

The Tribological investigation of A356/ Aluminium oxide Metal Matrix Composite by Taguchi's Techniques

Kiran Kumar N ^{a*}, B N Sarada ^b, P L Srinivasa Murthy ^c, Chethana K Y ^d

^aVemana Institute of Technology ,VTU Belagavi ,Bengaluru,560034,India

^{b,d}BMS College of Engineering ,VTU Belagavi,Bengaluru,560019,India

^cBNMIT ,VTU Belagavi,Bengaluru,560070,India

Abstract - The tribological behaviour of an A356 aluminium alloy/aluminium oxide (Al_2O_3) fabricated by powder metallurgy technique was examined. To evaluate the tribological properties of aluminum matrix composites, dry sliding wear tests have been conducted. Use a ducom made tribometer to check for friction and wear. Tribological examinations were executed in accordance with the statistical analysis. Taguchi's experiments have resulted in several findings. The data was analyzed using an L27 orthogonal array. An investigation was conducted to determine the impact of the parameters such as speed, distance of sliding, and the load applied on coefficient of friction and the wear rate throughout the wearing process, ANOVA was used to analyze the data. The model's goal was to analyze traits that were "smaller the better".

Keywords: Wear, A356 Aluminum alloy, Al_2O_3 , Taguchi.

1.0 INTRODUCTION

The exceptional property blends that can be accomplished, metal framework composites offer a wide scope of potential applications [1, 2]. Aluminium matrix composites were made to fulfill the developing need for materials with best tribological, high specific stiffness and strength. Due to its greater ability of conducting heat, low density, and expanded machinability, aluminum compounds are a significant designing material for mechanical and tribological applications in the automobile, aircraft, marine, and mineral processing sectors. It will not be suitable for many tribological applications because to its excessive wear loss. As a result, it is becoming increasingly vital to investigate the mechanical and tribological behaviour of aluminum-category materials. The wear resistance, strength, and creep resistance can be enhanced by combining the hard reinforcements with the Aluminium matrix alloy (soft material) [4, 5]. Alloy 6061 Al_2O_3 composites' dry sliding wear behavior is greatly affected by the matrix hardness, according to Straffellini et al. [6]. Yu et al. [7] studied the dry sliding wear characteristics of Al6061 SiC composites under the impact of applied loads and temperatures, concluding that the wear rate reduces with increasing applied stress. Taguchi technique was discovered by Radhika et al. [15] to be a useful technique for dealing with reactions influenced by multi variables. Among its functions are helping with process optimization and finding the best parameters to use for the outcomes. In comparison to a full factorial design, this approach drastically reduces the number of trials needed for model construction. This strategy has one essential advantage in which it allows you to discover potential interactions between variables.

Experimental designs aim to determine two or more parameters at the same time as moderating the particular process features or products' variability. The degrees of the components are strategically modified to do this in a valuable and statistically correct manner. As a result of studying all the results of the various combinations of tests, we determine the appropriate influence, as well as which levels of those factors can be increased or decreased to further enhance performance [16]. In order to select the best process design, signal-to-noise ratio is utilized for testing the results of an experiment. This approach is useful for analyzing the wear properties of composite materials [17].

2.0 EXPERIMENTAL METHODS AND MATERIALS USED

The A356/ Al_2O_3 composite was fabricated by powder metallurgy technique. Using digital electronic weighing equipment, the weight percent of Al_2O_3 particles was determined.

2.1 WEAR ANALYSIS

The pin-on-disc set up of wear test were utilized to assess the samples wear behavior in compliance with the standards of ASTM G99-95. The disc had a hardness of 62 HRc and was made of OHNS steel. The composites were used to make pins with a diameter of 6mm and a height of 15mm, which were subsequently metallographically polished for the wear test. At room temperature the experiments have been conducted beneath the load of 20, 30, and 40N, with a 2, 3 and 4 m/s of sliding speed, a sliding distance of 1000m, 1750 m and 2500 m with unlubricated conditions. For the 0.1mg resolution electronic weighing

equipment, using acetone the specimen have been cleaned by washing, dried, and their weights calculated to find out how much weight has been lost after running through the requisite sliding distance.

