International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 10 Issue 9 ǁ September 2022 ǁ PP. 60-69

Wear Behaviour of Al6061-B_4C-SiC Hybrid Metal Matrix Composites

Nenavath Gajanlal Naik[a], P. Anand Kumar[b], P.Naresh[c]
[a]*Nenavath Gajanlal Naik, PG Students, Department of Mechanical Engineering GATES Institute of Technology, Gooty, A.P, Email id- venkateshnaik5871@gmail.com*
[b]*P. Anand Kumar, Assistant Professor, Department of Mechanical Engineering GATES Institute of Technology, Gooty, A.P, Email id:- anand.pasyavula@gmail.com*
[c]*P.Naresh, Assistant Professor, Department of Mechanical Engineering GATES Institute of Technology, Gooty, A.P, Email id:- poppathi@gmail.com*

ABSTRACT
The present research work focuses to develop a new composite material of aluminium alloy AA6061 as a matrix material and reinforced with silicon carbide (SiC) and B_4C with a particle size of 25µm in different weight percentages varied from 2 to 10 wt.% in steps of 2wt.% by stir casting technique. This work aimed at evaluating the mechanical, wear and machining properties of AA6061/SiC/B_4C HMMC. The abrasive wear is observed in dry sliding wear test for fabricated samples to evaluate wear, wear rate. The experiments are conducted according to taguchi design with different parameters such as wt.% of SiC, applied load, sliding velocity and sliding distance. The test samples were prepared as per ASTM standards G 90-95. It was noticed that the wear is more at higher applied load for all wt.% of SiC samples. The wear resistance is improved for AA6061/SiC/B_4C MMC compared to aluminium alloy under all experimental conditions. The wear rate is increases with the increase of applied load, sliding velocity and sliding distance.
Keywords — *AA6061/SiC/B4C; stir casting; Pin-on-disc; Taguchi; Wear.*

Date of Submission: 25-08-2022 Date of acceptance: 09-09-2022

I. INTRODUCTION

In any tribological system, when two solid surfaces are in contact, there is damage to the surface and/or subsurface. Wear is erosion or the sideways displacement of the material from its original position on a solid surface, performed by the action of another surface. Wear is correlated to interactions between surfaces and more precisely, the removal and deformation of a material on a surface as a result of the mechanical action of the opposite surface [1]. Wear can also be defined as a process, where interaction between two surfaces or bounding faces of solids within the working environment results in the dimensional loss of one solid, with or without any actual decoupling and loss of material. Aspects of the working environment which affect wear include not only loads and features such as unidirectional sliding, reciprocating, rolling, impact loads, speed and temperature.

In order to achieve the optimum properties of the metal matrix composite, several factors that have to be considered, including achieving a uniform distribution of the reinforcement material in molten matrix, improving the wettability or bonding between the matrix and reinforcement, enhancing the solid solution strengthening mechanism by interfacial chemical reactions as well as minimizing the porosity. This requires the sound theoretical and practical knowledge on the part of composite material engineers.

Naresh et al. [2] fabricated aluminium matrix composites using stir casting method. Preheated reinforcements at 475K were added to the center of the vortex formed during stirring.

Chaudhury et al. [3] produced Al-2Mg-11 TiO2 (rutile) composite using vortex method. The melt was stirred with a stirrer at a rotational speed of 200rpm. It was observed that, the addition of rutile particles tend to increase the hardness of composites.

Ipek [4] fabricated SiC reinforced 4147 Al matrix composites using liquid metallurgy route. Melt was heated up to 910K and stirring was carried out approximately 400 rpm speed for 30min under CO2 gas atmosphere to avoid oxidation.

Sarkar et al [5] have employed impeller mixing technique to fabricate Al– fly ash composites and concluded that up to 17 wt. % fly ash could be incorporated in the matrix by liquid metallurgy route. Addition of magnesium increased the wettability which enhanced the wear resistance and mechanical properties. Although a larger number of investigations have been carried out on mixing in solid– liquid suspensions by applying chemical engineering principles, the number of studies reported on mixing phenomena in metallurgical systems is relatively few.

The principal tribological parameters that control the friction and wear performance of reinforced Al-MMCs are extrinsic (mechanical and physical) factors such as the effect of load normal to contact surface, sliding velocity, sliding distance, reinforcement orientation, environment, temperature, surface finish of the counterpart and intrinsic (material) factors such as the reinforcement type, size, shape and distribution of the reinforcement, the matrix microstructure and the reinforcement volume fraction [6]. Therefore, it is difficult to select the type of reinforcement and volume fraction that would give optimum wear properties [7]. Many investigators carried out experiments on the wear behaviour of MMCs against different counter surfaces with various test conditions [8]. Under the following sections the effect of different parameter on the wear of MMCs are discussed [9].

Presence of a particulate reinforcement in metal matrix enhances the tribological characteristics along with higher specific strength and stiffness making them good candidate materials for many engineering situations where sliding contact is expected [10]. Several investigations have been carried out experiments for analyzing the wear behaviour of aluminium matrix composites.

The most commonly employed metal matrix composite system consists of aluminium alloy reinforced with hard ceramic particles such as SiC, Al_2O_3, [11 and12] or soft particles such as Graphite and Talc [13]. Recently low-cost and low-density fly ash particulate reinforcements are being investigated as replacements for the relatively more expensive conventional reinforcements such as SiC, B4C and Al_2O_3.

