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Wear behaviour of modified ZA-27 alloy: a statistical analysis

This contemporary work has mainly engrossed on optimization of wear loss of modified zinc aluminium (ZA-27) alloy with varying inputs like sliding speed, normal load, and sliding distance were used to conduct dry sliding wear experiments on a friction and wear testing equipment. The experiments were designed using a Taguchi mixed design L16 (4^2 ^1) orthogonal array. The impacts of wear feature (input) on wear loss (output) of ZA-27 alloy were deliberated using Taguchi and ANOVA. Best parameters for minimum wear loss are a normal load of 9.81N, a sliding speed of 2 m/s, and a sliding distance of 2500m, according to the findings. The contributions of sliding distance, sliding speed and normal load were 0.07%, 6.01% and 81.48%, respectively, according to ANOVA. For the modified ZA-27 alloy, Taguchi and ANOVA results reveal the same influence order. At higher loads and speeds, the worn surface reveals that the sub-surfaces fractured and broken, forming a plate-like structure of wear debris.

Keywords: ANOVA, mixed design, orthogonal array, pin-on-disc testing machine, wear loss.

1.0 Introduction

Material wear is one of the most significant and unavoidable losses in engineering (Yuanyuan et al., 1996). As a result, the creation of novel wear-resistant materials has become a critical challenge that many researchers are working on (Babic et al., 2004). In the 1960s and 1970s, the ZA family of alloys, which include between 8 and 50 weight per cent aluminium, was created to replace cast, brass, and malleable iron in the production of wear-resistant components (Algur et al., 2014). ZA alloys have similar strength to aluminium casting alloys, wear resistance to bearing bronzes, and characteristics to many cast irons but are easier to manufacture (Murphy et al., 1984). They have been used to replace cast iron and aluminium alloys in numerous high-performance parts, and they have also been used to replace bronze in bearings and bushings (Janamatti et al., 2022).

The influence of several alloying constituents on the wear characteristics of zinc aluminium alloys has been studied extensively (Seenappa and sharma, 2011). (Choudhary et al., 2002) in one of these tests, researchers looked at the effect of Ni on the degree of wear loss of the zinc aluminium alloy. Results showed that with addition of Ni to ZA alloy boosts wear resistance due to the production of intermetallic phases. The influence of Si on mechanical and wear characteristics of zinc-based alloys was investigated by (Savaskan et al., 2004). The results show that as the silicon percentage increases up to 2 wt. per cent, the strength and rigidity of these alloys increases, but as the silicon level increases, it decreases. It was also determined that as the silicon content increases, the loss in the wear and frictional coefficient of the alloy decreased, up to a point where the value increased. Using the Taguchi and ANOVA approaches, the optimization of wear loss of modified ZA-27 alloy under dry sliding conditions with different wear parameters was determined in this study.

2.0 Experimental methods

2.1 Material preparation

The ZA-27 alloy was used to prepare the material for the experimental alloys in weight per cent (Al-27 wt. per cent, Cu-2wt per cent, Mg-0.04 wt. per cent, Si-3.5 wt. per cent and balance Zn). As a modified element, manganese (0.5 wt. %) is employed. Gravity die-casting is used to prepare an alloy.

Melting was conducted at 740°C in a crucible furnace. The chemical composition of various alloys was weighed and melted in a graphite crucible according to ratios. To prevent Zn loss, the alloying temperature was kept below 700ºC. The density of the alloys was estimated, and the thermal diffusivity figures were computed by dividing thermal conductivity by specific heat and density at constant pressure.

2.2 Wear test

Dry sliding wear experiments were performed by adjusting operating parameters on a wear and friction testing machine,

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as illustrated in Fig.1. Sliding speed, normal load, and sliding distance are the parameters of wear test used for our current work, as shown in Table 1. The lathe machine was used to cut the samples to the diameter and length are10 mm 30 mm, respectively. Before the examinations, the specimens were thoroughly cleaned to remove any oil or dirt. Before each test, emery paper is used to polish the superficial of each sample and the disc (Sharanabasappa et al., 2015). Burrs are removed from the faces of specimens at the end of each test to maintain smooth surfaces. An electronic microbalance (0.0001g, as shown in Fig.2) was used to weigh each sample before and after the wear test. The weight-loss approach was used to calculate wear loss.

