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Sliding Wear behaviour of Epoxy Composites Filled with Kota Stone Dust Particulates

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ABSTRACT

The present work aims are to study the sliding wear behaviour of the epoxy composites filled with micro-sized Kota stone dust particulates. A simple hand lay-up method is used for the preparation of the composites with a filler loading of 10 wt. % to 40 wt. %. For conducting the wear test, a well-known Taguchi's design of experiment method is implemented. This method is used to reduce the number of experiment and to understand the effect of different parameters on the wear rate of the material. The control factors selected are sliding velocity, applied load, sliding distance and filler loading each at five different levels. The experiment is designed as per L_{25} orthogonal array. From the experimental analysis, it is found that the Kota stone dust loading is the utmost significant factor, whereas normal load is the least significant factor that administrates the sliding wear rate of the composite system.

Keywords: Polymer matrix composites, Epoxy, Kota stone dust, Sliding wear behaviour.

1. Introduction

Over the past few decades, it is found that polymers have replaced many of the conventional metals/materials in various applications due to their many advantages such as ease of processing, productivity, cost reduction, etc. Polymers have a unique combination of hydrogen and carbon atoms and this combination makes polymer very versatile and highly durable to heavy sunlight in summers, very low temperatures in winters, and humidity in the rainy season. Also, they are not affected by any microorganisms and have a long-life span. With all these properties, petroleum-based plastics have been used in various applications, especially where strength is not of much concern. However neat polymers have several limitations owing to their various properties. Hence, they do not usually find practical applications in different fields. Therefore, proper reinforcing materials are added to the polymers to make them feasible for a large number of diverse applications. Recycling is considered an important aspect of today's world in every sector. The waste produced by different industries causes huge trouble to the environment. One such industrial waste is obtained from the stone industry. The major contributions of waste from such industries are in the form of dust representing around 50 % of the total generated waste. This waste is dumped on roads and scattered all over by the effect of the wind. In Rajasthan, a huge quantity of stone dust was produced during the process of machining and cutting the stone. The major portions of them are generated from the marble industry, granite industry, and Kota stone industry.

Marble stone dust obtained from the marble industry has been used as filler material in polymeric resin for quite since time. Cinar and Kar [1] used marble dust as a filler material with polyethene terephthalate (PTE) waste for the preparation of the composite body and studied the mechanical and thermal properties. From the experimental analysis, they found that the hardness and flexural strength of the samples increase with an increase in the filler content, whereas, the impact energy of the composite system decreases. While studying the thermal properties, they found that the thermal conductivity of the material increases as a function of marble dust content. Awad and Abdellatif [2] studied the effect of marble dust loading on different, physical, mechanical, and thermal properties of the low-density polyethylene (LDPE) composites and found improvement in the different properties with filler loading. Nayank and Satapathy [3] studied the sliding wear behaviour of polyester composites filled with micro-sized marble dust and found improvement in wear resistance of the material. Khan et al. [4] used the combination of low-density polyethene with marble dust and the composites was tested for their mechanical and thermal properties. Bakshi et al. [5] prepared polypropylene/marble dust composites for different filler content (20 wt. %, 40 wt. %, 60 wt. %, and 80 wt. %) and at varying processing temperatures (160 ºC, 180 ºC, and 200 ºC). The fabricated samples were tested for their physical, mechanical, and thermal properties.

Granite stone dust has also been explored by various researchers in the past as filler material in a polymeric resin. Subhash et al. [6] used granite dust with an epoxy matrix and performed the water absorption test, hardness test, and impact test on all sets of fabricated composites. From the measurement they found an improvement in the various properties of the material. Garigipati and Malkapuram [7] studied the hardness, and thermal properties of the poly benzoxazine-filled granite powder. From the hardness testing, they found that with an increase in filler content, the hardness of the material increases. Further, they performed the thermo-gravimetric analysis of the material. Mathavan and Patnaik [8] studied the effect of the inclusion of granite dust in a polyamide matrix in terms of its hardness and erosion wear rate. They reported that, with increased hardness, erosion wear resistance of the material also increases.

However, it has been found that very less report is available for the usage of Kota stone dust as filler material in the polymeric composites. Rajput et al. [9-11] used a combination of Kota stone dust with an epoxy matrix (Lapox L12) and explored the physical and mechanical properties of the composite body as a function of filler loading. They also implemented AHP and TOPSIS methods to evaluate the best possible combination of filler and matrix body on the basis of the physical and mechanical properties of the composite body. In their other work, Rajput et al. [12] used a hybrid combination of Kota stone dust with fly ash and prepared a hybrid composite with epoxy. From the experimental investigation, they found that the inclusion of fly ash in a hybrid combination of Kota stone dust results in the improvement of different properties under investigation. Hence, it is found that very few work is reported on the utilization of Kota stone dust as a filler material in the polymeric resin. Against this background, an attempt has been made in this research work to develop epoxy composites with micro-sized Kotas tone dust using a simple hand lay-up technique and to study their sliding wear behaviour.

