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# EXPERIMENTAL INVESTIGATION OF POLYMER JOURNAL BEARING UNDER DRY CONDITION

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## ABSTRACT

In this study, the effect of contact pressure, sliding velocity and sliding distance on friction, wear and contact temperature of polymer based bearings manufactured from “Polytetrafluoroethylene (PTFE)” & it’s composite of “20% Bronze filled PTFE” in drycondition have been investigated and evaluatedThe experiments were carried using full factorial design. Most of laboratory investigations are done on “test rigs” like pin-on-disc or pin-on-ring. But bearings have special geometrical and kinematical characteristics. The friction & wear results of the sample materials used on these setups are then related to the actual conditions which may not depict true performance of the bearings. Hence to overcome this drawback, ‘Dry Bearing Test Rig’ is used which gives friction & wear analysis by simulating the conditions in actual practice, i.e. test bearing being mounted on the shaft and enclosed in support bush. Hence simulated analysis of friction & wear of bearings can be performed and results give closeness to the true values of frictional force and wear of bearing.

***Key words:*** *journal bearing, Wear, Coefficient of friction, PTFE &PTFE+Br, surface roughness, sliding distance, sliding velocity.*

## I. INTRODUCTION

As the bearing is one of the important machine element, so it must have good wear resistance and low coefficient of friction to transmit maximum power.

Among the various materials used by researchers as mentioned in literature survey the Pure Polytetrafluoroethylene (PTFE) and Bronze fibre filled PTFE are the important materials. The PTFE has the highest “Wear Rate” among all other polymers for dry journal bearing. So it is necessary to predict its wear rate and thereby increase its utility for journal bearing application. As the fibres play important role in the wear and friction of polymers, therefore to understand the effect of Bronze fibre filling in PTFE, using 20% Bronze fibre filled PTFE.

Polytetrafluoroethylene(PTFE) is used for low load high speed bush bearings, piston rings for non-lubricated air compressors, guide bonds and piston seals for hydraulic and pneumatic actuators.

## II. LITERATURE SURVEY

Different research work shows innovative way of using new composite material, modification in the geometry and surface of bearings, to improve the tribological properties of bearings. Demirci and Duzcukoglu· [1] ,studied the effect of sliding velocity, bearing pressure and temperature on friction and wear of PA66, PA66+18% PTFE and PA66+20% GFR+25% PTFE using dry journal bearing LPV test apparatus. Lowest wear rates were observed at the PA66+20% GFR+25% PTFE journal bearings and PA66+18% PTFE journal bearings showed the highest wear rates. Abdelbary, Abouelwafa, Fahham, Hamdy[2] investigated the effect of single imposed vertical crack in the Nylon 66 surface upon its wear behaviour in dry and lubricated sliding conditions. The polymer was tested under different static and cyclic loading parameters.It was observed that under cyclic loading and wet sliding, the increase in load ratio increased the polymer wear rates.Jia, Jianmin, Zhou, Litian, Chen[3]showed that for carbon fiber reinforced polymer compositeseasier transfer of composite onto the counterpart steel surface resulted in large wear rate of polymer composite under dry sliding while the boundary lubricating action of water accounted for the much smaller

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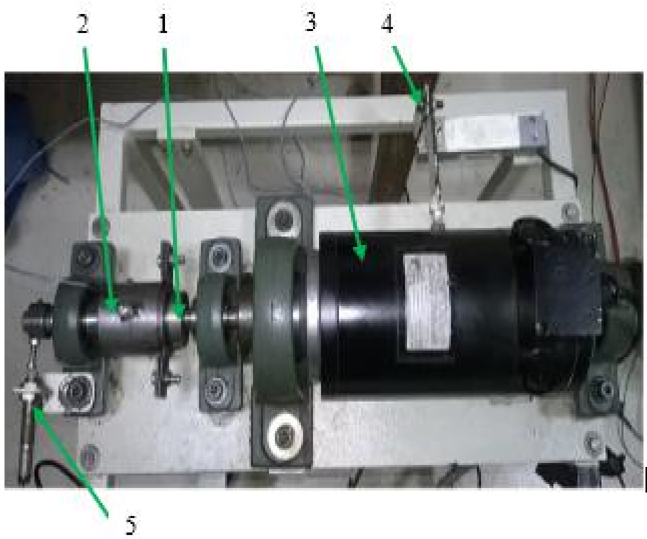
wear rate under water lubrication.Tevruz[4] [5] pointed that fillers play the most important role on the transferred film's structure, stability & adhesion to shaft surface. He also concluded that pure PTFE has the highest wear rate than Carbon filled, Bronze filled & Glass filled. Unal, Mimaroglu, Kadioglu, Ekiz[6]concluded that adding GF, bronze, carbon decreased the wear rate of PTFE composites.They concluded that pressure was the most effective factor affecting the wear rate than sliding speed at higher loads and friction coefficient decreased with increase in load.Kharade, Saisrinadh[9]studied the tribological properties of glass fibre filled PTFE with 3 compositions viz; PTFE+15% GF, PTFE+25% GF, PTFE+ 35% GF in oil and adding additive as graphite (5% wt) in oil. They concluded that for oil and oil with graphite lubrication condition for all material specific wear rate decreases with increase in load.

