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SLIDING WEAR PERFORMANCE OF NANO CUO PARTICLES - SHORT SISAL FIBERS - POLYAMIDE 66 HYBRID COMPOSITES

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ABSTRACT

Polymers and their composites are being increasingly employed in view of their good strengths and corrosion resistance. The features that make the polymer composites in industrial applications are the opportunities to tailor their properties with special fillers. For instance, short carbon and glass fibers have been successfully employed to improve the strength and therefore the load carrying capacity of polyamide composites can also be improved Optimization of parameters is an important in the tribological process. Response surface methodology (RSM) based optimal parameter analysis was performed to investigate the change of responses like wear rate (WR) and coefficient of friction (COF) with the change of input parameters to determine optimum setting of process parameters such as normal force, sliding velocity and reinforcement for achieving minimum WR and COF. The regression model generates the response surfaces. The present study is to optimize the parameter setting for combined responses.

Key words: *Friction coefficient, Wear Rate, Polyamide, Sisal Fiber and Copper oxide and Hybrid.*

1. Introduction

Polymers and their composites have tremendous potential on account of the versatility of its applications and it is expected that it will be successfully, commercially and economically utilized in the modern industries and research areas, although the effective utilization of this hybrid technology will require the application of a system approach to solve the predominant tribological problems[1-2]. Effects of reinforcements on the tribological performances of composites strongly depend on their mechanical property, shape, dimension, surface characteristics and concentration. Moreover several studies have shown that wear properties of polymer composites filled with smaller particles are superior to those with larger ones. In recent years, great efforts devoted to the development of nano particles filled polymer composites have made it possible to investigate the effect on the tribological properties of the nano composites [3–6]. However, for the tribological process of hybrid composites, optimal tribological parameters must be determine to achieve less wear rate and coefficient of friction. The principle of multiple performance optimizations is differ from those of single performance optimization. In multiple performance optimizations, there is more than one objective function, each of which may have a different optimal solution. Most of the time these objectives conflict with one another. In this study focused on the tribological behavior of hybrid composites, whose field of applications is in constant growth, is carried out. Consequently, an analyze on the influence of input parameters like normal force, sliding velocity and reinforcement, over technological variables such as WR and COF is performed using design of experiments (DOE) and regression analysis. The use of these techniques has enabled creation of second order polynomial models, which make it possible to explain the variability associated with each of the technical variables studied. In addition, these models can be used for optimization by which minimize WR and COF as objectives.

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2. Experimental Planning

Polyamide 66, nano CuO particles and treated sisal fibers were fabricated by twin screw extruder machine. The tribological test was conducted through pin on disc wear testing machine by varying predominant process parameters such as normal force, sliding velocity and reinforcement with fixed time interval. The size of the pin (test specimen) and disc are 10 mm X 20 mm and 55mm X 10 mm, with surface roughness of 0.1µm and a hardness of 60HRC. Mass loss was measured by an electronic balance of 0.01 mg accuracy before and after the tests. COF was measured by a load cell sensor directly from the computer running friction-measuring software.

3. Response Surface Methodology

Response surface methodology (RSM) approach is the procedure for determining the relationship between various process parameters with the various tribological criteria and exploring the effect of these process parameters on the coupled responses [7]. i.e. the WR and COF. In order to study the effect of the tribological parameters on the above-mentioned two most criteria, a second order polynomial response can be fitted into the following equation

$$Y_u = b_o + \sum_{i=1}^{k} b_i x_i + \sum_{i=1}^{k} b_{ii} x^2{}_i + \sum_{j>1}^{k} b_{ij} x_i x_j \qquad (1)$$

Table 1 Process parameters and their levels

Parameter	-1.682	-1	0	+1	+1.682
Normal force (N)	2	3	4	5	6
Sliding Velocity (m/sec)	0.2	0.4	0.6	0.8	1.0
Reinforcements %Vf (Sisal fiber + nano CuO)	(1.5 +1) =2.5	(1.5+1. 5)=3.0	(1.5+2. 0) =3.5	(1.5+2. 5)=4.0	(1.5+3. 0)=4.5

Where Y_U is response and the $x_{i\ (1,2,\ldots,k)}$ are coded level of k quantitative variables. The coefficient b_0 is the constant term, the coefficients b_i are the linear terms, b_{ii} are the quadratic terms and b_{ij} are the interaction terms.

