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INVESTIGATION OF ADHESIVE WEAR BEHAVIOUR OF ZIRCONIA REINFORCED ALUMINIUM METAL MATRIX COMPOSITE

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Abstract

Aluminium alloy reinforced with zirconia (10 wt%) was fabricated using stir casting technique and specimens with diameter 20 mm and 100 mm length were obtained. The adhesive wear test was done on the fabricated specimens using a pin-on-disc tribometer. Taguchi's method was used for designing the number of experiments and L_{27} orthogonal array was developed for analysis of wear rate. Optimisation of parameters like applied load (15 N, 25 N, 35 N), sliding distance (500 m, 1250 m, 2000 m) and sliding velocity (1.5 m/s, 2.5 m/s, 3.5 m/s) was done using Signal-to-Noise ratio analysis and Analysis of Variance. "Smaller the better" criteria was considered as objective model to analyse the wear resistance of the composite. Results revealed that applied load (73.83%) has major influence on wear behaviour followed by sliding distance (10.08%) and sliding velocity (8.25%). Scanning Electron Microscope analysis was done on the worn surfaces of the composite specimens and severe delamination was observed at high load condition.

Keywords**:** Metal matrix composite, Reinforcement, Taguchi method, Analysis of variance, Orthogonal array.

1. Introduction

The requirement for light weight, affordable and appreciable energy performance materials led to the development of cast aluminium matrix composites containing hard ceramic dispersions [1].The better mechanical and wear resistive properties of aluminium-silicon alloys accelerated their use in engineering applications, especially in automotive and aeronautical sectors [2]. Considerable applications of these composites are found in engine components like piston and cylindrical

Nomenclatures

Adj SS	Adjacent sum of squares
Adj MS	Adjacent mean of squares
DF	Degree of freedom
D	Sliding distance, m
F	Fisher's test
M	Mass loss due to adhesion, g
Seq SS	Sequential sum of squares
W	Wear rate, mm^3/m
ρ	Density, g/mm^3

Abbreviations

ANOVA	Analysis of Variance
DOE	Design of Experiments
MMCs	Metal Matrix Composites
SEM	Scanning Electron Microscopy

heads that are used for tribological requirements [3]. The wear performance of MMCs with ceramic reinforcement shows better result compared to unreinforced aluminium alloys. The major disadvantage is high cost involved in fabrication of MMCs which indirectly affected the use in various actual applications [4]. MMCs are fabricated using many techniques such as stir casting, powder metallurgy, squeeze casting, spray casting and pressure less metal infiltration techniques. Among these techniques, stir casting is most widely used technique to fabricate MMCs due to the attainment of uniform distribution of reinforcement, good wettability between substances and low porosities [5].

Generally metals with low density are chosen as matrix material for MMCs fabrication and metals such as aluminium, titanium and magnesium are preferable for recent research [6]. In order to improve the properties of matrix, hard reinforcements like alumina (Al_2O_3), silicon carbide (SiC), boron carbide (B_4C), titanium carbide (TiC), etc., in the form of particles or fibres are widely used in aluminium MMCs [7].The serious problem faced now a days is to withstand the wear, particularly adhesive wear leading to frequent replacement of components [8]. High wear resistance of the particulate reinforced aluminium composite is because of presence of hard ceramic particle that protects the matrix from wear [9, 10]. Effect of varying Al_2O_3 particle content (10, 20 and 30 wt%) and varying Al_2O_3 particle size (16, 32 and 64 µm) on mechanical properties of 2024 aluminium composite is studied, results show that hardness and tensile strength of the composites increases with decreasing Al_2O_3 particle size and with increase in weight fraction of Al_2O_3 particles [11].

Mechanical and tribological behaviour on in-situ composite of Al-7wt% Si reinforced with different wt % (0, 5 and 10) of TiB_2 particle (size 36 µm) synthesized by salt reaction route is researched and found that hardness, tensile strength and wear resistance of the composite increases with increasing TiB_2 content [12]. Tribological behaviour of LM13 Al alloy reinforced with varying wt% (0, 4, 8 and 12) of B_4C particles (33 µm) fabricated by stir casting route is investigated and result shows that wear resistance of the composites increases with increase in fraction of B_4C particles [13]. An investigation on dry sliding wear behavior of Al 6061/Beryl (60-75 µm) composite with four different wt % (2, 6, 10 and 15) of Beryl, synthesized by stir casting process is carried out. Results reveal that wear resistance of composite increases with varying wt% of Beryl particles and it also found that the wear resistance of the composite is maximum at 10 wt% of beryl [14].

