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Improved Wear Resistance of Polytetrafluroethane using Bronze Material Under Dry Condition

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Abstract: In this paper, the effects of load, velocity of sliding and sliding distance on friction and wear of material made of polytetrafluoroethylene (PTFE) and PTFE composites with filler materials such as 25% and 40% bronze, are studied. The experimental work is performed on a pin-on disc apparatus and analyzed with the help of Design-Expert 13 software. The results of experiments are presented in tables and graphs which show that the addition of bronze filler to the virgin PTFE decreases wear rate significantly and there is marginal increase in coefficient of friction. The highest wear resistance was found for 40% bronze filled PTFE followed by 25% bronze filled PTFE. Through this study, we can design and develop the best bearing material for industrial applications.

Key Word: PTFE, Box-Behnken Design, Bronze material, Wear resistance and polymer

I. Introduction

Polymer and their composites form a very important class of tribo-engineering materials and are invariably used in many mechanical components such as gears, cams, wheels, impellers, brakes, seals, bearings, bushes, bearing cages etc. where adhesive wear performance in nonlubricated condition is a key parameter for the material selection. For tribological loaded components, the coefficient of friction, the mechanical load carrying capacity, and the wear rate of the materials determine their acceptability for industrial applications. Polymer based composite materials are the ones employed in such tribological applications owing to their ever-increasing demand in terms of stability at higher loads, temperatures, better lubrication and wear properties. To combat these situations composites should possess better mechanical and tribological properties. In dry slide wear, the type of reinforcement material used is important from the point of improved performance under different tribo-situations [1-5].

PTFE has been significantly used throughout the purpose of dry conditions wear resistance material with his unique properties such as thermal and mechanical properties, with high contact angle make him hydrophobicity material, however cost wise very expensive material limit its use or partially replacement of PTFE with filler improve wear and tear resistance keep other properties same[6-11].

The literature contains conflicting views regarding the use of various fillers to lessen polymer wear. According to research by Unal, Mimaroglu, Kadıoglu, and Ekiz [6], PTFE can be effectively reduced by adding glass fiber, bronze, and carbon fillers. Whereas the wear rate values for PTFE composites were in the range of 10-8 and 10-9 mm2/N, the wear rate for pure PTFE was in the range of 10-7 mm2/N.
At this moment bronze provide best possible solution with PTFE materials. Design-Expert, software (DX13) is a powerful and easy-to-use program for design of experiments (DOE). With it you can quickly set-up an experiment, analyze your data, and graphically display the results. This intuitive software is a must for anyone wanting to improve a process or a product. Design-Expert software offers an impressive array of design options and provides the flexibility to handle categorical factors and combine them with mixture and/or process variables. After building your design, generate a run sheet with your experiments laid out for you in randomized run order. DX7 offers features for ease of use, functionality and power that you won't find in general statistical packages. Add, delete or duplicate runs in any design with the handy design editor. Rotatable 3-D color plots make response visualization easy.
In this paper we have performed, process optimization composite of PTFE with bronze material (25 and 50% replacement) with respect to velocity, load on pin and sliding distance using BBD (Box-Behnken Design) method. This method understands the interaction between these parameterswith respect to wear resistance and coefficient of friction of composite material under dry conditions.

II. Material And Methods

PTFE and bronze and all related material purchase from sigma-Aldrich India, Pin-on-Disc equipment.
Preparation of composite and testing
PTEF with plain and 25 and 40% Bronze loaded composite test material kept in pin on disc equipment as shown in fig 1. Using Box-Behnken Design (BBD) with 3 level- factor method (such -1, 0, and +1) of Sliding distance, load in pan and velocity were investigated. The entire experimental strategy for each value in both its actual and coded forms where, Z is the dependent variable. Y_1, Y_2 and Y_3 are coded independent variables. β_0, β_j, β_{jj}, and β_{jk} are variable regression coefficients for the model intercept, linear, quadratic, and interaction effects, respectively. For analysis of wear and coefficient of friction we used weight loss method as follows

$$\text{Wear rate} = (\text{weight loss})/(\text{Sliding distance (L)})$$

A set of tests based on BBD was carried out to collect data in a regulated manner to examine the impact of process factors on composite wear.
$Z= B_0 + B_1Y_1 + B_2Y_2 + B_3Y_3 + B_{11}Y_{12} + B_{22}Y_{22} + B_{33}Y_{32} + B_{12}Y_1Y_2 + B_{13}Y_1Y_3 + B_{23}Y_2Y_3$

