Research Article

Analysis of Wear Behaviour of AA5052 Alloy Composites by Addition Alumina with Zirconium Dioxide Using the Taguchi-Grey Relational Method

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The present study deals with preparation of Al hybrid metal matrix composites by the stir casting technique. In this work, Al5052 alloy was selected as the main metal which reinforces with zirconium dioxide and aluminium oxide. The wear test has been conducted on the POD apparatus. 9 specimens are produced by varying reinforcements' percentage for conduction of tests. The amount of ZrO_2 reinforcement is fixed to 8wt%, while the concentration of Al_2O_3 varied from 5wt% to 10wt%. The parametric optimization of wear behaviour is done through the Taguchi method with L9 orthogonal array. Minitab statistical software helped to find SN ratio and ANOVA reading for each parameter: load (N), sliding speed (rpm), and wt% of reinforcements. From the ANOVA outcome, the load parameter is the highest influencing element that improves wear resistance of made samples around 46%, followed by weight% of reinforcement 29% and sliding speed 26% as second and third influenced parameters, respectively.

1. Introduction

The preparation of machineries, products, and any shape of items has been carried out using the stir casting procedure. This method is relevant to dimensions and volume of % weight on reinforcements [1, 2]. The samples of AL6082/Tic are produced by liquid metallurgy, and many tests are conducted to analyse behaviour of materials [3]. Laser methodology was also used sometimes to make composites, for example, Al-Gr metal alloy was prepared in that way, the element of Gr augmented the wear resistance property in final result [4]. Aluminium-based alloy 5052 which is named

as aluminium-Mg alloy belonging to 5000-series category possesses more resist from oxidization. It is able to give high wear behaviour during ionization of surface film [5].

Zirconium dioxide is acting like a glowing particle that is mostly present in earth in the form crystalline structure [6, 7]. Aluminium oxide also called as alumina or Al oxide or aloxite is useful for producing AA-depended items [8]. Al_2O_3 was acknowledged in α-level which is suitable in pads (electrically padding) manufactured as well as cutting tool abrasive parts in mechanical field [9]. The research work of Ranjan et al. done on Al-356 along with a nanoalumina/ ZrO_2 (micro) hybrid composite specimens is made by

squeeze casting. The result of corrosion resistance and hardness of ready samples are improved by rising ceramic reinforcement's percentage [10]. In another article of AL-5052/zirconium oxide, HV, microhardness and rate of wear were investigated after standard dimension of samplings. From the output reading, it was noticed that HV improved from around 75 to 115 [11]. The change of ZrO_2 wt% level leads to change of the effect of behaviour of Al alloy (6061). Variation of zirconium oxide ranges with fly-ash approximately 5–10% that tends of increasing abrasion values (95 Hv) and tensile strength (280 MPa), and elongation (22%) expressively decreases due to addition of these particulates of ZrO_2/ash content [12]. Girisha and others have done an experiment on aluminium 356 with oxide of zirconium particle accumulation [13]. ZrB_2 has been utilized as AMC reinforcement, giving more strength of tensile by increasing from 10 to 15 wt% fraction [14]. Generally, density of AMCs materials reduced while adding TiO_2, TiB_2, and other particulates of oxide particles, but when adding fly-ash, RH ash and mica more balance to reduce weight of making components [15]. Value of wear property on both wet and dry conditions gets increased due to higher grain size of graphite 5 wt% in Al-Gr combination alloy [15]. Mostly, corrosion characterises depending on slide speed, pin-on-disc diameter, and load parameters. Mass in wear was found decreased by increasing extra speed of disc, and COF reductions by graphite accumulation were observed in AA-7075 [16]. LM6 alloy reinforced alumina Al_2O_3 elements in different fraction volumes (0.05–0.15 wt), and sizes of (44–125 lm) samples were being generated via the PDC technique [17]. The defects on prepared specimens can be found by conducting nondestructive testing [18]. The radiography test is a kind of NDT used for analysing defects present on welding plates of SS304 [19]. The EDs test is also utilized to check microstructure and chemical composition of objects [20, 21]. This kind of prepared AA 5052 with reinforcement composites were used in many applications such as pressure vessels, making the equipment in marine field, chassis in electronic arena, hydraulic type tubes, and also apparatus in medical domains.

From the various literature review articles, our intention is to create many Al alloy samples with different parameters. Statically, Minitab software was used to execute design of experiments on wear parameters.