Fig.1: Friction and wear testing machine

Fig.2: Micro-balance weighing M/C

2.3 Taguchi technique

The experiments were carried out to see how different testing parameters affected the wear of modified ZA-27 alloy. L16 (4^2 2^1) orthogonal array was used to plan the tests (mixed design). A total of 16 experiments were carried out using the Taguchi model's run order. Wear loss is the response (S/N ratio) examined for the model, with the goal of "smaller is better" quality attributes. For each level of process parameters, the response was computed. Finally, ANOVA was performed to evaluate whether or not parameters were statistically significant. The data was analyzed using the commercial software MINITAB 18, which is designed primarily for design of experiment applications.

2.4 Anova

The impacts of wear characteristics on wear loss of modified zinc aluminium alloy were investigated using analysis of variance (ANOVA). The percentage contribution of each independent variable can be determined using ANOVA. This study was conducted at a significant level of 5%. P-values less than 0.05 were measured statistically substantial contributors to the performance measures.

3.0 Results and discussion

3.1 Taguchi technique

Using the S/N ratio response type, the impact of control factors like sliding speed, normal load, and sliding distance was investigated. The intensity of the control factor's influence is defined by the value of (delta). For a given control factor, delta is the difference between the highest and least value of S/N ratios. The control factor becomes more dominating when the delta value is high. According to the S/ N ratio response table, normal load has the largest influence on wear loss, followed by sliding speed and sliding distance (Table 2). Fig.3 shows the effect of main plot for S/N ratio for

Table 1: Wear test parameters

Descriptions	Value
Normal load (N)	9.81, 19.62, 29.43, 39.24
Sliding speed (m/s)	0.5, 1.0, 1.5, 2.0,
Sliding distance (m)	1500, 2500
Motion	Reciprocating
Temperature (ºC)	23.1
Relative Humidity (RH)%	34

Table 2: Response table for signal to noise ratios

Level	Normal load	Sliding speed	Sliding distance
1	–5.718	–11.859	–12.746
2	–11.031	–13.302	–12.308
3	–16.661	–13.366	
4	–19.027	–11.580	
Delta	13.309	1.786	0.438
Rank	1	2	3

TABLE 3: ANALYSIS OF VARIANCE

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% of contribution
Normal load	3	138.573	46.1908	17.47	0.001	81.48%
Sliding speed	3	10.213	3.4042	1.29	0.343	6.01%
Sliding distance	1	0.122	0.1225	0.05	0.835	0.07%
Error	8	21.150	2.6438			12.44%
Total	15	170.058				100%

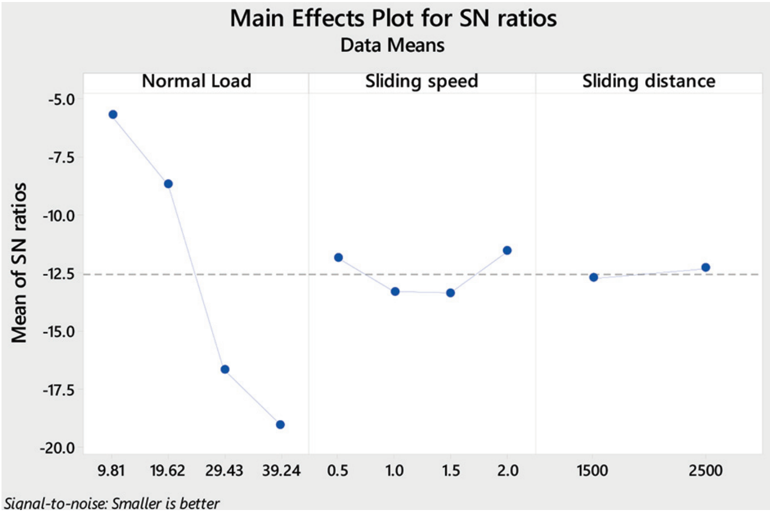

Fig.3: Main effects plot for SN ratios

wear loss of modified zinc aluminim 27 alloy. It appears that the best circumstances for minimizing wear loss are a normal load of 9.81N, a sliding speed of 2.0m/s, and a sliding distance of 2500m. Fig.4 shows the interaction graphs between the normal load and sliding speed are in nonlinear in nature, Hence, there is an interaction between the normal load and the sliding speed. Similarly, there is also an interaction between the sliding speed and sliding distance.