The wear parameters are considered to be the major factor controlling performance. Several researchers studied about the interaction between load, sliding velocity and sliding distance on the wear resistance of a material [15]. DOE is done using Taguchi's method developed by Taguchi and Konishi. The purpose of DOE is to find the impact of parameters and their interactions on the response by performing a minimum number of experiments [16].Impact of various parameters on the tribological behaviour of the MMCs is found by Taguchi DOE. In the present scenario, most of the engineers choose this method to optimise the effect of parameters on the engineering problems [17]. Effect of parameters such as applied normal load, sliding distance and sliding velocity on the adhesive wear behaviour of aluminium alloy reinforced with aluminium diboride (AlB_2) particles is analysed by using an orthogonal array and found that velocity (57%) is the dominant parameter on wear behaviour followed by load (23%) and distance (6%) [18].

Many researchers have fabricated MMCs with different aluminium alloys and with various reinforcements such as SiC, Al_2O_3 and B_4C. Research done with aluminium-silicon alloy with zirconia reinforcement is still in the starting era. Hence an attempt is made to fabricate LM25/zirconia MMC and analyse the tribological characteristics.

2. Method and Methodology

2.1. Material selection

Aluminium LM25 alloy having density 2.68 gm/cm^3 is selected because of novel properties like good machinability, light weight and high wear resistance. The addition of zirconia as reinforcement in pure aluminium matrix fabricated by powder metallurgy technique enhances hardness and wear resistance characteristics [19]. So, in order to increase the wear resistance of LM25alloy, zirconia (10 wt%, 50 µm) with density of 5.68 gm/cm^3 is selected as reinforcement. It possesses other physical properties like low thermal expansion (2.3×10^{-6}/K), higher melting point (2,715 °C) and lower thermal conductivity (2.7 W/m. K). It also shows high resistance to sudden volume changes at elevated temperatures compared to other reinforcements like SiC, Al_2O_3, B_4C and TiC. Also properties like resistance to abrasion, impact and chemical attack found interest in the research. Elemental composition of Al LM25 alloy is listed in Table 1.

Table 1. Elemental composition of Al LM25 alloy.

Chemical Composition	Al	Si	Mg	Cu	Fe	Mn	Zn
wt %	91.6	7.33	0.38	0.10	0.43	0.09	0.07

2.2. Synthesis of material

Fabrication of MMC is carried out by using stir casting method as this casting technique is a promising technique in obtaining homogeneity and isotropic property in the composite. Aluminium LM25 alloy is initially taken in a graphite crucible and melted at 750 ℃ in an inert argon gas environment to prevent unwanted chemical reaction. Preheated zirconia (400 ℃) particles are added as reinforcement to the molten metal and stirred at 300 rpm for 5 min to get proper distribution of reinforcement in the matrix. The composite material thus fabricated is poured in the mould and casting is obtained with diameter 20 mm and 100 mm length.

2.3. Microstructural evaluation

The composite specimens are polished for microstructural evaluation [20]. The surface is initially polished using grade 1/0 emery sheet followed by grade 2/0 emery sheet. It is then further polished using a velvet cloth and dipped in liquid alumina for smooth finishing. The surface is then etched using Keller's reagent. Microstructure is observed using Zeiss Axiovert 25 CA Inverted Metallurgical Microscope. Microstructural observation is done on aluminium composite surface to observe the zirconia reinforcement distribution in the aluminium matrix.

2.4. Taguchi plan of experiments

Effect of wear process parameters like applied load, sliding velocity and sliding distance on the cast Al LM25/zirconia MMC is analysed using Taguchi DOE. The parameters and the corresponding levels are mentioned in Table 2.Wear is a phenomenon occurs by relative motion of surfaces which contributes to friction and temperature at the surface. These two factors are imitated by the parameters load, sliding velocity and sliding distance. High friction at the surface can bring out the material's capability at high temperature due to which the maximum value of load 35N and sliding velocity 3.5 m/s were selected. To evaluate the durability of the material, sliding distance of maximum 2000 m was chosen.

Table 2. Parameters and their levels.

