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Investigation of wear behaviour of Al +Cu powder preforms.

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ABSTRACT: *This study deals with the investigation on the effect of Cu addition in Aluminium powder performs on their dry sliding behaviour against a hardened steel disc of EN-32 with hardness of 55 HRC. The Copper powder has been added in 5 different wt. Percentages of 10%, 155, 20%, 25%, & the eutectic composition of Al+ CU that is 33%. The investigation has been carried out by dry sliding experimentation on Pin on disc machine in ambient conditions. The powder performs were manufactured by CIP technique on a 40 ton UTM. The compacting pressures were 16KN, 18KN, & 20KN. the sintering temperatures were 450⁰C and 475⁰C. The applied loads during the experimentation were varied from 10 N TO 15 N AND 20 N. The track radii were 25 and 40mm and the RPM of the disc was kept constant at 1000 rpm. It has been observed that in low stress dry sliding conditions the instantaneous wear rate is function of Cu content for Al+ Cu powder performs. The addition of Cu has resulted in better wear resistance of the performs. The friction coefficient was also observed to be increasing with the increasing Cu content. The wear during the experimentation was purely adhesive at lower values of applied load and track radius. Whereas the wear rate was found to be changing its regime form mild to little severe one for higher applied loads and for longer duration of time of rubbing. This investigative experimentation may prove useful for the young and bidding technocrats to study the otherwise cryptic wear mechanism.*

Keywords - *Alternative materials, Copper content, Discontinuously reinforced Al composites, friction coefficient, Powder metallurgical forming, wear resistance.*

I. Introduction

Worldwide there is growing trend of optimizing the size and weight of the products. The advancement in Powder metallurgical forming techniques has also favoured this trend. The powder metallurgical forming techniques have helped in formation of new alternative materials. With the help of P/M forming methods and processes it is very convenient to manufacture the alternative materials in recent times. The reinforcement of the basic matrix with an intention to improve its wear and friction related properties is very easy with the implementation of P/M forming techniques like cold and hot compaction. The industrial application of the alternative materials in continuous and discontinuous form has been gaining more and more popularity in every engineering field applications. eg. Automobile industry, self lubricated bearings for all applications etc. [1, 2, 3, 4, 5] Among the alternative materials the aluminium in continuously and discontinuously reinforced form has been popularly used in major industrial applications. The discontinuously reinforced Aluminium metal matrix composites are more rapidly favoured in the industrial applications as with the help of P/M techniques the DRAMMCs is a better option for the newer manufacturing concepts like near net shape and green manufacturing. [3,4,] Wear as we all know is not a desirable entity in any practical applications. Wear in severe form may result into catastrophic conditions. Hence it should and must be treated seriously. Though, there is serious and extensive work carried out on wear related properties for more than 60 years now. Yet, wear a complex process altogether is a major field of research worldwide, and it presents challenge to the researchers all across the globe. There are too many parameters that need proper conditioning for the exact prediction of the wear behaviour of any components . As wear depend on ambient conditions heavily like lubrication between the contact the humidity level in the atmosphere it also is a function of time of contact, velocity and the applied loads, even the grain size of the reinforcing materials may play vital important role in determination of the wear and friction behaviour of the material composites. [6, 7,8] . Manier cost effective alternative materials are found to deficient in wear behaviour; hence the treatment of wear needs to be addressed carefully. Though, Aluminium in its pure or alloy also form has weak wear resistance and lack on frictional properties. The reinforcement has resulted in improving the wear and friction properties of the component. Literature vouched for the fact that the better wear resistance at increased sliding speeds and velocities have results in popularity of the aluminium composites.[4,5,6,7] The use of powder metallurgical techniques, in manufacturing of the discontinuously reinforced composites has resulted in reducing the waste and consumption of waste. The emergence of newer energy efficient technologies like Near Net Shape has gained quite lot because of the P/M forming techniques. The relationship between the compacting pressures, the sintering temperature, applied loads and the friction coefficient has been addressed extensively in the past for the convention materials, these properties too require a fresh approach with the availability of sophisticated testing machines and back up of information technology. In recent times after the advancement of the technology particularly the integration of digital electronics in measuring instruments and lab testing equipment the basic wear mechanism of Aluminium and copper powder performs are needed to be studied again. When we study the literature most of the research work is centred to the reinforced Al+ Cu composites, and has been carried out with addition of Cu at very low percentage by volume and with reinforcements like MoS_2, fibre, Sn etc. This investigation aims to examine the dry sliding (rubbing) behaviour of the Al+ Cu powder performs to analyse the wear phenomenon and attempt has been made to increase the Cu content till the eutectic composition of 33 % by wt. The investigation attempts to study the type of wear which takes place in the above mentioned conditions.

