Experimental Investigation and Optimization of Wear Characteristics of Brass Metal Matrix Composite Reinforced with Molybdenum Disulphide by using Taguchi Technique

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Abstract - *Brass (60%Cu and Zinc 5%-45%) is an important copper based alloy finds application in Bush Bearing of Air Motor, Mating Gears, Automobile sector, Electrical and Electronic applications because of it's mechanical properties like corrosion resistance in non acidic environment, high thermal and electrical conductivity and low cost as compared to Phosphor Bronze and Gunmetal. An investigation has done to improve and enhance mechanical properties of Brass material like Wear resistance, Friction resistance and hardness of base material. The investigation also makes analysis the tribological behavior of Stir cast brass composite with MoS_2 by varying Percentage Reinforcement, Load, Temperature and Sliding Velocity. The Taguchi approach is used to form an orthogonal array, calculation of S/N ratios and analysis of individual parameter using ANOVA is done in MINITAB 17.0 Software. The confirmation test has been done by using Multiple Linear Regression Analysis. The distribution of MoS_2 particulate reinforcement in brass metal matrix composite is done by using Scanning Electron Microscope (SEM).*

Key Words: Composite material, Brass, MoS_2, Specific Wear rate.

1. INTRODUCTION

Increasing in the Industrial demand of newer, strong, rigid, yet lightweight material leads to fabrication of composite material which may use in automobile, aerospace, engine parts, construction sites. By using proper fabrication methods for metal matrix composite it can be possible to improvement of physical and mechanical properties such as high strength, low density, high rigidity, higher specific modulus, high specific yield strength which is idle for any application[1,2]. A composite material is made up of two or more phases combining to form different and unique material which have significant improvement in the mechanical and physical properties. Individual material works together to give composite material unique properties. Wear of metals is probably the most important yet at least understood aspects of tribology. Bhargavi rebba et al.[5] fabricated Al-2024 compoite with MoS_2 studied mechanical properties tensile strength and hardness found that these properties increses upto 4% MoS_2 and then starts decreasing.

Figure 1: Stir Casting method for MMC

Ajith Arul Daniel et al.[8] studied composition with 5%, 10%, 15% Silicon carbide with constant 2% MoS_2. the result reveals that applied load and sliding distance are most influcing factors for friction coefficient and load and %SiC for wear rate. Ravi MISHRA et al. [18] conducted experimental investigation of flyash reinforced aluminium alloy Al6061 composite, % Wt varying from 10, 15and 20% with varying load, sliding distance. It is found that load and sliding velocity are most influential factor on wear, that are reduce by increase in % reinforcement. From literature review it has been found that it is less work has been done on chnges in the composite material when brass with MoS_2 as composite material is used. Also Optimisattion with taking Temperature and Sliding Velocity as input parameters were not studied.

2. Objectives of the Experiment

The objectives of this study are:

1. The primary objective of this investigation is to improve and enhance the mechanical properties like wear, friction coefficient and hardness of the base brass material by adding Molybdenum Disulphide as a reinforcement material.
2. To fabricate unique composite material addition of with molybdenum disulphide 2%, 4% and 6% (wt. % of base material) by using Stir casting material to observe the improvement in the mechanical properties.
3. To optimize and obtain mathematical relationship model between Percentage reinforcement, load, temperature and sliding velocity input parameters and their levels by using taguchi optimization technique.

3. EXPERIMENTAL SETUP

3.1 Speciman Details

Brass with MoS_2 was selected as a composite material mainly used in mating gears and bearings which are subjected to wear. Molybdenum Disulphide (MoS_2) is selected as a reinforcement material because of it's chemical stability, low friction coefficient does not rely on absorbed vapors and moisture. Molybdenum Disulphide with 2%, 4% and 6% (wt. % of base material) is fabricated by using Stir casting material to observe the improvement in the mechanical properties.

Figure 2: Pin produced after machining

The chemical composition of the brass material is shown in Table 1.