Level	Applied load, N	Sliding velocity, m/s	Sliding distance, m
1	15	1.5	500
2	25	2.5	1250
3	35	3.5	2000

2.5. Adhesive wear test

Adhesive wear behaviour is a common phenomenon in automotive applications and is found between mating surfaces during frictional contact. The wear test is performed on the composite specimens (12 mm diameter, 35 mm length) in the order according to L_{27} orthogonal array using a DUCOM (TR-20LE-PHM 200) pin-on- disc tribometer. It consists of a horizontal rotating EN31 hardened steel disc (65 HRC) and a dead load pan. A Group of weights connecting the fulcrum through the beam provides normal force on the pin (composite specimen). The rotating speed of the disc is controlled so that constant contact is provided at various test parameters. The weight of the specimen before and after conducting the test is measured using an electronic weighing machine with an accuracy of 0.1 mg. The wear rate is calculated using mass loss equation.

$$W = \frac{M}{\rho D} \tag{1}$$

Where W is wear rate in mm^3/m, M is mass loss in g, ρ is density in g/mm^3, D is sliding distance in m.

3. Results and Discussion

The purpose of experiment is to figure out the effect of different parameters on the adhesive wear characteristics to achieve minimum wear rate. The experiments are formulated according to the orthogonal array in order to relate the influence of the parameters on the adhesive wear behaviour. The microstructural results, adhesive wear characteristics, S/N ratio analysis of worn specimens of aluminium MMC are discussed in the following subsections.

3.1. Microstructural analysis

The microstructural analysis of Al LM25/zirconia composite and SEM image of powdered zirconia reinforcement are shown in Figs. 1 and 2 respectively. From the microstructural analysis (Fig. 1), it is observed that grey region represents LM25 aluminium matrix and white region represents zirconia particles and these particles are uniformly distributed in the aluminium matrix. It also reveals good interfacial bonding between matrix and reinforcement particles.

The JEOL-JSM 6390 Scanning Electron Microscope is used to observe the subangular shape of zirconia reinforcements (Fig. 2) at the magnification of 50X.

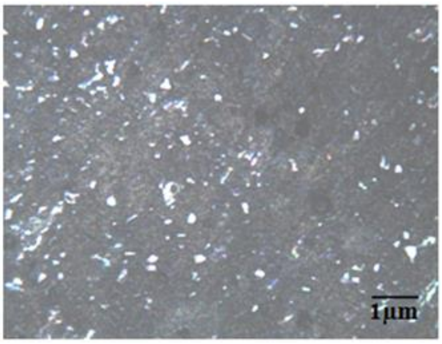

Fig. 1. Microstructural analysis of Al LM25/zirconia composite.

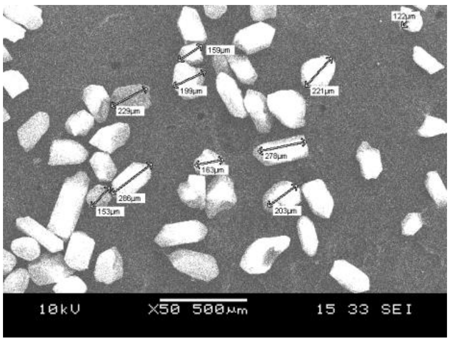

Fig. 2. SEM image of zirconia reinforcement.

3.2. Adhesive wear characteristics

The adhesive wear rate of the aluminium MMC is calculated for different combinations of wear parameters as per the L_{27} orthogonal array. The wear rate values to the corresponding combinations are listed in the TableA1 (*Appendix A*).

3.3. Signal-to-noise ratio analysis

In Taguchi's method, S/N ratio is used to rank the parameters considering their influence. Ranking is done based on the "smaller-the-better" criteria using Minitab. Response table is the response created by Minitab based on the parameters given for analysis and it is shown in Table3. The delta value is the difference between the highest and lowest values of the specific parameter. Ranking is done based on the delta value; highest delta value is ranked as one. From S/N analysis, it is observed that the delta value of applied load is 2.64 which is higher than that of sliding distance (0.8) and sliding velocity (0.77). Hence it is concluded that load is the most influential parameter on wear rate.

Table 3. Respone table for S/N ratio.

