Experimental Investigation and Optimization of Wear Characteristics of Brass/SiC by using Taguchi Technique

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Abstract: *Metal Matrix Composites (AMMCs), reinforced with particulates, have marked their importance in many engineering applications because of low wear rate and a significant hardness. In the present work, Brass metal matrix composite materials, varying in the particle percentage of Silicon Carbide reinforcement, were prepared by stir casting procedure and optimized volumetric wear at different parameters such as particle percentage of SiC, Load and Frequency. Through Taguchi's technique, a plan of experiment generated and it is used to conduct experiments based on L9 orthogonal array. The developed ANOVA used to find the optimum wear under the influence of percentage of SiC, Load, and Frequency.*

Keywords: *Taguchi Method, Tribometer, Brass, SiC, Wear Rate.*

1. INTRODUCTION

The use of different kind of composite materials is in constant growing over the years, because they have better physical, mechanical and tribological properties compared with matrix materials. Composite have already proven their worth as weight-saving materials, the current challenge is to make them cost effective. The efforts to produce economically attractive composite components have resulted in several innovative manufacturing techniques currently being used in the composites industry. It is obvious, especially for composites, that the improvement in manufacturing technology alone is not enough to overcome the cost purpose. It is essential that there be an integrated effort in design, material, process, tooling, quality assurance, manufacturing, and even program management for composites to become competitive with metals.

The composites industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities. Composite applications from aircraft to other commercial uses have become more prominent in recent years.

MMCs have also begun to substitute for conventional materials in household appliances, computers, audio and video equipment, as well as in sport appliances. Compressive and tensile strength, as well as the hardness at room and elevated temperatures, are also increased significantly, resulting an improvement in the wear resistance of the composite material.

Whilst the use of composites will be a clear choice in many instances, material selection in others will depend on factors such as working lifetime requirements, number of items to be produced ,complexity of product shape, possible savings in assembly costs and on the experience & skills the designer in tapping the optimum potential of composites. In some instances, best results may be achieved through the use of composites in conjunction with traditional materials.

2. EXPERIMENTATION

2.1 Methodology of Experiment

Some parameters like reinforcement, temperature and frequency etc. play an important role in minimum wear rate. So as to overcome the existing problems, few optimization techniques have to be incorporated. Based on the mentioned parameters the following study was conducted to achieve the objective. Once the root cause of the problems which impacted the wear rate was identified and objectives were set to overcome the problem. Based on the observation, Taguchi method was followed to design the experiment to study the major contributing factors. Minitab-19 software was used to optimize the DOE using Taguchi techniques.

