RESEARCHERID
THOMSON REUTERS

[IDSTM-18]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

TRIBOLOGICAL BEHAVIOUR OF Al-6063/RED MUD METAL MATRIX COMPOSITE

Naveen Kumar [1],Manmohan [2],Bhupender Sharma [3]

1 Asst. Proffessor in Mechanical Dept. , SET, Ganga Technical Campus Soldha, Bahadurgarh
2 M. Tech scholar, SET, Ganga Techanical Campus Soldha, Bahadurgarh
3 Asst. Proffessor in Mechanical Dept., SET, Ganga Technical Campus Soldha, Bahadurgarh

ABSTRACT

Metal matrix composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to Unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements. Among various discontinuous dispersoids used, Red Mud is one of the most inexpensive reinforcement available in large quantities as solid waste by-product during bayer process , the principal industrial means of refining bauxite in order to provide alumina as raw material for the electrolysis of aluminium by the Hall–Héroult process. Hence, composites with Red Mud as reinforcement are likely to overcome the cost barrier for wide spread applications in automotive and small engine applications. It is therefore expected that the incorporation of Red Mud particles in aluminium alloy will promote yet another use of this low-cost waste by-product and, at the same time, has the potential for conserving energy intensive aluminium and thereby, reducing the cost of aluminium products. Now a days the particulate reinforced aluminium matrix composite are gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components. The present investigation has been focused on the utilization of abundantly available industrial waste Red Mud in useful manner by dispersing it into aluminium to produce composites by stir casting method. Tribological behavior of the metal matrix composites was studied by performing dry sliding wear test using a pin-on-disc wear tester. Experiments were conducted based on the plan of experiments generated through Taguchi‟s technique. L9 Orthogonal array was selected for analysis of the data. Investigation to find the influence of sliding speed, applied load and sliding distance on wear rate, as well as the coefficient of friction during wearing process was v carried out using ANOVA and regression equation for each response were developed for both 5% and 10% Red Mud reinforced Al-6063MMCs. Objective of the model was chosen as "smaller the better‟ characteristics to analyze the dry sliding wear resistance. Results show that sliding distance has the highest influence followed by load and sliding speed. Finally Scanning Electron Microscope were done on wear surfaces.

I. INTRODUCTION

Monolithic materials have limitations in achieving good combination of strength, stiffness, toughness and density. To overcome these shortcomings and to meet the ever increasing demand of modern day technology, composites are most promising materials of recent interest. Metal matrix composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements. Among various discontinuous dispersoidsused, Red Mud is one of the most inexpensive and low density reinforcement available in large quantities as solid waste product of Bayer process. Hence, composites with Red Mud as reinforcement are likely to overcome the cost barrier for wide spread applications in automotive and small engine applications. It is therefore expected that the incorporation of red mud particles in aluminium will promote yet another use of this low-cost waste by-product and, at the same time, has the potential for conserving energy intensive aluminium and thereby, reducing the cost of aluminium products.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

now a days the particulate reinforced aluminium matrix composite are gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components. cast aluminium matrix particle reinforced composites have higher specific strength, specific modulus and good wear resistance as compared to unreinforced alloys. the particulate composite can beprepared by injecting the reinforcing particles into liquid matrix through liquid metallurgy routeby casting. casting route is preferred as it is less expensive and amenable to massproduction. among the entire liquid state production routes, stir casting is the simplest andcheapest one. the only problem associated with this process is the non uniform distribution ofthe particulate due to poor wet ability and gravity regulated segregation.

II. METHODOLOGY

In the present study, Al-6063/Red Mud metal matrix composite is developed for two different Compositions by using stir casting process. The wear and frictional properties of the metal matrix composites are studied by performing dry sliding wear test using a pin-on-disc wear tester. Experiments are conducted based on the plan of experiments generated through Taguchi‟s technique. A L9 Orthogonal array is selected for analysis of the data. Investigation to find the influence of applied load, sliding speed and sliding distance on wear rate, as well as the coefficient of friction during wearing process is carried out using ANOVA. the process for the development of Al-6063/Red Mud metal matrix composite is described. And finally the tribological experimentation is presented.