2.2 STATISTICAL ANALYSIS

Optimum results are observed after analyzing combinations of experimental data, calculating coefficients, fitting the data, and predicting the response. Here MINITAB 13 is used as optimization tool and optimization is done on two sets. In the first set of optimizations, by keeping the sliding distance as constant and varying the reinforcement percentage. In the second set by differing the sliding distances and maintaining a constant reinforcement.

Set 1. Constant sliding distance of 1000 m.

Table 1: Results of dry sliding wear of A356/ Al₂O₃ specimens and their design for constant sliding distance of 1000 m.

Level	Factors		
	Load Applied, L (N)	Sliding speed, S (m/s)	Al ₂ O ₃ Weight Percentage
1	20	2	0
2	30	3	2
3	40	4	4

Set 2: Constant reinforcement percentage

Table 2: Results of dry sliding wear of A356/ Al₂O₃ specimens and their design for constant reinforcement percentage

Level	For 0, 2 and 4 Wt% Al ₂ O ₃		
	LoadApplied , L (N)	Sliding speed, S (m/s)	Sliding Distance (m)
1	20	2	1000
2	30	3	1750
3	40	4	2500

Sliding speed, load, and sliding distance are the composites' independent factors, while the response variable of composites were coefficient of friction and wear rate.

3.0 RESULTS AND DISCUSSION

The high wear resistive composite is evaluated using the Taguchi analyzer. The wear properties of A356/ Al₂O₃ are demonstrated by the signal to noise ratio results.

3.1 WEAR BEHAVIOR

a. A356+0 Wt.% Al₂O₃

Table 3: Results for percentage of wear test for A356 with 0Wt.% of Al₂O₃

SL.No.	Load(N)	Speed (m/s)	Distance(m)	COF	Wear loss
1	20	2	1000	0.3496	0.1095
2	20	3	1750	0.3205	0.1071
3	20	4	2500	0.3016	0.1069
4	30	2	1750	0.3214	0.1047
5	30	3	2500	0.3098	0.1025
6	30	4	1000	0.2961	0.1021
7	40	2	2500	0.2854	0.0942
8	40	3	1000	0.2713	0.0715
9	40	4	1750	0.2706	0.0706

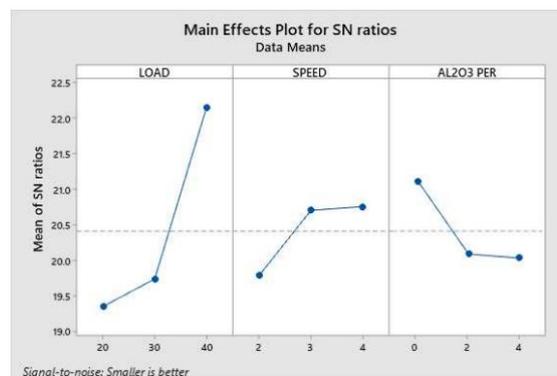
b. A356+2 Wt.% Al₂O₃**Table 4:** Results for percentage of wear test for A356 with 2Wt.% of Al₂O₃

SL.No.	Load (N)	Speed (m/s)	Distance (m)	COF	Wear loss
1	20	2	1000	0.34448	0.10438
2	20	3	1750	0.31538	0.10198
3	20	4	2500	0.29648	0.10178
4	30	2	1750	0.31628	0.09958
5	30	3	2500	0.30468	0.09738
6	30	4	1000	0.29098	0.09698
7	40	2	2500	0.28028	0.08908
8	40	3	1000	0.26618	0.06638
9	40	4	1750	0.26548	0.06548

c. A356+4 Wt.% Al₂O₃**Table 5:** Results for percentage of wear test for A356 with 4 Wt.% of Al₂O₃

SL. No.	Load(N)	Speed (m/s)	Distance (m)	COF	Wear loss
1	20	2	1000	0.34301	0.10291
2	20	3	1750	0.31391	0.10051
3	20	4	2500	0.29501	0.10031
4	30	2	1750	0.31481	0.09811
5	30	3	2500	0.30321	0.09591
6	30	4	1000	0.28951	0.09551
7	40	2	2500	0.27881	0.08761
8	40	3	1000	0.26471	0.06491
9	40	4	1750	0.26401	0.06401

Composites made from A356 and Al₂O₃ had a lower wear rate than base alloys. Figure 1 demonstrates that the lowest wear rate was 4 Wt% Al₂O₃ for a 1000 m sliding distance under various load situations.

