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Parametric optimization of abrasive wear of reinforced polytetrafluoroethylene composites using taguchi approach

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Abstract
Reinforced polymer composites are widely used for aerospace, automobile and structural applications owing to their exceptional combination of high specific modulus and strength. These dual behaviours make these materials attractive as compared to traditional ones. Parametric optimization abrasion resistance of glass, carbon and bronze fibres reinforced polytetrafluoroethylene (PTFE) using Taguchi method is studied in this article. Friction and wear experiments were carried out on pin-on-disc arrangement at normal temperature as per ASTM G99 standard. A plan of experiment based on Taguchi design was used to obtain data in a controlled way. An orthogonal array of L_9 (3^4) and analysis of variance (ANOVA) have been used to determine the influence of process variables on coefficient of friction (COF) and specific wear rate (Ks) of reinforced PTFE composites. Results revealed that increase in load and grit size decreased the COF while increase in sliding distance and sliding speed increased the COF. More so, Ks decreased as the load, grit size, sliding distance and speed increased. Optimal combination of parameters that minimized COF and Ks were determined as L2-G1-D2-S3 and L3-G3-D3-S3, respectively. Confirmatory test was done to validate the optimal testing parameters. ANOVA results revealed that applied load was the most significant parameter that influenced COF and Ks with a contribution of 80.79% and 82.13%, respectively. Confirmatory finding indicated good agreement between predicted and experimental values of signal-noise-ratios with an error of 1.10 dB and 1.98 dB for COF and Ks, respectively.

Keywords: bronze-reinforced composite, glass-reinforced composite, carbon-reinforced composite, coefficient of friction, wear, taguchi

Introduction

Polymeric materials and their composites are proving as potential substitutive materials for metals or their alloys in many advanced applications. Owing to the combination of high specific modulus and strength, the polymeric materials and their corresponding composites have been finding useful applications in automotive parts such as cams, wheels, gears, brakes, clutches, bearings and as well in other engineering fields like chute liners, mining, agriculture, conveyor aids and other related fields in which wear performance in dry condition is an important variable for materials selection [1]. Polymer based composites are prone to abrasive wear in several applications [2]. Most of abrasive wear problems occur in chute liners in mining, earth moving equipment and chute liners. The commonly used polymer matrices include vinyl ester, polyetherketone, epoxy and polytetrafluoroethylene. The extensively used fibres are Kevlar, boron, carbon and glass. As PTFE shows poor wear resistance, the wear resistance of PTFE can be significantly improved by addition of suitable filler materials like short aramid, carbon, or glass fibres [3]. Therefore, particle-filled polymers are very promising materials for various applications such as sliding elements, which require low friction and wear, whereas for other application, for example, in clutches, or brakes, low friction combined with lower wear is necessary [4]. The wear resistance and coefficient of friction are not intrinsic materials properties, but depend on the system in which these materials have to function [5-6]. There have been significant reports on the wear rate that changes considerably with the fibres, kinds, weight fraction and parameters [7-8] and wear behaviour of fibre reinforced epoxy composites [9-10]. Besides, the wear behaviour and friction of PTFE, bronze and carbon-filled and glass fibre reinforced polymers are investigated under various range of speeds and loads [11-12]. Shipway and Ngao (2003) concluded that the abrasive wear behavior and rates of polymers depended critically on the polymer type [13]. Additionally, the wear was related to indentation kind morphology in the wear scar and low values of tensile strain to failure. Abrasive wear behavior of short carbon/glass fiber reinforced with PEEK/polyphenylene sulfide (PPS) polymers showed that the wear rate was sensitive to the orientation of the fiber axis with respect to the sliding direction [5, 14]. Similar works confirmed that the normal orientation indicated better wear resistance than anti-parallel and parallel directions [15–17]. The inclusion of ultra-high-molecular weight polyethylene (UHMWPE) minimized the wear rate. The polymers without fillers exhibited better abrasive wear resistance than their composites [18]. Suresha, Kunigal and Kumar (2009) studied the three-body abrasive wear behavior of particulate filled PA66/PP composites at different conditions. It is indicated that addition of nanoclay/short carbon fiber in PA66/PP had significant influence on wear under varied abrading distance/loads. Further, it was found that nanoclay-filled PA66/PP composites exhibited lower wear rate compared to short carbon fiber-filled PA66/PP composites [19]. Ravi, Suresha and Venkataramareddy (2009) revealed that the wear volume loss increased with increase in abrading distance/abrasive particle size for the two-body abrasive wear behavior of glass/carbon fabric reinforced vinyl ester composites. However, the specific wear rate decreased with increase in abrading distance and decrease in abrasive particle size. The results showed that the highest specific wear rate was for glass fabric reinforced vinyl ester composite with a value of 10.89×10^{-11} m^3/N m and the lowest wear rate was for carbon fabric reinforced vinyl ester composite with a value of 4.02×10^{-11} m^3/N m [20]. Yousif, Nirmal and Wong (2010) exhibited higher values in frictional coefficient when it was subjected against coarse sand of the treated betel nut fiber reinforced epoxy (T-BFRE) composite. Besides, higher weight loss was noticed at high sliding velocities [21]. Recently, some attempt has been taken to study the wear anisotropy of natural fibers like cotton bamboo [22-23] sisal [24], date palm leaf [25], kenaf [26] and urena lobate [27]. Raju, Suresha and Swamy (2012) investigated the abrasive wear behavior of SiO_2 filled glass fabric reinforced epoxy (G–E) composites containing 5, 7.5, and 10 wt. %. The results showed that as the filler loading increased, the wear volume loss decreased and increased with increasing abrading distance [28-29]. The wear behavior of polymer composites indicated that tribofilm was formed on the counter face surface [30]. Apart from experimental studies, several numbers of models, which attempt to relate the abrasive wear resistance of polymer composites, have been proposed. Design of experiment (DOE) is an approach to get the greatest quantity of information from the least quantity of time, energy, work or other limited resources possible [31]. Taguchi as one of DOE's techniques has produced a powerful and unique quality improvement discipline that is different from the conventional process. Ramesh and Suresha (2014) studied the optimization of tribological parameters in abrasive wear mode of carbon-epoxy (C-E) hybrid composites. They implemented Taguchi approach, analysis of variance to determine the significance of control factors influencing wear and grey relational grade to optimize the tribological parameters having multiple responses. They concluded that filler loading and abrasive particle size have more significant effect on the specific wear rate of the composite and are therefore ranked first and second [32]. Pogosian, Cho & Bahadur (2005) applied Taguchi in their investigation of polyphenylene sulfide filled with a complex mixture MoS_2, Al_2O_3 and other compounds. They reported that change in molybdenum-concentrate had the most significant influence on the reduction of wear rate of the materials [33]. Three-body abrasive wear behavior of carbon fabric reinforced epoxy composite filled with graphite filler using Taguchi analysis was investigated by [34]. It was that applied load showed the major impact on abrasive wear, followed by abrading distance and filler content. A similar result on the glass–epoxy polymer composites with SiC and Graphite particles as secondary fillers was obtained under dry conditions [35]. Later on, however, effect of filler material on three-body abrasive wear behavior of glass–epoxy composites was investigated by [35] using a L_9 orthogonal array and analysis of variance (ANOVA). The result shows that the abrading distance has more effect on the wear compared to other parameters. The filler material (SiC) contributes a significant wear resistance of the G–E composites. Sahin (2005) developed weight loss model of aluminum alloy composites with 10 wt. % SiC particles using Taguchi method. They reported that the abrasive grain size was the major parameter, which affect the abrasive wear, followed by the reinforcement size [36]. Chauhan et al. (2010) concluded that, the sliding wear of the of glass fiber reinforced vinyl ester composites filled with fly ash particulate composites was affected by the (pv) factor and filler content, whereas the effect of sliding distance was insignificant [37]. The effect of the filler weight fraction, normal load, and sliding distance on the abrasive wear behavior of glass–epoxy composite showed that among the control parameters, sliding distance had the highest statistical influence on the abrasive wear of the composites, followed by normal load and filler content [38]. It was also found that the specific wear rate for all the vinyl ester composites decreases with the sliding distance and after certain duration attains approximately a steady state value [39]. The aforementioned reviews show that wear behaviour studies are based on experimental work. Therefore, the aim of this article is to optimize the parameters that influence the abrasive wear rate of reinforced PTFE using Taguchi approach and analysis of variance (ANOVA) to identify process variables which significantly influence COF and Ks of the tested composites.