III. EXPERIMENTALWORK

A stir casting setup (Figure.2), which consisted of a resistance furnace and a stirrer assembly, was used to synthesize the composite. The stirrer assembly consisted of a stainless steel impellor type stirrer, which was connected to a variable speed electric motor (speed 0 to 890 rpm) by means of a steel shaft. The stirrer was made by cutting and fixing blades in a stainless steel block. The stirrer consisted of four blades at angles of 90° apart. Figure-1show the photograph of the stirrer from two different angles. Clay graphite crucible of 1.5 Kg capacity was placed inside the furnace**.**

The stirrer assembly consisted of a stainless steel turbine stirrer fixed to a steel rod. Approximately 1.2Kg of alloy was then melted at 810°C in the resistance furnace of stir casting setup. Preheating of Red Mud mixture at 400°C was done for one hour to remove moisture and gases from the surface of the particulates. The stirrer was then lowered vertically up to 3 cm from the bottom of the crucible (total height of the melt was 9 cm). The speed of the stirrer was gradually raised to 650 rpm and the preheated Red Mud particles were added with a pipe at the rate of 10- 20g/min into the melt.

The speed controller maintained a constant speed, as the stirrer speed got reduced by 50-60 rpm due to the increase in viscosity of the melt when particulates were added into the melt. After the addition of Red Mud particles, stirring was continued for 10 minutes for better distribution. The melt was kept in the crucible for one minute in static condition and it was then poured in the metal moulds

.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Fig 1: Red Mud particle size 80 µm

Composites Preparation by Stir Casting

The stirrer assembly consisted of a stainless steel turbine stirrer fixed to a steel rod. Approximately 1.2Kg of alloy was then melted at 810°C in the resistance furnace of stir casting setup. Preheating of Red Mud mixture at 400°C was done for one hour to remove moisture and gases from the surface of the particulates. The stirrer was then lowered vertically up to 3 cm from the bottom of the crucible (total height of the melt was 9 cm). The speed of the stirrer was gradually raised to 650 rpm and the preheated Red Mud particles were added with a pipe at the rate of 10- 20g/min into the melt. The speed controller maintained a constant speed, as the stirrer speed got reduced by 50-60 rpm due to the increase in viscosity of the melt when particulates were added into the melt. After the addition of Red Mud particles, stirring was continued for 10 minutes for better distribution. The melt was kept in the crucible for one minute in static condition and it was then poured in the metal moulds.

