SSRG International Journal of Mechanical Engineering
ISSN: 2348 – 8360 /doi:10.14445/23488360/IJME-V5I10P105

Volume 5 Issue 10, 22-25, October 2018

A Study on Dry Sliding Wear Behavior of Metal Matrix Composites using Taguchi Technique

B. P. Darshan[1], G. S. Shivashankar[2], B. Lathashankar[3],
[1,2]*Department of Mechanical Engineering, Siddaganga Institute of Technology, Tumkur-572103, Karnataka, India.*
[3]*Department of Industrial Engineering and Management, Siddaganga Institute of Technology, Tumkur-572103, Karnataka, India.*

Abstract
In today's industrial scenario, the use of Metal Matrix composites for tribological applications has been increasing. In this regard, a study on MMC's was carried out. The tribological behavior of MMC's, including different types and amounts of filler materials, were examined. Effects of operating parameters such as Load, Speed and Sliding distance on MMC's tribological performance were studied. Wear tests were performed on a pin-on-disc setup using a plan of experiments based on Taguchi's technique. Analysis of variance has been carried out to establish the relative significance of wear performance factors. An empirical relation between wear and operating parameters were established for all composite materials using linear regression analysis. The Load, Speed and sliding distance duration plays an important role in MMC's tribological performance. It was observed that MMC's reinforced with Nano MgO, B_4C, and MoS_2 could effectively improve the tribological performance.

Keywords-*MMC, Tribology, Load, Speed, Sliding distance, Wear test.*

I. INTRODUCTION

Many modern technologies require materials with an unusual combination of properties that cannot be met by conventional materials. This is especially in materials for aerospace, automotive and space applications. The materials available for engineers include metal, ceramic and plastic. The use of composite materials, a combination of two and more metals, ceramics and polymers, is another class of materials that increases rapidly. Composite materials are likely to provide engineers with materials that are impossible to obtain in conventional materials.

A composite material consists of two or more constituent materials with significantly different physical or chemical properties, which, when combined, produce a material with different characteristics from the individual components. The physical properties of composite materials are non-isotropic (regardless of the application directionforce) in nature. Still, they are typically anisotropic (different depending on the direction of applied force or load). The compounds are appreciated for their lightness, high resistance, corrosion resistance, design flexibility, low thermal conductivity and non-conductivity, non-magnetic, durable. In composite materials, engineers and scientists combined various metals, ceramics and polymers to produce a new generation of high-performance materials. Most of the composite materials have been created to improve the combination of mechanical properties such as hardness, rigidity, toughness and resistance to room temperature and high temperature. Many composite materials are composed of only two phases; one makes a phase of the "matrix," which is continuous and surrounds the other phase called "reinforcement." The composite materials' properties depend on the type of reinforcement; its quantities, the orientation, and the geometry of the reinforcement. The MMCs are made with high strength to weight ratio, creep resistance, high resistance to abrasion and corrosion, good dimensional stability and high-temperature operability. Commonly, aluminum is used as a metal matrix

II. TAGUCHI TECHNIQUE

Taguchi's experimental design method is a simple, efficient and systematic approach to optimizing the experiment's design. It is considered better than the traditional design of experiments, which reduces the number of tests, times and costs. A series of the standard orthogonal matrix (OA) is used for many other experimental situations, and therefore the results of the experiments are analyzed. The selection of OA depends on the number of parameters, their levels of operation and interaction. The number of columns in a matrix indicates the maximum number of parameters, and the number of rows indicates the number of tests that will be performed.The experimental values are analyzed using the variance analysis to identify the influence of each parameter on the response.

III. EXPERIMENTAL DETAILS

Table 1.Material Composition of MMC's

Combination	MgO (%)	B_4C (%)	MoS_2 (%)
M1	3	0	3
M2	3	3	3

A. *Material Details*

To improve the performance of pure MMCs, Nano MgO, B_4C, and MoS_2 have been selected as fillers. The compositions of all these materials are listed in Table 1. All these materials were available in the form of bars from which small samples were cut. The samples were cut into a cylindrical pin with a diameter of 10 mm and a length of 30 mm.