Materials and Methods

Materials

The abrasive wear behaviour of filled-PTFE composites sliding against silicon carbide abrasive paper on hardened steel under non-lubricated conditions is investigated using pin-on-disc tribometer. In this article, three kinds of filled-PTFE composites are tested which are: 25 wt. % carbon, 25 wt. % glass and 40 wt. % bronze fibres coded as CF25, GF25 and BF40, respectively. Polymer Chemical Industry Ltd, Turkey, supplied the materials in the form of square plaques (100 × 100 × 6) mm.

Abrasive Test

Abrasive wear studies under sliding conditions were performed according to ASTM G99 on a pin-on-disc tribometer (Model: Arton Paar, Made in Switzerland) as shown in Fig 1. The counter face materials for the abrasive wear experiment is a steel disk of 100 mm in diameter and 10 mm thick. From the plaques, samples of square size 25 × 25 mm^2 were cut using Computer Numerical Control (CNC) water jet cutting for abrasive testing. The samples were loaded against SiC abrasive papers fixed to the steel holder by means of glue. The pin was then mounted in a steel holder in the tribometer so that it is held firmly perpendicular to that of the flat surface of the rotating counter steel disk. The samples for the filled-PTFE composites were tested under various loads of 5, 8 and 10 N, sliding speed 0.1, 0.12 and 0.15 m/s, sliding distance of 60, 75 and 90 m. Water-resistance silicon carbide (SiC) abrasive papers of different grit sizes (P220, P320, and P1000) were used. The abrasive wear was measured by the loss in mass (g). The wear pin was cleaned with a brush before and after the experiment to get rid of debris and then weighed on digital weighing balance (Model: PS 1000.RS RADWAG, Made in Poland) with 10^{-3} g sensitiveness. The wear rate was measured by converting the loss in mass to wear volume using density data. The specific abrasive wear rate (Ks) was computed using Eq. 3:

$$K_S = \frac{W_L}{\rho L D} \quad (3)$$

where W_L weight loss (g), ρ is the density (gcm^{-3}), L is load (N) and D is the sliding distance (m). Two replicates were performed for each sample and the outcomes are averaged from the two runs. The coefficient of friction (COF) of the samples was displayed on the computer monitor attached to the tribometer.