II. Literature Review.

Wear and Friction are the two most processes in any field application. As friction is a primary necessicity for any motion to take into actual action. Wear becomes more serious issue with the increase in the velocity of any mating parts. In the German standard DIN 50320 four wear mechanisms are classified as [6]

Tribochemical wear,
Surface fatigue,
Adhesive wear,
Abrasive wear

Vencl A., et all [1] reported in 2004 that Aluminium alloys have favourable physical and mechanical properties, primarily low density, but their tribological properties are unsatisfactory. One of the solutions is reinforcement of the basic alloy (matrix) and formation of composites. The AMCs have been used for manufacturing pistons, cylinders, engine blocks, brakes and power transfer system elements. Performance benefits of using the AMCs in automotive industry are reduced weight and improved wear resistance, together with better thermal conductivity comparing to the traditional materials like steel and gray cast iron.

Chowdhury M. A. et all, [2] investigated in 2010, that the presence of sliding speed and normal load affects the friction force and wear rate of aluminium considerably. The values of friction coefficient decrease with the increase of sliding speed and normal load. As there is a declination in friction coefficient and wear rate increases with the increase of normal load and sliding speed, therefore maintaining appropriate level of sliding speed and normal load friction and wear may be kept to some lower value to improve mechanical processes.

Jami Winzer, etc. et all, [4] reported in 2011 that, the wear mechanisms of pure copper and pure alumina were adhesive and abrasive, respectively. Further they concluded in that in alumina–copper interpenetrating composites, increasing the amount of copper resulted in decreased hardness and increased wear, except where cyclic tribolayer behaviour occurred or where the alumina grains were weakly bonded.

Dheerendra Kumar Dwivedi, [11] studied the wear behaviour of cast hypereutectic aluminium silicon alloys. He reported the influence of alloying elements on wear behaviour of binary (Al–17%Si) and multi-component (Al–17Si–0.8Ni–0.6Mg–1.2Cu–0.6Fe) cast hypereutectic aluminium alloys. They mentioned that the addition of alloying element not only reduces the wear rate in mild oxidative wear condition but also increases the transition load. Temperature of wear pin near the sliding surface was measured and it was related to wear and friction behaviour of experimental alloys. Increase in hardness was also noticed due to alloying.

N.B.Dhokey and K. K.Rane, [2011] investigated the wear behaviour and Its Correlation with Mechanical Properties of TiB2 Reinforced Aluminium-Based Composites . Aluminium-based TiB2 reinforced composite is a promising material to be used as brake drum material, and it may emerge as substitute for conventional gray cast iron. They concluded that mechanical properties are strongly affected by the content of TiB2 in Al-MMCs. Secondly, the Wear behavior gives a reasonable correlation with hardness, ultimate tensile strength, fracture strength, and strain hardening exponent of Al-MMCs. The relationship between wear rate and mechanical properties validates Archard's equation.

A. Vencl,et [2010] all investigated the posibilty of determination of abrasive wear resistance by scratch testing. Upon coating a Al-Sin alloy(EN ALSI10Mg) with two different metco suzler pta powders and then on comparing results they concluded that there is stable behaviour at low loads, hey also reported there exixts dominant type of abrasive wear in the initial scratching.

III. Materials And Methods.

3.1 Disc :

En-32 disc has been used on the pin on disc machine the hardness of the disc was 60 HRC and the surface roughness value of 1.5 to 1.6 µm. The composition of the disc material is shown in table 1.

TABLE 1 Chemical Composition Of EN-32 steel disc.

Constituents	C	Cr	Si	Mn	P	S	Mg	Fe
Wt. Percentage	0.45	0.25	0.27	0.65	0.04	0.04	0.25	Balance

3.2 Test Pins:

3.2.1 Powder Blending.

The Pin on disc friction and wear testing machine has been supplied by M/s Ducom. Banglore India (TR-20) requires pins to be of size 6 to 12 mm maximum which fits best in their supplied pin holder assembly. The aluminum and copper powder has been brought from M/s. Polychem(I) Pvt. Ltd. Vadodara, India. The chemical composition of both the powders are presented in the Table 2 and 3 respectively.