**Figure 1:** Wear optimization of by constant sliding distance

A composite had an improved wear resistance as compared to base matrix. Fig 1 exhibits a high wear rate due to substantial plastic deformation of the unreinforced aluminium alloy that results from being softer than the Al₂O₃ reinforced composites.

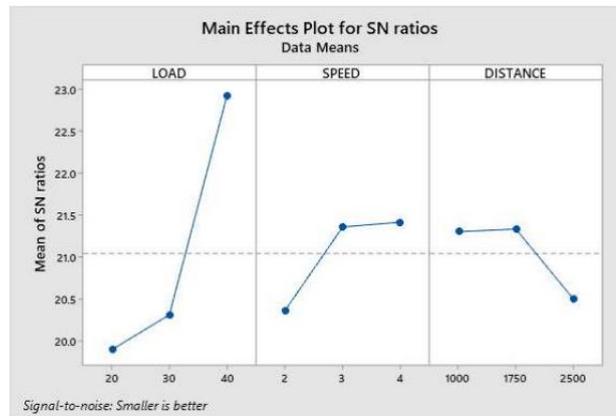


Figure 2a: Wear optimization of A356/ 0 wt% Al₂O₃ reinforcement Specimen

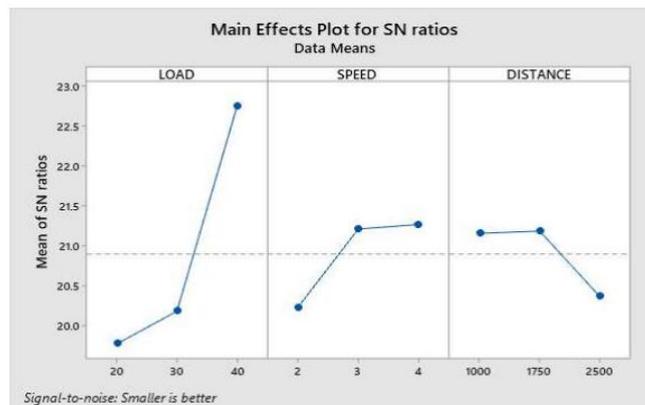


Figure 2b: Wear optimization of A356/ 2 wt% Al₂O₃ reinforcement Specimen

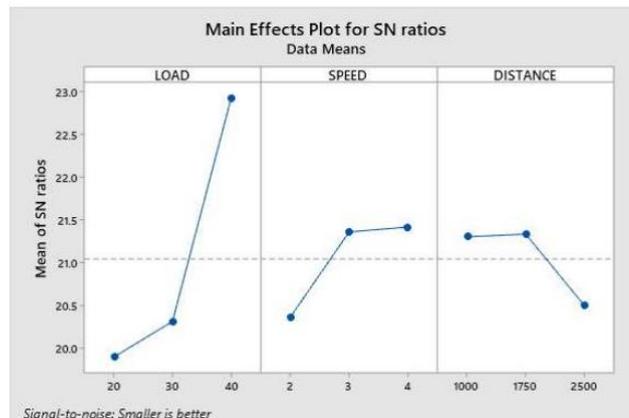


Figure 2c: Wear optimization of A356/4 wt% Al₂O₃ reinforcement Specimen

Figure 2a, 2b and 2c shows the wear loss Variation under Various Load Conditions also (a) A356/ 0 wt% Al₂O₃ (b) A356/ 2 wt% Al₂O₃ (c) A356/ 4 wt% Al₂O₃ composites. The base alloy has the highest wear mass loss, while Al₂O₃ composites with a 4-wt. percent Al₂O₃ content have the lowest wear mass loss. In response to higher temperatures, wear rates enhances because of applied load, and MML forms no longer. When the load is higher, huge uncertainties arise, preventing the development of a protective MML. In all load settings, the increasing applied load leads to the enhancement of wear rate, and the lowest had been found at 4 wt. percent Al₂O₃ composites. In the course of abrasive wear, the aluminium matrix has been protected by the particles of Al₂O₃ at the time of reinforcing Al matrix. In addition, this condition also holds for the case where the distance of sliding and the impact of applied load enhances, resulting in higher wear mass losses.

