iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 2 **Issue:** XI **Month of publication:** November 2014

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Studies on Mechanical and Dry sliding wear of 2014Al–SiC composites produced by powder Metallurgy route

Pradeep Kumar yadav[1], Dr. G.Dixit[2], Gaurav kumar Gupta[3]
[1]Research scholar in Department of mechanical engineering, Maulana Azad National Institute of Technology, Bhopal, India
[2] Professor in Department of mechanical engineering, Maulana Azad National Institute of Technology, Bhopal, India
[3]Scientist-C in CSIR Bhopal, India

Abstract: The aim of the present study was to investigate the effect of SiC content on the Mechanical and Dry sliding wear characteristics of a 2014Al-SiC composite. The alloy and its composites were compacted at 500 MPa and sintered in nitrogen atmosphere at 590 °C. It was found that SiC reduces the compressibility of aluminum alloys. The addition of SiC reinforcement adversely affects sintered density due to poor wetting between SiC and alloy. Hardness increased up to (5 vol %) composite and then decreases for the remaining composites having a higher SiC content. Wear studies were carried out at different load and sliding speed conditions. At a low speed wear rate, alloy with 5 vol% SiC was more than the alloy itself. However, the wear rate was lower when the SiC content was increased to 10 and 15 vol %. At higher speed the wear rate decreased with the increasing SiC content.
Keywords: 2014Al-SiC Composites, Sintering, Densification, Microstructure, Mechanical and Tribological Properties.

I. INTRODUCTION

In recent years, the increasing global demand for energy efficient and cost effective engineering solution has focused the attention of researchers and manufacturers towards adopting novel materials and processing approaches. Furthermore, its mechanical properties can be readily enhanced using a range of heat-treatment methodologies. This has made aluminum a strong candidate for applications such as, automotives and aerospace industries, business machines, farm and garden appliances, etc [1-2]. One of the potential major usages of aluminum alloys is envisaged in the automotive industry wherein substitution of steels with a lightweight, high performance Component is desired for achieving higher fuel efficiency. Al-matrix composites are preferred in many applications such as, bearings, gears, seals, guides, piston rings, pistons, cylinder heads, brakes and clutches .It has been observed that abrasive characteristics are of importance in such applications [3-6].Wear is one of the most commonly encountered industrial problems, leading to frequent replacement of components [7]. As SiC is most commonly used dispersoid in aluminum alloys. The unique attribute of SiC is that, among the existing structural ceramics, it has highest thermal conductivity (120 W/mK), high modulus of elasticity and hardness .Powder metallurgical (P/M) processing of aluminum based composites with SiC reinforcement results in more homogeneous distribution of SiC in the matrix [8-12]. The aluminum alloys in the 2xxx series do not have as good corrosion resistance as most other aluminum alloys, and under certain conditions they may be subject to intergranular corrosion. Aluminum grades in the 2xxx series are good for parts requiring good strength at temperatures up to 150°C (300°F). Except for the grade 2219, Aluminum grade 2024 is the most popular alloy and is commonly used in aircraft construction.

