International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 22 (2015) pp 43199-43206
© Research India Publications. http://www.ripublication.com

Statistical Analysis of Optimization of Abrasive Wear Behavior of PEEK/Nano Alumina Particles Reinforced UHMWPE Composites

S. Selvam[1]

Department of Mechanical Engineering, Coimbatore Institute of Technology, Coimbatore-641014, Tamilnadu, India
selvamcit29@gmail.com

K. Marimuthu[2]

Department of Mechanical Engineering, Coimbatore Institute of Technology, Coimbatore-641014, Tamilnadu, India
kmmcit@gmail.com

Abstract –
The abrasive dry sliding wear tests were conducted to study the wear behavior of the UHMWPE matrix composites reinforced with PEEK and nano Alumina particles fabricated by compression moulding method. Filler content, applied load and sliding speed has been selected as wear parameters and specific wear rate and COF were considered as responses. The wear experiments were conducted on pin-on-disc wear test rig as per RSM based five level three factor central composite design matrix by sliding the pin shaped samples against 1000 grit size SiC abrasive papers, which were glued on the high chromium high carbon steel disc under dry sliding conditions. The test results revealed that the specific wear rate of the composite decreases with the increase of filler content and applied load and average COF increases with the increase of applied load while decreases with the increase of filler content. The optimum wear parameter combination for minimum specific wear rate and average COF were found using desirability method. The optimum wear parameter combination is found to be 4.19 wt. % of filler content, 17.35N of applied load and 0.57m/s of sliding speed. Analysis of variance (ANOVA) has been used to find out the most significant factor which affects the specific wear rate and average COF. From the test results, it is concluded that the filler content is the most significant factor which leaves an effect on specific wear rate followed by applied load. For average COF the most significant factor is applied load followed by filler content. Sliding speed provides less contribution to specific wear rate and average COF. To study the surface morphology of the abraded surfaces of the composites after the wear test, the micrograph of the samples has been recorded using scanning electron microscope. From the studies carried out on the UHMWPE composites it is observed that PEEK and Alumina particles can be used to increase the wear resistance of UHMWPE composites.

Keywords: Polymer matrix composites, UHMWPE, Statistical analysis, RSM, Wear and friction, Optimization.

1. Introduction

Nowadays, polymers and their composites are widely used in tribological components such as gears, cams, wheels, brakes, bearing liners, rollers, seals, clutches, bushings, transmission belts because of its outstanding strength to weight ratio, corrosion resistance, non-toxicity, design flexibility, easy fabrication, self-lubrication, high wear resistance and low coefficient of friction [1, 2]. Ultra High Molecular Weight Polyethylene (UHMWPE) is widely used in bearing applications because of its high wear resistance, low friction and chemical inertness. Especially because of its biocompatibility and high resistance to the biological environment UHMWPE is used as bearing material in Total Joint Replacement applications [3]. UHMWPE shows good performance in short term applications, whereas, in long-term applications it has some limitations for typical usage. The limitations are wear, creep and fatigue failures [4]. Several investigations have been done by various researchers to enhance the strength, modulus, surface hardness and wear resistance of the UHMWPE reinforced with micro and nano fibers along with particulate fillers. The fillers used include carbon nanotubes, kaolin, carbon fiber, hydroxyapatite, titanium di-oxide, Zirconium particles; Zinc oxide [5-11] etc., Boon Peng Chang [12] has investigated the mechanical and tribological properties of zeolite reinforced UHMWPE composite for implant applications. The results revealed, zeolite reinforcement significantly improves the mechanical properties and wear resistance of the UHMWPE. In recent years, inorganic materials are used as polymer filler due to their excellent mechanical properties, ability to induce electrical, low cost and their role as anti-blocking agent and nucleating agent in polymer. Liu et al [13] studied the mechanical and tribological properties of organic polymer PEEK filled UHMWPE. In their study they have reported that 12 wt. % PEEK reinforced UHMWPE composite gives better wear resistance and hardness.

PEEK is one of the most important engineering plastic material having higher yield strength and stiffness than UHMWPE with outstanding properties such as strength, modulus, toughness, resistance to creep, abrasion and fatigue, high temperature resistance (T_g=143°C, T_m=338°C, continuous service temperature of 250°C, heat distortion temperature often above 300°C), good resistance to aggressive solvents, favourable processing capability, high wear resistance, self-lubrication etc. [14]. Alumina is the most cost-effective and widely-used material in the family of engineering ceramics. It is hard and wear resistant, and has excellent dielectric properties, resistance to strong acid and alkali attacks at elevated temperatures, high strength, and stiffness. High purity alumina is widely used as load bearing component because of its excellent wear and corrosion resistance, and excellent biocompatibility [15]. So far surprisingly, there has been no study about enhancing the properties of UHMWPE composite using both organic and inorganic filler reinforcement. Hence, in this research work PEEK and nano α Alumina particles have been reinforced in UHMWPE to enhance the wear properties of UHMWPE composites. Majority of research work carried out by different researchers so far has been carried out the objective to study the effect of one factor by keeping all other factors fixed, this approach is not suitable because in actual environment there will be combined effects of interacting factors influencing the abrasive wear.