In all such type of investigations, the authors have selected the various ceramic reinforcements, in the current research has been constricted to few reinforcement types such as Al_2O_3, SiC, B4C, ZrO_2 Joel hamanth [14]. Limited work has been reported on fabrication and wear characterization of aluminium composites reinforced with zircon and garnet particles. Hence, there is a need to reduce the cost component by optimizing its volume fraction and avoiding/minimizing the use of finer particles Uyyuru et al [8]. As the load increased, the proportion of metallic wear debris increased and the size of the delamination increased for the composite Naresh et al [15].

The amount of the constituents of the counter-body in the transfer layer is seen to increase as sliding speed increases thus forming a protective cover which tends to reduce wear rate Shorowordi and Haseeb [16]. Gopalakrishana *et al*. [17] developed AA6061/ TiC MMCs using stir casing technique and observed that, specific strength and wear resistance of composite has been increased with increase of wt. % of TiC.

Ranjith kumar and Velmurugan [18] performed dry sliding wear experimental studies on aluminum hybrid metal matrix composites. The results reveals that increasing the applied load, sliding velocity and sliding distance the wear rate was also increasing.

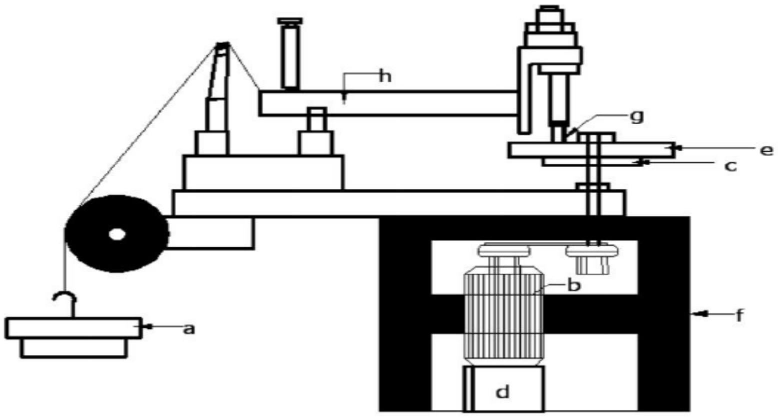
II. MATERIALS & METHODS

The work material used for the present study is AA6061/SiC/B_4C hybrid metal matrix composites are fabricated using stir casting techniques with the varying reinforcing of SiC/B4C particles by wt.% as 5-25% in steps of 5%. To investigate the wear behavior of AA6061/SiC/B4C MMCs as a function of reinforcing material at different process parameters such as wt.% of SiC, applied load, rotational speed, sliding velocity using pin-on-disc apparatus and executed wear and wear rate.

A. Experimental Details

A pin on disc apparatus (Figures 1 and 2) is used to investigate the dry sliding wear characteristics of the aluminium alloy and the composites. Wear specimens (Figure 3) of 10mm diameter and 30mm height were machined from the cast samples and polished metallographically for the wear test. Wear tests are conducted at room temperature (29°C) wt.% of reinforcement, applied load, sliding velocity and rotational speed and under non-lubricated conditions with a wear track diameter of 30 mm. The initial weight of the specimen was determined in a digital balance machine. The pin was kept pressed against a rotating OHNS disc of hardness 62 HRC in the loaded condition. The frictional traction encountered by the pin in sliding is measured by a PC based data logging system. On completion of the running through the required sliding distance, the specimen pins are cleaned with acetone, dried and the load is again determined, for ascertaining the weight loss. Before each test, the disc surface was polished with grade 220 SiC paper to a Central Line Average (CLA) value of 2µm. A digital weighing balance machine is used for determining the weight of the pins before and after the wear test.

Sliding wear is calculated by varying Wt. % of SiC/B4C, sliding velocity, applied load and rotational speed. The test duration is controlled by the control unit. When the load is applied, the frictional force is exerted and can be read by the controller. The 31runs has been conducted with various input parameter. Each test was done for 3 times and noticed average value for analysis. The weight loss of sample is determined for each test using electronic weight balance with accuracy of 0.001grams. Pin specimens were cleaned with acetone before doing experiment. The wear rate and wear resistance were calculated by the following formulae.



a-	Load	b-	Motor
c-	Base plate	d-	Damper
e-	Disc	f-	Frame
g-	Specimen	h-	Lever arm

Figure 1. Layout of pin-on-disc apparatus

Figure 2 Photograph of pin-on-disc apparatus

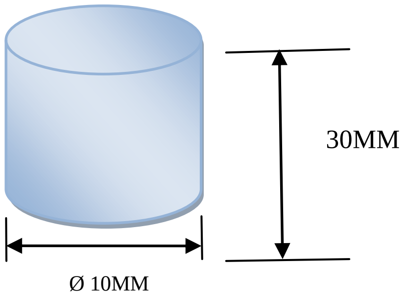


Figure 3 Wear test specimens

Determined the feasible limits by conducting trail experiments with large number of specimen with different values of factors. The experiments were conducted at atmospheric and dry sliding condition. The twobody abrasion mechanism is noticed in present investigation. The results were stated are as follows.

- The wear behaviour of AMC having weight fraction of reinforcement is < 2% is almost near to aluminium alloy. The better results were observed at less than 10% of Wt.% of SiC/B4C particles in matrix.
- The load range of sample is 9.81N - 50N. Beyond 50N applied load, severe wear was observed at pin material. At maximum load condition abrasion is majorly takes place but at around 30N it is noticed that peeled off the abrasion bond.