II. EXPERIMENTAL DETAILS

In the Present study, premixed alloy powder was synthesized using three elemental powders (Al and Cu and Si). All as received powder was carried out by Nova Nano SEM 430 (FEI Make powders were supplied by Alfa Aesar, USA).The Al, Cu and Si powder purity were 99.9% and particle size was -325 meshes. The alloy composition chosen was Al-4Cu-0.5Si. SiC was used for the synthesis of the composite. The avg. particle size of the SiC particle was 2 micron. The powder was supplied by Alfa Aesar, USA. Three composites systems were synthesized by varying SiC volume fraction (5, 10 and 15 vol % of SiC). The mixing of constituent powders was carried out in Turbula mixer (Hexagon design, Baroda make). The time of mixing was kept at 2 Hrs for all compositions. The premixed alloy powders and composites were compacted to cylindrical pellets (10mm dia and 8 mm height), TRS samples (31.7mm x12.7 mm x 6 mm) according to MPIF 41 and Flat dog bone shaped sample according to MPIF 10 .The cylindrical samples were prepared using 40 Ton semi automatic motorized hydraulic press supplied by PES Hydraulics, Haryana. The other two types of samples were prepared using 40 Ton manual motorized hydraulic press with higher daylight supplied by PES Hydraulics, Haryana. The TRS and Flat dog bone samples were prepared using floating die and cylindrical samples were prepared by Normal die. The daylight in 40 Ton semi automatic press was less for floating dies therefore manual press with higher daylight was used for floating dies. The compaction pressures were 500 MPa. To facilitate compaction, a small amount of zinc stearate was used as die and punch wall lubricant. The green compacts were sintered in a Kanthal based tubular furnace (supplied by Mahindra scientific, Kanpur). The compacts were sintered in High purity Nitrogen. Compacts were sintered at 590 for 30 min. The Heating rate was kept at 10 degC/min. Samples were cooled in the furnace. Density of as-pressed compact (Green) was evaluated through dimensional measurement. In order to facilitate comparison between different alloys, density was normalized with respect to theoretical density of alloy. The theoretical density was calculated by inverse rule of mixtures further the sintered densities of the cylindrical pellets were calculated from mass and dimensional measurements of the sample. The density was reconfirmed by Archimedes principle. Sintered density was also normalized to theoretical density. The green strength (S) in MPa of compacts was calculated according to MPIF specification 15using the following expression $S=3PL/2wt^2$ Where, P is force in N required to rupture, L is the length of specimen span of fixture, t is the thickness and w is the width of the specimens. The polished sintered samples were tested for their hardness using Vickers hardness testing machine (FIE Make) under an applied load of 1 Kg for 10 sec. Hardness was measured at least 5 different places to obtain an estimated average. Three point bending test setup (Technochem Engineers, Ratlam) was used for the measurement of Transverse Rupture Strength of sintered samples. The TRS test was carried out in Universal testing machine (Instron, 100 KN capacity) at a cross head speed of 1 mm/min using span length of 25 mm. The TRS strength is calculated with the UTM machine. An optical microscope (motorized) M/S LEICA, GERMANY Model No-LEICA DM 6000 M was used to observe to microstructure features of sintered sample. The metallographic preparation of sample was done by polishing on 120,320,600 and 1000 grit SiC emery paper. This was followed by cloth polishing with 1µm,.05µm alumina suspension. For revealing the microstructure feature the sample was etched with Keller's reagent (3ml HNO_3, 2ml HCl, 1ml HF and 94 ml of H_2O). The dry sliding wear of the as sintered and heat treated composite was conducted using pin on disc type wear machine**.** Dry sliding wear conducted on ASTM-G 99 standard. Prior to testing the pin and disc surface are cleaned with the acetone. The sintered samples to be tested were used as a pin and the disc was made of the EN 32 steel of hardness 65 HRC. The samples were weighed before and after wear testing (sliding distance of 500 m) to calculate the wear rate as a function of load and speed. The wear track radius was fixed at 40 mm and constant sliding velocity of 1 m/s, 2 m/s, 3m/s was maintained for all samples. Correspondingly, the disc rotated at 239 rpm, 476 rpm, and 717 rpm at testing load levels (10 N, 30N and 50 N). Each experiment was carried out for a total sliding distance of 500 m. After each experiment of wear test, sample must be clean with acetone before weighing otherwise there can be an error in measurement of weight loss.

III. RESULTS AND DISCUSSION

A. Green density

Green density is defined as-pressed density after cold compaction here or this can be assumed as density before sintering process. In order to take account the variation in density due to change in composition; the green density was normalized with respect to theoretical density.

Table 1: Data for green density with standard deviation for aluminum alloy and it's composite.

Sample	Condition	Green density (%th density)	Theoretical density (gm/cc)
Al-4Cu-0.5Si	590 N_2	96.03±0.68	2.77
Al-4Cu-0.5Si-5vol%SiC	590 N_2	91.55±0.54	2.79
Al-4Cu-0.5Si-10vol%SiC	590 N_2	89.06±0.70	2.82
Al-4Cu-0.5Si-15vol%SiC	590 N_2	86.26±0.33	2.84

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

In Table 1 shows the green density variation in 2xxx-SiC composite with varying amount of SiC addition. At 500 MPa, the premixed alloy powder attained a density of 96% but density reduces with increasing SiC. The addition of SiC therefore reduces the compressibility of aluminum alloys. This can be attributed to hard and non-deforming nature of SiC particle which constricts Al particle deformation, sliding and rearrangement during compaction [2, 19].

B. Sintered Density

Variation of sintered density and densification parameter with SiC content is shown in Table no 2. In order to take account the variation in density due to change in composition; the sintered density was also normalized with respect to theoretical density. It can be inferred that the sintered density reduces significantly with increasing SiC content. In similar condition, aluminum alloy attained the density of 93%. In comparison up to 5vol% SiC addition, the reduction in the sintered density is less. Beyond 5vol%, density decreases more drastically means more pores are created after sintering process. It can be inferred that SiC reinforcement adversely affects both the sintered density as well as the densification parameter. The adverse influence of SiC on densification results was attributed to the poor wettability of the SiC surface by the melt during sintering. This has been attributed to the associated stress field that activates sintering in Al-composites.

Table 2: Data for sintered density for aluminum alloy and it's composite.

