



Tribological Investigation on B83 Babbitt reinforced with silicon carbide

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Abstract - In this research work the stir casting method is used to fabricate babbitt metal matrix composite by reinforcing silicon carbide with 2%, 4%, 6% respectively. Wear test was conducted at ambient temperature by using lubricating oil. Pin on disc apparatus was used to conduct wear test by considering different affecting parameters i.e. Normal load, sliding velocity, sliding distance. The specimen pins of composite materials were tested against EN8 disc. Result of wear test is studied and compared with existing babbitt. The babbitt+2% SiC composite possesses minimum wear rate. Experimental validation was carried out by using Design of Experiment (DOE) approach. It is clear that % of SiC has high influence on wear and it is an important control factor to be taken into consideration during the wear process followed by applied loads and sliding speed respectively. The microstructure of composite material after conducting wear test is studied by using Scanning Electron Microscopy. By addition of 2% SiC in Babbitt alloy, microstructure get refined which leads to increase in wear resistance. From this study it is concluded that wear resistance is increases by addition 2% silicon carbide as compared to the existing babbitt alloy and other composition of material.

Key Words: Wear test, B83 Babbitt, Pin on Disc, Composite material, Scanning Electron microscopy, Tribology, Metal matrix composites

1. INTRODUCTION

The metal matrix composite (MMC) is usually an alloy, rather than a pure metal. A metal matrix composite (MMC) is a composite material with at least two constituent parts, one being a metal. The other material may be a different metal or another material, such as a ceramic or organic compound. The need for composite materials has become a necessity for modern technology, due to the improved physical and mechanical properties. Metal matrix composites (MMC) have been developed in recent years. A composite material is a material consisting of two or more physically and/or chemically distinct phases. The composite generally has superior characteristics than those of each of the individual components. Usually, the reinforcing component is distributed in the continuous or matrix component. Russian grade B83 Babbitt is the most popular material for fabrication of sleeve bearings by casting, hard facing, and metallization in Russian engineering. In addition to a low friction coefficient, this alloy has such attractive properties as rapid conformability, good thermal conductivity, high impact viscosity, and compatibility with oils (petroleum and synthetic). However, low fatigue strength upon alternating loads and moderate wear resistance of Babbitt decrease the operating life of items made of it. At present babbitt, i.e., alloys of the Sn-Sb-Cu are widely used as the material for sliding bearings that operate in oil (for example, bearings used in various industries, as well as in sugar industry, shipbuilding and car industry). They are also applied in hydroelectric power plants to support hydraulic turbines and electric generators. A bearing operates in the steady mode when a lubricating film of a required thickness is formed and retained between the shaft and the bearing. However, under inadmissibly heavy loads and at high velocities of the rotation of the shaft, damage to the bearing often occurs, especially if no oil film of a sufficient thickness appears between the shaft and the bearing. Under these conditions, the shaft and the bearing lining made from a babbitt metal can come into partial contact in the course of sliding friction.

2. LITERATURE REVIEW

I.E. Kalashnikov, L.K. Bolotova, P.A. Bykov, L.I. Kobeleva, I.V. Katin, R.S. Mikhnev, and N.V. Kobornik has developed technological processes to fabricate composite materials based on B83 babbitt using hot pressing of a mixture of powders in the presence of a liquid phase. As a result, the structure of the matrix B83 alloy is dispersed, the morphology of intermetallic phases is changed, and reinforcing micro- and nanosized fillers are introduced and uniformly distributed in the matrix.

D. Venkata rao, M. V. S. Babu, K. Santa rao and P. Govinda rao has experimentally investigated the mechanical behaviour of tin alloy based particulate metal matrix composites. In the present work, Tin alloy based particulate Metal Matrix Composite (MMC) with Ilmenite and SiC as reinforcements were fabricated. Stir casting was used for fabricating MMC. Then, its mechanical behaviour is investigated by conducting tensile test and hardness test. SEM images and microstructures were studied for understanding the behavior. Tensile strength is improved by reinforcing Tin with the

Silicon carbide and Considerable change in hardness is also observed in this composite when compared with other two specimens.

Bhaskar Chandra Kandpal, Jatinder Kumar, Hari Singh has reviewed on Manufacturing and technological challenges in Stir casting of metal matrix composites. The study on the composites, production technologies related to metal matrix composites exclusively stir casting. By controlling various parameters of stir casting process like stirring temperature, stirring speed, stirring time, preheating time ,etc. and selection of matrix and reinforcements the quality of components can be improved.

A. Kh. Valeeva, I. Sh. Valeev, and R.F. Fazlyakhmetov studied the effect of conditions of crystallization in the course of the production of a bearing lining on the structure and wear of the B83 babbit has been studied. It is seen that the pressing of the melt being crystallized makes it possible to form a homogeneous structure with fine crystals of the cubic SnSb phase. The babbit produced by liquid forging has the highest wear resistance.

