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EFFECT OF WEIGHT PERCENTAGE OF SILICON CARBIDE ON THE MECHANICAL PROPERTIES AND MICROSTUCTURE OF ALUMINIUM COMPOSITES

Patrick.A.O Adegbuyi, Muhammed O.Alabi, Ridwan O.Ola-Gbadamosi, Olumide Aderibigbe, Usman Ibrahim, Agbedun Sola

Department of Mechanical Engineering, Faculty of Engineering, Lagos State University, Epe Campus, Lagos, Nigeria, Rocket Propellant Development Systems, Bola Ahmed Centre for Space Transport and Propulsion, Lasu, Epe Campus, Lagos, Nigeria

Corresponding Author: **Email**: patrick.adegbuyi@lasu.edu.ng
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ABSTRACT

The effects of silicon carbide (SiC) addition on the mechanical properties and microstructure of aluminum metal matrix composites are investigated. Aluminum alloy samples with 2%, 4%, 6%, 8%, and 10% SiC composition by weight were fabricated by casting along with a control sample consisting only the Aluminum matrix. The samples were machined to standard specimen for the purpose of Mechanical testing which includes tensile test, hardness test, impact toughness as well as micro- structural examination. The results of the investigations illustrate that the tensile property of the composite is enhanced when the SiC additions are augmented. The 10wt% SiC specimen showed a maximum ultimate tensile strength of 171.85 MPa and fracture stress of 170.59 MPa. Hardness also improved proportionally with increased SiC reinforcement, 135.4 Vickers Pyramid Number (HV) was observed for 10wt%compared to 100.2 HV for the control the specimen. However, the impact energy absorbed before fracture by specimens decreased as the SiC reinforcement increased across the specimens. The result shows sufficient Silicon Carbide reinforcement can be applied in Aluminium composites for applications requiring improved strength and lower Impact toughness. Micrographs detected refined grains and finely dispersed strengthening precipitates for higher SiC compositions which accounts for the superior strength. Spectrometry analysis for control specimen verified that silicon was the key alloying element. The 10% SiC composite displayed an optimal balance of enhanced strength and hardness coupled with substantial ductility.

Keywords: Silicon Carbide, Aluminum Composites, Casting, Mechanical Testing, Spectrometry.

INTRODUCTION

COMPOSITES

Composites are materials built up of numerous constituent materials with varied physical and chemical properties. When compared to the constituent materials, composites offer increased strength, stiffness, low density, and better performance. They also allow for a significant weight reduction. [1a].The matrix and reinforcing phases of composites are formed by particles, flakes, and fibers in the reinforcement phase, and polymer, metals, or ceramics in the matrix phase [1a]. [1b].

Metal matrix composites (MMCs), ceramic matrix composites (CMCs), and polymer matrix composites (PMCs) are the three types of composites classified by matrix phases [2]. However, particulate composites (made of particles), fibrous composites (composed of fibers), and laminate composites can all be classified based on the kind of reinforcement (composed of laminas) [3] When compared to conventional materials, composites offer high specific stiffness and strength, low electrical conductivity and thermal expansion, and good fatigue resistance [4].

The reinforcement phase of a particle metal matrix composite is made up of particles (ceramics) Because of its high temperature and abrasion resistance, silicon carbide can be utilized as reinforcement. Because of its low melting point and wide range of engineering applications, aluminum and its alloys are commonly utilized to manufacture MMC. [1] Aerospace, biotechnology, automotive, electronics, nuclear, and sports industries all use Al metal matrix composites [5].Non-metallic materials such as Si-C, B4C, Flash, and others can improve the basic Al-si mechanical and tribological properties. The Al also improves the physical properties of the base matrix, such as its modulus and coefficient of thermal expansion [6]

2.4 LITERATURE REVIEW

The mechanical properties of a cast aluminum alloy composite reinforcing with SiCp and graphite particles were examined by S.Basavarajappaet colleagues (2004) [34]. The results show that when the reinforcement content increases, the composite's mechanical properties such as ultimate tensile strength, yield strength, hardness, and compressive strength improve, while the density decreases. The synergistic influence of the dislocation density formed due to variations in coefficients of thermal expansion between the constituents of the composite is attributed to the improved strength of aluminum 2004/SiCp-Gr composite.