Sample	Condition	Sintered Density (%th density)	Theoretical density (gm/cc)	Densification
Al-4Cu-0.5Si	590 N_2	933	2.77	-0.30
Al-4Cu-0.5Si-5vol%SiC	590 N_2	91.07	2.79	-0.05
Al-4Cu-0.5Si-10vol%SiC	590 N_2	87.37	2.82	-0.15
Al-4Cu-0.5Si-15vol%SiC	590 N_2	82.69	2.84	-0.25

C. Densification parameter

Mathematically Densification parameter can be defined as-

$$\text{Densification parameter} = \frac{\text{Sintered density} - \text{green density}}{100 - \text{green density}}$$

It the ratio of pores fraction reduction after sintering process to the initial porosity fraction. In order to take into account the effect of variation in compressibility, the densification response was expressed in terms of densification parameter. From Table no 2, it can be inferred that all composites along with alloy underwent swelling during sintering. 5vol% SIC resulted in slight swelling and beyond 5% SiC, extent of swelling increases with increasing SiC [15]. Due to poor wettability of SiC and melt (forms during sintering), the green compacts swells. This poor wettability and stress field (for the activation of sintering) reduces with SiC resulted in increased swelling with increasing SiC. The alloy also swells due to the kerkindel effect (Diffusion of Cu in Al is faster Al in Al)

D. Hardness

The Hardness of the sample is measured using vicker's Hardness tester at 1kg, each data point is the average of five readings. The hardness is carried out for sample compact at 500MPa and sintered at 590 degC in N_2 Atmosphere. Table 3 shows the variation of hardness of sintered composite with varying SiC content. As expected, the addition of hard reinforcing phase results in an increase in the hardness of composites (only up to 5vol%) but beyond 5vol%SiC hardness reduces inspite of higher SiC content due to higher porosity in the sintered compacts. In identical condition, the alloy had a hardness of 42 VHN. In overall the hardness of the composite is higher than alloy (up to 10vol %) and 15vol% composite has slightly lower hardness than alloy. In these cases, increment effect due to hard particle is suppressed by decrement effect of porosity.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Table 3: Vickers hardness data for aluminum alloy and it's composite

Material	Hardness (HV)
Al-4Cu-0.5Si	41.975
Al-4Cu-0.5Si-5%vol SiC	57.275
Al-4Cu-0.5Si-10%vol SiC	53.175
Al-4Cu-0.5Si-15%vol SiC	39.125

E. Transverse Rupture Strength (TRS)

TRS strength is known as 3 point bending (Flexural) strength. It is measure of flexibility (bending). Table 4 shows the effect of flexural strength on the varying SiC content. It can be inferred that the flexural strength decrease rapidly with SiC content. In identical sintering condition, the alloy had a flexural strength of 254 MPa. Flexural strength seems to be more sensitive to the SiC content. The strength reduces due to both SiC content as well as porosity level. During this test, the tensile stress field generated in the center portion of the sample. Since porosity/cracks and SiC behaves adversely in stress field leads to pronounced cracking resulted in sharp reduction in strength. As porosity increase with SiC, effect of tensile stress is more with increasing SiC resulted in sharp reduction in flexural strength.

Table 4: Resultant data for tensile rupture strength (MPa)

Material	Tensile rupture strength (MPa)
Al-4Cu-0.5Si	254.5
Al-4Cu-0.5Si-5%vol SiC	59.99
Al-4Cu-0.5Si-10%vol SiC	10.98
Al-4Cu-0.5Si-15%vol SiC	5.28

WEAR TEST of composite: While there is abundant literature on mechanical properties of sintered Al alloys and composite, very little has been reported on wear behavior of these alloys. Wear phenomena are governed by large number of independent factor like hardness, roughness, composition and of sintered material is rather difficult. In the present study, alloy and composite were subjected to sliding wear test in as-sintered condition. Wear loss rate, were measured in each set of speed and load. The effect is discussed in following sections.