A. Kh. Valeeva, I. Sh. Valeev, R. F. Fazlyakhmetov, and A. I. Pshenichnyuk have experimentally investigated on the Mechanism of Running in during Wear Tests of a Babbitt B83. Based on analysis it is observed that changes in the structure of cast babbit. Wear mechanism at the running in stage of B83, which is reduced to the spalling off of coarse particles of the intermetallic β phase, pressing in of the cleaved particles into the soft plastic matrix, and the formation of a fairly homogeneous coating uniformly paved by small, hard particles. Thus, the mechanism of the running in upon the wear tests of cast babbitt is reduced to the dispersion of large intermetallic particles of the β phase, to the pressing in of the spalled particles into the soft plastic matrix.

3. PROBLEM STATEMENT

The boiler feed pump must be reliable and it can operate for desired life period without failure. Bearing failure due to excessive wear is one of the important reasons for failures of boiler feed pump. In sugar industry failure of feed pump can stop subsequent operations which lead to heavy financial loss. To ensure the desired life of bearing element it must possess low friction coefficient, high wear resistance, good fatigue strength upon alternating loads, rapid conformability, good thermal conductivity, high impact viscosity, and compatibility with oils. The single base material not possesses all this good operating properties, so the properties of base material can be improved by modification with ceramic particles. This problem can eliminate by reinforcing metal matrix composites by silicon carbide particles which can improve the base material in terms of wear resistance, damping properties and mechanical strength.

3.1 Objectives

The main purpose in accomplishing of this project is:

1. To conduct wear test on B83 Babbitt and B83 Babbitt-SiC composite materials of different compositions at varying loads and sliding speeds.
2. To Study tribological properties of babbit and there composite materials of different compositions to select best composite material for boiler feed pump bearing on the basis of wear.

3.2 Scope of work

Babbit alloy is used as bearing lining material in boiler feed pump bearing. Babbit material has low fatigue strength and moderate wear resistance at alternating loads which lead to decrease in operating life of bearings made of it. This can be overcome by reinforcing silicon carbide in to babbit alloy. The introduction of Silicon Carbide particles into a matrix alloy can increase the load-bearing capacity and the wear resistance of composite materials. The scope of this project work is fabricate composite material by reinforcing 2%, 4% and 6% silicon carbide respectively in to babbit alloy to study its wear behaviour at different loading conditions and find new composite material for boiler feed pump bearing. Also to study the microstructure of composite material as it affects the wear rate.

4. EXPERIMENTATION

4.1 Fabrication of Composite Material

The fabrication of composite material by using stir casting is done in Advance material Laboratory of Mechanical Engineering Department at DVVP COE, Ahmednagar.

Table No. 1. Composition of Babbitt Composite Materials

Sr. No	Materials	% of Silicon Carbide
1	Material- 1	0
2	Material- 2	2
3	Material-3	4
4	Material-4	6

Stir casting process has been used to fabricate the Babbitt metal and silicon carbide composites. An electric furnace was used at the first stage for melting the Babbitt in a crucible under atmospheric conditions. The melting of Babbitt takes place at 240°C. Initially 500°C temperature is set and which is to be achieved in 60 minutes. After achieving the 500°C temperature furnace is kept on constant temperature of 500° for 30 minutes. Preheated SiC particles were added in molten metal through funnel. Silicon carbide particles were preheated and added 2%, 4% and 6% by weight in melted Babbitt to form different compositions. An electrical resistance furnace assembled with graphite impeller used as stirrer was used for stirring purpose. After SiC addition, the liquid metal-reinforcements mixture was stirred for 30 minutes. Finally composites were poured in preheated metal moulds at 500°C. The melt was allowed to solidify in the mould.



Figure No. 1. - Sample prepared by Stir casting

The prepared specimen sample was ready for processing; it is to be machined on lathe after cutting on power hack saw. The sample turned on lathe to get required dimensions and finishing. The required dimension of Ø10×30 mm is obtained on lathe. In this way the specimen of different compositions were ready for wear test. The counterpart is selected with consideration of application i.e. centrifugal pump. Generally the outer race of journal bearing is made up of stainless steel and grey cast iron. With this reference the counterpart is also selected as made up of same material. So the disc material selected as steel with grade EN8. The main aim of selection of counter surface of EN8 is, generally the rotating shaft inside the pump are used of EN8 grade.



Figure No. 2. Specimen pin for wear test

4.2 Wear Test

The prepared samples were used for tribological test on Wear and friction monitor at PG Laboratory, Department of Mechanical Engineering in at DVVP COE, Ahmednagar. The pin on disc is an apparatus used to determine Tribological properties of composite materials. The specimen is placed on a rotating disc spinning at a variable angular speed. A ball held by a vertically reciprocating pin is pressed against the sample for a fixed amount of full rotations of the disc. The tangential force and the frictional coefficient are measured and the volume of removed material can be measured by additional techniques. The basic aim of the wear test to minimize the wear rate of existing bearing material of boiler feed pump. The specimen pin 10 mm diameter and 30 mm long was run against the disc of grade EN-8. The sliding velocity is calculated by pump motor rpm and shaft diameter. After that the track diameter of disc is taken from 140 mm to 80 mm. according to track diameter the speed for each track diameter is calculated. The wear test is conducted at wet conditions by using lubricating oil of SAE 20W40 oil. The Normal load for wear test is 49.05N, 68.67N and 88.26N is selected. Before conducting wear test on pin-on disc apparatus, some calculations were done. The sliding velocity (V_s) is calculated from equation $V = \pi \times D \times N / 60$. The Shaft diameter and Speed is taken as 50 mm and 2900 rpm respectively from pump specification data. The respective speed corresponding to Track diameter is calculated by above equation. The test was conducted at Wet condition by using SAE 20W40 lubricating oil. The wear test was conducted on each specimen samples by varying load of 49.05 N, 68.67 N & 88.29 N. The track diameter is set before starting the test. At