Fig 1: Experimental Setup of Friction and Wear Test Rig

Table 1: Experimental run and their response

	Factor 1	Factor 2	Factor 3	Response 1	Response 2	Response 3	Response 4	Response 5	Response 6
Run	A:Load in pan	B:Disc Speed (N)	C:Sliding distance	Wear rate	Coefficient of friction	WR PTFE-25% Bronze	COF PTFE-25 % Bronze	WR PTFE-40% Bronze	COF PTFE-40% Bronze
	kg	RPM	km	(gm/m)	mirco	(gm/m)	micro	gm/m	micro
1	1	500	1.5	8.6777E-05	0.2101	3.667E-05	0.2012	1.888E-05	0.2078
2	1	700	3	0.0001333	0.2124	6.333E-05	0.2077	2.225E-05	0.2115
3	1	900	4.5	0.0001422	0.2101	7.333E-05	0.2211	3.22E-05	0.2233
4	2	500	3	0.00022333	0.209	1.2E-06	0.2179	7.9E-05	0.22455
5	2	700	4.5	0.00023555	0.2079	1.477E-06	0.2101	6.667E-05	0.2156
6	2	900	1.5	8.677E-05	0.2068	4E-05	0.2112	1.77E-05	0.2155
7	3	500	4.5	0.00043333	0.1961	3.0889E-	0.2101	9.778E-05	0.212

						06			
8	3	700	1.5	0.00011333	0.1947	5.33E-05	0.221	1.667E-05	0.2258
9	3	900	3	0.00012333	0.1954	7.667E-05	0.219	2.33E-05	0.2223

Calculation for Wear Rate (WR) and Coefficient of friction (COF)

For all material such plain PTFE, PTFE-25% Bronze and PTFE-40% bronze calculation as follow base on Tab 1 reading

Observations:

- L1 = Distance of loading point from lever pivot = 660 mm
- L2 = Distance of pin center from lever pivot = 250 mm
- L3= Distance of load cell link connected on lever from lever pivot = 146 mm
- d = Track diameter of pin = 2 × R = 2 × 50 = 100 mm

1) **Wear Rate (I):**

Velocity of sliding **Vr** $= \frac{\pi \times d \times N}{60}$ m/s

Sliding distance **L** = Vr x T ....m

$\therefore$ **TimeT** $= \frac{L}{Vr}$ Sec

$$\text{Wear rate} = \frac{\text{weight loss}}{\text{Sliding distance (L)}}$$

2) **Coefficient of Friction (μ):**

Frictional Force **Ff** = load indicator reading x (L3/L2) Kg

Load on pin **W** = Dead weight x (L1 / L2) Kg

Coeficient of Friction (μ) $: \frac{Ff}{W}$

Statistical analysis

Using Design of experiment software, we done statistical analysis for all experiments. All analysis or measurement has been done in triplet.

III. Result and discussion

Optimization of process parameters using BBD technique

The tests were designed to establish a relationship between the dry sliding wear of the PTFE and sliding speed, load, sliding distance, besides % of bronze addition to the PTFE. Based on the data gathered in table 1 accordance with the design of experiments, linear regression analyses were performed for the response factor, linear models described the best fit, while quadratic models were aliased as shown in statically Tab.2.

Table 2: Statically model fitting design

Source	Std dev	R^2	Adjusted R^2	Predicted R^2	Lack of fit p-value	Remarks
Wear Rate for plain PTFE						
Linear	**0.0000**	**0.9001**	**0.8122**	**0.8880**	0.0001	
2FI	**2.477E-06**	**0.9974**	**0.9853**		< 0.0001	**Suggested**
Quadratic						**Aliased**
Wear Rate PTFE+25% C						
Linear	**0.0000**	**0.8755**	**0.8103**	**0.8530**	< 0.0001	**Suggested**
2FI	**2.7707E-06**	**0.9842**	**0.9988**		< 0.0001	
Quadratic						**Aliased**
Wear Rate PTFE+40% C						
Linear	**0.0000**	**0.8583**	**0.7520**	**0.8298**	< 0.0001	**Suggested**
2FI	**1.852E-08**	**1.0000**	**1.0000**		< 0.0001	
Quadratic						**Aliased**
COF PTFE						
Linear	**0.0030**	**0.9080**	**0.8390**	**0.6571**	**<0.0001**	**Suggested**
2FI	0.0038	0.9619	0.7336			
Quadratic						**Aliased**
COF PTFE+25%B						
Linear	0.0009	0.9414	0.8410	0.9012		**Suggested**
2FI	0.0009	0.8400	-80.8203			
Quadratic						**Aliased**
COF PTFE+40% B						
Linear	0.0044	0.918	0.7894	0.8871	**<0.0001**	**Suggested**
2FI	0.0070	0.4201	0.0596			
Quadratic						**Aliased**