F. Weight loss rate vs.. load (for different material)

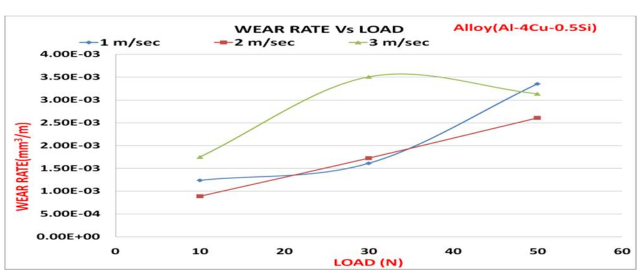


Fig-1 Graph for Weight loss rate vs. load for alloy

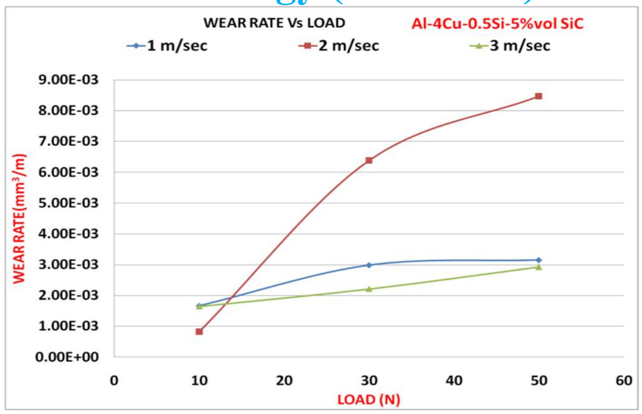


Fig-2 Graph for Weight loss rate vs. load for 5%vol SiC

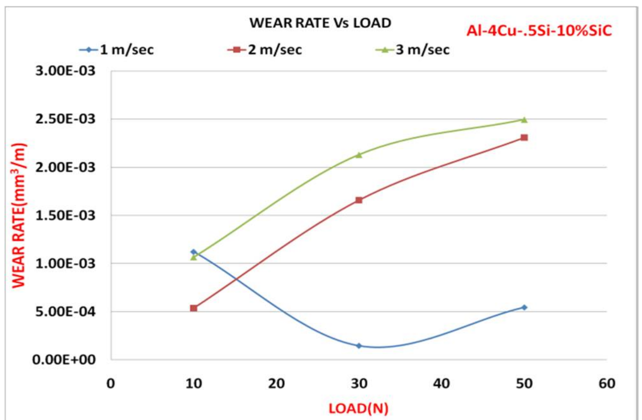


Fig-3 Graph for Weight loss rate vs. load 10%vol SiC

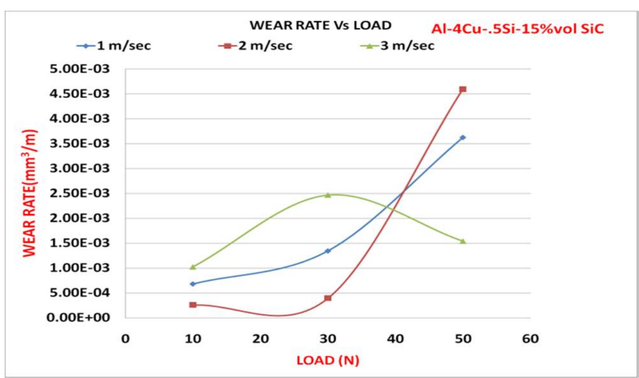


Fig-4 Graph for Weight loss rate vs. load 15%vol SiC

Fig-1, Fig 2, Fig 3 and Fig 4 shows the graph between Weight loss rate vs. load (for each material) at same condition (1m/s, 2m/s, 3m/s velocity). As shown in figure 1, alloy at low speed (1m/s) the wear rate increases as the load increases. Similar behavior is observed at medium speed (2m/s) the wear rate increases as the load. wear rate is similar in value. As shown in figure 2, aluminum alloy composite with 5%vol SiC at low speed, the wear rate firstly increases with load and become constant. At medium speed the wear increases with the load. At high speed the wear rate is again showing the similar trend as 1m/sec. In this case wear rate at 3m/sec is showing lesser than 1m/sec and 2m/sec. Applied load affects the wear rate of Al-alloy and composites significantly and is the most dominating factor controlling the wear behavior[17] .As shown in figure 3, 10%vol SiC composite at 1m/sec decreases then increases with load. At medium speed and high speed the wear rate increases with the load. Wear rate is higher in 3m/sec speed and lowest in 1m/sec.As shown in figure 4, 15%vol SiC composite at low and medium speed the wear rate is increasing with the load at high speed the wear is increases and then decreases with load. The wear rate varies with the normal load, which is an indicative of Archard's law, and is significantly lower in case of composites [18].Wear rate at 2m/sec is lower than 1m/sec up to 30N load and it is higher. Wear rate at 3m/sec is showing higher wear rate up to 30N and then it is lower than 1m/sec or 2m/sec at 50N load**.**

G. Weight loss rate vs.. load (for different speed)

Fig-5, Fig-6, Fig-7 shows the Graph for Weight loss rate vs.. load for different Al alloy and its composite at (at each speed of 1m/sec. 2m/sec and 3m/sec) As shown in Fig-5, at low speed the wear rate of the alloy and 5vol% are showing increasing trend with load and 10 and 15% are showing

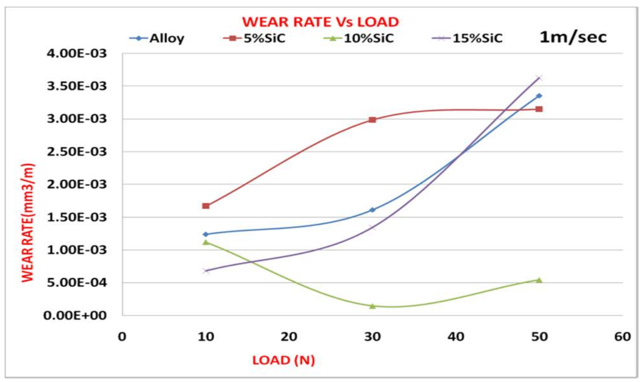


Fig-5 Graph for Weight loss rate vs. load for Al alloy and it's composite at 1 m/sec

Fig-5 Graph for Weight loss rate vs.. load for Al alloy and its composite at 1 m/sec mixed behavior. It is inferred from the curve that the wear rate of 5vol% is higher than alloy but as vol% increases, the wear rate curves shifted below to alloy. 10vol% and alloy are showing similar wear rate values. As shown in Fig-7, At high speed the wear rate for alloy increases till 30N load and then decreases. For 5 and 10 %vol Sic wear rate increases with load and for 15%SiC wear rate increase till 30N and then decrease with load. At all loads, composite is showing lower wear rate than alloy. At higher load (50N), wear rate decrease with increasing SiC. At 30N, all composite is showing similar wear rate.