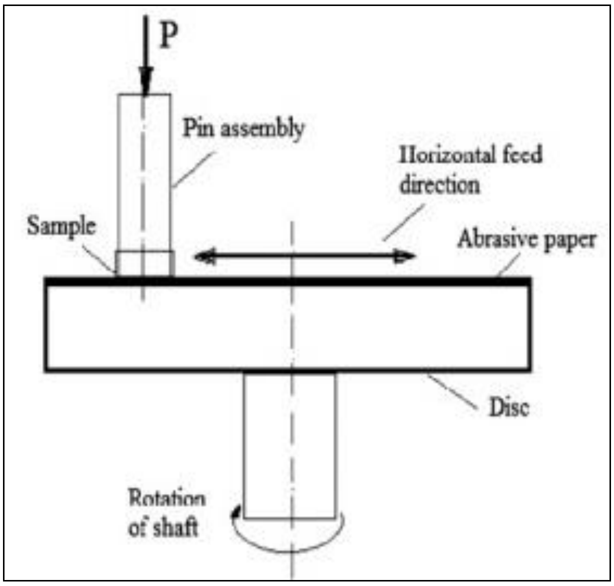


Fig 1: Schematic view of a pin-on-disc kind of arrangement

Experimental Design

An orthogonal array and analysis of variance (ANOVA) were used to study the significance of process variables on specific abrasive wear rate (Ks) of PTFE based composites. Genichi Taguchi used a loss function which is the difference between experimental and target values which are then converted to S/N ratio. S/N ratio described as the ratio of mean to standard deviation. Taguchi used the terms noise and signal to refer to unwanted value (standard deviation) and wanted response (mean), respectively. On the basis of the requirements, Taguchi split S/N ratio into three classes namely: higher-the-better, medium-the-better and smaller-the-better. In this article the quality characteristics like Ks and COF are the smaller-the-better to improve the abrasive wear resistance. Therefore, Eq. (4) has been applied to compute the S/N ratio. Taguchi analysis has been performed using Minitab 17 software tool and the means of mean plot, means of S/N ratio as well as analysis of variance (ANOVA) were obtained and presented in the subsequent sections. Signal noise (S/N) ratio the smaller-the-better is expressed in Eqn. 4 below. Table 2 shows the experimental set up and results obtained including the S/N ratios.

$$\text{S/N ratio} = -\log 10 \frac{1}{n} \left(\sum_{i=0}^{n} (yi)^2\right) \quad (4)$$

where n = is the number of observations and “y” is the observed data.

Four fundamental wear testing conditions which are load, L (N), grit size (P), sliding distance D, (m) and sliding speed V, (m/s) defined the process variables of the tested materials. Codes and levels of process variables are indicated in Table 1. Table 1 indicates that the experimental plan is made up of three levels. Each combination of experiment was performed twice to obtain a more accurate result in the experiment. The experiment was conducted according to a standard Taguchi experimental plan with notation L_9 (3^3) (Table 2).

Table 1: Process variables and their levels

Symbol	Process variables	Level 1	Level 2	Level 3
S	Sliding speed, (m/s)	0.10	0.12	0.15
D	Sliding distance, (m)	60	75	90
L	Load, (N)	5	8	10
G	Grit size, mesh or (P)	220	320	1000

Results and Discussion

Effect of load on COF and Ks of the PTFE reinforced composites

Fig 2 (a) shows the effect of load on COF for PTFE reinforced composites. Table 2 provides the results for COF. As seen in Fig. 2, COF of PTFE reinforced composites decreases as load increased from 5 N to 8 N and then increases as the load increased to 10 N. The decrease in COF is related to the major function played by the fibres that formed a layer at the contact region and the viscoelastic and temperature-related properties of polymer reinforced composites. Sliding of two materials leads to heat production at the asperities. This increases the temperature at the frictional surfaces of the two materials affecting the viscoelastic behaviour response of materials to stress, adhesion and transferring property. This agrees with the result of [45] when they investigated friction coefficient and wear rate of polymer based composites against rough and smooth surfaces. The increase in COF due to increase in load is attributed to tearing of tribo layer at the contact region. More so, as rubbing continues the disc materials becomes worn out and the reinforcing fibres come in touch with roughening of the disc surface leading to ploughing and thus COF increases with increase in load. This finding was contrary to results obtained by [46] when epoxy polymer was reinforced with fly ash at different percentage ratios. Fig 2 (b) depicts the variation of Ks with load. As seen in the figure, increasing load decreases Ks of PTFE reinforced composites. The decrease in Ks of PTFE reinforced composites is due to micro cutting and peeling off fibres which happened as a result of abrasive action, large contact area that allowed for particles to come in contact with the interface and share the stress. Furthermore, formation of uniform, adherent and thin transfer film along the counter surface led to decrease in Ks of PTFE reinforced composites. Different values of Ks computed using Eq. 3 for the three PTFE reinforced composites were presented in Table 4 highlighting the magnitudes of GF25, CF25 and BF40 composites. This agrees with literature data that indicated that addition of strong reinforcement into polymeric materials reduced wear of polymer [47]. Of all the materials in this article, CF25 composite proved to be highly abrasive wear resistant than its counterparts at high load.

Effect of grit size on specific wear rate of the PTFE and its composites

Fig 2 (a) shows the variation of COF as function of grit size. As seen increasing the grit size COF from P220 to P320 increases COF and then drastically decreases at P1000. This implies that at P320 COF was high but low at P1000. High COF is attributed to high roughness of the SiC paper that offers significant amount of resistance to the samples while the low COF is attributed to smoothness of the SiC paper that offers little resistance to the materials investigated. Similarly, Fig 2 (b) shows the effect of grit size on Ks. It was observed that as the grit size increases there was a corresponding decrease in Ks. Maximum and minimum Ks were obtained at P220 and P1000, respectively.

Maximum Ks can be explained on the basis of attack by rough SiC particles in which the individual abrasive grains penetrated deeply into the surface of the PTFE reinforced composites. Consequently, materials are removed from the surfaces of the materials by extensive microploughing process. During this action, huge amount of plastic deformation occurs. However, the minimum Ks at higher grit size of 1000 mesh is associated with the track becoming clogged with wear debris and transfer films and consequently reduces the abrasive ability of the grits leading to lower Ks. Of all the PTFE reinforced composites, CF25 composite proved to be the most efficient against abrasion. This finding agrees with the literature data [48].