Interaction of process parameter on WR

a) Keeping Sliding distance constant L=3km

As shown in figure 2, has great influence on WR for plain PTFE and with different combination of bronze. Both interaction show maximum influence on at increasing concentration for plain PTFE whereas bronze loaded PTFE show reduction in wear rate at same time

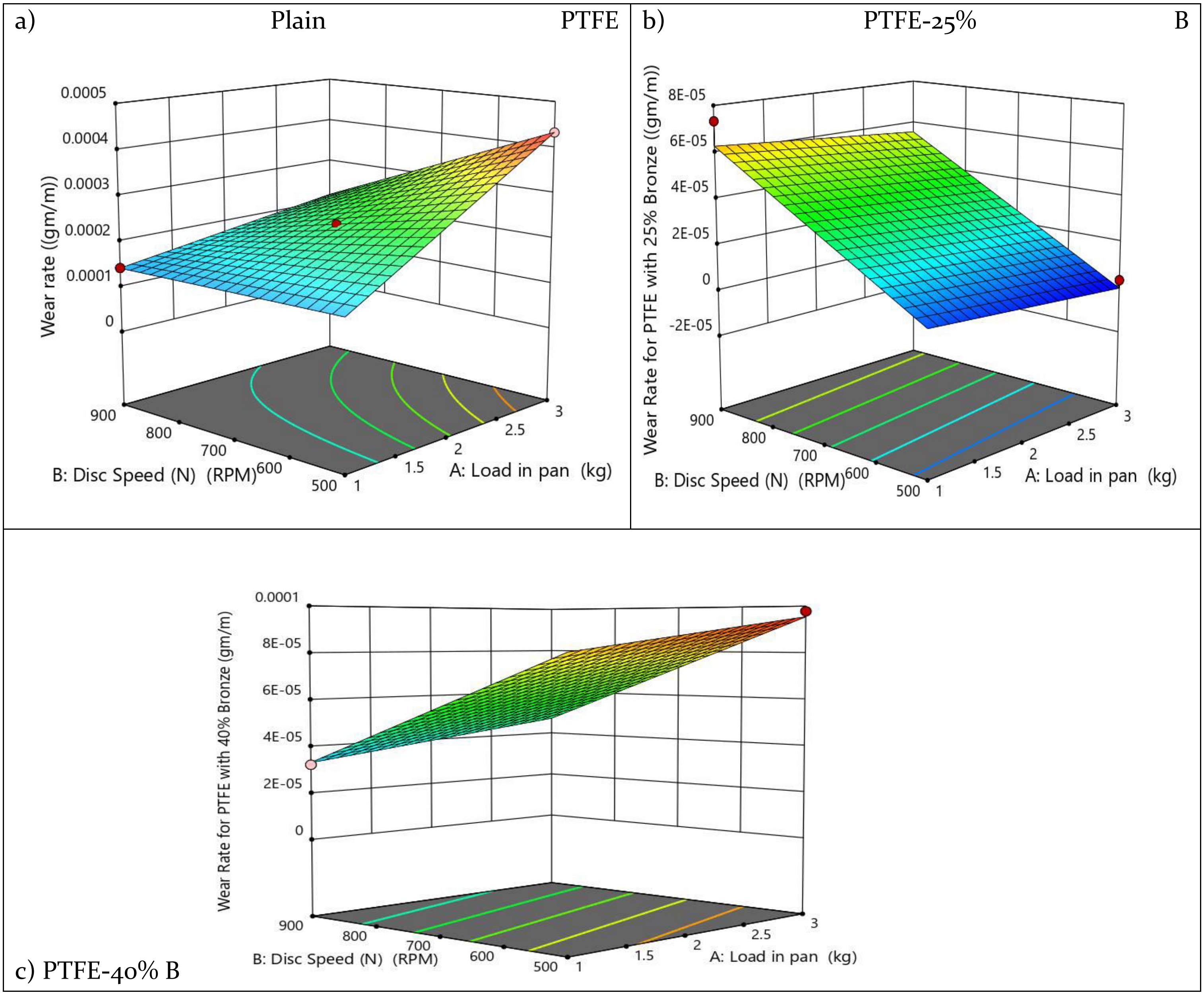


Fig 2: Interaction of A and B on WR (Keeping constant C at 3km)

