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Study of Tribological and Morphological Properties of Epoxy Composites Reinforced with Aluminium Oxide and Talc

Snehal Jojare[#1], N. A. Kadam[*2]
[#]*Student at Mechanical Dept. MGMCOE, Nanded, Maharashtra, India*

Abstract — *In applications like aerospace, automotive, ship building, construction, and other engineering, composites are gaining importance. Properties like lightweight, superior strength to weight ratio make them more advantageous. With fillers like aluminum oxide, Talc, MoS2, Teak wood dust, etc., the properties like wear resistance, toughness, chemical resistance, and strength improved. In our study, epoxy reinforced with* Al_2O_3 *and Talc is considered. The following four influencing factors like normal load, time, filler content, wear rate, and morphological characteristics were studied. Taguchi's design of experiment method is used to investigate the influence of four factors on the response and the optimum combination of these four factors for maximum wear resistance. Pin-on-Disc apparatus is used to study wear characteristics. Morphological characteristics are studied with the help of Scanning Electron Microscope(SEM) images. The result is an increase in normal load increases the wear rate.*

Keywords — *Epoxy, Aluminium oxide, Talc, Tribological properties, Taguchi's DOE, Morphological characteristics.*

I. INTRODUCTION

Epoxy is a common thermoset, can be used with various fillers to check the behavior of composites. Composites made with Micro Tungsten Disulphide showed better abrasion resistance and reduced wear rate. With increasing WS_2 content, epoxy has shown mild fatigue wear. This is effective in lowering the frictional coefficient and wear rate. J.S. Sidhuet. Al.[1]

In the case of silicon carbide, aluminum oxide, and zinc oxide, the friction coefficient decreases with increased filler content and sliding distance. Specific wear rate increases with an increase in sliding velocity applied normal load and sliding distance and decrease with an increase in filler content. Kali Dasset. al.[2]

Alumina filled Gas Fabric has exceptionally improved the abrasive wear performance. The wear volume loss increases with an increase in abrading distance. Bhadrabasol Revappa Rajuet. Al.[3]

Erosive rate is higher of plane epoxy than graphite filled epoxy. It resists the formation of crack growth, which improves the resistance of erosive wear rate. Basawa. tet.al[4]

As Zirconium oxide and Molybdenum oxide increases, the wear resistance of composites also increases. Here the normal load is the predominant factor. Kavhale S.D.et.al. [5]

Filler content like ABS(Acrylonitrile Butadiene Styren) with 1% alumina shows better wear resistance characteristics than pure ABS and 3% alumina added ABS. Pure ABS material is observed to have uniform wear, and composite material exhibits non-uniform wear track due to reduced wear rate.T.Panneerselvamet. al.[6]

II. MATERIAL and METHOD

The base material selected is epoxy resin (Araldite AW106), and the hardliner is HV9531N. The fillers are Aluminium oxide(Al_2O_3) and Talc. Aluminum oxide(Kemphasol, Mumbai) is an odorless white solid powder with high thermal conductivity but is an electrical insulator. It is used to increase hardness and strength. Tiles used in pulverized fuel lines have alumina as one of the content to protect high wear areas. Talc (Dipa chemical Industries, Aurangabad) is a Metamorphic mineral combination of minerals such as Serpentine, Pyroxene, Amphibole, and Olivin with carbon dioxide and water. It has low shear strength, thus known as the oldest solid lubricant. Its limited use is helpful in lubricating oil to reduce friction.

The weight proportion for composites is as per Table 1.

TABLE 1: WEIGHT % FOR COMPOSITES

SAMPLE NAME	EPOXY(%)	ALUMINIUM OXIDE(%)	TALC(%)
C_1	75	0	25
C_2	80	5	15
C_3	82.5	7.5	10
C_4	87.5	12.5	0

Composites are manufactured by the simple stir cast method. This is an easy and low-cost method to manufacture composites. The amount of epoxy and hardener required are added in a beaker. Then fillers Al_2O_3 and Talc are mixed with epoxy and hardener so that bubble formation is avoided. This mixture is mixed well with the help of a stirrer. After mixing it well, it is poured into a mold cavity whose inner surface is sprayed silicon. This mold is kept in a furnace for 1 hour at 100^0C. In this way, all specimen are manufactured with different weight percentages.

