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An integration using Taguchi/response surface method on wear and friction of stainless steel-pin-on-pure Al block

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ABSTRACT – In this study, integration of Taguchi and Response Surface methods (RSM) was applied for wear rate and coefficient of friction of stainless steel-pin-on pure aluminium block. Integration factors and levels were planned according to orthogonal arrays and analysis of testing parameters was done using analysis of variance (ANOVA) technique. Multiple linear regression models were used to determine the regression equation for both wear rate and coefficient of friction. Finally, the morphology and microstructure of wear were analysed using Scanning Electron Microscope (SEM) and Energy-dispersive X-ray spectroscopy (EDAX). For wear rate the error percentage ranging from 6.6% to 22.5% and for coefficient of friction (COF) the error percentage was ranging from 9.5% to 36.9%.

1. INTRODUCTION

Many researchers have studied on tribological properties of metal and alloy as early as 50's. Cree and Pugh have reported the dry sliding wear and friction behaviors of A356/SiC foam [1]. Group of researchers have also investigated tribological properties Al-Si alloy using different approaches. Some have also tested Al alloys and its composites on heat treatment but none pure Al. Rice has studied the microstructure of Al/SiCP composite [2]. Recently, many researchers have opted for statistical study to optimise the parameters used in their respective study using Al alloys[3]. In this work, integration of Taguchi and response surface for the wear and friction of stainless steel pin-on-pure Al block was scrutinized and its parameters were optimised.

2. METHODOLOGY

Wear tests were carried out for all 25 pure Al specimens using pin-on-disc from DUCOM TR-20 with inputs of 230V, 50Hz and 2kW. The tests were conducted by following ASTM G133. The maximum speed was selected at 100rpm while the maximum load was 50N and time was fixed at 30 minutes. The graphs generated using Winducom v.5 software. The direction of the relative motion between sliding surfaces reverses in a periodic fashion in a linear straight line. This test method encompassed on un-lubricated conditions. A sensitive Shimadzu AUW220D dual-range semi-micro balance with +/- 0.01mg readings was used for measurement. For morphology monitoring, SEM model Hitachi S-3400N with a resolution of 10nm at 3kV with 5-axes motorized stage with -20/+90 degrees tilt was utilised. This machine was incooperated with analytical specimen chamber with simultaneous accommodation of Energy-dispersive X-ray spectroscopy (EDAX), for elemental compositions were obtainable. Minitab v.16 was used for RSM.

3. RESULTS AND DISCUSSION

The experiments using orthogonal array, the results for 25 specimens with different combinations of parameters were obtained. Figures 1and 2 show the wear rate and COF of pure aluminium at 100rpm increases with loads which was consistent with the findings as supported by [4]. Hence the conditions were maintained.

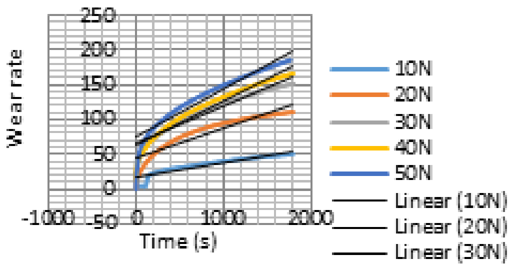


Fig. 1 Wear rate of pure aluminium at 100rpm.

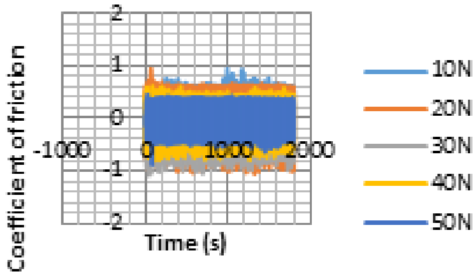


Fig. 2 COF of pure aluminium at 100 rpm.

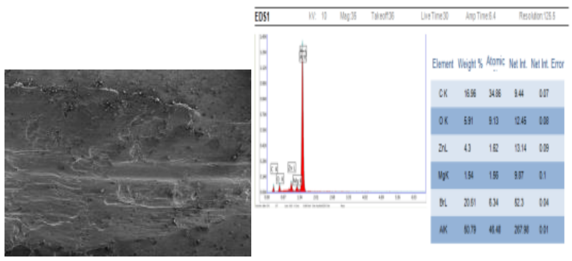


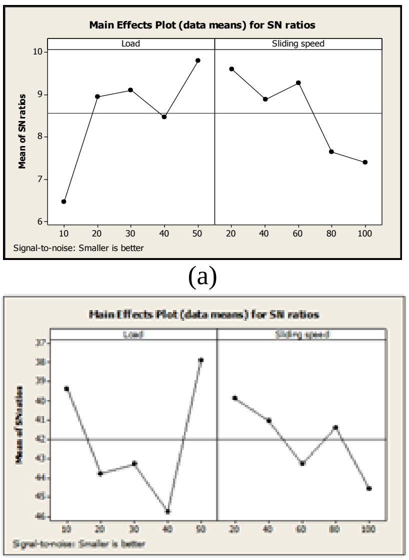
Fig. 3 SEM and EDAX analysis for specimen at wear test of 50N and 100rpm.

