ANALYSIS OF WEAR BEHAVIOUR OF AA5052 HYBRID COMPOSITE FABRICATED USING STIR CASTING PROCESS

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Abstract

This project aims to increase the wear resistance of AA5052 by forming a hybrid metal matrix composite with Silicon Carbide and Fly ash as reinforcements. Composite was fabricated using AA5052 reinforced with Silicon Carbide 5% and Fly ash 2% by weight of the matrix using stir casting method. The design of experiments was designed in full factorial method using Minitab software. Wear analysis was performed in Pin-on-disc apparatus. Optimization was carried out with the process parameters Load, Speed, Time and optimum results were obtained. Microstructural analysis of the composite was done in Inverted Microscope and it revealed proper distribution of reinforcement particles. The wear test results showed that the wear resistance of the composite increased with the introduction of reinforcement particles and the sliding speed.

Key words: stir casting, hybrid composite, pin-on-disc apparatus, full factorial method

1. Introduction

Composites are made up of individual materials referred to as constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. There are two main categories of constituent materials: matrix and reinforcement. Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated applications.

Dinesh kumar et al [1] investigated the mechanical properties of Aluminium 6063 based hybrid metal matrix composites. One reinforced with silicon carbide, graphite and second reinforced with silicon carbide, boron carbide by stir casting technique. Found that tensile strength, ultimate tensile strength, hardness value and flexural strength are increased in SiC and B4C particulates in comparison to the SiC, graphite reinforced composite. Balasivanandha Prabu et al [2] concluded that during lower speed and lower stir time, particle clustering occurred in some places, and some places were identified without SiC inclusion. By increasing the stirring speed and stirring time better homogeneous distribution of SiC in the Al matrix were found. Better distributions of SiC were found at 600 rpm and 10 min stirring time condition. N.Natarajan et.al [3] suggest at 4.5 m/s sliding speed, 10 N applied load 5min sliding time and 15% of reinforcement are the optimum conditions for both wear rate and the coefficient of friction. ANOVA test concluded that as percentage of reinforcement increases the wear rate also decreases significantly. From confirmation tests, the errors associated with wear rate ranges between 6.90% to 11.76 % and 4.66 % to 9.23 % for coefficient of friction resulting in the conclusion that the design of experiments by Taguchi method was successful for calculating wear rate and coefficient of friction from the regression equation.

2. Experimental Work

2.1 Design of experiments

Design of experiment is a powerful analysis tool for modeling and analyzing the influence of process variables over some specific variable, which is an unknown function of these process variables. Design of Experiments has been designed using Minitab'18 software under Factorial design. FFD is a multi-factor cross-group design. It not only can test the differences between various levels of each factor, but also can test the interaction between the factors. This method requires greater number of experiments compared with fractional design or Taguchi method and provides very accurate results on the interaction between any two factors. The design determines the effect of each factor on each response as well as how the effect of each factor varies with the change in the level of the other factors, i.e., interactions. The parameters chosen for analysis are Load, Speed and Time.

2.2 Composite fabrication

The experimental setup of stir casting essentially consists of an electric furnace and a mechanical stirrer. The electric furnace carries a crucible of capacity 2kg. The maximum operating temperature of the furnace is 1000°C. The current rating of furnace is single phase 230V AC, 50Hz. AA5052 rods of the required weight are heated in the crucible until they are completely molten. Reinforcement powders Silicon Carbide and Fly ash are preheated externally to a temperature of 250°C to oxidize their outer surface and ensure proper mixing. The reinforcement are introduced into the melt pool and stirred at 600 rpm for 5 minutes. Argon gas is passed in to the molten metal to remove the soluble gases present in the liquid state metal. The completely molten hybrid composite is poured into the die of required length and diameter.

2.3 Wear Test

A pin-on-disc test apparatus, was used to investigate the dry sliding wear characteristics of the aluminium alloy and its composites as per ASTM G99-95 standards. The wear specimen size of 10 mm diameter and height of 20 mm was cut from cast samples, machined and then polished metallographically. The tests were conducted as per the design of experiments.

