Wear Resistance of Poly(ether-etherketone)/Polytetrafluoroethylene Composite Coating

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Abstract

Polyetheretherketone/polytetrafluoroethylene (PEEK/PTFE) composite coatings were prepared on low carbon steel via flame spraying. The friction and wear rate of the composite coatings were performed using a ball-on-disc test rig in environments of air. The morphologies and worn surfaces of the PEEK/PTFE coatings were also observed using the optical microscope and the scanning electron microscope. The specific wear rate, friction coefficient and hardness of the different compositions were improved with an increase of PEEK content.

Keywords : PEEK/PTFE composite coating, Flame spray coating, Wear

1. Introduction

Thermal sprayed polymer coatings have been widely applied for petrochemicals, automotives and aircraft industries [1]. Polytetrafluoroethylene (PTFE) is well-known as polymer solid lubricant with its chemical inertness, very low coefficient of friction and good thermal stability. However, PTFE has been limited by its higher wear rate and abrasion resistance [2]. To minimize this problem, suitable fillers have been added into PTFE to combine both low coefficient of friction and excellent wear resistance. Poly-ether-ether-ketone (PEEK) is one of an interesting polymer with excellent mechanical properties, such as high strength and modulus, good toughness, and high wear resistance [3]. In this study, PEEK was introduced in PTFE matrix to enhance wear resistance, mechanical property and still have low friction coefficient. The influence of PEEK content on the friction and wear of flame sprayed PEEK/PTFE composite coating was of our interest.

2. Experimental methods

2.1 Materials and Composites Processing

PTFE (Zonyl MP1200, Dupont) and PEEK (Victrex 150XF) powders with an average particle size of 3 µm and 25 µm, respectively, were used as precursor materials. Properties of PTFE and PEEK are presented in Table 1. PEEK contents in a range of 10-50 wt% were mixed with PTFE and prepared by a ball mill technique.

Table 1 Properties of PTFE and PEEK

Properties	PTFE	PEEK
Density [g/cm^3]	0.45	0.30
Melting point [C°]	325±5	343
Thermal degradation [C°]	>400	527
Hardness [Shore D]	55-72	85
Average particles size [µm]	3	25
Thermal expansion [10^{-6} m/ C°]	126-216	72-85

2.2 Coating preparation

Composite coatings were deposited by the flame spraying process, SULZER METCO DJ Diamond Jet Gun, onto low carbon steel substrates. Propane and nitrogen gases were used as a fuel gas and a powder carrier gas, respectively. The spraying parameters are presented in Table 2.

2.3 Charactreization

Microstructures of the composite coatings were examined by optical microscopy (Olympus, Japan).

The hardness of the composite coatings was measured by Vickers micro hardness tester (SV3000, Mitutoyo, Japan).

The crystallinity and functional group in the composite coatings can be used to determine by XRD (D8 Discover series 2, Bruker AXS, Germany) and FTIR (Model Nicolet iS5 FTIR) technique, respectively.

The friction and wear tests were performed with a Ball-on-Disc test rig. The tests were conducted under dry conditions with a sliding speed of 0.1 m/s and a load of 1 and 3 N. The morphologies of the worn surfaces were observed by scanning electron microscopy (SEM, JSM-5800 LV, JEOL, USA).

Table 2 Flame spray parameters for composites coating

Parameters (units)	Value
Gas compression (psi)	
- O_2	60
- C_3H_8	65
- N_2	50
Gas flow rate (FMR)	
- O_2	48
- C_3H_8	45
Powder feed rate (g/min)	20
Spray distance (mm)	70
Inverter speed (rpm)	30
Preheat temperature (°C)	300

3. Results and Discussion

Figure 1 illustrates the cross section of the PTFE composite coating with 50 wt% PEEK. The microstructure showed that the darker areas were PTFE, while the lighter areas were PEEK. The coatings exhibited little porosity with a uniformly distribution of PEEK particles.

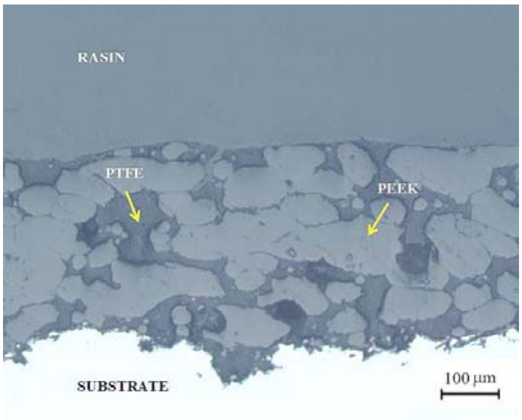

Figure 1. Cross sectional view of the PTFE composite coating with 50 wt% PEEK contents.

