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STUDIES ON WEAR LOSS OF STIR CAST ALUMINIUM ALLOY 8011

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ABSTRACT

The dry sliding wear loss behavior of AA8011 matrix composite manufactured by stir casting process was considered. A regression model was established to predict the wear loss of the prepared composite. The wear test was steered with pin-on-disc apparatus with the controlling three-factor, three-level central composite rotatable design matrix was used to minimize the parameters were, applied load of 5, 10, 15 N and sliding velocity of 0.5,1.0,1.5 m/s with interval of 5,10 ,15 min at running time. A statistical investigation of wear test was shown using Response Surface Methodology under the Design of Experiments with Regression Equation using MINITAB 17 software.

Keywords*: Stir casting, AA 8011, Response Surface Methodology and Design of Experiments*

1. Introduction

Metal matrix composites MMC are the new class of materials and are quickly replacing conventional materials in different engineering applications such as the aerospace and automobile industries. Some of the characteristic applications are bearings, automobile pistons, cylinder liners, piston rings, connecting rods etc. [1]. The composite materials are widely used in applications like dry sliding concerned with situations to enhance the tribological performance of it. In several applications, the generally selected base alloy for Metal Matrix Composites MMCs is aluminium [2] because of its high strength to weight ratio, environmental conflict and high stiffness. However, they are poor resistant to wear; mainly at partial or boundary lubricating conditions. Through the solid lubricant, particle dispersal in the matrix of aluminium alloy can exhibition good prospective for wear resistance. Graphite is the commonly used solid lubricant because of its favorable combination of properties like low friction. The addition of an appropriate level of the graphite particulate with Aluminium Matrix Composites (AMCs) can reduce the wear rate of the AMCs. Matrix and reinforcement phase work together to produce a combination of material properties that cannot be met by a conventional material [3-5]. Boron carbide B_4C is one of the most favorable ceramic materials due to its high strength, low density 2.52 g/cm^3, high hardness and good chemical stability [6-8]. Earlier research [10] had reported that the addition of B_4C with the aluminium alloy AA 7075 will enhance the wear resistance of the base alloy with an best amount of ceramic content also usage of aluminium matrix can provide good potential of mechanical and wear properties.

2. Evaluation of Tribological Properties

The cylindrical composite pin test specimen of 10mm ϕ X 50mm L was tested in pin-on-disc POD wear tester with data achievement system are presented in Fig.1, as per ASTM-G99 Standard. It is multipurpose equipment designed to study wear and friction under different parametric conditions. Sliding generally occurs between a stationary pin and rotating disc. The disc rotates with a help of a D.C. motor having the speed range of 0-600 rev/min. The smooth and hardened steel disc surface SS 316 HSS, hardness 72 HRC served as a counterpart and was finished by an abrasion against 1200-SiC grade sheet with provided a roughness of Ra 0.6-0.7μm. The pin was perpendicular to the counterpart and parallel to the sliding direction. Prior to the test the pin was rubbed over a 400-SiC grade sheet to ensure proper contact between pin and disc. The surface of both pin and disc were cleaned with a soft paper soaked in acetone prior to actual testing. The material loss from the composite surface was measured using a precision electronic weighing balance with an accuracy of ±0.001 mg. The real time data has been collected from data acquisition system.

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Fig.1. Tribological Test samples and Pin-on-Disc tester

Table 1. Process parameters and their levels

Parameter	-1	0	1
Load (N)	5	10	15
Time (min)	5	10	15
Sliding Velocity(m/sec)	1.5	3	4.5

Table 2. Values of coded and actual of each parameter used in this work

S.No	Load (N)	Time (min)	Sliding Velocity (m/sec)	Wear loss (g)x10^{-3}
1	5	5	1.5	2.20000
2	15	5	1.5	2.54000
3	5	15	1.5	2.13333
4	15	15	1.5	12.56000
5	5	5	4.5	2.22000
6	15	5	4.5	4.98000
7	5	15	4.5	4.91333
8	15	15	4.5	17.96000
9	5	10	3.0	3.17000
10	15	10	3.0	9.79000
11	10	5	3.0	3.48000
12	10	15	3.0	9.86667
13	10	10	1.5	4.99000
14	10	10	4.5	7.74000
15	10	10	3.0	6.72000
16	10	10	3.0	6.72000
17	10	10	3.0	6.80000
18	10	10	3.0	6.72000
19	10	10	3.0	6.78000
20	10	10	3.0	6.80000

3. Results and Discussion

3.1 Response Surface Methodology

Response surface methodology (RSM) is the procedure for determining the correlation various between process parameters with the various tribological conditions and exploring the effect of these process parameters on the coupled responses [9]. In order to study the effects of the tribological parameters on the above-mentioned two most important tribological criteria. A second-order polynomial response surface empirical model can be developed as follows to evaluate the parametric effects on the various tribological criteria.

$$Y_u = b_o + \sum_{i=1}^{k} b_i x_i + \sum_{i=1}^{k} b_{ii} x^2{}_i + \sum_{j>1}^{k} b_{ij} x_i x_j \quad \text{-----1}$$