Hence in the present work, an attempt has been made to develop novel UHMWPE composites reinforced with organic material PEEK with constant weight percentage and inorganic material nano crystalline alpha Alumina of different weight percentage using compression moulding route. RSM based central composite design was adopted to conduct the abrasive wear experiments and to develop models to predict abrasive wear behavior of UHMWPE matrix composites. Using ANOVA, statistical analysis was carried out to study the interacting effects of wear parameters such as filler content (A), normal load (B) and sliding speed (C) on the abrasive wear behaviour of UHMWPE composites by considering responses specific wear rate and average COF. Optimization of the wear parameters to minimize specific wear rate and average COF of UHMWPE composites using RSM based desirability method is also reported in this work. Scanning electron microscopy (SEM) study has been carried out to study the abraded surfaces of the composites after the wear test.

2. Experimental Details

2.1 Materials

Compression moulding grade UHMWPE Powder with a bulk density of 0.933 g/cc, particle size of 150-180 µm, molecular weight of about 4×10^6 mole/g was purchased from Reliance Industries India Ltd and used as such. PEEK polymer with a density of 1.3 g/cc was procured from Mumbai. An Alumina nano particle with a density of 3.75g/cc was purchased from SRL chemicals, Chennai. UHMWPE, PEEK and nano Alumina and nano particles were quantified and mixed in a rotary ball mill to obtain nearly homogeneous mixture. Hot compression moulding process was used for fabricating 6 mm thickness UHMWPE composite plates.

2.2 Abrasive wear test

DUCOM TR-20 pin-on-disc wear test rig shown in Fig.1 was used for abrasive wear experiments. The square shaped wear test specimens with dimensions of 6 x 6 x 35 mm were cut from compression moulded plates.

The square-shaped specimen was clamped on the specimen holder as shown in Fig.1 and abraded against the Silicon carbide (SiC) abrasive paper of grit 1000 glued on the high chromium high carbon steel disc surface which act as a counter face in dry sliding conditions to simulate abrasive wear condition for 10 min. Design layout of wear parameters and their levels are as shown in Table-1. The responses in this work are specific wear rate and average COF. Winducom software was used to record the height loss and friction force of each sample during the wear experiments. Eqn. (1) and Eqn. (2) were used to compute the specific wear rate and average COF.

Fig.1. Pin on disc wear tester

TABLE.1. Design layout of wear parameters and their levels

Parameters		Levels				
		-1.68	-1	0	1	1.68
Filler content (wt. %)	PEEK	12	12	12	12	12
	Al_2O_3	1	1.81	3	4.19	5
Applied load (N)		9.81	13.8	19.6	25.5	29.4
Sliding speed(m/s)		0.21	0.34	0.53	0.71	0.84

$$Sp.wear\ rate = \frac{volume\ loss}{load\ x\ sliding\ distance} \quad (1)$$

$$Coefficient\ of\ friction = \frac{Friction\ force}{Normal\ force} \quad (2)$$

2.3 Design of experiment

Response surface Methodology (RSM) is a collection of statistical and mathematical techniques and is useful to realize the relationships between the independent and dependent parameters by modeling the process and optimize the processes [16]. In this work, a three factor five level Central composite rotatable design (CCD) has been used to design the experiments and built the regression models for the responses in terms of wear parameters to represent the relationship between the wear parameters and responses. The design matrix randomly generated using Design Expert statistical software consists of 20 experimental data including 8 factorial points, 6 axial points and 6 centre points as shown in Table 2 and are used to fit second order quadratic models to the responses. The wear tests were conducted as per the experimental design at room temperature.

2.4 Microstructural analysis

Microstructural analysis of the UHMWPE composites has been carried out using Field Emission Scanning Electron Microscope (FESEM). Before scanning, the abraded surfaces of the composites are coated with gold/palladium (Au-Pd) using a vacuum sputter chamber.

3. Results and Discussion

3.1 Analysis of variance (ANOVA)

The responses, specific wear rate and average COF were obtained for various combinations of wear parameters and are shown in Table 2. In statistical analysis, in order to find out statistical significance of the wear parameters and their interaction with the responses, analysis of variance (ANOVA) is performed. ANOVA is a collection of statistical design method used to check the level of significance of the input factors affecting the abrasive wear and the adequacy of the second order quadratic models. Model summary statistics for specific wear rate and average COF are given in Table 3 and Table 4. The results reveal that the quadratic models are the best suggested models for the responses. So, for further analysis, these models are used. Table 5 and Table 6 shows the results of ANOVA for full model of the specific wear rate and average COF and it is observed that the model *F* value for specific wear rate is 94.07 and for average COF it is 57.62 which indicate that the models are highly significant.