- The speed limit is in the range of 0.6 – 3m/sec for smooth operated dry sliding wear. The wear rate is almost negligible below lower limit and severe at beyond range of sliding velocity.
- The counter disc speed is also main factor in abrasive wear. If the speed of disc is less than 200rpm, wear is observed to be negligible but more than 600rpm it will be more. So in between these ranges wear will have optimum values.

From the above results the feasible limits of input parameters for pin-on-disc in the determination of dry sliding were listed in Table 1. The upper and lower limits were coded from -2 to +2 with 5 intermediate levels, which can be evaluated using following equation 1.

$$X_i = [2X - (X_{max} + X_{min})] / [(X_{max} - X_{min})/2] \quad (1)$$

Where is estimated coded value, is upper level factor and is lower level factor.

Table 1 Process parameters and levels used for dry sliding wear.

Levels / Parameters	Units	Levels				
		-2	-1	0	1	2
Weight percentage of SiC/B4C, (wt.%)	%	2	4	6	8	10
Rotational sped, (N)	RPM	200	300	400	500	600
Applied Load, (W)	N	9.81	19.62	29.23	39.24	49.05
Sliding Velocity, (V)	m/s	0.6	1.2	1.8	2.4	3

The loss of weight in specimen is calculated as wear rate per unit sliding distance from Equation 2. The results of wear, wear rate and wear resistance is tabulated and are shown in Table 2.

$$WearRate = \frac{VolumeLoss}{SlidingDis\tan ce} \quad (mm^3m) \qquad (1)$$

B. Response Surface Methodology (RSM)

The wear behaviour in pin-on-disc of HMMCs composite is important in manufacturing engineering applications from the economical point of view. The quality of the part depends on proper election of wear conditions. RSM is a statistical techniques and is useful for modeling and analysis of problems in which a response is influenced by several variables and the objective is to optimize this response. In many engineering problems, there is a relationship between an output variable 'y' and a set of control variables [x_1,x_2……x_n], in some problems, the relationship between y and x values might be known. Then, a model can be written in the form.

$$Y = f(x_1, x_2 .... x_n + \varepsilon \qquad 3$$

Where ε represents noise or error observed in the response 'y'If we denote the expected response be E(Y) = f (x_1, x_2, -----x_n) = $\widehat{Y}$ is called response surface.

The first step is to find suitable approximation for the true functional relationship between y and set of independent variables employed usually a quadratic model is used in RSM.

$$\widehat{Y} = \beta_0 + \sum_{i=1}^{k} \beta_i X_i + \sum_{i=1}^{k} \beta_{ii} X_i^2 + \sum_i \sum_j \beta_{ij} X_j + \varepsilon \qquad 4$$

MINITAB-18 software was used to determine the regression coefficients of the model for the wear and wear rate.

C. Taguchi's S/N Ratios

Taguchi S/N ratio is a statistical measure of performance or quality for data analysis and prediction of optimal parameters setting [19]. The S/N ratio is the ratio of the mean signal to the standard deviation (Noise). It depends on the quality characteristics of the process to be optimized. The standard S/N ratios generally used include: Nominal-is-Best (NB), Lower-the-better (LB) and Higher-the-Better (HB). In this investigation, MINITAB-18 was used to solve the optimization problem. Specific energy consumption was taken as LB characteristic, aimed at minimizing the response. The LB-S/N ratio was computed using equation 5.

$$S/N = -10 \log \frac{1}{n} \sum_{i=1}^{n} y_i^2 \qquad 5$$

III. Results and discussion

In this research work wear behavior of AA6061/SiC/B4C MMCs are investigated. Experiments are planned according to central composite design and are executed on Pin-on-Disc apparatus. The wear phenomena depends on various factors, it is more influenced by the parameters such as wt.% of SiC, rotational speed, applied load and sliding velocity. The influence of various parameters on AA6061/SiC/B4C MMCs can be studied based on response table 2 to 3 and response graphs 4 to 5 for wear and wear rate. From the graphs it is observed that, the wear at high wt.% of SiC/B4C is low as compared to low wt.% of SiC/B4C. The experimental results it indicates that the low wear was observed at moderate rotational speed, low applied load and low sliding velocity.

The response tables 2 to 3 for wear shows the effect of parameters on wear and wear rate it can be asserted that rotational speed is the most influencing factor which affect the wear followed by applied load sliding velocity and wt.% of SiC/B4C. Similarly it is observed for the calculated responses i.e., wear rate. Sliding velocity is the most influencing parameter which affects the wear rate and wear resistance followed by rotational speed, wt.% of SiC/B4C and applied load.

Table 2 Response table for wear.

Level	wt. % of SiC/B4C	Rotational speed (N), RPM	Applied Load (W), N	Sliding velocity (V), m/s
1	33.000	49.000	8.000	12.000
2	27.500	25.375	25.250	28.375
3	24.245	17.388	29.388	28.673
4	26.125	28.250	28.375	25.250
5	24.000	56.000	13.000	14.000
Delta	9.000	38.612	21.388	16.673
Rank	4	1	2	3

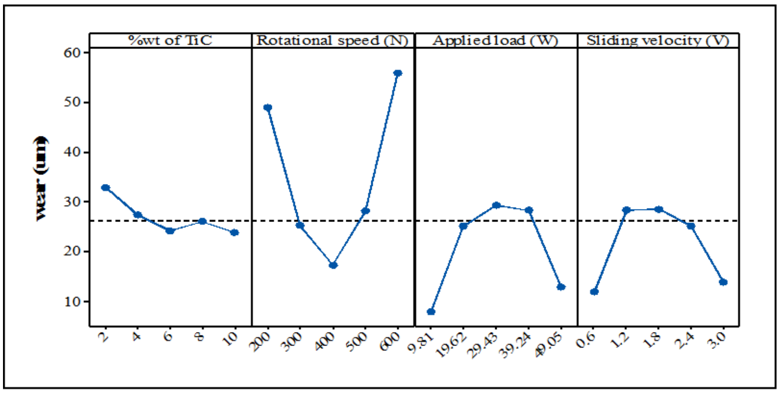


Figure 4. Response Graphs for wear.