Figure 3 and 4 show interaction for AC and BC keeping B and A constant respectively on WR. Both parameters show minimum to maximum curve interaction for all composite as case in PTFE with bronze show more wear resistance than virgin PTFE. Bronze pairs in a fat-on-fat sliding configuration in dry nitrogen or hydrogen environments. In inert gas conditions, moisture is generally required to passivate dangling bonds and promote low friction of graphite or other carbons with sp2 configuration.

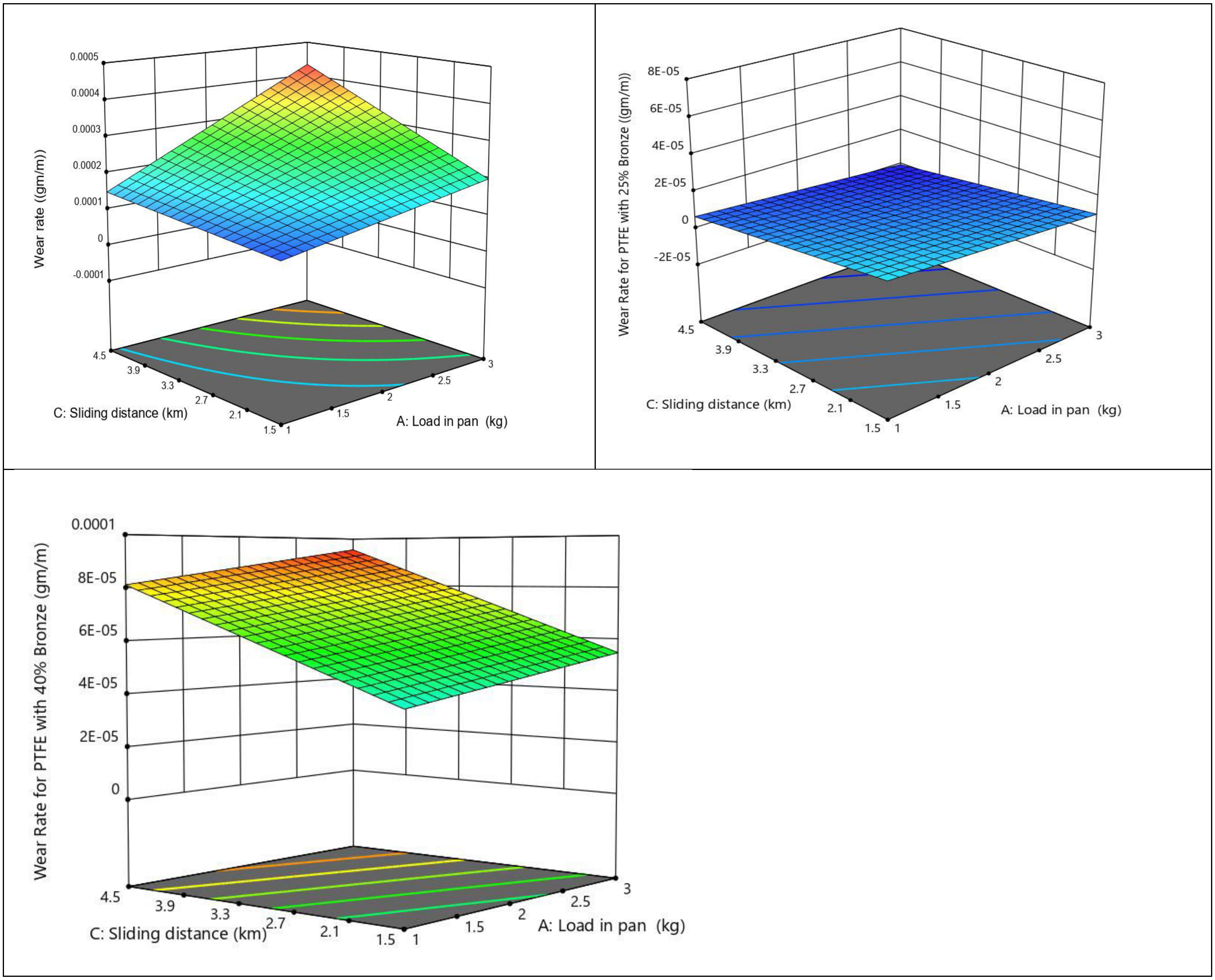


Fig 3: Interaction of sliding distance and load in pan on WR (B: Speed constant)

