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FRICTION AND WEAR BEHAVIOR OF POLYDICYCLOPENTADIENE UNDER DRY SLIDING AND BOUNDARY LUBRICATION

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Abstract

In this investigation the influence of test load and roughness of steel on the friction and wear behaviour of polydicyclopentadiene (PDCPD) were studied. Friction and wear tests of PDCPD and R6M5 steel were carried out under dry friction and boundary lubrication on a pin-on-disc arran-gement. Tribological tests were performed at room temperature at different pressures (10 N and 18 N), the different roughness of steel (0.08 μm and 0.15 μm), sliding speed 0.5 m/s and sliding distance 3500 m. It is shown that under dry friction sliding, the wear increases with increasing pressure. In addition to this, decreasing of the roughness of steel from 0.15 μm to 0.08 μm reduces the wear intensity more than 2.0 times. It was found that in the presence of boundary lubrication friction coefficients are significantly reduced linearly with the decrease in viscosity of lubricants (polydimethylsiloxane fluids).

Keywords: polydicyclopentadiene; ring-opening metathesis polymerization; coefficient of friction; boundary lubrication; dry sliding.

1. Introduction

With the recent development of ruthenium-based catalysts for olefin metathesis which are tolerant to the presence of a wide range of polar functionalities, the ring-opening metathesis polymerization (ROMP) has recently emerged as a powerful tool to synthesize well-defined macro-molecular materials [1-3]. Another advantage of ROMP is the production of industrially appli-cable polymers. Dicyclopentadiene (DCPD) has received much attention as a monomer for ROMP due to its high polymer modulus of elasticity, excellent impact strength, and chemical resistance [4]. It can be polymerized via ROMP giving polydicyclopentadiene (PDCPD) which is used in high performance structures as a matrix material [5]. PDCPD is a highly cross-linked polymeric material with high toughness. This polymer has been extensively studied to improve mechanical properties since its appearance, and many fillers such as elastomers [6-8], poly-ethylene fiber [9], binder and glass fibers [10], modified clay [11-12], carbon nanotube [13], have been used to prepare PDCPD matrix composites, partly because the monomer of PDCPD is a by-product with relatively large output in petroleum industry. However, few investigations have been done on the frictional and wear properties of PDCPD materials [14-17].

The goal of this research is to investigate friction and wear behaviors of PDCPD under dry friction and boundary lubrication on a pin-on-disc arrangement. The influence of steel disc roughness and load on friction and wear of PDCPD were studied.

2. Experimental

2.1. Materials

PDCPD samples were synthesized by ring opening metathesis polymerization. For that purpose DCPD and Ru-catalyst [18] solution in ratio 1:15000 were mixed vigorously using a magnetic stirrer for about 30 seconds. The mixture was then placed in glass tubes and was polymerized by heating from 60^{0}C to 180^{0}C. After polymerization, the obtained polymer was cooled to ambient temperature. The polymethylsilicon liquids with viscosity 50, 100, 200, 10000, 30000, 60000 cSt were used as boundary lubricants.

2.2. Friction and wear tests

The friction and wear behaviors of PDCPD sliding against steel were evaluated using a PC-Operated High Temperature Tribometer THT-S-AX0000 (CSEM, Zwitserland). Sliding tests were conducted on a pin-on-disk model. The cylindrical pin specimens of size 5.5 mm diameter and 18 mm length were tested against R6M5 steel disk with 50 mm diameter and 5 mm thick dry under sliding condition and under the presence of boundary lubricants. The tests were carried out at a sliding velocity 0.5 m/s, a load of 10 N and 18 N, and duration of 120 min at room temperature. Before each test, the steel disk was abraded with No. 600 or No. 2500 abrasive papers to reach a surface roughness 0.15 μm or 0.08 μm, respectively; the polymer pin was abraded with No. 2500 abrasive paper. Then, the material was cleaned with ethanol-dipped cotton. For each group, three samples were selected, and the friction coefficient was the average result of the three repetitions. Before and after tests the roughness of steel disc was determined by using optical microscopy MICRO MEASURE 3D station (STIL, France).

3. Results and discussion

Tab.1 shows the friction coefficients values and mass loss for PDCPD tested at room temperature, under dry wear conditions and load of 10 N and 18 N, and steel disc roughness 0.08 μm and 0.15 μm. It is obvious that the wear mass loss of PDCPD increases with the increase in loading. The wear mass loss is increased by 230% and 170% for steel disc roughness 0.08 μm and 0.15 μm, respectively, while the loading was changed from 10 N to 18 N.

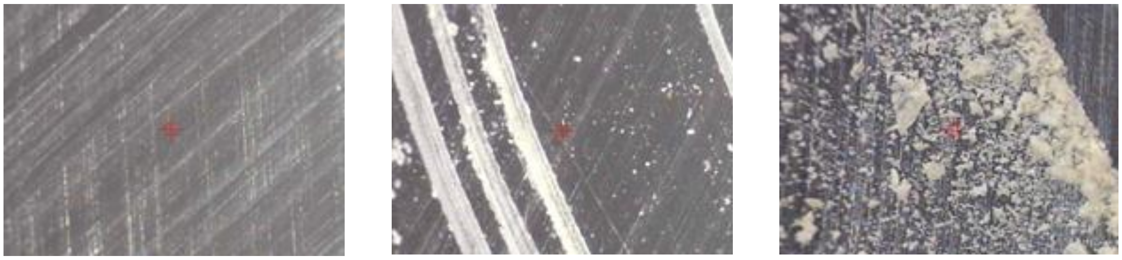
Table 1. Coefficient of friction and mass loss for PDCPD obtained under dry sliding

Load (N)	Steel disc roughness (μm)	Coefficient of friction, μ	Mass loss (mg)
10	0.08	0.66	1.9
10	0.15	0.60	4.7
18	0.08	0.60	6.2
18	0.15	0.57	12.8

It also is found that decreasing of steel disc roughness from 0.15 μm to 0.08 μm reduces the mass loss by about 50-60 % both for loading 10 N and 18 N, however, the values of friction coefficients change insignificantly.

