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Tribological Properties of Flame Sprayed Hexagonal Boron Nitride/Polyetheretherketone Coatings

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Abstract

Hexagonal boron nitride (h-BN)/polyetheretherketone (PEEK) composite powders were deposited on carbon steel substrate via the flame spray coating technique. The content of hexagonal boron nitride with a mean particle size of 0.5 micrometer was varied from 2 to 8 wt% in this work. Tribological properties, namely specific wear rate and friction coefficient, at room temperature, 100 ^oC and 200 ^oC were performed using Ball-on-Disc sliding wear test. At elevated temperature, h-BN could result in marked decrease in the friction coefficients and specific wear rates.

Introduction

Polyetheretherketone (PEEK) is high temperature thermoplastic material with excellent mechanical properties, e.g. high strength and stiffness, good chemical resistance, low coefficient of friction and high wear resistance without lubrication. PEEK has high glass transition (T_g) and melting temperatures (T_m) and continuous service temperature. Therefore, PEEK and its composites have been extensively studied in tribological applications, even under elevated temperatures. Hanchi and Eiss [1] studied tribology of short carbon fiber/PEEK composite at elevated temperature. It was found that the temperature below and above T_g exhibited the different wear performances. In addition, the friction coefficient and wear rate of short carbon fiber/PEEK composite decreased at temperature above T_g. Zhang et al. [2] found that the addition of sub-micro particles (TiO_2 and ZnS) in graphite+SCF/PEEK exhibited an improvement of wear performance at elevated temperature.

At present, solid lubricants have been increasingly studied and used in composite materials for tribological applications. Hexagonal boron nitride (h-BN) is one of the most interesting solid lubricants. Thus, the objective of this research is to study the tribological properties of flame sprayed h-BN/PEEK coatings at elevated-temperatures.

Experimental

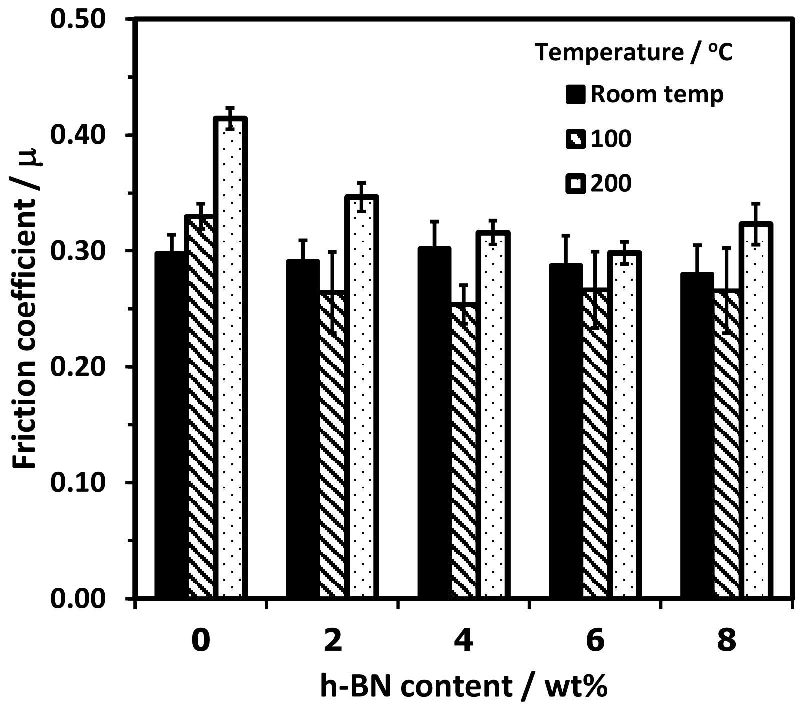
PEEK (150PF, size ~48 μm) was obtained from Victrex-MC Inc.,Japan. The h-BN powder (0.5 μm) was supplied by M K Impex Canada., Canada. PEEK with additions of 2, 4, 6 and 8 wt% h-BN were mixed into ethanol solvent in an ultrasonic bath under frequency 50 Hz for 15 min. As-mixed composite particles were dried at temperature of 80 °C for 6 hour in an oven. The h-BN/PEEK composite particles were sprayed on low carbon steel substrate (Ø 25.4 mm×5 mm in thickness) using the low velocity oxy-fuel (LVOF, DJ 1400, SULZER METCO) spraying method.