3.2 COEFFICIENT OF FRICTION

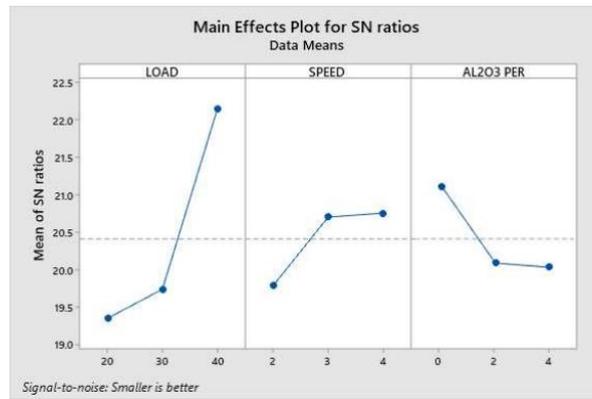


Figure 3: Coefficient of friction optimization of by constant sliding distance

COF varies as the Al₂O₃ wt percent enhances which is illustrated in fig 3. The friction coefficient varies with Al₂O₃ content in these samples which can be seen in fig. Friction coefficient decreases at 4 wt% Al₂O₃ as the weight percentage of Al₂O₃ increases. In addition to serving as the material's sliding surface, the Al₂O₃ particles act as a load on the composite's surface. In contrast to basic alloys, composite disc and pin materials have a lower COF. Increasing the applying load, sliding distance and sliding velocity lead to the same decreasing trend of coefficient friction.

4.0 CONCLUSIONS

Powder metallurgy has been successfully used to analyze the A356/ Al₂O₃ composites' properties of tribological as well as mechanical. With the inclusion of Al₂O₃ particles, the composites wear resistance improved. When compared to pure matrix material, the composites' wear rate is much lower. On the worn surface of composites the mechanically mixed layer (MML) serves a vital character in determining the composite's wear characteristics. A reduction in friction coefficient occurs when Al₂O₃ is added to the process. The composite is 100 percent Al₂O₃. Using these findings, A356/4 weight percent Al₂O₃ composite was developed for tribological applications.

REFERENCES:

- [1] Modi, O.P, Prasad, B.K. Yegnewaran, A.H., and Vaidya, M.L. 1992. Dry sliding wear behaviour of squeeze cast aluminium alloy silicon carbide composites. *Materials Science Engineering A*, 151, 235-44. [https://doi.org/10.1016/0921-5093\(92\)90212](https://doi.org/10.1016/0921-5093(92)90212).
- [2] Zhang, Z., Zhang, J., and Mai, Y.W., 1994. Wear behaviour of SiCp/Al-Si composites. *Wear*, 176; 231-7.
- [3] Toptan, F., Kilicarslan, A., and Kertil, I., 2010. The Effect of Ti Addition on the Properties of Al-B4C Interface: A Microstructural Study. *Materials Science Forum*, 636-637, 192-197. <https://doi.org/10.4028/www.scientific.net/MSF.636-637.192>.
- [4] Yang JB, Lin CB, Wang TC and Chu HJ "The tribological characteristics of A356.2Al alloy/Gr(p), composites *Wear*, 257, 941-952. DOI:10.1016/J.WEAR.2004.05.015.
- [5] Yilmaz and Butoz, "Abrasive wear of Al₂O₃-reinforced Aluminium-Based MMC's , *Composite science and technology*, 61, 2381-2392. DOI:10.1016/S0266-3538(01)00131-2.
- [6] Straffellini, G., Bonollo, F., Tiziani, A., 1997. Influence of matrix hardness on the sliding behaviour of 20 vol% Al₂O₃-particulate reinforced 6061 Al metal matrix composite. *Wear*, 211, 192-197. [https://doi.org/10.1016/S0043-1648\(97\)00119](https://doi.org/10.1016/S0043-1648(97)00119).
- [7] Ying Yu, Hitoshi Ishii, Keiichiro Tohgo, Young Tae Cho, Dongfeng Diao, 1997. Temperature dependence of sliding wear behavior in SiC whisker or SiC particulate reinforced 6061 aluminum alloy composite. *Wear*, 213, 21-28. [https://doi.org/10.1016/S0043-1648\(97\)00207](https://doi.org/10.1016/S0043-1648(97)00207).
- [8] How, H.C, Baker, T.N., 1997. Dry sliding wear behaviour of Saffil-reinforced AA6061 composites. *Wear*. 210, 263-272.
- [9] Hongya Xua, Fen Wangb, Jianfeng Zhub, Yuxing, Xie, 2011. Microstructure and Mechanical Properties of HoAl- Al₂O₃/Ti Al Composite, *Materials and Manufacturing Processes*, 26 (4), 559-561. <https://doi.org/10.1080/15394450902996585>.
- [10] Kim, S. W., Kim, D. Y., Kim, W. G., and Woo K. D. 2001. The study on characteristics of heat treatment of the
- [11] Direct squeeze cast 7075 wrought Al alloy. *Materials Science and Engineering A*, 304-306, 721-726. DOI:10.1016/S0921-5093(00)01594-X.
- [12] Han, N. L., Wang, Z. G., and Sun, L. Z., 1995. Low Cycle Fatigue Behaviour of SiCp Reinforced Aluminium Matrix Composite at Ambient and Elevated Temperature, *Scr. Metall. Mater.*, 32, 11, 1739-1745. [HTTPS://DOI.ORG/10.1016/0956-716X\(95\)00006](https://doi.org/10.1016/0956-716X(95)00006).