Tamer Ozben et al (2008) [35] They looked at how silicon carbide particles (SiC-p) affected the mechanical machinability of aluminum metal matrix composites. The effect of reinforced SiC-p ratios of 5, 10, and 15% on mechanical properties was investigated. Increased reinforcing element addition resulted in improved mechanical parameters such as impact toughness and hardness, while tensile strength followed a different pattern, increasing up to 10% SiC-p reinforced and then decreasing when 15% SiC-p reinforcement was added. The machinability features of the chosen material were investigated, and it was discovered that increased SiC-p reinforcement caused more tool wear; surface roughness was influenced by feed rate and cutting speed in general.

H.C. Anilkumaret al (2010) [36]They looked at how fly ash particles affected the mechanical characteristics of Al6061 alloy composites. They found that when the weight percentage of reinforced fly ash grew, the tensile strength, compression strength, and hardness increased, while the particle size of the fly ash dropped. The composite's ductility declined as the weight fraction of reinforced fly ash increased, and as the particle size of the fly ash increased.

Chennakesava Reddy et al (2010) [37] They looked at how the tensile qualities of Al2O3 affected the mechanical properties of Al6063 alloy composites. With an increase in Al2O3 volume fraction, yield strength and fracture strength increase, while ductility declines.

The influence of particle reinforcements such as tungsten carbide and graphite on the mechanical characteristics of Al6061 alloy composites was investigated by A.R.K. Swamy et al (2011) [38]. The results of this investigation demonstrated that as the tungsten carbide particle content was raised, the ultimate tensile strength, hardness, and young's modulus increased significantly, but the ductility decreased.

Madhu Kumar Y.C, Uma Shankar et al (2012) [39]The impact of glass particles on the mechanical characteristics of Al6061 alloy composites was investigated. The produced aluminum matrix composites' microstructure and mechanical characteristics were investigated. The mechanical properties of the unreinforced alloy and composites, such as hardness and tensile strength, have been measured.

SouravKayala et al (2012) [40] The impact of silicon carbide on the mechanical characteristics of LM6 alloy matrix composites was investigated. Tensile properties and hardness tests were used to determine the as cast MMC's tensile strength, modulus of elasticity, and hardness. The experimental results show that increasing the weight % of silicon carbide particles in the matrix metal improves the tensile characteristics and hardness of the as cast composites.

EXPERIMENTAL METHODOLOGY

3.1 MATERIALS AND EQUIPMENTS

The materials and equipment required for this experiment includes Aluminum alloy, Silicon carbide powder, Melting Furnace, Stirrer, Grinding Machine, Vickers Hardness Testing Machine, Universal Testing Machine(UTM), Charpy Impact Testing Machine

3.2 EXPERIMENTAL PROCEDURE

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3.2.1 CASTING PROCESS fficult or expensive to create using other procedures. Rather than fabricating by combining multiple small parts, heavy equipment such as machine tool beds and ship propellers can be readily cast in the needed size.

The various steps involve in a casting process are;

i) Melting of the matrix material

ii) Preheating of reinforcement in different a furnace to remove moisture and impurities

iii) stirring and pouring of reinforcement through the feeder

iv) The molten mixture is then poured in preheated mold and kept for natural cooling and solidification.

FIG 3.1 Melting of the Aluminum in a furnace

FIG 3.2 Heating of the Aluminum in a furnace

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FIG 3.3 Melted Aluminum alloy with silicon carbide powder (stirred)

FIG 3.4 Pouring of the composite in a former

FIG 3.5 Cooled

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Aluminum Composite

The cast specimens of the composites are then prepared for Testing through, turning, grinding, polishing, etching milling etc. Tensile, Hardness and Impact tests were carried out on all the specimens. Micro-structural examination was also done.

