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Optimization of sliding specific wear and Frictional force behaviour of Modified ZA-27 alloy using Taguchi Method

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***Abstract*-**Dry sliding wear behavior of Modified ZA-27 alloy was prepared by gravity die casting. The specific wear rate and frictional force of Modified ZA-27 alloy was studied by performing wear test using a pin-on-disc wear tester. Experiments were conducted according to plan of experiments generated using taguchi method. A L25 orthogonal array was used for analysis of data. ANOVA is used to study the influence of process parameters such as Normal load and sliding speed on specific wear rate and frictional force. Regression analyses are employed to find the optimal process parameter levels and to analyze the effect of these parameters on Modified ZA-27 alloy. The result reveals that Normal load and sliding speed were the more sensitive parameters.

Keywords*-ANOVA, orthogonal array, signal-to-noise ratio, sliding speed, specific wear rate*

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I. INTRODUCTION

The wear of material is one of the tremendous and unavoidable losses in engineering. So the developments of new wear-resistance materials become an important task in which many researches are interested[1]. Wear is reflected by a loss of surface material from contacting surfaces when they are subjected to a relative motion. Zinc based alloy have been used for past few decades[2]. In particular, the ZA-12 and ZA-16 families were developed by the International Lead Zinc Research Organization (ILZRO) during 1960’s, while the ZA-8 and ZA-27 were developed by Noranda Co. in the late 1970’s[3]. They exhibit good mechanical properties, easy machinability and low density when compared with cast iron, bronze and aluminium based alloy[4-10]. LI Yuanyuan and C. Dominguez et.al., have added Mn in the ZA-27 alloy and studied the characterization and tribological properties. By adding Mn into a ZA-27 alloy, more and harder intermetallic compound were formed thus reducing the tribological properties when compared to ZA-27 alloy. Zulkuf Balalan et.al added Si to ZA-27 alloy and found that increases the tensile strength, hardness and wear resistance. From the literature survey we found that, few works have addressed by varying the percentage of Mn and keeping the silicon percentage constant, on the improvement of wear properties of ZA-27 alloy at room temperature. Thus the study of the investigation is to optimize the process parameter on specific wear rate of Modified ZA-27 alloy using taguchi method.

II. EXPERIMENTAL PROCEDURES

A. Alloy preparation

The chemical composition of the alloy studies was based on the ZA-27 containing Al – 27 wt%, Cu – 2 wt%, Mg – 0.04 wt% and balance Zn with an addition of 1% Mn alloy and Si – 3.5% as a Modified element was prepared. The chemical compositions of these alloys were weighted according to ratios and melted in a graphite crucible. Alloying temperature was controlled below 700^0 C to avoid the loss of Zn. The melt was then degassed and stirred well before being poured into the molds, which were preheated to approximately 150^0 C in open air.

B. Wear test

In the present research one of the commonest and simplest methods to test for wear rate was by using a pin-on-disc wear tester (Model: TR-20, DUCOM) as per ASTM: G99 – 05 as shown in Fig 1. The counterpart disc was made of quenched and tempered EN-32 steel having a surface hardness of 65 HRC. The specimens of size Ø10×33 mm were machined out from all the as cast specimens. The track diameter of 80mm enabled the rotational speeds of 136, 272, 409, 545 and 682 rpm to attain linear sliding speeds of 0.5, 1.0, 1.5, 2.0 and 2.5 m/s respectively. Wear tests were carried out up to a sliding distance 2500m.The wear losses of sample pins were recorded using an electronic microbalance having an accuracy of ± 0.001mg. After wear test specimens were cleaned thoroughly and weighed again. The wear rate was calculated by a weight-loss method.

$$\Delta W = (w_1 - w_2) \qquad \text{--------- (1)}$$

Where, ΔW = Weight loss of the specimen (g)

w_1 = Weight loss of the specimen before test

w_2 = Weight loss of the specimen after test

The volume loss (ΔV) is evaluated by the following equation.

$$\Delta V = \frac{(w1-w2)}{\rho} X\ 1000 \qquad \text{--------- (2)}$$

Where, ρ = Density of the specimen (g/mm^3)