All these tests were conducted at room temperature. The track diameter was kept at a constant 70mm. During the test the pin was pressed against the counterpart rotating against EN32 steel disc with hardness 65HRC by applying the load. An approximately strain-gauged friction detecting arm holds and loads the pin specimen vertically in to a rotating hardened steel disc. After running through a fixed sliding distance at specific time, the specimen was removed, cleaned and the process was repeated.

3. RESULTS AND DISCUSSION

3.1 Wear Test

In the wear test the pin was pressed against EN32 steel disc with hardness 65HRC by applying the load. Table 3.2 show the values of Frictional force and wear obtained from wear test. Figure 3.1 and 3.2 show the wear graphs of sample 6 and base alloy respectively.

After running for a specific time, the specimen was removed and cleaned. The wear values were obtained directly from the computer and the coefficient of friction was calculated using the formula.

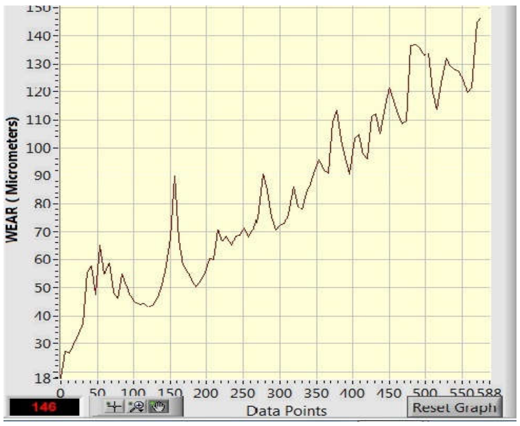


Figure 3.1 Wear graph of sample 6

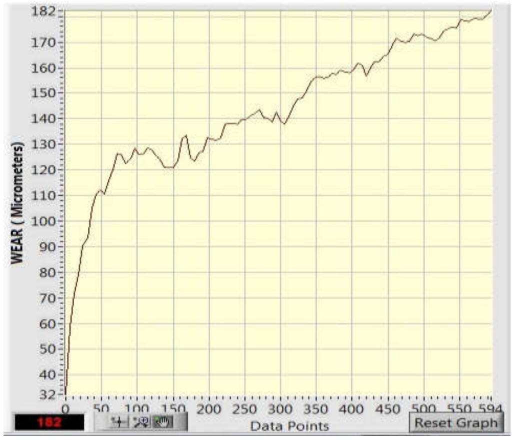


Figure 3.2 Wear graph of base alloy

Table 3.2 Results of wear analysis

SAMPLE NO.	**LOAD**(kg)	**SPEED**(rpm)	**TIME**(min)	**Wear** (µm)
1	2	500	7	144
2	4	500	7	150
3	2	550	7	141
4	4	550	7	145
5	2	500	10	141
6	4	500	10	146
7	2	550	10	140
8	4	550	10	144
Base alloy	4	500	7	182

3.2 Optimization

3.2.1 Optimization for Wear

The responses obtained from wear analysis are optimized with respect to the process parameters Load, Speed and Time with each factor having two levels namely low and high.

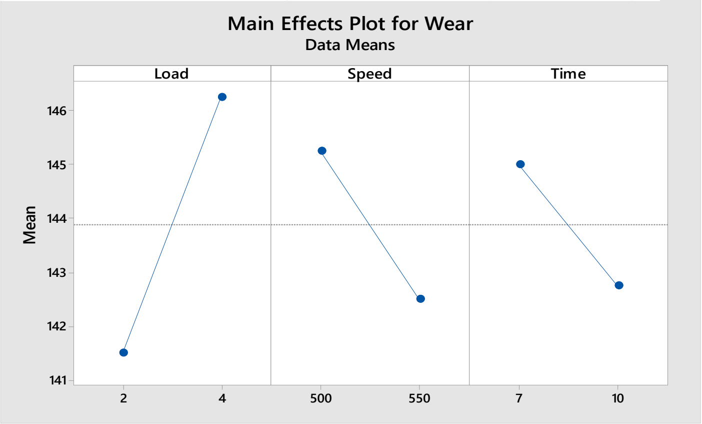


Figure 3.3 Main effects plot for wear

The figure 3.3 shows the main effects of factors on the response Wear. The optimum value of wear is considered to be the lowest. It can be clearly seen from the graphs that the optimum value of wear occurs at 2 kg load, 550 rpm speed and for the time 10 mins.