RESULTS AND DISCUSSIONS

	Length (mm)	Thickness (mm)	Width (mm)	Diameter (mm)	Maximum Tensile stress (MPa)
1	28.00000			4.00000	234.90477
Mean	28.00000			4.00000	234.90477
Standard Deviation	-----			-----	-----

Table 4.1.1 Dimension of control specimen (100% Al)

	Load at Maximum Tensile stress (N)	Tensile strain at Maximum Tensile stress (mm/mm)	Tensile extension at Maximum Tensile stress (mm)	Energy at Maximum Tensile stress (J)	Tensile stress at Break (Standard) (MPa)
1	2951.90029	0.05862	1.64150	2.59716	234.90477
Mean	2951.90029	0.05862	1.64150	2.59716	234.90477

Table 4.1.2 Tensile Analysis test result of control specimen (100% Al)

	Load at Break (Standard) (N)	Tensile strain at Break (Standard) (mm/mm)	Tensile extension at Break (Standard) (mm)	Energy at Break (Standard) (J)	Tensile stress at Yield (Zero Slope) (MPa)	Modulus (E-modulus) (MPa)
1	2951.90029	0.05862	1.64150	2.59716	234.90477	14550.81329
Mean	2951.90029	0.05862	1.64150	2.59716	234.90477	14550.81329
Standard Deviation	-----	-----	-----	-----	-----	-----

Table 4.1.3 Tensile Analysis test result of control specimen (100% Al)

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Discussions:

Table 4.3: Vicker's Hardness Test result

S/N	Sample Identification	Test1(HV)	Test 2 (HV)	Test 3(HV)	Average (HV)
1	Control	104.2	98.1	98.3	100.2
2	98%AI, 2%SIC	109.3	112.0	110.2	110.5
3	96%AI, 4% SIC	129.1	127.3	130.0	128.8
4	94%AI, 6%SIC	118.9	122.1	120.2	120.4
5	92%AI, 8%SIC	126.0	127.2	125.4	126.2
6	90%Al,10%SIC	135.3	136.0	134.9	135.4

