TEST Engineering & Management

January - February 2020
ISSN: 0193 - 4120 Page No. 14360 - 14367

Development, Manufacture and Characterization of Al-Si based wear Resistant Material

V. Gnanasekaran[1], V. Leela Vinodhan[2], P. Ramesh[3], P. Arun karthick[4]

[1,3]Assistant Professor, Mechanical Engineering, AMET, Chennai.
[2] Associate Professor, Mechanical Engineering, AMET, Chennai.
[4]Assistant Professor, Mechanical Engineering, Sri Krishna College of Technology, Coimbatore.

Article Info
Volume 82
Page Number: 14360 - 14367
Publication Issue:
January-February 2020

Article History
***Article Received**: 18 May 2019*
***Revised**: 14 July 2019*
***Accepted**: 22 December 2019*
***Publication**: 28 February 2020*

Abstract

Alloys of Aluminium and Silicon (Al-Si) found to be a potential replacement material due to the less weight (approximately one third compared to the steel and gray cast iron), lower production cost, machinability, mechanical properties and ability of recycling. However, one of the major limitation of these alloys is low wear resistance. In order to improve its wear characteristic many Particle reinforced Aluminium Matrix Composites (PAMCs) were developed using SiC, TiC, B_4C, $TiB_{2,}$ Gr, $MoS_{2,}$ and fly ash as reinforcement particles by different methods (Stir casting, Compo casting, Powder Metallurgy, *in-situ* method using salts and spray deposition) and their wear characteristics were also studied But there is no research work done on wear characteristics of semisolid processed PAMCs. So a Metal Matric composites (MMC) of Aluminium A356 reinforced with 5%TiB_2 was developed by semi solid process and its dry sliding wear characteristic were studied using pin on disc machine with disc material of EN31 steel (55-60 HRC) under the condition at sliding velocity varies from 1m/s to 3m/s and applied load varies from 10N to 30N at constant sliding distance 3000m.A comparative study was done between A356 alloy, A356-5%TiB_2 *in-situ* composite and Semisolid processed alloy, composite it was found that semisolid processed alloy and composite shows more wear than commercial alloy and *in-situ* composite.

Keywords: *in-situ MMCs Al, Thixoforming , Dry sliding wear, Taguchi techniques.*

I. INTRODUCTION

The advantages of the MMCs were higher strength-to-weight ratio, excellent dimensional stability, elevated temperature stability, enhanced cyclic fatigue characteristics. The advantages of MMCs over PMCs were higher - strength, stiffness, service temperatures, electrical conductivity, thermal conductivity, improved transverse properties, better joining characteristics, radiation survivability, tiny or no contamination. Wear is the common industrial problems result in replacement of parts and assemblies in engineering. [1]

Wear is due to the following actions such as abrasive, adhesive, erosion, fretting and chemicals. Wear is mainly due to abrasive upto 55% and adhesive upto 15% [2]. Applications of Aluminium alloys are commonly used in the transport, production and construction. Aluminium MMCs becomes the choice of material in Naval vessel manufacturing due to its benefits like good corrosion resistance, thermal properties, better electrical conductivity and good mechanical properties [3]. The wear behavior of aluminium alloys can be enhanced by addition of reinforcement either by ex-situ or in-situ [4-8]. Moving parts in internal combustion engines with dry and lubricated contact were manufactured in hypoeutectic & hypereutectic Al-Si alloys. Wear rate decrease and load carrying capacity increases with higher percentage of silicon content [9]. The wear rate of hypoeutectic Al-Si

January - February 2020
ISSN: 0193 - 4120 Page No. 14360 - 14367

alloy is less than the wear rate of hypereutectic alloy [9,10].