Table 3 Response table for wear rate.

Level	wt. % of SiC/B4C	Rotational speed (N), RPM	Applied Load (W), N	Sliding velocity (V), m/s
1	36.00	56.00	48.00	98.00
2	51.00	59.38	54.00	41.00
3	100.76	99.47	92.18	72.61
4	65.13	56.75	62.13	75.13
5	34.00	23.00	82.00	169.00
Delta	66.76	76.47	44.18	128.00
Rank	3	2	4	1

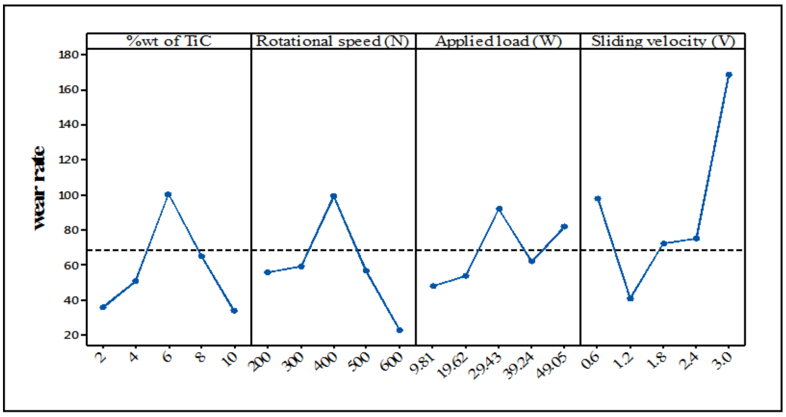


Figure 5. Response Graphs for wear rate.

A. EFFECT OF PROCESS PARAMETERS ON WEAR BEHAVIOUR

In present research, the wear behaviour of AA6061/SiC/B4C MMCs is carried out to study the effect of various process parameters viz, wt.% of SiC, rotational speed (N), applied load (W) and sliding velocity (V). For analyzing the affect of process parameters on wear response of AA6061/SiC/B4C MMCs graphs have been drawn using response surface model and are shown in Figure 6-5.6 In these plots keeping only one parameter is in variation in nature and other parameters kept constant at the middle level.

A/I. Effect of Applied Load on Wear Characteristics

The applied load is the dominating parameter in the determination of wear behavior of AA6061/SiC/B4C MMCs. Generally, as the intensity of the applied load increases, the wear of specimen is also increases. Wear is also depending on hardness of the work piece. The effect of applied load on wear is determined for different wt.% of SiC/B4C in aluminium under dry condition. The graph is drawn in between applied load and wear by keeping the other parameters are sliding velocity and rotational speed are constant at middle level. The graphs are plotted with the help of response surface model.

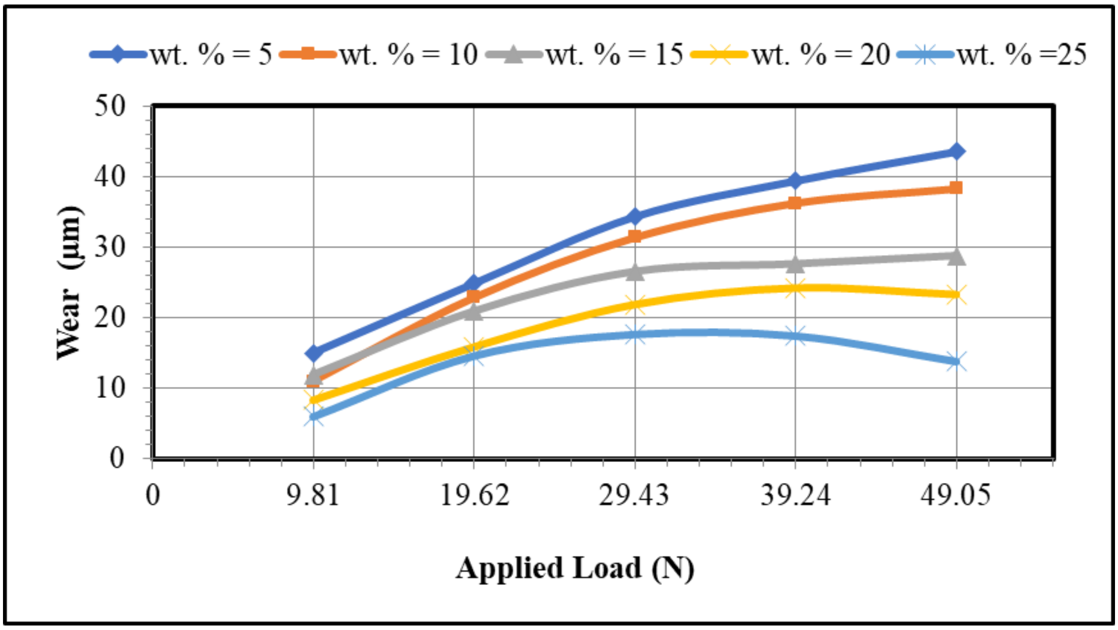


Figure 6. Variation of wear with applied load for different wt.% of SiC/B4C.