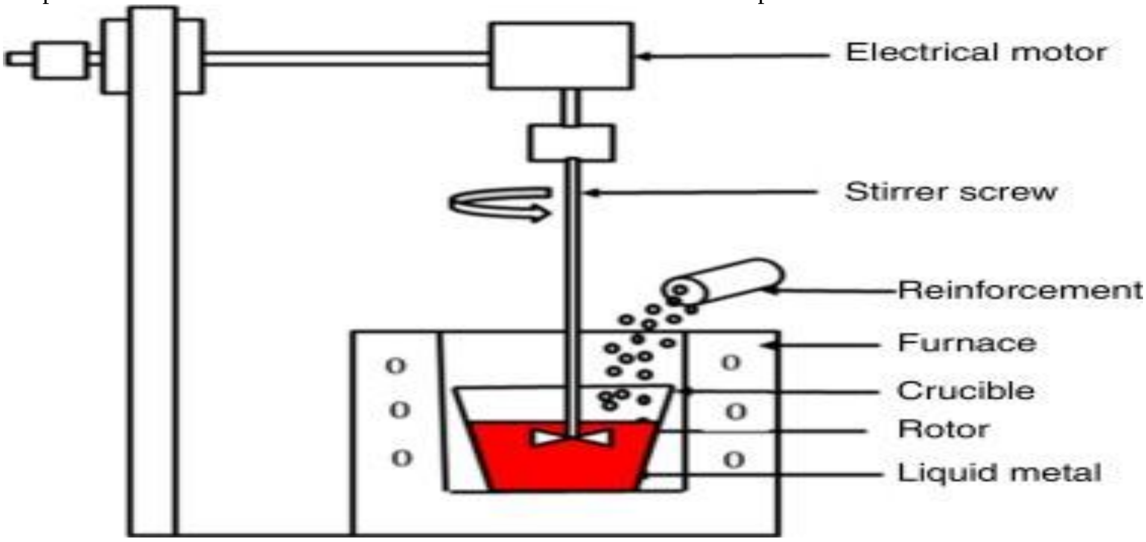

Figure 4.4 MMC preparations by Stir casting route

Plan of Experiments

Dry sliding wear test was performed with three parameters: applied load, sliding speed, and sliding distance and varying them for three levels. According to the rule that degree of freedom for an orthogonal array should be greater than or equal to sum of those wear parameters, a L9 Orthogonal array which has 9 rows and 3 columns was selected as shown below:

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Table 1: Orthogonal array L9 of Taguchi

EXPERIMENT NO.	COLUMN 1	COLUMN 2	COLUMN 3
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

The selection of Orthogonal array depends on three items in order of priority, viz., the number of factors and their interactions, number of levels for the factors and the desired experimental resolution or cost limitations. A total of 9 experiments were performed based on the run order generated by the Taguchi model. The response for the model is wear rate and coefficient of friction. In Orthogonal array, first column is assigned to applied load, second column is 46 assigned to sliding speed and third column is assigned to sliding distance and the remaining columns are assigned to their interactions. The objective of model is to minimize wear rate and coefficient of friction. The Signal to Noise (S/N) ratio, which condenses the multiple data points within a trial, depends on the type of characteristic being evaluated. The S/N ratio characteristics can be divided into three categories, viz. „nominal is the best, "larger the better" and smaller the better characteristics. In this study, "smaller the better" characteristic was chosen to analyze the dry sliding wear resistance. The S/N ratio for wear rate and coefficient of friction using "smaller the better" characteristic given by Taguchi, is as follows:

S/N Ratio for SMALLER-THE-BETTER (Minimize), S/Ns :
= -10 Log$\left(\mathbf{1/n \sum_{i=1}^{n} y_i^2}\right)$

Where y1, y2...yn are the response of friction and sliding wear and n is the number of observations. The response table for signal to noise ratios shows the average of selected characteristics for each level of the factor. This table includes the ranks based on the delta statistics, which compares the relative value of the effects. S/N ratio is a response which consolidates repetitions and the effect of noise levels into one data point. Analysis of variance of the S/N ratio is performed to identify the statistically significant parameters.

IV. RESULTS AND DISCUSSION

The aim of the experimental plan is to find the important factors and combination of factors influencing the wear process to achieve the minimum wear rate and coefficient of friction. The experiments were developed based on an orthogonal array, with the aim of relating the influence of sliding speed, applied load and sliding distance. These design parameters are distinct and intrinsic feature of the process that influence and determine the composite performance. Taguchi recommends analyzing the S/N ratio using conceptual approach that involves graphing the effects and visually identifying the significant factors.

1. The control factors are statistically significant in the signal to noise ratio and it could be observed that the sliding distance is a dominant parameter on the wear rate and coefficient of friction followed by applied load and sliding speed.