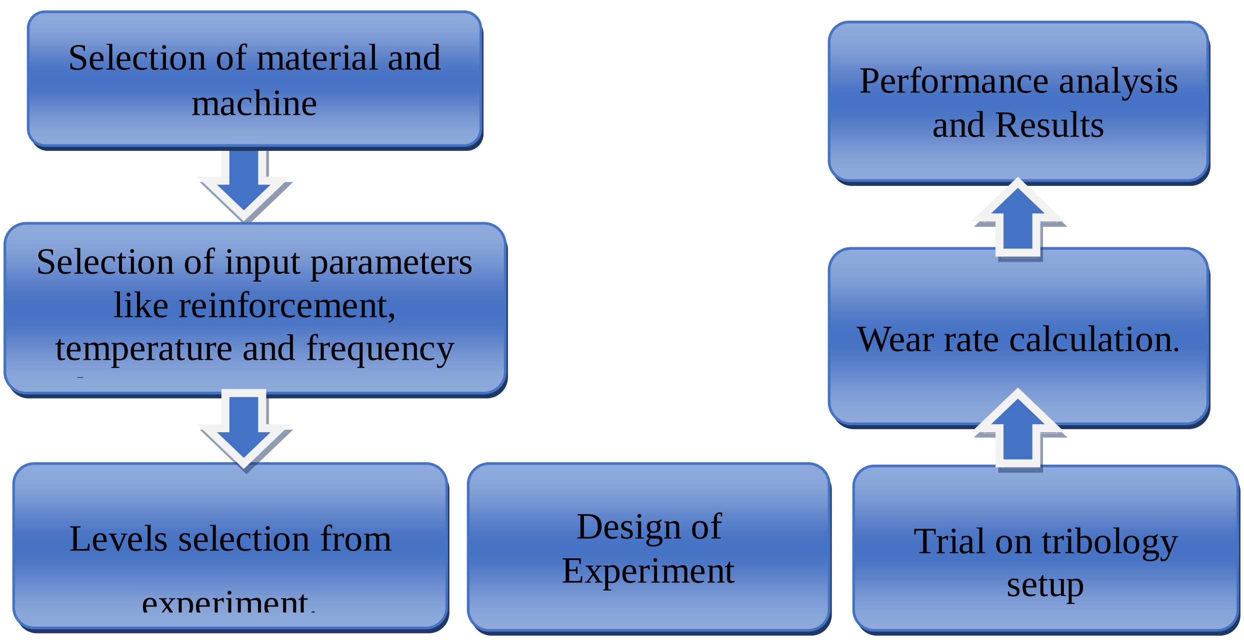


Figure *Flow chart of methodology*

2.2 Experimental Machine Selection

Table 1 states the specification of the Tribometer setup used in this study. All the experiments were conducted Government engineering College, Aurangabad, and Maharashtra, India.

Figure 2. *Tribometer Setup*

Table 1. *Tribometer Specification.*

Make Model	**Ducom Ltd. Banglore, India**
Upper Specifications	Pin (dia.x1)-- Φ4x15mm, Φ 6x15mm, Φ 8x15mm, Φ 10x15mm. Pin Rectangular (bxhxl)-4x6x15 Pin Square (lxbxh)- 4x4x15mm, 6x6x15mm, 8x8x15mm. Ball- Φ10mm
Lower Specifications	Rectangular Block (lxbxh)- 40x40x5, 30x30x5, 20x20x5mm
Hardness Lower Specifications	60HRC
Lower Specifications	EN31 Steel
Stroke Length Ranges	10, 20 and 30 fixed.
Temperature Ranges	Ambients 200 to 200^{o}C, Ambients 200 to 200^{o}C Least count.- 0.21^{o}C, Sensor: PT-100
Load Ranges	5 to 100 N

Frequency (Speed) Range	1-20Hz (1200rpm) Least count: 1rpm, Sensor, Proximity Sensor

2.3 Selection of material

Silicon Carbide

Silicon carbide is better wear resistance properties, high hardness and melting point It has good mechanical properties and at high temperature. It provide corrosion resistance and it not solubles in water and diluted acid

Figure 2 *Raw material for casting SiC* powder

3. RESULTS AND DISCUSSION

To get complete understanding of effects of input parameters Reinforcement, load and frequency on output Wear Rate, you usually assess signal to noise ratio or main effects plot for means. For this purpose, Minitab 18 statistical software has been used. Wear rare have been done. ANOVA has been conducted to find out effect each parameter on wear rate and linear regression model has established to predict values of wear rate.

3.1 Typical Orthogonal Array (OA)

While there are many standard orthogonal arrays available, each of the arrays is meant for a specific number of independent design variables and levels.

Standard notation for Orthogonal Arrays is

Ln (X^m)

Where, n=Number of experiments to be conducted

X=Number of levels

m= Number of factors

Table3 *Standards L9 orthogonal array*

Sr. No.	Reinforcement (%)	Load (N)	Frequency (Hz)
1	6	30	3
2	6	40	5
3	6	50	7
4	9	30	5
5	9	40	7
6	9	50	3
7	12	30	7
8	12	40	3
9	12	50	5