In this study the effect of sliding distance, sliding velocity and contact pressure on friction and wearof PTFE and 20% Bronze filled PTFE bearings at low, medium and high speed and pressure values in dry and minimum lubricated condition were investigated. Experimental results were analyzed and the results are given in the form of graphs and tables.

## III. EXPERIMENTAL SETUP

### 3.1 Experimental Setup

The experiments are performed on Dry Bearing Test-rig shown in Fig.1.A dc –electrical motor is provided with speed range from 0 – 1500 rpm, which is thyrister controlled by a control switch provided on the control panel with digital display of speed as shown in Fig.2.Friction force is measured by means of force sensor & same is depicted in control panel.The provision has been made to measure the number of rotations of motor shaft by using a counter. S-type load cell (0-20 Kg) is used in loading arrangement for load measurement as shown in Fig.3.




***1. Pedestal Bearing. 2. Journal-Bearing Assembly. 3. Thyrister Controlled DC Motor. 4. Load Cell for Friction Force. 5. RPM Counter.***
***Fig.1. Dry Bearing Test-rig***

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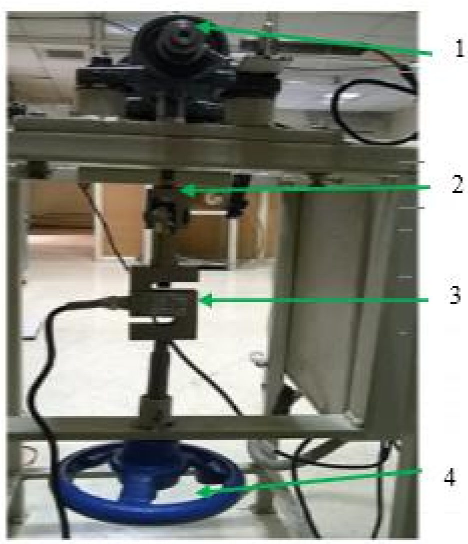
*Fig.2. Control Panel*

**3.2 Material and Experimental Conditions**

The bearing materials used in this experiment are PTFE and 20% Bronze Filled PTFE. The inner diameter of bearing is 32mm. The average roughness of PTFE bearing is 6.38 µm and of 20% Bronze filled PTFE is 4.16 µm. The shaftmaterial used is EN8. The average roughness of shaft is 0.68µm.




*1. Shaft. 2. Tie rod. 3. Load Cell for Externally Applied Normal Load. 4. Hand Wheel to Apply Normal Load*
*Fig.3. Side View of Dry Bearing Test-rig*

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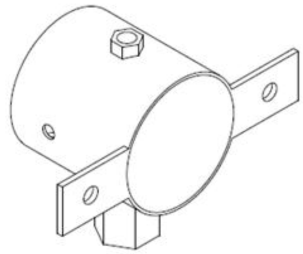


*Fig.4. Housing*

To allow free rotating motion in between journal and bush inner diameter surface, a clearance fit is provided. At the same time the bush must remain stable in housing. For this purpose interference fit is provided in between the bush outer diameter and housing's inner diameter surfaces. One hexagonal nut with threading of 6mm inner diameter hole is provided on the top side of outer surface to adjust the height of RTD sensor through it in bush as shown in Fig.4.

**3.3 Experimental procedure:**

For each experiment, below process were used.

First the shaft surface was cleaned with acetone by a cloth. The bearing to be experimented was weighed and its weight was noted. The bearing was then fit in the Mild Steel housing with the shaft inside the bearing. The load cell was attached below the housing with the help of tie-rod. The desired load was applied by rotating the hand wheel in anticlockwise direction. The motor was started and the RPM of the motor was maintained at the required value with the help of rheostat. Various temperature levels at the friction interface were noted during the experiment for further analysis. The experiment was continued till motor run for 1.50km. After that experiment were stopped and bearing was taken out of shaft to observed the surfaces of bearing and shaft. The shaft surface was once again cleaned with acetone by a cloth and dried. The surface roughness of shaft was then examined. The bearing was weighed and the weight was noted. Thus, the wear was determined by difference in weight.

Similarly, all the experiments were carried out and the wear, friction coefficient for each experiment was determined.

## IV. EXPERMIENTAL CONDITIONS

After carrying out the literature survey following parameters were selected for the experimentation with three levels as low, medium, and high. The respective values are as shown in Table 1.