The analysis of these experimental results using S/N ratios gives the optimum conditions resulting in minimum wear rate and coefficient of friction. The optimum condition for wear rate and coefficient of friction as shown in Table -2.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Table 2: Optimum level Process Parameters for Wear Rate and Coefficient of Friction

S.No.	MMCs	Load(N)	Sliding Speed (m/s)	Sliding Distance(m)	Wear Rate (mm3/m)	Coefficient of Friction(mm3/m)	S/N ratio (db)
1	10% Red Mud	30	3	1000	0.0037	0.268	48.6360
2	15% Red Mud	10	3	1750	0.00317	0.273	49.9788
3	10% Red Mud	10	4	2500	0.00325	0.277	11.1504
4	15% Red Mud	10	4	2500	0.00343	0.290	10.7520

2. The experimental results were analyzed with Analysis of Variance (ANOVA) which is used to investigate the influence of the considered wear parameters namely, applied load, sliding speed, and sliding distance that significantly affect the performance measures. By performing analysis of variance, it can be decided which independent factor dominates over the other and the percentage contribution of that particular independent variable. 5% &10% Red Mud MMCs of the ANOVA results for wear rate and coefficient of friction for three factors varied at three levels and interactions of those factors. This analysis is carried out for a significance level of α=0.05, i.e. for a confidence level of 95%. Sources with a P-value less than 0.05 were considered to have a statistically significant contribution to the performance measures.

It can be observed that for aluminium (5% & 10%) Red Mud Metal Matrix Composites, that the sliding distance has the highest influence (Pr =62.5% & Pr=7.1%) on wear rate. Hence sliding distance is an important control factor to be taken into consideration during wear process followed by applied loads (P=1.25% & P=57.2%) & sliding speed (Pr=37.5% & Pr=7.1%) respectively. In the same way coefficient of friction, it can observe that the load has the highest contribution of about 85.5% & 87.2%, followed by sliding distance (13.4% & 9.7%) &sliding speed (0.6% & 1.7%) for Al-606 with (10% & 15%) SiC metal matrix composites. The interaction terms has little or no effect on coefficient of friction & the poolederrors accounts only 0.5% & 1.4%. From the analysis of variance & S/N ratio, it is inferred that the sliding distance has the highest contribution on wear rate & coefficient of friction followed by load & sliding speed.

V. CONCLUSION

The following conclusions can be drawn from the present investigation:

- From the study it is concluded that we can use Red Mud for the production of composites and can turn industrial waste into industrial wealth. This can also solve the problem of storage and disposal of Red Mud.
- AA 6063 alloy matrix composites reinforced with Red Mud particles can be successfully synthesized by the stir casting method.
- For synthesizing of hybrid composite by stir casting process, stirrer design and position, stirring speed and time, melting and pouring temperature, particle-preheating temperature, particle incorporation rate, mould type and size, and reinforcement particle size and amount are the important process parameters.
- Microstructural observations show that the Red Mud particles are uniformly distributed in the Al6063 alloy matrix and good interfacial bonding between reinforcing particles and matrix.
- XRD results showed the presence of Red Mud particles in alloy matrix.
- Sliding distance (62.5%) has the highest influence on wear rate followed by sliding speed(37.5%) and applied load (1.25%) and for coefficient of friction, the contribution of applied load is 85.5%, sliding distance is 13.4% for Al ¡V 6063/ 5% Red Mud metal matrix composites.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

- Applied load (57.2%) has the highest influence on wear rate followed by sliding distance (7.1%) and sliding speed (7.1%) and for coefficient of friction, the contribution of applied load is 87.2%, sliding distance is 9.7% for Al ¡V 6063/ 10% Red Mud metal matrix composites.
- Increasing incorporation of Red Mud (5% & 10%) increases the wear resistance of composites by forming a protective layer between pin & counterface.67
- From the above conclusion we predict that sliding distance & applied load have the highest influence on wear rate in both composites.
- Similarly applied load is only parameter which largely influences the coefficient of friction in both composites.
- Regression equation generated for the (5% & 10% Red Mud MMCs) present model was used to predict the wear rate & coefficient of friction of Al ¡V 6063/ (5% & 10%) Red Mud MMCs for intermediate conditions with reasonable accuracy.

