Materials Letters 62 (2008) 4161–4163

Contents lists available at ScienceDirect

Materials Letters

journal homepage: www.elsevier.com/locate/matlet

Friction and wear properties of UHMWPE/nano-MMT composites under oilfield sewage condition

Jianping Wen *, Pu Yin, Minghui Zhen

College of Materials Science and Technology, Nanjing University of Aeronautics and Astronautics, 29 Yudao Street, Nanjing 210016, People's Republic of China

ARTICLE INFO

Article history:
Received 23 July 2007
Accepted 2 June 2008
Available online 6 June 2008

Keywords:
Composite materials
Wear
Friction
Ultra-high molecular weight polyethylene
Montmorillonite

ABSTRACT

A new stabilizer material ultra-high molecular weight polyethylene (UHMWPE) was reinforced with modified nano-montmorillonite (MMT) in different contents. Tribological properties of the materials, together with the polyamide (PA) material used as stabilizer for the purpose of comparison, were tested against a J55 steel counterfact on a reciprocating tribometer under oilfield sewage condition. The experimental conditions were a contact pressure 7.0 MPa, a stroke length of 15 mm, and a reciprocating frequency of 1 Hz. The results show that the 10 wt.% nano-MMT composite exhibits the lowest friction coefficient and the best wear resistance among all specimens; that furrow and larger area of brittleness break are dominant for the PA specimen, and that plowed scratches and abrasive wear are dominant for the 10 wt.% nano-MMT composite. The new material proves to be better than PA material when used as stabilizer materials.

1. Introduction

In the petroleum exploitation's pumping system, in order to reduce friction and wear between the sucker rod and pipeline, stabilizer, which is widely made of polyamide (PA) materials, is often fixed on the sucker rod to resolve the problem. From the research on PA materials stabilizers' service condition [1], it is found that their wear resistance and impact resistance is still not very good and service life is short. So it is very important to develop a new stabilizer material which exhibits better wear resistance and owns the merit of low cost and long service life.

Ultra-high molecular weight polyethylene (UHMWPE) is one of the most widely used thermoplastic polymers for mechanical and wear-resistance applications [2–4]. UHMWPE possesses many excellent properties, such as high toughness, good chemical stability, low friction coefficient and minimal water absorption etc. [5]. However, UHMWPE has some disadvantages: its hardness and Young's modulus are low, and it easily creeps under load. In order to improve these properties, wollastonite fibers, carbon fibers and inorganic particles etc. have all been used as reinforcing or filler materials [6–8].

In recent years, polymers reinforced with montmorillonite (MMT), which consisting of silicate layers, have aroused significant attention due to their unexpected properties. In the literatures, various polymer/clay nano-composites have been extensively reported in the form of different polymer matrixes, such as polyamide [9], epoxy [10] and polyacrylonitrile [11]. However, few research reports on the tribological properties of nano-MMT reinforced UHMWPE composites have been appeared. In this study, the friction and wear performance of UHMWPE/nano-MMT blend, together with the PA materials for the purpose of comparison, were investigated using a reciprocating tribometer. The objective of this work is to develop a new stabilizer material that has high wear resistance, low cost and long service life.

2. Experiment

2.1. Specimen preparation

Montmorillonite with a particle size of about 100 nm was treated by a silicon coupling agent (KH570), and then fully mixed with the UHMWPE powder of the 3,000,000 molecular weight in different weight percentages. The mixtures were filled into a mould and pressed under 50 MPa then sintered at (175±5) °C for 2 h in a stove, followed by hot-pressing under 30 MPa. After cooling to room temperature, the composites were machined to the dimensions of 40×30×10 mm.

2.2. Wear tests

The friction and wear behavior of the composites were evaluated in laboratory air using a computer controlled reciprocating sliding tribometer. The schematic representation of the part related to loading of the apparatus is shown in Fig. 1. The friction force and normal load were measured with the aid of linear variable strain

* Corresponding author. Tel.: +86 25 52112626; fax: +86 25 84894772.
E-mail address: zlmwjp@nuaa.edu.cn (J. Wen).