each loading conditions the Wear Vs Time and Temperature Vs Time graph is generated, these graphs are used for result and its analysis.



Figure No. 3. - Pin on Disc Apparatus (TR20PHM400)

Table No. 2 - Operating parameters

Sliding velocity(mm/sec)	7592.18
Normal Loads(N)	49.05 to 88.29
Test Duration (Sec)	900
RPM	1035-1812
Track Diameter(mm)	80-140

Table No. 3 Observation table of wear test

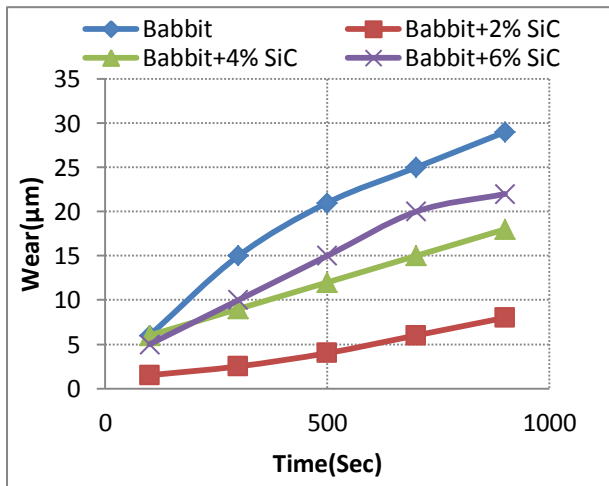
Sr. No	Material	% of SiC	Normal Load(N)	Wear (μm)	Temp.($^{\circ}\text{C}$)
1	Babbitt	0	49.05	29	32
2		0	68.67	36	33
3		0	88.29	39	33
4	Babbitt + 2% SiC	2	49.05	8	26
5		2	68.67	13	27
6		2	88.29	14	29
7	Babbitt + 4% SiC	4	49.05	16	30
8		4	68.67	18	32
9		4	88.29	22	32
10	Babbitt + 6% SiC	6	49.05	22	31
11		6	68.67	24	31
12		6	88.29	28	33

5. RESULTS & DISCUSSIONS

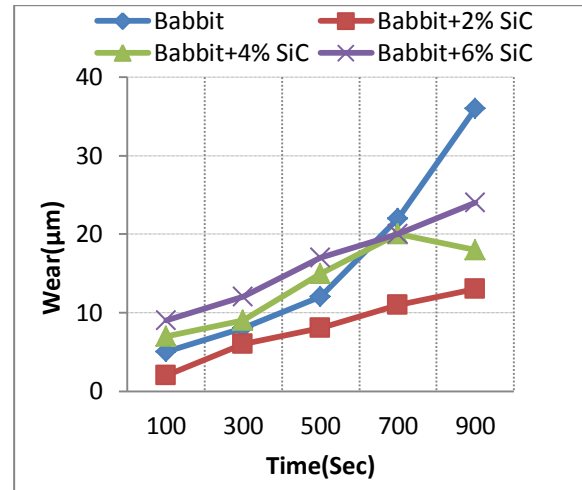
After conduction of were test on pin-on disc apparatus for different loading conditions, The Wear vs. Time and Temperature vs. Time graph is generated. This graph is used for comparison of different composition at same load. This comparison graph is used to analysis of wear rate of different compositions. For all the four materials, the wear was compared by considering effect of the affecting parameters i.e. Normal Load and Temperature.