The influence of applied load on dry sliding wear behaviour, the wt.% of SiC/B4C in aluminium is shown in Figure 6. Due to the increase of applied load, the contact area of specimen with counter disc would be more, so that heat is generated between the contact surface, which results in formation of fine grooves towards the sliding direction were noticed. A fine plastic deformation is noticed at grooves and craters were observed without cracks confirm abrasive wear mechanisms, which results in more wear. From the Figure 5.3 it is observed that wear is increases with the increase of applied load for all wt.% of reinforcement. The low wear (5.99µm) is observed for 25% of SiC MMC at low loads 9.81N and high wear (43.5µm) is observed for 5 wt.% of TiC at higher applied load of 49.05N. The wear is decreases because of the presence of TiC particulates spreads on the surface of the pin & formation of secure layer in between of pin & steel disc. So developed composites have less wear by increasing the wt.% of TiC.

The study of wear rate is important in the analyzation of wear behaviour of material. The wear rate is calculated by using following Equation 1.

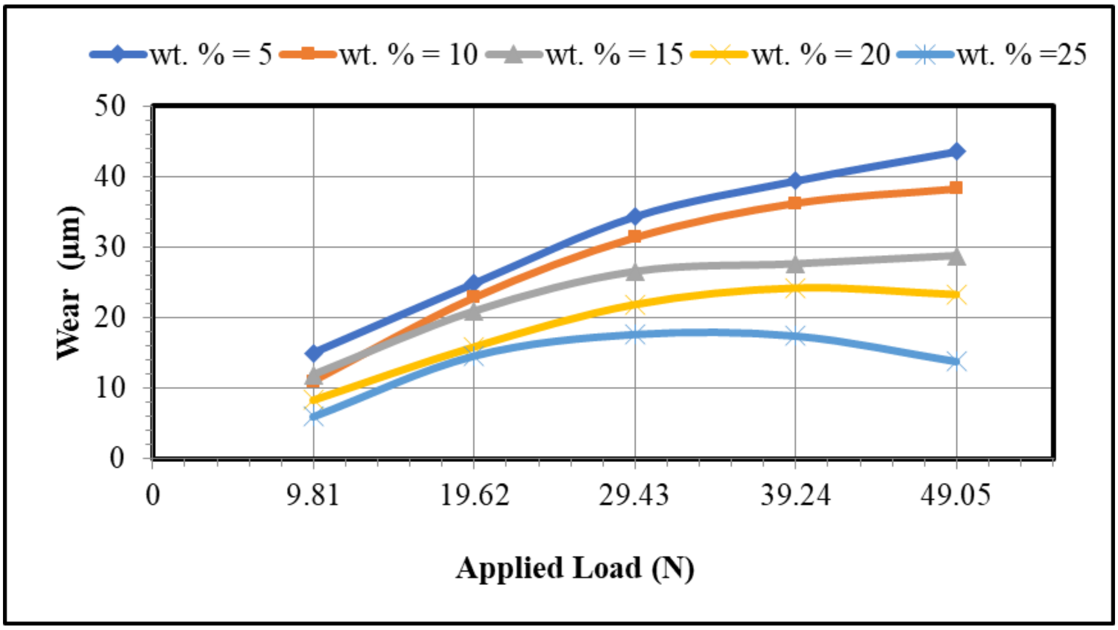


Figure 7. Variation of wear rate with applied load for different wt.% of SiC/B4C.

Figure 7 shows the variation of the wear rate with respect to the applied load on AA6061/SiC/B4C MMCs considered in this investigation. From the plot it is inferred that wear rate is gradually increasing with the increase of the applied load for all the AMCs considered in this investigation. The wear rate reaches the maximum value at an applied load of 39.42N then after decreasing slightly. At 25wt.% of SiC/B4C reinforced AMC exhibits lower wear rate (98.08mm^3/m) and 5wt.% of SiC AMCs exhibits higher wear rate at low load.

B/II Effect of Sliding Velocity on Wear Characteristics

The sliding speed is important factor in the determination of wear behaviour. This parameter shows multiple effects on wear of composite material which depends on matrix and reinforcement materials.

Graphs 8 and 9 shows the variation of wear and wear rate with respect to sliding velocity for all the AMCs considered in this investigation. These plots are drawn using responses surface model.