***Table1. Coding of variables for the Dry Bearing test set up***

| **Levels** | **Low (-1)** | **Medium (0)** | **High (+1)** |
|---|---|---|---|
| Pressure ($N/mm^2$) | 0.0545 | 0.01875 | 0.109 |
| Sliding Velocity (m/s) | 0.5 | 1.25 | 2 |
| Sliding Distance (Km) | 1.5 | 3.0 | 4.5 |

Full factorial method is used for Design of Experiments. Total 12 experiments were conducted for dry condition on both bearings.

*Table 2. L12 OA factor column assignment*

| Sr.No | Pressure (P N/m$^2$) | Sliding Velocity (V m/s) | Sliding Distance (L Km) |
|---|---|---|---|
| 1 | -1 | -1 | -1 |
| 2 | +1 | -1 | -1 |
| 3 | -1 | +1 | -1 |
| 4 | +1 | +1 | -1 |
| 5 | -1 | -1 | +1 |
| 6 | +1 | -1 | +1 |
| 7 | -1 | +1 | +1 |
| 8 | +1 | +1 | +1 |
| 9 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 |

## V. EXPERIMENTAL RESULTS AND ANALYSIS

In this study, the effect of each input factor is individually compared with the each output factor.All those 12 input factors are needed to sort in increasing order with their corresponding response. And then average of 4 – responses of each low, medium & high level is calculated. And those three average points are taken to plot a graph for Mean - Response Vs Input factor.

***Table 3. Experimental results for PTFE journal bearing under dry condition***

| Expt. No. | P (N/mm$^2$) | V (m/s) | L (Km) | Wear (gms) | $F_f$ (Kg) | μ | Contact Temp (°C) |
|---|---|---|---|---|---|---|---|
| 1 | 0.0545 | 0.5 | 1.5 | 0.252 | 2.1856 | 0.2732 | 49 |
| 2 | 0.109 | 0.5 | 1.5 | 0.335 | 4.2096 | 0.2631 | 55 |
| 3 | 0.0545 | 2 | 1.5 | 0.225 | 2.4112 | 0.3014 | 78 |
| 4 | 0.109 | 2 | 1.5 | 0.345 | 4.7264 | 0.2954 | 101 |
| 5 | 0.0545 | 0.5 | 4.5 | 0.575 | 2.184 | 0.2730 | 51 |
| 6 | 0.109 | 0.5 | 4.5 | 0.590 | 4.2146 | 0.2651 | 65 |
| 7 | 0.0545 | 2 | 4.5 | 0.610 | 2.5264 | 0.3158 | 104 |
| 8 | 0.109 | 2 | 4.5 | 0.620 | 5.0368 | 0.3148 | 145 |
| 9 | 0.08175 | 1.25 | 3 | 0.438 | 3.4356 | 0.2863 | 95 |
| 10 | 0.08175 | 1.25 | 3 | 0.404 | 3.3552 | 0.2796 | 65 |
| 11 | 0.08175 | 1.25 | 3 | 0.420 | 3.2448 | 0.2704 | 71 |
| 12 | 0.08175 | 1.25 | 3 | 0.422 | 3.3012 | 0.2751 | 75 |

***Table 5. Wear and friction values for 20%Bronze-PTFE in dry condition***

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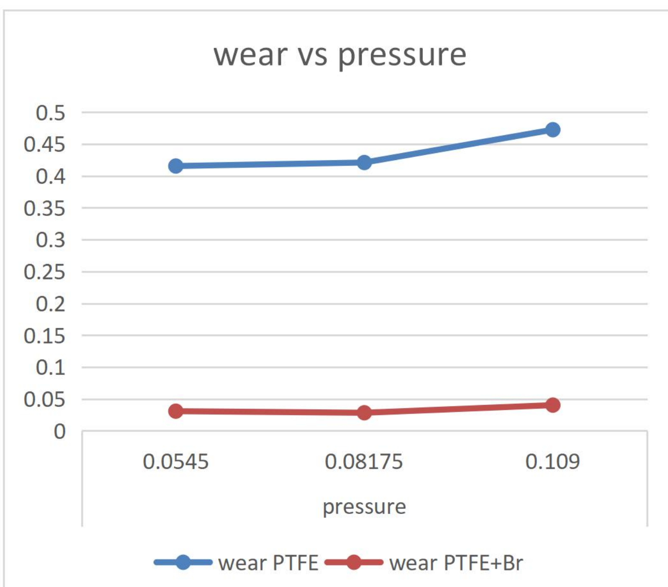
| Expt. No. | P ($N/mm^2$) | V (m/s) | L (Km) | Wear (gms) | $F_f$ (Kg) | μ | Contact Temp (°C) |
|---|---|---|---|---|---|---|---|
| 1 | 0.0545 | 0.5 | 1.5 | 0.004 | 2.144 | 0.268 | 44 |
| 2 | 0.109 | 0.5 | 1.5 | 0.017 | 4.000 | 0.250 | 54 |
| 3 | 0.0545 | 2 | 1.5 | 0.008 | 2.24 | 0.280 | 68 |
| 4 | 0.109 | 2 | 1.5 | 0.012 | 4.384 | 0.274 | 94 |
| 5 | 0.0545 | 0.5 | 4.5 | 0.042 | 2.24 | 0.280 | 47 |
| 6 | 0.109 | 0.5 | 4.5 | 0.056 | 4.304 | 0.269 | 59 |
| 7 | 0.0545 | 2 | 4.5 | 0.069 | 2.32 | 0.290 | 90 |
| 8 | 0.109 | 2 | 4.5 | 0.076 | 4.592 | 0.287 | 116 |
| 9 | 0.08175 | 1.25 | 3 | 0.028 | 3.204 | 0.267 | 74 |
| 10 | 0.08175 | 1.25 | 3 | 0.030 | 3.336 | 0.278 | 81 |
| 11 | 0.08175 | 1.25 | 3 | 0.026 | 3.3 | 0.275 | 71 |
| 12 | 0.08175 | 1.25 | 3 | 0.029 | 3.36 | 0.280 | 79 |