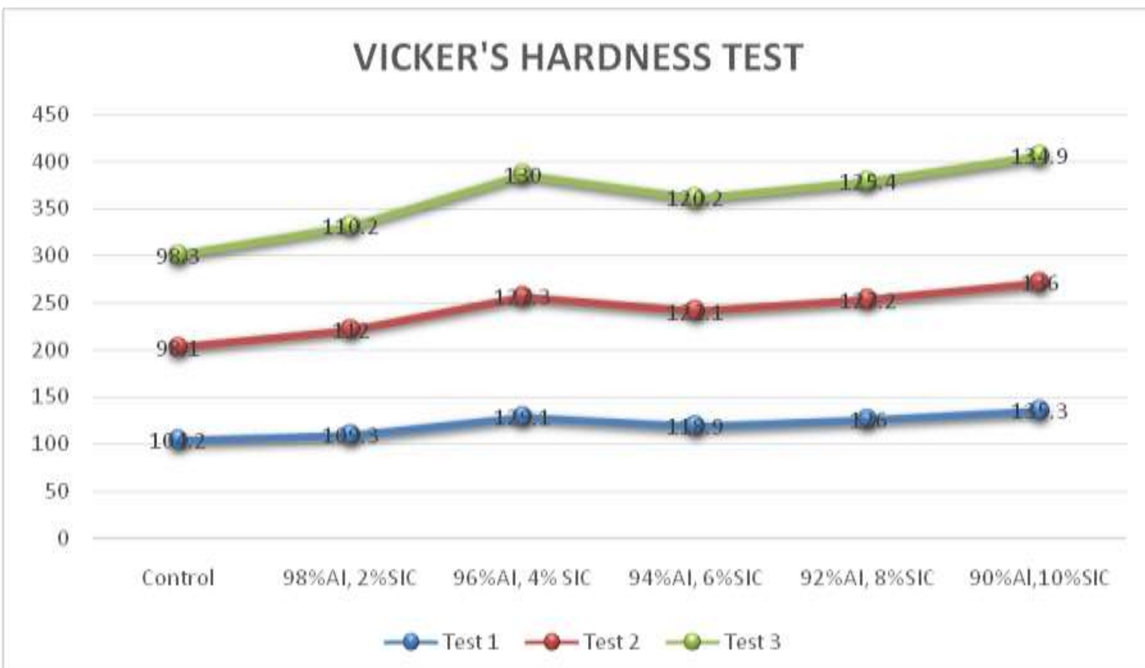

Fig 4.3: Vicker's Hardness Test result

4.1.2 IMPACT TEST

The results obtained from impact test conducted using the Charpy test method and three indentations are presented in Table 4.4.

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S/N	Sample Identification	Test 1(J)	Test 2 (J)	Test 3(J)	Average(J)
1	Control	12.21	11.99	12.18	12.13
2	98%AI, 2%SIC	12.06	12.10	11.97	12.04
3	96%AI, 4% SIC	11.48	11.57	11.51	11.52
4	94%AI, 6%SIC	11.90	11.61	11.53	11.68
5	92%AI, 8%SIC	11.18	11.00	11.12	11.10
6	90%Al,10%SIC	10.49	10.44	10.51	10.48

