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Statistical Analysis of the Tribological Properties of Epoxy/TiCNanocomposites

Abdallah K.Mohamed, Samah S. Mohammed

Faculty of Engineering at Shoubra, Benha University, Cairo, Egypt.

Abstract. This paper investigates the effect of nanoparticles (TiC) on the Tribological properties of epoxy, by Taguchi method to develop the quality of machined product. Volume fraction of TiCnano particles of 0.5 vol.%, 1 vol.% and 1.5 vol.% were reinforced into the epoxy. The tribological properties of the composites were investigated using a pin on ring conventional wear machine. The process parameters (nano addition, load, sliding speed) for minimum wear and coefficient of friction were optimized via Taguchi method. The results revealed that the sliding speed has most significant influence on wear rate and coefficient of friction. In addition, theminimum wear rate was obtained at 0.5% TiC, 300RPM and 1710 g, while, minimum coefficient of friction was obtained at1% TiC, 1000 RPM and 1710 g.

Keywords; Nanocomposite, Epoxy matrix, wear rate, coefficient of friction, TiC.

1. INTRODUCTION

All mechanical systems, artificial or natural, comprise the relative motion of solid components. Wherever two surfaces slide or roll against each other, there will be frictional resistance, and wear will occur[1,2]. The studying of the wear and coefficient of wear rate is important for choosing the contact materials. One effective way to reduce the wear is to use nano composite materials[3–5]. Biswas [6] studied mechanical and thermo mechanical of bi-directional and short carbon fiber reinforced epoxy composite. They found that Bidirectional carbon fiber reinforced epoxy composites show better mechanical properties, i.e., tensile strength, inter laminar shear strength, flexural strength and impact strength except for that of hardness where values for short carbon fiber reinforced epoxy composites are higher than that for bidirectional composites.

Prashanthakuamr and Bhanuprakash[7]investigated the effect of process parameters on friction coefficient and wear behavior of polymer matrix composite. They found that nano % was the most significant parameter. Yaman and Çalış[8] studied the dry sliding behavior of boron waste reinforced epoxy matrix composites. It has been found that boron waste particles can be used to modify the tribological properties of epoxy matrix.

Badran et al.[9]investigated the tribological properties of epoxy composites. They concluded that Slight increase in friction coefficient is observed for composites filled by Al_2O_3 as the normal load increased. Besides, friction coefficient increases as Al_2O_3 content increases. Wear observed for composites filled by Bz particles shows relatively lowest values.

The main aim of this study is to investigate the influence of the process parameters parameters (nano addition, load, sliding speed) on the wear behavior and coefficient of friction of nanocomposite/ epoxy. In addition, is to determine the main significant parameter via ANOVA method.

2. Materials and methods

Nano-filler of TiC with volume fraction of 0.5, 1 and 1.5% was reinforced in Epoxy (KEMAPOXY 150) resin matrix. The TiCnano particles have a size range of 20-60 nm Fig. 1. The TiC were addedto the resin and stirred mechanically for 20 minutes at room temperature, then the hardener was added to the mixture and then stirred mechanically again for 10 minutes. The epoxy/nanofillers slurry was poured in silicon moldtubes. Finally, the mixture was allowed to fully harden at room temperature for 7 days according to the specification of the matrix.Experiments have been conducting L27 orthogonal array. Table 1. Wear test were performed using pin-on-ring machine apparatus shown schematically in Fig. 2.

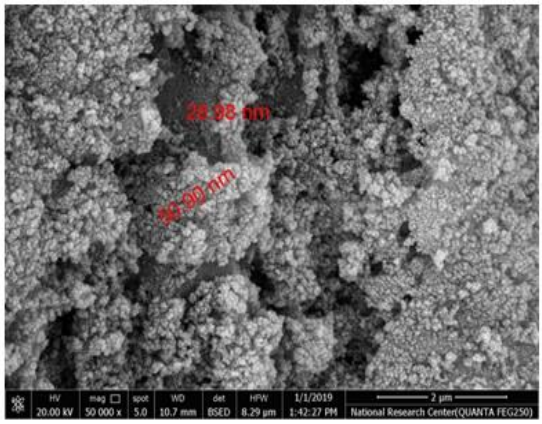

Fig 1. SEM image of TiC.