B. *Test Set-Up and Wear Runs*

Tribological tests were performed using the Pin-On-Disc machine according to ASTM G99-95. The Pin-On-Disc test setting is commonly used to evaluate tribological properties in laboratories. A pin was used in the disk unit (Figure 1) to perform dry sliding wear tests. The samples were worked in the form of a pin. The height and diameter of the samples were 30 mm and 10 mm, respectively. The steel disc (class EN 31) of 120 mm diameter was used as a surface. The chemical composition (% by weight) of the steel disk was as follows: C: 0.15%, Mn: 0.8%, Si: 0.26%, S and P: 0.04%. The tensile strength, hardness and roughness of the disc surface were 430 MPa, 62 HRc and 1.6 Ra.

All wear tests were performed without lubrication. The ASTM G 99-05 standard was followed for dry sliding wear tests. After each analysis, the samples were cleaned with ultrasonic acetone, dried and weighed in a digital balance (METTLER, precision: 0.01 mg). The specific wear rate (mm3 Nm-1) of the compounds was calculated by taking the ratio between the mass loss (g) and the density (g mm-3), the applied load (N) and the sliding distance (m)). The morphology of the composite material's wear surface is characterized with the help of SEM with energy dispersive spectroscopy (EDS) (GEMINI ULTRA 55) to understand the possible mechanisms operating at different speeds and load conditions.

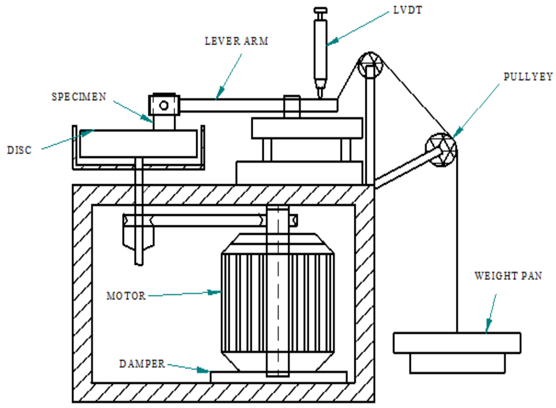

Fig.1. Pin-On -Disc set up.

The initial weight of each composite sample was measured using an electronic scale. During the test, the pin sample was pressed against the rotating disk by applying the load. Wear tests were performed under various levels of process parameters. After each experiment, the samples were weighed to determine the wear rate in terms of weight loss. The wear tests were performed with variable sliding speed, pressure and duration of the test. The levels of the process parameters are shown in Table 2. The experiments were performed according to the orthogonal L9 matrix.

Table 2: Level of operating parameters

Factors / Levels	Speed (rpm)	Load (kg)	Distance (m)
1	200	3	500
2	300	5	1000
3	400	7	1500

IV. RESULTS AND DISCUSSION

The experiments were conducted to know the influence of the operating parameters such as load, speed and sliding distance under dry running conditions. Table 3 shows the results of all composite materials.

A. *Signal-to-Noise ratio*

In response to a factor introduced in the experimental design, the change in the quality characteristics of a product under investigation is a "signal" of the desired effect. However, when experimenting, numerous external factors are not designed in experiments that influence the result (response). These external factors are called noise factors, and their effect on the test result is called "noise." The signal-to-noise ratio measures the sensitivity of the quality characteristics investigated in a controlled manner to external factors of influence (noise) not under control. The interaction diagrams for the S / N ratios of all composite materials are shown in Figures 2, 3 and 4. In the present study, the wear rate must be lower, so the S / N ratio is considered "lower is better" "and S / N the ratio is calculated using the equation shown below.

Fig.2. Interaction plot for S/N ratios of M1.

Table 3: Orthogonal Array with Experimental Results and S/N Ratio.