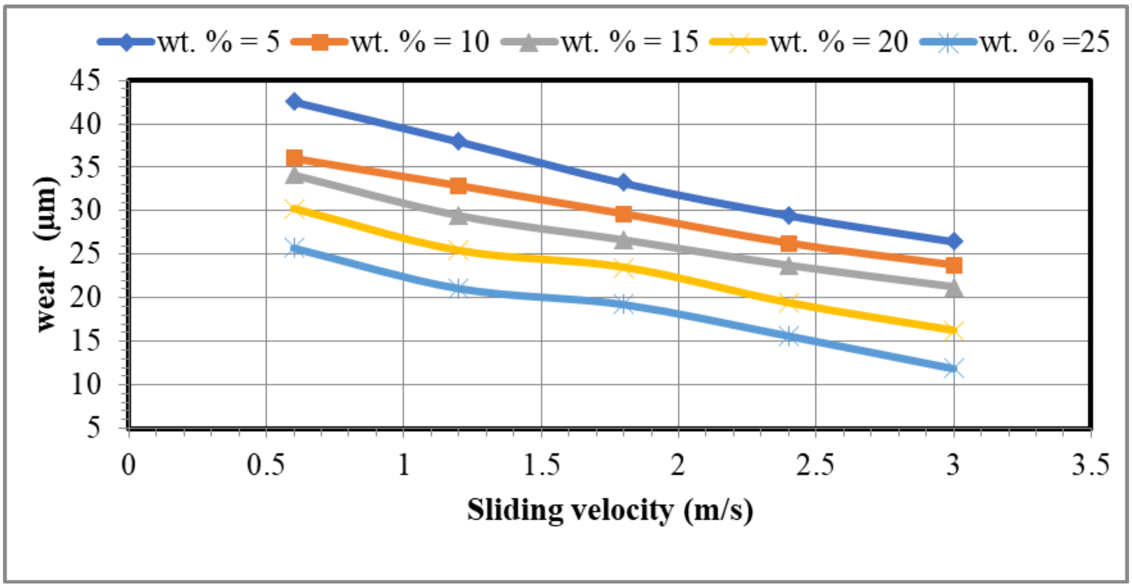


Figure 8. Variation of wear with sliding velocity for different wt.% of SiC/B4C.

From the Figure 8 it is observed that the wear decreases linearly with the increase of sliding velocity, this is due to lack of contact is caused at high sliding velocities which leads to less wear of AMCs. The low wear (11.9µm) is observed for 25 wt.% of AA6061/SiC/B4C MMC at high sliding velocity of 3m/s.

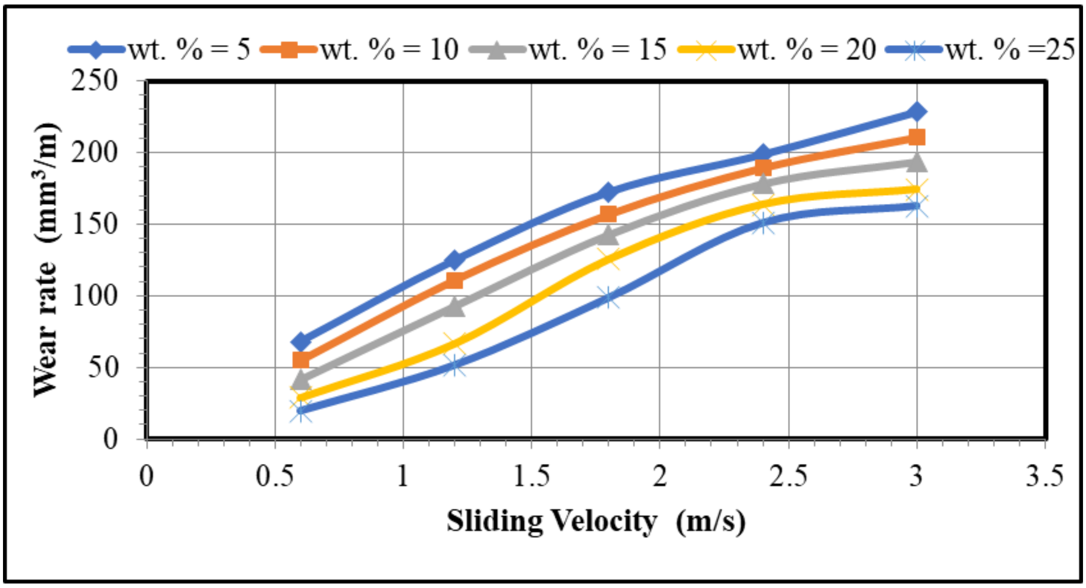


Figure 9. Variation of wear rate with sliding velocity for different wt.% of SiC/B4C.

The variation of sliding velocity on wear rate of AA6061/SiC/B4C MMCs is shown in graph 9. From the graph it is noticed that the trend increases with constant slope has been observed with respect to increase of sliding velocity for all wt.% of SiC/B4C reinforced MMCs. This is due to the fact that, as the sliding velocity increases the interfacial temperature between the specimen and disc increases which causes softening of the base metal and de-bonding of the reinforcing phase. This leads to craters and grooves on the surface of the sample. The low wear rate (19.47mm^3/m) is observed at 25wt.% of SiC/B4C at low sliding velocity (0.6m/s). The high wear rate is observed for 5wt.% of SiC/B4C at higher sliding velocity condition in present investigation.

C/III Effect of Rotational Speed on Wear Characteristics

The rotational speed is a main parameter influencing the wear behaviour of AA6061/SiC/B4C MMCs. This parameter has positive or negative effects on wear characteristics.

The graph 10 is plotted between rotational speed and wear. This graph is drawn by keeping rotational speed is in variation and other parameters kept constant at the middle level using response surface model.