3.2 ANOVA

The findings of the experiments were examined using analysis of variance (ANOVA), a statistical tool for identifying the effect of wear factors such sliding speed, normal load, and sliding distance. Using ANOVA, we may identify which

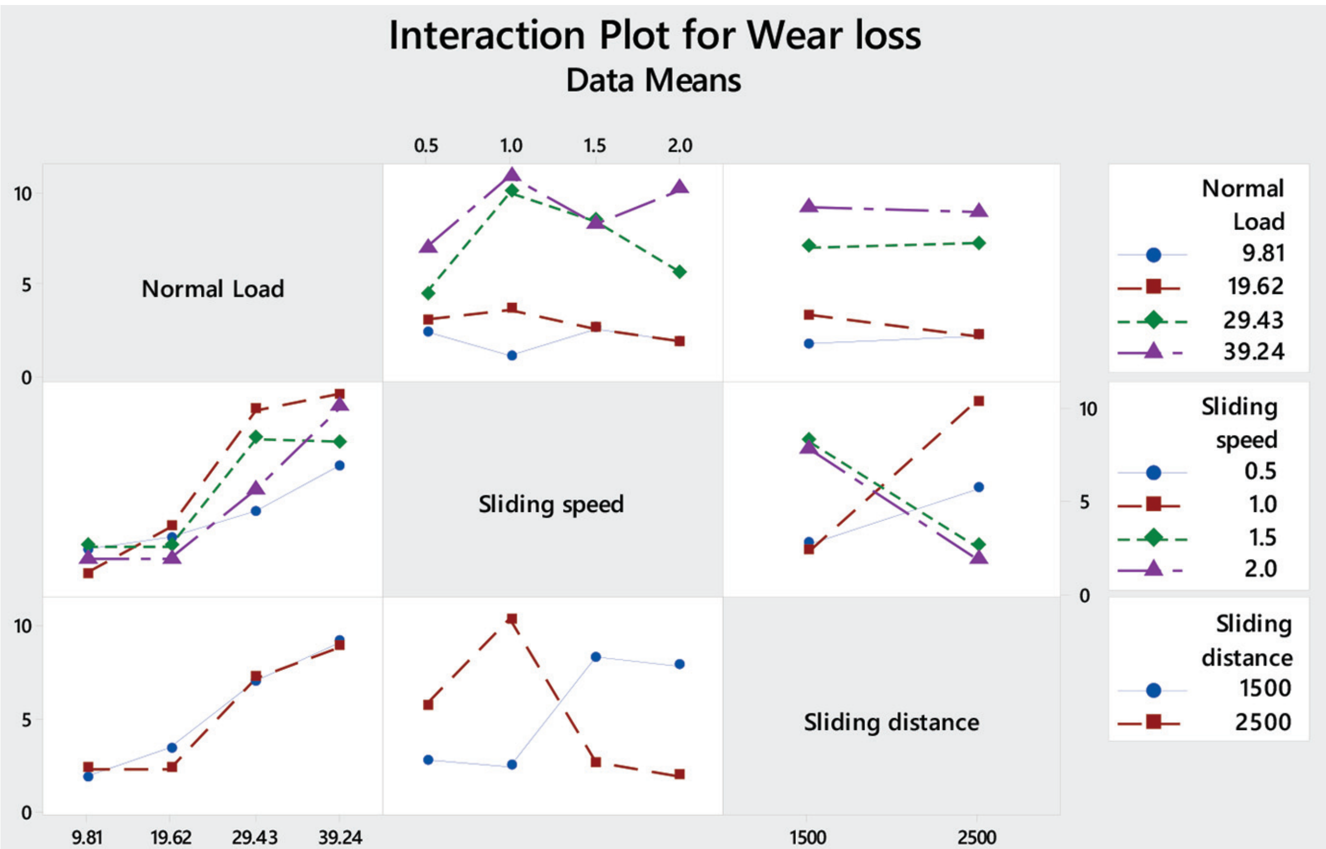

Fig.4: Interaction plot for wear loss

independent variable outperforms the others and what percentage of the contribution that independent variable makes. The significant threshold for this study was set at 5%. P-values less than 0.05 were measured statistically important contributors to the performance measures.

The normal load has the greatest impact on the wear loss of the zinc aluminium alloy. Table 3 shows that normal load (81.48%) seems to have highest influence on wear loss, followed by sliding speed (6.01%) and sliding distance (0.07%) for modified ZA-27 alloy. The same parameter influences are observed in the response table of the S/N ratio of the Taguchi optimization technique in Table 2.