The specific wear rate (W_s) of the specimen is calculated by the equation

$$Ws = \frac{\Delta V}{L_n\ X\ S_s} \qquad \text{--------- (3)}$$

Where, L_n = Normal Load (N) and S_s = Sliding distance (m)

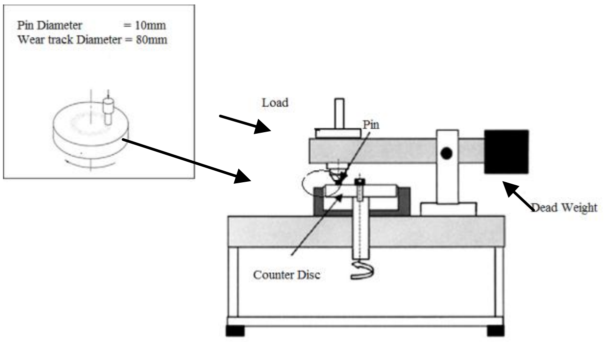

Fig 1: Schematic representation of Pin-on-Disc wear testing machine.

Table 1: Control and Noise Factors.

SN	Process Parameters	Codes	Level 1	Level 2	Level 3	Level 4	Level 5
1	Normal Load (N)	A	4.905	9.81	19.62	29.43	39.24
2	Sliding Speed (m/s.)	B	0.5	1.0	1.5	2.0	2.5

C. Experimental Design

The experiments were conducted to analyze the influence of testing parameters on specific wear rate and friction force of Modified ZA-27 Alloy. The experiments were planned according to L25 Orthogonal array as shown in Table 2. The first column is assigned by Normal Load and second column by Sliding speed. A total of 25 experiments were conducted based on the run order generated by taguchi model. The response (S/N ratio) studied for the model is volumetric wear rate with the objective of "Smaller the better" type of quality characteristics. The response was calculated for each level of process parameters. Finally, analysis of variance was carried to verify which parameters were statistically significant. The measured results were analyzed using the commercial software MINITAB 16 specifically used for design of experiment applications. The process parameters, code and their levels are shown in the Table 1, each process parameters having five levels.

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2644 - 2649

III. RESULTS AND DISCUSSION

A. Analysis of Control factors

The examination of influence of control parameters such as Normal Load and Sliding speed has been studied by using S/N ratio response type. The calculated S/N ratio for each level of parameters has shown in the Table 2. The strongest influence of the control factor is determined depending on the value of Δ (delta) as shown in Tables 3 and 5. Delta is the difference between maximum and minimum value of S/N ratios for a particular control factor. When the value of delta is high, more dominant is the control factor. It can be seen in Table 3 and 5, that the strongest influence was exerted by the Normal Load (A) followed by Sliding speed (B). Means response table presented in Table 4 and 6 also give the same results on the ranking of the influence of the factor. From the Fig 2 show that main effect plot for S/N ratio and mean of specific wear rate for Modified ZA-27 Alloy. Fig 3 show that main effect plot for S/N ratio and mean of Frictional force for Modified ZA-27 Alloy It suggests that the optimum condition for minimum Specific wear rate is the combination of A_3B_5 and for Frictional force is A_1B_5. The optimum condition for specific wear rate and Frictional force is shown in Table 9.

