Analysis of Wear Behavior of Thermoplastic Bio-Composite

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Abstract: In the present work, response surface methodology (RSM) has been used to model and predict the wear properties of Bio-composites fabricated in this study. Polished stainless steel counterface has been used to analyze the wear response of the bio-composite under dry contact condition. Three process variables namely applied sliding speed, normal load, and sliding distance were taken to investigate their effect on output response (specific wear rate). Statistical analysis was performed in the form of the analysis of variance (ANOVA) to analyze the significance and interaction of experimental parameters. The mathematical relationship between sliding wear input process parameters and output responses has been established to determine the values of output responses.

Keywords: Friction, Natural fibers, Sliding wear, Thermoplastic composites.

1. INTRODUCTION

Polymer based composites are being used in various sectors such as railways, automobiles, constructions and household applications. Light weight and high strength characteristics of such polymer composites have increased their utilization and replaced conventional materials and plastics. But fibers used as reinforcement in these composites are not environment loving and also involves various health hazards. Therefore, attempts have been made towards utilization of natural fibers as reinforcement in such composites. Several studies are available on mechanical and wear studies of natural fiber reinforced bio-composites which show that these have enough potential to capture different application areas. Now, several components of an automobile are based on bio-composites due to their lightweight characteristic. These natural fiber based bio-composites are environment loving, low cost, easily available and have good strength [1-4].

Studies show that bio-composites can be used tribological applications to some when components of natural fiber based polymer composites are under such loading conditions [4-5]. Researches have shown that failure of mechanical part is high when subjected to tribological loading condition. Therefore, it becomes important to study the wear and frictional characteristics of natural fiber reinforced polymer composites [5-6]. Kranthi and Satapathy
carried out the implementation of artificial neural network (ANN) in analysing the wear behavior of a new class of epoxy based composites filled with pine wood dust. This work showed that pine wood dust possessed good filler characteristics as it improved the sliding wear resistance of the polymeric resin and that factors like filler content, sliding velocity and normal load, in this sequence, were the significant factors affecting the specific wear rate [7]. In another study, it has been shown that incorporation of different natural fibre mats to polypropylene has improved the wear resistance of neat polymer [4]. Basavarajappa et al. [8] studied tribological behaviour of glass/epoxy composites with SiC and Graphite particles as fillers using a pin-on-disc apparatus. The effect of applied load, sliding speed, sliding distance and percentage of secondary fillers was investigated on the wear rate of developed composite using Taguchi optimization technique. An orthogonal array and analysis of variance (ANOVA) results showed that the inclusion of SiC and Graphite as filler materials in glass/epoxy composites increased the wear resistance of the fabricated composite. Patnaik et al. [9] carried out parametric optimization to study dry sliding wear behaviour of flakes of pine-bark reinforced polyester composit with kiln-dust of a cement plant as the filler. The plan of experiments were based on Taguchi’s orthogonal arrays. The analysis results showed that the rate of wear was greatly influenced by various control factors. Analysis of variance (ANOVA) is performed on the measured data and signal-to-noise (S/N) ratios. The authors developed a mathematical correlation, based on the experimental findings to estimate sliding wear rate of the developed composites. Genetic algorithm was used to determine optimal factor settings for minimum wear. Chegdani et al. [10] studied the influence of natural fiber types on tribological behavior during profile milling process of the fabricated natural fiber reinforced plastic (NFRP). Bamboo, sisal and miscanthus reinforced polypropylene (PP) composites were investigated. The quality of NFRP machined surface was quantified using a multiscale analysis based on wavelets decomposition. The study concluded that the bamboo fibers reinforced plastics exhibited high contact stiffness and showed the smoother surface finish after machining. The present work aims to investigate the effect of applied load, sliding distance and speed on wear behavior of PP/nettle bio-composite statistically using response surface methodology (RSM) technique.

2. Experimental Detail

Nettle fiber mats (NF) were obtained from Uttarakhand Bamboo and Fiber Development Board, Dehradun, India. The melting temperature (Tm) of polypropylene is 170 °C. The laminated composite was developed using hot compression method through film stacking technique. The wear experimental tests were carried out against polished stainless steel counter face using pin on disc apparatus for different sliding velocities (1-3 m/s), applied loads (10-30 N) and sliding distances (1000-3000 m). A pin-on-disc tribometer (Ducom India; TR20LE) was used to evaluate the wear characteristics of the developed composite.

