Effect of h-BN content on Tribological Behavior of PEEK Composite Coating

*Jirasak Tharajak *, Tippaban Palathai , Narongrit Sombatsompop*
Polymer Processing and Flow (P-PROF) Group, Division of Materials Technology,
School of Energy, Environment and Materials,
King Mongkut's University of Technology Thonburi (KMUTT),
Bangmod, Bangkok 10140, Thailand.
Tel: (662) 4708643, Fax: (662) 4709062
E-mail: jirasak.t@hotmail.co.uk

Low velocity oxy-fuel (LVOF) spraying technique was used to deposit PEEK and h-BN/PEEK powders onto the low carbon steel substrate. The effect of h-BN contents on surface roughness, hardness, degree of crystallinity, specific wear rate and friction coefficient was investigated. It can be found that top-surface roughness, hardness and degree of crystallinity increased with an increase in h-BN contents. The specific wear rate of the h-BN/PEEK composite coatings decreased as compared with the PEEK coatings. Increased h-BN content at 8 wt% exhibited the lowest friction coefficient.

Keywords: Flame spraying technique, Polyether-ether-ketone, Hexagonal Boron Nitride, Tribology

Introduction

Polyetheretherketone is an engineering thermoplastic material with high melting point and high mechanical strength relative to other polymers, excellent chemical resistance and good tribilogy properties [1]. A combination of its properties is of great interest and increasingly used in various industrial applications such as bearing, bolted liner coupling, and non-stick cooking ware [2]. Numerous researchers study on an effect of organic, inorganic and fiber fillers on the wear rate and friction coefficient. A number of fillers have been reported to reduce the wear rates but the friction coefficient are increased [3]. The objective of this research is to study the h-BN contents on hardness and tribological behavior of PEEK composite coating.

Experimental

Materials and preparation of samples

The PEEK powder (grade Victrex 150PF, size ~ 48 μm) was purchased from Victrex-MC Inc., Japan, as shown in Fig. 1a). The h-BN powder with average particle sizes of 100 nm was supplied by M K Impex Canada., Canada, as shown in Fig. 1b). The substrate was low carbon steel grade AISI 1040 (Ø 25.4 mm×5 mm in thickness). The nano h-BN contents of 2, 4, 6, 8 and 10 wt% and PEEK powders were added into ethanol solvent in an ultrasonic bath under frequency 50 Hz for 15 min. As-mixed composite particle was dried at temperature of 80 °C for 6 hour in an oven.

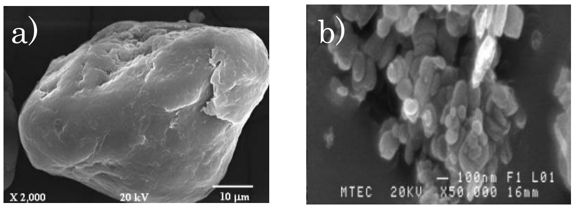

Figure 1 SEM images of a) PEEK; and b) 100 nm h-BN

Coatings preparation

The h-BN/PEEK composite particles were sprayed on low carbon steel substrate using the low velocity oxy-fuel (LVOF, DJ 1400, SULZER METCO) spraying method under spray parameters given in Table 1. The substrates were grit-blasted by Al_2O_3 grit and subsequently cleaned with acetone.

Microhardness measurement and Ball-on-Disc sliding wear test

• Microhardness testing was performed using a FM-700e (Future Tech, PRC) microhardness tester employing under a 300 gf load and dwell time of 15 sec. The average hardness was obtained from 10 measurements on each sample.

• Wear test was carried out on a Ball-on-Disc sliding wear tester. The sliding wear tests were performed under loads of 5 and 25 N with a sliding distance of 1000 m and a sliding speed of 0.1 ms^{-1}. A new harden steel ball was employed as the counterface for each test.

Table 1 The spraying parameters used in this work.

Parameter	Value
Pressure gas [psi] O_2 C_3H_8 N2	 60 65 160
Gas flow rate [l/min] O_2 C_3H_8	 47.34 27.70
Powder feed rate [g/min]	12
Spray time [s]	20
Preheat [^{o}C]	200
Spray distance [mm]	120
Surface roughness [Ra ; μm]	~ 8.00
Spray gun speed [m/s]	80

Characterization

• Powder morphology, worn surface and wear debris were observed by a scanning electron microscope (SEM, JSM-5800 LV, JEOL, USA). The cross sectional microstructure of coatings was investigated with a polarized light microscopy (BHM Metallurgical Microscope, OLYMPUS, Japan).