Sl. No	Speed (rpm)	Load (kg)	Sliding Distance (m)	Wear rate for M1 (mm^3/m)	Wear rate for M2 (mm^3/m)	SNRA1 For M1	SNRA1 For M2	Speed (rpm)
1	200	3	500	0.0045973	0.06206	45.5420	24.1438	200
2	200	5	1000	0.0029179	0.00264463	50.5286	51.5527	200
3	200	7	1500	0.0054385	0.229306	53.7056	12.7917	200
4	300	3	1000	0.00031593	0.000300182	49.1617	70.4523	300
5	300	5	1500	0.0017128	0.011592	54.4405	38.7168	300
6	300	7	500	0.0022919	0.0017149	54.2529	55.3152	300
7	400	3	1500	0.0076912	0.10933	50.1692	19.2252	400
8	400	5	500	0.0105	0.000026363	61.8835	91.5799	400
9	400	7	1000	0.002623	0.09005	79.8060	20.9103	400

B. Analysis of Variance

Analysis of variance (ANOVA) is commonly used to establish the relative importance of individual parameters in response to responsible behavior. In the present study, ANOVA is used to analyze the influence of operational parameters, such as pressure, flow rate, and duration of the test, on composite materials' wear characteristics. The analysis was performed for a significance level of 5% with a confidence level of 95%. The percentage of influence factorcontributions was calculated based on the sum of the square. The greater the value of the sum of the square, the more influential the parameter will be in the response. These sum values of the squares are used to find the percentage contribution of the parameters. Tables 4 and 5 show the results of ANOVA for the wear performance of composite materials.

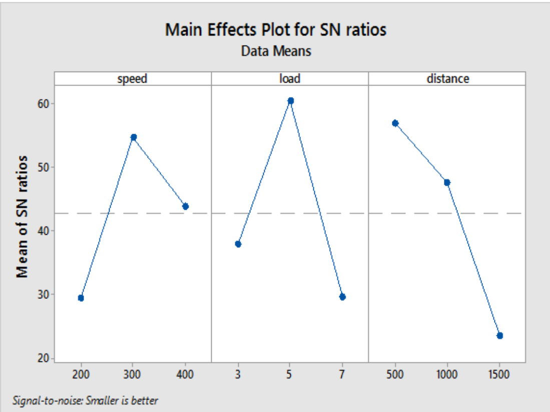

Fig. 3.Interaction plot for S/N ratio of M2.

Table 4.ANOVA for S/N ratios of M1.

Source	DF	Adj SS	Adj MS	F-Value	P-value	P (%)
Load	1	0.000006	0.000006	17.79	0.008	31.3%
Speed	1	0.000010	0.000007	26.89	0.004	52.6%
Sliding Distance	1	0.000001	0.000010	0.41	0.548	5.26%
Error	5	0.000002	0.000000			
Total	8	0.000019	0.000000			

The ANOVA result for the wear performance of M1 is shown in Table 4. It shows that the wear test speed (P = 52.6%) is the most influencing factor, where the load (P = 31, 3%) and the sliding distance V (P = 5.26%) has a great influence on wear performance. It has been observed that when the velocity and the sliding pressure are increased, the wear rate under dry running conditions also increases. An increase in sliding speed leads to an increase in the contact area temperature due to frictional heating. Therefore, an increase in the contact region occurs due to the softening of the matrix material. This softening of the material led to a higher wear rate.

Table 5.ANOVA for M2.

Source	DF	Adj SS	Adj MS	F-Value	P-value	P (%)
Load	1	0.000006	0.000006	17.79	0.008	22.07%
Speed	1	0.000010	0.000007	26.89	0.004	50.15%
Sliding Distance	1	0.000001	0.000010	0.41	0.548	5.2%
Error	5	0.000002	0.000000			
Total	8	0.000019	0.000000			

Table 5 shows the ANOVA for M2, the speed (P = 50.15. %) And the load (P = 22.07%) has a significant effect on wear performance. It has been examined that with the addition of filling materials in the matrix material, the wear rate decreases considerably. However, all interactions have a negligible influence on wear performance, so they are neglected. Nano MgO is commonly used as filler, and MoS_2 is used as a lubricating material. Therefore, adding MgO to the matrix material results in less wear compared to other composite materials.