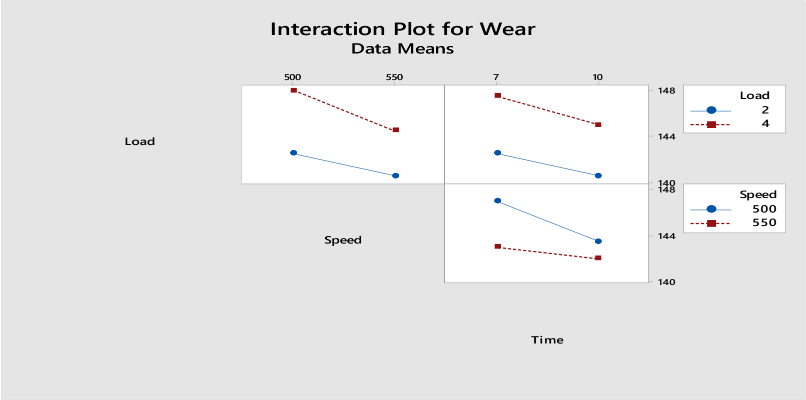


Figure 3.4 Interaction plot for wear

The figure 3.4 shows the interaction of factors on the response. It is seen from the graph that the curves that do not intersect, which implies there is no significant interaction between the factors.

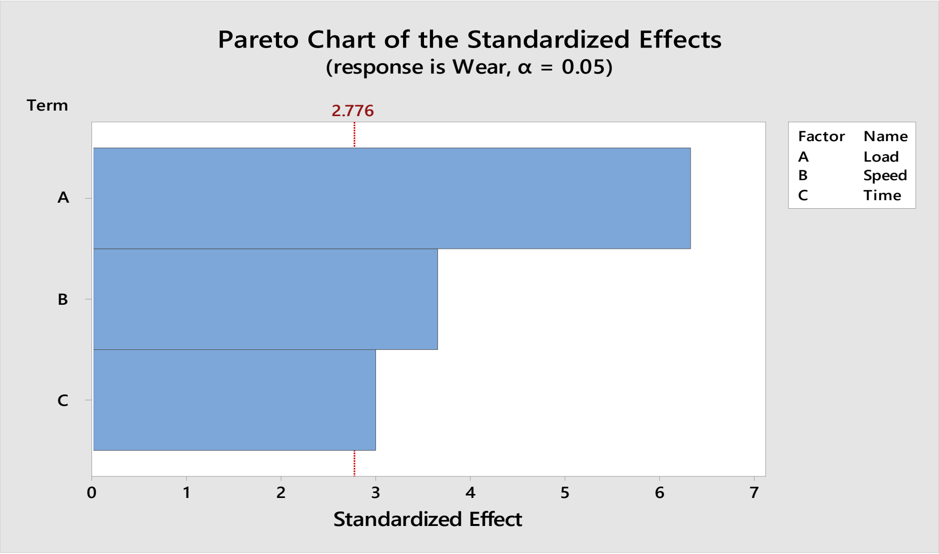


Figure 3.5 Pareto chart of the standardized effects

The figure 3.5 shows the Pareto chart of the standardized effects i.e the contribution of the effects of the main parameters. It is clear from the figure that the factor A: has the highest impact whereas the factor C: Time has the least impact. It is also clear that the individual effect of each factor is greater than the cumulative critical effect of the factors combined. The figure 3.6 shows that all the three factors considered are significant.

Figure 3.6 Normal plot of the standardized effects

3.2.2 ANOVA FOR WEAR

The inferences made from the above said graphs can be arrived at mathematically with the help of ANOVA. The confidence limits are taken as 95% for all the factors. Factors with P-value less than 0.05 are considered to be significant. The table 3.3 shows the values obtained for ANOVA test. It is clear from the table that all the inferences made from the figures 3.5 and 3.6 are statistically true.