Results and Discussion

h-BN/PEEK particles

Fig. 2a) and 2b) show the h-BN/PEEK powders that contain 2 wt% and 10 wt% h-BN, respectively. It was found that surface of PEEK particles was covered with white small particles of h-BN powders. The white small particles also increase with an increase in h-BN contents.

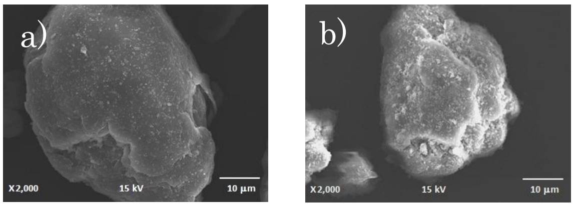

Figure 2 SEM images of a) 2 wt% h-BN/PEEK; and b) 10 wt% h-BN/PEEK

As-sprayed PEEK and h-BN/PEEK coatings

Fig. 3 shows the SEM images of top surface of PEEK and h-BN/PEEK flame sprayed coatings. A small quantity of unmelted PEEK particles were found in Fig. 3a).The unmelted particles increased with an increase in h-BN contents, as shown in Fig. 3b) and 3c), respectively. The cross sections of PEEK and h-BN/PEEK coatings were shown in Fig. 4. It can be seen that the PEEK coating had a high density and smooth top-surface. The interface layer of molten particles in polarized mode can be also observed in the Fig 4a). For the h-BN/PEEK coatings, it was found that the PEEK particles were covered with the white line, as shown in Fig. 4b) and 4c). The high quantity of h-BN contents placing onto PEEK particles caused rapidly solidified PEEK particles presenting unmelted particles. This was because h-BN had good heat transfer and heat dissipation to environmental surrounding [4], as revealed in Fig. 3c). Moreover, a higher amount of the rapidly solidified PEEK particles produced a greater degree of top-surface roughness of h-BN/PEEK coatings (Fig. 5). The rapidly solidified PEEK particles also act as reinforcements in h-BN/PEEK coatings. Thus, the hardness values increased with an increase in the rapidly solidified PEEK particles (Fig. 6). Furthermore, the increase in the degree of hardness values resulted from the increase in the crystallinity [5] by addition of h-BN particles that behaved as nucleating agents, a similar finding being published by Huaiyuan et al. [6].

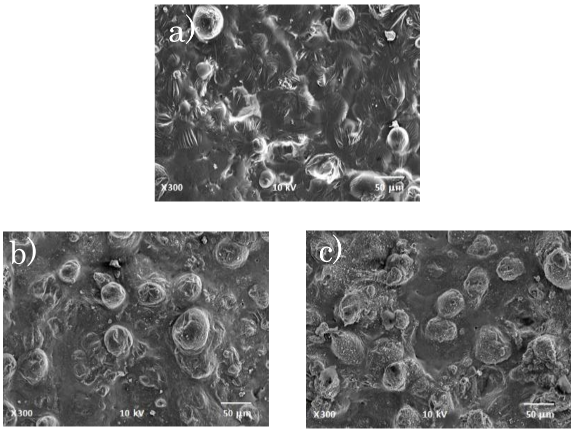

Figure 3 SEM images of top surface of the flame sprayed h-BN/PEEK coating showing