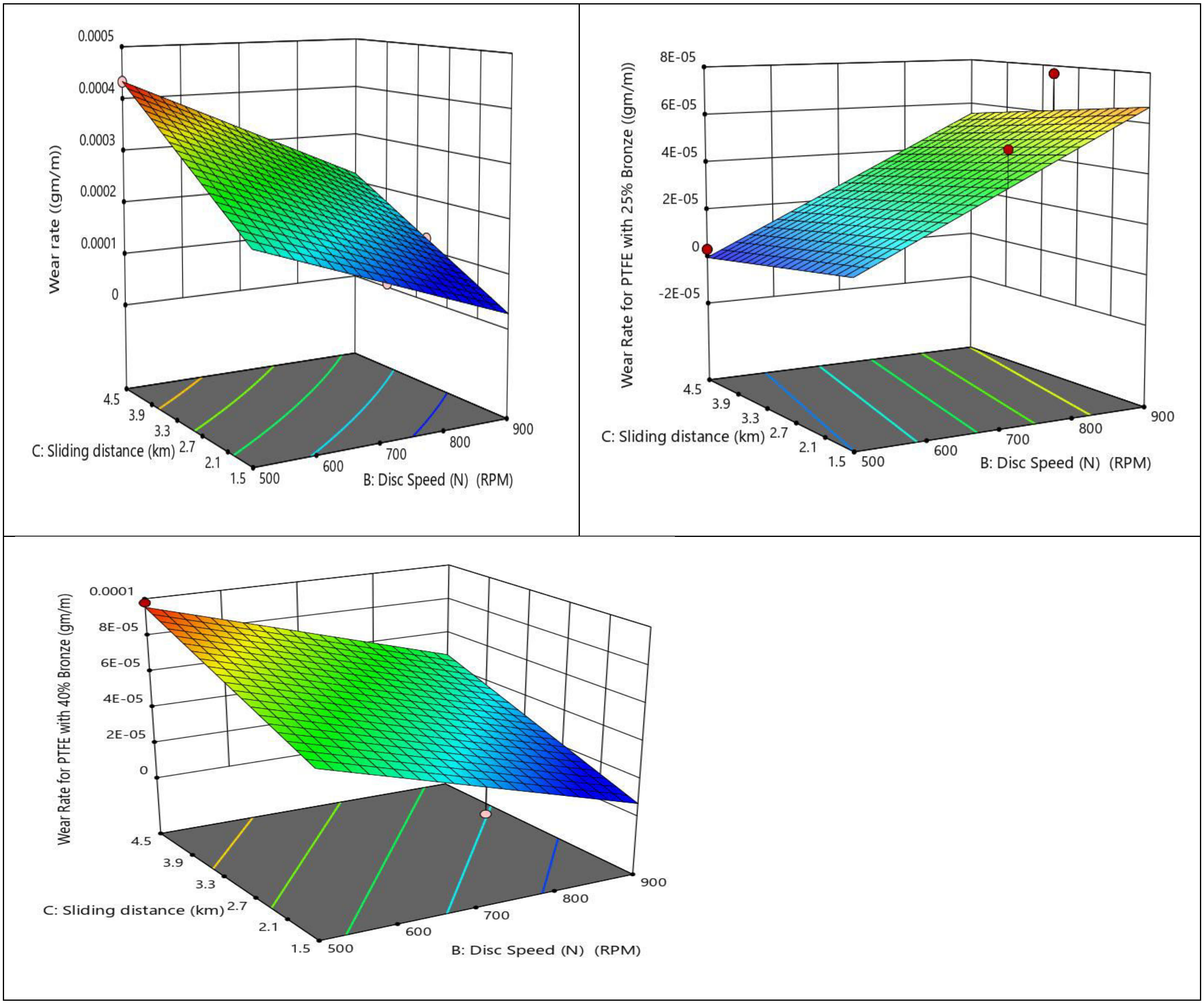


Fig 4: Interaction of sliding distance and Disc speed on WR (A: load in pan Constant)

Interaction of Sliding distance, load in pan and disc speed on COE for composite

The interaction impact of sliding velocity and load , distance on COE is depicted in Figure 5-7. The load's effect on COF is marginally greater at the minimum sliding distance than the sliding velocity, while at the maximum sliding distance, the load's effect is significantly more than the sliding velocity.