V. REGRESSION ANALYSIS

Regression analysis was performed for all composite materials to study wear performance under dry run conditions. The empirical equation for wear performance in terms of load, speed and sliding distance was obtained. The linear regression equation for the wear rate of all materials under examination can be expressed as follows

The regression equation for M1 is

Wear rate = 0.00209 + 0.000013 speed - 0.000188 Load - 0.000001 Sliding distance ……………………………………1

The regression equation for M2 is
Wear rate = -0.054 - 0.000158 speed + 0.0124 loads + 0.000095 Sliding distance……………………………2

VI. CONCLUSION

The Taguchi analysis method has helped to successfully analyze the wear performance of MMC in dry run conditions. The operating parameters' effects were examined, such as load, speed, and sliding distance on wear performance. The following conclusions are drawn from the study:

- The ANOVA for the wear performance of composite materials shows that the wear test duration that is considered more like the distance traveled is the factor that most affects when the speed and load have a more significant effect on the performance of the wear.
- Analysis of linear regression analysis successfully used to develop the correlation between the percentage of wear and the selected operating parameters.
- The reinforcement of the filler fiber in the matrix material has a great influence on the material's wear behavior. MMC reinforced with special fillers such as Nano MgO, and MoS_2 can improve the wear rate.
- MMC reinforced with NanoMgO, and MoS_2 presented the best material compared to other composite materials. He exhibited less wear in all experimental conditions.

REFERENCES

[1] J.K.Lancaster, Tribology (1973) 219-251.
[2] K. Friedrich, J. Karger-Kocsis, Z. Lu, Wear 148(1991) 235-247.
[3] Z. Zhang, C. Breidt, L. Chang, K. Friedrich,Tribology International 37 (2004) 271–277.
[4] VinayChandran R., Dr.DeviprasadVarma P.R., Abdul Samad P.A*"CFD Simulation of Centrifugal Casting of Al-SiC FGM for the Application of Brake Rotor Disc,"* International Journal of Engineering Trends and Technology (IJETT), V28(6),304-306 October 2015.
[5] Hong-Bin Qiao, QiangGuo, Ai-GuoTian, Guo-Liang Pan, Le-Bo Xu, Tribology International 40 (2007) 105–110.
[6] Li Chang,ZhongZhang, Lin Ye, Klaus Friedrich, *"Tribology"* International 40 (2007) 1170–1178.
[7] G. Zhang, C. Zhang, P. Nardin, W.-Y. Li, H. Liao, C. Code, *"Tribology"* International 41 (2008) 79–86.
[8] Nithin K Mani, Prof.Cijo Mathew., Prof. Prakash M Kallanickal*"Optimization of Cutting Parameters & Nanoparticle Concentration in CNC Turning of EN8 Steel using Al2O3 Nanofluids as Coolant"*, International Journal of Engineering Trends and Technology (IJETT), V29(6),290-294 November 2015.
[9] G. Zhang, A.K. Schlarb, Wear 266 (2009) 337–344.
[10] J. Paulo Davim,Rosária Cardoso, Wear 266 (2009) 795–799.
[11] G. Zhang, H. Yu, C. Zhang, H. Liao, C. Code, *"ActaMaterialia56"* (2008) 2182–2190.
[12] G. Zhang, Z. Rasheva, A.K. Schlarb, Wear 268 (2010) 893–899.
[13] T. R.HemanthKumar, R.P.Swamy, T. k.Chandrashekar, *"J. of minerals and materials characterization &engg."* 10 (2011) 1179-1188.
[14] S. Basavarajappa, K. V. Arun, J. Paulo Davim, *"J. of minerals and materials characterization &engg"* .8 (2009) 379-391.