0167-577X/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.matlet.2008.06.003

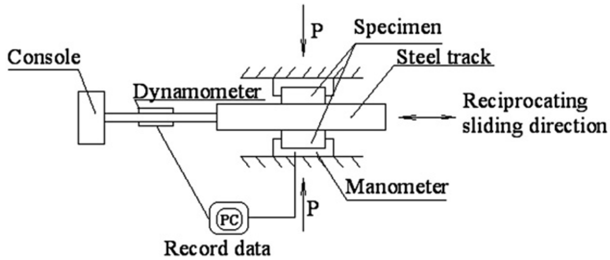

Fig. 1. Schematic representation of the part related to loading of the apparatus.

gauges and recorded automatically throughout the tests connected to a PC. Sewage blob, which are produced from a self-assembled device, were continuously dropped from the top of the tribometer to the contact surface of the friction pair at the rate of 100 drop/min for wear testing. A J55 steel commonly made into oil tubing(C=0.41 wt.%, Si=0.32 wt.%, Mn=1.44 wt.%, P,S≤0.025 wt.%, Cr,Ni,Cu≤0.25 wt.%, Mo≤0.03 wt.%) bar of the size 210×80×41 mm was used as a track material. Surface roughness of the J55 steel track and specimens is about 0.1 µm (R_a) and 0.2 µm (R_a) respectively. Prior to the test, the specimens and J55 steel track were cleaned with acetone and used after drying.

Sliding tests were carried out at room temperature in ambient atmosphere (65±2% RH) under oilfield sewage condition, with a contact pressure 7.0 MPa and a reciprocating frequency of 1 Hz. The stroke length was 15 mm. The wear mass loss of the specimens was determined by an electronic analytical balance with an accuracy of 0.01 mg. The wear traces of specimens were examined by scanning electron microscopy (SEM).

3. Results and discussion

3.1. Effect of nano-MMT content on friction and wear

Fig. 2 shows the variation of friction coefficient with sliding distance. It was observed that the initial friction coefficient of all materials is relatively low, but it increased rapidly to maximum points and decreased rapidly within short sliding distance, followed a relatively steady-stage sliding until the friction coefficient remained unchanged due to the formation of the steady transfer films between contact surfaces of friction pair during the repetitive sliding action.

The effect of nano-MMT content on the wear of UHMWPE composites is shown in Fig. 3. The wear rate of composites decreased with the content of nano-MMT from 5 wt.% to 10 wt.%, and then increased with the content of nano-MMT from 10 wt.% to 15 wt.%.

It can be seen from Figs. 2 and 3 that the 10 wt.% nano-MMT composite showed the lowest wear rate and friction coefficient, while the PA specimens exhibited the highest wear rate and friction coefficient amongst all samples.

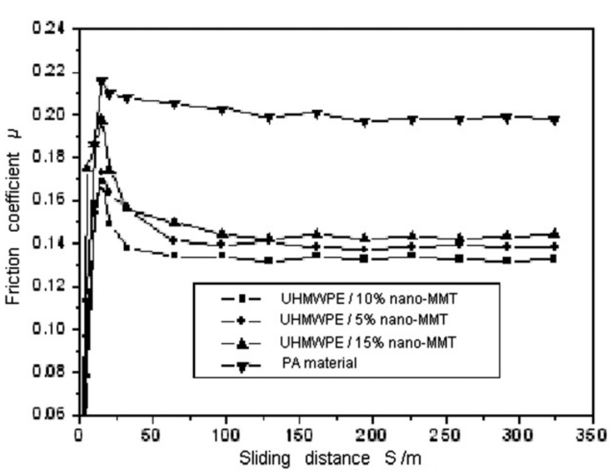

Fig. 2. Variation of friction coefficient with sliding distance.