Wear rate of A356-SiCp decreases with increase in SiCp on Pin on Disc experiment at load 192N, sliding speed 1 to 5m/s and sliding distance 15 Km [11]. The eutectic alloys possess the lowest wear rate in comparison with all Al-Si alloy system and the wear is mild when applied load is less than 35N and sliding speed 5.8m/s in Pin on Disc experiment [12]. During wear test of the Al-7Si alloy different wear observed were delaminative wear, oxidative wear and abrasive wear [13]. The behaviour of aluminium reinforced with TiB2 exhibited better mechanical properties than the TiC, SiC and B4C [14]. Mechanical properties of A356 is improved by compo casting than in stir casting [15]. The in-situ techniques to fabricate aluminium based composite has improved the adhesion at interface and its mechanical properties [16]. The presence of TiB2 greater than 2.5% in T6 treated A356 increase co-efficient of friction at sliding speed 1m/s and 1800m of sliding distance for varying loads (19.6-78.4 N) in Pin on Disc experiment not varying the sliding velocity [17]. Thixoformable alloys should have solidification interval range between 50-100¬0C, Temperature sensitivity at 0.4 fraction liquid is around 0.03/0C [18].

This paper presents the wear behavior of dry sliding A356-TiB2 MMCs synthesized by an semisolid processing technique thixoforming which is used to manufacture near net shape components.

II. FABRICATION WORK

A. Fabrication Process

The A356 – 5% TiB2 Composite was prepared by in-situ process using K2TiF4 and KBF4 salts. The synthesis of composite is based on work done in [17]. The composite was prepared by regular stirring the mixture at 10 minutes intervals for 60 minutes in electric resistant furnace then the melt is poured into moulds and allowed to solidify. The semisolid processed composite is made by thixoforming process where the in-situ composite is reheated to 5930c and hold for 40 min to obtain non-dendrite structure then this reheated composite is poured into high pressure die for forming process at semisolid state. semisolid processed A356 alloy is also prepared by same process.

B. Material Properties

The elemental composition of as cast A356 alloy is shown in Tab1e I

TABLE I

Chemical composition of A356 alloy

Alloying Elements	Si	Fe	Mn	Mg	Ti	Al
Percentage (%)	7.01	0.406	0.0430	0.760	0.0610	91.4%

The micro Vickers hardness of Alloy and composite are obtained at 200g load for dwell time of 10s, hardness value is shown in Table III which shows there is increase in hardness value between as cast and thixoformed alloy and composite. The reason is due to formation of non-dendrite structure which is absent in alloy and in-situ composite which is shown in Fig 1.The density of the alloy and composite are measured by Archimedes principle the value of densities are shown in Table II.

TABLE II

Hardness and Density of Materials

S.no	Materials	Micro Hardness (VHN)	Density (g/cm^3)
1	A356 alloy	71	2.649
2	THIXOFORMED A356 alloy	76.3	2.698
3	A356-5%TiB_2	81	2.848
5	THIXOFORMED A356-5%TiB2	103	2.845

Published by: The Mattingley Publishing Co., Inc.

January - February 2020
ISSN: 0193 - 4120 Page No. 14360 - 14367

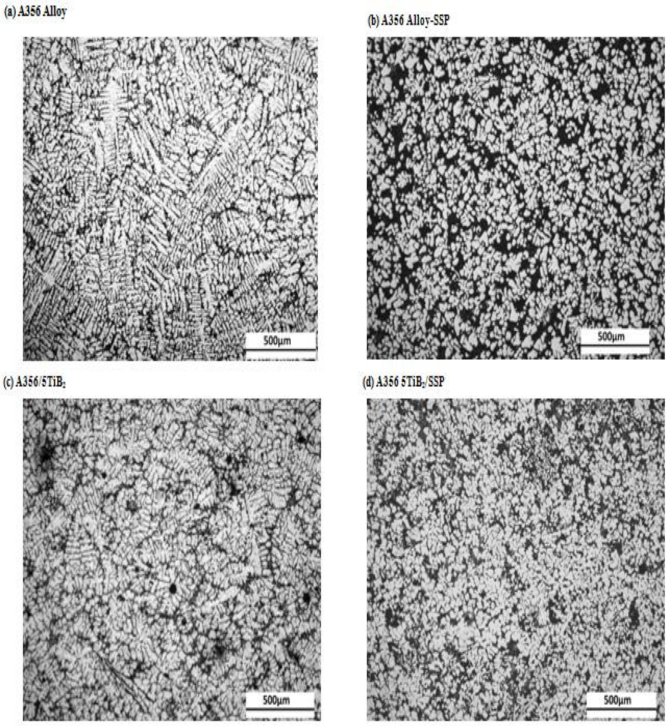

Fig.1 Optical Micro structure of Alloy (a, b) and Composite (c, d)

There is slight increase in density in range of (0.005-0.050) for thixoformed composite and alloy.