Level	Applied load, N	Sliding velocity, m/s	Sliding distance, m
1	51.95	50.49	50.37
2	51.35	50.80	50.99
3	49.32	51.26	51.77
Delta	2.64	0.77	0.80
Rank	1	3	2

3.4. Influence of parameters on the response

S/N ratios and Mean plot for the wear rate are shown in Figs. 3 and 4 respectively. S/N ratio plot gives the optimum value of the parameter for improving the adhesive wear behaviour whereas mean plot describes the trend of responses for the three parameters. From Fig. 3 it is inferred that, low applied load (15 N), high velocity (3.5 m/s) and sliding distance (2000 m) as optimum conditions for enhancing the adhesive wear properties. The impact of applied load, sliding velocity and sliding distance on the wear characteristics are discussed as follows.

3.4.1. Influence of applied load on wear behaviour

Figure 4a explains the trend followed by the applied load on wear behaviour. The wear process of material removal in aluminium composite is by plastic deformation and gouging [21]. It is observed that the wear rate increases with the increase in the applied load (15 N, 25 N and 35 N) almost in linear proportion. This trend in the plot is due to the increase in contact pressure between the composite specimen and disc that causes greater surface damage. When applied load varies from 15 N to 25 N, the wear is caused because of rubbing action between the disc and composite specimen, whereas severe wear phenomenon is caused due to adhesion when applied normal load increases from 25 N to 35 N and similar phenomenon is observed [22]. Though the wear rate increases as load increases, there is a delay in transition of wear rate. The presence of Si (7.33 wt %) content in LM25 Al matrix has more affinity towards Mg (0.38%) and due to which an intermetallic compound (Mg_2Si) is formed during solidification stage which contributed to increase strength and hardness of alloy which in turn enhances wear resistance of the composite, similar behaviour is observed [23, 24].

3.4.2. Influence of sliding velocity on wear behaviour

From Fig. 4b it is observed that wear rate decreases with increase in sliding velocity from 1.5 m/s to 3.5 m/s. As the sliding velocity of the disc increases from

1.5 m/s to 2.5 m/s, the reinforcement particles crushes and forms a thin sub layer which is called as mechanically mixed layer and provides protection to matrix. So the layer thus formed withstands high stress and reduces the sliding wear as the sliding velocity increases to 3.5 m/s [25].

3.4.3. Influence of sliding distance on wear behaviour

From Fig. 4c it is inferred that the wear rate decreases with increase in sliding distance. The negative slope shows an indirect relation between the sliding distance and wear rate. Wear rate decreased to a larger extent from 500 m to 1250 m. This trend is due to presence of the zirconia reinforcements which projects out of the composite surface are sharp and decreases the contact surface area between two sliding surfaces and reduces the wear rate. With further increase in the sliding distance (2000 m), the projections of reinforcements becomes blunt and reduces the contact area between the composite specimen and disc and this reduces the wear rate to much lower value [26].

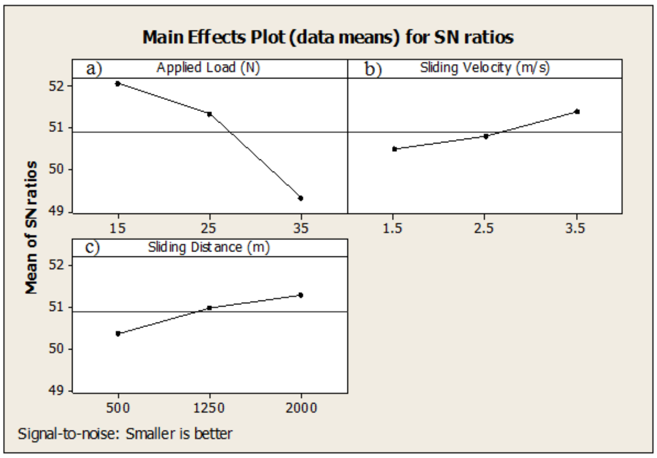

Fig. 3. Main effect plot (data means) for S/N ratio.

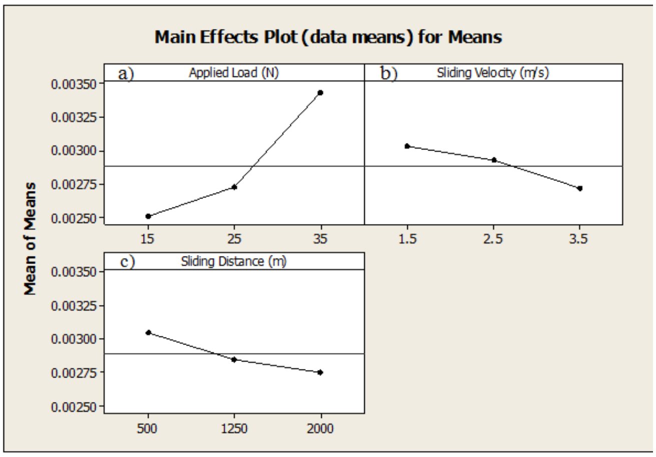

Fig. 4. Main effect plot (data means) for means.