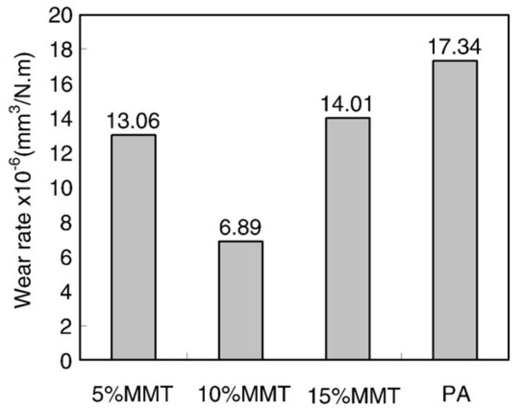

Fig. 3. Wear rate of composites and PA specimens.

3.2. Analysis of worn surfaces and discussion

Fig. 4 is SEM micrographs of the worn surfaces for the PA specimen and the 10 wt.% nano-MMT composite after 325 m of wear test. It can be seen that the surface worn of the PA specimen was stricter than that of the 10 wt.% nano-MMT composite. Except the furrow, there is larger area of brittleness break (Fig. 4(a)). The worn surface of the 10 wt.%

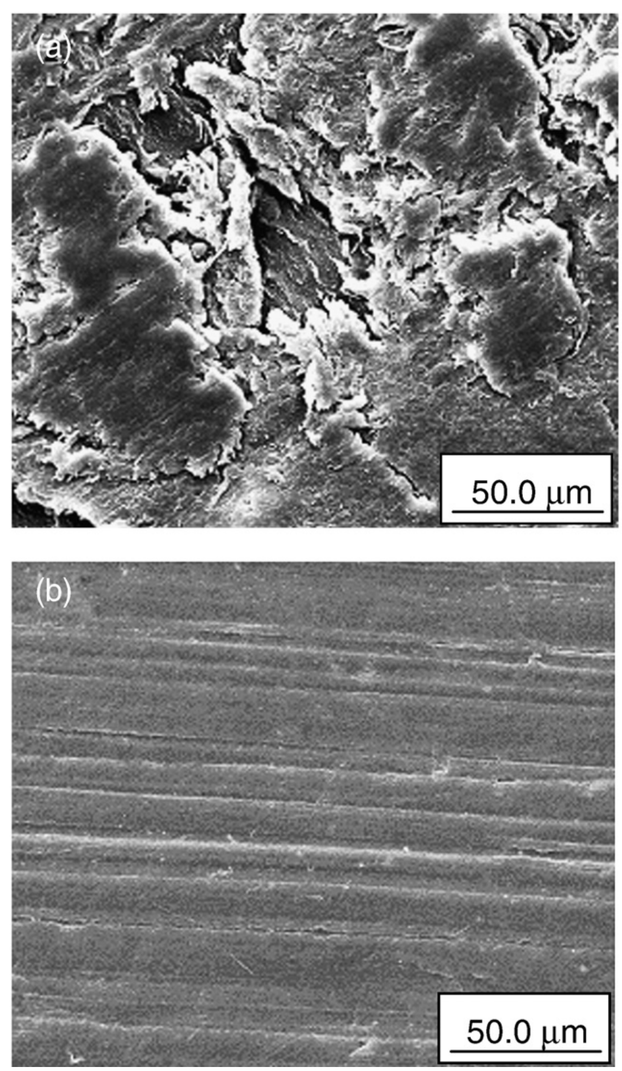

Fig. 4. SEM micrographs of worn surfaces of the PA material (a) and the 10 wt.% nano-MMT composite (b).