a) PEEK coating,
b) 4 wt% h-BN/PEEK coating,
c) 10 wt% h-BN/PEEK coating

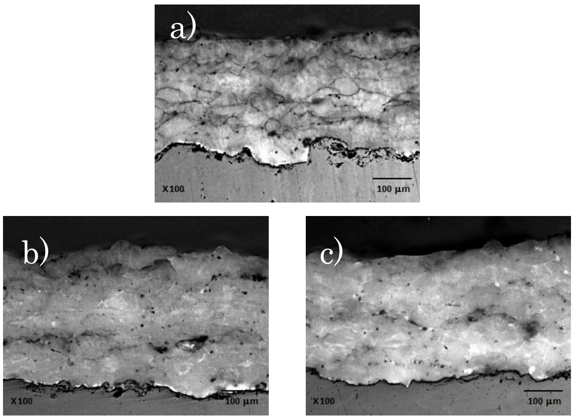

Figure 4 SEM images of cross section of

a) PEEK coating,
b) 4 wt% h-BN/PEEK coating,
c) 10 wt% h-BN/PEEK coating

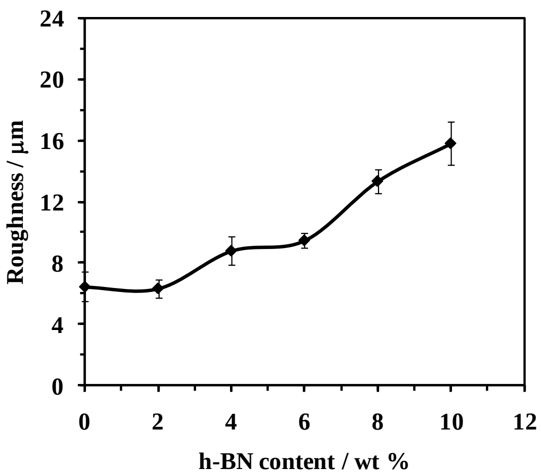

Figure 5 Surface roughness measurements of PEEK and h-BN/PEEK coatings

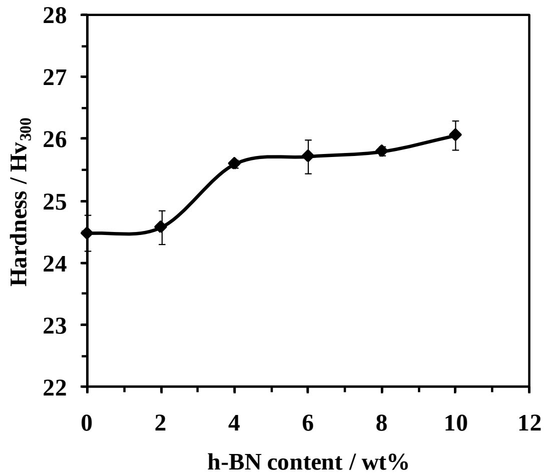

Figure 6 Hardness values of PEEK and h-BN/PEEK coatings

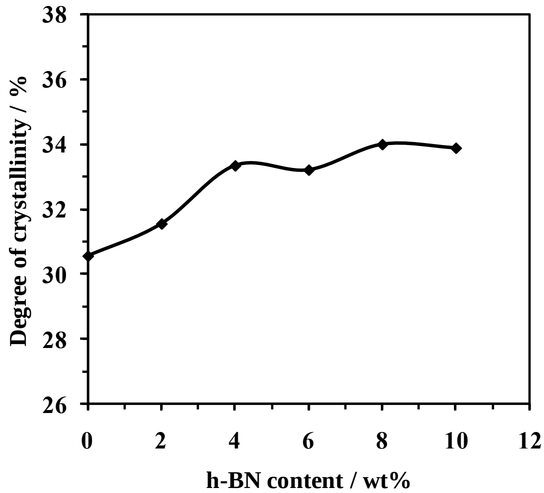

Figure 7 Degree of crystalline of PEEK and h-BN/PEEK coatings

Effect of h-BN contents on the specific wear rate

The specific wear rate of PEEK and h-BN/PEEK coatings is given in Fig. 8. It can be seen that the specific wear rate of PEEK and h-BN/PEEK coatings were dependence on loads. Fig. 8 can be separated into 2 parts. The first part was an initial state (0 to 4 wt% h-BN contents) that the specific wear rate was reduced with an increase in h-BN contents. This was due to a higher hardness value of h-BN/PEEK coatings. For the second part (6 to 10 wt% h-BN), the specific wear rate testing under a load of 5 N of h-BN/PEEK coatings was relatively constant, while, the specific wear rate testing under a load of 25 N of h-BN/PEEK coatings was increased because the wear debris promoted an abrasive wear mode. It can be found that the groove appeared on the worn surface (Fig. 9). This resulted in a higher removed of coating.

Effect of h-BN contents on the friction coefficient

Fig. 10 reveals the average friction coefficient of PEEK and h-BN/PEEK coatings. It can be found that the average friction coefficients of h-BN/PEEK coatings was decreased with an increased of h-BN content. The 8 wt% h-BN/PEEK coatings exhibited the best average friction coefficient testing with both loads. This was due to its self-lubricating nature of h-BN with same crystal structure of graphite and molybdenum disulfide. Thus it could be sheared easily to provide a low friction coefficient in the sliding condition [7].