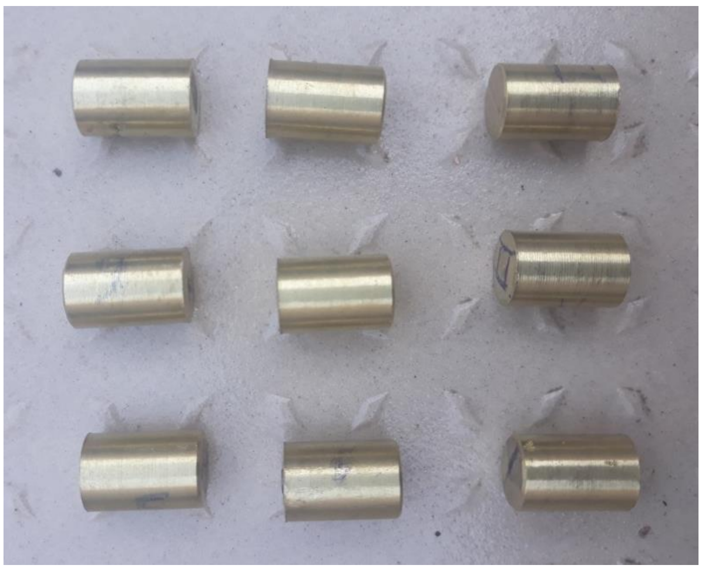


Figure 3 *Testing Specimens*

3.2 Experimental Result

Table 3 shows L9 OA with measurement of wear rate for runs one to nine. It also shows S/N ratio for the all nine experiments.

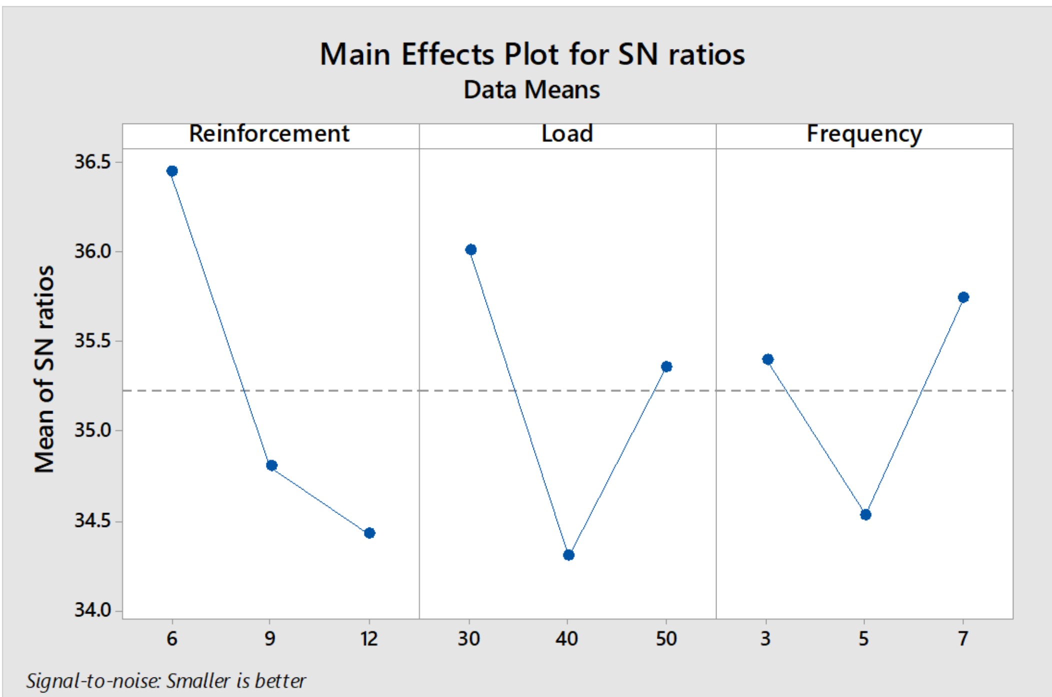
Table 4 *L9 orthogonal array with response characteristic.*

Experiments	Input Factors			Output Responses	
Trial No.	**Reinforcement (%)**	**Load (N)**	**Frequency (Hz)**	**Wear rate (mm^3/ Nm)**	**S/N Ratio**
1	6	30	3	0.0141	37.3933
2	6	40	5	0.0182	34.7986
3	6	50	7	0.0140	37.1397
4	9	30	5	0.0179	34.9429
5	9	40	7	0.0191	34.3793

6	9	50	3	0.0176	35.0897
7	12	30	7	0.0164	35.7031
8	12	40	3	0.0206	33.7227
9	12	50	5	0.0203	33.8501

The S-N ratio values are calculate with help of Minitab 19 software. It can be seen that variation in S/N ratio is minimum for all experiment.