Table 3.3 ANOVA table for wear

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Load	1	45.125	60.27%	45.125	45.125	40.11	0.003
Speed	1	15.125	20.20%	15.125	15.125	13.44	0.021
Time	1	10.125	13.52%	10.125	10.125	9.00	0.040
Error	4	4.500	6.01%	4.500	1.125		
Total	7	74.875	100.00%				

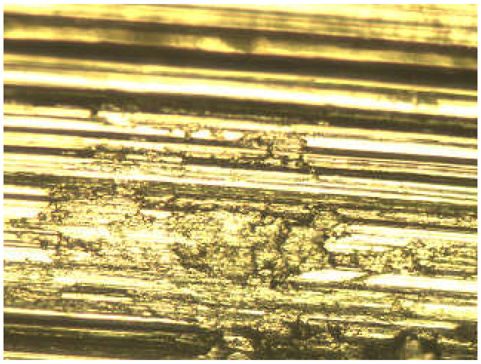
3.2.3 MULTIPLE LINEAR REGRESSION FOR WEAR

The data adequacy and analysis of the model designed in Full Factorial model can be evaluated using multiple linear regression model. The results from regression analysis can be used to cross check the results drawn from the graphs and ANOVA test. Regression test also gives the regression equation which is generalised equation corresponding to the effects of all the parameters on the responses. Substituting the optimum conditions namely 2 kg load, 550 rpm speed and 10 mins time in the regression equation the optimum value of wear obtained is 139 µm.

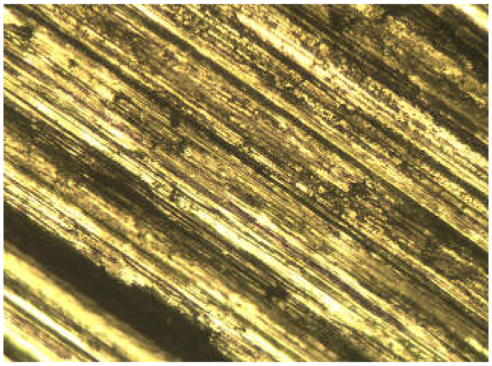
$$\text{Wear} = 172.00 + 2.375\ \text{Load} - 0.0550\ \text{Speed} - 0.750\ \text{Time}$$

The base alloy is subjected to wear with the maximum wear conditions corresponding to the design of experiments in table 5.2. It is found to have 182 µm wear. Comparing the result with the optimum value of the composite's wear, it can be concluded that the wear resistance of the composite has increased by 66% compared to that of the base alloy.

