	Wt. after	Difference	
1	1	4.3118	4.3104	0.0014	2
2	2	4.3603	4.3589	0.0014	5.3
3	3	4.3404	4.3393	0.0011	2.2
4	4	4.4038	4.4017	0.0021	3.1

AA7075+4% SiC	Load (Kg) L	Wear-Weight Loss In grams(g)			Frictional Force (N)
Trail No		Wt. before	Wt. after	Difference	
1	1	4.4016	4.4005	0.0011	0.9
2	2	4.4058	4.4048	0.001	1.4
3	3	4.4008	4.3988	0.002	3.6
4	4	4.4500	4.4485	0.0015	2.7
AA7075+6% SiC	Load (Kg) L	Wear-Weight Loss In grams(g)			Frictional Force (N)
Trail No		Weight before	Wt. after	Difference	
1	1	4.3573	4.3550	0.0023	1.0
2	2	4.2886	4.2884	0.0002	1.7
3	3	4.3227	4.3220	0.0007	2.6
4	4	4.3858	4.3843	0.0015	3.9
AA7075+8% SiC	Load (Kg) L	Wear-Weight Loss In grams(g)			Frictional Force (N)
Trail No		Weight before	Wt. After	Difference	
1	1	4.4091	4.4082	0.0009	1.4
2	2	4.4716	4.4696	0.0002	2.0
3	3	4.3511	4.3509	0.0002	3.4
4	4	4.4455	4.4435	0.0020	2.7

Table 4 Wear rate and Co-efficient of friction values for Different loads

Alloy No.	Alloy Composition	Load (N)	Weight loss (g)	volume loss (mm^3)	wear rate $x10^{-3}$ (mm^3/m)	Wear Resistance $x10^3$ (mm^3/Nm)	Co-Efficient Of Friction
A1	7075	9.81	0.0021	0.7315	2.6738	10.521	0.3669
A2	7075+2% SiC		0.0014	0.4896	1.7825	15.72	0.1427
A3	7075+4% SiC		0.0011	0.3765	1.4005	20.426	0.0917
A4	7075+6% SiC		0.0230	0.7959	1.3184	9.671	0.1019
A5	7075+8% SiC		0.0009	0.3078	1.1459	25.006	0.1630
A1	7075	19.62	0.0020	0.6972	2.5465	22.101	0.1121
A2	7075+2% SiC		0.0014	0.4844	1.7825	31.811	0.2701
A3	7075+4% SiC		0.0010	0.3423	1.2732	44.018	0.0968
A4	7075+6% SiC		0.0020	0.7034	1.1465	21.907	0.0866
A5	7075+8% SiC		0.0020	0.6745	1.0435	22.865	0.1019
A1	7075	29.43	0.0013	0.4297	1.6552	53.792	0.1121
A2	7075+2% SiC		0.0011	0.3822	1.4005	60.477	0.0747
A3	7075+4% SiC		0.0020	0.6852	1.0465	33.733	0.1223
A4	7075+6% SiC		0.0007	0.2442	0.8912	94.652	0.0883
A5	7075+8% SiC		0.0002	0.0693	0.2546	34.448	0.1135
A1	7075	39.24	0.0023	0.8173	2.9284	37.708	0.0815
A2	7075+2% SiC		0.0021	0.7191	2.6138	42.857	0.0790
A3	7075+4% SiC		0.0015	0.5083	1.9098	60.631	0.0688
A4	7075+6% SiC		0.0015	0.5758	1.7109	59.751	0.0993
A5	7075+8% SiC		0.0019	0.6445	1.04191	47.819	0.0688