TABLE 2 Chemical Composition Of Aluminium powder.

Constituents	Fe	Cu	Si	Mn	Hydrogen Loss	Mg	Al
Wt. Percentage	0.17%	0.0015	0.1313%	0.005%	0.48795%	0.25%	Balance

TABL 3 Chemical Composition Of Copper powder.

Constituents	Substance insoluble	Sb	Arsenic	Fe	Mn	Ag	Sn	Cu
Wt. Percentage	0.005%	0.25%	0.0002%	0.005 %	0.005 %	0.005 %	0.005 %	Balance

The powders were mixed in 5 groups each containing 10%, 15%, 20%,25%,33% Cu by weight percentage in balance Al matrix. The metal powders are mixed with lubricant to form a homogenous blend. 0.5 - 1.5% lubricant is normally added in the mix, and metallic stearate and waxes are commonly used lubricants. The main function of the lubricant is to reduce friction between the powder mass and the surfaces of the tool, die walls, core rods etc., along which the powder must slide during compaction. This assists the achievement of uniform density from top to bottom of the compact.

3.2.2 Cold compaction:

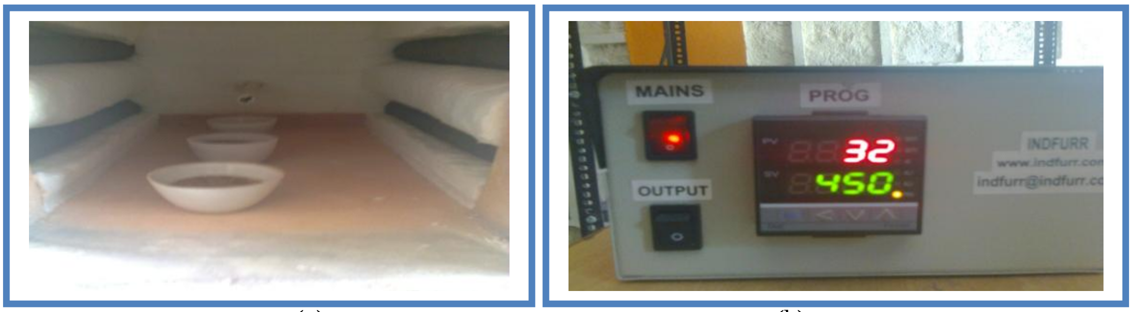
The specimen pins were manufactured by cold compaction P/M forming technique on a UTM-40 machine. The Fig. 1.2 shows the photographs of the Die and Punch and the UTM respectively. The compacting pressure plays vital role in achieving the density and hardness of the resultant product. Though sintering temperature also has its effect on these properties. The compacting pressures were kept at 16 KN, 18 KN for all the five variants of the mix. Fig. 1 (a) and (b) shows the Die & Punch and compaction process on a UTM.

Fig. 1 Photographs of (a) Die & Punch.

Fig. 2 Cold compaction on UTM.

3.3.3 Sintering:

In order to provide uniformity to the structure of the green compact and improvising its strength, sintering is being carried out. In this experimentation the sintering has been carried out at relatively higher temperature of 450° C, 475° C and 500° C in endothermic atmosphere in a muffle furnace. Fig. 2 shows the photographs of muffle furnace and the controller for timing cycle provided on the muffle furnace. The sintering cycle for the three different temperatures is shown in Fig.3 (a) & (b)



(a) (b)

Fig. 3 (a) Crucibles in muffle furnace. (b) The timing controller.

3.3.4. Wear testing:

In order to investigate the dry sliding characteristics of the powder performs with respect to the % Cu content; experimentations were carried out on a Pin-On-Disc type wear testing machine. The finished sample specimen's photograph is presented here in Fig.4. We are all aware about the fact that the friction and wear resistances of any material depends on it's on its strength. However wear is not a material property alone. It is dependent on quite many other parameters too. Alloying of any metal or material often results into enhancement of its physical and technological properties. The rotating disc of Ø 165 mm is fixed on the wear testing machine shown in photograph in Fig.5. The machine is incorporated with a LVDT for wear rate measurement. Further a strain gauge type force measuring instrument is also mounted on the machine which helps us to find the coefficient of friction for every 10 seconds of elapsed testing time. All the specimen were tested for minimum of 5 minutes at different applied loads of 10 N, 15 N , & 20 N, the results were recorded on a PC by means of a controller. The results obtained, are then analysed for the purpose of investigation of wear behaviour in next section.