TABLE.2. Design matrix with experimental results

Std	Filler content (A) wt.%	Applied load (B) N	Sliding speed (C) m/s	Specific wear rate mm^3/Nm	COF
1	-1	-1	-1	0.000504	0.3194
2	1	-1	-1	0.000368	0.2565
3	-1	1	-1	0.000305	0.3132
4	1	1	-1	0.000282	0.3069
5	-1	-1	1	0.000641	0.2716
6	1	-1	1	0.000358	0.2068
7	-1	1	1	0.000441	0.3597
8	1	1	1	0.000224	0.3497
9	-1.682	0	0	0.000493	0.2715
10	1.682	0	0	0.000224	0.1915
11	0	-1.682	0	0.000506	0.2368
12	0	1.682	0	0.000303	0.3772
13	0	0	-1.682	0.000323	0.3675
14	0	0	1.682	0.000356	0.3236
15	0	0	0	0.000203	0.2463
16	0	0	0	0.000224	0.2578
17	0	0	0	0.000223	0.2576
18	0	0	0	0.000203	0.2601
19	0	0	0	0.000203	0.2439
20	0	0	0	0.000233	0.2472

The models are considered as significant at 95% confidence level when the value of P is less than 0.05. Furthermore, the significance of each coefficient in the full model was examined by the values of F and P. The coefficient which is having larger F value and smaller P value is the most significant factor [17]. Eqn. (3) and Eqn. (4) correspond to the final empirical models in terms of coded values for specific wear rate and for average COF of UHMWPE composites. It should be noted that the equations (3) and (4) are valid for only the selected range of wear parameter conditions for abrasive wear behavior of UHMWPE composites reinforced with PEEK and nano Alumina particles against 1000 grit size abrasive paper. In the models the coefficient value greater than 0.1 indicates that the model terms are not significant. It is noted that the filler content (A), normal load (B), sliding speed (C), AB, AC, A^2, B^2 and C^2 terms in the model are significant for specific wear rate. Only the interaction term BC is not significant. For average COF A, B, AB, BC, A^2, B^2 and C^2 terms are significant. Only the terms C and AC are not significant.

TABLE.3. Model summary for specific wear rate

Source	R^2	Adj.R^2	Pre. R^2	PRESS
Linear	0.5318	0.444	0.3294	2.06E-07
2FI	0.5933	0.406	-0.1348	3.48E-07
Quad	0.9883	0.978	0.9281	2.20E-08 Suggested
Cubic	0.9951	0.985	0.5699	1.32E-07 Aliased

TABLE.4. Model summary for average COF

Source	R^2	Adj.R^2	Pre. R^2	PRESS
Linear	0.4685	0.369	0.1065	4.80E-02
2FI	0.578	0.383	0.0818	5.00E-02
Quad	0.9811	0.964	0.8849	6.22E-03 Suggested
Cubic	0.9953	0.985	0.9867	7.19E-04 Aliased

TABLE.5. ANOVA for specific wear rate

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob>F
Model	3.03E-07	9	3.37E-08	94.07	< 0.0001
A	9.05E-08	1	9.05E-08	252.86	< 0.0001
B	6.75E-08	1	6.75E-08	188.82	< 0.0001
C	4.97E-09	1	4.97E-09	13.89	0.0039
AB	4.01E-09	1	4.01E-09	11.2	0.0074
AC	1.45E-08	1	1.45E-08	40.64	< 0.0001
BC	3.00E-10	1	3.00E-10	0.84	0.3812
A^2	4.15E-08	1	4.15E-08	116.04	< 0.0001
B^2	7.05E-08	1	7.05E-08	197.03	< 0.0001
C^2	3.18E-08	1	3.18E-08	88.81	< 0.0001
Resi	3.58E-09	10	3.58E-10		
L. of Fit	2.68E-09	5	5.35E-10	2.97	0.1286
P. Error	9.01E-10	5	1.80E-10		
C.Total	3.06E-07	19			

A higher value of regression coefficient will be honestly translated into a higher effect of the wear parameters to the responses. From the specific wear rate and average COF eqns. (3) and (4), one can identify which wear parameter and parameter interaction mostly affects the responses. For specific wear rate the filler content shows the highest regression coefficient values, followed by normal load and sliding speed. So it is evident that the filler content is the most significant parameter followed by normal load and sliding speed and for average COF normal load is the most significant parameter followed by filler content and sliding speed. Similar observations were noticed by Boon Peng Chang et al [15] in their work of optimization of wear performance of UHMWPE composites using response surface methodology.