Reflection spectra of internal surface of neat PEEK, PTFE and the composite coatings were presented in Figure 2. The sharp band intensity of CF_2 symmetric stretching mode at 1199-1146 cm^{-1} which corresponds to the presence of PTFE can be seen. Strong bands at 800, 1400 and 1600 cm^{-1} can be assigned to O-C-O, aromatic and C=O groups, respectively [4]. The spectra indicated no chemical changes of the composite material, while PTFE contents were decreased after flame spraying. The hardness values as a function of PEEK contents were presented in Figure 3. It was found that the hardness values of PEEK/PTFE composite coatings increased significantly with increasing in PEEK contents. This was because an increase in the crystallinity of PEEK, as showed in Figure 4.

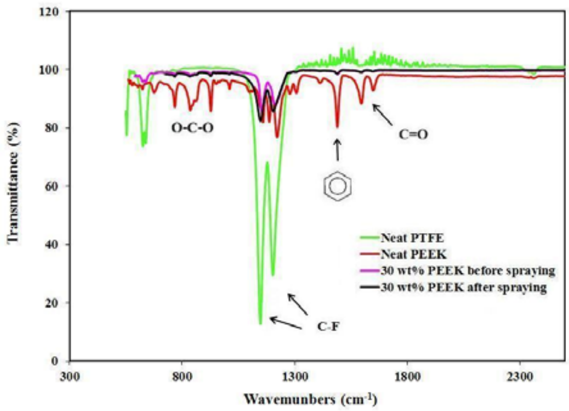

Figure 2. ATR-FTIR spectra for neat PTFE, neat PEEK and the PTFE composite coating with 30 wt% PEEK contents before and after spraying.

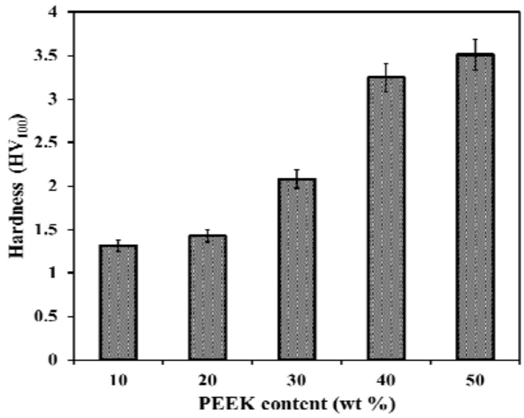

Figure 3. The effect of PEEK content on hardness of PEEK/PTFE composite coatings.

Figure 5 shows the specific wear rate and the coefficient of friction of composites as a function of PEEK content in PTFE. It can be seen that the coefficient of friction and specific wear rate of PEEK/PTFE composite coatings decreased with an increasing PEEK content. The worn surfaces of the PEEK/PTFE composite coatings are shown in Figure 6. The arrows indicated the sliding directions. In Figure 6a, it can be seen cracks at the rim of the wear track. Also, the composites material was extruded at the rim of wear track.

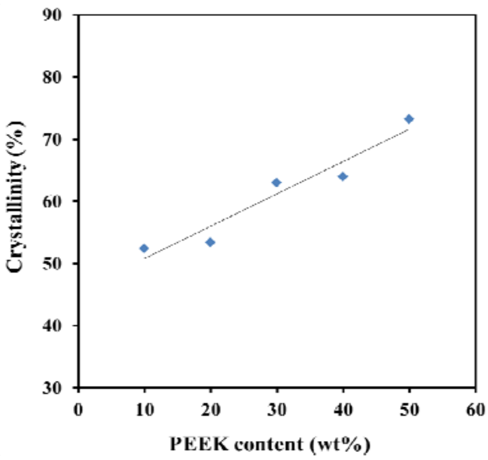

Figure 4. The effect of PEEK content on crytallinity of PEEK/PTFE composite coatings.

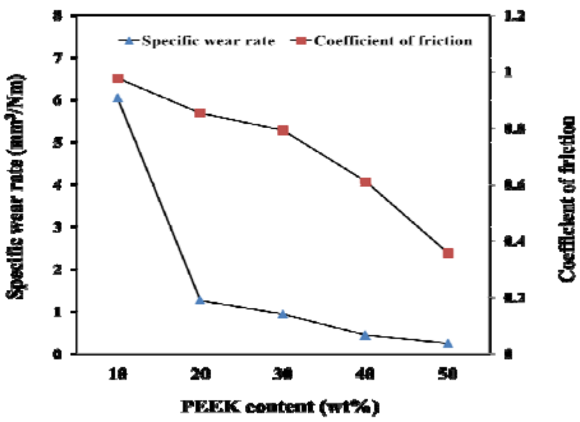

Figure 5. Variations in coefficient of friction and specific wear rate as a function of PEEK content (test condition: load 1N, sliding speed 0.1 m/s).

As shown in Figure 6b and 6c, the worn surfaces of two compositions (40 and 50 wt% of PEEK) were not different in that the detached debris were pressed in the wear track.