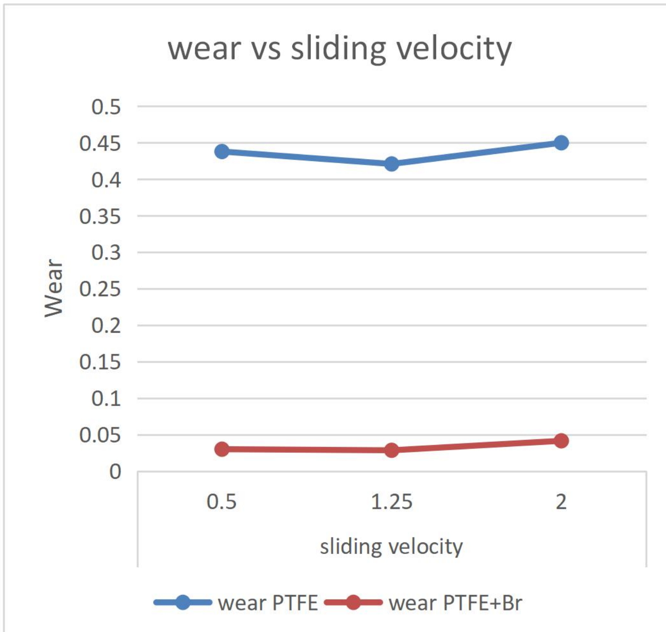
**5.1 Results related to wear**

Graph 1 shows the effect of Pressure on wear, as the pressure increases the wear slowly increases. Approximately there is a rise of 0.06 gms in wear for PTFE in dry condition as pressure level rises from low to high. Approximately there is a rise of 0.009 gms in wear for 20% Bronze-PTFE in dry condition as pressure level rises from low to high



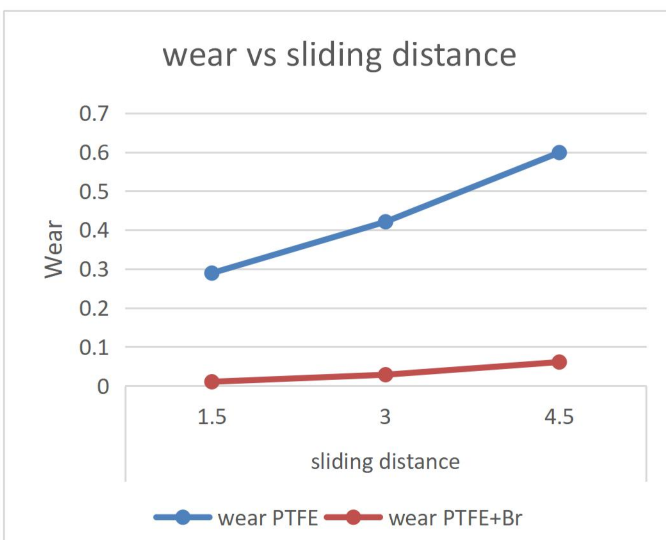

***Graph.1 shows the effect of Pressure on wear***

Graph 2 shows the effect of sliding velocity on wear, as the sliding velocity increases the wear slowly increases. Approximately there is a rise of 0.012 gms for both PTFE in dry condition as sliding velocity level rises from low to high.Approximately there is a rise of 0.012 gms for 20% Bronze-PTFE in dry condition as sliding velocity level rises from low to high.