Table 1: Chemical Composition of Brass material

Sr. No.	Element	Percentage
1	Cu(copper)	55.43
2	Zn	39.58
3	Mg	1.20
4	Al	0.16
5	Sn	0.49
6	Mn	0.047
7	Cr	0.011
8	Ni	0.34
9	Pb	2.10
10	P	0.016
11	Si	0.02
12	Sb	0.002
13	Fe	0.60

3.2 Microstructure

Microstructure of developed composite was analyzed through electron microscope in order to identify the distriburion of reinforcement particles in metal matrix. SEM was done at Dr. Babasaheb Ambedkar Marathwda University, Aurangabad.

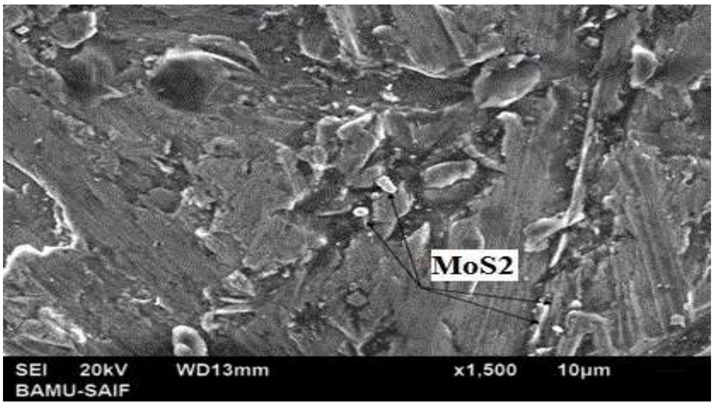

Figure 3: Brass + 2% of MoS2

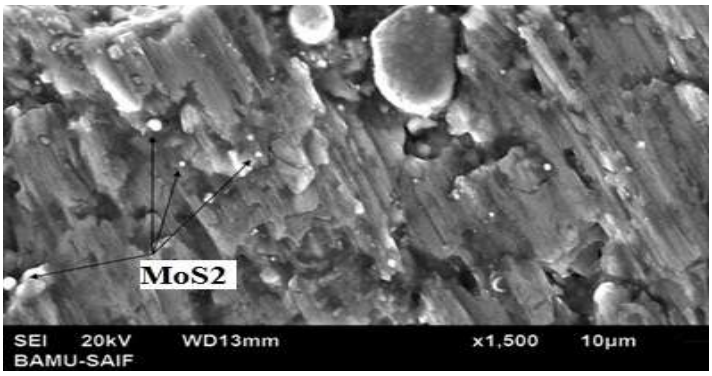

Figure 4: Brass + 4% of MoS2

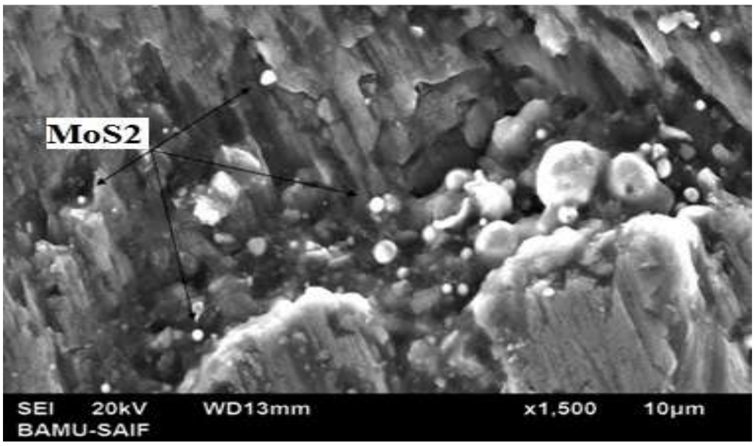

Figure 5: Brass + 6% of MoS2

From the images of Scanning Electron Microscope it was clear that there is a presence of MoS_2 reinforcement particles in brass metal matrix composite. The distribution of reinforcement MoS_2 particle was homogeneous and uniform.