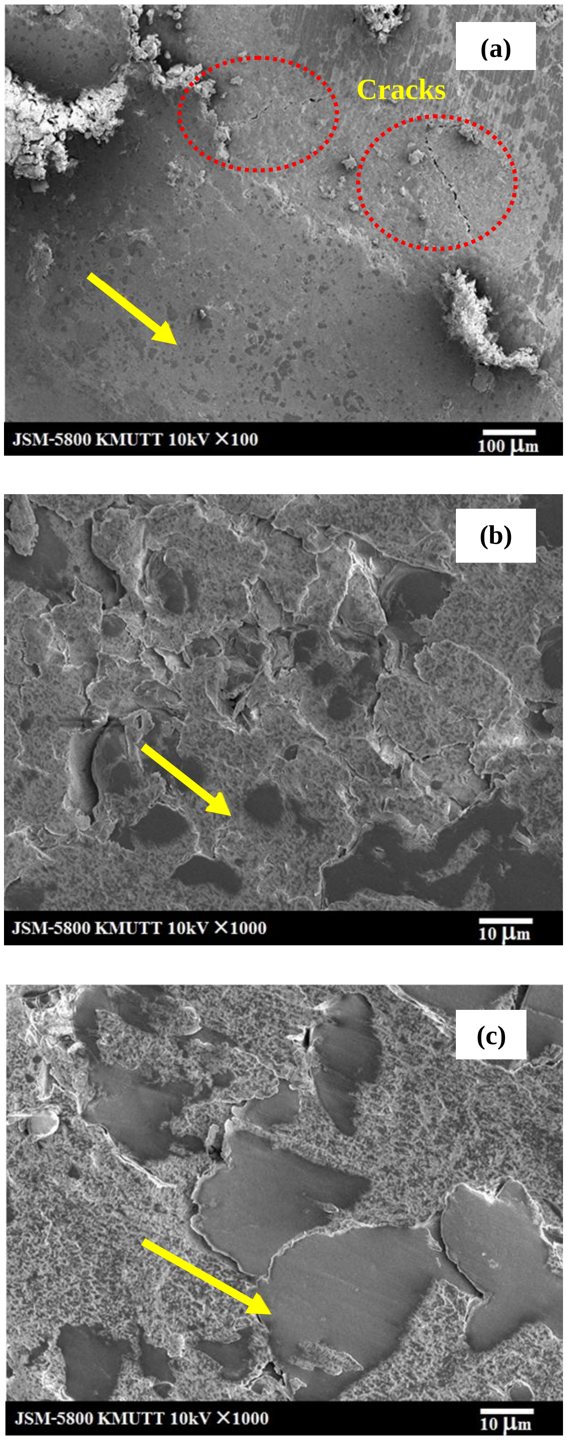

Figure 6. Worn surfaces of the PEEK/PTFE composite coatings (a) 30 wt%, (b) 40 wt% and (c) 50 wt% of PEEK (test condition: load 1N, sliding speed 0.1 m/s).

Figure 7 presents the worn surfaces of the 50 wt% PEEK/PTFE composite coating tested under a load of 1 N exhibited smoother than the composite coating tested under a load of 3 N, as shown in Figure 7a and 7b. From Figure 7B, it can be seen that the higher load induced more plastic deformation in the coating. This was due to an increase of the frictional heat at the contact surface from a high load [5]. However, PEEK pullout can be observed (in a circle). This resulted from weakened bonding between PTFE and PEEK.

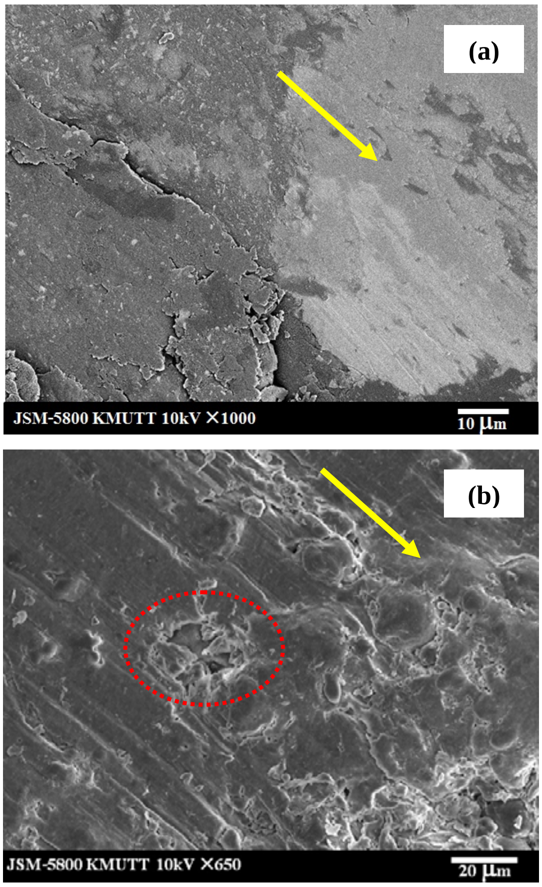

Figure 7. Worn surfaces of the PEEK/PTFE composite coatings with 50 wt% of PEEK after testing with different load (a) 1 N and (b) 3 N.

4. Conclusion

The hardness and wear resistance of PTFE coatings could be improved with an introduction of PEEK in the coatings. The lowest coefficient of friction and wear rate was achieved by 50 wt% PEEK ratio.

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