3.5. Analysis of Variance

The main purpose of conducting ANOVA on wear results is to find out the percentage influence of each parameter on the wear characteristics. It gives the individual effect as well as the combined effect of parameter on the adhesive wear mechanism. The impact of parameters like applied load, sliding velocity and sliding distance on the wear rate are analysed using ANOVA .It is conducted for a significance level of 5% and the major impact of the parameter is obtained from the 'p' value less than 0.05.Percentage contribution of influence of parameter is shown in the last column of ANOVA table for wear rate (Table4). From the results, it is concluded that applied load (73.83%) has major impact on wear rate followed by sliding distance (10.08%) and sliding velocity (8.25%).In the interactions, applied load with sliding velocity shows less impact (2.62) followed by applied load with sliding distance (1.47).Hence applied load shows significant influence on wear properties.

Table4. Analysis of variance results.

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Percentage (%)
Applied load	2	32.2274	34.1290	17.0645	236.07	0.000	73.83
Sliding velocity	2	3.6044	4.0613	2.0306	28.09	0.000	8.25
Sliding Distance	2	4.4028	4.4019	2.2009	30.45	0.000	10.08
Applied load*Sliding velocity	4	1.1471	0.8972	0.2243	3.10	0.091	2.62
Applied load * sliding distance	4	0.6491	0.7005	0.1751	2.42	0.145	1.47
Sliding velocity * sliding distance	4	0.1128	0.1128	0.0282	0.39	0.810	0.25
Residual error	7	0.5060	0.5060	0.0723			1.15
Total	25	43.6496					

3.6. Scanning Electron Microscope Analysis

SEM Analysis is conducted on the worn composite specimens to observe the wear behaviour. As the applied load has greater impact on the wear mechanism, SEM is conducted for different load conditions at a constant sliding velocity of 3.5 m/s and for a sliding distance of 2000 m and is shown in Figs. 5 (a) to (c). From Fig. 5(a) at low load (15 N) a minimal amount of material removal is observed on composite specimen. SEM for 25 N, Fig. 5(b), shows that the scratches on the worn specimens are due to sliding friction between two surfaces. As the load increases to 35 N (Fig.5c), the wear phenomena is accelerated and depth of the grooves on the surface are observedcompared to that in the low load 15 N. These images reveal that the transformation of wear from mild to severe takes place as the applied load is increases from 15 N to 35 N.