C. Experimental Details

Pin on Disc machine is used to characterise the dry sliding wear behavior of the materials. Dry sliding wear test were conducted according to ASTM standard G99-04a.A cylindrical pin of dia 8mm and height 25mm is prepared for A356 alloy, in-situ A356-5%TiB2 ,thixoformed A356 alloy and thixoformed A356-5%TiB2 composite for wear test .The disc material is En31 steel (55-60 HRC) . Trail experiment was carried out in A356 alloy at sliding velocity 5m/s, sliding load 50 N and sliding distance 3000m and it was found that A356 alloy undergo severe adhesive wear called Galling as shown in Fig.2(a) and Fig.2(b) at 1000m on further continuation of experiment leads to seizure phenomenon. So, the significant parameter which affect wear property are Load and Sliding Velocity

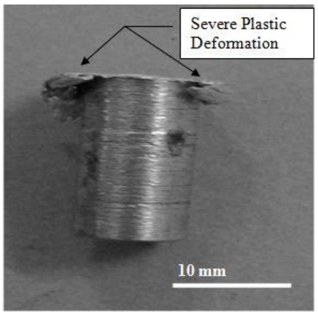

Fig.2(a) Galling in Pin

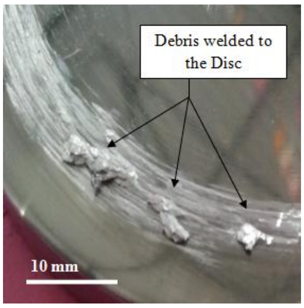

Fig.2(b) Galling in Disc

Taguchi L9 orthogonal array is used for characterize the dry sliding wear behaviour of the materials where sliding velocity and load were taken as significant factor which varies from 1m/s to 3m/s and 10N to 30N respectively. As shown in Table III.

TABLE III

L9 Orthogonal array

S.no	Sliding Velocity(m/s)	Load(N)
1	1	10
2	1	20
3	1	30
4	2	10
5	2	20
6	2	30
7	3	10
8	3	20
9	3	30

III. RESULTS

A . Wear test

The effect of load and sliding velocity on wear rate is shown in Fig.3 which shows that wear rate of in-situ A356-5%TiB2 is lesser than A356 alloy and the wear rate of thixoformed A356 alloy and

Published by: The Mattingley Publishing Co., Inc.

TEST Engineering & Management

January - February 2020
ISSN: 0193 - 4120 Page No. 14360 - 14367

thixoformed composite has greater wear rate than commercial A356 alloy whereas increase in velocity decrease the wear rate. The impact of load on co-efficient of friction is shown in Fig.4(a) which shows that all four materials have average co-efficient of friction ranges from (.3 to .5) even on addition of TiB2 particles.

The decrease in wear rate in in-situ composite than alloy is due to existence of secondary phase such as Si and TiB2¬¬ as shown in fig.5(a) which confines the flow of metal during sliding [18]. Increase in wear rate in thixoformed A356 alloy is due to breakage of Silicon needles which tends to increase the ductility of the material which is shown in fig.6(a).Wear rate of all four material shows that increase in load will increase the wear rate but increase in velocity decrease the wear rate which is due to decrease in contact time between pin and disk to form micro welds on the disc surface, if the velocity is low micro welds will form which restricts the sliding movement of pin at contact surface which leads to removal of material and formation of grooves on pin.[18]