Table 4.4 Charpy impact test result

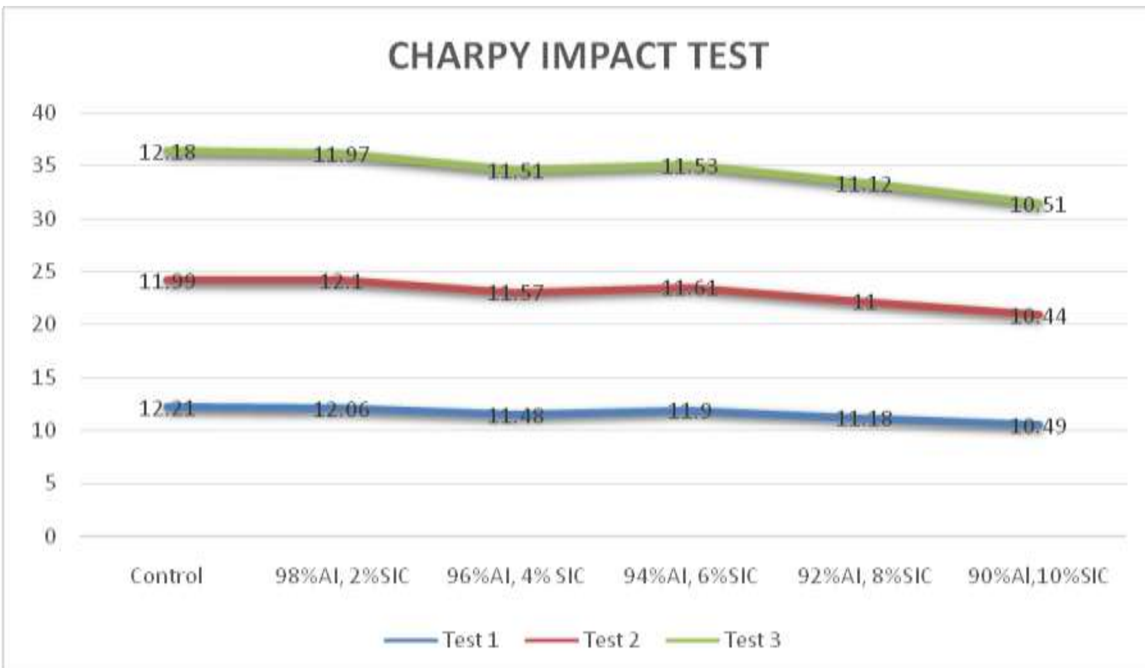

Fig 4.4 Charpy impact test result

DISCUSSION OF RESULT

The results of the tensile strength test are shown in Table 4.1.1 through Table 4.2.3 when the samples composition of Silicon was increased. The highest ultimate tensile strength values were obtained in samples which contains 90% of Al, 10% Silicon. The corresponding ultimate tensile strength was 171.85 MPa. Similarly the yield strength obtained was 171.85 MPa, fracture stress at 170.59 MPa. The values for the control system are ultimate tensile strength 234.90 MPa and yield strength of 234.90 MPa, fracture stress of 234.90 MPa. Samples with 90% Al , 10% SiC showed a marginal increase in reduced strengths (ultimate and yield strength) when compared to the values for the control sample. The values of tensile strength are influenced by the microstructure of the aluminum alloy sample, which are controlled by the addition of Silicon. In contrast to the behaviour of the control sample specimen, specimens with 10% SiC exhibited high values tensile strength at the same time maintaining high tensile strain values. This show that the high strength produced is due to the effectiveness of the increased Silicon Content.

4.2.2 VICKER'S HARDNESS TEST

The results are presented also in graphical form (Figure. 4.3). The homogenous distribution of the fine precipitate of copper, in Aluminum matrix is largely responsible for the hardness of aluminum alloy. The hardness of the aluminum alloy specimens mixed with Silicon increased in comparison to the control specimen. This is as a result of the fact that the specimen alloy is no longer in "equilibrium" which precipitate silicon. The hardness of the aluminum alloy increased significantly as compared to the control sample. With the 90% Al, 10% SiC having the highest hardness of 135.4 compared to 100.2 of the control sample on an average.

4.2.3 IMPACT TEST (CHARPY)

The results for the impact test are shown in Table 4.4 and graphically shown in fig 4.4. The treated samples in all cases show a remarkable decrease in the toughness when compared to a value of 12.13 Joules for the control sample. However, the sample with 90% Al , 10% SiC has the lowest value of 10.48 Joules.

4.2.4 MICROSTRUCTURE EXAMINATION

The result of micro-structural examination of the specimens shows that the specimens with 90% Al,10% SiC show higher values of ultimate tensile strength as shown in Table 4.1.1 through Table

4.2.3. This is associated with fine precipitates, which impact improved strength as compared to other specimens, which have a little coarse dispersion of precipitates. The changes in structure of the specimen are associated with addition of the silicon component as the 100% Al grains appear to be more finely and other specimens grain appear to be more coarse as the silicon content increased up to 10%.

The very low composition of silicon could be said to be responsible for the fine microstructure observed in the control specimen. The precipitates are also uniformly distributed in Aluminum matrix. Generally, hardness and strength increase as grain size decreases. Both properties are proportional to the reciprocal of the square root of the average grain diameter.

4.2.4 SPECTROMETRY ANALYSIS OF CONTROL SPECIMEN

		Al	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Zn**	**Cr**
		99.01	0.227	0.469	0.0501	0.0344	0.0489	0.0609	0.0195
Avg	**Avg**	98.75	0.288	0.482	0.0549	0.0329	0.0490	0.0200	0.0617
SD	**SD**	0.0285	0.4839	0.1971	0.4981	0.0118	0.0144	0.0611	0.0008

	Ni	**Ti**	**Sr**	**Zr**	**V**	**Ca**	**Be**
	<0.000	<0.005	<0.000	<0.000	<0.005	0.0060	<0.000
Avg	<0.000	<0.005	<0.001	<0.000	<0.009	0.0008	<0.000
SD	0.0000	0.0000	0.0002	0.0000	0.0045	0.0049	0.0000

