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Effects of fibrous fillers on friction and wear properties of polytetrafluoroethylene composites under dry or wet conditions

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Abstract

The friction and wear behavior and mechanism as well as the mechanical properties of polytetrafluoroethylene (PTFE) composites filled with potassium titanate whiskers (PTW) and short carbon fibers (CF) under dry, wet and alkaline conditions were investigated. Experiments indicated that owing to appropriate cooling and boundary lubricating effects, the filled PTFE composites showed much lower frictional coefficient and better wear resistance under alkaline than dry and wet sliding conditions. The wear resistance of carbon-fiber-filled PTFE was much better than that of potassium titanate-whisker-filled PTFE composites in water. Results also showed that the transfer film on counterpart rings was significantly hindered by water and alkali. Hydrophilic-filler-reinforced PTFE composites yield higher wear rate when sliding under water.

Keywords: PTFE composites; Whiskers; Carbon fibers; Friction and wear properties; Alkaline solution

1. Introduction

Special materials are often required in the petroleum and chemical industry, where acid, alkali or other media are to be dealt with. Polymer is a promising sealing and wear-resistant material in such corrosive environments, especially polytetrafluoroethylene (PTFE) which is widely used as a special plastic due to its self-lubricating capacity, high chemical inertness and thermal stability. However, poor wear resistance and severe creep deformation limit its wider use (Khedkar, Negulescu, & Meletis, 2002). Tribological properties of PTFE composites filled with various fillers have been extensively studied (Li, Hu, Li, & Zhao, 2002; Tanaka, 1986), though most of the published investigations have been on the friction and wear of PTFE composites sliding under dry conditions (Tanaka, 1986; Unal, Mimaroglu, Kadıoglu, & Ekiz, 2004), and but few for water conditions (Bao & Cheng, 2006; Borruto, Crivellone, & Marani, 1998; Jia, Chen, Zhou, Wang, & Zhou, 2004) and practically none for acid or alkali solutions.

High-strength, wear- and corrosion-resistant PTFE composites are needed for conduit pipes, pump impellers, paddings and gaskets, as well as piston rings for compressors, which are exposed to wet or corrosive environments, for all of which tribological performance of PTFE composites needs to be studied.

Carbon fibers (CF) have been found to be good reinforcing materials to improve the tribological properties of PTFE (Bijwe, Neje, Indumathi, & Fahim, 2002; Unal et al., 2004), and potassium titanate whiskers (PTW), for their excellent mechanical properties, wear resistance, chemical and thermal stability, are widely used as an inorganic filler for structural reinforcement of polymers, metals, and ceramic composites (Feng et al., 2006; Lv and Lu, 2001). PTW is especially excellent for micro-reinforcing because of its tiny dimension, and is suitable for reinforcing very narrow regions which conventional fillers cannot easily enter.

The aim of this work is to study the friction and wear properties of PTFE composites reinforced with various amounts of PTW and CF, sliding under dry, wet and alkaline as well as other rigorous conditions.

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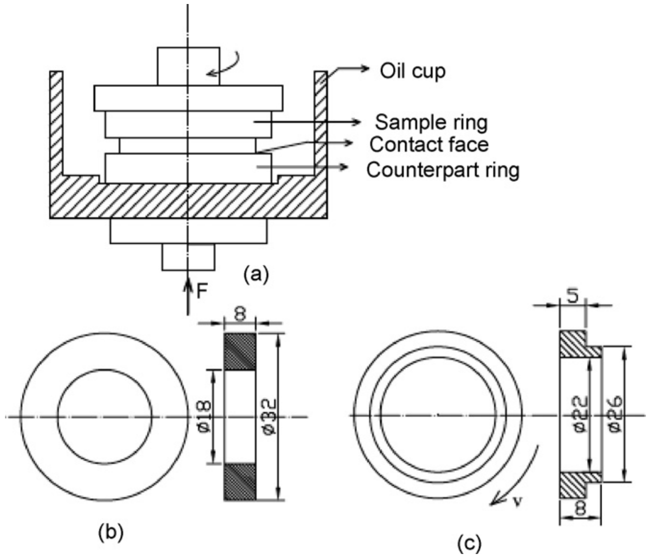

Fig. 1. Schematic diagram of frictional contact parts (unit: mm). (a) Ring on ring contact; (b) counterpart ring; (c) sample ring.

2. Experimental details

2.1. Materials and preparation of PTFE composites

PTFE powder with average particle size of 25 μm was supplied by Dupont (7A-J). CF with average diameter and length of 9 and 90 μm respectively were from Nanjing Fiberglass Research & Design Institute. PTW with average diameter and length of 1 and 20 μm respectively was synthesized by ourselves (Feng et al., 2006; Lv and Lu, 2001) and was modified by an amino silane coupling agent. Lubricants consisted of de-ionized water and 10 wt% sodium hydroxide alkaline solution.