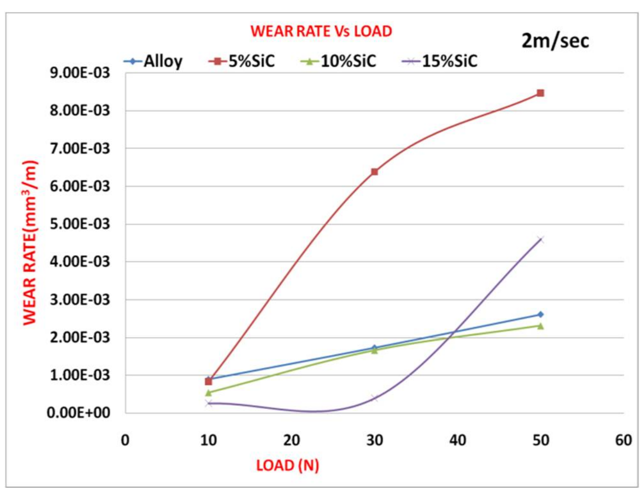


Fig-6 Graph for Weight loss rate vs. load for Al alloy and its composite at 2 m/sec

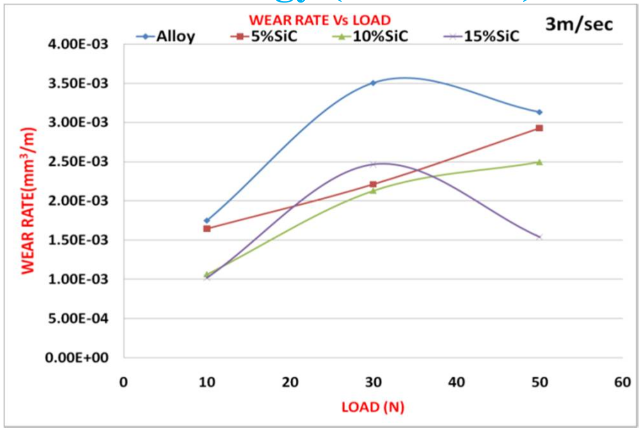


Fig-7 Graph for Weight loss rate vs. load for Al alloy and its composite at 3 m/sec

It is observed that the SiC in the alloy gives rise to more wear with increase in SiC content but its positive effect can be noted at higher volume fraction because of higher level of porosity .For the alloy as well as composite (up to 5vol%SiC), adhesive or sliding wear was the predominant mechanism but for the higher SiC content, a transition to abrasive wear mode was normally observed due to the expulsion of SiC particle from the surface resulted in very high wear rate. .Here in this case even at higher volume fraction resulted in lesser wear, it may be due to the higher porosity and also due to the finer size of SiC particle (2micron) which allow them to remains intact in the surface

H. Optical Microstructure

Fig (8-13) show the optical microstructure of 5vol%, 10vol% and 15vol% at 100 and 500x respectively. it is clearly visible that the pore fraction and average pore size is increasing with SiC content. In case of 5vol% pores are mostly intergranular but as SiC is increasing the pores are intergranular and intragranular. Due to the presence of intragranular pores mechanical property has reduces