$$\begin{aligned}\text{Specific wear rate} &= 2.14E\text{-}04 - 8.14E\text{-}05*A \\ &- 7.03E\text{-}05*B + 1.91E\text{-}05*C + 2.24E\text{-}05*A*B \\ &- 4.26E\text{-}05*A*C - 6.13E\text{-}06*B*C \\ &+ 5.37E\text{-}05*A^2 + 6.99E\text{-}05*B^2 + 4.70E\text{-}05*C^2 \qquad (3)\end{aligned}$$

$$\begin{aligned}\text{Average COF} &= 0.25 - 0.020*A + 0.037*B - 6.01E\text{-}03*C \\ &+ 0.014*A*B - 7.00E\text{-}04*A*C + 0.023*B*C \\ &- 7.15E\text{-}03*A^2 + 0.02*B^2 + 0.033*C^2 \qquad (4)\end{aligned}$$

TABLE.6. ANOVA for average COF

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob>F
Model	0.053	9	5.89E-03	57.62	< 0.0001
A	5.68E-03	1	5.68E-03	55.57	< 0.0001
B	0.019	1	0.019	187.25	< 0.0001
C	4.93E-04	1	4.93E-04	4.82	0.0529
AB	1.55E-03	1	1.55E-03	15.17	0.003
AC	3.92E-06	1	3.92E-06	0.038	0.8487
BC	4.36E-03	1	4.36E-03	42.66	< 0.0001
A^2	7.37E-04	1	7.37E-04	7.21	0.0229
B^2	5.50E-03	1	5.50E-03	53.83	< 0.0001
C^2	0.016	1	0.016	155.11	< 0.0001
Resi	1.02E-03	10	1.02E-04		
L. of Fit	7.71E-04	5	1.54E-04	3.06	0.1223
P. Error	2.52E-04	5	5.03E-05		
C.Total	0.054	19			

3.2 Checking Adequacy of Mathematical Models

Using determination coefficients R^2 and adj. R^2 the developed mathematical models were tested for goodness of fit. The determination coefficient (R^2) is proportional to the variation of the dependent variable and adjusted determination coefficient (adj. R^2) is adjusted for the number of wear parameters in the mathematical model. The R^2, adj. R^2 and predicted R^2 values of mathematical models for specific wear rate are 0.9883, 0.9778 and 0.9281 respectively. For average COF R^2, adj. R^2 and predicted R^2 values are 0.9811, 0.9641 and 0.8849 respectively. High R^2 value, which is close to 1, is desirable for both the models. The predicted R^2 is in good agreement with the adjusted R^2. These values obviously show the excellent correlation existing between the experimental and predicted values of the responses.

3.3 Residual plots for specific wear rate and COF

Using regression models the residuals (difference between the measured values and predicted values) of each experiment were calculated. The adequacy of the developed regression models for specific wear rate and average COF were checked by using the normal probability plots shown in figs. 2 and 3. The normal probability plot is used to vary the normality assumption. From normal probabilities of residuals figs. 2(a) and 3(a) it can be observed that the data are spread roughly very close to the inclined straight line. Therefore it can be concluded that the data are normally distributed [18]. Figs. 2(b) and 3(b) show the correlation between the residuals. The residuals are evenly distributed in both positive and negative sides along the run and it indicates the presence of a definite correlation. Figs. 2(c) and 3(c) show the plot of residuals versus fitted values. This plot does not expose any obvious pattern and hence the fitted models are sufficient. Figs.4 (a) and 4 (b) show the two dimensional perturbation graph of the specific wear rate and average COF as a function of dry sliding wear parameters of filler content, normal load, and sliding speed. Fig.4 (a) depicts that the specific wear rate decreases and it is directly proportional to the filler content and normal load while the specific wear rate slightly increases with increase in sliding speed. Fig.4 (b) depicts that the average COF increases with increase in normal load and decreases with the increase of filler content.