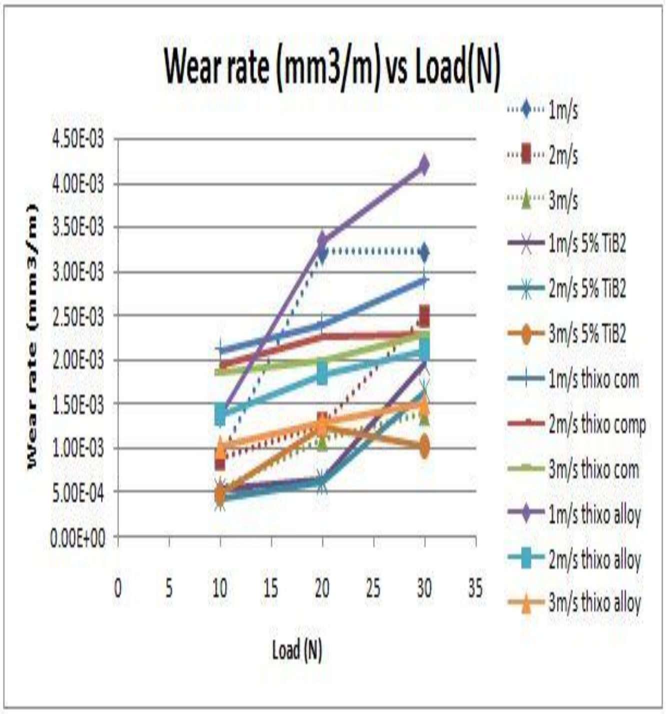

Fig.3 Wear rate vs Load

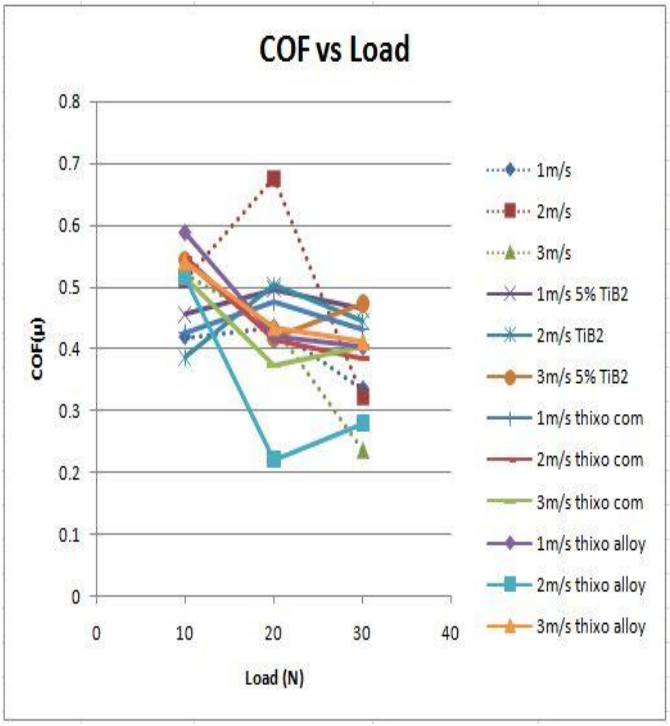

Fig.4(b) COF vs Load

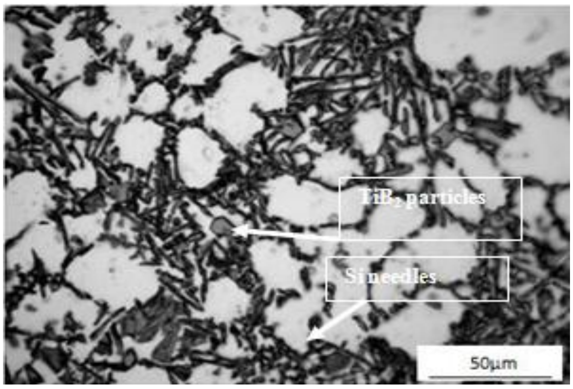

Fig.5(a) Optical Micro structure of in-situ A356-5%TiB2

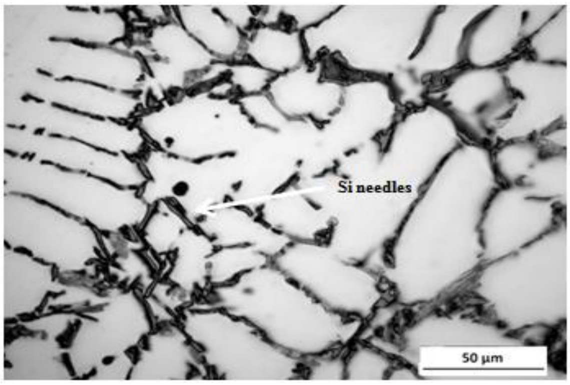

Fig.5(b) Optical Micro structure of A356 alloy

Published by: The Mattingley Publishing Co., Inc.