VI. SCOPE OF FUTURE WORK

The present study is a preliminary work so far as the optimization of tribological testing parameters of the Al-5% Red Mud and Al-10% Red Mud is concerned. Future study on the topic may evaluate one or more of the following aspects:

- Other Metal Matrix Composites can be manufactured and tested by using stir casting method.
- More numbers of design parameters may be studied at a time for better control over the design space so that improved tribological performance of Al-5% Red Mud and Al- 10% Red Mud is obtained.
- Similar studies could be conducted considering other volume fraction of Red Mud in aluminium on the tribological behavior of the MMCs could be conducted.
- Similar studies may also be done with reinforcement other than Red Mud such as Alumina (Al2O3), Boron Carbide (B4C), silicon carbide (SiC) etc.
- There is always a quest for obtaining hard and wear resistant materials for industrial applications which is simultaneously cheaper to produce. The studies concerning the MMCs, if properly conducted could well reveal its potential to be a tribologically suited for industrial applications.68

I. REFERENCES

[1] *A.M. Qutub, I.M. Allam and M.A.A. Samad, (2007). ¡§Wear and friction of Al-Al2O3 composites at various sliding speeds¡¨, Journal of Material Science 43, pp.5797-5803.*
[2] *A.T. Alpas, J. Zhang, (1992). ¡§Effect of SiC particulate reinforcement on the dry sliding wear of aluminium-silicon alloys¡¨, Wear 155, Issue 1, pp. 230-256*
[3] *B. Venkataraman and G Sundararajan, (1996). ¡§The sliding wear behaviour of Al-SiC particulate composite-I¡¨, Macrobehaviour, Acta Metallurgica Inc Vol-44, No-2, pp. 451-460.*
[4] *Dheerendra Kumar Dwivedi, (2006). ¡§Wear behaviour of cast hypereutectic aluminium silicon alloys¡¨,Materials & Design Volume 27, Issue 7, pp. 45-76.*
[5] *E. Candan , H. Ahlatci , H. C .meno glu , (2001). ¡§Abrasive wear behaviour of Al¡VSiC composites produced by pressure infiltration technique/ Wear 247, pp.133¡V138.*
[6] *G. B. Veeresh Kumar, C. S. P. Rao, N. Selvaraj, M. S. Bhagyashekar, (2010). ¡§Studies on Al6061-SiC and Al7075-Al2O3 Metal Matrix Composites, Journal of Minerals & Materials Characterization & Engineering¡¨, Vol. 9, No.1, pp. 43-55.*
[7] *G. Straffelini, F. Bonollo, A. Molinari and A. Tiziani, (1997). ¡§Influence of matrix hardness on the dry sliding behaviour of 20 vol. % Al2O3-particulate-reinforced 6061 Al metal matrix composite¡¨, Wear 211, pp.192-197.*
[8] *Geetha Mable Pinto, Jagannath Nayak, A Nityananda Shetty, (2009). ¡§Corrosion Behaviour of 6061 Al - 15vol. Pct. SiC Composite and its Base Alloy in a Mixture of 1:1 Hydrochloric and Sulphuric Acid Medium¡¨, J. Electrochem. Sci., 4, pp. 1452 ¡V 1468.*
[9] *H. Ahlatci, E. Candan and H Cimenoglu, (2004). ¡§Abrasive wear behavior and mechanical properties of Al¡VSi/SiC composites¡¨, Wear 257, pp.625-632.*
[10] *J. Rodriguez, P. Poza, M.A. Garrido and A. Rico, (2007). ¡§Dry sliding wear behaviour of aluminium-lithium alloys reinforced with SiC particles¡¨, Wear 262, pp. 292-30069*
[11] *J. Zhu, L.H. Hihara, (2010). ¡§Corrosion of continuous alumina-fibre reinforced Al¡V2 wt.% Cu¡VT6 metal¡Vmatrix composite in 3.15 wt.% NaCl solution¡¨, Corrosion Science 52, pp. 406¡V415.*