***Graph. 2 shows the effect of sliding velocity on wear***

Graph 3 shows the effect of sliding distance on wear, as the sliding distance increases the wear rapidly increases. Approximately there is a rise of 0.3 gms for PTFE in dry condition as sliding distance level rises from low to high.Approximately there is a rise of 0.05 gms for 20% Bronze-PTFE in dry condition as sliding distance level rises from low to high.




***Graph. 3 shows effect of sliding distance on wear***

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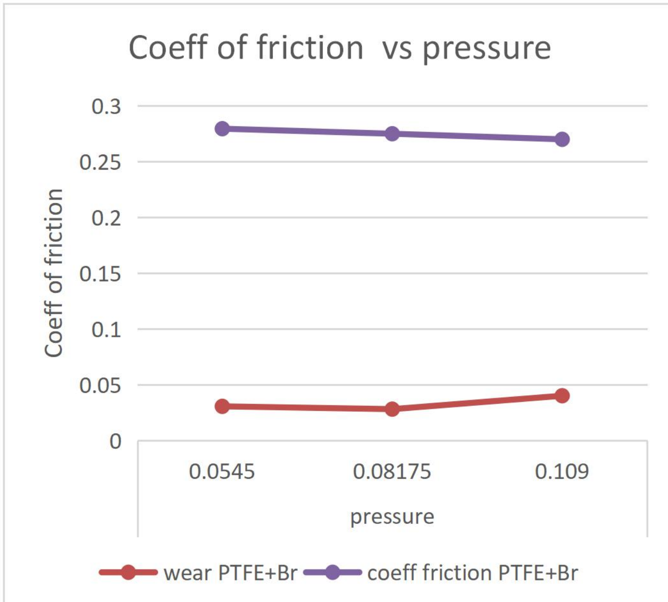
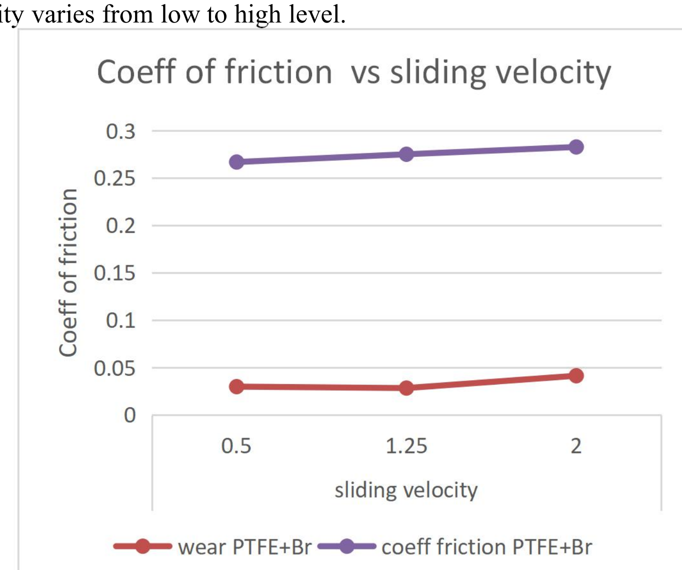
**5.2 Results related to Friction**

Graph 4 shows the effect of Pressure on Coefficient of Friction, as the pressure increases thereis very slow decline in the Coefficient of friction;it goes down approximately by 0.0063 for PTFE in dry condition as the pressure increases there is very slow decline in the Coefficient of friction, it goes down approximately by 0.083 for 20% Bronze-PTFE in dry condition.



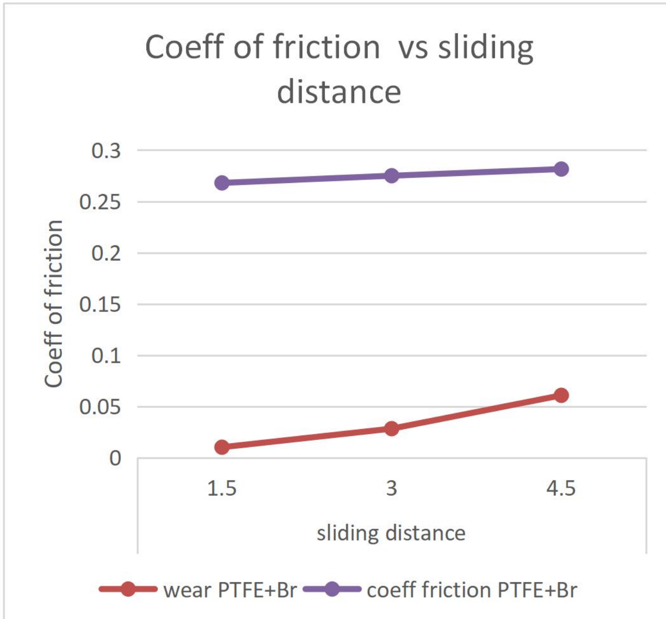

***Graph. 4 shows effect of pressure on coeff. of friction***

Graph 5 shows the effect of sliding velocity on Coefficient of Friction, as the sliding velocity increases the Coefficient of friction increases, it goes up approximately by 0.038 for PTFE in dry condition As the sliding velocity increases the Coefficient of friction increases, it goes up approximately by 0.015 for 20% Bronze-PTFE in dry conditionas sliding velocity varies from low to high level.