January - February 2020
ISSN: 0193 - 4120 Page No. 14360 - 14367

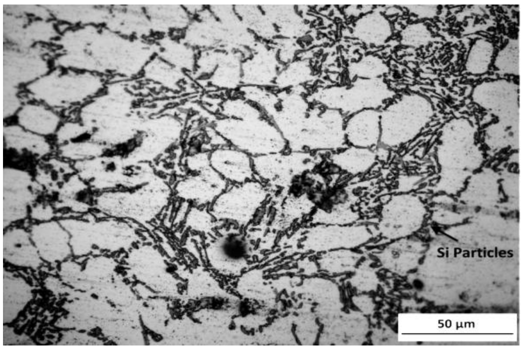

Fig.6 (a) Optical Micro structure of Thixoformed A356 alloy

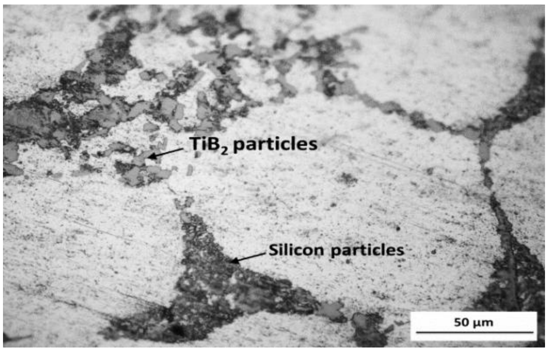

Fig.6 (b) Optical Micro structure of Thixoformed A356-5%TiB2

From Fig.5(a),(b) and Fig.6 (a),(b) we can see that the size of silicon needles get reduced which is smaller in Semisolid processed alloy and composite because of high pressure used in thixoforming. This breakage leads to increase the wear rate.

B. Mini Tab Results

Taguchi L9 orthogonal array is used to characterize the wear behavior of the all four materials. The wear rate and COF of four materials is shown in below Table IV

Table .IV

Wear rate and COF of four Materials

S.no	sliding velocity (m/s)	Load(N)	A356 alloy		A356-5%TiB$_2$		THIXOFORMED A356 alloy		THIXOFORMED A356-5%TiB$_2$	
			Wear rate (mm^3/m)	COF (µ)	Wear rate (mm^3/m)	COF (µ)	Wear rate (mm^3/m)	COF (µ)	Wear rate (mm^3/m)	COF (µ)
1	1	10	8.92E-04	0.41950	5.27E-04	0.455500	1.36E-03	0.5870	2.11E-03	0.4260
2	1	20	3.21E-03	0.43525	6.32E-04	0.496750	3.34E-03	0.4200	2.40E-03	0.4760
3	1	30	3.22E-03	0.33466	1.95E-03	0.464160	4.20E-03	0.4030	2.91E-03	0.4311
4	2	10	8.79E-04	0.51200	4.21E-04	0.386600	1.38E-03	0.5155	1.94E-03	0.5470
5	2	20	1.26E-03	0.67500	6.20E-04	0.503250	1.84E-03	0.2207	2.26E-03	0.4145
6	2	30	2.49E-03	0.32233	1.64E-03	0.444000	2.10E-03	0.2791	2.28E-03	0.3830
7	3	10	5.45E-04	0.52100	4.80E-04	0.542500	1.01E-03	0.5395	1.85E-03	0.5160
8	3	20	1.09E-03	0.43725	1.24E-03	0.417368	1.27E-03	0.4355	1.98E-03	0.3740
9	3	30	1.39E-03	0.23660	1.02E-03	0.473500	1.50E-03	0.4121	2.28E-03	0.4040

Wear rate and co-efficient of friction of A356 alloy is less at 3m/s and 30N as shown in Fig .7.

Published by: The Mattingley Publishing Co., Inc.