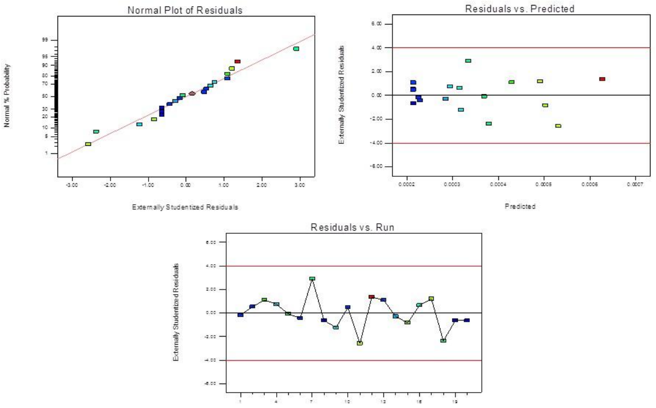

Fig.2. Residual plots for specific wear rate

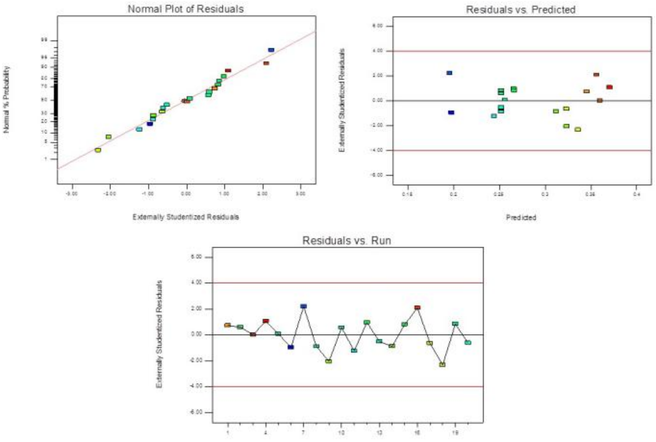

Fig.3. Residual plots for average COF

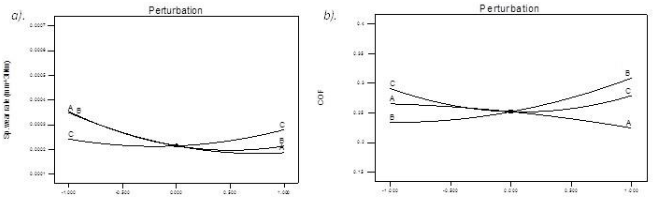

Fig.4. perturbation plots for specific wear rate and average COF

3.4 Effect of wear parameters on specific wear rate

Fig.5 shows the 3D surface plot which gives a thorough translation of specific wear rate as a function of filler content, normal load, and sliding speed for PEEK and nano Alumina particles filled UHMWPE composites. Fig. 5(a) shows the combined effect of filler content and sliding speed of UHMWPE composites. The plot reveals that the specific wear rate decreases with increase of filler content and slightly decreases to some extent and then increases with the increases of sliding speed. Fig.5(b) shows the combined effect of applied load and sliding speed on UHMWPE composites. The plot reveals that the specific wear rate decreases with the increase of normal load and slightly decreases with the increase of sliding speed to some extent and then increases with the increase of sliding speed. Fig.5(c) shows the combined effect of filler content and applied load on the specific wear rate of UHMWPE composites. The plot reveals that the specific wear rate decreases steadily with the increase of filler content and normal load. From the plots, it is observed that the filler content is the most significant affecting factor on the specific wear rate of UHMWPE composites followed by normal load. The sliding speed slightly affects the specific wear rate of UHMWPE composites.

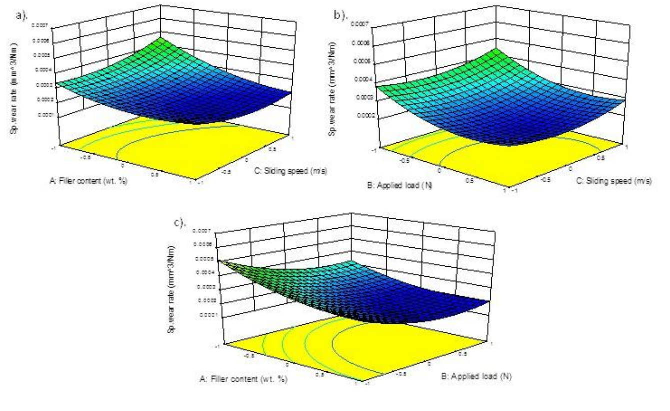

Fig.5. 3D surface plots for specific wear rate

The specific wear rate is moderately high at lower load because of less penetration of abrasive particles in to the UHMWPE composites. The specific wear rate decreases significantly with the increase of normal load because of the increasing contact stress between the sample and abrasive paper [19], high depth of girt penetration into the polymer surface and also because of the severe plastic deformation. Hence, the specific wear rate decreases with the increase of normal load. The specific wear rate decreases considerably with the increase of filler content when compared to normal load because the mechanical properties such as hardness of the UHMWPE composites increased due to the reinforcement of hard filler particles into the soft UHMWPE polymer matrix material. Hence even at higher loads, energy generated by abrasive particles is not sufficient, to penetrate deeper into the matrix material [20]. The wear rate decreases considerably with increase of sliding speed to some extent and then increases with the increase of sliding speed. Because sliding contact area increases due to plastic deformation of sliding surface when the sliding speed is increased.