The pertinent process parameter selected for the present investigations are normal force, sliding velocity and reinforcement on the WR and COF during the tribological process. For the three variables the design required 20 experiments with 8 factorial points, 6 axial points to form face centred composite design with $\alpha = 1$ and 6 centre points for replication to estimate the experimental error. The design was generated and analyzed using MINITAB.16 software.

4. Development of Empirical Models Based on RSM

The mathematical relationship, obtained for analyzing the influences of the various dominant tribological parameters on the WR is given by,

$$WR=1.32703 - 0.11760A - 0.40523B - 0.17380C + 0.01609A^2 + 0.49150B^2 - 0.00914C^2-0.10750AB + 0.03550AC+0.21250BC \qquad (2)$$

The mathematical relationship, obtained for analyzing the influences of the various dominant tribological parameters on the COF is given by,

$$COF=0.310648 - 0.023756A - 0.36506B - 0.068239C + 0.000227A^2 - 0.106818B^2 + 0.003409C^2 + 0.009375AB + 0.004250AC + 0.03875BC \qquad (3)$$

5. Results and Discussions

The estimated response surface plot for WR is presented in Fig.1.WR increases with the increase of normal force. It is attributed to the excessive frictional heat originated for the increasing of normal force. The frictional heat can result in excessive deterioration of the composites transfer from materials to the disc counterpart. Furthermore, increase of normal force will lead to excessive damage of the fibers and thus result in a disproportionate increase in wear loss [8]. On the other hand by the addition of reinforcement, WR decreases. This is because of addition of reinforcements are impossible to rub markedly against the surface of polyamide based composites and counterpart surface and the debris form a thin lubricating film on the counter surface thereby reducing the abrasion process drastically.