3. Result and Discussion

3.1 Coefficient of friction

The sliding wear process was studied using the box-behnken design (BBD) approach within RSM, as per the design scheme. Three levels levels of input process parameters are speed (1, 2
and 3m/s), applied load (10, 20 and 30 N) and sliding distance (1000, 2000 and 3000 m). Effect of process parameters on friction coefficient can be explained with the help of perturbation curve generated after analysis as shown in figure 1. Figure 1 depicts the effect of applied load, sliding speed and sliding distance on friction coefficient of bio-composite. From the curve, it is clear that friction coefficient continuously decreases with increase in applied load but with sliding speed, friction coefficient first decreases and then tends to become constant. As the sliding distance increases, friction coefficient first increases and after 2000 m distance, it shows constant behaviour and declines thereafter. The regression equation to determine the predicted values of friction coefficient in actual factors is given in Eq. 1.

$$\text{Friction coefficient} = +0.91998 \text{ -0.18517 } \times \text{ speed} +1.79472 \times 10^{-4} \times \text{ distance} -0.010662 \times \text{ load} -3.72556 \times 10^{-7} \times \text{ speed } \times \text{ distance} -6.98172 \times 10^{-4} \times \text{ speed } \times \text{ load} +7.22025 \times 10^{-7} \times \text{ distance } \times \text{ load} + 0.034384 \times \text{ speed}^2 -4.70895 \times 10^{-8} \times \text{ distance}^2 +2.86421 \times 10^{-5} \times \text{ load}^2$$

(1)

![Friction Coefficient Graph](image)

**Fig. 1** Effect of process parameters on friction coefficient.

### 3.2 Specific Wear Rate

Similarly, specific wear rate (SWR) was statistically analysed and the effect of different process variables is shown in the perturbation curve in figure 2. It can be seen from the figure that specific wear rate is decreasing with increase in applied load, sliding speed and sliding distance.
The significance of process variables can be analysed from analysis of variance (ANOVA) for specific wear rate model shown in table 1.

As shown in the table 1, the associated P value for the model is lower than 0.05 (i.e. $\alpha = 0.05$ or 95% confidence) which indicates that the model is significant. The lack of fits in the model are insignificant, this indicates that the proposed model fits well. The value of determination coefficient for the specific wear rate model is 0.9708 which shows that the fit of the model is good.
Experimental data is satisfactory and the model explains approximately 97.08% of the variability in specific wear rate. As can be observed from the table, sliding speed (A), sliding distance (B), applied load (C) and interaction effect of speed with load (A x C) and distance with load (B x C) have significant effects on specific wear rate. The P values of other model terms are more than 0.05 and hence these are non-significant model terms. Observing the F-values in the ANOVA table, it can be seen that applied load has the maximum effect on specific wear rate of developed composite followed by sliding distance whereas sliding speed has the minimal effect. The regression equation to determine the predicted values of specific wear rate in actual factors is given in Eq. 2.

\[
\text{SWR (mm}^3/\text{N mm)} = +8.55933 \times 10^{-08} - 1.16210 \times 10^{-08} \times \text{speed} - 8.97451 \times 10^{-12} \times \text{distance} - 2.82113 \times 10^{-09} \times \text{load} + 2.16781 \times 10^{-12} \times \text{speed} \times \text{distance} + 2.68371 \times 10^{-10} \times \text{speed} \times \text{load} - 4.85939 \times 10^{-13} \times \text{distance} \times \text{load} - 4.50893 \times 10^{-10} \times \text{speed}^2 - 2.93674 \times 10^{-15} \times \text{distance}
\]

(2)

4. CONCLUSION

In the present work, the wear behavior of polypropylene/nettle bio-composite was statistically analyzed using response surface methodology (RSM) technique. The following conclusions can be drawn:

1. Specific wear rate and Coefficient of friction decreases with increase in applied load, sliding distance and speed.
2. Applied load is the most significant parameter and has strong effect on friction and wear properties of developed composite.
3. Sliding speed has greater influence on friction coefficient as compared to sliding distance whereas specific wear rate is much affected by sliding distance than sliding speed.
4. The regression equations developed for friction coefficient and specific wear rate significantly predicts the responses within the range of process parameters.

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