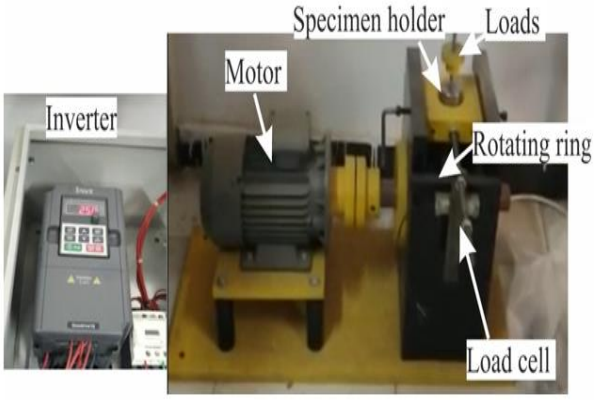

Fig 2. Pin-on-ring machine tester.

Experiments have been conducting according to Taguchi L27 orthogonal array using a Pin on ring machine tester shown in Fig. 2. The variables were selected for the experimental study and their levels were listed in Table 1

Table 1 Factors and their Levels used in the experimental study

Levels	Level 1	Level 2	Level 3
Speed (RPM)	300	600	900
Load (N)	1710	2010	2410
TiCvol.%	0.5	1	1.5

3.Results and discussion

The results of wear rate and coefficient of friction at defferent process paramters are listed in Table 2.

Table2. Measuement results of wear rate and coefficient of frictions

N.O	Nano type (%)	Speed (RPM)	Load (N)	COF	Wear rate (mg/min)
1	0.5	300	17.1	0.202341	13.9
2	0.5	300	17.1	0.209162	14.2
3	0.5	300	17.1	0.209162	14.8
4	0.5	600	20.1	0.195858	15.9
5	0.5	600	20.1	0.189805	16.2
6	0.5	600	20.1	0.219575	16.7
7	0.5	900	24.1	0.201377	18.8
8	0.5	900	24.1	0.175471	19.1
9	0.5	900	24.1	0.201377	19.5
10	1	300	20.1	0.177944	8.7
11	1	300	20.1	0.172141	9.1
12	1	300	20.1	0.183999	9.6
13	1	600	24.1	0.18074	10.5
14	1	600	24.1	0.206426	10.9
15	1	600	24.1	0.206426	11.3
16	1	900	17.1	0.2441577	12.2
17	1	900	17.1	0.272128	12.8
18	1	900	17.1	0.278857	13.7

19	1.5	300	24.1	0.211695	4.5
20	1.5	300	24.1	0.216745	5.33
21	1.5	300	24.1	0.216745	5.5
22	1.5	600	17.1	0.23704	5.9
23	1.5	600	17.1	0.258097	6.3
24	1.5	600	17.1	0.278857	6.9
25	1.5	900	20.1	0.225378	7.6
26	1.5	900	20.1	0.231512	8.2
27	1.5	900	20.1	0.183999	8.5

The maximum value of wear rate was 19.5 mg/min at nano ratio of 0.5%, speed of 900 RPM and load of 24.1N, while the minimum value was 4.5 mg/min at 1.5%, 300 RPM and 24.1 N. The minimum coefficient of friction was 0.172 and obtained at 1% TiC, 300 RPM and 20.1 N.