The microphotograph of specimens is presented in the figures below;

Fig 4.5 Microstructure of control (100% Al)

Fig 4.6 Microstructure of test specimen (98% Al, 2% SiC)

Fig 4.7 Microstructure of test specimen (96% Al, 4% SiC)

Fig 4.8 Microstructure of test specimen (94% Al, 6% SiC)

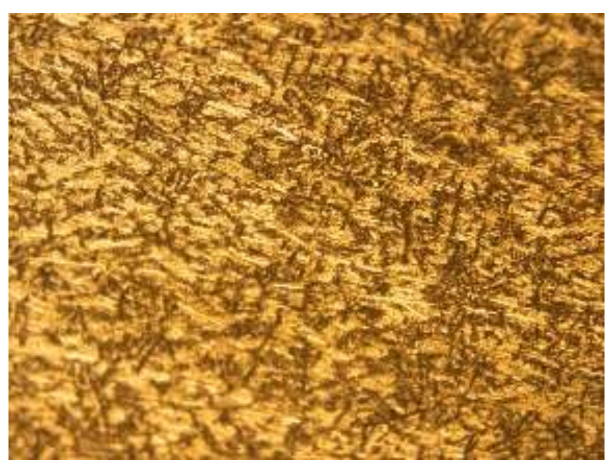

Fig 4.9 Microstructure of test specimen (92% Al, 8% SiC)

Fig 4.10 Microstructure of test specimen (90% Al, 10% SiC)

Conclusion

The study on the effect of various percentage addition of Silicon to Aluminium matrix alloy was conducted and attempt was made to relate mechanical properties to microstructure. As a result of this investigation, the following conclusions were made regarding the effect of several silicon percentages on the alloy. Increase silicon content was found in improved insoluble precipitates in the alloy, and the silicon content of the aluminum matrix also contributed to the formation of fine precipitates. The Specimen with 90% Al, 10% SiC proved to have considerably improved properties. Improvements in properties may be correlated with a more refined metallurgical structure. High values of strength, hardness and notch strength were typically associated with fine precipitate distribution.

Careful choice of Silicon and Aluminum content in the matrix were effective in producing desired mechanical properties. The study shows a correlative increase in strength as the percentage of silicon is increased, it can be deducted that more percentage increase will yield an aluminum matrix that has considerably high tensile strength compare to the control specimen. Also an increase in the hardness with accompanying decrease in toughness is noticeable as the silicon content is increased.

REFERENCES

[1] Bartakke Nikhil N, ChivelkarAmeya,DevrukhkarVaibhavl,JamsutkarSahil,RajnituRakshaskhar.Mechanical properties of AluminiumAlumina composite by varying the percentage of Alumina. ISSN 2320-2092 volume 4,issue 6 IJMPE (2016).

[1b] R. M. Jones, Mechanics of composite materials, Second Edi. CRC press, 1998.

[2] A. K. Kaw, Mechanics of composite materials. CRC press, 2006.

[3] J. Fan and J. Njuguna, "An introduction to lightweight composite materials and their use in transport structures," Light. Compos. Struct. Transp., pp. 3-34, 2016.

[4] P. P. Adrian and B. M. Gheorghe, "Manufacturing process and applications of composite materials," Fascicle Manag. Technol. Eng., vol. 9, no. 19, pp. 3.1-3.6, 2010.

[5]. P. O. Babalola, C. A. Bolu, A. O. Inegbenebor, and K. M. Odunfa, "Development of aluminium matrix composites?: A review," Online Int. J. Eng. Technol. Res., vol. 2, pp. 1-11, 2014.

[6]. G. S. Cole and A. M. Sherman, "Lightweight materials for automotive applications," Mater. Charact., vol. 35, pp. 3-9, 1995.

[7]. U. Cocen and K. Onel, "Ductility and strength of extruded SiCp/aluminium-alloy composites," Compos. Sci. Technol., vol. 62, pp. 275-282, 2002.