3.5 Effect of wear parameters on average COF

Fig.6 shows the 3D response surface plots of coefficient of friction as a function of filler content, applied load and sliding speed. Fig.6 (a) shows the combined effect of filler content and sliding speed on average COF of UHMWPE composites. From the plot it can be seen that the average COF decreases with the increase in filler content. Fig.6 (b) shows the combined effect of applied load and sliding speed. From the plot it can be seen that the COF increases with the increase in applied load. From both figures it is observed that average COF slightly increases with the increase in sliding speed. However, increase in sliding speed decreases the average COF to a certain extent and then makes it to increase with further increase in sliding speed. It is seen that the maximum value is observed at the maximum applied load and speed conditions. Fig.6(c) shows the combined effect of applied load and filler content. From the plot it is observed that the average coefficient of friction increases with the increase in applied load and decreases with the increase in filler content.

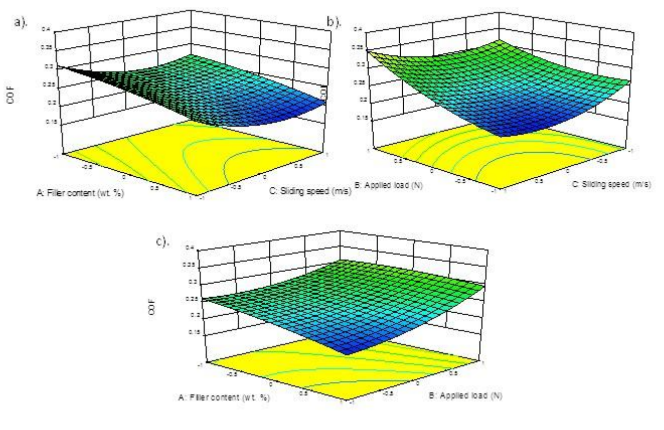

Fig.6. 3D surface plots for average COF

The increase of applied load increases the frictional contact between the sample surface and counterface. Due to this the average COF increases with the increase in applied load. The average COF is found to decrease with increase in sliding speed to certain extent and then increases with further increase of sliding speed. This may be due to the increase in area of contact between the sample surface and counterface because of plastic deformation producing an increase in friction force.

3.6 Optimization of responses

The wear performance of a material not only depends on the material properties but also on external factors such as load, sliding speed, sliding distance etc., [21]. To increase the life of the UHMWPE composites, it is required to find the optimum condition of wear parameters. So with the aim to increase the life of the UHMWPE composites, abrasive wear experiments were carried out with in the selected range of wear parameters to optimize the abrasive specific wear rate and average COF of the UHMWPE composites using RSM based CCD. Desirability approach has been used to find the optimum solutions. The obtained optimized best solutions are presented in Fig.7 in the form of contour plots. The solution which is having high desirability is prepared. The predicted best optimal condition of the wear parameters to produce lowest specific wear rate of 0.0002135mm^3/Nm and average COF of 0.2057 are filler content of 4.19wt.%, applied load of 17.35N and sliding speed of 0.57m/s with a desirability of 0.949.

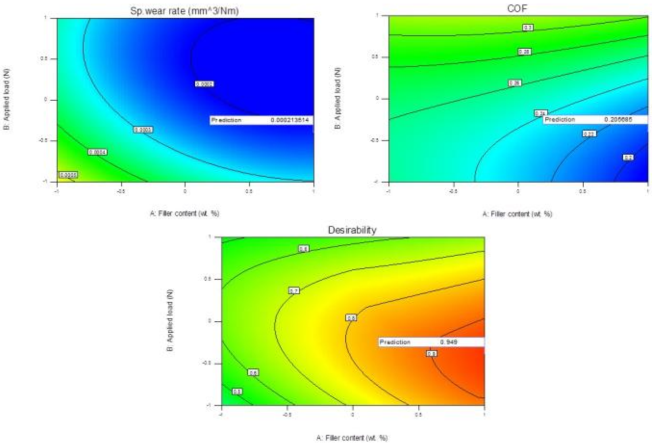

Fig.7. Contour plots for optimized values and desirability

Fig.8, the ramp function graph shows the combined desirability of responses. The dot on each ramp reflects the factor setting or response prediction for those response characteristics.

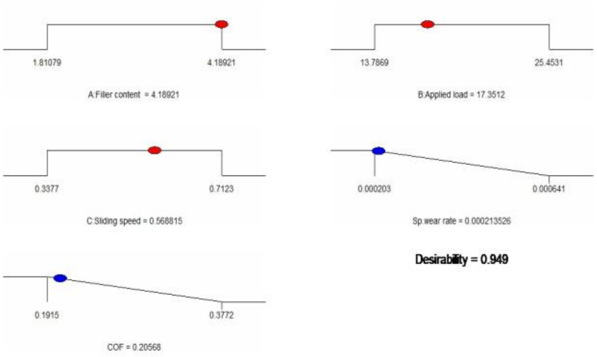

Fig.8. Ramp function graph

The dot height on the inclined line shows how much it is desirable. A linear ramp function is created between the range and the goal as the weight for each parameter is set equal to one. Fig.9, the bar graph shows the combined desirability function of the responses. Desirability varies from 0 to 1 depending upon the closeness of the response towards target. The bar graph shows how well each variable satisfies the criterion. A value near to one is considered to be good.