2. Procedure for Experimentation

The initial stage has to be metal collection and then start making sample on Al5052 in a stir-cast procedure. Subsequently prepared specimens with ASTM standards were taken to conduct examinations for analyse characterises. The cast process is mostly used to produce the desired shape of objects through mold parts. In this experimental work, the stirrer is made by stainless steel as a main part, mixing Al alloy and selected reinforcements at particular speeds. Rotation of the stirrer is maintained around 600–800 rpm, by inserting the furnace that manage heat to melting of solid metal and powders. Before addition particulates, zirconium dioxide and aluminium oxide in 5052 alloy in the crucible need to be preheated at 350°C. Three import parts available in stir position are the solid rod and impeller with angle of blades.

The motor is a source which supplies the power to stir the rod to perform mixing operations of materials once conversion of solid into liquid (molten metal) is done and poured to designed dies. The total setup of furnace with other parts is shown in Figure 1, and also, elements of 5052 Al are given in Table 1.

Smooth cleaning or polish of work piece is most important to remove unnecessary chips from surfaces. This process can be done by application of some solvents or sand papers. Those samples are kept on the POD apparatus with DOE orthogonal array (L9); material is removed from alloy metal due to abrasion between disc and AL samplings; in the entire procedure, weight before and after experiments needs to measured. For analysis of corrosion behaviour optimization, three levels have been selected on three parameters load: Ld (20, 25, and 30 N), sliding velocity Sd (300, 400, and 500 rpm), reinforcements Rt (5–10%w.t) as given in Table 2. Signal-to-noise and wear performance readings are given in Table 3.

3. Result and Discussion

Nine wear experiments are conducted on the POD machine from those wear results (Table 3) design of experiments carried out by giving various input factors on optimize software (Minitab 18). The responding mean and SN ratio are shown in Figure 2 and Figure 3. Optimum wear behaviour was observed at third levels of load (I[st] rank) and reinforcement wt (2nd rank) and 2nd level in sliding speed (3rd rank), as given in Table 4 and Table 5.

A contribution of each parameter on ANOVA results has been calculated, and the load is a major contributed factor that influenced wear performance about 45.12%; next, substantial parameter is reinforcement percentage of ZrO_2/ Al_2O_3, which contributed around 29.48%, and sliding speed is the last influencing factor that considered 25.40% for wear rate (Table 6).

The lowest SN ratio among all chosen factors is 41.92, identified at load level 1, but at the same time, the highest value was also found in level 3 long with delta 2.73 (Table 4). The response of mean given in Table 5 provides that Ld level 2 is more compared to other levels of Sd and Rt. The minimum wear rate (0.00432 mm³/Nm) has found the combination of load (25 N), sliding speed (300 rpm), and weight percentage reinforcement (5%). The predicted regression equation for wear rate obtained from Minitab 18 is exposed as in the following equation:

$$\text{Wear rate} = 0.01017 - 0.000093\text{Ld} + 0.000004\text{Sd} - 0.000314\text{Rt}.$$

(1)

The surface plot for wear performance against Ld, Sd, and Rt is drawn. It was noticed that rate or value of wear increased with increased slide speed and decrement of load (Figure 4); at the same way, wear value slightly comes down due to increase of reinforcement and load (Figure 5), and finally, wear rate was changed while changing of reinforcement% and Sd (Figure 6).
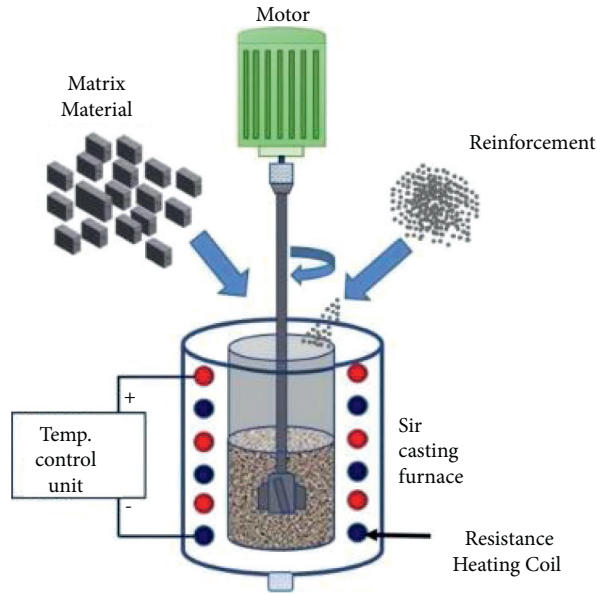
Figure 1: Stir casting furnace.

Table 1: Composition AA5052 (% wt).

Materials	Si	Cu	Fe	Mg	Cr	Mn	Zn	Al
Percent	0.25	0.12	0.39	2.5	0.21	0.1	0.15	Balance

Table 2: Stages in test factors.

Parameters:	Level 1	Level 2	Levels 3
Ld (N)	20	25	30
Sd (rpm)	300	400	450
Rt (wt%)	5	7.5	10

Table 3: Observation results.