[8]. Y. Sahin, "Preparation and some properties of SiC particle reinforced aluminium alloy composites," Mater. Des., vol. 24, pp. 671-679, 2003.

[9]. I. M. El-Galy, M. H. Ahmed, and B. I. Bassiouny, "Characterization of functionally graded Al-SiCp metal matrix composites manufactured by centrifugal casting," Alexandria Eng. J., 2017.

[10]. B. Venkataraman and G. Sundararajan, "The sliding wear behaviour of Al-SiC particulate composites-I. Macrobehaviour," Acta Mater., vol. 44, no. 2, pp. 451-460, 1996. [11]. T. Ozben, E. Kilickap, and C. Orhan, "Investigation of mechanical and machinability properties of SiC particle reinforced Al-MMC," J. Mater. Process. Technol., vol. 198, pp. 220-225, 2008.

[12]. T. B. Rao, "An experimental investigation on mechanical and wear properties of Al7075/SiCp composites: effect of SiC content and particle size," J. Tribol., 2017.

[13]. S. Ozden, R. Ekici, and F. Nair, "Investigation of impact behaviour of aluminium based SiC particle reinforced metal-matrix composites," Compos. Part A Appl. Sci. Manuf., vol. 38, pp. 484-494, 2007.

[14]. K. L. Meena, A. Manna, and S. S. Banwait, "An analysis of mechanical properties of the developed Al/SiC-MMC's," Am. J. Mech. Eng., vol. 1, no. 1, pp. 14-19, 2013.

[15]. M. B. Karamis, A. Tasdemirci, and F. Nair, "Failure and tribologicalbehaviour of the AA5083 and AA6063 composites reinforced by SiC particles under ballistic impact," Compos. Part A Appl. Sci. Manuf., vol. 34, pp. 217-226, 2003.

[16]. M. Uzkut, "Abrasive wear behaviour of SiCp-reinforced 2011 Al-alloy composites," Mater. Technol., vol. 47, no. 5, pp. 635-638, 2013.

[17]. A. H. Idrisi and A. I. Mourad, "Fabrication and wear analysis of aluminium matrix composite reinforced by SiC micro and nano particles," in Proceedings of the ASME 2017 Pressure Vessels and Piping Conference, 2017, pp. 1-8.

[18]. I. Manivannan, S. Ranganathan, S. Gopalakannan, S. Suresh, K. Nagakarthigan, and R. Jubendradass, "Tribological and surface behavior of silicon carbide reinforced aluminum matrix nanocomposite," Surfaces and Interfaces, 2017.

ISSN: 3141-6071

[19]. A. T. Erturk, M. Sahin, and M. Aras, "Tribological behavior of SiC particulate reinforced AA5754 matrix composite under dry and lubricated conditions," Trans. Indian Inst. Met., 2016.

[20]. S. Pradhan, S. Ghosh, T. K. Barman, and P. Sahoo, "Tribological behavior of Al-SiC metal matrix composite under dry , aqueous and alkaline medium," Silicon, 2017.

[21]. S. Pradhan, T. K. Barman, P. Sahoo, and G. Sutradhar, "Effect of SiC weight percentage on tribological properties of Al-SiC metal matrix composites under acid environment," J. Tribol., vol. 13, pp. 21-35, 2017.

[22]. P. Sadagopan, H. K. Natarajan, and P. K. J, "Study of silicon carbide-reinforced aluminum matrix composite brake rotor for motorcycle application," Int J AdvManufTechnol, 2017.

[23]. S. Das, "Development of aluminium alloy composites for engineering applications," Trans. Indian Inst. Met., vol. 57, no. 4, pp. 325-334, 2004.