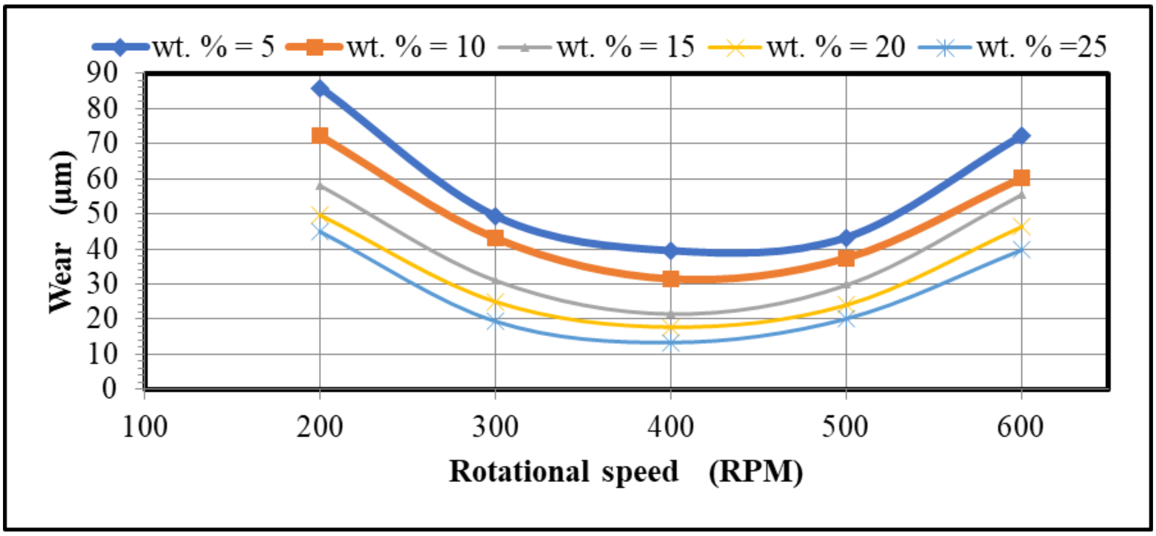


Figure 10. Variation of wear with rotational speed for different wt.% of SiC/B4C

From Figure 10 it is noticed that the increase of rotational speed the wear decreases gradually up to 400 rpm for all wt% of SiC/B4C considered in this investigation and increases furthermore with the increase of the rotational speed. This may be caused due to local plastic deformation at SiC particles premises at high speed conditions which lead to delamination and sub cracking of surface. The minimum wear (13.27µm) is observed for 25wt.% of SiC at rotational speed of 400 rpm. Highest wear is (85.91µm) observed for 5wt.% of SiC at 200rpm of disc speed.

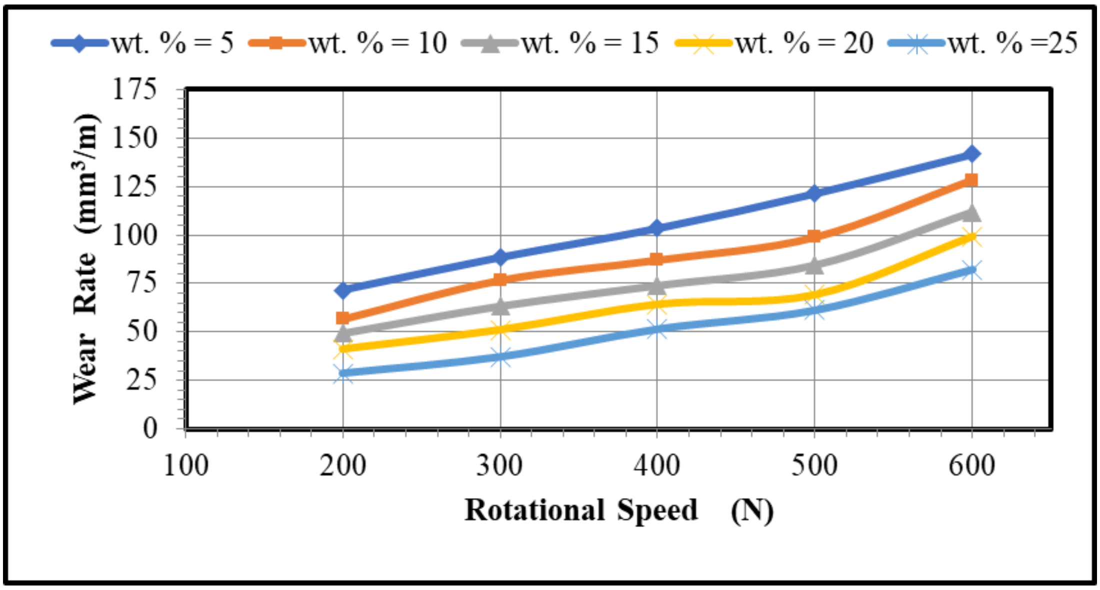


Figure 11. Variation of wear rate with rotational speed for different wt.% of SiC/B4C

Graph 11 shows the variation of wear rate with respect to rotational speed for all AA6061/SiC/B4C MMCs considered in this study. Form the plot it is observed that wear rate is increases with constant slope with increasing of rotational speed form 200rpm to 600rpm. More material is removed from pin surface at high rotational speed due to debris present at contact of surface, and also cracks are initiated and propagated on the surface of the pin. The minimum wear rate (28.68mm^3/m) is observed for 25wt.% of SiC reinforced AMC at minimum rotational speed 200rpm and maximum wear rate has been observed for 5 wt.% of SiC at maximum rotational speed. AMCs with higher wt.% of SiC subjected to lower wear rate as compared to AMCs with low wt.% of SiC reinforcement.

IV. CONCLUSIONS

The following conclusions are derived from the present investigation on Tribological behaviour of AA6061/SiC/B4C hybrid metal matrix composites (MMCs). The tests are led to examine the wear behavior of MMCs. Scientific relations are set up between the wear affecting parameters. Based on the examination, the accompanying conclusions are

- A new class of aluminium based particle reinforced metal matrix composites (MMCs) have been developed at different wt.% of SiC (5% to 25% in steps of 5%) reinforced particles using stir casting technique.
- The amount of wear in aluminium metal matrix composites decreases with increase in wt.% of SiC particle reinforcement. Low wear of (5.99µm) is observed for 25wt.% of SiC MMC at low applied loads 9.81N and high wear (43.5 µm) is observed for 5 wt.% of SiC at higher applied load of 49.05N.
- The wear of AA6061/SiC/B4C MMCs gradually decreases with increase of sliding velocity for all composites considered in this investigation.
- The Response surface models (RSM) developed for wear and wear rate are adequate and their R^2 values are 0.9792 and 0.9798.
- Verification of test results revealed that the determined optimal combination of wear parameters satisfy the real requirements in wear test of MMCs.