***Graph. 5 shows effect of coeff. of sliding velocity on friction***

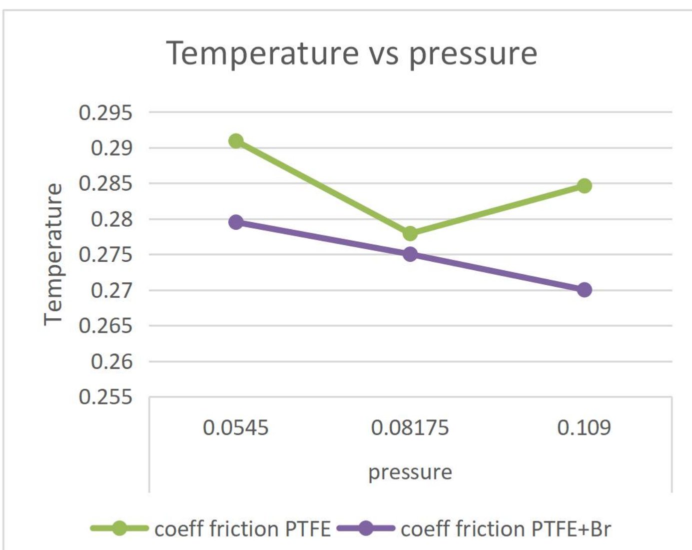
Graph 6 shows the effect of sliding distance on Coefficient of Friction, as the sliding distance increases the Coefficient of friction increases, it goes up approximately by 0.009 for PTFE in dry condition as sliding velocity varies from low to high level.As the sliding distance increases the Coefficient of friction increases, it goes up approximately by 0.013 for 20% Bronze-PTFE in dry conditionas sliding distance varies from low to high level.




*Graph. 6 effect of sliding distance on coeff. of friction*

### 5.3 Results related to Temperature

Graph 7 shows effect of Pressure on Contact temperature attained by the friction interface, as the pressure increases there is rapid rise in the temperature of the friction interface, it goes up approximately by 21 ºC for PTFE in dry condition as pressure varies from low to high level.As the pressure increases there is rapid rise in the temperature of the friction interface, it goes up approximately by 18 ºC for 20% Bronze-PTFE in dry condition as pressure varies from low to high level.




*Graph. 7 effect of pressure on temperature*

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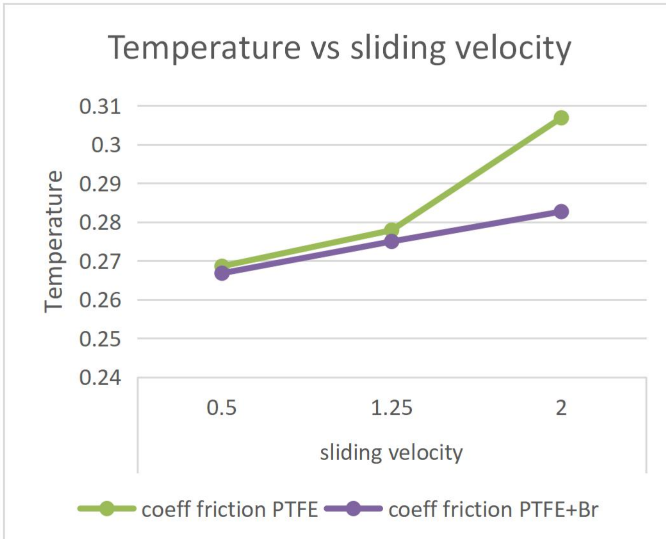
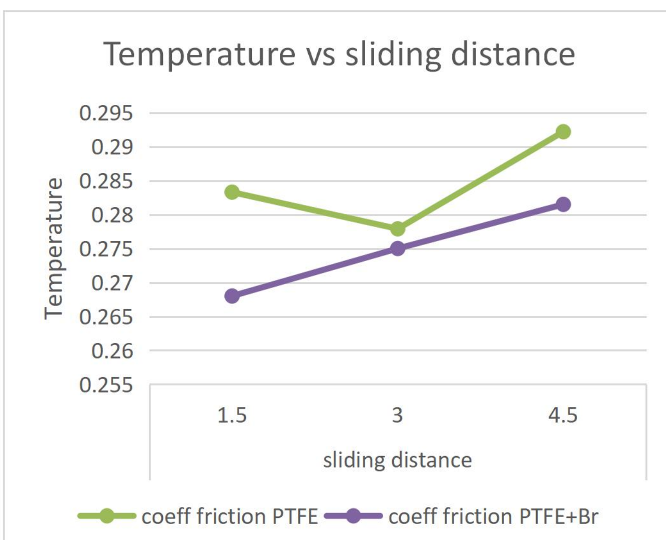
Graph 8 shows effect of sliding velocity on Contact temperature attained by the friction interface, as the pressure increases there is rapid rise in the temperature of the friction interface, it goes up approximately by 50 ºC for PTFE in dry condition as sliding velocity varies from low to high level.As the pressure increases there is rapid rise in the temperature of the friction interface, it goes up approximately by 40ºC for 20% Bronze-PTFE in dry condition as pressure varies from low to high level.