[24]. S. M. S. Kumar, K. P. Rao, and D. P. Girish, "Corrosion-erosion wear analysis of Al/SiC metal matrix composites by taguchi's technique," Int. J. Adv. Eng. Technol., vol. 4, no. 1, pp. 23-26, 2013.

[25]. M. Ramachandra and K. Radhakrishna, "Sliding wear, slurry erosive wear, and corrosive wear of aluminium/SiC composite," Mater. Sci., vol. 24, no. 2/1, pp. 333-349, 2006.

[26]. S. V. S. N. Murty, B. N. Rao, and B. P. Kashyap, "On the hot working characteristics of 6061Al-SiC and 6061-Al2O3 particulate reinforced metal matrix composites," Compos. Sci. Technol., vol. 63, pp. 119-135, 2003.

[27]. D. J. Lloyd, H. Lagace, A. McLeod, and P. L. Morris, "Microstructural aspects of aluminium-silicon carbide particulate composites produced by a casting method," Mater.

Sci. Eng. A, vol. 107, pp. 73-80, 1989.

[28]. A. Razaghian, D. Yu, and T. Chandra, "Fracture behaviour of a SiC-particulate-reinforced aluminium alloy at high temperature," Compos. Sci. Technol., vol. 58, pp. 293-298, 1998.

[29]. S. M. L. Nai and M. Gupta, "Synthesis and characterization of free standing , bulk Al/SiCp functionally gradient materials?: effects of different stirrer geometries," Mater. Res. Bull., vol. 38, pp. 1573-1589, 2003.

[30]. Z. Z. Chen and K. Tokaji, "Effects of particle size on fatigue crack initiation and small crack growth in SiC particulate-reinforced aluminium alloy composites," Mater. Lett., vol. 58, pp. 2314-2321, 2004.

[31] M. Patel, B. Pardhi, M. Pal, and M. Singh, "SiC Particulate Reinforced Aluminium Metal Matrix Composite", Adv. J. Grad. Res., vol. 5, no. 1, pp. 8-15, Sep. 2018. Doi: 10.21467/ajgr.5.1.8-15

[32] Muzakkir Ahmed Khan ,"An overview on effect of reinforcement and process parameters of aluminium based metal matrix composites.ISSN 2320-9364(IJRES).

[33] R Venkatesh, DrVaddiseshagiri Rao, "Preparation of Al-SiC metal matrix composites and evaluation of its properties ISSN 2319-1058 Volume 6 issue 3 (IJIET) 2016.

[34] S.Basavarajappa, G.Chandramohan, A. Dinesh (2004) Mechanical properties of mmc's an experimental investigation.

[35] Tamer Ozben, ErolKilickap, Orhan C ak?r(2008)¸ Investigation of mechanical and machinability properties of SiC particle reinforced Al-MMC, 198 (2008) pp. 220– 225.

[36] H.C. Anilkumar, H.S. Hebbar and K.S. Ravishankar (2010), Mechanical properties of fly

ash reinforced aluminium alloy (Al6061) composites, vol.6, No.1, 41-45.

[37] Chennakesava Reddy. A, EssaZitoun(2010), Tensile behavior of 6063/Al2o3 particulate metal matrix composites fabricated by investment casting process, vol. 1, No 3.

[38] A.R. K. Swamy, A. Ramesh, G.B. Veeresh Kumar, J. N. Prakash(2011), effect of particulate reinforcements on the mechanical properties of Al6061-WC and Al6061-Gr MMC's, vol. 10, No. 12, pp. 1141-1152.

[39] Madhu Kumar YC, Uma Shankar (2012) Evaluation of Mechanical Properties of Aluminum Alloy 6061-Glass Particulates reinforced Metal Matrix Composites,Vol.2, and Issue.5 pp-3207-3209.

[40] SouravKayala, R. Beherab, G.Sutradhara (2012), Mechanical properties of the as-cast silicon carbide particulate reinforced Aluminium alloy Metal Matrix Composites, ISSN 2277 – 4106, pp 318-322.