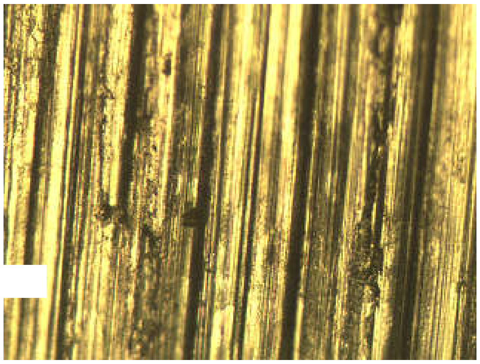
3.3 WEAR MORPHOLOGY



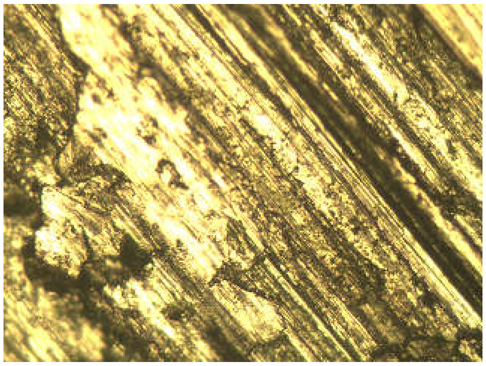
Sample 1



Sample 2



Sample 3



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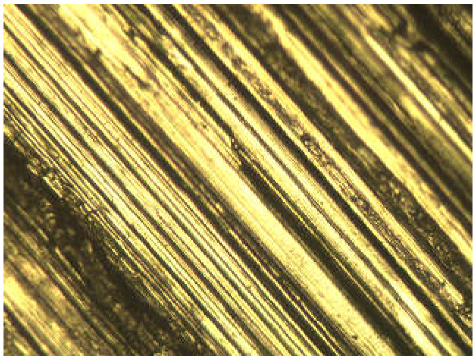
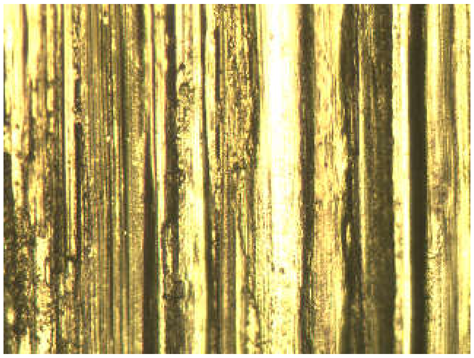
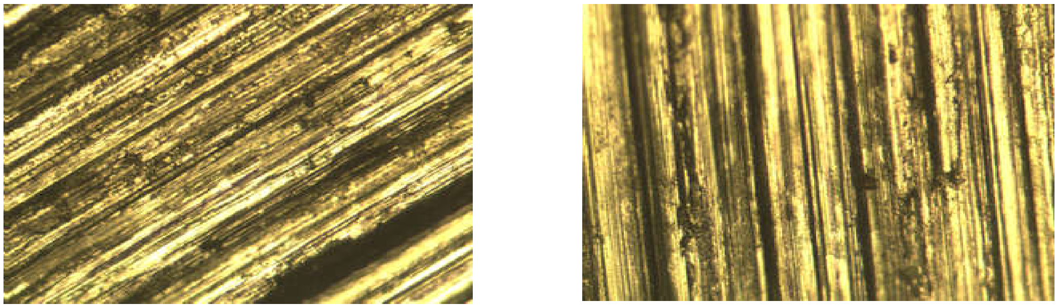


Sample 5



Sample 6



Sample 7 Sample 8

Figure 3.7 Worn surface micrograph of base alloy

A morphological feature of worn surface is an important quantitative aspect of wear surface analysis. Wear measurement depends on tribological features at interspaces. Image analysis technique with microscope is the best way to recognize the main cause of the particle generation. Figure 3.7 shows the micrographs of the worn surface of the samples studied. It shows the presence of reinforcement particles over the worn surface which acts as a resistant to the material's wear. Figure 3.8 shows the micrograph of the worn surface of base alloy

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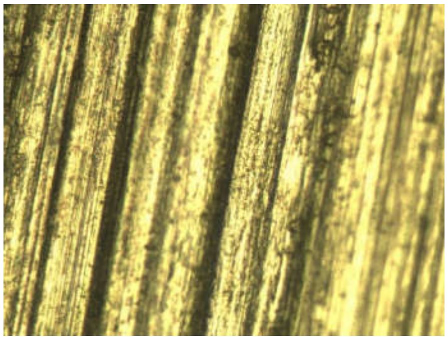

Figure 3.8 Worn surface micrograph of base alloy

4. CONCLUSION

The hybrid composite samples of AA 5052 as matrix, and SiC and Fly ash as reinforcements were fabricated using stir casting process. The wear behaviour and microstructure were investigated for the fabricated samples. From the results it is observed that the microstructure of the dual particulate reinforcements has shown an impact in the wear resistance of the composite. The microstructure analysis shows fairly even distribution of particles and some agglomerations of SiC and Fly ash.

- The hybrid composite exhibited superior wear resistance when compared with the base aluminium Al 5052 matrix alloy and the wear resistance increased by 66%.
- It is clear from the analysis that Load is the most significant factor with 60.27% contribution followed by Speed at 20.20% and Time at 13.52%
- The process parameter combination of 2 kg Load, 550 rpm Speed and 10 min time was found to be the optimum condition for the wear of the fabricated hybrid composite. The optimum value of wear was found to be 139 µm.

- This hybrid composite can be explored for use in marine applications like ship hulls, underwater natural gas tanks and pipelines.

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