Effect of distance on Ks of PTFE reinforced composites

Fig 2 (a) and (b) displays COF and Ks as a function of sliding distance, respectively. As seen in the figures, there was increase in COF but a decrease in Ks as the sliding distance increases. This is more noticeable at a distance of 90 m when COF of PTFE reinforced was high while Ks was low. In the course of repeated sliding of polymeric material pin surface over circular wear track on abrasive paper, circular path tends to become clogged with wear debris and transfer films. This progressively reduced the abrasive capacity and thus Ks is significantly minimized. The decrease in abrading effectiveness of the counter surface occurred due to fracture or pull out of abrasive grains due to presence of hard fibres (GF, BF and BF) and transfer of wear debris of polymer on counter surface. The wear debris collects in the crevices or depressions on the paper leading to clogging effect. Therefore, after a certain number of traverses, abrasion of materials is reduced and reached a minimum condition. CF25 composite was found as the best wear material.

Effect of sliding speed on COF and Ks PTFE and its composites

The effect of speed on COF and Ks of PTFE reinforced composites is indicated in Fig 2 (a) and (b), respectively. It was observed that the trend of COF is similar to Ks. From this graph it is seen that COF slightly increases and decreases with increase in speed while Ks keeps decreasing as the sliding speed increases. COF increase up to

0.12 ms^{-1} and then slightly decrease at the maximum sliding speed of 0.15 ms^{-1} for PTFE reinforced composites. The decrease in COF and Ks can be explained on the basis of adhesion between the counterface and the samples. As the speed increases the strength of the materials decrease while temperature raises up leading to increased adhesion between the samples and the counterface. Increasing speed increases the steady formation of transfer film at the interface of the counterface and the samples. Heat generation, albeit, is increased with increase in speed it is in a way helpful in the formation of tribo layer that will impact on the layer formation at the contacting surfaces.

Nevertheless, when the speed goes above 0.12 ms^{-1}, high heat is produced resulting in the formation of strong, uniform and thin tribo layer between the counterface and samples thereby preventing direct contact of samples with abrasive paper. CF25 composite shows the lowest Ks as compared to its counterparts.

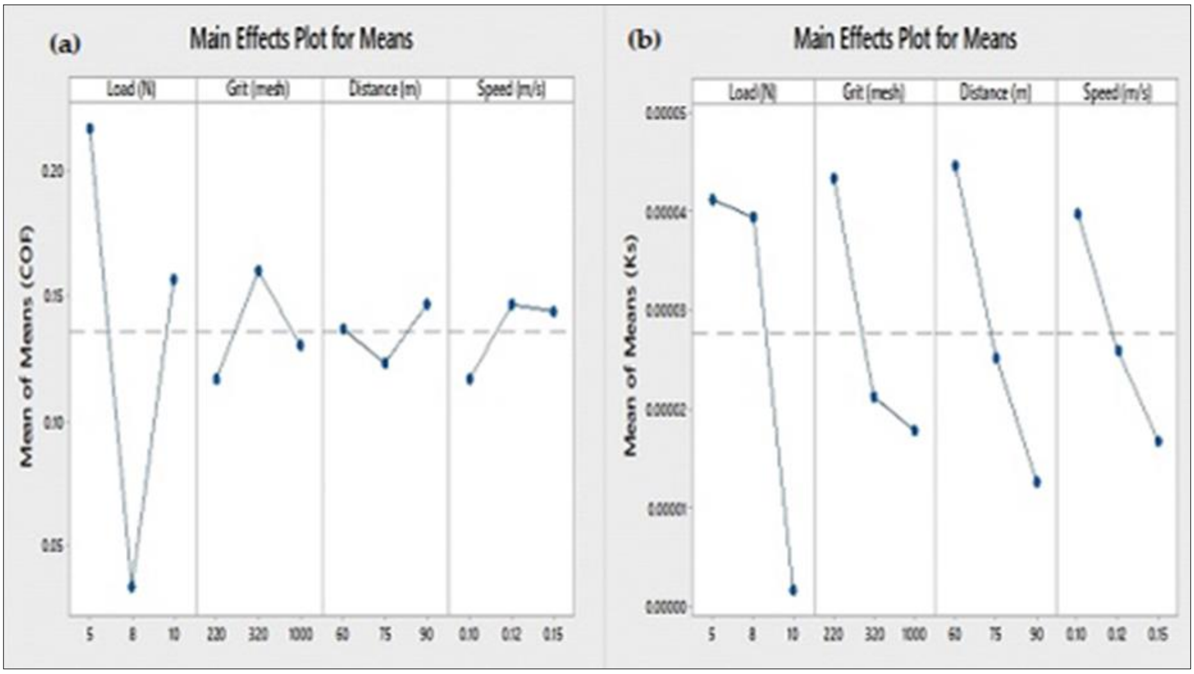


Fig 2: Effect of process variables on (a) COF and (b) Ks

Table 2: Experimental results of $L_9(3^4)$ orthogonal array design

Trials	L (N)	G (P)	D (m)	S (m/s)	COF	Ks (mm^3/Nm)	COF S/N ratio (dB)	Ks S/N ratio (dB)
1	5	220	60	0.1	0.18	0.0000867	14.8945	81.243
2	5	320	75	0.12	0.24	0.0000311	12.3958	90.136
3	5	1000	90	0.15	0.23	0.0000060	12.7654	104.442
4	8	220	75	0.15	0.01	0.0000423	40.0000	87.469
5	8	320	90	0.1	0.05	0.0000307	26.0206	90.243
6	8	1000	60	0.12	0.04	0.0000455	27.9588	86.839
7	10	220	90	0.12	0.19	0.0000011	15.9176	117.376
8	10	320	60	0.15	0.16	0.0000019	14.4249	115.363
9	10	1000	75	0.12	0.12	0.0000020	18.4164	113.843

