Optimization of friction coefficient of kenaf/epoxy composites as an alternative friction material using Taguchi method

A. Mustafa[1], M.F.B. Abdollah[1,2,*], H. Amiruddin[1,2], F.F. Shuhimi[1], N.A.M. Tahir[1], N. Muhammad[1,2], S.E. Mat Kamal[1,2], N. Ismail[1,2,3]

[1)] Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[2)] Center for Advanced Research on Energy, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[3)] Department of Surface Technology and Tribology, Faculty of Engineering Technology, University of Twente, P.O. box 217, 7500 AE Enschede, The Netherlands

[*]Corresponding e-mail: mohdfadzli@utem.edu.my

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ABSTRACT – This paper introduces the application of Taguchi optimization methodology in optimizing the design factors for obtaining high friction coefficient of kenaf/epoxy composites under dry sliding condition. An orthogonal array of the Taguchi method was set-up and used to analyse the effect of the design parameters on the friction coefficient. Tribological testing was conducted using a pin-on-disc tribometer. For the highest friction coefficient, 45wt.% non-treated kenaf fiber sliding at 19.62N, 500rpm and 100ºC is found to be the optimized combination of levels of all the six control factors. The confirmation test proves that the optimized friction coefficient is within the range of friction coefficient of conventional friction material.

1. INTRODUCTION

Recently, the interest in using natural fibers as a reinforcement for polymeric composites is increased due to their properties such as less weight, renewability, low density, high specific strength, non abrasivity, combustibility, non-toxic, low cost and biodegradability [1,2].

Kenaf fibers have a long history of cultivation in Asia and southeast Europe. The fiber has been mainly used in rope, twine, coarse cloth and paper. However, nowadays, there is demand for the fibers to be used as reinforcement for polymers.

However, the potential of using high interfacial adhesion kenaf fibers as reinforcement for tribo-composites based polymer has not been explored yet. This motivates the current work in determining the optimal design parameters for high friction coefficient of kenaf/epoxy composites under dry sliding condition using Taguchi method.

2. METHODOLOGY

2.1 Design of experiment

In this study, Taguchi method consists of L_{18} orthogonal array was selected using Minitab statistical software. The 18 total runs with 6 factors and 2-3 mixed levels are shown in Table 1 and 2. The response in this study is friction coefficient, where larger value is better.

A confirmation test was carried out to verify the quality characteristic using optimal levels of each factor.

2.2 Sample preparation and tribological test

The kenaf polymer composite was prepared by mixing several weight percentages of kenaf with epoxy, as a resin, where the ratio of epoxy to hardener is 4:1. The sample was fabricated as a pin with 10mm diameter using hot-cold compression machine.

Table 1 Design parameters at 2-3 mixed levels.

Level	Factors					
	Types	Tr	wt. %	Load (N)	Speed (rpm)	Temp (°C)
1	P	NT	30	19.62	200	24
2	F	T	45	49.05	500	100
3	-	B	60	98.1	1000	150

P:Powder; **F**:Fibers; **Tr**:Treatment; **NT**:Non-treated; **T**:Treated; **B**:Bleached; **wt**:Kenaf weight composition

Table 2 Taguchi L_{18} orthogonal arrays.

Run	Types	Tr	wt.%	Load	Speed	Temp
1	1	1	1	1	1	1
2	1	2	1	2	2	2
3	1	3	1	3	3	3
4	1	1	2	1	2	2
5	1	2	2	2	3	3
6	1	3	2	3	1	1
7	1	1	3	2	1	3
8	1	2	3	3	2	1
9	1	3	3	1	3	2
10	2	1	1	3	3	2
11	2	2	1	1	1	3
12	2	3	1	2	2	1
13	2	1	2	2	3	1
14	2	2	2	3	1	2
15	2	3	2	1	2	3
16	2	1	3	3	2	3
17	2	2	3	1	3	1
18	2	3	3	1	1	2

Eighteen run (L_{18}) of tribological tests, as shown in Table 2, were carried out using a pin-on-disc tribometer according to the ASTM G99-10 standard. The sample was slided against polished JIS-SKD 11 steel disc. The friction coefficient, μ was calculated using Equation (1):

$$\mu = \frac{F_f}{F_n} \quad (1)$$

Where F_f is the frictional force and F_n is the normal load. Both loads are in unit N.