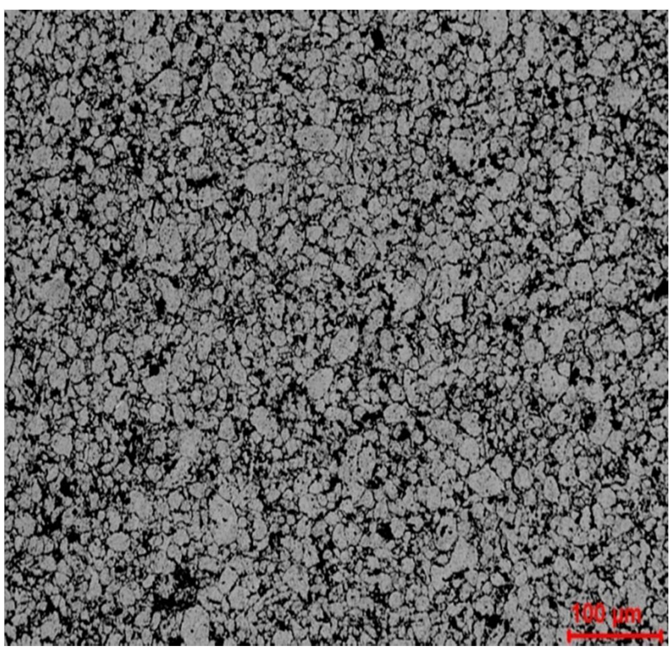


Fig-8 Optical Microstructure of 5vol% SiC at 100X

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

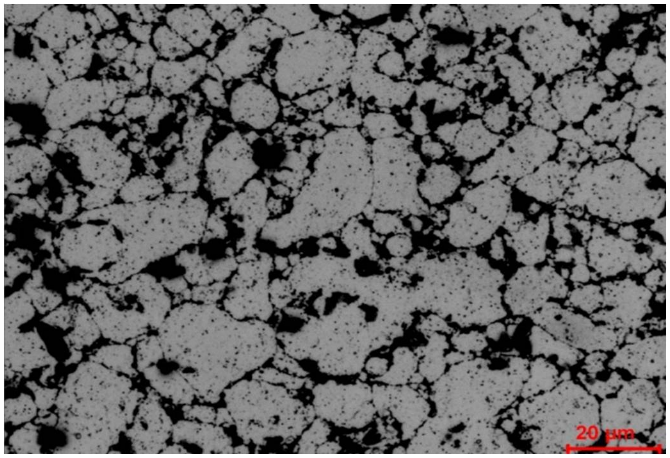


Fig-9 Optical Microstructure of 5vol% SiC at 500X

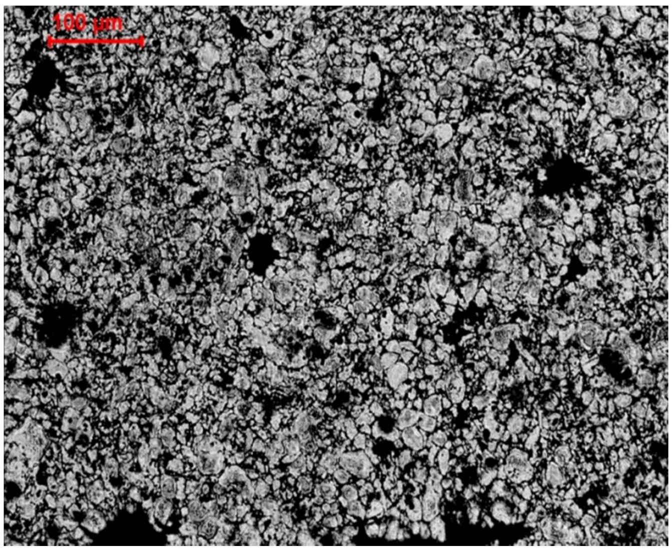


Fig-10 Optical Microstructure of 10vol% SiC at 100X

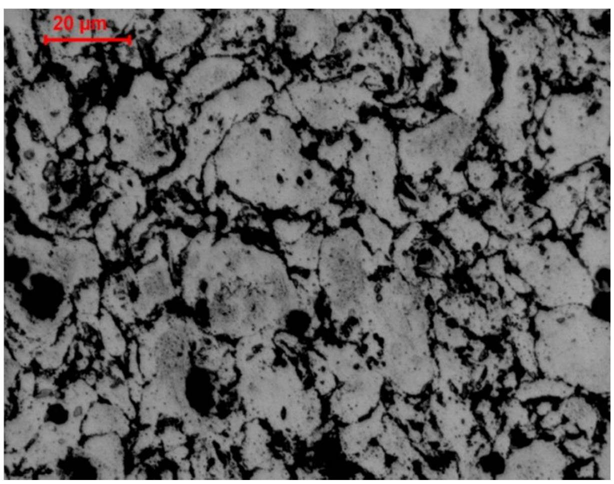


Fig-11 Optical Microstructure of 10vol% SiC at 500X

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

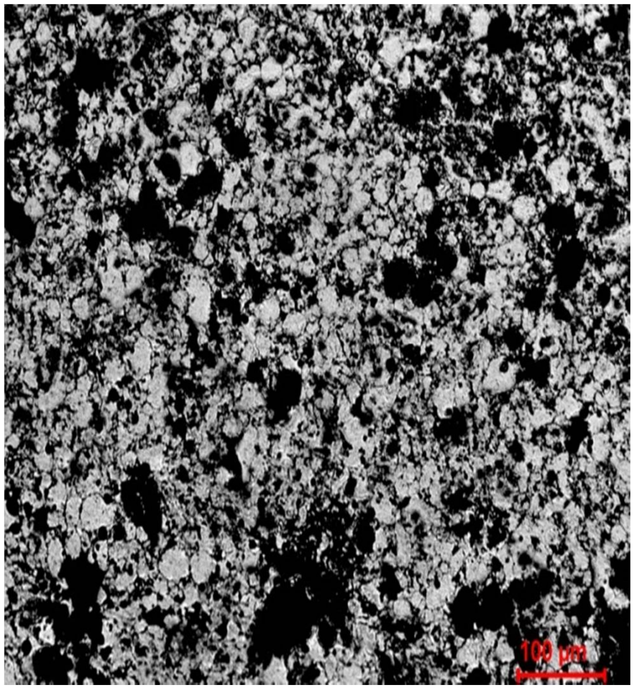


Fig-12 Optical Microstructure of 15vol% SiC at 100X

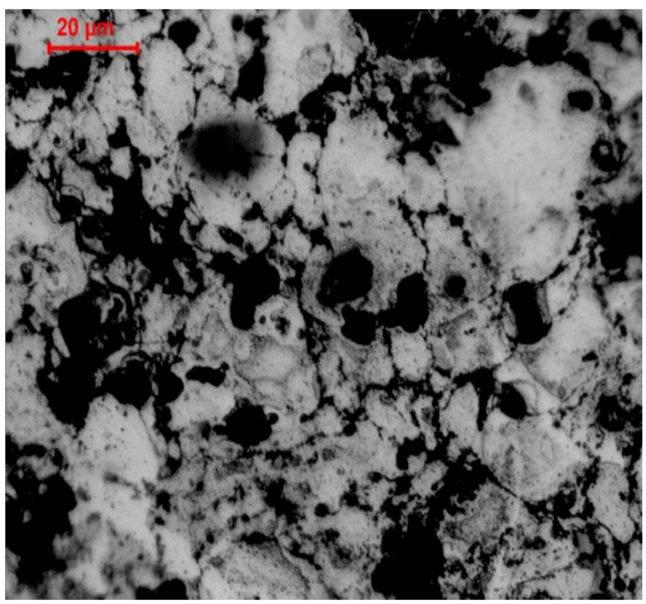


Fig-13 Optical Microstructure of 15vol% SiC at 500X

Drastically. The grain size is also affected by SiC content. In case of 5%SiC grain are finer and of uniform size whereas as SiC increases large variation in grain size is observed. It is due to the effect that higher SiC content forms cluster in matrix resulted in non-uniform