5.1 Wear vs. Time

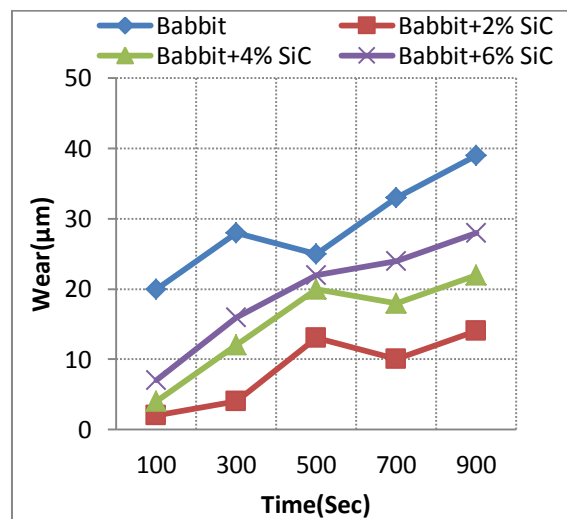
Graph obtained from wear test is compared by considering affecting parameters i.e. Normal load, % of silicon carbide in babbitt and sliding speed for all four material compositions. The Wear vs. Temperature graph plot at different loading condition. Highest wear was observed in babbitt for all loading conditions. At 88.26 N the babbitt shows highest wear which is also highest comparing to all materials. Silicon carbide shows minimum wear for all loading conditions. The minimum wear observed is 8 micrometer at 49.05 Normal load. The Babbitt+4% SiC shows highest wear than Babbitt+4% SiC but which is low as compare to Babbitt+6% SiC and Babbitt for all normal loads. The nature of increasing wear is almost linear except 88.29 N load. At 88.29 N load the wear plot vs. Time instances shows peak and drop of wear. From above Wear vs. Time plot it is seen that Babbitt+2% SiC material composition possesses minimum wear compared to other all other material. The wear rate is increases with increasing silicon carbide percentage in material composition.



(a)



(b)



(c)

Figure No. 4. Wear vs. Time at (a) 49.05N (b) 68.67N & (c) 88.29N Load

5.3 Wear vs. Normal Load

The Wear vs. Normal load plot is shown in Figure No.5. The wear is increased with increase in normal load. The Babbit material shows highest wear at all normal loads. The minimum wear is observed in Babbit+2% SiC composite material.

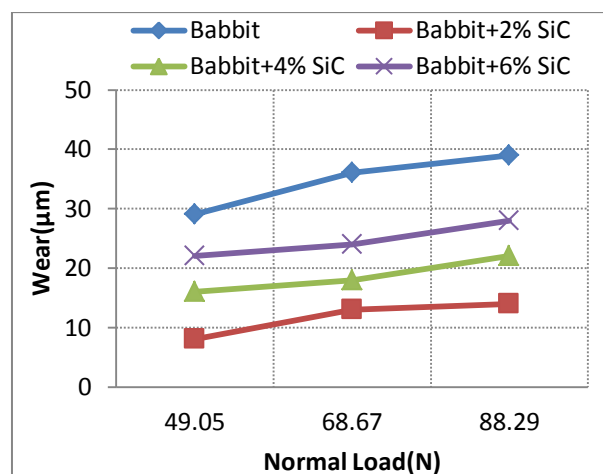


Figure No. 5. Wear vs. Normal Load

5.4 Wear vs. Pin Temperature

The plot of Wear vs. Pin temperature is shown in Figure No. 6. From graph it is observed that pin temperature is increases with increase in wear of material. Lowest temperature is 26 °C and the highest temperature observed is 33 °C