[12] *J.L. Lin, C.L. Lin, (2002). ¡§The use of the orthogonal array with grey relational analysis to optimize the electrical discharge machining process with multiple performance characteristics,¡¨ International Journal of Machine Tools & Manufacture, 42, pp.237¡V244.*

[13] *J.T. Burnell Jr, (1957). ¡§Survey of possible wear mechanism¡¨, Wear 1, pp. 119-141.*

[14] *K.M. Shorowordi, A.S.M.A Haseeb and J.P. Celis, (2006). ¡§Tribo-surface characteristics of Al¡V B4C and Al¡VSiC composites worn under different contact pressures¡¨, Wear 261, pp.634-641.*

[15] *K.S. Al-Rubaie, H.N. Yoshimura and J.D.B de Mello, (1999). ¡§Two-body abrasive wear of Al-SiC Composites¡¨, Wear 233-235, pp.444-454.*

[16] *Karl Ulrich Kainer, (2004). ¡§Basics of Metal Matrix Composites¡¨, custom-made material for automotive and aerospace engineering, McGraw-Hill.*

[17] *Kori S A, Chandrashekharaia T M, (2007). ¡§Studies on the dry sliding wear behaviour of hypoeutectic and eutectic Al¡VSi alloys¡¨, Wear,Volume 263, pp.745-755.*

[18] *M. Kok and K. Ozdin, (2007). ¡§Wear resistance of aluminum alloy and its composites reinforced by Al2O3 particles¡¨, Journal of Material Processing Technology 183, pp. 301-309.*

[19] *M. Kok, (2006). ¡§Abrasive wear of Al2O3 particle reinforced 2024 aluminium alloy composites fabricated by vortex method¡¨, pp. 457¡V464*

[20] *M.M. Haque A. Sharif, (2001). ¡§Study on wear properties of aluminium¡Vsilicon piston alloy/Journal of Materials Processing Technology¡¨,Volume 118, Issues 1¡V3, pp.30-48.*

[21] *Minitab User Manual 13.2, (2001). ¡§Making data analysis easier¡¨, State College, PA, USA: Minitab Inc.*

[22] *N. Axen,I.M. Hutchings.S. Jacobson, (2006). ¡§A model for the friction of multiphase materials in abrasion¡¨, Tribology International, pp. 245-265.*

[23] *Nigamanada ray, Dilip kumar kerketta, (2010). ¡§Some Studies on Aluminium Matrix in Situ Composites Produced by Stir Casting Method¡¨, ME Thesis NIT Rourkela.70*

[24] *O. Yilmaz and S. Buytoz, (2001). ¡§Abrasive Wear of Al2O3-reinforced aluminium-based MMCs¡¨, Composites Science and Technology, pp. 2381¡V2392*

[25] *Olivier Beffort, Siyuan Long, Cyril Cayron, Jakob Kuebler, (2007). ¡§Composites Science and Technology¡¨, pp. 737¡V745.*

[26] *R. Ipek, (2005). ¡§Adhesive wear behaviour of B4C and SiC reinforced 4147 Al matrix composites (Al/B4C¡VAl/SiC)¡¨, Journal of Material Processing Technology 162-163, pp.71-75.*

[27] *Rajaram G, Rao T. Srinivas, (2010). ¡§High temperature tensile and wear behaviour of aluminum silicon alloy¡¨, Materials Science and Engineering A 528,pp. 247-253.*

[28] *S. Balasivanandha Prabu , L. Karunamoorthy, S. Kathiresan , B. Mohan, (2006). ¡§Influence of stirring speed and stirring time on distribution of particles in cast metal matrix composite¡¨, Journal of Materials Processing Technology 171, pp. 268¡V273.*

[29] *S.C. Sharma, B.M. Girish, R Kamath and B.M. Satish, (1997). ¡§Effect of SiC particle reinforcement on the unlubricated sliding wear behaviour of ZA-27 alloy composites¡¨, Wear 213, pp. 33-40.*