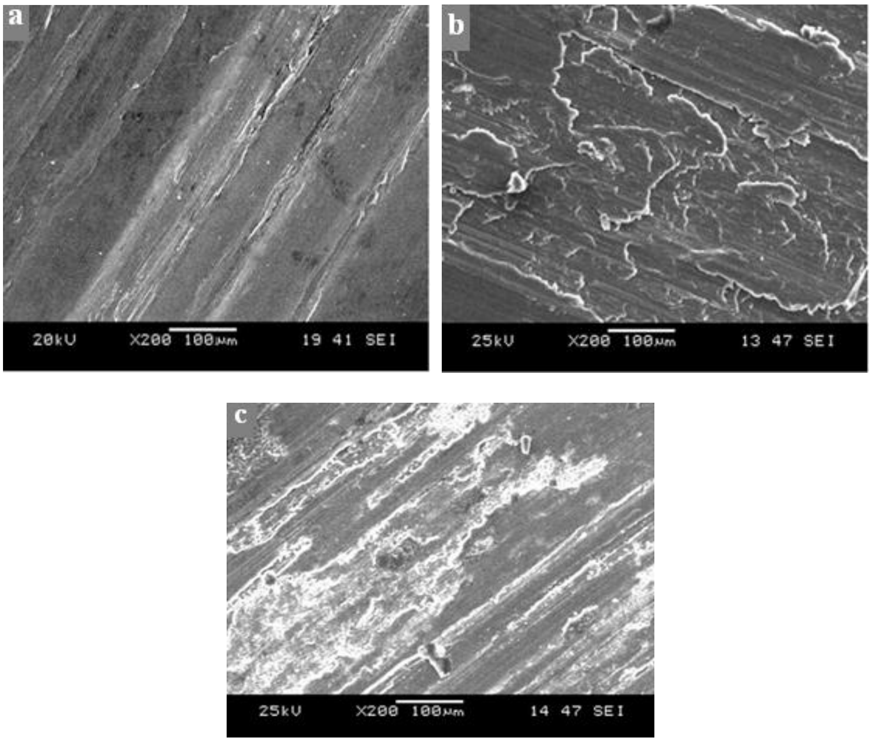

Fig. 5. SEM analysis of worn specimens at various loads (a) 15 N (b) 25 N (c) 35 N.

4. Conclusion

Al LM25/zirconia (10 wt. %) composite was fabricated successfully using stir casting technique. It was found that wear rate has direct variation with applied load and inverse variation with sliding distance and sliding velocity. From the ANOVA, it was concluded that applied load (73.83%) has major impact on wear characteristics followed by sliding distance (10.08%) and sliding velocity (8.25%).Optimum conditions for enhancing the adhesive wear characteristics were obtained as a low lad of 15 N with a sliding velocity of 3.5 m/s and a sliding distance of 2000 m. SEM analysis shows that severe wear behaviour was observed at high load condition (35N).The present research on the adhesive wear behaviour of LM25/zirconia MMC can be used for applications in automotive engine components such as piston, cylinder liner and connecting rod, where wear resistance is of major consideration.

References

1. Meena, K.L.; Manna, A.; Banwait, S.S.; and Jaswanti. (2013). An analysis of mechanical properties of the developed Al/SiC-MMC's. *American Journal of Mechanical Engineering*, 1(1), 14-19.
2. Al-Rubaie, K.S.; Yoshimura, H.N.; and De Mello, J.D.B. (1994). Two-body abrasive wear of Al–SiC composites. *Wear*, 233-255, 444-454.

3. Sahin, Y.; and Ozdin, K. (2008). A model for the abrasive wear behaviour of aluminium based composites. *Materials and Design*, 29(3), 728-733.
4. Reddy, B.S.B.; Das, K.; and Das, S. (2007). A review on the synthesis of in situ aluminum based composites by thermal, mechanical and mechanical–thermal activation of chemical reactions. *Journal of Materials Science*, 42(22), 9366-9378.
5. Hashim, J.; Looney, L.; and Hashmi, M.S.J. (1999). Metal matrix composites: Production by the stir casting method. *Journal of Materials Processing Technology*, 92-93, 1-7.
6. Das, S.; Udhayabanu, V.; and Das, K. (2006). Synthesis and characterization of zircon sand/Al–4.5 wt.% Cu composite produced by stir casting route. *Journal of Material Science*, 41(14), 4668-4677.
7. Bodunrin, M.O.; Alaneme, K.K.; and Chown, L.H. (2015). Aluminium matrix hybrid composites: A review of reinforcement philosophies; mechanical, corrosion and tribological characteristics. *Journal of Materials Research and Technology*, 4(4), 434-445.
8. Pirkle, F.L.; and Podmeyer, D.A. (1993). Zircon: origin and uses. *Transactions*, 292, 1-21.
9. Venkataraman, B.; and Sundararajan, G. (2005). Correlation between the characteristics of the mechanically mixed layer and wear behaviour of aluminium, Al-7075 alloy and Al-MMCs. *Wear*, 245(1-2), 22-38.
10. Das, S. (2004). Development of aluminium alloy composites for engineering applications. *Transactions of the Indian Institute of Metals*, 57(4), 325-334.
11. Kok, M. (2005). Production and mechanical properties of Al_2O_3 particle-reinforced 2024 aluminium alloy composites. *Journal of Materials Processing Technology*, 161(3), 381-387.
12. Kumar, S.; Chakraborty, M.; Sarma, V.S.; and Murty, B.S. (2008). Tensile and wear behaviour of in situ Al–7Si/TiB_2 particulate composites. *Wear*, 265(1), 134-142.
13. Radhika, N.; and Raghu, R. (2015). Evaluation of dry sliding wear characteristics of LM 13 Al/B_4C composites. *Tribology in Industry*, 37(1), 20-28.
14. Reddappa, H.N.; Suresh, K.R.; Niranjan, H.B.; and Satyanarayana, K.G. (2010). Dry sliding friction and wear behavior of Aluminum/Beryl composites. *International Journal of Applied Engineering Research, Dindigul*, 2(2), 502-511.
15. Singh, M.; Mondal, D.P.; and Das, S. (2006). Abrasive wear response of aluminium alloy–sillimanite particle reinforced composite under low stress condition. *Material Science and Engineering*, 419(1-2), 59–68.
16. Zhang, Z.; and Zhang, F. (1994). Modelling friction and wear of scratching ceramic particle reinforced metal composites. *Wear*, 176(2), 231-237.
17. Karabulut, S. (2015). Optimization of surface roughness and cutting force during AA7039/Al_2O_3 metal matrix composites milling using neural networks and Taguchi method. *Measurement*, 66, 139–149.