***Graph. 8 effect of sliding velocity on temperature***

Graph 9 shows effect of sliding distance on Contact temperature attained by the friction interface, as the pressure increases there is rapid rise in the temperature of the friction interface, it goes up approximately by 20 ºC for PTFE in dry condition as sliding distance varies from low to high level. As the pressure increases there is rapid rise in the temperature of the friction interface, it goes up approximately by 13 ºC for 20% Bronze-PTFE in dry condition as pressure varies from low to high level.




***Graph. 9 effect of sliding distance on temperature***

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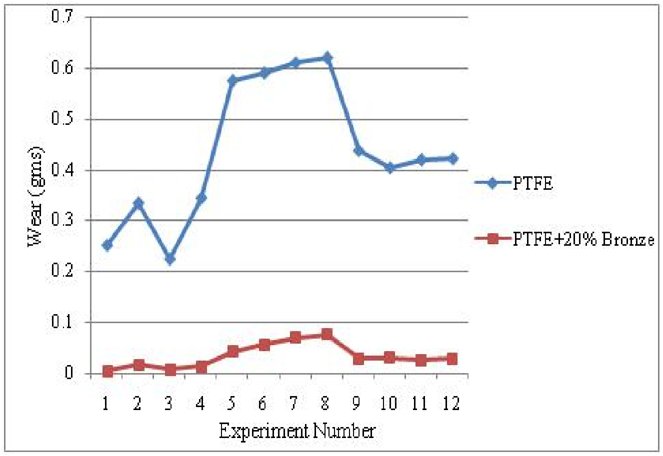
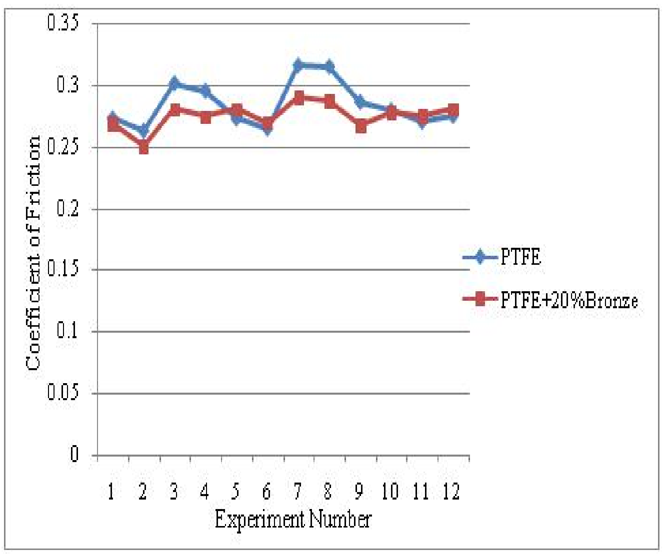
### 3.4 Comparison Plots for Dry Condition




***Graph. 10 Comparison for Wear***

Graph 10 shows the average Wear of all test specimens for PTFE is 0.436 and that of 20% Bronze-PTFE is 0.033. So the wear is decreased approximately by 13 times for 20%Bronze-PTFE.




***Graph 11. Comparison for Coefficient of Friction***

Graph 11 shows the average Coefficient of Friction of all test specimens for PTFE is 0.284 and that of 20% Bronze-PTFE is 0.274. So the coefficient of friction is decreased approximately by 1.04 times for 20%Bronze-PTFE.

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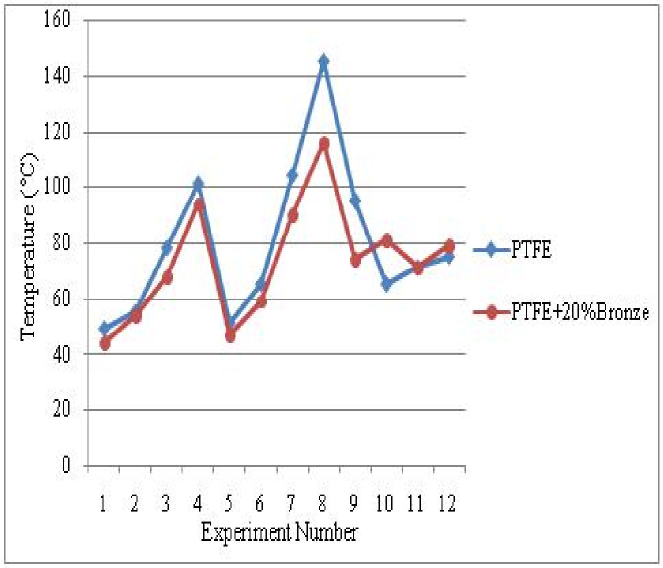
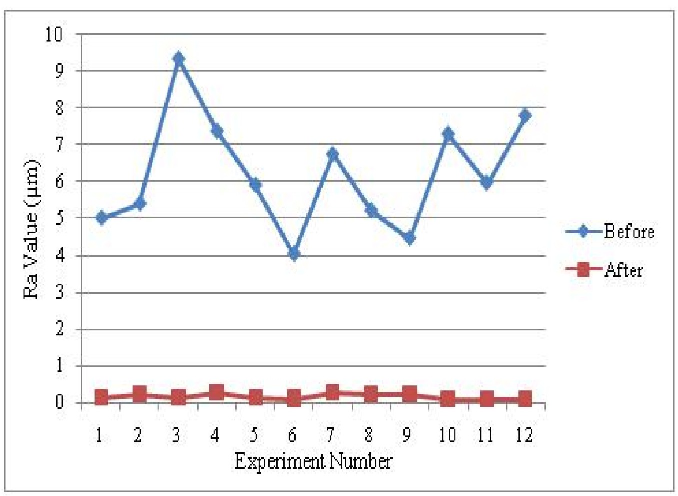



***Graph. 12 Comparison for Temperature***

Graph 12 shows the average of Temperature for PTFE specimens is 80 and that of 20% Bronze-PTFE is 73. So the Temperature is decreased approximately by 1.09 times for 20%Bronze-PTFE.

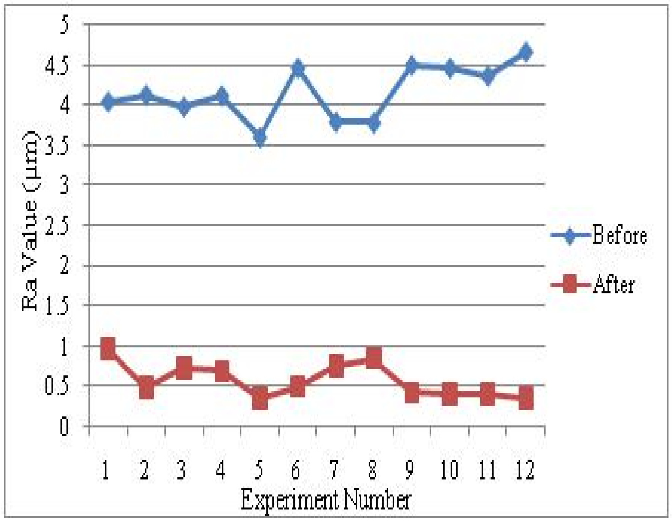
**5.6 Surface Roughness Plots**

Graph 13 shows the graphical representation of Ra values measured on wear zone, before and after the experiment. The average Ra value for all test specimens before experiment was around 6.22 µm and after experiment it was around 0.17 µm.




***Graph. 13 Ra values for PTFE***

Graph 14 shows the graphical representation of Ra values measured on wear zone, before and after the experiment. The average Ra value for all test specimens before experiment was around 4.16 µm and after experiment it was around 0.57 µm




***Graph. 14 Ra values for PTFE+20%Br***

## VI. CONCLUSION

With reference to above study following conclusions are drawn,

1. Among the three input factors, sliding distance is most affecting factor to cause the wear as for PTEF it is 0.5987 gms and for PTFE+20% bronze it is 0.0608 gms for sliding distance of 4.5km
2. Sliding velocity is observed as most effecting factor on the coefficient of friction. For sliding velocity of 2m/s coefficient of friction 0.3069 is for PTEF, whereas 0.2827 is for PTFE+20% bronze
3. Temperature is most affected by the sliding velocity, at the sliding velocity of 2m/s temperature of $107^0$C is observed for PTFE and $92^0$C is for the PTFE+20% bronze is recorded
4. For the given experimental conditions, PTFE is having more wear rate as compared to the PTFE+20% bronze so, it is preferable to use PTFE+20%Br as a bearing material
5. For the given experimental conditions, PTFE and PTEF+20%Br shows almost same coefficient of friction and temperature

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