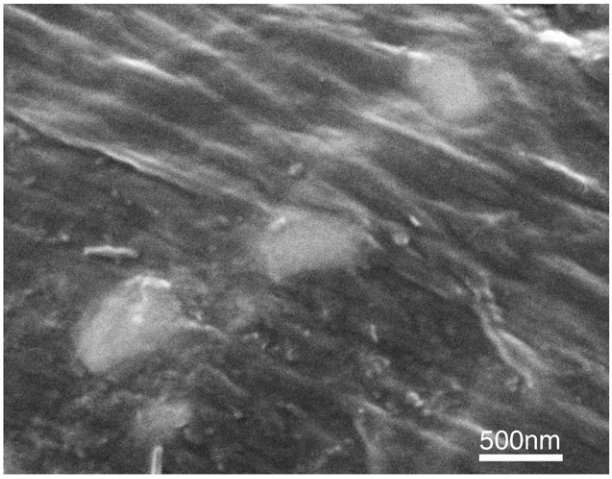

Fig. 5. SEM micrograph of agglomerates for 15 wt.% nano-MMT in UHMWPE composite.

nano-MMT composite was smoother, and only exhibited plowed scratches and abrasive wear (Fig. 4(b)). This was in agreement with the results obtained by Xiong et al. [12], who tested UHMWPE under physiological saline condition. Erosive ion, such as chloride ion, played a corrosive role for J55 steel track. The surface roughness of the counterface material increases with the surface corrosion of J55 steel. On the other hand, phenomenon similar to three-body wear occurs due to the hard fine sand grain contained in the oilfield sewage. Therefore, the abrasive wear and plowed are the main wear mechanism of the 10 wt.% nano-MMT composite.

Interestingly, 10 wt.% composite exhibited lower friction coefficient and wear rate than 5 wt.% composite. This behavior was attributed to the presence of the nano-MMT particulates, which acted as effective barriers to prevent large-scale fragmentation of UHMWPE. Increasing the percentage of the nano-MMT particulates in the UHMWPE increased the hardness and strength of composites, and consequently decreased the real contact area of the pair, i.e. decreased the friction force. When the nano-MMT particulate increased to 15 wt.%, friction coefficient and wear rate of composite increased compared to with composite of the 10 wt.%. This may be that the nano-MMT particulates stuck together and formed agglomerates in the size of several microns, as shown in Fig. 5.

The PA specimens exhibited the higher wear rate and friction coefficient than UHMWPE composite. This may be the reason of high water absorption of the PA material, result in the PA specimens swell and lowered the surface rigidity or hardness, and consequently increased the real contact area of the pair.

4. Conclusions

Under oilfield sewage condition, Friction coefficient and wear rate of the nano-MMT reinforced UHMWPE composite are all very much lower than that of PA material. The nano-MMT particulates played an important role in impeding large-scale fragmentation of UHMWPE. The new composite is rather a kind of stabilizer material compared to the PA material.

References

[1] Li JK, Gou YJ, Xie WX. Oil Mach 2000;28:32–3 [in Chinese].
[2] Jacobs O, Mentz N, Poeppel A, Schulte K. Wear 2000;244:20–8.
[3] Ge SR, Wang QL, Zhang DK, Zhu H, Xiong DS, Huang CH, et al. Wear 2003;255:1069–75.
[4] Unal H, Mimaroglu A. Mater Des 2003;24:183–7.
[5] Liu GJ. Ultra-High Molecular Weight Polyethylene. Beijing: Chemistry industry publishing company; 2001. p. 11–5.
[6] Xiong DS. Mater Lett 2005;59:175–9.
[7] Gong GF, Yang HY, Fu X. Wear 2004;256:88–94.
[8] Tong J, Ma YH, Jiang M. Wear 2003;255:734–41.
[9] Fornes TD, Yoon PJ, Paul DR. Polymer 2003;44:7545–56.
[10] Guo BC, Jia DM, Cai CG. Eur Polym J 2004;40:1743–8.
[11] Yu TS, Lin JP, Xu JF, Chen T, Lin SL. Polymer 2005;46:5695–7.
[12] Xiong DS, Ge SR. Wear 2001;250:242–5.