The tribological test was carried out on a Ball-on-Disc sliding wear tester. The sliding wear tests were performed at constant 25 N normal load with a sliding distance of 1000 m and a sliding speed of 0.1 ms^{-1} at room temperature, 100 and 200 °C. Powder morphology, as-sprayed composite coatings worn surface and wear debris were investigated by a scanning electron microscope (SEM, JSM-5800 LV, JEOL, USA). Cooling rate of the surface coatings was measured with thermocouple type K in the cooling time interval of coatings process (350 to 100 °C).

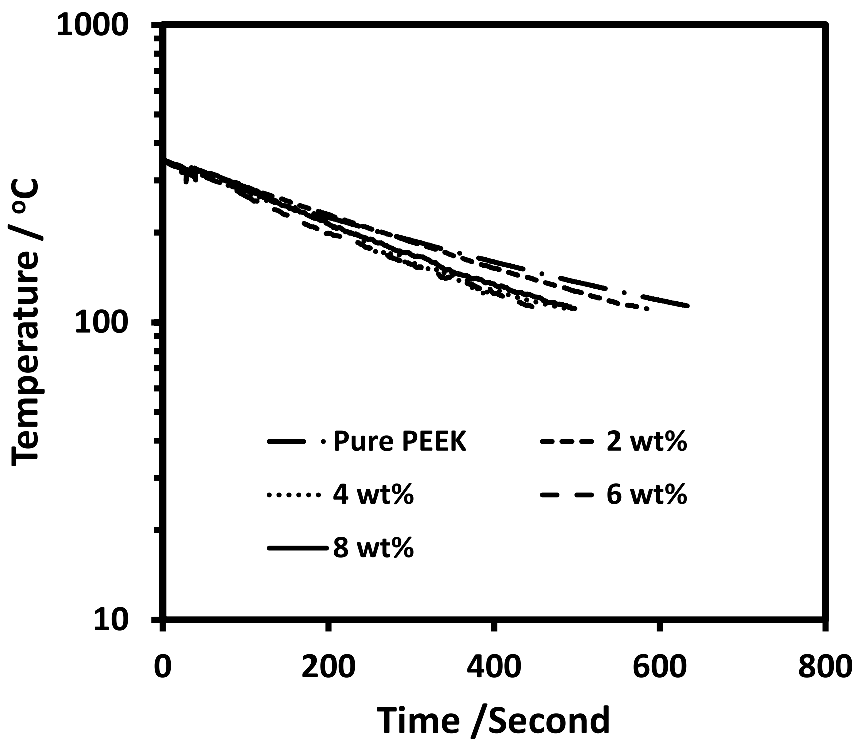
Results and discussion

Fig. 1 shows the effects of temperature and h-BN content on friction coefficient of neat PEEK and h-BN/PEEK composite coating. It can be seen that the friction coefficients of neat PEEK coating increased with increasing temperatures. This was because of the worn surface softening with test temperature [1, 2, 3]. At room temperature, the friction coefficient remained constant with an increase in h-BN contents. When the test temperature of 100 °C was used, the friction coefficient of 2-8 wt% h-BN/PEEK composite coatings decreased significantly. When the test temperature of 200 °C, the h-BN content played an important role in a highly decrease of the friction coefficient of h-BN/PEEK composite coatings. This was because high thermal conductivity of h-BN decreased heat build-up on surface coating during the wear test. It can be supported by Fig. 2 that the cooling rates of h-BN/PEEK composite coatings increased with increasing h-BN content. However, the friction coefficients of h-BN/PEEK composite coatings were higher than those of the neat PEEK and h-BN/PEEK composite coatings with the testing temperature of 100 °C.