4.0 Conclusions

(1) The loss in zinc aluminium alloy due to wear was increased with increasing normal load for utmost all sliding speed and distances.

(2) The response table of S/N ratio shows that influence of normal load is higher than the sliding speed and sliding distance.

(3) The best criteria for minimizing wear loss include a normal load of 9.81N, a sliding speed of 2.0m/s, and a sliding distance of 2500 m.

(4) According to ANOVA results, the most intrinsic factors for wear loss of modified ZA-27 alloy is normal load.

(5) For the modified ZA-27 alloy, normal load (81.48%) has the highest effect on wear loss, followed by sliding speed (6.01%) and sliding distance (0.07%).

(6) For the modified ZA-27 alloy, both Taguchi and ANOVA analyses reveal the same order of influence.

References

1. Algur Veerabhadrappa, V R Kabadi, Ganechari S M, Vithal Rao Chavan. (2017): Effect of Mn content on tribological wear behaviour of ZA-27 alloy. Materials today: Proceedings 4: 10927- 10934.
2. Algur Veerabhadrappa, V R Kabadi, Ganechari S M and Sharanabasappa. (2014), Experimental Investigation on Friction Characteristics of Modified ZA-27 Alloy Using Taguchi Technique. *Int. J. Mech. Eng. & Rob.* Res 3(4): 24-32.
3. Algur Veerabhadrappa, V R Kabadi, Sharanabasappa M, Ganechari S M, P B Shetty. (2015): Optimization of sliding specific wear and frictional force behaivour of modified ZA-27 alloy using taguchi method. *International journal on recent and innovation trends in computing and communication* 3(5): 2644 -2649.
4. Algur Veerabhadrappa, Poornima Hulipalled, V Lokesha, Madeva Nagaral, V Auradi. (2022): Machine Learning Algorithms to Predict Wear Behaviour of Modified ZA-27 Alloy Under Varying Operating Parameters, *Journal of Bio-and Tribo-Corrosion*, 8(1): 1-10.
5. Babic M, R Ninkovic. (2004): Zn-Al alloys as Tribo materials. *Tribology in industry* 26 (1&2): 3-7.
6. Babic M, R Ninkovic. (2004): Zn-Al alloys as Tribo materials. *Tribology in industry* 26 (1&2): 3-7.
7. B. K. Prasad, A. K. Patwardhan, A. H. Yegneswaran. (1998): Microstructure and property characterization of a modified zinc-base alloy and comparison with bearing alloys. *Journal of materials engineering and performance* 7(1): 130-135.
8. Janamatti Santosh, Umesh Daivagna, Madeva Nagaral, Veerabhadrappa Algur. (2022): Investigation on Microstructural Characteristics of Zn Alloy MMC for Bearing Application, Proceedings of Fourth International Conference on Inventive Material Science Applications, Springer, Singapore: 217-225.
9. Murphy Samuel, Temel Savaskan. (1984): Comparative wear behaviour of Zn-Al based alloys in an automotive engine application. *Wear,* 98: 151-161.
10. P Choudhury, S Das, B. K. Datta. (2002): Effect of Ni on the wear behaviour of a Zinc aluminium alloy. *Journal of materials science* 37: 2103-2107.
11. Savaskan T, Aydmer A. (2004): Effect of silicon content on the mechanical and tribological properties of monotectoid- based zinc-aluminium-silicon alloys. *Wear* 257: 377-388.
12. Sevik Huseyin. (2014): The effect of silver on wear behaviour of zinc-aluminium based ZA-12 alloy produced by gravity casting. *Materials Characterization* 89: 81-87.
13. Sharanabasappa M, V R Kabadi, Veerabhadrappa Algur. (2015): The effect of pearlite, cementite, and martensite phases on volumetric wear rate of hypereutectoid steel under dry sliding conditions. *International journal of metallurgical and materials science and engineering* 5(1): 2278-2524.
14. Seenappa, K. V. Sharma. (2011): Characterization of mechanical and micro structural properties of ZA alloys. *International journal of Engineering science and technology* 3(3): 1783-1789.
15. Yuanyuan Li, Tungwai Leo Ngai, Wei Xia, Wen Zhang. (1996): Effects of Mn content on the Tribological behaviours of Zn-27% Al-2% Cu alloy. *Wear*, 198: 129-135.