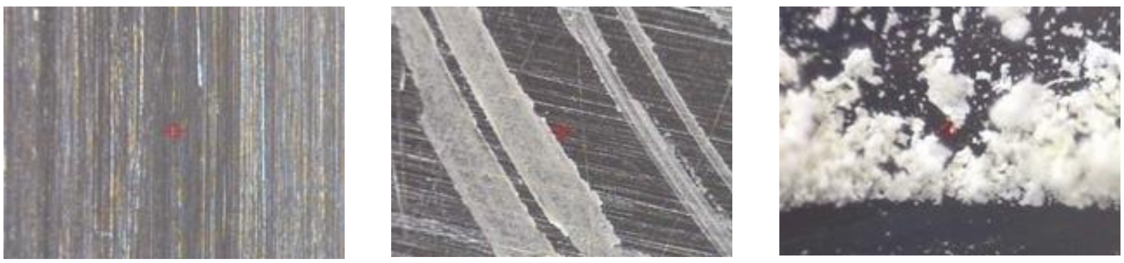
In order to obtain more knowledge about the variation in friction and wear mechanism due to the increase of loading and roughness, the surface of steel disc before and after the test was investigated by profilometry. Images of the steel disc wear surface at loading 10 N and 18 N and with different roughness are shown in Figs. 1-4. According to profilometry, the worn surface was characterized by mild micro-ploughing and the wear mode is typical abrasive wear. Further-more, PDCPD has a hardness that is able to abrade the steel (Figs. 3b, 4b).

To sum up, reducing steel disc roughness leads to slight rising in coefficients of friction simultaneously with significant decreasing of mass loss. However, on an industrial scale, the low roughness of metal can be achieved only by using expensive equipment, particularly for items with irregular or cylindrical shape. In this case, the lubricants are used for decreasing friction energy.



a). b). c).

Fig. 1. Surface of the steel disk with roughness 0.15 µm before (a) and after experiment: the track of friction with polymer roads (b) and with polymer particles (c) under load of 10 N, the linear velocity of 0.50 m/s

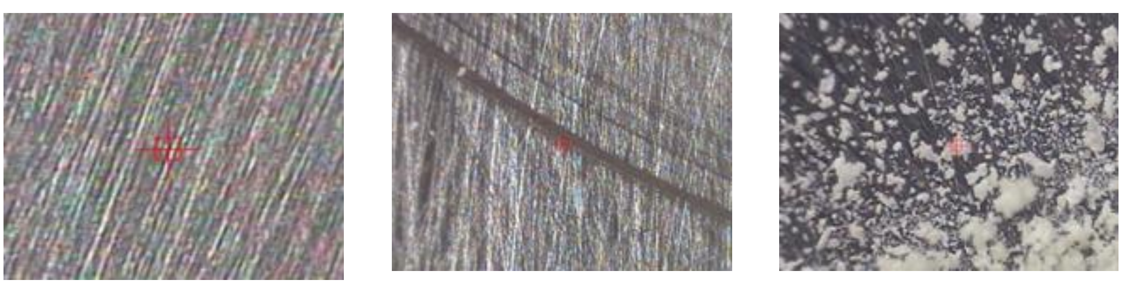


a). b). c).

Fig. 2. Surface of the steel disk with roughness 0.15 µm before (a) and after experiment: the track of friction with polymer roads (b) and with polymer particles (c) under load of 18 N, the linear velocity of 0.50 m/s

a). b). c).

Fig. 3. Surface of the steel disk with roughness 0.08 µm before (a) and after experiment: the track of friction with polymer roads (b) and with polymer particles (c) under load of 10 N, the linear velocity of 0.50 m/s



a). b). c).

Fig. 4. Surface of the steel disk with roughness 0.08 µm before (a) and after experiment: the track of friction with polymer roads (b) and with polymer particles (c) under load of 18 N, the linear velocity of 0.50 m/s

In order to investigate the wear and friction behavior of PDCPD in the presence of boundary lubrication, the polymethylsiloxane liquids (PML) were applied. PML are characterized by their chemical inertness, low cost and a wide range of applications. Tab.2 illustrates the main results of this investigation.

Table 2. Coefficient of friction for PDCPD obtained under sliding in the presence of boundary lubricants PML (sliding velocity 0.5 m/s, steel disc roughness 0.15 µm, length of wearing 3500 m)

Viscosity of PML, cSt	Coefficient of friction, μ	
	10 N	18 N
Without lubrication	0.60	0.57
53	0.10	0.11
100	0.04	0.08
200	0.05	0.09
10000	0.12	0.11
30000	0.16	0.14
60000	0.20	0.15

As a result, using the simplest lubricant – polymethylsiloxane liquid allows reducing friction coefficients more than 4.0 times without losing the polymer weight after 3500 m sliding.

4. Conclusions

As a result of the study, the following conclusions were drawn:

1. The wear and friction properties of pure PDCPD against steel R6M5 were investigated under dry friction and boundary lubrication and can be considered as a good wear-resistant polymer between materials used in this study.
2. The friction coefficient of pure PDCPD rises insignificantly when applied load or steel disc roughness increase.
3. It is found that the friction in the presence of boundary lubrication and friction coefficients are significantly reduced linearly with the decrease in viscosity of lubricants PML.
4. As for the specific range of load and roughness explored in this study, the load under dry friction has a stronger effect on the wear behaviour of PDCPD than the steel disc roughness.

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