Selection of optimum abrasive test conditions

The computed S/N ratio response table for COF is depicted in Table 3. Fig 3 (a) and (b) shows the mean S/N ratio for COF and Ks obtained using Minitab software tool. Higher S/N ratio indicates the minimum variation difference between desirable response and the measured response. From Fig 3(a) it was observed that the maximum mean S/N obtained for COF are load at 8 N, grit size at P220, distance at 75 m and speed at 0.15 ms^{-1}. Thus, the predicted optimum process variables for obtaining low COF using Taguchi technique were found as L= 8 N, G = P220, D= 75 m and S = 0.15 ms^{-1} and the corresponding level values were made bold to facilitate understanding from the mean S/N ratio response table. These predicted combination of optimum variables was coded as L2-G1-D2-S3 for COF.

Table 4 shows the obtained mean S/N ratio response table for Ks. From Table 4 the computed optimum process variables for obtaining low Ks was found to be load = 10 N, grit size = P1000, distance = 90 m and speed = 0.15 ms^{-1}.The combination of these optimum process variables was thus designated as L-3-G3-D3-D3 for the Ks as depicted in Fig 3 (b).

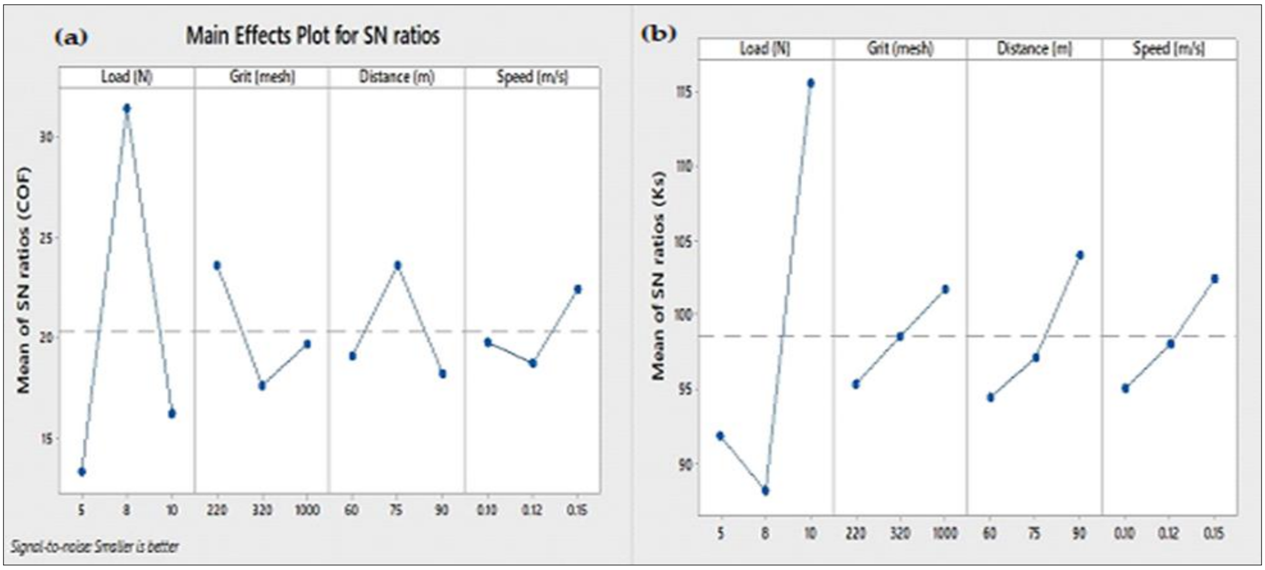


Fig 3: Main effects plot for (a) COF and (b) Ks

Table 3: Mean S/N ratio response table for COF (Smaller is better)

Symbol	Process variables	Mean S/N ratio				
		Level 1	Level 2	Level 3	Delta	Rank
L	Load (N)	13.35	31.33	16.25	17.97	1
G	Grit size (P)	23.60	17.61	19.71	5.99	2
D	Distance (m)	19.09	23.60	18.23	5.37	3
S	Speed (m/s)	19.78	18.76	22.40	3.64	4

Table 4: Mean S/N ratio response table for Ks (Smaller is better)

Symbol	Process variables	Mean S/N ratio				
		Level 1	Level 2	Level 3	Delta	Rank
L	Load (N)	91.94	88.18	115.53	27.34	1
D	Distance (m)	94.48	97.15	104.02	9.54	2
S	Speed (m/s)	95.11	98.12	102.42	7.32	3
G	Grit size (P)	95.36	98.58	101.71	6.35	4

Analysis of variance (ANOVA)

ANOVA furnishes the process variable that most significantly affect the performance characteristics. ANOVA outcomes obtained for COF and Ks are shown in Table 5 and Table 6, respectively. From Table 5 it was found that COF is significantly affected by load followed by grit size, distance and speed in the rank of first, second, third and fourth, respectively. The percentage contribution of load, grit size, distance and speed on COF are 80.79, 8.90, 6.71 and 3.60%, respectively. In a similar fashion, the Ks is significantly influenced by load, distance, speed and finally grit size as exhibited in Table 6. The percentage contribution for load is 82.13, for distance is 9.06, for speed is 5.05 and for grit size is 3.76%. Consequently, from this study it is vivid that for various compositions of fibre reinforced PTFE composites, rank of the experimental factors in ascending order for COF and Ks are load> grit size>distance>speed and load>distance>speed>grit size, respectively.