distribution of SiC. Due to this effect, grain grows in areas where SiC is absent or present in smaller quantity whereas grain size is small in the areas where SiC is more. The pore size is higher in SiC rich areas and pore is mostly intergranular but pores is smaller and Intragranular in larger grain. Intragranular pores and non-uniform grain size is also responsible for poor mechanical properties.

ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

IV. CONCLUSIONS

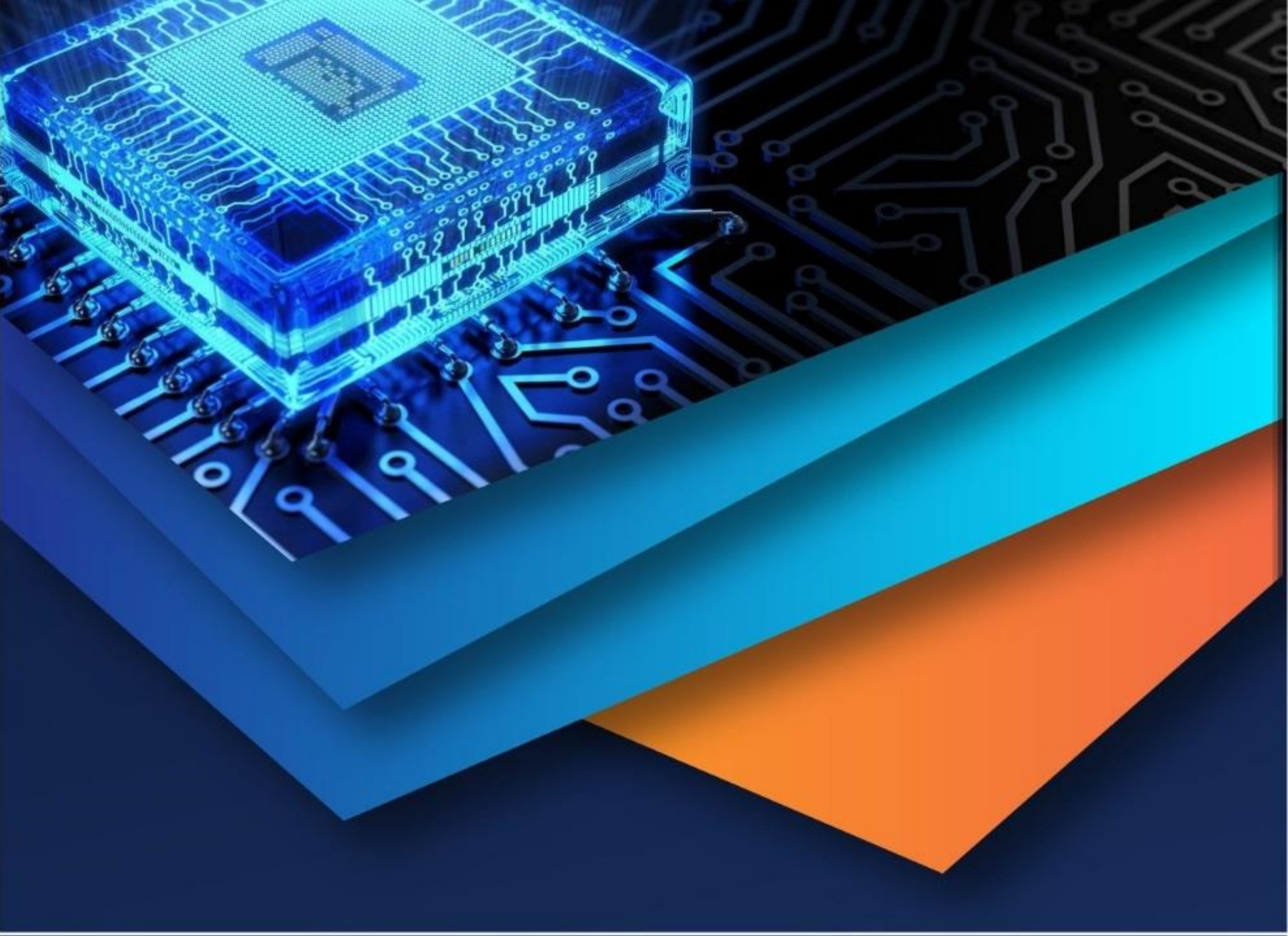
The Objective of the present study was to investigate the effect of compaction pressure and sintering temperature on the consolidation aspect of 2xxx series alloy (Al-4Cu-0.5Si) and their respective composite (SiC of 5, 10, 15 %vol).the material was compacted at 500MPa and sintered at 590℃ in Nitrogen atmosphere. The sintered material was characterized for densification, hardness, TRS and wear phenomenon. The findings can be as following;