Table 2: Results of L25 Orthogonal array for Modified ZA-27 Alloy

S. N	Nr. Pressure (N)	Sliding Speed (m/s)	Specific Wear rate (mm^3/N-m)	S/N Ratio for specific wear rate (db)	Fr.Force (N)	S/N Ratio for Fr. Force (db)
01	4.905	0.5	2.0387E-4	73.813	4.8	-37.3626
02	4.905	1.0	1.4665E-4	76.674	4.8	-37.6930
03	4.905	1.5	4.3684E-5	87.194	4.7	-38.8097
04	4.905	2.0	1.4509E-4	76.767	4.6	-37.7035
05	4.905	2.5	1.2013E-4	78.407	3.8	-37.8871
06	9.81	0.5	2.1101E-4	73.514	9.4	-37.3274
07	9.81	1.0	1.3456E-4	77.422	8.4	-37.7773
08	9.81	1.5	1.0907E-4	79.246	8.0	-37.9795
09	9.81	2.0	1.0499E-4	79.577	7.0	-38.0158
10	9.81	2.5	4.2904E-5	87.350	5.8	-38.8253
11	19.62	0.5	6.8298E-5	83.312	9.7	-38.4141
12	19.62	1.0	5.2497E-5	85.597	8.9	-38.6492
13	19.62	1.5	1.6772E-5	95.508	7.6	-39.6008
14	19.62	2.0	8.9709E-6	100.943	6.7	-40.0815
15	19.62	2.5	3.3153E-5	89.590	5.4	-39.0451
16	29.43	0.5	8.3248E-5	81.593	12.0	-38.2330
17	29.43	1.0	6.1502E-5	84.222	11.5	-38.5085
18	29.43	1.5	5.2667E-5	85.569	11.2	-38.6464
19	29.43	2.0	4.7231E-5	86.515	10.5	-38.7419
20	29.43	2.5	4.1115E-5	87.720	7.0	-38.8620
21	39.24	0.5	6.1927E-5	84.162	13.8	-38.5024
22	39.24	1.0	5.5046E-5	85.185	12.9	-38.6073
23	39.24	1.5	4.3578E-5	87.215	12.5	-38.8118
24	39.24	2.0	4.893E-5	86.208	11.2	-38.7110
25	39.24	2.5	2.1452E-5	93.371	10.8	-39.4042

Table 3: Response Table for Signal to Noise Ratios (Specific wear rate)

Level	A	B
1	78.57	79.28
2	79.42	81.82
3	90.99	86.95
4	85.12	86.00
5	87.23	87.29
Delta	12.42	8.01
Rank	1	2

Table 4: Response Table for Means (Specific wear rate)

Level	A	B
1	0.000132	0.000126
2	0.000121	0.000090
3	0.000036	0.000053
4	0.000057	0.000071
5	0.000046	0.000052
Delta	0.000096	0.000074
Rank	1	2

Table 5: Response Table for Signal to Noise Ratios (Friction force)

Level	A	B
1	-13.11	-19.44
2	-17.64	-18.90
3	-17.50	-18.41
4	-20.22	-17.62
5	-21.72	-15.82
Delta	8.61	3.62
Rank	1	2

Table 6: Response Table for Means (Friction force)

Level	A	B
1	4.540	9.940
2	7.720	9.300
3	7.660	8.800
4	10.440	8.000
5	12.240	6.560
Delta	7.700	3.380
Rank	1	2

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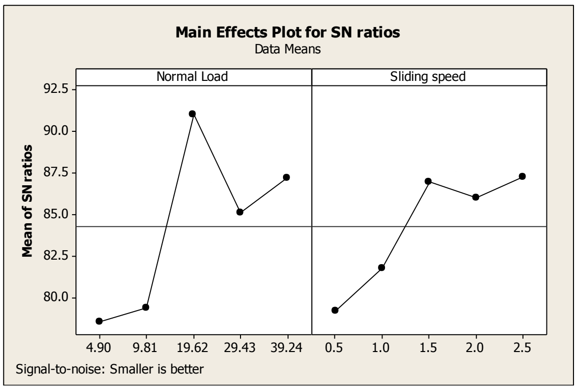
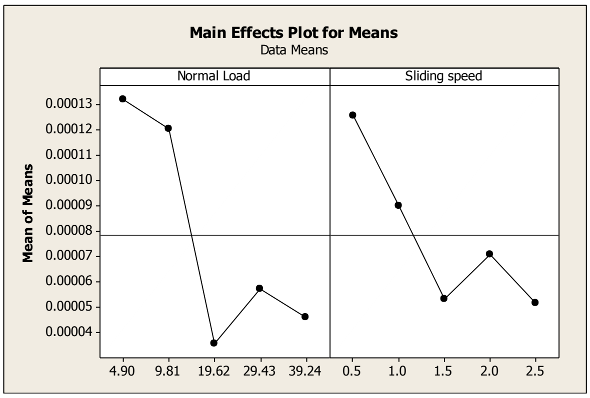
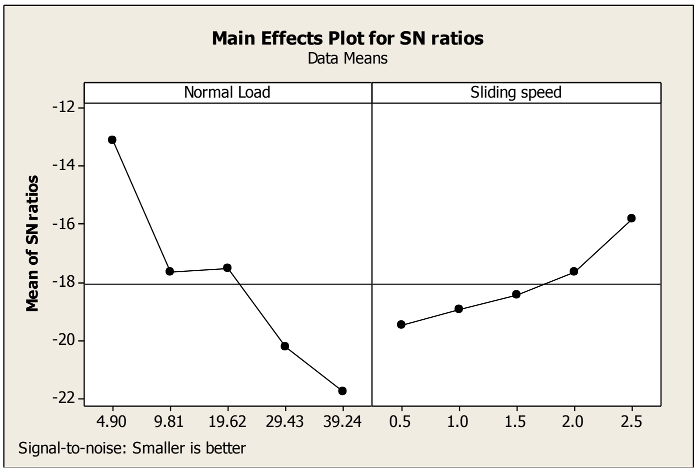