The fillers and PTFE powder were weighed in the proportions as needed and blended mechanically. The mixtures were compressed into test samples at 25 °C and 70 MPa for 5 min, which were then sintered and kept at 380 °C for 4 h, and finally cooled at 40 °C/h to room temperature. Finally, the sintered samples were cut into shape (Fig. 1(c)). The stainless steel counterpart ring (Fig. 1(b)) and the sample ring were polished to Ra (surface roughness) = 0.15–0.3 μm with number 900 SiC grit abrasive paper and cleaned with acetone.

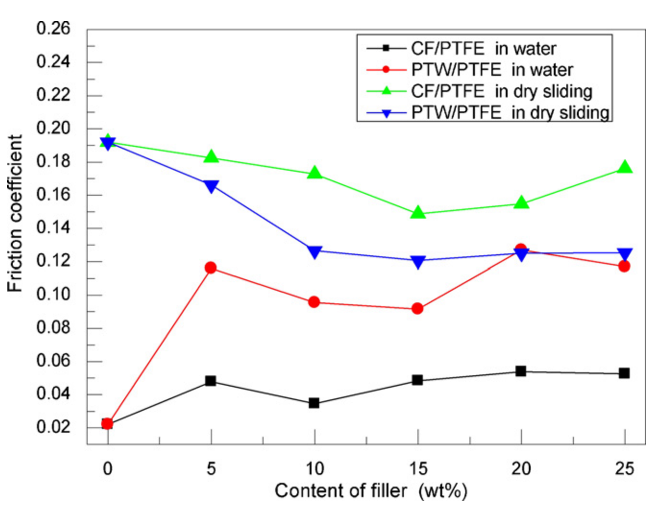

Fig. 2. Frictional coefficient of PTFE composites in water and dry conditions at 1.4 m/s and 200 N.

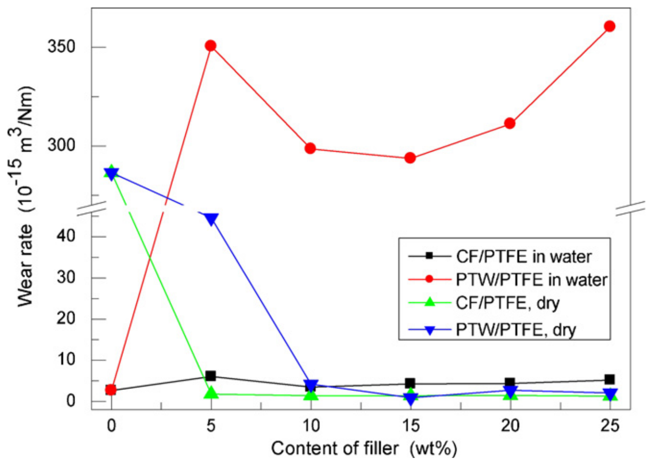

Fig. 3. Wear rate of PTFE composites in water and dry conditions at 1.4 m/s and 200 N.

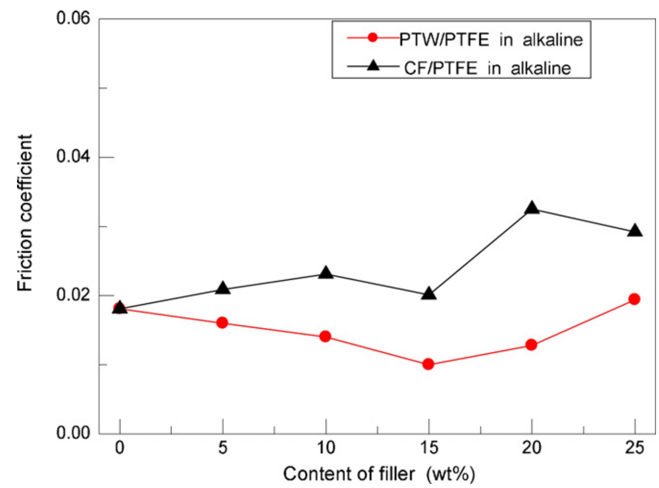

Fig. 4. Frictional coefficient of PTFE composites in alkali at 1.4 m/s and 200 N.

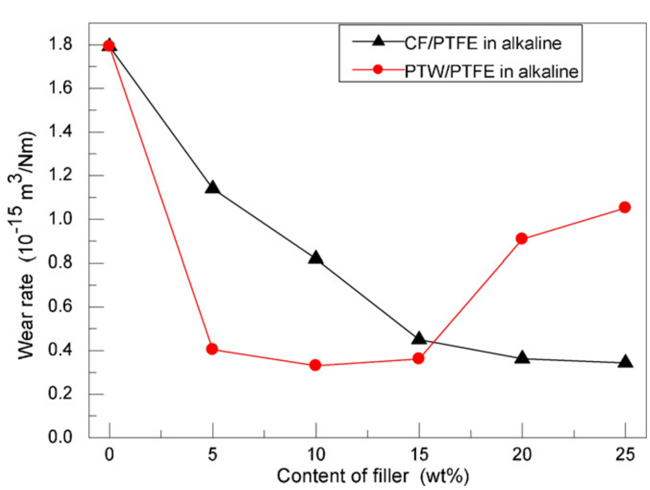

Fig. 5. Wear rate of PTFE composites in alkali at 1.4 m/s and 200 N.