2. Material considered and composite fabrication

Epoxy (LY 556) is chosen as the matrix material for the present research work. It provides a solvent-free room temperature curing system when it is combined with the hardener tri-ethylene-tetramine (TETA). Kota stone dust in the form of micro-particulates is used as a filler material in the epoxy matrix. In the present investigation, a Kota stone dust filled epoxy composite is fabricated using a simple hand lay-up technique. Composites were fabricated with different weight fractions of filler ranging from 0 to 40 wt. %.

3. Experimental details

In the present study, two-body abrasive wear tests have been performed with the help of a computerized pin-on-disk tribometer. The two-body abrasion tests were performed as per ASTM G99-04 standards. The wear test was designed as per Taguchi's design of experiment method. Through literature review, it has been found that filler loading, normal load, sliding distance, and sliding velocity mainly affect the sliding wear characteristics of the composite body. In the present work, the effect of four parameters with five levels was examined using L_{25} orthogonal arrays. Table 1 shows the selected control factors and their levels.

Table 1 Control factors and their selected levels

Control factor	**Level**					
	I	**II**	**III**	**IV**	**V**	**Units**
A: Sliding velocity	50	100	150	200	250	cm/s
B: Normal Load	10	20	30	40	50	N
C: Sliding distance	400	800	1200	1600	2000	m
D: Kota stone dust content	0	10	20	30	40	wt. %

4. Results and Discussion

The sliding wear rates of the micro-sized Kota stone dust-filled epoxy composites under different test conditions are given in Table 2. Sliding wear loss is otherwise called mass loss. The loss obtained in terms of weight is then converted into volume loss which is called a specific wear rate. The specific wear rate calculated is then transformed into a signal-to-noise ratio.

Table 2 Dry sliding wear test results with the corresponding S/N ratios

Test Run	**A Sliding velocity (cm/s)**	**B (Normal Load) (N)**	**C (Sliding distance) (m)**	**D (KSD content) (wt. %)**	**Specific Wear Rate (10^{-5} mm^3/N-m)**	**Signal-to-Noise Ratio (dB)**
1	50	10	400	0	1.862	94.600
2	50	20	800	10	1.575	96.054
3	50	30	1200	20	1.123	98.992
4	50	40	1600	30	0.938	100.556

5	50	50	2000	40	0.822	101.703
6	100	10	800	20	1.303	97.701
7	100	20	1200	30	1.231	98.195
8	100	30	1600	40	0.923	100.696
9	100	40	2000	0	2.001	93.975
10	100	50	400	10	1.692	95.432
11	150	10	1200	40	1.152	98.771
12	150	20	1600	0	2.069	93.685
13	150	30	2000	10	1.765	95.065
14	150	40	400	20	1.444	96.809
15	150	50	800	30	1.367	97.285
16	200	10	1600	10	1.861	94.605
17	200	20	2000	20	1.572	96.071
18	200	30	400	30	1.469	96.660
19	200	40	800	40	1.233	98.181
20	200	50	1200	0	2.259	92.922
21	250	10	2000	30	1.643	95.687
22	250	20	400	40	1.371	97.259
23	250	30	800	0	2.471	92.143
24	250	40	1200	10	2.089	93.601
25	250	50	1600	20	1.773	95.026

Figure 1 Effect of control factors on sliding wear rate of composites

Figure 1 shows graphically the effect of the four control factors i.e. sliding velocity, normal load, sliding distance and Kota stone dust content on the specific wear rate. From the figure, it is clear that the variation in sliding velocity and Kota stone dust content significantly alters the wear rate of the composite material, whereas, variation of normal load and sliding distance has less effect on the specific wear rate.

Table 3 Response table for a signal-to-noise ratio

Level	**A**	**B**	**C**	**D**
1	-1.988	-3.961	-4.111	-6.735
2	-3.107	-4.022	-4.022	-5.291
3	-3.912	-3.596	-3.745	-3.379
4	-4.576	-3.663	-3.414	-2.655
5	-5.498	-3.837	-3.787	-1.019

Delta	3.510	0.426	0.697	5.716
Rank	**2**	**4**	**3**	**1**

The S/N ratio response is given in Table 3, from which it can be concluded that among all the factors, Kota stone dust content in the composites is the most significant factor followed by sliding velocity and sliding distance while the normal load has the least or negligible significance on the wear rate of these Kota stone dust filled epoxy composites. It also leads to the conclusion that the factor combination of A_1, B_3, C_4, and D_5 gives minimum wear in dry sliding situations.

5. Conclusions

This study reveals that Kota stone dust possesses good filler characteristics as it improves the sliding wear resistance of the epoxy resin. The dry sliding wear characteristics of these composites can be gainfully analyzed using a design-of-experiment approach based on the Taguchi method. The analysis of experimental results shows that factors like filler content, sliding velocity, sliding distance, and normal load, in this sequence, are identified as the significant factors affecting the specific wear rate of the epoxy/Kota stone dust composites under investigation. Further, it leads to the conclusion that the factor combination of A_1, B_3, C_4, and D_5 gives minimum wear in dry sliding situations which is the requirement of any material.

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