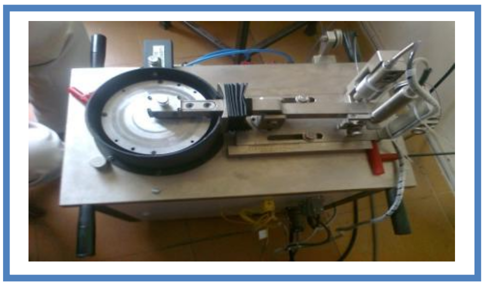


Fig. 4 The finished Specimen. **Fig. 5 Pin-On-Disc Machine**

The track radii during the experimentations were varied from 25 mm to 40 mm and 55 mm.

4. R

3.3.4.1 Correlation between the wear rate and the % Cu content.

The Fig. 6, 7, and 8 shows the correlation in between the wear rate and the applied loads at a fixed track radius of 25 mm for all the five each Cu variants.

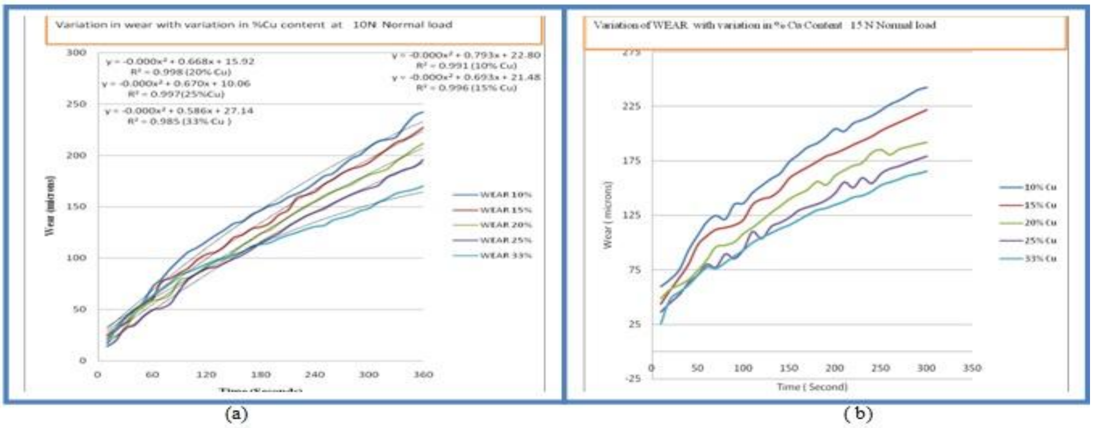
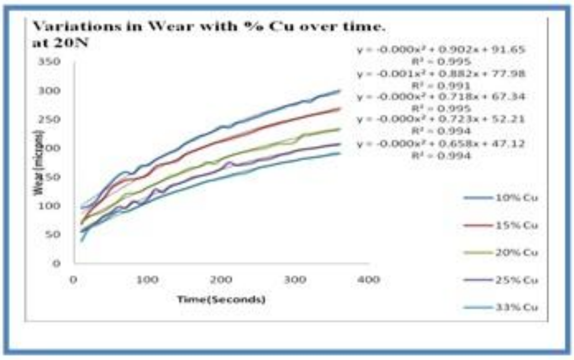


Fig. 6 Variation in wear rate for different % Cu content at fixed load.(a) at 10N & (b) at 15 N.



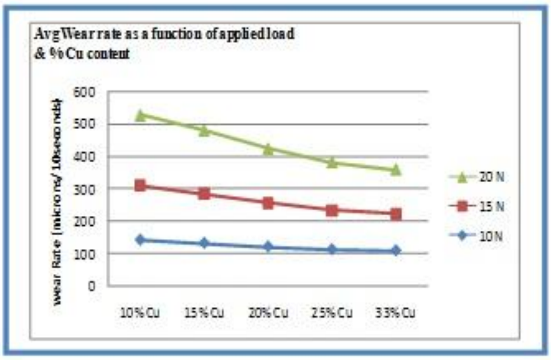


Fig. 7. Variation in wear at 20N applied load.