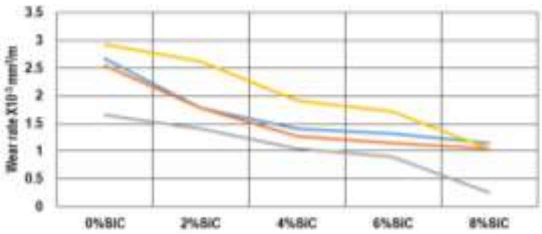

Figure 7 %SiC Vs Wear rate of AA7075

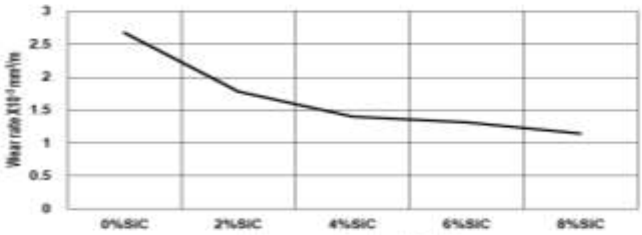

Figure 8 Wear rate for 9.81N

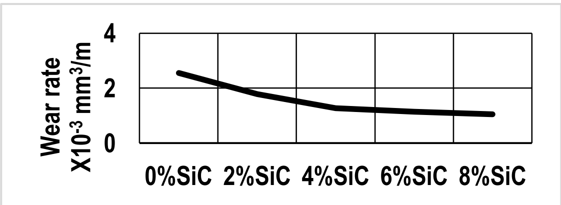

Figure 9 Wear rate for 19.62N

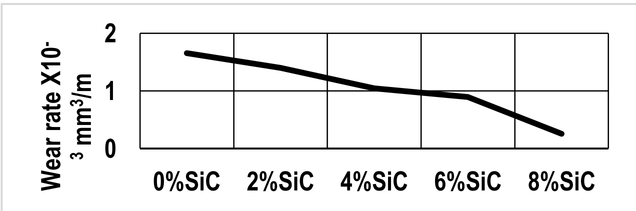

Figure 10 Wear rate for 29.43N

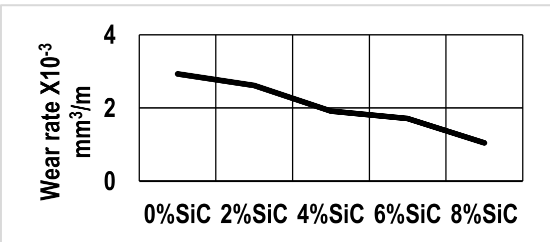

Figure 11 Wear rate for 39.24N

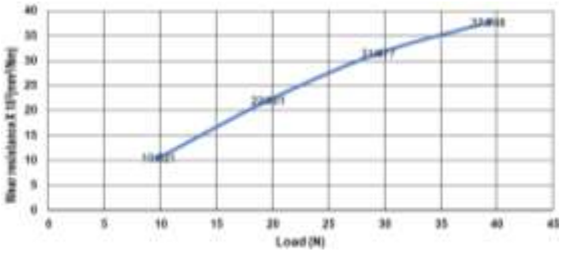

Figure 12 Loads Vs Wear resistance of AA7075

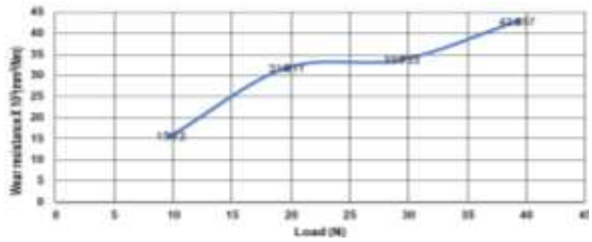

Figure 13 Loads Vs Wear resistance of AA7075+2%SiC

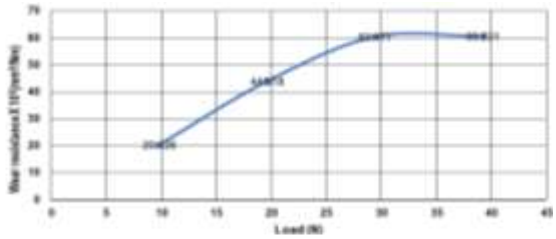

Figure 14 Loads Vs Wear resistance of AA7075+4%SiC

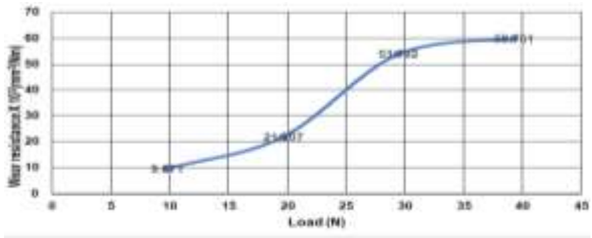

Figure 15 Loads Vs Wear resistance of AA7075+6%SiC

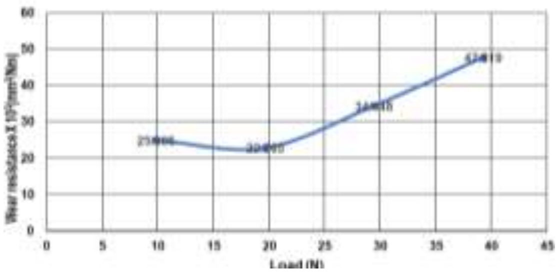

Figure 16 Loads Vs Wear resistance of AA7075+8%SiC

5. CONCLUSIONS

- Wear test results showed that addition of wt.% SiC increased wear resistance significantly. Also, wear rate is drastically reduced for 8% SiC for 30N. Hence weight increment in the Submicron sized SiC Particles leads to improved wear resistance.
- Wear rates were compared with cast AA7075 unreinforced sample and results ensures that increase of SiC weight fractions provided better tribological properties than metal alloys.
- EDAX analysis ensures that agglomerates and clusters SiC in the Al Matrix, with presence of Fe, Cu, Cr, Mg and Mn.
- SEM analysis shows that there was distribution of SiC particles in AA7075 matrix alloy.
- From microstructure images, observations reveal that there is a low wettability issues with the smaller size of SiC reinforcements in matrix metal combined using stir casting.