Taguchi technique were performed using Minitab17 software. Smaller is better function was used

4.1 Analysis of coefficient versus nano percent, speed, load

The rank of each parameter is listed in table 3

Table 3 Response for Means

Level	Nano(%)	Speed(RPM)	Load(N)
1	0.2005	0.2000	0.2433
2	0.2136	0.2192	0.1978
3	0.2289	0.2238	0.2019
Delta	0.0284	0.0238	0.0455
Rank	2	3	1

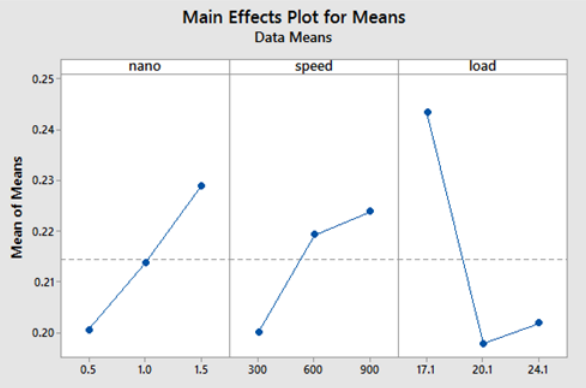

Fig. 3 main effects plot means of coefficient of frication.

*The most effect on main effect plot of coff is load 17.1(N)

4.2Analysis of wear rate versus nano, speed, load

Table 4 Response for Means

Level	Nano(%)	Speed(RPM)	Load(N)
1	16.567	9.514	11.189
2	10.978	11.178	11.167
3	6.526	13.378	11.714
Delta	10.041	3.863	0.548
Rank	1	2	3

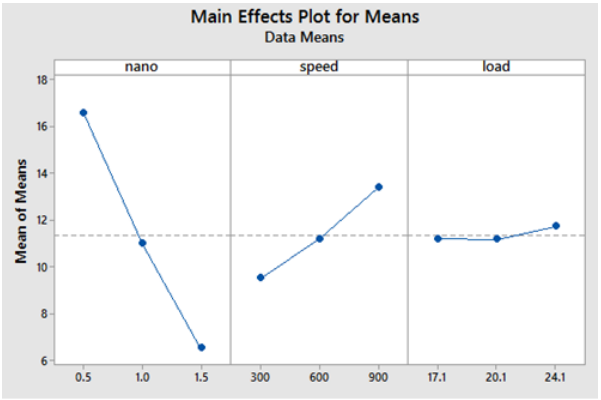

Fig. 4 Main Effects Plot for Means of wear Rate.

The most effect on Main Effects Plot for Means of wear Rate is Nano (0. 5%)

Table 5 Analysis of Variance of cof versus nano, speed, load

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Nano(%)	2	0.003646	0.001823	5.44	0.013
Speed(RPM)	2	0.002872	0.001436	4.28	0.028
Load(N)	2	0.011411	0.005706	17.02	0.000
Error	20	0.006706	0.000335		
Lack-of-Fit	2	0.002318	0.001159	4.75	0.022
Pure Error	18	0.004388	0.000244		
Total	26	0.024635			

Table 6 Analysis of Variance of wear rate versus nano, speed, load

Source	DF	Adj SS	Adj MS	F-Value	P-Value
nano	2	455.646	227.823	857.73	0.000
speed	2	67.596	33.798	127.25	0.000
load	2	1.730	0.865	3.26	0.060
Error	20	5.312	0.266		
Lack-of-Fit	2	0.953	0.476	1.97	0.169
Pure Error	18	4.359	0.242		
Total	26	530.284			

The Load has been most significant on coefficient of frication, while the speed has been the most significant on wear rate

4-Conclusion

The process parameters;applied load, sliding speed and volume percentage of TiC were optimized via Taguchi technique with ANOVA. The wear rate and coefficient of friction wereselected to be the control parameters during experimental work. Based on the results we can conclude:

1 Based on Taguchi analysis, the most influence parameter affects the wear rate and coefficient of frictionwas the sliding speed.

2 the minimum wear rate was obtained at 0.5% TiC, 300 RPM and 1710 g, while, minimum coefficient of friction was obtained at 1% TiC, 1000 RPM and 1710 g.

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