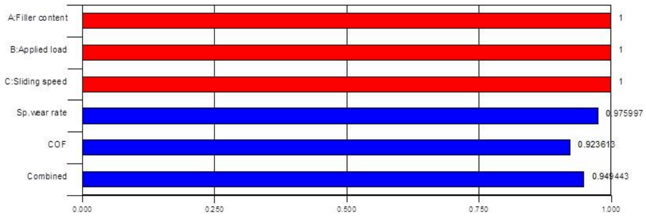

Fig.9. Bar graph

3.7 Microstructural analysis on abraded surfaces

Before conducting SEM examination, abraded surfaces were sputtered with a gold coating. Fig.10(a) to 10(d) shows SEM micrograph of abraded surfaces of UHMWPE composites after abrasive wear test. In the polymer composites commonly occurring wear mechanisms are adhesive, abrasive and fatigue wear. While sliding wear grooves would form due to indentation of some abrasive particles into UHMWPE composites surfaces under applied load and plastic deformation, micro-ploughing would result due to shear stress.

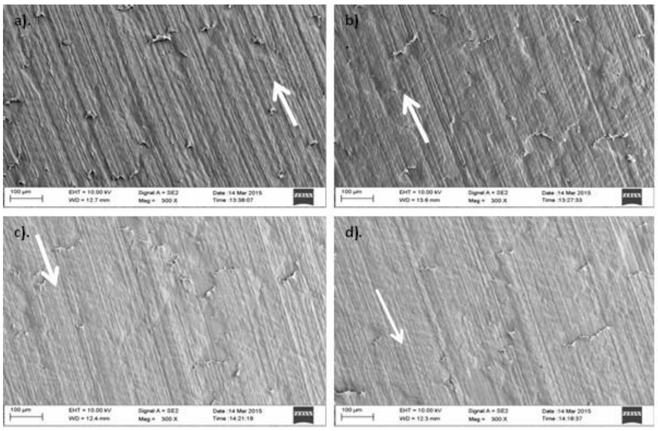

Fig.10. SEM micrographs of the abraded surface of UHMWPE composites under a) 1.81 wt. % filler content, 25.45N, 0.34m/s b) 3 wt. % filler content, 29.43N, 0.53 m/s c) 5 wt. % filler content, 19.62N and 0.53 m/s d) optimized condition of 4.19 wt. % filler content, 17.35N and 0.57m/s. The arrow indicates the sliding direction.

Fig.10(a), Fig.10(b) and Fig.10(c) are SEM micrograph images of the samples corresponding to the wear parameters of 1.81 wt. % filler content, 25.45 N applied load and 0.34 m/s sliding speed, of 3 wt. % filler content, 29.43 N applied load and 0.53m/s sliding speed and of 5 wt. % 19.62N applied load and 0.53m/s sliding speed respectively. The images show the presence of wear grooves from deeper to shallower on the surfaces for all UHMWPE composites. This indicates that reinforcement of nano Alumina / PEEK particles into UHMWPE increases the micro cutting and micro ploughing resistance. The high surface mechanical strength of the UHMWPE/PEEK/ nano Alumina composite helps in preventing serve plastic deformation and formation of deeper wear grooves during sliding action. From the ANOVA results, it is found that the filler content is the main parameter affecting the wear of UHMWPE composite followed by applied load. The SEM micrographs support the above said statement. Fig.10 (d) shows the SEM micrographs of abraded surface of UHMWPE composites at the optimized wear parameter condition of 4.19 wt. % filler content, 17.35N applied normal load, 0.57m/s sliding speed. The micrograph show the presence of smoother and shallow wear grooves instead of deep wear grooves. It supports the optimized result.

4. Conclusion

- PEEK and nano Alumina particles reinforced UHMWPE composites have been successfully fabricated using compression moulding route to study the wear behavior.
- RSM based full central composite rotatable design has been implemented to develop second order polynomial equation for describing the effect of filer content, applied load and sliding speed on the abrasive wear behaviour of UHMWPE composites at 95% confidence level.
- The models show the correlation between the wear parameter and responses. From the models it is observed that specific wear rate is highly influenced by filler content followed by applied load and average COF is highly influenced by applied load followed by filler content. The sliding speed is found to have very little effect on specific wear rate and average COF.
- The developed regression models are highly adequate as their R^2 values are very close to one and hence the models can be used for reliable prediction.
- The predicted optimum values of specific wear rate and average COF are 0.0002135mm^3/Nm and 0.2057 respectively. The relevant abrasive dry sliding wear parameters are 4.19wt% filler content, 17.35N applied load and 0.57 m/s sliding speed respectively.
- The wear resistance of the composites increased with addition of PEEK and nano Alumina particle content.