(a)

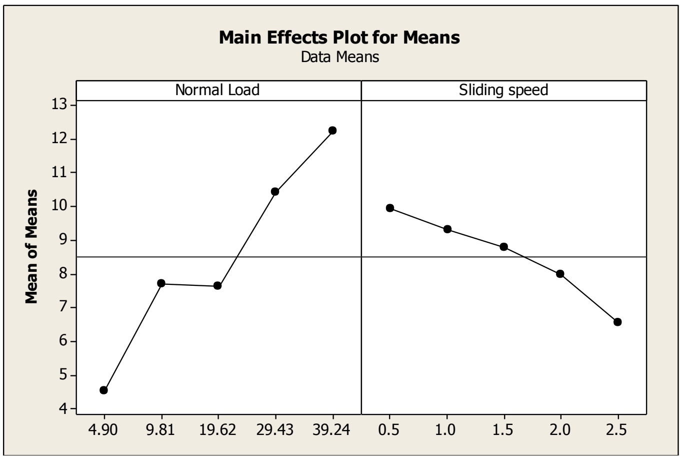


(b)

Fig 2: Main effects plots for Specific wear rate of Modified ZA-27 Alloy (a) S/N Ratios (b) Mean.



(a)



(b)

Fig 3: Main effects plots for Frictional force of Modified ZA-27 Alloy (a) S/N Ratios (b) Mean.

B. Analysis of variance (ANOVA)

The conducted experimental results were analyzed by using Analysis of Variance (ANOVA) which is used to examine the influence of wear parameters like Normal Load and Sliding speed. By using ANOVA, it can be decided which independent factor dominates over the other and the percentage contribution of that particular independent variable. This analysis was carried out for a level of 5% significance that is up to a confidence level of 95%. Sources with a P-value less than 0.05 were considered to have a statistically significant contribution to the performance measures. Tables 7 and 8 show the results of ANOVA analysis of Modified ZA-27 alloy of specific wear rate and frictional force. It can be noticed from the Tables 7 & 8 both Normal Load and sliding distance has significant influence on specific wear rate and frictional force respectively. The Normal Load and sliding distance can be considered as statistically significant from the Tables 7 & 8.

Table 7: Analysis of Variance for Specific Wear rate

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% of contribution
Nr. Load	4	0.0000038	0.0000038	0.0000010	11.44	0.000	54.29
Sliding speed	4	0.0000018	0.0000018	0.0000005	5.44	0.006	25.71
Error	16	0.0000013	0.0000013	0.0000001			20
Total	24	0.0000070					

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2644 - 2649

Table 8: Analysis of Variance for Frictional Force

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% of contribution
Nr. Load	4	173.724	173.724	43.431	86.86	0.000	80.50
Sliding speed	4	34.076	34.076	8.519	17.04	0.000	15.79
Error	16	8.000	8.000	0.500			3.71
Total	24	215.800					

Table 9: Optimum level Process parameters for specific wear rate and Frictional force

Sl.No	Response	Nr. Load (N)	Sliding speed (m/s)	S/N ratio (db)
01	Specific wear rate	19.62 (A_3)	2.5 (B_5)	89.590
02	Frictional Force	4.905 (A_1)	2.5 (B_5)	-37.8871

C. Multiple Linear Regression Models

The multiple linear regressions is used to develop the correlation between the effective factors (Normal Load and sliding speed) and the specific wear rate and frictional force (quality characteristic) to observed data.