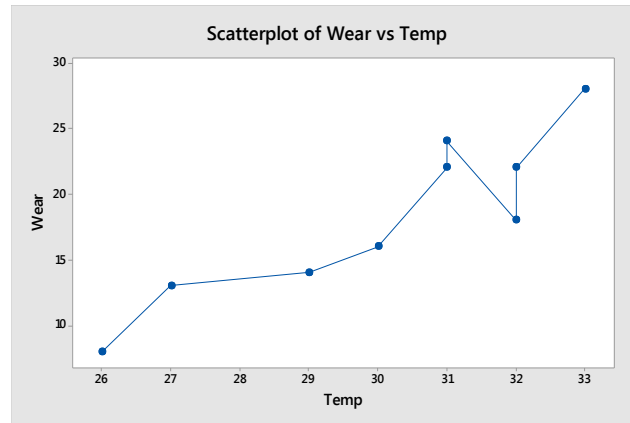


Figure No.6. Wear vs. Pin Temperature

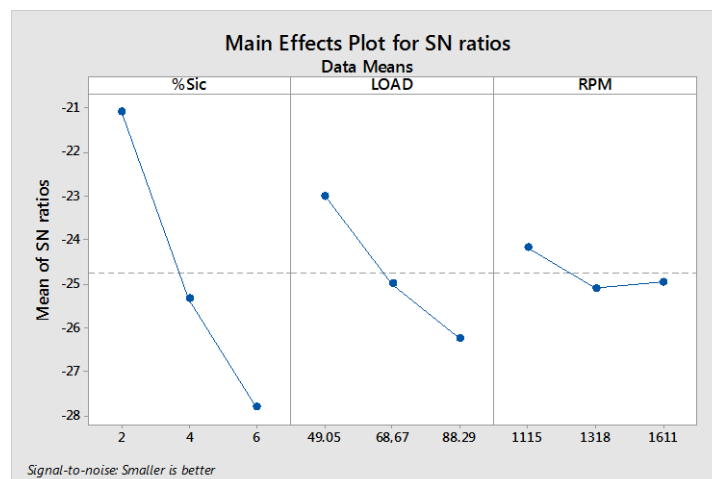
6. EXPERIMENTAL VALIDATION

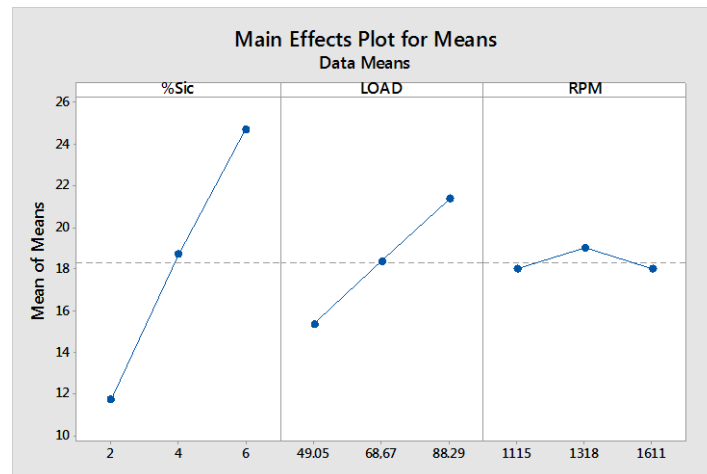
The experimental plan was formulated considering three parameters (variables) and three levels based on the Taguchi technique. The aim of the experimental plan is to find the important factors and the combination of factors influencing the wear process to achieve the minimum wear rate. The experiments were developed based on an Orthogonal Array, with the aim of relating the influence of sliding speed, applied load and % of Silicon carbide in composite material. 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.

Table No. 4. Process parameters and levels

Level	% of SiC	Load(N)	RPM
1	2	49.05	1115
2	4	68.67	1318
3	6	88.29	1611

The results for various combinations of parameters were obtained by conducting the experiment as per the OA. The measured results were analyzed using the commercial software MINITAB 18 specifically used in DOE applications. The aim of the experimental plan is to find the important factors and the combination of factors influencing the wear process to achieve the minimum wear rate. The experiments were developed based on an OA, with the aim of relating the influence of % of SiC, applied load and RPM. 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.





It can be observed that for Composite materials that the % of Silicon carbide has the highest influence on wear rate. Hence % of silicon carbide is an important control factor to be taken into consideration during the wear process followed by applied loads and sliding speed respectively.

Table No.5. Analysis of variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
%SiC	2	3.72633	1.86316	57.23	0.017
Load	2	0.81367	0.40683	12.50	0.074
RPM	2	0.03834	0.01917	0.59	0.629
Error	2	0.06511	0.03256		
Total	8	4.64345			