Table 5: ANOVA table for COF

Source	Degree of freedom	Sum of squares	Mean squares	%Contribution
Load (N)	2	558.71	279.36	81.54
Grit (mesh)	2	55.43	27.71	8.09
Distance (m)	2	49.92	24.96	7.29
Speed (m/s)	2	21.15	10.58	3.08
Total	8	685.21		100

Table 6: ANOVA table for Ks.

Source	Degree of freedom	Sum of squares	Mean squares	% Contribution
Load (N)	2	1318.12	659.06	82.13
Distance (m)	2	145.32	72.66	9.06
Speed (ms-1)	2	81.12	40.56	5.05

Grit size (P)	2	60.4	30.2	3.76
Total	8	1604.95		100

Confirmatory test

The final phase is to validate the improvement of the quality characteristic using the optimal combination of parameters namely L2-G1-D2-S3 and L3-G3-D3-S3 for COF and Ks, respectively according to Eq. (4).

$$\varepsilon_{predicted=\varepsilon_t} + \sum_{i=1}^{x}(\varepsilon_o - \varepsilon_t) \quad (4)$$

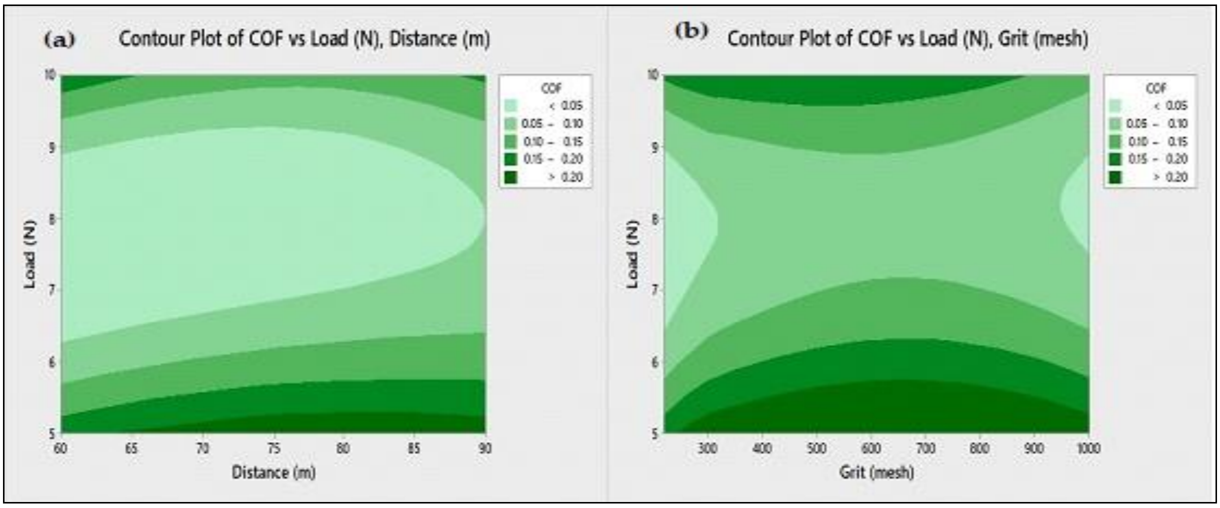
where ε_t = total of S/N ratio, ε_o = mean noise ratio at optimum level and x number of input process variables. According to the S/N ratios, the best testing factors for the COF of the tested composites were the parameter L at level 2, parameter G at level 1, parameter D at level 2 and parameter S at level 3. Based on the prediction, the predicted result of the S/N ratio was computed as 38.90 dB corresponding to 0.01 which is the minimum value of COF obtained in the experiment (Table 2). This table shows that a comparison of the theoretical COF with the real COF using the optimal combination of parameters. It cab deciphered that the error between confirmation and computation is within reasonable limit (1.10 DB). Similarly, the optimal combination of parameters for Ks was determined to be L3-G3-D3-S3. The S/N ratio was computed using Eq. (4). The predicted S/N ratio value was 119.03 dB. This corresponds to 1.1000E-06 mm^3/Nm which is the minimum value obtained in the experiment.

Table 7: Confirmatory test results for COF and Ks

Response	Error	Experiment	Prediction
COF	$\gamma exp - \gamma pre$ 0.01	L2-G1-D2-S3 0.02	L2-G1-D2-S3 0.01
S/N ratio(dB)	1.10	40.00	38.90
Ks (mm^3/Nm)	$\gamma exp - \gamma pre$ 2.1093E-07	L3-G3-D3-S3 1.34787E-06	L3-G3-D3-S3 1.1000E-06
S/N ratio (dB)	1.98	122.01	120.03

Contour plots

Contour plots x-rays the correlation among three variables one being the dependent variable (response) and two other independent variables (control factors) by visualizing discrete contours of the predicted variables. Fig. 8 indicates the contour plots illustrating the relation between process variables and COF value. From Fig. 4(a) it was exhibited that low COF was obtained at high levels of load and high level of distance. Fig 4 (b) depicts that low COF was found at medium load level and high speed level. In Fig 4 (c) it was noticed that low of COF was determined at low level of load and high level of speed. Fig 4 (d) exhibits that at high level of load and low level of grit size low COF was obtained. Fig 4 (e) showcases that low COF was found at high levels of distance and speed and finally Fig 4 (f) indicates that low COF was found at high level of grit and low level of speed. Fig. 5 depicts the contour plots of describing the correlation between process variable and the Ks. From Fig 5 (a) it was found to be high level of load and high level of distance leads to generation of low Ks. Fig. 5 (b) indicates that high level of grit size and load leads to production of low Ks. Fig 5 (c) shows that high level of load and speed results in low Ks. Fig 5 (d) indicates that high level of distance and low level of grit size leads to generation of low Ks. Fig 5 (e) unveils that high level of distance and high level of speed produces low Ks. Fig 5 (f) shows that high level of grit size and high level of speed leads to generation of low Ks.