The regression equation for Modified ZA-27 alloy (Specific wear rate)

Specific Wear rate = 0.00178204 - 0.000248795 (A) - 0.000327421 (B) -----Eq (4)

R-Sq = 80.84%

The regression equation for Modified ZA-27 alloy (Frictional force)

Frictional Force = 6.80715 + 1.96707 (A) - 1.612 (B) ------Eq (5)

R-Sq = 96.29%

From Eq(4) it can noticed that the negative value of coefficient of Normal load and sliding speed reveals that increase in normal load and sliding speed decreases the specific wear rate and Eq(5) that the negative value of coefficient of sliding speed reveals that increase in sliding speed decreases the frictional force of Modified ZA-27 alloy.

IV. CONCLUSION

The experimental reveals the following conclusions:

1. Taguchi method has been applied to analyze the specific wear rate and frictional force of Modified ZA-27 alloy.
2. Normal Load (54.29%) has the highest influence on specific wear rate followed by sliding speed (25.71%) for Modified ZA-27 alloy.
3. Normal Load (80.50%) has the highest influence on frictional force followed by sliding speed (15.79%) for Modified ZA-27 alloy.
4. The optimal tribological testing combination for minimum specific wear rate and frictional force are found to be A_3B_5 & A_1B_1 for Modified ZA-27 alloy.
5. Normal Load and sliding speed can be considered as statistically significant parameters for specific wear rate and frictional force.

REFERENCES

[1] Veerabhadrappa Algur, V R Kabadi, Ganechari S M, P B Shetty, "Analysis of Wear Behaviour of a Heat Treated Modified ZA-27 Alloy by Taguchi Technique", International Journal of Recent and Innovation Trends. Volume -2, Issue-12, December – 2014.

[2] Amar Patnaika, Alok Satapathy , Navin Chand, N.M. Barkoula , Sandhyarani Biswas , "Solid particle erosion wear characteristics of fiber and particulate filled polymer composites: A review", Wear 268 (2010) 249–263.

[3] B. Bobic, S. Mitrovic, M. Babic, A. Vencl, I. Bobic, "Corrosion behaviour of the As-cast and Heat-treated ZA-27 Alloy", Tribology in industry, Vol. 33, No.2, 2011, pp- 87-93.

[4] Sharma, S. C., Girish, B. M., Kamath, R., Satish, B. M. "Graphite particles reinforced ZA-27 alloy composite materials for journal bearing applications" ,Wear 219,1998,162- 168.

[5] Veerabhadrappa Algur, V R Kabadi, Ganechari S M and Sharanabasappa 'Experimental Investigation on Friction Characteristics of Modified ZA-27 Alloy Using Taguchi Technique'. Int. J. Mech. Eng. & Rob. Res. 2014 ISSN 2278 – 0149 www.ijmerr.com Vol. 3, No. 4, October 2014 © 2014 IJMERR, pp. 24-32.

ISSN: 2321-8169
2644 - 2649

[6] Sharma, S. C., Rao, P. R., Girish, B. M. "Mechanical properties of as-cast and heat-treated ZA-27/silicon carbide particulate composites" ,Materials and Design, 16 ,(5) 1995: 277-280.

[7] Ahmet Turk, Mehmet Durman, E. Sabri Kayali "The effect of Ti-B and Sr on the mechanical behavior of the Zinc-aluminum based ZA-12 alloy produced by gravity casting" , Intl Journal of Materials Research, Volume 97, 2006(8), 1-6.

[8] Mukundadas Prasanna Kumar, Kanakuppi Sadashivappa "Dry sliding wear behaviour of garnet particles reinforced Zinc aluminium alloy metal matrix composites", Materials Science, Volume 12, 2006 ,1392–1320.

[9] Shanta Satry, M.Krishna, Jayagopalan Uchil "A study on damping behavior of aluminite particulate reinforced ZA-27 alloy metal matrix composites", J. Alloys and Compounds, Volume 314, 2001, 268-274.

[10] Yuanyuan, Tungwai,Wei Xia,Wen Zhang "Effect of Mn content on the tribological behaviour of ZA27%Al-2%Cu alloy", Wear, Volume 198, 1996, 129-135.

[11] Seenappa, K.V.Sharma "Effect of alloying additions on tribological properties of ZA alloys", International Journal of Advanced Engineering & Application, Volume2, Jan 2011, 152–155.