Exp. no.	Ld (N)	Sd (rpm)	Rt (wt%)	Wear rate (mm^3/Nm)	SN ratio
1	20	300	5	0.00735	42.6743
2	25	400	7.5	0.00526	45.5803
3	30	500	10	0.00814	41.7875
4	30	300	5	0.00949	40.4547
5	20	400	7.5	0.00615	44.2225
6	25	500	10	0.00882	41.0906
7	25	300	5	0.00432	47.2903
8	30	400	7.5	0.00715	42.9139
9	20	500	10	0.00649	43.7551

The lowest SN ratio among all chosen factors is 41.92, identified at load level 1; but at the same time, the highest value was also found in level 3 long with delta 2.73 (Table 4). The response of mean given in Table 5 provides that Ld level 2 is more compared to other levels of Sd and Rt. From Table 6, result of ANOVA, it was observed that F value is higher at load (0.85) factor compared to other remaining factors, so that contribution of Ld is most influenced in wear performance.
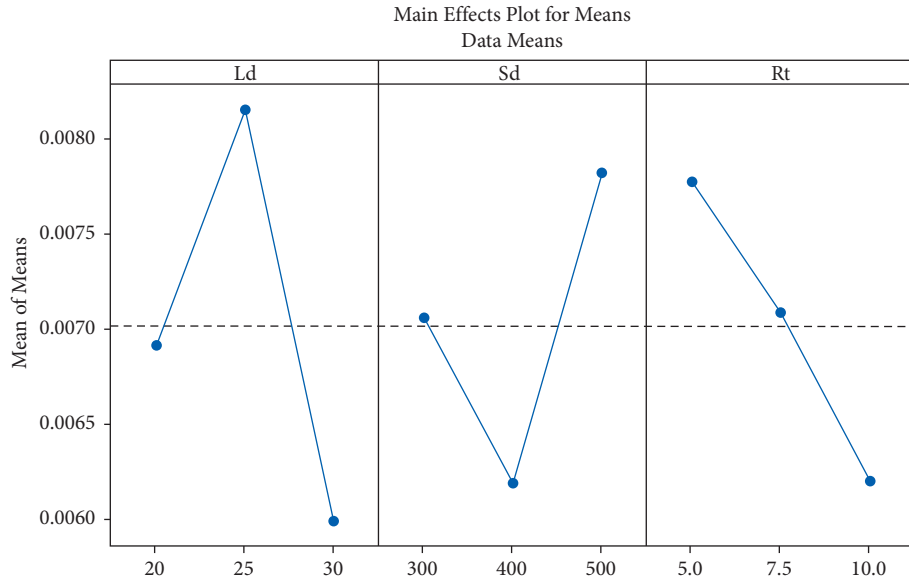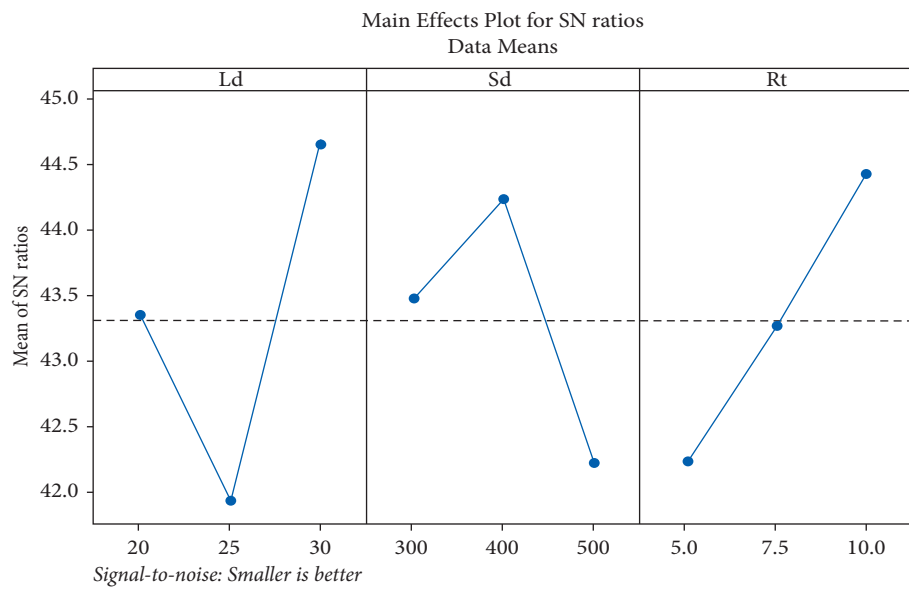
Main Effects Plot for Means
Data Means

Figure 2: WR means plot.