Fig. (a) shows Araldite, which is the base material and hardener. Fig(b) shows casting die (Fig. d)

Fig.(a) Epoxy and Hardener

Fig.(b) Casting Die

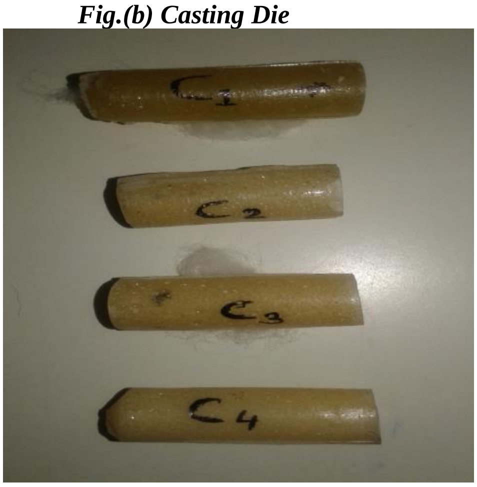


Fig.(d)Specimen

III. TAGUCHI METHOD

Taguchi method 321` how different factors affect the performance of specimen and investigate process carried out. With the help of orthogonal array study of factors like normal load, filler content, time, and speed affecting the response at different levels can be done. I n our study, we have four factors, each at four different levels. According to Taguchi, orthogonal array L16 is sufficient instead of performing all combinations.

From these 16 observations, Signal-to-Noise(S/N) ratio is calculated by:

$$n = -10 \log 1/n \left(\sum y^2\right)$$

Where 'n' is the number of observations, and 'y' is the observed data.

Thus, 'smaller is better' helps to minimize the wear rate. Factors and levels are as shown in table 2.

TABLE 2. FACTORS AFFECTING and LEVELS

Sr.No	Factors	1	2	3	4	Units
1	Normal load	19.62	39.24	58.86	78.48	N
2	Filler content	C_1	C_2	C_3	C_4	Wt%
3	Time	5	10	15	20	Min.
4	Speed	300	400	500	600	RPM

IV. EXPERIMENTAL SET UP

To know how these composites behave against dry sliding, Pin-On-Disc apparatus is used. The experiment is performed on Pin on Disc apparatus, DUCOM Engineers, Bangalore, India, available at SGGS IE&T, Nanded.

This apparatus has specifications such as sample disk diameter 165 mm thickness8 mm, sample track diameter 50mm to100mm. Disk rotation speed from 200 to 2000rpm(variable). Normal hanging load ranging from 10N to 200N can be applied in steps of 5N. The operation performed on this apparatus shows wear rate under different dry sliding conditions.

Fig.(f) and Fig(g) shows the setup of Pin-on-Disc

Apparatus.

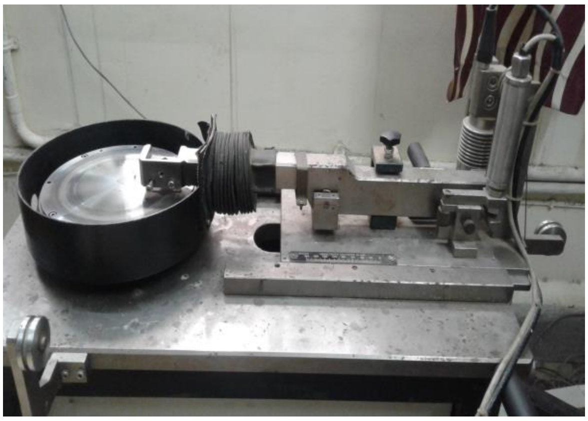


Fig.(f) Pin-on-Disc apparatus

Fig.(g)

TABLE 3. SPECIFIC WEAR RATE AND S/N RATIO

Sr. No.	Composites	Speed (m/sec)	Load(N)	Time (Min)	Specific wear rate (mm^3/sec)	S/N Ratio %
1	C_1	3.518	19.62	5	0.01258	38.006
2	C_2	4.691	19.62	10	0.00876	41.14
3	C_3	5.864	19.62	15	0.004406	47.119
4	C_4	7.037	19.62	20	0.00356	48.97
5	C_2	5.864	39.24	5	0.0366	28.73
6	C_1	7.037	39.24	10	0.00414	47.65
7	C_4	3.518	39.24	15	0.00438	47.17
8	C_3	4.691	39.24	20	0.00471	46.53
9	C_3	7.037	58.86	5	0.00198	54.06
10	C_4	5.864	58.86	10	0.00226	51.70
11	C_1	4.691	58.86	15	0.00443	47.07
12	C_2	3.518	58.86	20	0.00555	45.11
13	C_4	4.691	78.48	5	0.00175	55.13
14	C_3	3.518	78.48	10	0.00210	53.53
15	C_2	7.037	78.48	15	0.0114	38.86
16	C_1	5.864	78.48	20	0.00273	51.27