The wear-causing effect of sliding distance and load is nearly equal at minimum sliding velocity; however, at maximum sliding velocity, sliding distance has a greater effect than weight which reduce the overall coefficient of friction.

The interaction impact of sliding velocity and sliding distance (2.21%) which show the impact of sliding velocity on COF is greater than sliding distance at minimal load for plain PTFE.

Overall PFTE loaded with carbon show unchanged for interaction of all parameter compare to plain PTFE.

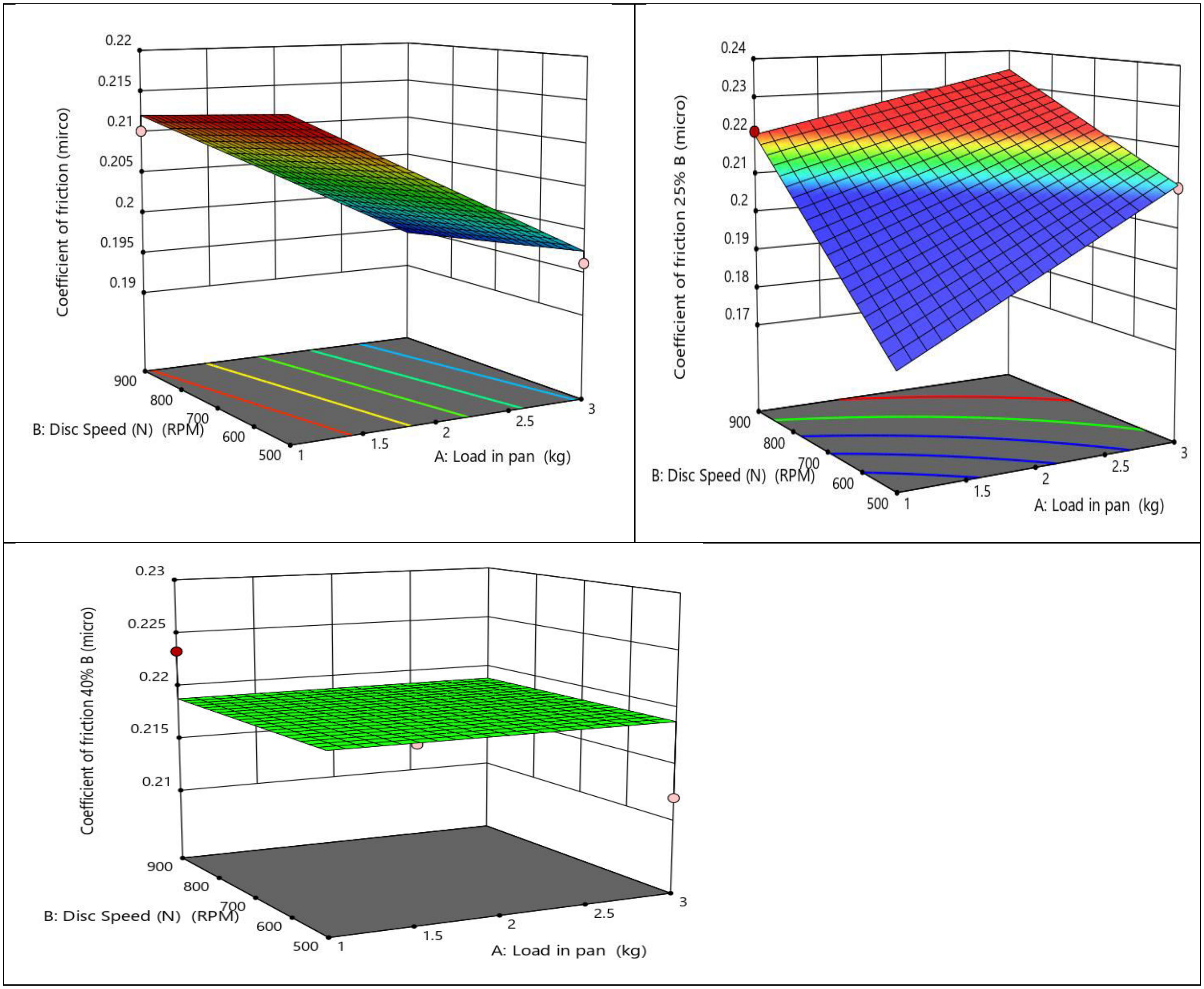


Fig 5 : Interaction of A and B on COE (Keeping constant C at 3km)