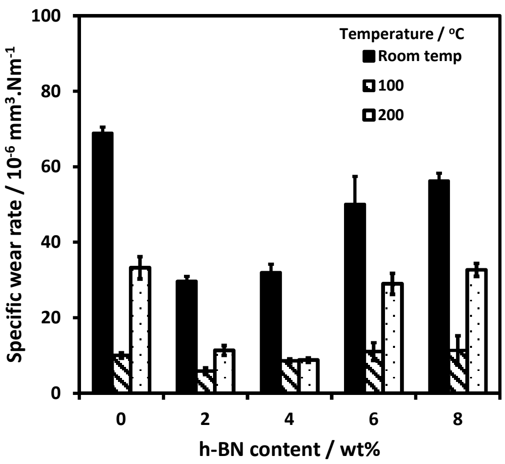
Fig. 3 exhibits the specific wear rate of neat PEEK and h-BN composite coatings. At room temperature, it can be seen that the addition of 2-4 wt% h-BN resulted in a reduction of the specific wear rate due to film formation in the wear track, as shown in Fig. 4d). In the other hand, the addition of 6-8 wt% h-BN generated a high degree of the specific wear rate resulting from abrasive mode failure, as shown in Fig. 4g). At the test temperatures of 100 °C and 200 °C, the h-BN/PEEK composite coatings showed lower specific wear rates than PEEK coatings. At the test temperature of 100 °C, SEM image (Fig. 4b) revealed smooth worn surface as result of plastic plowing of PEEK. This resulted in a reduction of material loss [1]. In addition, transfer film formation can be seen in h-BN/PEEK composite coatings, as shown in Fig. 4e) and 4h). The transfer film of solid lubricant h-BN/PEEK prevented the direct contact between a ball and composite coatings [4, 5] and thus caused low specific wear rates over entire range of h-BN contents. At the test temperature of 200 °C, the severe deformation on worn surface (Fig. 4c) was found due to transferring of PEEK from solid state to rubbery state at the T_g temperature. The addition of h-BN contents could improve heat transfer and heat dissipation [6]. This resulted in a reduction of specific wear rates. However, the addition of 6-8 wt% h-BN contents generated a decrease in adhesion between worn surface and transfer film, as shown in Fig. 4i). This resulted in an increase of specific wear rate.



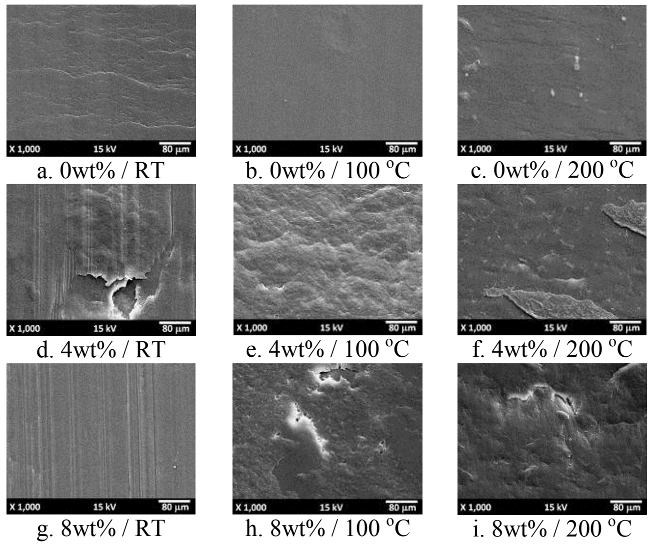
Figures 1. Effect of h-BN contents on friction coefficient of PEEK composites at different elevated temperature



Figures 2. Effect of h-BN contents on cooling rate



Figures 3. Effect of h-BN contents on specific wear rate of PEEK composites at different elevated temperature



Figures 4. Worn surfaces of PEEK and h-BN/PEEK composite at different temperature

Conclusion

Friction coefficients and specific wear rates of the h-BN/PEEK composite coatings deposited by the flame spray coating technique were examined with sliding wear test at room and elevated temperatures. The results suggested that h-BN/PEEK composite coatings could improve friction coefficient and specific wear rate at elevated temperature. This was because solid lubricating and high thermal conductivity properties of h-BN. Moreover, the effect of thermal softening of h-BN/PEEK composite coatings caused good compression of wear debris in worn surface. Wear tests of h-BN/PEEK composite coatings at room temperature showed a different wear mode from those at elevated temperature due to transferring of PEEK from solid state to rubbery state at the T_g.

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