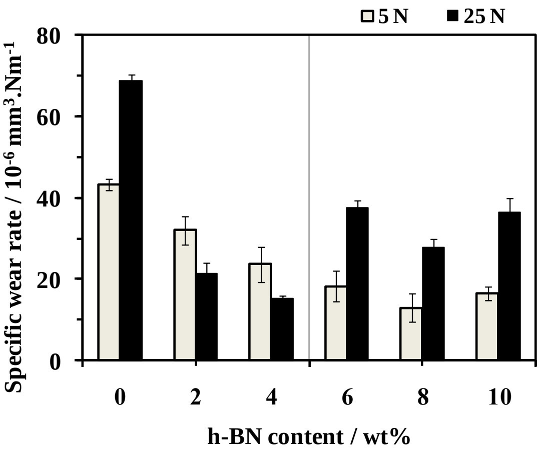

Figure 8 Specific wear rates of PEEK and h-BN/PEEK coatings

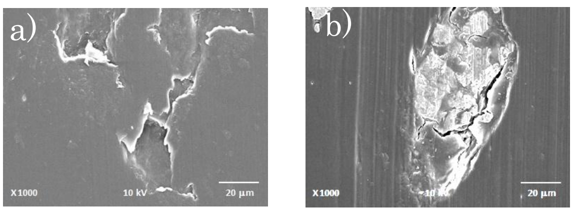

Figure 9 SEM images of the worn surfaces of 10 wt% h-BN/PEEK coating under a load of a) 5N and b) 25N

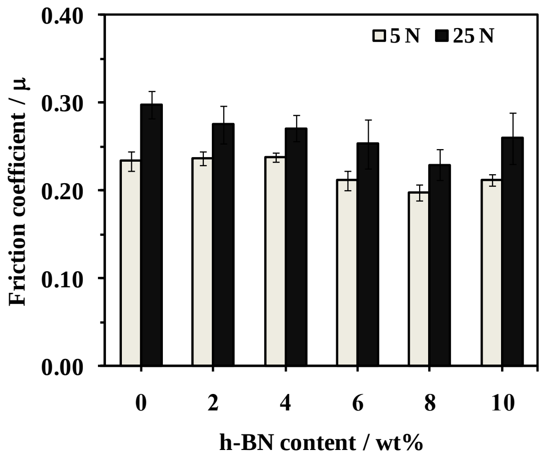

Figure 10 Average friction coefficients of PEEK and h-BN/PEEK coatings

Conclusions

The preliminary results presented the enhancements of the top surface roughness, hardness and degree of crystallinity with an increase in h-BN contents. The wear resistance of PEEK can be improved by the use of h-BN particles. The lowest specific wear rate has been confirmed with 8 wt% h-BN/PEEK coating and 4 wt% h-BN/PEEK testing under a load of 5 N and 25 N, respectively. The average friction coefficient was reduced by adding h-BN particles. The lowest average friction coefficient was 8 wt% h-BN/PEEK coating.

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References

[1] T. Palathai, J. Tharajak, N.Sombatsompop, Mater. Sci. Eng. A. Vol. 485 (2008), p. 66-73.

[2] G. Pan, Q. Guo, W. Zhang, A. Tian, Wear. Vol. 266 (2009), p. 1208-1215.

[3] M. Sumer, H. Unal, A. Mimaroglu, Wear. Vol. 265 (2008), p. 1061-1065.

[4] Z. Wenying, Q. Shuhua, L. Haidong, S. Shiyu, Themochim. Acta. Vol. 452 (2007), p. 36-42.

[5] G. Zhang, W.Y. Li, M. Cherigui, C. Zhang, H. Liao, J.M. Bordes, C. Coddet, Progress in Organic Coatings. Vol. 60 (2007), p. 39-44.

[6] W. Huaiyuan, Z. Yanji, F. Xin, L. Xiaohua, Wear. Vol. 269, p. 139-144.

[7] B. Suresha, Siddaramaiah, Kishore, S. Seetharamu, P.S. Kumaran, Wear. Vol. 267 (2009), p. 1405-1414.