A. SCOPE FOR FUTURE WORK

1. Similar work can be replicated by changing the matrix and reinforcing materials.
2. More number of machining parameters can be included and hence, data base can be improved by extensive experimentation.

3. In this work predictive models were developed using RSM apart from this other modelling techniques like Neural networks, fuzzy logics can also be used.
4. Various Optimization techniques are to be improved the wear performance.

References

[1]. Rabinowicz, E., Friction and Wear of Materials, New York, John Wiley and Sons, 1995.
[2]. P.Naresh, Syed Altaf Hussain, B. Durga Prasad "A Review On Multiple Responses Process Parameters Optimization Of Turning Al-TiCp Metal Matrix Composites", Journal of Achievements in Materials and Manufacturing Engineering ISSN: 1734-8412, Volume 80, Issue 1, Pg.no 32- 40.
[3]. Chaudhury, S. K., Singh, A. K., Sivaramakrishnan, C. S. S. And Panigrahi, S. C. "Preparation and thermo mechanical properties of stir cast Al-2Mg-11TiO2 (rutile) composite", Bulletin of Material Science, Vol. 27, No. 6, pp. 517-521, 2004.
[4]. Ipek, R. "Adhesive wear behaviour of B4C and SiC reinforced 4147Al matrix composites (Al/B4C-Al/SiC)", Journal of Materials Processing Technology, Vol. 162, No. 163, pp. 71-75, 2005.
[5]. Sarkar, S., Sen, S., Mishra, S. C, Kudelwar, M. K. and Mohan,S. "Aluminum – fly ash composite produced by impeller mixing", Journal of reinforced plastics and composites, Vol. 29, No. 1, pp. 1-6, 2008.
[6]. P.Naresh, Syed Altaf Hussain, B. Durga Prasad, "Ananlysis of Dry sliding wear behavior of AA068/TiC MMCs" International Journal of Materials Engineering Innovation (IJMATEI), Vol. 11, No. 1, 2020
[7]. Miyajima, T. and Iwai, Y. "Effects of reinforcements on sliding wear behavior of aluminum matrix composites", Wear, Vol. 255, pp.606-616, 2003.
[8]. Uyyuru, R.K., Surappa, M.K. and Brusethaug S. "Effect of reinforcement volume fraction and size distribution on the tribological behavior of Al-composite/brake pad tribocouple", Wear, Vol.pp. 1248–1255, 2006.
[9]. Veeresh Kumar, G.B., Rao, C.S.P. and Selvaraj, N. "Mechanical and tribological behavior of particulate reinforced aluminum metal matrix composites-a review", Journal of Minerals and Materials Characterization & Engineering, Vol. 10, No.1, pp. 59-91, 2011.
[10]. Ibrahim, A., Mohammed, F. A. and Lavernia, E. J. "Metal matrix composites- A review", Journal of Material Science, Vol. 26, pp. 1137-1157, 1991.
[11]. Ma, Z.Y., Zhang, Y. Z., Lu, Y. X. and Bi, J. "Sliding wear behaviour of SiC particle reinforced 2024 Al alloy composites", Materials Science Technology, Vol. 12, pp. 751-756, 1996.
[12]. Muratoglu, M. and Aksoy, M. "The effects of temperature on wear behaviours of Al-Cu alloy and Al-Cu/SiC composite", Materials Science and Engineering. A, Vol. 282, pp. 91-99, 2000.
[13]. Zhang, J., Perez, R. J. and Lavernia, E. J. "Effect of SiC and graphite particulates on the damping behavior of metal matrix composites", Acta Metallurgica, Vol. 42, pp. 395-409, 1994.
[14]. Joel Hamanth, "Development and property evaluation of aluminium alloy reinforced with nano-ZrO2 metal matrix composites", Materials Science and Engineering A, Vol. 507, pp. 110-113, 2009.
[15]. P.Naresh and B. suresh, "Effect of Sliding Velocity and Normal Applied Load on Wear Behaviour of Al-Ti-SiC Composites for Automobile Brake Pad System Under Dry Sliding Condition", Internation Journal of Recent Technology and Engineering, Vol.8, No. 9, November 2019
[16]. Shorowordi, K.M. and Haseeb, A.S.M.A. "Velocity effects on the wear, friction and tribo-chemistry of aluminum MMC sliding against phenolic brake pad", Wear, Vol. 256, pp. 1176–1181, 2004.
[17]. P.Naresh, Syed Altaf Hussain, B. Durga Prasad "Mechanical Characterization of AA7068/TiC Metal Matrix Composites" Internationl Journal of Mechanical and Production Engineering Research and Development (IJMPERD), Special Issue, Page No. 22-28, ISSN 2249-6890, June 2018.
[18]. RajneshTyagi,"Synthesis and tribological characterization of insitu cast Al-TiC composites", Wear 2005:569-576, 2005.
[19]. V.Ramakoteswara Rao, N.Ramaniah , and MMM.Sarcar,"Tribological properties of Aluminium MMCs", International Journal of Advanced Science and Technology, Vol.88, pp.-13-25, 2016.
[20]. Schoutens, J. E. and Tempo, K. Introduction to metal matrix composite materials, MMCIAC tutorial series, Santa Barbara, CA, 1982.