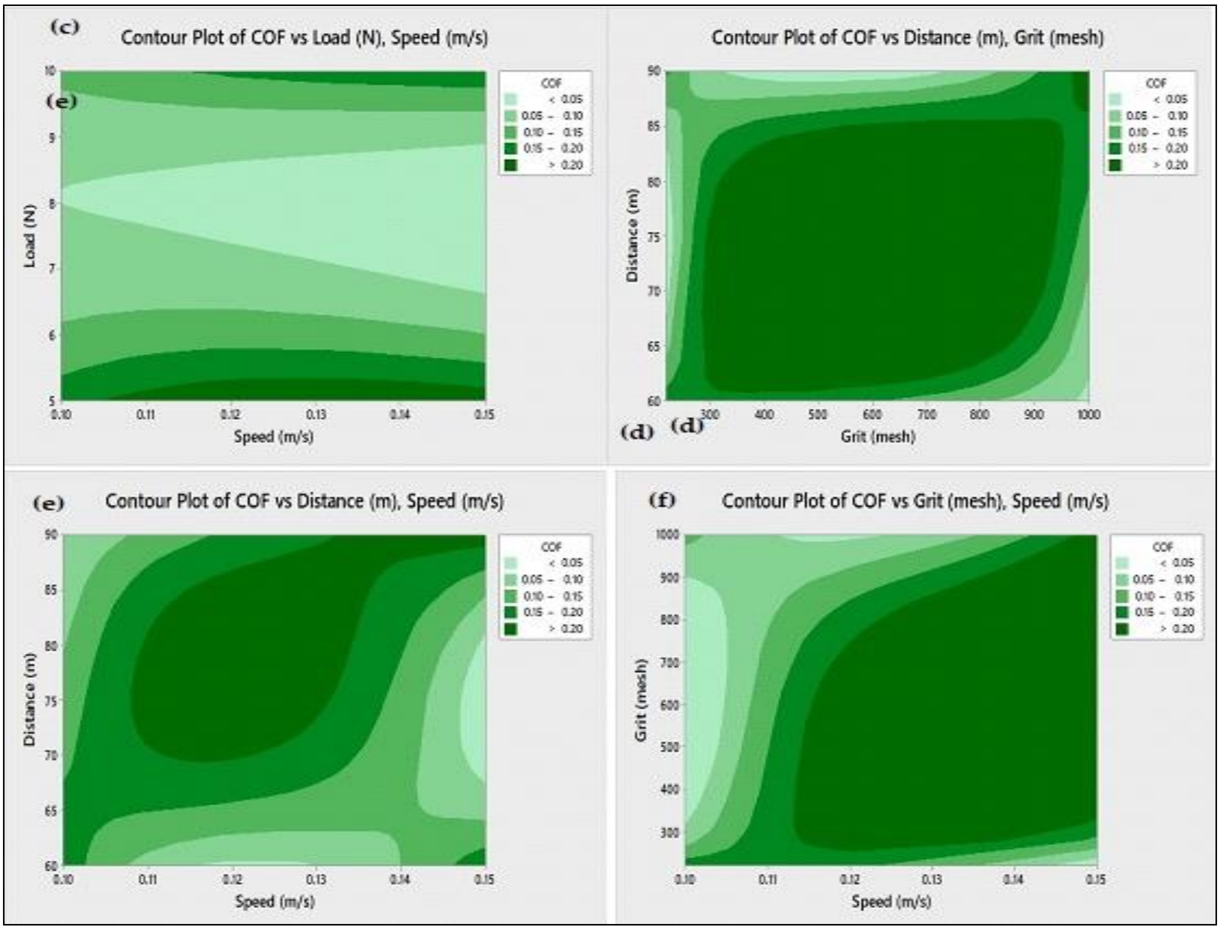
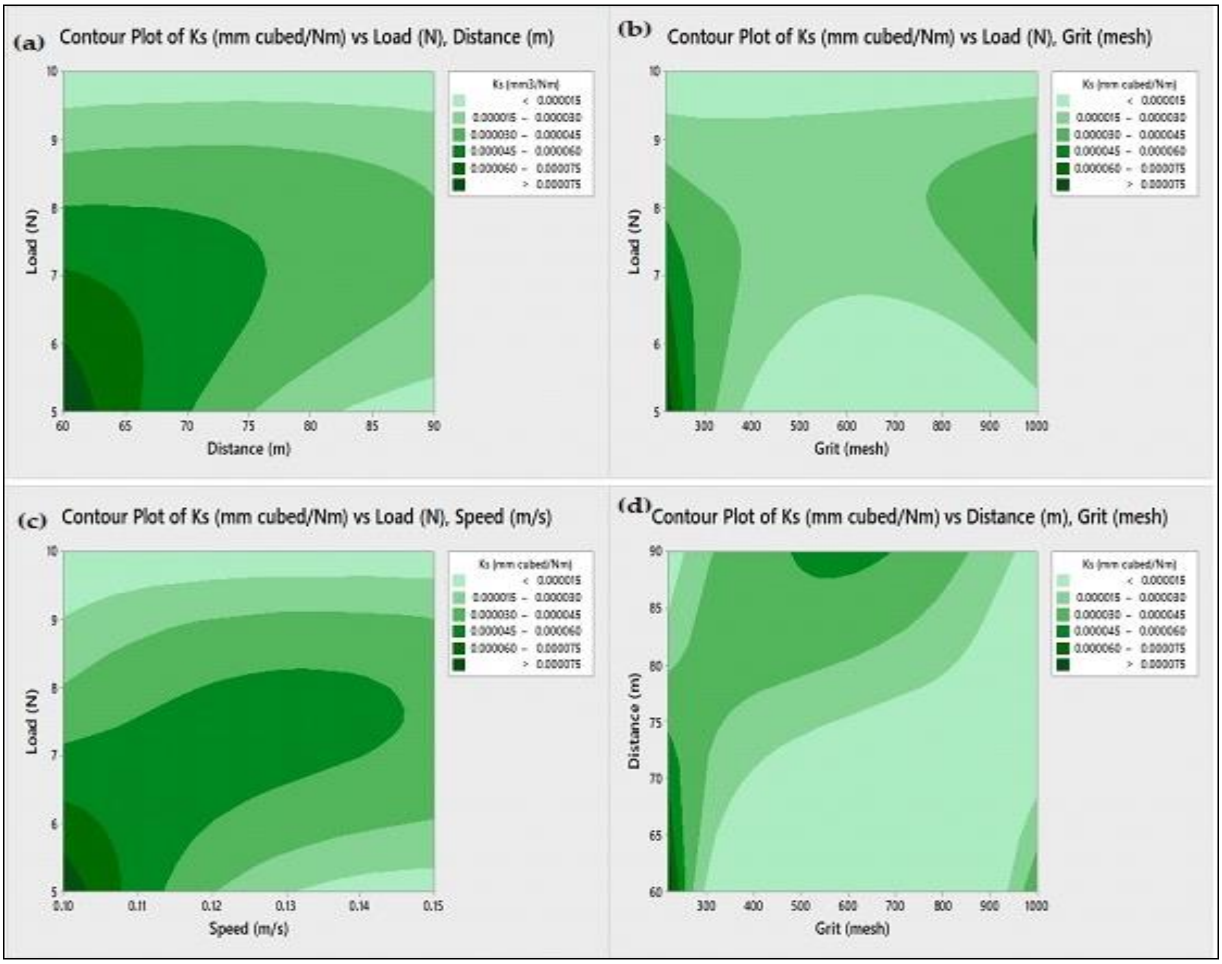