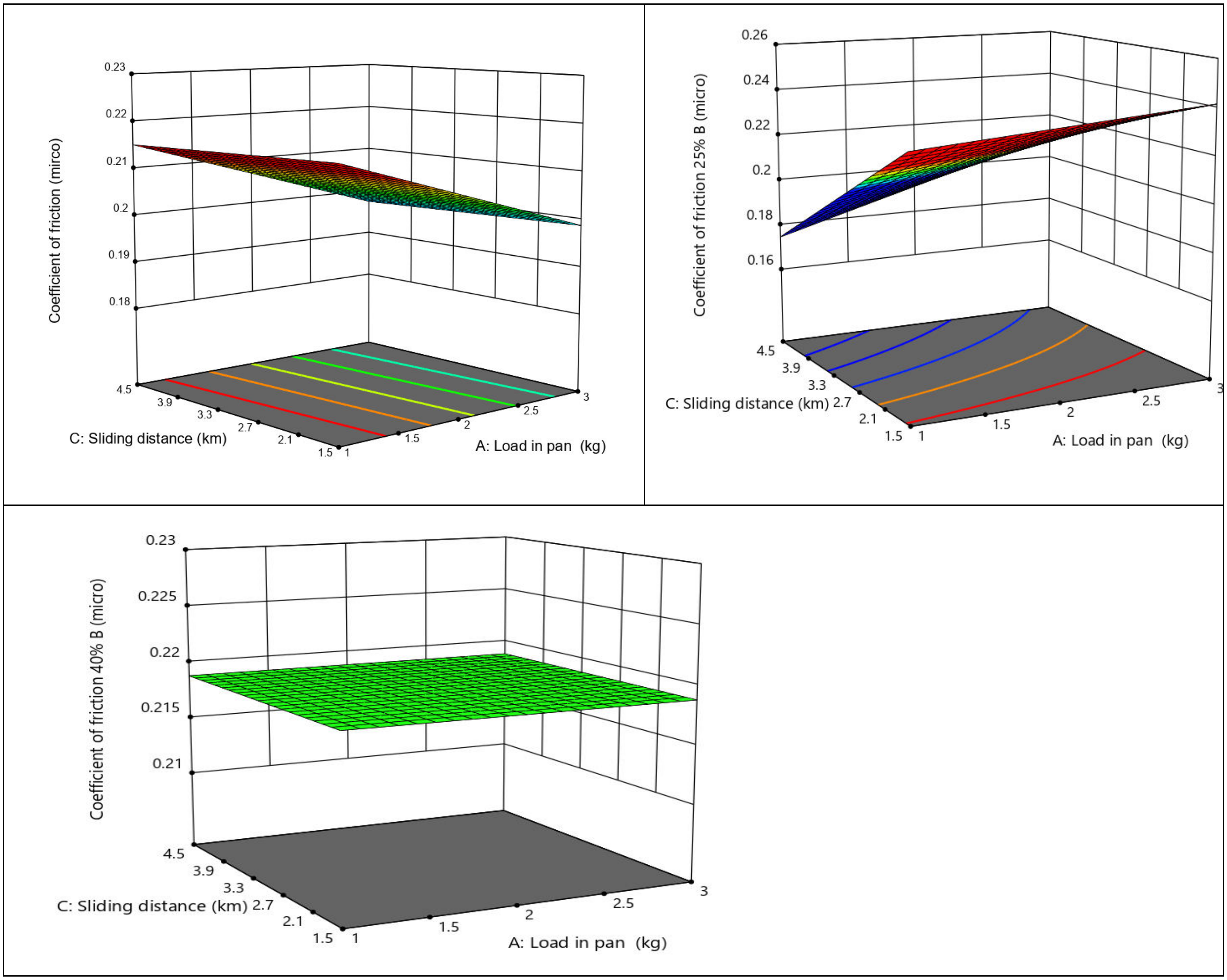
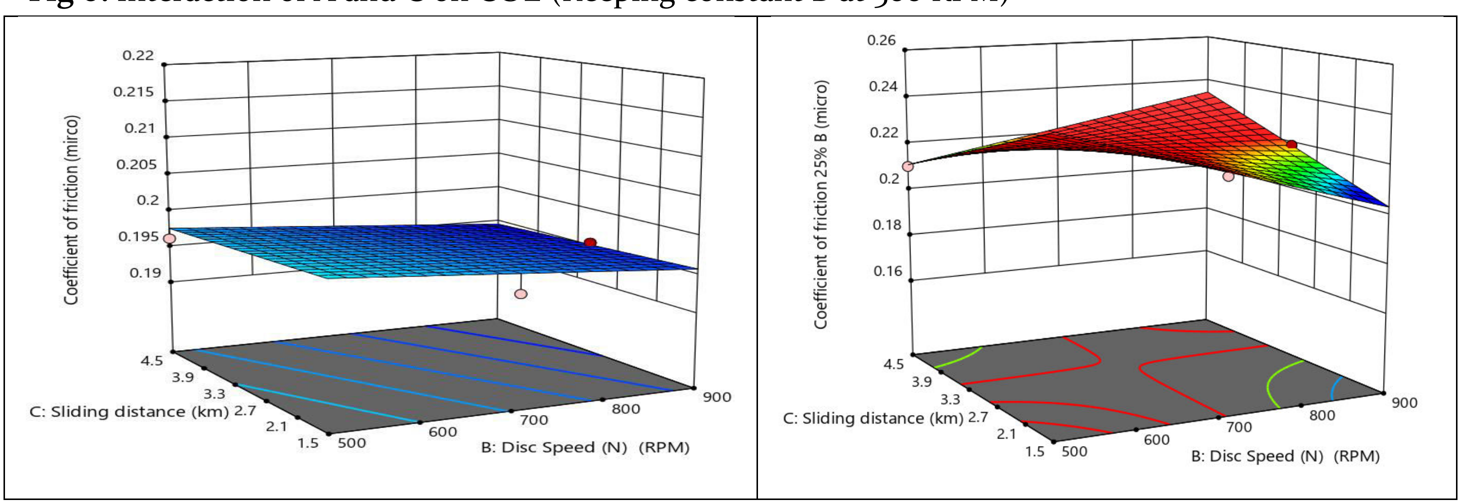