[30] *S.L. Colenman, V. D. Scott, (1994). ¡§Materials Science¡¨, University of Bath, UK, Journal of Materials Science, pp. 2826-2834.*

[31] *Sanjeev Das V. Udhayabanu S. Das K. Das, (2006). ¡§Synthesis and characterization of Zircon Sand/Al-4.5 wt% Cu Composite produced by Stir Casting Route¡¨, Journal of Material Science, pp. 4668¡V4677.*

[32] *Shailove kumar, (2010). ¡§Effect of thermal ageing on Al -SiC MMC¡¨, ME Thesis, Thapar University Patiala.*

[33] *Singla Manoj, Singh Lakhvir, Chawla Vikas, (2009). ¡§Journal of Minerals and Materials Characterization and Engineering, Vol. 8, No.10, pp. 813-819.*

[34] *Sudipt Kumar, J. Ananda Theerthan, (2008). ¡§Production and Characterisation of Aluminium Fly Composites using Stir Casting Method¡¨, Department of Metallurgical & Materials Engineering National Institute of Technology Rourkela71*

[35] *Sanjeev Das V. Udhayabanu S. Das K. Das, (2006). ¡§Synthesis and characterization of Zircon Sand/Al-4.5 wt% Cu Composite produced by Stir Casting Route¡¨, J Mater Sci 41, pp.4668¡V4677.*

[36] *T. Ma, H. Yamaura, D.A. Koss and R.C. Voigt, (2003). ¡§Dry sliding wear behavior of cast SiCreinforced Al MMCs¡¨, Materials Science and Engineering A360, pp.116-125.*

[37] *T. P. D. Rajan, R.M. Pillai, B.C. Pai, K.G. Satyanarayana, P.K. Rohatgi, (2007).¡§Fabrication and characterisation of Al¡V7Si¡V0.35Mg/fly ash metal matrix composites processed by different stir casting routes¡¨, Composites Science and Technology 67, pp.3369¡V3377.*

[38] *T.P.D. Rajan, R.M. Pillai, B.C. Pai, K.G. Satyanarayana, P.K. Rohatgi, (2001) Proceedings of National Conference on: Recent Advances in Materials Processing, India, pp. 327¡V 334.*

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

[39] *Torabian H, Pathak JP and Tiwari SN, (1994). ¡§Wear characteristics of Al-Si alloys¡¨, Wear, volume172, pp. 49-58.*

[40] *Tuti Y. Alias and M.M. Haque, 2010. ¡§WEAR PROPERTIES OF ALUMINUM ¡V SILICON EUTECTIC ALLOY¡¨, pp. 456-486.*

[41] *Vencl Aleksandar, (2009), ¡§Scientific problems of machines operation and maintenance¡¨, Tribology Laboratory, Mechanical Engineering Faculty, University of Belgrade, pp. 104-176.*

[42] *Vishal Sharma, (2007). ¡§Synthesis and Interfacial Charaterization of Al-4.5wt%Cu/Zircon /SiliconCarbide Hybrid Composite¡¨, ME Thesis, Thapar University Patiala.*

[43] *Y Sahin, (2010). ¡§Abrasive wear behaviour of SiC/2014 aluminium composite¡¨, Tribology International 43, pp.939-943.*

[44] *Y. Iwai, T. Honda, T. Miyajima, Y. Iwasaki, M.K. Surappa and J.F. Xu, (2000). ¡§ Dry sliding wear behavior of Al2O3 fiber reinforced aluminum composites¡¨, Composites Science and Technology, pp. 1781¡V1789.*

[45] *Y. Yalcin and H. Akbulut, (2006). ¡§Dry wear properties of A356-SiC particle reinforced MMCs produced by two melting routes¡¨, Materials and Design 27, pp.872-881.*

[46] *y.sahin, (2009). ¡§Wear Behavior of Al-Al2O3 Reinforced Composites¡¨, Advanced Materials Research (Volumes 308 - 310), Advanced Design Technology, pp.366-385..*