3.3 Main Effects of Wear Rate



Graph 1 *Main Effects Plot for S/N Ratio*

From main effects plot for S/N ratio, parametric effect on response characteristic i.e The optimal input parameters were Reinforcement 6% (level 1), Load 30 N (level 1) and Frequency 7 Hz (level 3). The graph shows the effect of the control factors on Brass material

3.4 ANOVA Result

To decide two assessments of populace difference, one dependent on between tests fluctuation and other dependent on inside example change. At that point the said two evaluations of populace fluctuation are contrasted and F-Test. Compare the determined estimation of F with the table estimation of F for level of opportunity at certain degree of importance. On the off chance that the determined estimation of F is equivalent to or more prominent than the table an incentive at pre decide level of criticalness the invalid theory is dismissed in any case acknowledged.For this ANOVA table is readied. In this ANOVA table, the amount of squares (SS) because of autonomous variable and amount of squares because of blunder is independently given. Level of opportunity is the quantity of way one can choose the segments for a set up under limitations. On account of investigation there is loss of one degree in amount of squares because of relapse. Mean amount of squares are acquired by partitioning the amount of squares by dof, each for relapse and mistake. The mean amount of squares identified with mistake is called difference

Table 5 *ANOVA Result*.

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% Contribution
Reinforcement	2	2	0.000025	0.000013	288.69	0.003
Load	2	2	0.000017	0.000009	199.00	0.005
Frequency	2	2	0.000006	0.000003	97.92	0.010
Error	2	2	0.000002	0.000000		
Total	8	8	0.000051			

It shows table 4.7 that the Reinforcement (49.01%), the Load (33.35%) and the Frequency (11.76%) have major influence on the Wear Rate. Contribution of Reinforcement (49.01%) is highest among all three parameters hence it is most dominating parameter while Frequency is least affecting parameter.

3.5 Development of Regression Model for Wear Rate

Regression model has been developed using Minitab software. Substituting the experimental values of the parameters in regression equation, values for Wear rate have been predicted for all levels of study parameters. Graphical representation also shows that a predicted and experimental value of Wear rate correlates with each other.

Regression Equation –

$$\text{Wear Rate} = 0.0070 + 0.000439\ \text{Reinforcement} + 0.000163\ \text{Load} + 0.00010\ \text{Frequency}$$

Table number 5 gives comparison between experimentally measured and predicted wear rate by developed mathematical equation

Table 6 *Experimental and Predicted Values of Wear rate*

Sr. No.	Experimental value	Predicted value	Error %
1	0.0141	0.0148	4.27
2	0.0182	0.0166	9.63
3	0.0140	0.0184	6.52
4	0.0179	0.0163	9.81
5	0.0191	0.0181	5.52
6	0.0176	0.0194	9.27
7	0.0164	0.0178	7.86
8	0.0206	0.0190	8.42
9	0.0203	0.0209	2.87

Difference between wear rate values calculated using regression equation and experimental values for each experience found less than 10%. Hence, we can say that the regression equation developed is valid.

3.6 Confirmation Experiment Result

Experiments was conducted for Reinforcement at level 1, Load at level 1 and Frequency level 3

Table 7 *Confirmation experiment result for Wear Rate*

Parameter	Predicted value	Experimental value	Error %
Wear Rate (mm^3/Nm)	0.0152	0.0139	9.35

Confirmation experiment is conducted by keeping parameters at optimum levels suggested by Taguchi method and the wear rate value obtained has been compared with value predicted by the regression model keeping the parameters at same levels. It can be seen that the difference between experimental result and the predicted result is 9.35%. This indicates that the experimental value correlates to the estimated value.

4. CONCLUSIONS

In this study the influence of operating parameters such as Reinforcement, Load, Frequency and their optimization for Brass with SiC has been studied by using Taguchi Method. Following conclusions are drawn.

- The optimal solution obtained for Wear Rate based on the combination of curing oven parameters and their levels is Reinforcement 6% (level 1), Load 30 N (level 1) and Frequency 7 Hz (level 3)
- ANOVA results indicate that Load plays prominent role in determining the Wear Rate. The contribution of Reinforcement, Load and Frequency to the quality characteristics Wear Rate is 49.09%, 33.35% and 11.76% respectively.
- ANOVA results indicate that contribution of Frequency on Wear Rate is lower followed by Reinforcement and Load. Reinforcement is most dominant factor.
- Value of Wear Rate is lower obtained in confirmation experiment. Hence, good quality of Brass with SiC can be achieved using suggested level of parameters by Taguchi method.
- Values of Wear Rate calculated using regression model correlates with experimental values with error less than 10%. Hence the model developed is valid and experimental results of Wear Rate with any combination of operating parameters can be estimated within selected levels.

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