Fig 6: Interaction of A and C on COE (Keeping constant B at 500 RPM)



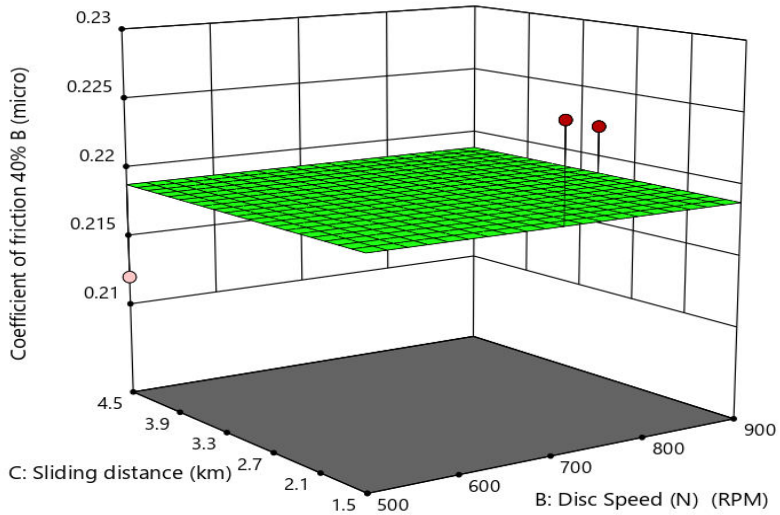


Fig 7: Interaction of B and C on COE (Keeping constant A)

IV. Conclusion

We accomplish data, present research when bronze filler materials are added to PTFE, the hardness and wear resistance rise and the coefficient of friction remain unchanged. Wear rate lowers as the percentage of bronze increases. The results of the confirmation test indicate that the wear percentage variation ranges from 1 to 5.66%, indicating the significance of the mathematical model created for each of the materials.

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