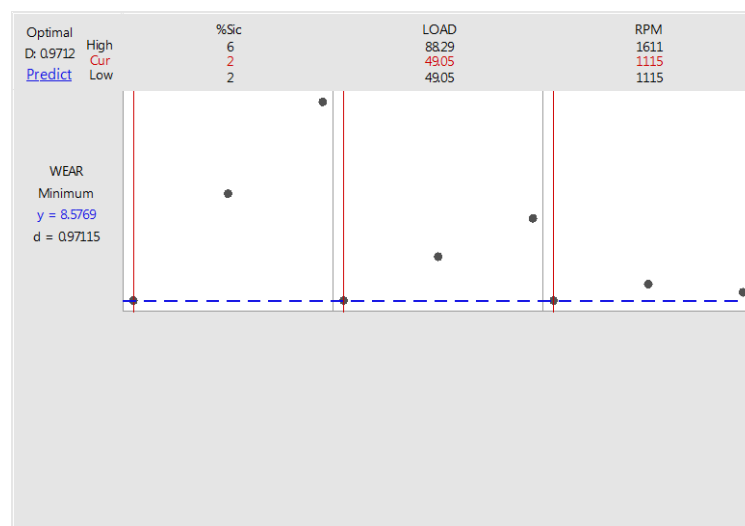


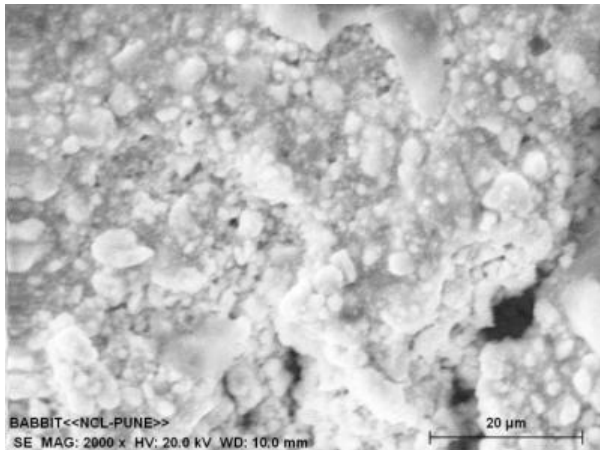
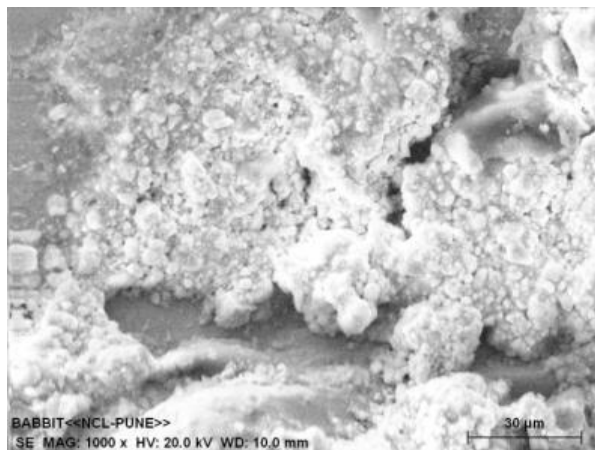
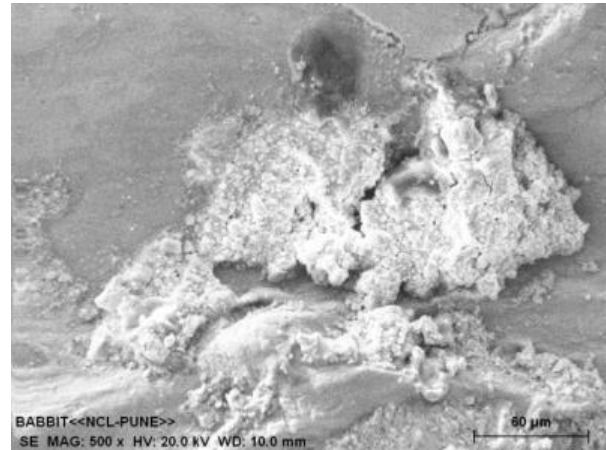
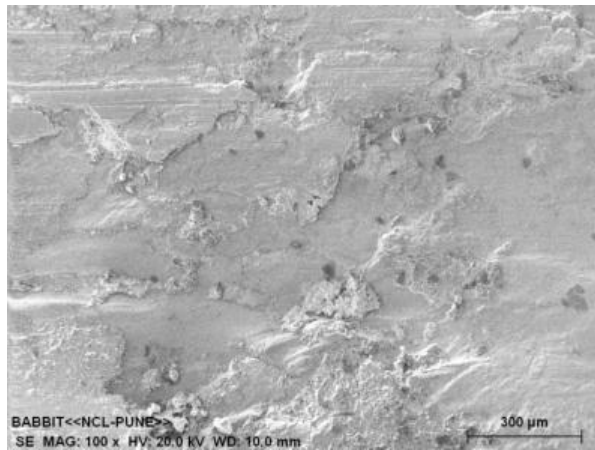
Figure No.7. Response Optimization for Wear

From response optimization plot for wear it is observed that percentage of silicon carbide in composite materials has large influence on wear. Figure No.7. shows the optimum level for minimum wear for 2% Silicon carbide composites with 49.05 Normal Load and 1115 RPM.

7. SCANNING ELECTRON MICROSCOPY

The SEM analysis is carried out so as to interpret the results obtained. The SEM analysis of Babbit material, Babbit+ 2% SiC, Babbit+ 4% SiC and Babbit+ 6% SiC composite material pin samples was done under scanning electron microscope at national chemical laboratory, Pune.

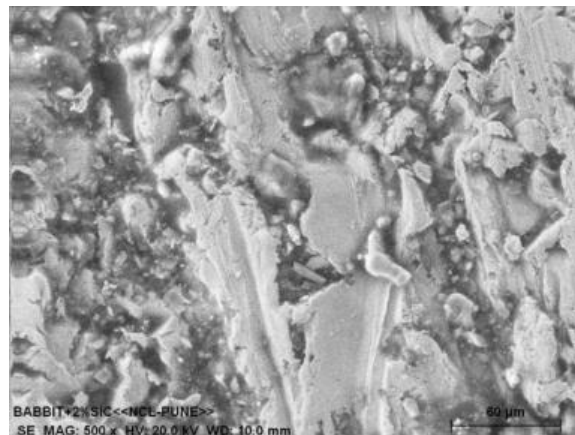
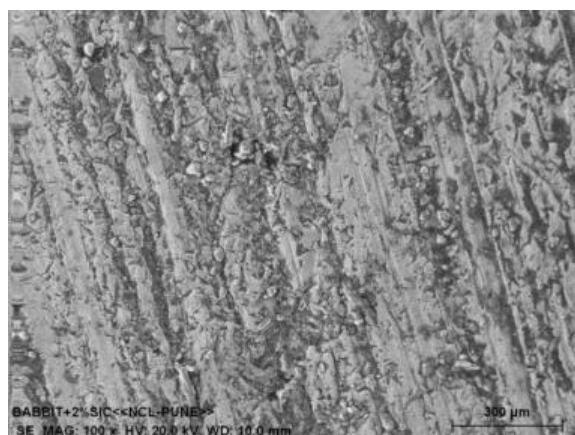
7.1 SEM Images of Babbit Alloy