References

[1] Happer, C. A., 2004, Handbook of Plastics, Elastomers and Composites, 4th edition, McGraw-Hill, New York.

[2] Li, J., and Liang, Z. N., 2010, "Sliding wear performance of TiO2/short carbon fibre/polyamide 66 hybrid composites," Polym. Plast. Technol., 49(8), pp. 848-852.

[3] Ankur Gupta., Garima Tripathi., Debrupa Lahiri., and Kantesh Balani., 2013, "Compression Molded Ultra High Molecular Weight Polyethylene Hydroxyapatite-Aluminum Oxide-Carbon Nanotube Hybrid Composites for Hard Tissue Replacement," J.Mater.Sci. Technol., 29(6), pp. 514-522.

[4] Ramakrishna, S., Mayer, J., Wintermantel, E., and Leong, K. W., 2001, "Biomedical application of polymer composite materials: A review," Comp.Sci.Tech., 61, pp.1189-1224.

[5] Zoo, Y.S., An, J. W., Lim, D. P., and Lim, D. S., 2004, "Effect of Carbon Nanotube Addition on Tribological Behavior of UHMWPE," Tribol. Lett., 16, pp. 305-309.

[6] Guofang, G., Huayong, Y., and Xin, F., 2004, "Tribological properties of kaolin filled UHMWPE composites in unlubricated sliding," Wear., 256, pp. 88-94.

[7] Dangsheng, X., 2005, "Friction and wear properties of UHMWPE composites reinforced with carbon fiber," Mater. Lett., 59, pp. 175-179.

[8] Fang, L., Leng, Y., and Gao, P., 2006, "Processing and mechanical properties of HA/UHMWPE nanocomposites," Biomaterials., 27, pp. 3701-3707.

[9] Xiong, D.,Lin, J., Fan, D., and Jin, Z., 2007, "Wear of nano-TiO_2/UHMWPE composites radiated by gamma ray under physiological saline water lubrication," J Mater Sci: Mater M., 18, pp. 2131-2135.

[10] Plumlee, K., and Schwartz, C.J., 2009, "Improved wear resistance of orthopaedic UHMWPE by reinforcement with Zirconium particles," Wear., 267, pp. 710-717.

[11] Chang, B. P., Akil, H. M., Nasir, R. M., and Nurdijati, S., 2013, "Abrasive wear performance and antibacterial assessment of untreated and treated ZnO-reinforced polymer composite, "Polym. Composite., 34,pp. 1020-1032.

[12] Boon Peng Chang, Hazizan Md Akil, and Ramdziah Md. Nasir, 2013, "Mechanical and Tribological Properties of Zeolite-reinforced UHMWPE Composite for Implant Application," Procedia Engineering, 68, pp. 88-94.

[13] Yemei, Liu., and Sujeet, K. Sinha, 2013, "Mechanical and tribological properties of PEEK particle-filled UHMWPE composites: The role of counterface morphology change in dry sliding wear," J Reinf. Plast. Comp., 0(00), pp. 1-10.

[14] Mallick, P. K., 2008, Fibre-reinforced composites: Materials, manufacturing, and design, Third edition, CRC Press Taylor & Francis Group, New York.

[15] Basu, B. D., Katti, S., and Ashok kumar., 2009, Advanced biomaterials, fundamentals, processing and applications, John wiley and sons,Inc., Hoboken, New Jersey.

[16] Montgomery., and Douglas, C., 2005, Design and Analysis of Experiments: Response surface method and design, New Jersey, John Wiley and Sons, Inc.

[17] Majumder, A., and Goyal, A., 2008, "Enhanced production of exocellular glucansucrase from Leuconostoc dextranicum NRRL B1146 using response surface method," Bioresource Technol., 99, pp. 3685-3691.

[18] Boon Peng Chang, Hazizan Md Akil, Ramdziah Bt Nasir., and Abbas Khan., 2015, "Optimization on wear performance of UHMWPE composites using response surface methodology," Tribol. Int., 88,pp. 252-262.

[19] Mohd Shadab Khan., Zahir Hasan., and Yaqoob Ali Ansari., 2014, “Statistical Analysis for the Abrasive Wear Behavior of Al 6061,” J. Minerals and Materials Characterization and Engineering., 2, pp. 292-299

[20] Boon Peng Chang, Hazizan Md Akil., and Ramdziah Bt Nasir., 2013, “Comparative study of micro-and nano-ZnO reinforced UHMWPE composites under dry sliding wear,” Wear., 297, pp. 1120-1127

[21] Basavarajappa, S., Joshi Ajith, G., Arun, K. V., Praveen Kumar, a., and Prasanna Kumar, M., 2010, “Three-body abrasive wear behaviour of polymer matrix composites filled with SiC Particles,” J. Polym. Plast. Technol., 49, pp. 8-12.