January - February 2020
ISSN: 0193 - 4120 Page No. 14360 - 14367

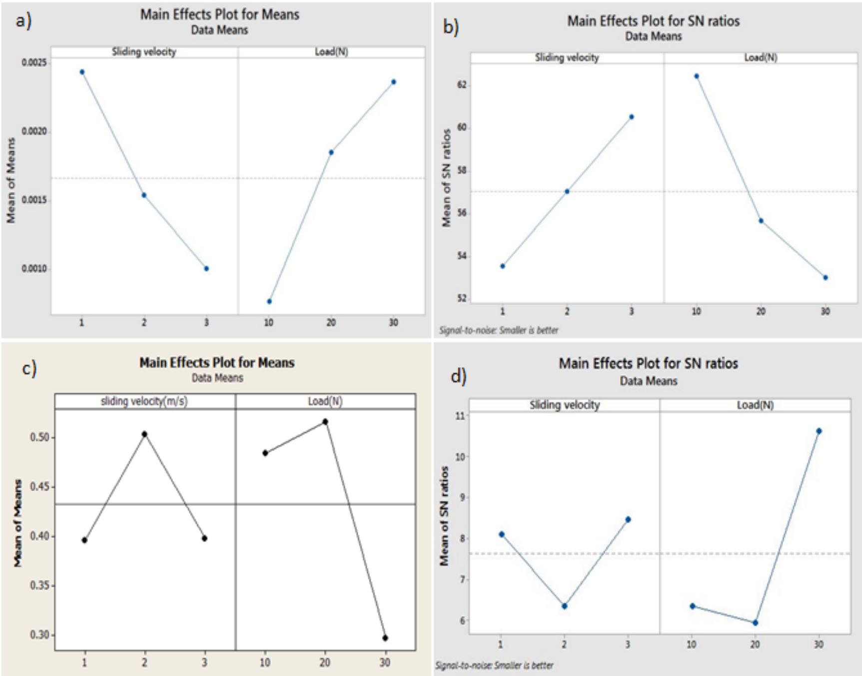

Fig.6 Main effects plot for means a)Wear rate, c) COF, Main effect plots for SN ratio b) Wear rate, d)COF

Wear rate and Co-efficient of friction of in-situ A356-5%TiB2 composite is low at 2m/s 10N and 30N as shown in Fig.7

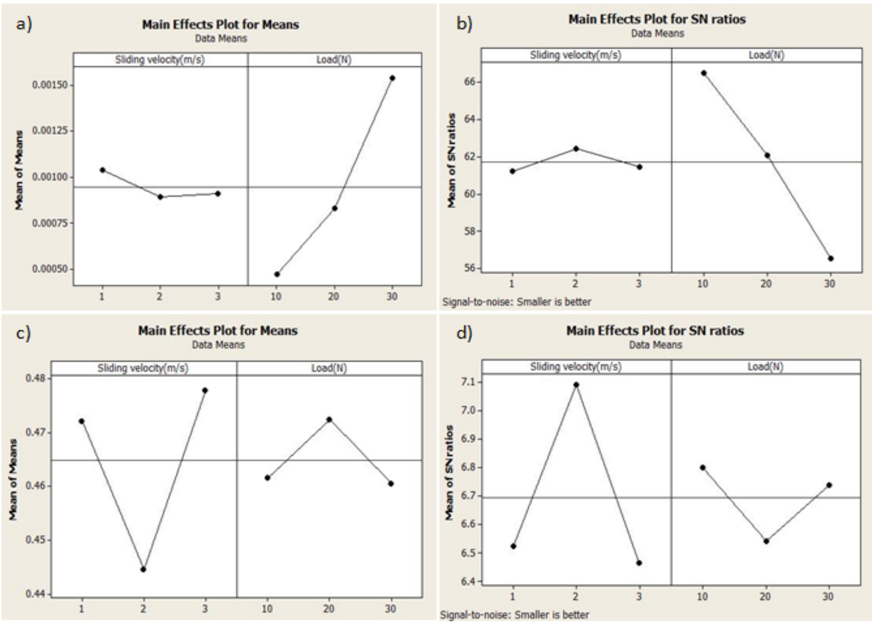

Fig.7 Main effect plot for Mean a) Wear rate, c) COF. Main effect plot for SN ratio b) Wear rate, d) COF

January - February 2020
ISSN: 0193 - 4120 Page No. 14360 - 14367

Wear rate and for thixoformed A356 alloy is less at 3m/s 10N and Co-efficient of friction is minimum at 2m/s and 20N as shown in fig.8.