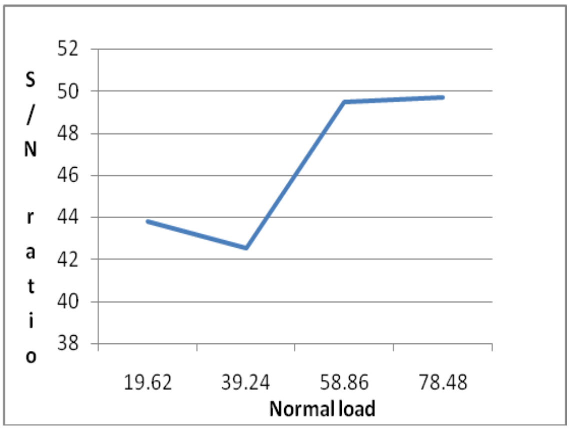
V. RESULT

Table 4. Ranking of Factors

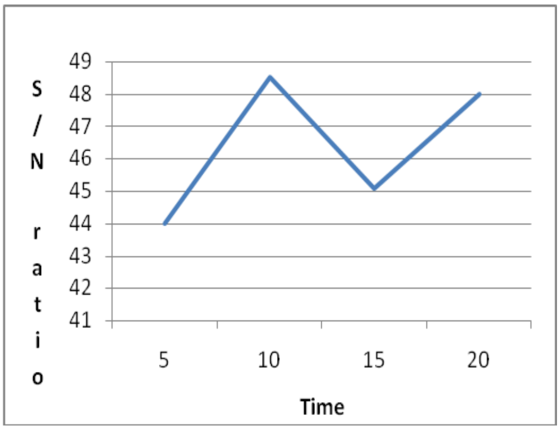
	A	**B**	**C**	**D**
Sr. No.	**Filler content**	**Time**	**Speed**	**Normal Load**
1	45.99	43.98	45.95	43.80
2	38.46	**48.50**	**47.46**	42.52
3	50.25	45.05	44.70	49.48
4	**50.74**	47.97	47.46	**49.69**
Delta	12.28	4.52	2.76	7.17
Rank	1	3	4	2

From the S/N Ratio analysis shown in table 4, among all the factors, Filler content is the predominant factor, followed by the normal load, time, and speed. The combination $A_4\,B_2\,C_2\,D_4$ gives a better result than its minimum wear rate. It shows as load increases wear rate of components increases. Speed also affects wear rate; increased speed causes a higher wear rate.

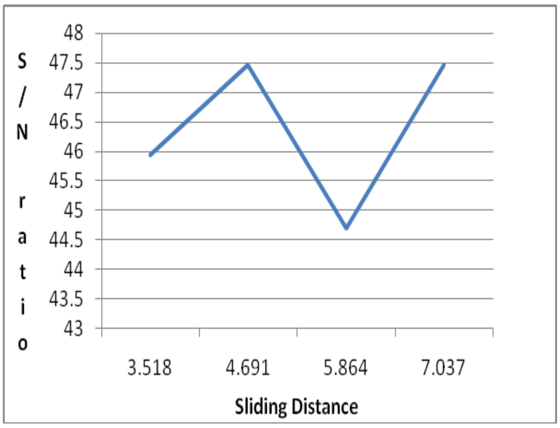
Graph 1,2,3,4 shows different parameters Normal load, time, sliding distance (speed), and Al_2O_3, respectively.



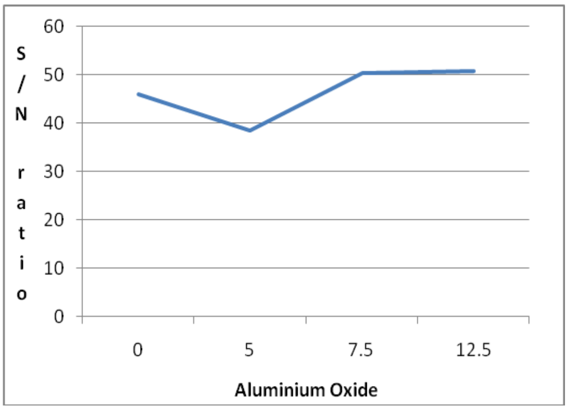
Graph 1



Graph 2



Graph 3



Graph 4

VI. MORPHOLOGICAL STUDY

The SEM images are taken from National Chemical Laboratory, Pashan, Pune. These are the images of three composites. Fig.(h) shows the microstructure of C_1 containing 0 % aluminum oxide and 25% talc sliding under normal load 19.62N and speed 300rpm. At higher load and higher speed, wear rate is high as more epoxy material was exposed to the rotating disc due to the absence of aluminum oxide, which improves the composite's hardness. Slightly plowed marks are seen on the surface of this composite.