REFERENCES

[1] Baradeswaran, A., ElayaPerumal, A., (2013). Influence of B4C on the tribological and mechanical properties of Al 7075–B4C composites. Composites Part B: Engineering 54(0):146-152.

[2] Baradeswaran, A., Elaya Perumal, A., (2014). Study on mechanical and wear properties of Al 7075/Al2O3/graphite hybrid composites. Composites Part B: Engineering 56(0): 464-471.

[3] Bhushan, R. K., Kumar, S., (2011). Influence of SiC particles distribution and their weight percentage on 7075 Al alloy. Journal of materials engineering and performance 20(2):317-323.

[4] Candan, S., (2009). An investigation on corrosion behavior of pressure infiltrated Al– Mg alloy/SiC p composites. Corrosion Science 51(6):1392-1398.

[5] Doel, T. J. A., Bowen, P., (1996). Tensile properties of particulate-reinforced metal matrix composites.

[6] Flores-Campos, R., Mendoza-Ruiz, D. C., Amézaga-Madrid, P., Estrada-Guel, I., Miki-Yoshida, M., Herrera- amírez, J. M., Martínez-Sánchez, R., (2010). Micro structural and mechanical characterization in 7075 aluminum alloy reinforced by silver nanoparticles dispersion. Journal of Alloys and Compounds 495(2):394-398.

[7] Jiejun, W., Chenggong, L., Dianbin, W., Manchang, G., (2003). Damping and sound absorption properties of particle reinforced Al matrix composite foams. Composites Science and Technology 63(3):569-574.

[8] Kalkanlı, A., Yılmaz, S., (2008). Synthesis and characterization of aluminum alloy 7075 reinforced with silicon carbide particulates. Materials & Design 29(4):775-780.

[9] Karunanithi, R., Bera, S., Ghosh. K. S., (2014). Electrochemical behavior of TiO2 reinforced Al 7075 composite. Materials Science and Engineering: B 190(0):133-143.

[10] Kumar, R., Dhiman, S., (2013). A study of sliding wear behaviors of Al-7075 alloy and Al-7075 hybrid composite by response surface methodology analysis. Materials & Design 50(0):351-359.

[11] T.W. Clyne and P.J. Withers. “An Introduction to Metal Matrix Composites” 1st Ed., Cambridge University Press, Cambridge, 1993. pp.1-10.

[12] D.M. Skibo, D.M. Schuster and L. Jolla. “Process for preparation of composite materials containing nonmetallic particles in a metallic matrix and composite materials “US Patent No. 4-786-467(1988)

[13] F. Khomamizadeh and A. Ghasemi “Evaluation of Quality Index of A-356 Aluminum Alloy by Microstructural Analysis, Scientia Iranica, Vol.11(4) (2004)386-391.

[14] Mohan Vanarotti, Shrishail P, B R.Sridhar, K.Venkateswarlu & S A. Kori,“Study of Mechanical Properties & Residual Stresses on Post Wear Samples of A356-SiC Metal Matrix Composites” Procedia Material Science, Vol 5 (Elsevier, 2014) 873– 882.

[15] George E Deiter “Mechanical Metallurgy” SI Metric Edition (McGraw-Hill1988)

[16] Sidney H Avner “ Introduction to Physical Metallurgy” (Tata McGraw Hill1997).

[17] N. Cayetano-Castro, H. J. Dorantes-Rosales, V. M. López- Hirata, J. J. Cruz- Rivera, J.Moreno-Palmerin, and [18] J. L. González-Velázquez, “Coarsening kinetics of coherent precipitates in Fe-10% Ni-15% alloy,” Revista de Metalurgia de Madrid, vol. 44 (2),(Elsevier 2008), pp. 162–169.

[18] K. Thornton, N. Akaiwa, and P. W. Voorhees, “Large-scale simulations of Ostwald ripening in elastically stressed solids: Development of microstructure” Acta Materialia, vol. 52 (5), (Elsevier 2004), pp.1365–1378

[19] M.Schober, C. Lerchbacher, E. Eidenberger, P. Staron, H. Clemens, and H.Leitner, “Precipitation behavior of intermetallic NiAl particles in Fe-6 at.%Al-4at.%Ni analyzed by SANS and 3DAP” Intermetallics, vol. 18 (8), (Elsevier 2010) pp. 1553–1559.