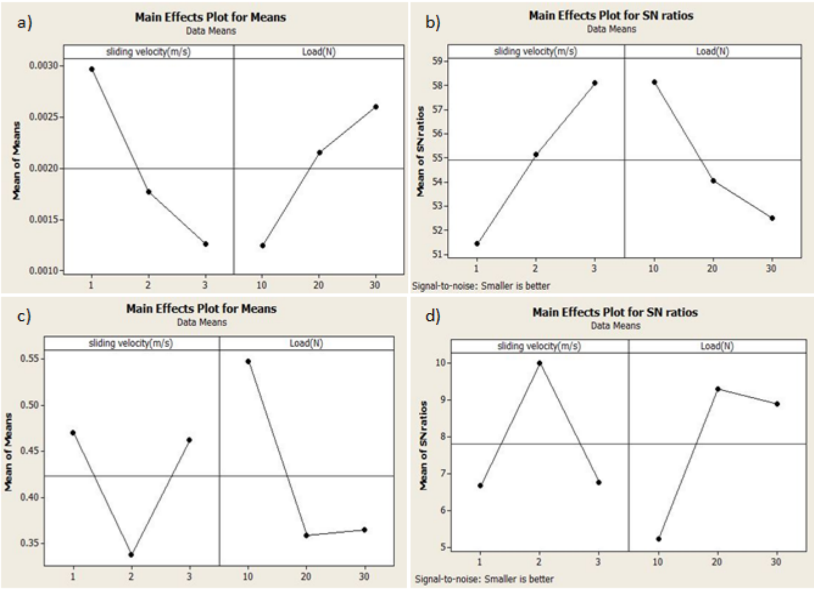

Fig.8 Main effect plot for mean a) Wear rate, b) COF, Main effect plot for SN ratio c) Wear rate, d) COF

Wear rate and Co-efficient of friction of thixoformed A356-5% TiB2 is less at 3m/s 10N as shown in Fig.9

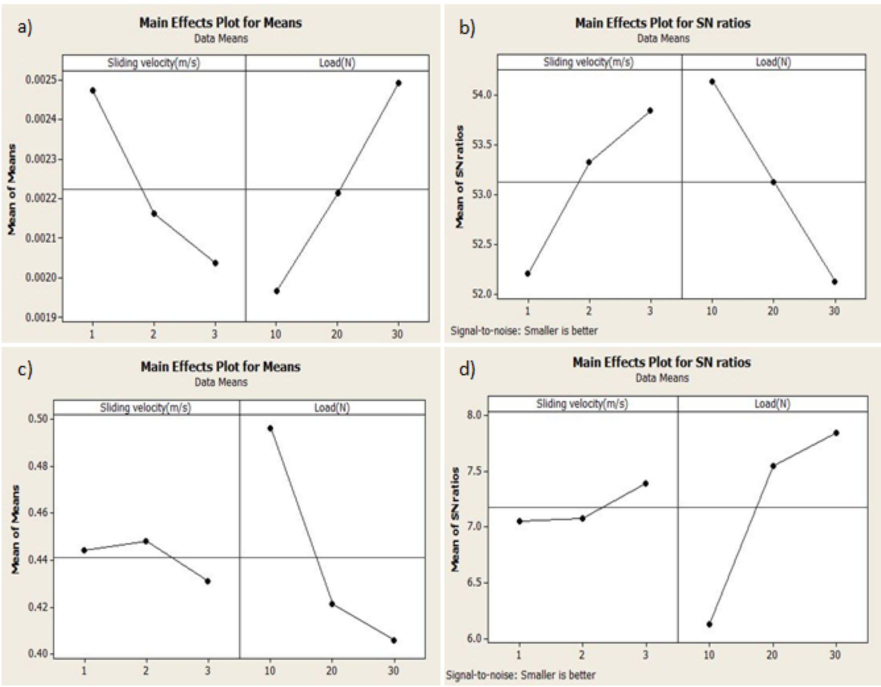

Fig.9 Main effect plot for Mean a) Wear rate, c) COF, Main effect plot for SN ratio b)Wear rate, d) COF

Published by: The Mattingley Publishing Co., Inc.

Thus from Minitab Main effect plot of Mean and S/N ratio of wear rate and co-efficient of friction shows that wear rate is significantly affected by load and sliding velocity.