3.3 Wear test

Tribological tests under dry condition was carried out on Pin ON Disc machine according to American Society of Testing Materials (ASTM) G99 standards. The wear test samples was machined with pin dimension 12 mm diameter and 29 mm length. The connterface surface is made up of EN31 steel with hardness 62 HRC. The readings were taken for constant 100mm track diameter and 10 min. of testing time. To remove debris and impurities the disc and pin were clean with aceton after each test.

The weight loss was measured by using weighing machine having least count of 0.0001g. Percentage Reinforcement, Load, temperature, sliding velocity were taken as input parameter and readings of wear rate were obtained.

Figure 6: Schematic Setup of Pin ON Disc Machine

Wear rate calculations:

$$Specific\ Wear\ Rate = \frac{(M1 - M2)X10\text{^}3}{\rho FL}$$

Wear rate calculations:

Wear rate in mm^3/N-m
M_1-M_2= Mass loss in grams
ρ: Density of Brass in gm/cc
L: Sliding distance in the meter.
F: Load in Newton.

3.4 Design of Experiment

Important objective of Taguchi design is to minimize the number of experiments, which gives information about all the effect of input parameters on output responses. The arrangement of levels of input parameters in systematic way knows as orthogonal array. In Taguchi design the response was normalized in form of Signal to Noise ratios. S/N ratios with 'Smaller is better' is selected and calculated as follows.

$$SN\ ratio = -10 \times \log(\sum((wear_1^2 + wear_2^2 + wear_3^2) \div 3)$$

Table 2: Layout of Orthogonal Array

SR.NO.	%MoS2	Load	SV	Temperature
1	2	25	3.5	100
2	2	30	4.5	125
3	2	35	5.5	150
4	4	25	4.5	150
5	4	30	5.5	100
6	4	35	3.5	125
7	6	25	5.5	125
8	6	30	3.5	150
9	6	35	4.5	100

3.5 ANOVA

ANOVA technique is a Statistical tool which shows the degree of adequacy for number of different variables. -The results were carried out for 95% level of confidence i.e., P values are less than 0.05. It also shows the percentage contribution of each factor and it's variation which influence on the result is most.

4. RESULTS AND DISCUSSION

4.1 Analysis of Process parameters

SN ration is used to normaliszed the experimental data in specific range. SN ratios were calculated and the response for SN ratio smaller is better selected.

SN ratio for one trial

$$SN\ ratio = -10 \times \log(\sum((0.4841^2 + 0.4829^2 + 0.4631^2) \div 3)$$

*SN ratio=6.3*1566

Similarly, Signal to Noise ratio values can be obtained for other experimental runs in orthogonal array.

Table 3: Cumulative data for SN ratio Brass Composite Wear

SRNO	%MoS2	Load	SV	Temperature	Specific Wear rate×10^{-3} (mm^3/N-m)	S/N RATIO
1	2	25	3.5	100	0.4833	6.31566
2	2	30	4.5	125	0.5019	5.98766
3	2	35	5.5	150	0.5253	5.59185
4	4	25	4.5	150	0.4722	6.51748
5	4	30	5.5	100	0.4808	6.36071
6	4	35	3.5	125	0.5015	5.99458
7	6	25	5.5	125	0.4671	6.61180
8	6	30	3.5	150	0.4856	6.27443
9	6	35	4.5	100	0.4807	6.36252

The level of a factor which having highest SN ratio is selected as optimum respond measured. The optimum parameter for wear rate were 6% percentage MoS_2 (level 3), 25N of load (level 1), 100◦C temperature (level 1), 4.5 m/s sliding velocity (level 2).