3. RESULTS AND DISCUSSION

Friction coefficient obtained range from 0.21-0.52. The response was analysed using combination methods of signal-to-noise (S/N) ratio, means and Analysis of Variance (ANOVA) in order to identify the optimal design parameters. Table 3 shows the percentage of contribution, obtained from ANOVA, for S/N ratio and means of each factor. A higher contribution is required in determining the optimal design parameters either using S/N ratio or means value.

From Figure 2, a greater S/N ratio or means value corresponds to a better performance, where high friction coefficient can be obtained. For the highest friction coefficient, 45wt.% non-treated kenaf fiber sliding at 19.62N, 500rpm and 100ºC is found to be the optimized combination of levels of all the six control factors. This is believed due to the presence of waxy layers and impurities of non-treated kenaf fiber [2]. Besides, rougher surfaces may produce larger variations in the contact area and, thereby exhibit more friction. The experimental study proved that the arithmetic mean surface roughness, *Rz* of non-treated sample (*Rz*=0.105) is larger than treated sample (*Rz*=0.089).

Table 3 Percentage of contribution obtained from ANOVA for S/N ratio and means of each factor.

Source	DOF	SS S/N	SS Mean	S/N Cntrb. (%)	Mean Cntrb. (%)
Types	1	6.956	0.00761	7.68	5.742
Wt.%. Kenaf	2	10.41	0.01730	11.50	13.048
Treatments	2	2.477	0.00471	2.74	3.554
Load (N)	2	16.44	0.03613	18.16	27.245
Speed (rpm)	2	13.52	0.01820	14.94	13.721
Temperature (ºC)	2	16.26	0.02022	17.97	15.2461
Error	6	24.47	0.02844		
Total	17	90.55	0.13264		

A confirmation test, as shown in Figure 3, can successfully verify the friction coefficient of 45wt.% non-treated kenaf fiber is within the range of 0.40 to 0.44 of conventional friction materials. This friction coefficient value is recommended for friction material performance [3].

4. CONCLUSION

In this study, Taguchi method was applied to determine the optimal parameters leading to the maximum friction coefficient of kenaf/epoxy composites. It was found that the friction coefficient of 45wt.% non-treated kenaf fiber sliding at 19.62N, 500rpm and 100ºC is within the range of conventional friction material (0.35-0.45).

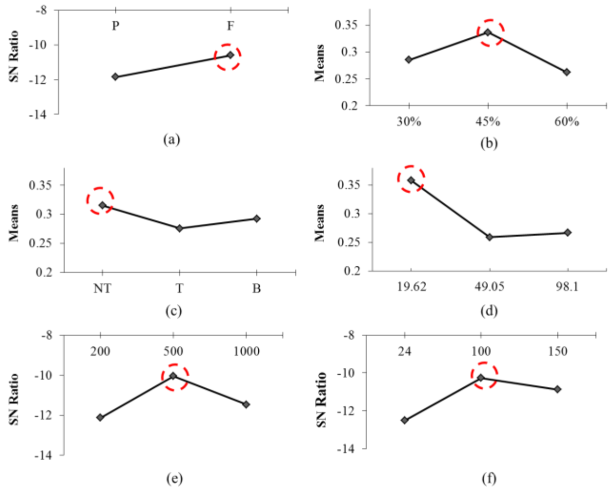

Figure 1 The selected optimal design parameters for (a) type of kenaf, (b) wt.% kenaf, (c) treatment method, (d) normal load, (e) speed and (f) temperature.

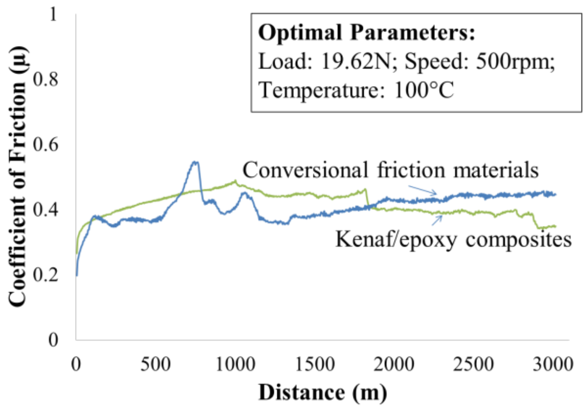

Figure 2 A confirmation test results by comparing the friction coefficient of kenaf/epoxy composites and conventional friction material using optimal design parameters.

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