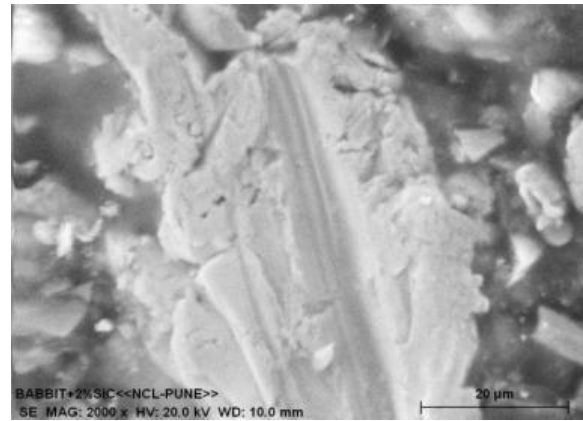
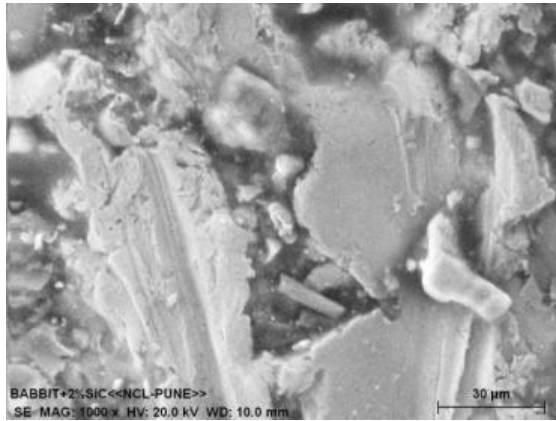


From SEM analysis of babbitt alloy it is seen that larger β -phase phase of the Sn-Sb compound. The structure is heterogeneous which creates stress concentrations in the material which leads to increase in wear rate. At 100x magnification the high rubbing surface of babbitt is shown, which is due to high wear rate occurs in Babbitt. Mag 500x and mag 1000x shows the heterogeneous structure.

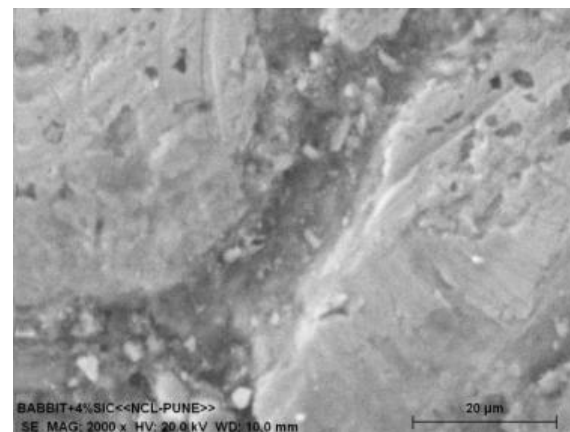
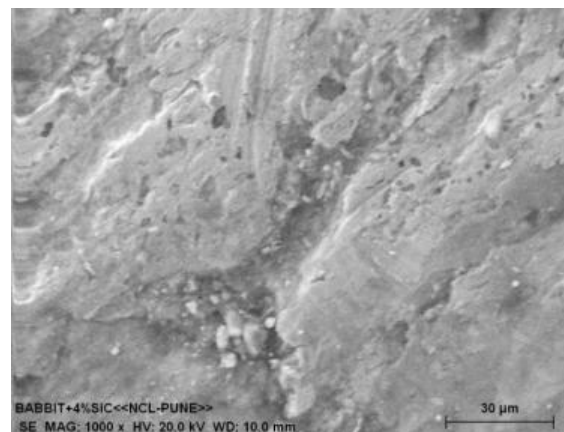
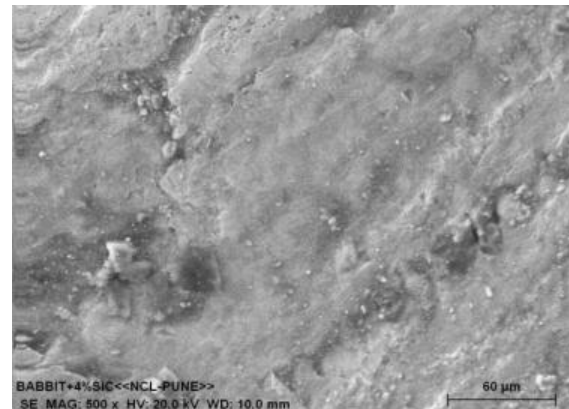
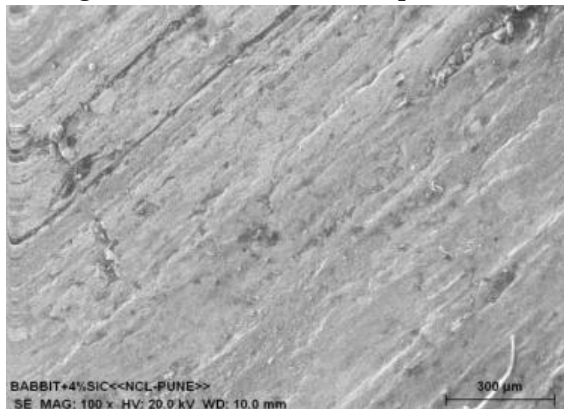
7.2 SEM Images of Babbitt+ 2% SiC Composite Material

The SEM analysis for Babbitt+2% SiC is shown in above Figures. From wear test it is clear that the wear is minimum in Babbitt+2% SiC. Microstructure images for this material composition at various magnification shows clear refined structure of babbitt alloy after reinforcing 2% silicon carbide. Due to refinement of microstructure of Babbitt+2% SiC the stress concentration is less which leads to high wear resistance and improved fatigue strength.