In SEM/EDAX analysis shown in Fig. 3, the amount of aluminium for the specimens ranged from 50% to 60% with impurities such as bromine (Br), thulium (Tm) and carbon (C). Carbon (C) was present as the specimen was prepared using electrical discharge machine (EDM).

Table 1 Response table for S/N ratio (wear rate).

Level Wear Rate Wr	Applied load, W	Sliding speed, v	Level COF	Applied load, W	Sliding speed, v
1	39.39	39.87	1	6.470	9.598
2	43.77	41.03	2	8.954	8.888
3	43.28	43.28	3	9.110	9.272
4	45.74	41.36	4	8.474	7.654
5	37.88	44.53	5	9.806	7.402
Delta	7.86	4.66	Delta	3.336	2.196
Rank	1	2	Rank	1	2

Table 1 showed the ranking of process parameters obtained for different parameter levels for both wear rate and COF respectively. From Table 1, it shows that load was a dominant parameter on both wear rate and COF followed by sliding speed. Fig. 4 showed the influence of process parameters on wear rate and COF. The analysis of the data collected gave the optimum conditions resulting in minimum wear rate and COF. The optimum condition for wear rate and COF of condition to be set at 50N while the sliding speed to be set at 100rpm.



(a)

(b)

Fig. 4 Effect of control factor on (a) the wear rate (b) the coefficient of friction.

A multiple linear regression equation was developed to establish the correlation among the significant factors on the response. In Table 2 multiple regression analysis for wear rate and COF and in Table 3 ANOVA data was collected. It has shown that the regression equation had negative coefficient for applied load meaning that the COF increases with decreasing applied load. Conversely, increasing the sliding speed increases the COF as well as sliding speed had a positive coefficient.

The regression formulations generated are shown in equations (1) and (2) for wear rate and COF respectively:

$$\text{Wear Rate, } W_r = 91.7 + 0.717v + 0.169\, W \quad (1)$$

$$COF = 0.440 - 0.00302\, W + 0.000848v \quad (2)$$

Table 2 Multiple Regression for Wr and COF.

Predictor (Wr)	Coef	SE Coef	T	P
Constant	91.69	35.80	2.56	0.018
Sliding speed	0.7168	0.4002	1.79	0.087
Load	0.1691	0.8005	0.21	0.835
S = 56.6027	R-Sq = 12.9%	R-Sq(adj) = 5.0%	-	-
Predictor (COF)	**Coef**	**SE Coef**	**T**	**P**
Constant	0.44014	0.08484	5.19	0.000
Sliding speed	0.0008480	0.0009485	0.89	0.381
Load	-0.003018	0.001897	-1.59	0.126
S = 0.134142	R-Sq = 13.1%	R-Sq(adj) = 5.3%	-	-

Table 3 Analysis of Variance (ANOVA) for Wr and COF

Source (Wr)	DF	SS	MS	F	P
Regression	2	10420	5210	1.63	0.219
Residual Error	22	70485	3204		
Total	24	80905			
Source (COF)	**DF**	**SS**	**MS**	**F**	**P**
Regression	2	0.05992	0.02996	1.67	0.212
Residual Error	22	0.39587	0.01799		
Total	24	0.45579			

Table 4 Confirmation experiment for wear rate and coefficient of friction.

Sliding speed (rpm)	Exp. Wear rate	Reg. model equation wear rate	% Error	Exp. Coefficient of Friction	Reg. model equation coefficient of friction	% Error
40	159.826	123.76	22.5	0.457	0.41352	9.5
40	149.596	125.45	16.1	0.656	0.41352	36.9
60	149.677	139.79	6.6	0.350	0.40028	14.4

Based on confirmation test done as shown in Table 4, for wear rate, COF and the errors was calculated. For wear rate the error percentage ranging from 6.6% to 22.5% and for COF the error percentage was ranging from 9.5% to 36.9%.

4. CONCLUSION

It can be concluded that in statistically load is a dominant parameter on both wear rate and COF followed by sliding speed. The optimum condition found to minimize the wear rate is applied load at 50N while sliding speed at 100rpm. By using the multiple linear regression model, the empirical formulations for both wear rate and COF stainless steel pin-on-pure aluminium block can be determined using Eq.(1) and (2) respectively:

5. REFERENCES

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