Fig. 8. Avg. Wear rate as function of load and % Cu content

From the Fig. 6,7& 8 it is very much clear that the instantaneous wear is function of applied load and it is also a function of % Cu content by wt. %. The relation between the wear rate and the Cu contents best fits into a second order polynomial equation of higher value of R^2. Along with the increase in the load and the Cu content the wear rate increases.

3.3.4.2 Correlation between the % Cu content and the friction coefficient :

"Fig. 9" shows the dependence of coefficient of friction on the % Cu content.

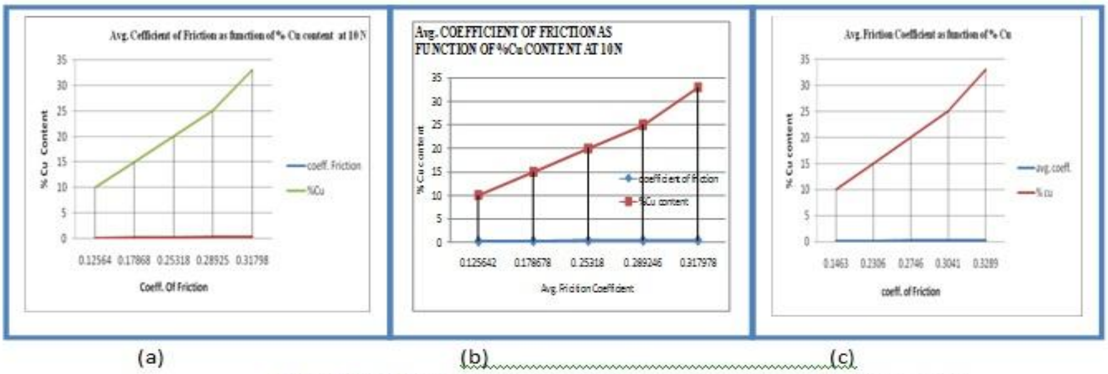


Fig. 9 The Avg. Friction coefficient as function of % Cu content.

"Fig. 10" shows the relation between the sliding distance and the friction coefficient for all 5 variants of specimens. It is very evident from the fig. that the friction coefficient increases with the increase in Cu content. As it is low stress sliding conditions the change in the friction coefficient with the Cu content is almost same for all the tests. The sliding distance is calculated for the track radius of 25 mm. And the effect of sliding distance is plotted in the fig. 10.

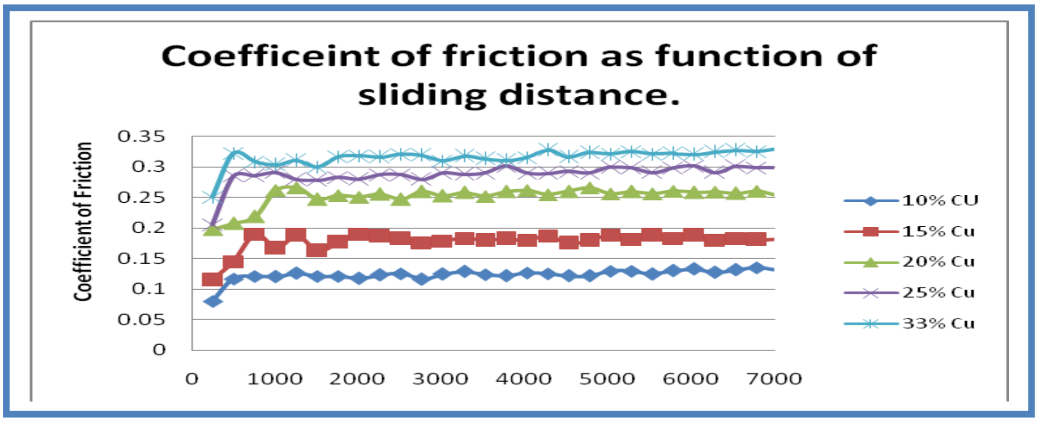


Fig. 10. The Friction coefficient as a function of the sliding distance.

"Fig. 10", shows the combined wear rate results for various combination of the tests. That is the wear rate for different Cu contents at different loads.