A. The addition of SiC reduces the compressibility of aluminum alloys hence green density of the composite reduces with the SiC content.
B. The addition of SiC reinforcement adversely affects both the sintered density as well as the densification parameter due to the poor wetting between sic and melt (forms during sintering) hence sintered density also reduces with the SiC content.
C. All composites underwent swelling during sintering and swelling increases with SiC content.
D. the addition of SiC results in an increase in the hardness of composites (only up to 5vol%) but beyond 5vol%SiC hardness reduces inspite of higher SiC content due to higher porosity in the sintered compacts.
E. Flexural strength decrease rapidly with SiC content due to higher porosity and higher tensile stresses field in the material.
F. Wear rate increases with load for almost all cases (alloy and composite)at lower speed (1 and 2m/s) where as wear rate is showing increasing and then decreasing trend with load at higher speed (3m/s)in alloy and 15% SiC. The rest composite are showing increasing trend in wear rate at higher speed(3m/s)
G. Wear rate of the alloy is higher than the composite (beyond 5%SiC) almost at all loads and lower and medium speed (1m/s, 2m/s) whereas the wear rate is higher than the composite at high speed.

At high speed wear rate decreases with SiC content at all loads whereas in lower and medium speed the wear rate maxima is observed in 5%SiC.

REFERENCES

[1] C. Padmavathi, Anish Upadhyaya, Densification, Microstructure and Properties of Supersolidus Liquid Phase Sintered 6711Al-SiC Metal Matrix Composites, (2010) 363-382.
[2] Dwivedi R. Performance of MMC rotors in dynamometer testing. SAE Technical Paper Series, 940848. Warrendale, PA, USA.
[3] M. Kok, Composites: Part A 37 (2006) 457–464.
[4] R.L. Deuis, C. Subramanian, J.M. Yellup, Wear 201 (1/2) (1996) 132–144.
[5] S.M. Seyed Reihani, Materials and Design 27 (2006) 216–222.
[6] S. Das, D.P. Mondal, S. Sawla, N. Ramakrishnan, Wear 264 (2008) 47–59.
[7] Adem Onat, Mechanical and dry sliding wear properties of silicon carbide particulate reinforced aluminum–copper alloy matrix composites produced by direct squeeze casting method (2009).
[8] Y. B. Liu, S.C. Lim, L. Lu, M.O. Lai, J. Mater. Sci., 29 (1994) 1999.
[9] Y. B. Liu, S.C. Lim, L. Lu, M.O. Lai, J. Mater. Sci., 29 (1994) 1999.
[10] R.J. Arsenault, Mater. Sci. Eng. A 64 (1984) 171.
[11] F.E. Swindells, P.J. Lare, Metall. Trans. A 4 (1986) 402.
[12] F.L. Riley, Structural Ceramics: Fundamentals and Case Studies, Cambridge University Press, England, 2009.
[13] T. George, R. Rajkumar, F. Richard, in: "Proc of Powder Metallurgy Aluminum & Light Alloys for Automotive Applications Conference", Eds. W.F. Jandeska Jr., R.A. Chernenkoff, MPIF, Princeton, New Jersey, 1998, p. 35-42.
[14] F.E. Swindells, P.J. Lare, Metall. Trans. A 4 (1986) 402.
[15] R.M. German, Liquid Phase Sintering, Plenum Press, New York, USA, 1985.
[16] Sharmilee Pal, R. Mitra, V.V. Bhanuprasad, Mater. Sci. Eng. A 480 (2008) 496.
[17] Mondal DP, Das S, Jha AK, Yegneswaran AH. Abrasive wear of Al alloy–Al_2O_3 particle composite: a study on the combined effect of load and size of abrasive. Wear 1998;223:131–8.
[18] Tyagi Rajnesh. Synthesis and tribological characterization of in situ cast Al–TiC composites. Wear 2005;259:569–76.



10.22214/IJRASET

INDEX COPERNICUS
45.98

IMPACT FACTOR:
7.129

TOGETHER WE REACH THE GOAL
IMPACT FACTOR:
7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY