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# Dry sliding wear behaviour of Industrial semi-crystalline and crystalline polymers

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**Abstract:** At present, polymers are used in many static and dynamic industrial applications such as bushes, gears, bearings, rollers, timing screws and washers having replaced traditional materials like steel brass, bronze, copper and aluminum which undergo wear and tear. The present investigation was made to study the adhesive wear characteristics of semi-crystalline polyurethane polymer and crystalline polyacetal (Polyoxymethylene-POM) polymer. Polymers considered for this study are potential materials for rollers in hybrid chains in food processing industry and medical equipments. The wear tests were performed under dry conditions using a pin-on-disc (ASTM G99) arrangement against a mild steel disc (HRB 67) at room temperature under various loads (60, 80,100N) and sliding speeds (1.8, 2.3, 2.8 m/s). Cylindrical shaped polymers of 25 mm diameter were used for the wear tests. Polyacetal was observed to have the lesser wear rate and coefficient of friction irrespective of load and speed because of its crystalline nature. Polyurethane exhibits higher frictional coefficient at higher sliding velocity.
**Keywords:** Polymers; Coefficient of friction; Wear rate; Sliding distance.

## Introduction and Experimental

Polymers are extensively used for manufacturing sliding components (against metals or other materials) because of their excellent tribological properties such as good wear resistance and low friction. In food processing industries, the use of lubricants for metal rollers is forbidden to avoid food contamination. Hence, polymers are used owing to their inert behavior to chemical contamination. Watanabe [1] investigated the friction and wear properties of polyamide (N6) and reported that the sliding velocity and load influence the frictional heating, thereby increasing the wear rate due to increase in temperature. Franklin [2] studied the friction and wear behaviour of POM and UHMWPE polymer under different conditions of sliding speed, mating surface roughness and roughness orientation and reported that the effect is dependent mainly on mating surface roughness. It is reported that the wear rates of POM and UHMWPE can decrease with increasing sliding speed when the roughness of the mating surface is low. Unal et al. [3] investigated the influence of speed and applied pressure on the friction and wear behaviour of Polyamide 66 (PA 66), Polyoxymethylene (POM), High Molecular Weight Polyethylene (UHMWPE) and Aliphatic Polyketone (APK) and reported that the temperature rise influenced by sliding speed results in considerable increase in friction coefficient and the sliding speed has stronger effect on the wear rate than the applied pressure**.** Samyn et al. [4] studied the tribological properties of some engineering polymers namely PET/Teflon, PTFE, UHMWPE/carbon under various interface materials such as high alloy steel, stainless steel, and epoxy resin. They reported that PET/PTFE sliding against the stainless steel causes the development of a transfer layer on the steel surface, which leads to reduction in coefficient of friction. No wear debris is found for UHMWPE/carbon against stainless steel, as it has higher toughness and allows the surface to tear without particle detachment, resulting in higher friction. The present research work is focused on the adhesive wear behavior of the polymers, which are mainly used as hybrid rollers in industrial applications.

In the present research work, cylindrical shaped polymers of 25 mm diameter Polyurethane and Polyacetal were selected for wear test. Computer assisted Pin-on-disk tribometer arrangement (ASTM G99) was used for performing dry sliding wear tests against a mild steel disc (HRB 67) at room temperature under various loads (60, 80,100N) and sliding speeds (1.8, 2.3, 2.8 m/s). The disc was cleaned with acetone and thoroughly dried, before and after the commencement of wear tests. For every test, the coefficient of friction at various loads and sliding speeds were correlated with the sliding distance, which was determined using a cantilever loading device with load cell. The wear rates of the polymers were measured from weight loss measurements using electronic weighing balance of 0.001 mg accuracy.

## Results and Discussion

The wear rate and coefficient of friction of polymers were correlated with applied load, sliding distances and sliding speed. Optical micrographs of the worn out surfaces of the polymers were also recorded in order to study the mechanism of wear.

### (a) Effects of applied load and sliding speed on the coefficient of friction

**Figure-1** shows the variation of coefficient of friction with sliding distance of the two polymers at constant applied load (80N) and at a sliding velocity of 2.3m/s respectively. Polyurethane shows a drastic increase in coefficient of friction at higher sliding distances and applied load which can be attributed to high temperature softening of the polymer which leads to dominance of adhesive mechanism of friction. In polyurethane, due to the continuous formation of transfer film, adhesion occurs. This causes deformation of the asperities at contact points and it breaks off due to the incremental plastic deformation. Because of the weak linkage of the COHN group breakage of transfer film forms wear debris results in fatigue wear. Polyacetal exhibit almost constant coefficient of friction value with respect to sliding distance. This may be attributed to the hard and strong bonding of electrons in H-C-H group. Among the two polymers, polyurethane has higher frictional coefficient irrespective of sliding velocity and applied load. The preferential orientation of molecular chains in the case of crystalline polymers (Polyacetal) could reduce the interfacial shear stress, thereby resulting in considerable reduction in coefficient of friction and wear.

### (b) Effects of applied load on the wear rate

The wear rate of polymers has been accurately determined from weight loss measurement corresponding to the loads of 60, 80 and 100N respectively. The rate of increase in wear rate was observed to be minimal initially at lower loads up to a certain threshold value of sliding distance for both polymers. The right ordinate of **Figure 1** depicts the variation of wear rate with sliding distance at constant applied load (80N). A steep increase in wear rate was observed for polyurethane. The wear rate of Polyacetal (0.044 g/s) was lower compared to polyurethane (0.1798 g/s) at 80N of applied load and 2.3 m/s sliding speed due to its inherent property of high hardness and strong bonding between the molecules. Polyurethane was observed to undergo higher wear rates as a result of its increased shear strength on surface with increase in sliding velocity.

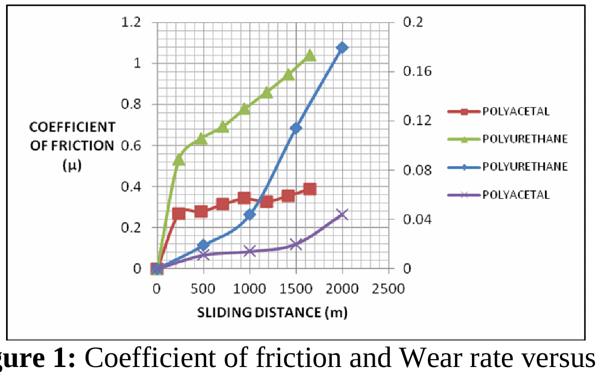


**Figure 1:** Coefficient of friction and Wear rate versus sliding distance at constant load of 80N

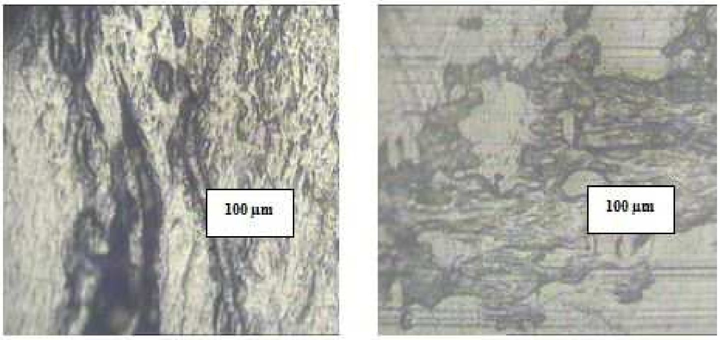


Figure-2(a) Figure-2(b)

**Figure 2:** Photomicrographs of wear pattern (a) Polyurethane (b) Polyacetal

**(c) Wear pattern**

The wear pattern of the polymers worn out morphology subjected to maximum wear rate under highest applied load and sliding velocity were chosen for wear pattern analysis as shown in the **Figure 2.** It was clearly evident that some local melting and sub-surface crack propagation due to heat generation at the contact interface has occurred in the case of polyurethane corresponding to the highest load and sliding velocity. Polyurethane invariably exhibited higher frictional coefficient irrespective of loads and sliding velocities. Fragments of material had detached from the interface as a result of heating. The adherence of such detached fragments on to the counterface leads to irregular film, which results in enhancement of friction and wear causes the fatigue wear and delamination wear. The wear pattern of polyacetal is depicted in **Figure 2(b)**. Scattered sections of wear pattern were visualized in the figure and less number of sub-surface deformations was observed. This may be the cause that the polymer is subjected to less influence over the applied loads and sliding distances. Micro cutting edges and patchy film transfer were also observed in the wear pattern of Polyacetal polymer which reduces the friction coefficient.

It can be concluded that at higher loads, there is increase in coefficient of friction for polyurethane. This is possibly attributed to visco-elastic transitions taking place due to rise in temperature. Polyacetal shows moderate frictional coefficient and low wear rate and no stick- slip, irrespective of the applied load and sliding velocities. Polyacetal exhibits better properties for sliding applications with high wear resistance and lower friction coefficient compared to Polyurethane.

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