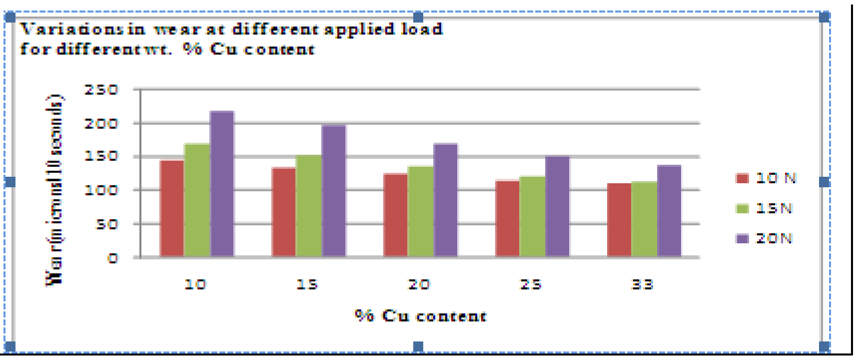


Fig. 11 Variations in wear at different applied loads for various wt % of Cu contents.

IV. Conclusions :

From the experimentations and the results analysis following conclusions can be can be drawn.

1. The instantaneous wear rate is a function of Cu content present in the mix and it also effectively controls the friction coefficient in low stress rubbing contact of the composites with harder material. This is due to the fact the wear mostly during this work is of adhesive type and the wear debris formed a third layer in the contact zone. The presence of hard Cu particulates in the wear debris may have been acted as lubricating pool in otherwise dry sliding contact of the specimen and hardened steel disc..
2. The investigation shows that the general behaviour may be applied to the wear resistance as it increases with the increases of Cu content. All the relation between the wear rate and the % Cu content were best fit into a second order polynomial equation. So it may be said that these results may very well be used to develop a model for prediction of wear behaviour of AL + Cu powder performs.
3. The wear mechanisms during this work were adhesive for lower applied loads and at lower track radii. For 20N applied load and 55 mm track radi wera was observed to be changing towards severe type one and it was like abrasive wear as the harder Cu particulates were now getting out from the surface contact zone rapidly.
4. Though all the results were analysed based upon the avg. readings of more than 60 basic experimentations, during the experimentation it has been found that the wear testing machine should also be fitted with one more transducer that shall ensure constant initial contact pressure for each and every trial.
5. The work can be extended by investigating the effect of variations of the grain size of the Cu powder.
6. The results and trends observed in this investigation may very well be used to model the wear behaviour of Al+ Cu powder performs. And the same work can be carried out by incorporating various reinforcement in the mix.eg. 2% MoS_2, 2 to 5 % Sn etc.
7. Further this work may work out useful to the young technocrats mushrooming all over India with regards to the wear related studies and to the small scale industries in developing world.

References

Journal Papers:

[1] Rac A., A. Vencl. (New wear resistant Al based materials and their application in automotive industry, *MVM – International Journal for Vehicle Mechanics, Engines and Transportation System, 30, Special Edition, December 2004, 115-139.*

[2] Chowdhury M.A,, M. K. Khalil, D. M. Nuruzzaman, M. L. Rahaman,*The Effect of Sliding Speed and Normal Load on Friction and Wear Property of Aluminum. International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS Vol: 11 No: 01*

[3] M. Asif, K. Chandra, P.S. Misra. Development of Aluminium Based Hybrid Metal Matrix Composites for Heavy Duty Applications. *Journal of Minerals & Materials Characterization & Engineering, Vol. 10, No.14, pp.1337-1344, 2011*

[4] Jami Winzer, Ludwig Weiler, Jeanne Pouquet,Jurgen Rödel. *Wear behaviour of interpenetrating alumina-copper composite. Wear 271(2011)3845-2851.*

[5] A. vencl,A.Rac,I.Boric. *Tribological behaviour of Al-Based Mmcs aand their applications in automobile Industry. Tribology in industry,volume 26, No. 3& 4 2004.*

[6] N.B.Dhokey & K.K. Rane 2011. *Wear Behaviour and its Correlationn with Mechanical properties of* TiB_2 *reinforced Aluminium based composites. Advances in Tribology,Vol.2011 No. 837469,8 PAGES.*

[7] P.Sentil Kumar & K.Manisekar *(2012) Wear and Mechanical properties of Sinterd Cu-Sn-MoS2 Powder Pre-Forms at Dry atmosoheric Condition. European Journal of Scientific research Vol 72 no.1pp 148-155.*

[8] Dheerendra Kumar Dwivedi,(2006)*Wear behaviour of cast hypereutectic aluminium silicon alloys, Materials and Design 27, p.610–616.*