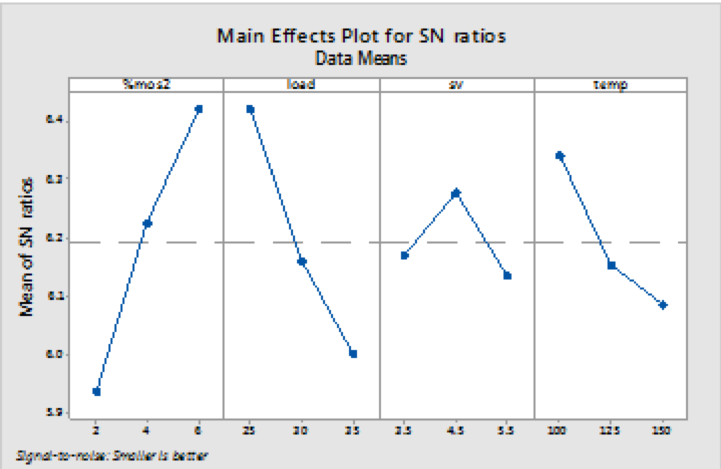

Figure 7: Main Effect plots of Signal to Noise ratio for Wear

4.2 Analysis of Variance

Table 4 shows the ANOVA result of wear for Brass with MoS2 composite. It is clear from the table that Applied Load (46.94%),) has great influence on lowering the wear rate followed by Reinforcement (40.83%), temperature (9.35%) and sliding velocity (2.40%) which indicates that there is appreciable increase in wear rate by increasing load and sliding velocity of the experimentation.

Table 4: ANOVA result of Brass Composite for Wear

Source	DOF	Adj SS	Adj MS	F-Value	P-Value	%Contribution
%MoS2	2	0.71549	0.357747	49.64	0.012	44.92%
Load	2	0.53576	0.267878	37.17	0.037	33.63%
SV	2	0.06644	0.033222	4.61	0.32	5.17%
Temperature	2	0.21050	0.105250	14.61	0.046	12.2%
Residual Error	9	0.064486	0.007206			4.04%
Total	17	1.59305				100%

R-Sq	R-Sq (adj)	R-sq (Pred)
95.93%	92.31%	83.71%

4.3 Regression Model

To estabish the relationsip between input parameter Load, % reinforcement, temperature and sliding velocity with output parameter wear rate, linear regression model for best fitting curve is used. The equation obtained using MINITAB 17.0 is given Below.

Regression Equation:

Specific Wear Rate = 0.39550 - 0.00643 MoS_2% + 0.00283 load + 0.00047 sv + 0.00025 temp ....(1)
Sustituting the values of different variables in above equation we can get the value of specific wear rate.

4.4 Confirmation Test

The confirmation test is carried out by to test the accuracy of the model by selecting different variables. The results obtained by compairing the equation correlate the evaluation of wear rate in the composite with the degree of approximation. It can be observed from table 6 that the calculated error varies 4.35 % for wear.

Table 5: Optimum level of parameters for Brass composite

Sr. No.	Parameter	Optimum level
1	%MoS2	6 %
2	Load	25 N
3	Sliding Velocity	4.5 m/sec
4	Temperature	100◦C

Table 6: Confirmation experiment result of Brass composite

Parameter	Model value	Experimental value	Error %
Wear rate	0.4798	0.4589	4.35%

5. CONCLUSIONS

1. The composite with 2%, 4% and 6% was fabricated through stir casting technique.
2. Taguchi optimization technique obtaines optimum parameter for wear rate were 6% percentage MoS2 (level 3), 25N of load (level 1),100◦C temperature(level 1), 4.5 m/s sliding velocity (level 2).
3. ANOVA analysis results percentage contibution of each parameter load with (46.94%), and %reinforcement (40.83%), temperature (9.35%) sliding velocity (2.40%).
4. The Multiple Linear Regression equation is obtained from MINITAB 17.0 correlate the evaluation of wear rate in the composite.
5. It can be observed from table 6 that the calculated error varies 4.35% for wear.

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