IV. CONCLUSION

• Wear rate of in-situ A356-5%TiB2 is less than A356 alloy

• Wear rate is Maximum at 1m/s 30N and Minimum at 3m/s 10N

• Wear rate of thixoformed alloy and thixoformed Composite is greater than commercial alloy and in-situ composite

• Which is due to breakage of silicon needles which increase the ductility of the material

•Wear behavior of thixoformed alloy and thixoformed Composite is yet to interpret.

•Co-efficient of friction doesn't change much which is contradictory result from other research paper which require further interpretation

REFERENCE

[1] K.K.Chawla, Composite Materials: Science and Engineering, 3rd ed. Springer, 2012.

[2] T.S.Eyre, "Wear characteristics of Metals", Tribology International, Vol.9, pp.1-10, 1976.

[3] S.Suresh, N. ShenbagaVinayagaMoorthi , "Aluminium-Titanium Diboride (Al-TiB2) Metal Matrix Composites: Challenges and Opportunities" , Procedia Engineering, vol.38, pp.89-97, 2012.

[4] R.L.Deuis, C.Subramanian and J.M.Yellup, "Dry sliding wear of Aluminum Composite-A review", Composite science and Technology,vol.57,pp.415-435,1997.

[5] DS Balaji, S Prabhakaran, K Umanath "Multi-objective optimization in abrasive water jet drilling of AA6061 alloy" Journal of Advanced Research in Dynamical and Control Systems, 9 (2), 2017.

[6] Sundaraganesan, R., Prabhakaran, S., Balaji, D.S., Umanath, K. "International Journal of Mechanical and Production Engineering Research and Development" 2018.

[7] A.R.Sivaram , S.K.Krishnakumar, K.Umanath, R.Rajavel, N.Jayakumar, Experimental Study On Hardness Of Aluminium Alloy (Lm25) And ZrO2 Metal Matrix Composite , Journal of Advanced Research in Dynamical and Control Systems, S2, 877-882, 2017.

[8] K.Umanath ,Palanikumar K, Comparison Of Experimental And Predicted Wear Beahiour Of Al6061 With Al2O3P, And SicpHmmc Materials , Journal of Advanced Research in Dynamical and Control Systems, S2, 716-721, 2017.

[9] H.Torbian, J.P.Pathak and S.N.Tiwari, "Wear characteristics of Al-Si alloys", Wear, vol.172, pp.49-58, 1993.

[10] A.D.Sarkar, "Wear of Aluminium-Silicon Alloys", Wear, vol.31, pp.331-343, 1975.

[11] R.C.Shivamurthy, M.K.Surappa, " Tribological characteristic of A356 Al alloy-SiCp composite discs", Wear, vol. 271, pp. 1946-1950,2011.

[12] K.MohammedJasim, E.S.Dwarakadasa., "Wear in Al-Si alloys under dry sliding condition", Wear, vol.119, pp.119-130,1987.

[13] S.A.Kori, T.M.Chandrashekharaiah, " Studies on Dry sliding wear behaviour of hypoeutectic and eutectic Al-Si alloys", Wear, vol. 263, pp.745-755, 2007.

[14] S.Suresh, N.ShenbagaVinayagaMoorthi, S.C.Vettivel and N.Selvakumar, "Mechanical behaviour and wear prediction of stir cast Al-TiB2 composite using response surface methodology", Material and design, vol.59, pp.383-396, 2014.

[15] S.A.Sajjadi, H.R.Ezatpour and M. TorabiParizi, "Comparison of microstructure and mechanical properties of A356 aluminum alloy/Al2O3 composite fabricated by stir and compo castigprocess",Materials and Design, vol.34,pp.106-111,2012.

[16] S.Kumar, M.Chakraborty, V.SubramanyaSarma and B.S.Murty, "Tensile and Wear behaviour of in-situ Al-7Si/TiB2 particulate composite",Wear, vol.265,pp.134-142,2008.

[17] A.Mandal,B.S.Murty and M.Chakraborty , "Sliding wear behaviour of T6 treated A356-TiB2 in-situ composites", Wear, vol.266,pp.865-875,2009.

[18] LI.yuan-dong.D.Apelian,XingBo,MA Ying and HAO Yuan, "Commericial AM60 alloy for semisolid processing: Alloy optimization and thermodynamic analysis",Trans. Nonferrous Met.Soc.China,vol.20,pp.1572-1578.2010.