Fig 4: Contour plots for COF (a) L vs. D (b) L vs. G (c) L vs. S (d) D vs. G (e) D vs. S (f) G vs. S



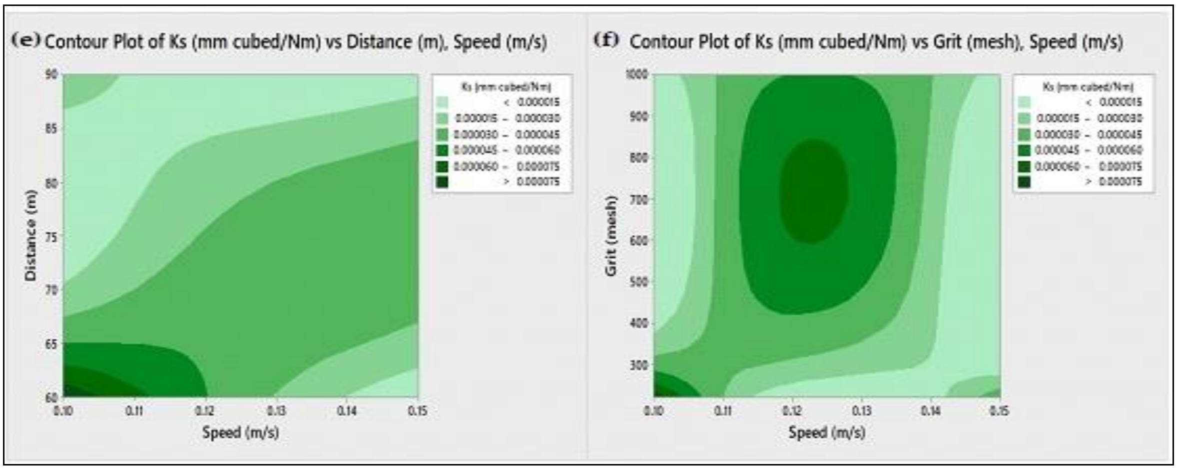


Fig 5: Contour plots for Ks (a) L vs. D (b) L vs. G (c) L vs. S (d) D vs. G. (e) D vs. S. (f) G vs. S

Conclusion

Parametric optimization of abrasive wear of PTFE based composites has been performed, results presented and the following conclusions were drawn: The COF increased with increase in load and distance but partially decreased with increasing grit size and speed for the PTFE reinforced composites tested against SiC abrasive papers. The Ks decreased when load, grit size, distance and speed increased. Introduction of 25 wt. % carbon fibre, 40 wt. % bronze fibre and 25 wt. % glass fibre into PTFE improved the abrasive wear resistance of the PTFE but CF25 composite was found to be more abrasive wear resistance than BF40 and GF25 composites. Taguchi approach for optimal process variables that minimize the COF and Ks were variables of combination of L2-G1-D2-S3 and L3-G3-D3-S3, respectively. From ANOVA results it was observed that COF and Ks were significantly influenced by load with a contribution of 80.76 and 82.13%, respectively. Confirmatory test revealed consistency between the predicted and experimental results for both COF and Ks. Confirmatory results revealed that predicted value of COF and Ks were found to lie close to the observed values with an error of 1.10 dB and 1.98 dB, respectively.

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