Where Y_u is the corresponding response, e.g. the WEAR LOSS created by the various process variables of tribological parameters.a_i represents the linear effect of x_i, a_{ii} represents the quadratic effect of x_i and a_{ij} reveals the linear-by-linear interaction between x_i and x_j. The second term under the summary sign of the polynomial equation i.e. Eq. (1) characteristics to linear properties, whereas the third term of the above equation embodies the higher order effects and finally the fourth term of the above equation includes the interactive effects of the process parameters. Due to wide range of factors, it was absolute to set three factors, three levels. The present investigation studied the results of the effects of Load (N), Time (min) and Sliding Velocity (m/sec) on wear loss. In the present study, since three factors, each with three levels were selected as controllable variables, a three factor three level central composite rotatable design was selected for conducting the experiments. The actual and coded parametric values for each parameter are listed in Table 1. The design matrix comprises, a full replication of 2^3 (=8) factorial design, plus six centre points and six star points at a distance of 1 units from the centre points. The first 8 rows correspond to the factorial portion, the rows from 9 to 14 correspond to the axial portion and last 6 rows correspond to the centre point portion. Therefore, the experimental design consists of 20 (8+6+6=20) experimental runs. The values of process parameters and their levels are listed in Table.1. The values of coded and actual of each parameter used in this work based on Central

Composite Rotatable Design (CCD) was adopted in the present study is shown in Table.2

4. Development of Empirical Models Based on RSM

After perceptive the values of the experimental response, the values of the different regression coefficients of second order polynomial empirical equation i.e. Eq. (1) have been evaluated and the empirical models based on RSM have been developed by utilizing test results of different responses obtained through the entire set of experiments by using a computer software, MINITAB.17.

$$\text{Wear loss (gms/min)} \times 10^{-3} = 4.371 - 0.4388 A - 0.6511 B - 0.0340 C - 0.00840 A^2 - 0.00067 B^2 - 0.1444 C^2 + 0.101867 A*B + 0.08400 A*C + 0.09533 B*C \quad \text{----- (2)}$$

Equation 2 developed empirical models based on composite desirability optimization technique.

5. Analysis of the Developed Empirical Models

The analysis of variance (ANOVA) and the F-ratio test have been performed to justify the goodness of fit of the empirical models. The calculated values of F- ratio for lack of fit have been compared to standard values of F-ratio corresponding to their degrees of freedom to find the adequacy of the different developed empirical models. The F-ratio has been calculated as a ratio of Mean sum of square of source to mean sum of experimental error. The fit summary recommended that the quadratic model is statistically significant for analysis of wear loss. The value of R^2 is over 99.99 %, which means that the regression model provides an excellent explanation of the relationship between the independent variables factors and the response wear loss. The associated P-value for the model is lowers than 0.05 i. e., $\alpha = 0.05$, or 95% confidence indicates that the model is considered to be statistically significant. The ANOVA table for the quadratic model for wear loss is shown in Table 3.

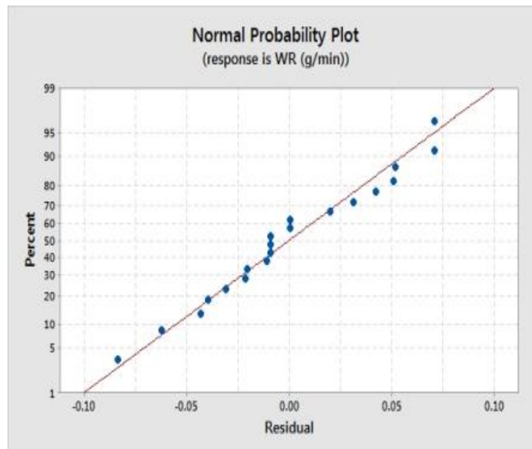

Fig. 2 Standard probability plot residuals for Wear loss

Table 3. Analysis of Variance Table for Wear loss

Analysis of Variance Table for Wear loss

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	9	289.852	32.2058	9226.83	0.000
Linear	3	3.408	1.1360	325.47	0.000
Square	3	1.169	0.3897	111.64	0.000
2-Way Interaction	3	58.638	19.5460	5599.85	0.000
Error	10	0.035	0.0035		
Lack-of-Fit	5	0.027	0.0053	3.19	0.114
Pure Error	5	0.008	0.0017		
Total	19	289.887			

The standard percentage point of F distribution for 95%confidence limit is 0.05.The F-values 3.19 for lack of fit are smaller than the standard value. Thus both the models are adequate. It is also seen that from the P-value for the model is lowers than 0.05. The P-values 0.114 for wear loss the linear and interaction effects are significant and for surface roughness the linear, square and interaction effects are significant.

6. Conclusions

AA8011 were successfully fabricated using stir casting method. The second order polynomial model developed for Wear loss was used for optimization. The experiments were conducted on a pin on disc wear testing machine for Al 8011 and responses were wear loss. The optimum maximum values from the plot are wear loss=14.9989X10-3 (g/min) and the relevant parameters like load, time and sliding velocity are 13.9899 N, 0.2970(min) and3.5707 (m/sec) respectively. The optimum minimum values from the plot are wear loss=2.1437 X10-3 (g/min) and the relevant parameters like load, time and sliding velocity are 5 N, 15 (min) and 1.5 (m/sec) respectively.

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