Main Effects Plot for SN ratios
Data Means

Signal-to-noise: Smaller is better

Figure 3: WR-SN plot.

Table 4: Responses signal-to-noise ratios.

Level	Ld	Sd	Rt
1	43.35	43.47	42.23
2	41.92	44.24	43.26
3	44.65	42.21	44.43
Delta	2.73	2.03	2.21
Rank	1	3	2

TABLE 5: Responses means.

Level	Ld	Sd	Rt
1	0.006917	0.007053	0.007773
2	0.008153	0.006187	0.007080
3	0.005987	0.007817	0.006203
Delta	0.002167	0.001630	0.001570
Rank	1	2	3

TABLE 6: ANOVA result.

Sources	Degree of freedom (DF)	Squares sum (seq SS)	Mean square (adj MS)	F value	P value	Contribute level (%)
Ld	2	11.191	5.595	0.85	0.541	45.12
Sd	2	6.291	3.146	0.48	0.677	25.40
Rt	2	7.316	3.658	0.55	0.643	29.48
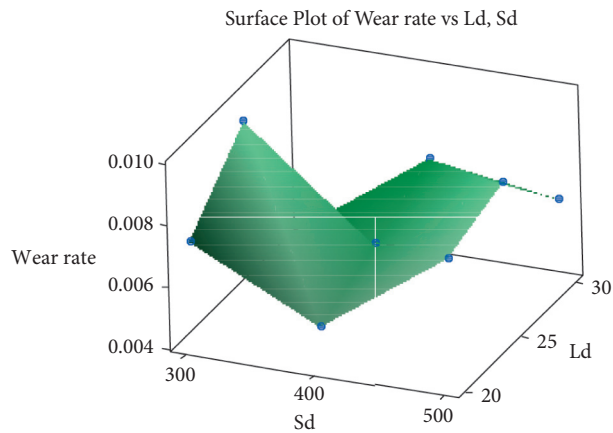
FIGURE 4: Plot of Ld, slide speed versus WR.

FIGURE 5: Plot of WR versus Ld and Rt.

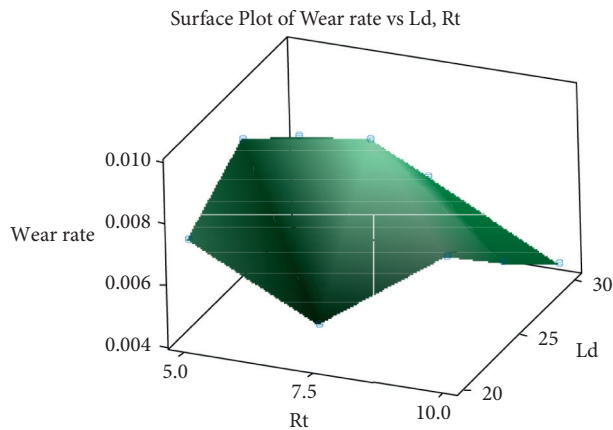Surface Plot of Wear rate vs Sd, Rt

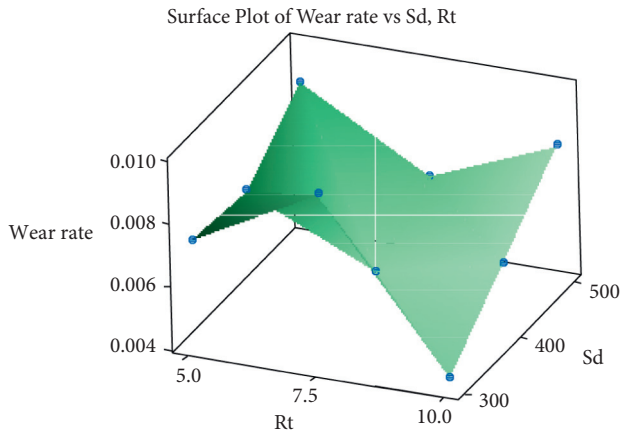

Figure 6: Plot on wear rate versus Sd and Rt.

4. Conclusion

Al 5052 alloy is main material which reinforced with zirconium dioxide and alumina. Nine specimens are prepared as per ASTM standard by the help of the stir casting technique to conduct the wear test on pin-on-disc (POD). Design of experiments for wear parameters have been analyzed via the Minitab optimize software. It is observed that load is leading parameter that influences wear behaviour of prepared samples about 45.12%; weight percentage of reinforcements (29.48%), and sliding speed (25.40%) are considered as second and last influence factors, respectively, in wear rate performance. Finally, the least wear rate is obtained in the combination of 25 N load, 300 rpm sliding speed, and 5 wt% of reinforcement.

Data Availability

The data used to support the results of this study are included within the article and are available from the corresponding author upon request.

Disclosure

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

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