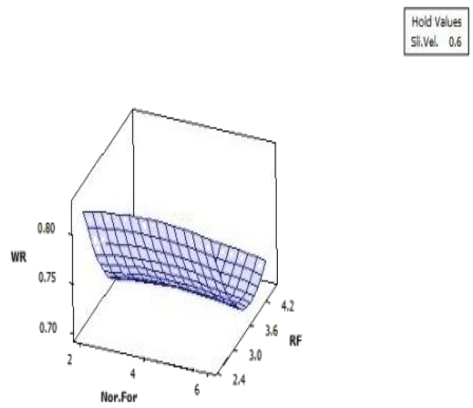

Fig.1 Influence of Normal Force

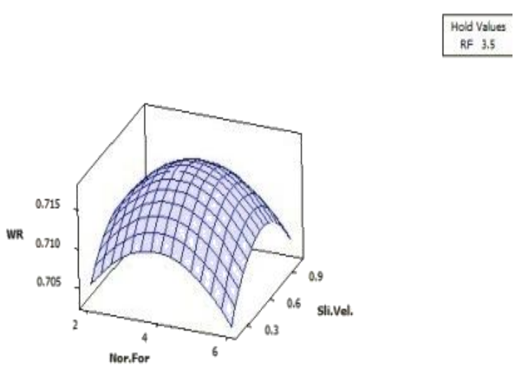

Fig.2 Influence of Normal Force and RF on WR and Sliding Velocity on WR

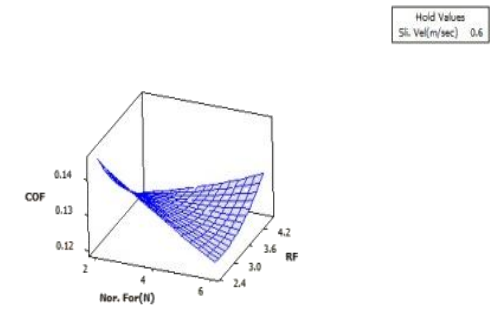

Fig.3 Influence on Normal Force

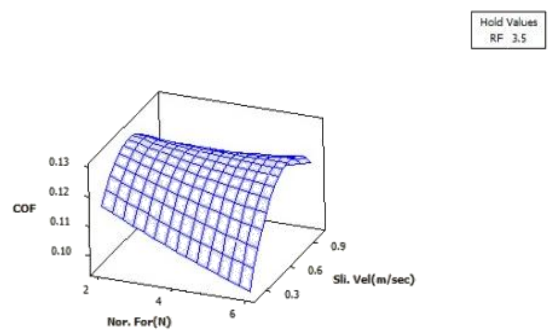

Fig.4 Influence on Normal Force RF of COF and Sliding Velocity on COF

Surface plot of WR with respect to normal force and sliding velocity is shown in Fig.2. It is clear from the graph that sliding velocity and normal force increases, WR increases. This could be due to during sliding the two surfaces are in contact and move relative to each other under high sliding conditions, hence the friction that exists between these two surfaces converts kinetic energy into heat energy because of brittleness behavior of polyamide resin which causes decrease the shear strength and thermal softening of the composites which results in an increase in the WR. Further increase in normal force and sliding velocity WR decreases. It is owing to the mechanism of heat energy barrier by third body particles at the counter-face is not sufficient, as a result, particles cannot penetrate deeper into the matrix, which acts as a solid lubricant and form wear scar, plucked and ploughed marks and micro fracture on the composites [9].

Fig.3 highlights the COF on normal force and reinforcement. It can be found that COF decreased almost linearly with increasing the normal force. While sliding, the friction-induced heat increased rapidly with the increasing load, which resulted in two contrary effects on the COF. On the one hand, the real contact area increased, increasing the COF. On the other hand, the worn surface became smoother with increasing load, the shear strength decreased, and thus the COF decreased. With an increase of reinforcement COF increases for all levels of normal force. This is attributed that reinforcement particles are generally embedded in the polyamide matrix at the frictional surfaces, and easily move to the counterpart surface of the matrix and it leads to plough some grooves and minute puncture occurs on the transfer-film during sliding. Further addition of reinforcement, it is impossible to rub against the counterpart surface of the composites [10]. The effect of normal force and sliding velocity on COF is shown in fig.4. Initially, surface of the composite and the steel counterparts were rough and thus strong interlocking took place, resulting in a high COF. As the wear process continued, the rough profiles of the steel counterpart that protected the materials, and then the COF decreases. Therefore, when the sliding velocity was higher, which caused a rise of friction temperature, the viscosity of the surface layer would decrease. Hence the COF was lower [11]. The normal force has the same effect of sliding velocity.

6. Multi – Objective Optimization Using Response Surface Methodology

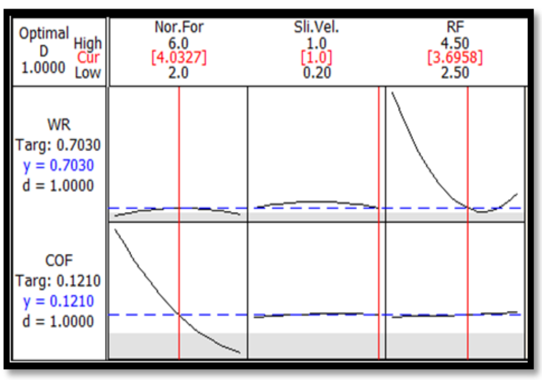

Fig. 5 Optimal Chart obtained through RSM

As analysis for the optimization of the process parameter has been carried out using RSM optimization technique. The desirability of the optimization has also been calculated to show the feasibility of the optimization parameter. After that both the responses have been optimized with respect to the target value, thus getting the parameter setting for the whole process optimization. Desirability for the whole process optimization has been calculated to show the feasibility of optimization, i.e., to explore whether all the parameters are within their working range or not. The goal was to minimize WR and COF while both are considered at a time. The composite desirability is close to one. Fig.5 exhibits optimization plot for the both responses. The optimum values obtained from the plot are WR is 0.7030 (mm^3/Nm), COF is 0.1210 (µ) and the relevant parameters such as normal force, sliding velocity and reinforcement are 4.0327 N, 1.0 (m/sec) and 3.6958 (%V_f) respectively.

7. Conclusions

The experiments were conducted on a pin on disc wear testing machine for hybrid composites. The responses were WR and COF. The second order polynomial model developed for WR and COF were used for optimization. The optimum values obtained through RSM were WR is 0.7030 mm3/Nm and COF is 0.1210 µ, and the relevant parameters normal force, sliding velocity and reinforcements are 4.0327 N, 1.0 m/sec and 3.6958 V_f respectively.

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