18. Arunagiri, K.S.; and Radhika, N. (2016). Studies on adhesive wear characteristics of heat treated aluminium LM25/AlB_2 composites. *Tribology in Industry*, 38(3), 277-285.
19. Ramachandra, M.; Abhishek, A.; Siddeshwar, P.; and Bharathi, V. (2015). Hardness and wear resistance of ZrO_2 nano particle reinforced Al nano composites produced by powder metallurgy. *Procedia Materials Science*, 10, 212-219.
20. Radhika, N.; and Raghu, R. (2016). Development of functionally graded aluminium composites using centrifugal casting and influence of reinforcements on mechanical and wear properties. *Transactions of Nonferrous Metals Society of China*, 26(4), 905-916.
21. Bai, M.; Xue, Q.; Wang, X.; Wan, Y.; and Liu, W. (1995). Wear mechanism of SiC whisker-reinforced 2024 aluminum alloy matrix composites in oscillating sliding wear tests. *Wear*, 185(1), 197-202.
22. Radhika, N.; Vaishnavi, A.; and Chandran, G.K. (2014). Optimisation of dry sliding wear process parameters for aluminium hybrid metal matrix composites. *Tribology in Industry*, 36(2), 188-194.
23. Hiteshkumar, P.; and Jyoti, M. (2012). Wear characteristics of unalloyed and alloyed LM25-aluminium casting. *Journal of Metallurgy and Materials Science*, 54(2), 131-135.
24. Cruz, K.S.; Meza, E.S.; Fernandes, F.A.; Quaresma, J.M.; Casteletti, L. C.; and Garcia, A. (2010). Dendritic arm spacing affecting mechanical properties and wear behavior of Al-Sn and Al-Si alloys directionally solidified under unsteady-state conditions. *Metallurgical and Materials Transactions A*, 41(4), 972-984.
25. Deuis.; Subramanian, R.L.; and Yellup. (1997). Dry sliding wear of aluminium composites- A review. *Composite Science and Technology*, 57(4), 415-435.
26. Zhang, L.; He, X.B.; Qu, X.H.; Duan, B.H.; Lu, X.; and Qin, M.L. (2008). Dry sliding wear properties of high volume fraction SiCp/Cu composites produced by pressure less infiltration. *Wear*, 265(11-12), 1848–1856.

Appendix A

Table A-1. Experimental conditions and wear results

S. No.	Applied Load (N)	Sliding Velocity (m/s)	Sliding Distance (m)	Wear rate (mm^3/m)
1	15	1.5	500	0.00294
2	15	1.5	1250	0.00251
3	15	1.5	2000	0.00230
4	15	2.5	500	0.00271
5	15	2.5	1250	0.00249
6	15	2.5	2000	0.00234
7	15	3.5	500	0.00254
8	15	3.5	1250	0.00243
9	15	3.5	2000	0.00231
10	25	1.5	500	0.00297
11	25	1.5	1250	0.00274
12	25	1.5	2000	0.00281
13	25	2.5	500	0.00285
14	25	2.5	1250	0.00263
15	25	2.5	2000	0.00259
16	25	3.5	500	0.00279
17	25	3.5	1250	0.00260
18	25	3.5	2000	0.00251
19	35	1.5	500	0.00379
20	35	1.5	1250	0.00368
21	35	1.5	2000	0.00353
22	35	2.5	500	0.00369
23	35	2.5	1250	0.00358
24	35	2.5	2000	0.00341
25	35	3.5	500	0.00321
26	35	3.5	1250	0.00302
27	35	3.5	2000	0.00299