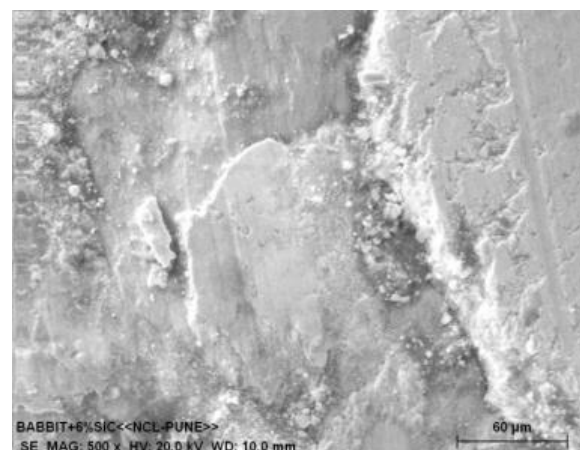
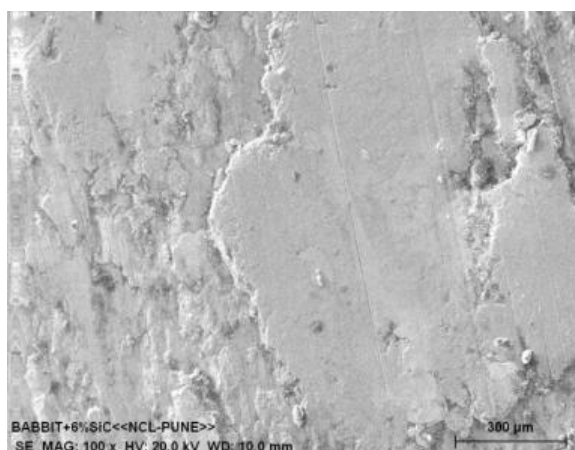


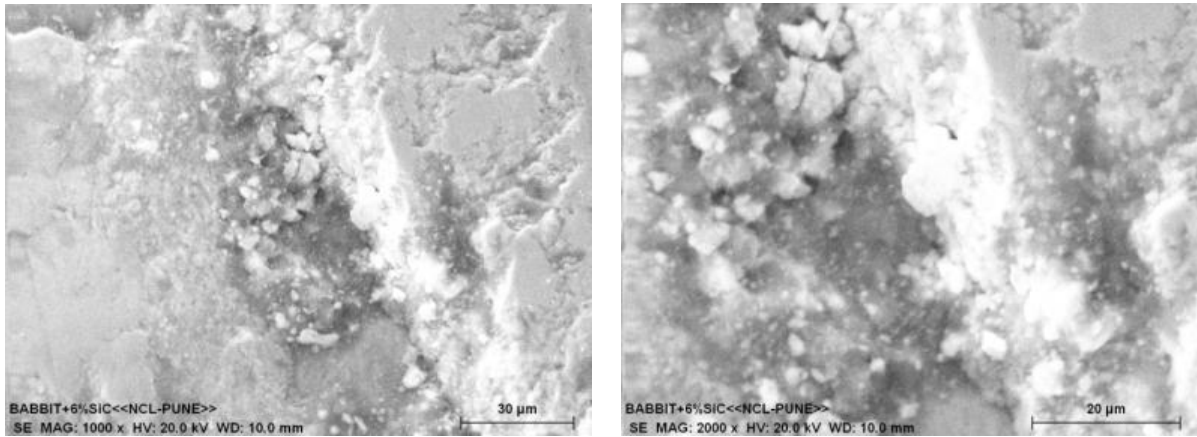


7.3 SEM Images of Babbitt+ 4% SiC Composite Material



7.4 SEM Images of Babbitt+ 6% SiC Composite Material





As we know that the hardness of babbitt is increases with increase in percentage of silicon carbide. High scratches are observed in low magnification images, it is due to increase in hardness due to addition of silicon carbide. At high magnification the deep scratches is observed which is due to more wear in Babbitt+4% SiC and Babbitt+6% SiC composition but it is below that of Babbitt alloy. There is improvement in microstructure compare to existing babbitt alloy. From SEM analysis test it is clear that there is refinement in microstructure of Babbitt+2% SiC material composition which lead to lower wear rate.

8. CONCLUSIONS

- The wear test is conducted on babbitt & there composites material at different normal loads and sliding speeds, from wear test it is concluded that the wear increases with increase in Normal loads and pin temperature.
- From wear test it is concluded that Wear is Minimum in Babbitt+ 2 % silicon carbide composite material as compared to the existing Babbitt, Babbitt+4% SiC and Babbitt+6% SiC composite materials.
- From statistical analysis it is concluded that Percentage of Silicon carbide in composite material is the highest influencing factor for wear.
- Response optimization for wear shows optimum level for minimum wear at 2% Silicon carbide composites with 49.05 Normal Load and 1115 RPM.

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