- [13] Caracostas, C. A., Chiou, W. A., Fine, M. E., and Cheng, H. S., 1997. Tribological Properties of Aluminium Alloy Matrix TiB₂ Composite Prepared by In-Situ Processing. *Metall. Mater. Trans. A*, 28A, 491-502. DOI:10.1007/S11661-997-0150-2.
- [14] Boq-Kong, H., Su-Jien, L., and Min-Ten, J., 1996. The Interfacial Compounds and SEM Fractography of Squeeze-Cast SiCp/6061 Al Composites. *Mater. Sci. Eng., A*, 206, 110-119. DOI:10.1016/0921-5093(95)09979-4.
- [15] Hashim, J., Looney, L., and Hashmi, M. S. J., 1999. Metal Matrix Composites: Production by the Stir Casting Method. *J. Mater. Process. Technol.*, 92-93, 1-7. [HTTPS://DOI.ORG/10.1016/S0924-0136\(99\)00118](https://doi.org/10.1016/S0924-0136(99)00118).
- [16] Radhika, N., Subramanian, R., and Venkat Prasad, S., 2011. Tribological Behaviour of Aluminium/Alumina/Graphite Hybrid Metal Techniques, *Journal of Minerals & Materials Characterization & Engineering*, 10, 5, 427-443. DOI:10.1108/00368791311311169.
- [17] Ross, P. J., 1996. *Taguchi Techniques for Quality Engineering*, 2nd Edition, McGraw-Hill Book Co., New York, 23-42.
- [18] Siddhartha, Patnaik, A., and Bhatt, A. D., 2011. Mechanical and Dry Sliding Wear Characterization of Epoxy-TiO₂ Particulate Filled Functionally Graded Composite Materials Using Taguchi Design of Experiment, *Material & Design*, 32 (2), 615-627. [HTTPS://DOI.ORG/10.1016/J.MATDES.2010.08.011](https://doi.org/10.1016/j.matdes.2010.08.011).
- [19] Basavarajappa, S., Chandramohan, G., Mahadevan, A., Thangavelu, M., Subramanian, R., and Gopalakrishnan, P., 2007. Influence of sliding speed on the dry sliding wear behaviour and the subsurface deformation on hybrid metal matrix composite. *Wear* 262(7/8), 1007-1012. [HTTPS://DOI.ORG/10.1016/J.WEAR.2006.10.016](https://doi.org/10.1016/j.wear.2006.10.016).
- [20] Doel, T.J.A., and Bowen P., 1996. Tensile Properties of Particulate-reinforced metal matrix composites, 655-665, [HTTPS://DOI.ORG/10.1016/1359-835X\(96\)00040-1](https://doi.org/10.1016/1359-835X(96)00040-1).
- [21] Song, J.J., Bong, H.D., Han, K.S., 1995. Characterization of mechanical and wear properties of Al/Al₂O₃/C hybrid metal matrix composites. *Scripta Metall Mater*, 33, 1307-1313. [https://doi.org/10.1016/0956-716X\(95\)00359-4](https://doi.org/10.1016/0956-716X(95)00359-4)

ACKNOWLEDGMENT

I thank department of mechanical engineering BMS College of Engineering and Vemana Institute of Technology for their kind support and motivation in completing this work.