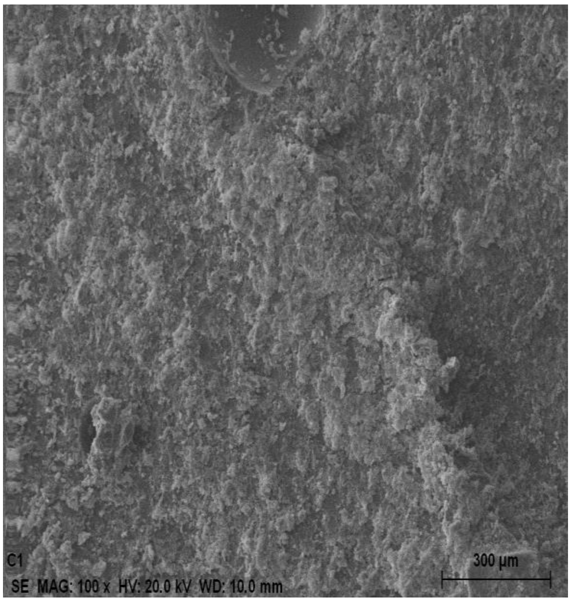


Fig.(h)

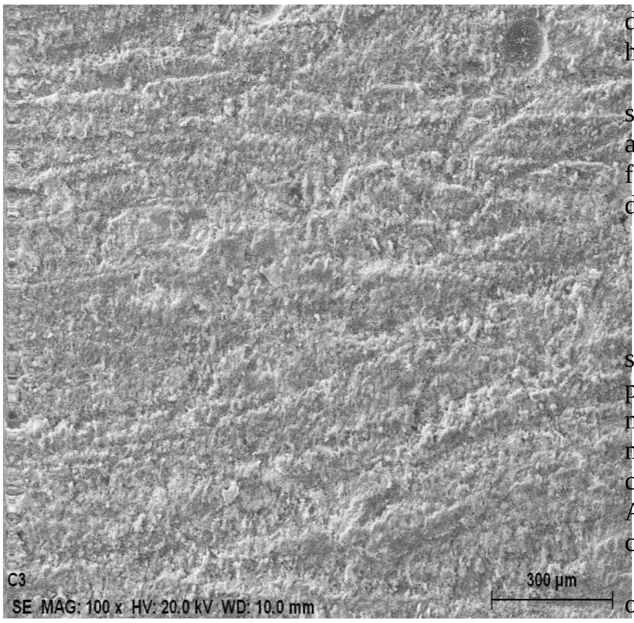


Fig.(i)

Fig.(i) shows the microstructure of C_3 combination of 7.5% Al_2O_3 and 10% Talc at normal load 39.24N and speed 400 rpm. From the image, it is seen that voids are formed due to non-uniform distribution. The direction of wear is parallel to the sliding direction. Here the wear rate is reduced. The surface shows plowed marks due to material removal under increased load and speed.

Fig.(j)

Fig.(j) shows the microstructure of C_4, Containing 12.5% aluminum oxide and 0% talc under normal load 78.48N and speed 400rpm. High frictional temperature is generated due to increased normal load, which further causes plastic deformation. This results in cracks or debris and helps to form transfer film on the surface.

Here the wear rate is minimum. SEM image shows a discontinuous transfer film due to the absence of lubricant. The appearance of transfer films depends on various interrelated factors in different forms, making it complex.

VII. CONCLUSION

Tribological properties of this composite show maximum to minimum wear rate as a proportion of aluminum oxide increases. At minimum wear rate, the amount of Al_2O_3 is maximum. Due to more addition of filler, composites may become brittle; thus, 7.5% of Al_2O_3 and 10% of Talc is found to be a suitable combination of fillers.

Morphological properties show voids form on the surface due to improper distribution of fillers. Transfer films are seen at higher temperatures due to friction.

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