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Morphological and physical properties and friction/wear behavior of h-BN filled PEEK composite coatings

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Hexagonal boron nitride (h-BN) powder with different particle sizes and contents was incorporated in polyether ether ketone (PEEK) under ultrasonic conditions and deposited using flame-spray coating technique. Specific wear rate and friction coefficient of the h-BN/PEEK composite coatings were determined using a ball-on-disk sliding wear tester under applied loads of 5–25 N. Microstructure, microhardness, degree of crystallinity and surface roughness of the h-BN/PEEK composite coatings were investigated. The results showed that the microhardness and degree of crystallinity could be improved with h-BN particles. At an applied load of 5 N, the addition of h-BN particles into PEEK gave a lower specific wear rate. A higher content of h-BN added to PEEK coating resulted in a decrease in the friction coefficient. At an applied load of 25 N, 8 wt.% h-BN/PEEK composite coatings provided good friction reduction while the composite coatings formed severe wear with grooves.

1. Introduction

Polyether ether ketone (PEEK) is a high-performance thermoplastic engineering material with excellent thermal stability and chemical resistance as well as good tribological properties and high mechanical strength relative to other thermoplastics [1–3]. PEEK has a glass transition temperature of 145 °C, a melting temperature of 346 °C, a crystallization temperature of 293 °C and a thermal decomposition of 579 °C [1]. This combination of properties is of great interest, and hence PEEK has been increasingly used in various industrial applications, such as hybrid PEEK bearing or bushing, outer and inner PEEK bearing, bolted joints, flexible couplings, and non-stick cookware [4–7]. Numerous PEEK products can be fabricated by injection molding, extrusion, compression and coating. Flame-spray coating is one of the thermal spray coating techniques which is used for applying PEEK coating onto a substrate, with good adhesion [2,8–11]. In addition, damaged PEEK parts can be refurbished by flame-spray coating.

A number of researchers [12] have studied the effects of metal, ceramic and fiber fillers on the wear rate and friction coefficient of PEEK-based composites. Several types of fillers have been reported to reduce the wear rate; however, the friction coefficient still increased [13]. To improve the friction and wear resistance of PEEK, various lubricating fillers, such as molybdenum disulfide (MoS_2), fullerene-like tungsten disulfide (IF-WS_2), graphite, and polytetrafluoroethylene (PTFE), have been studied. Adding IF-WS_2 self-lubricating solid nanoparticles to PEEK-based nanocomposite was found to significantly decrease the friction coefficient owing to the lower shear strength of IF-WS_2 particles [14]. However, an excess of IF-WS_2 particles caused a slight increase in the friction coefficient. PTFE has been widely used because of its low friction coefficient. A blend of PTFE with PEEK has a lower friction coefficient than that of neat PEEK [15]. Variation of PEEK contents in a PTFE matrix was studied by Burris and Sawyer [16]. It was reported that PEEK/PTFE composites showed lower wear rates and friction coefficients than unfilled PEEK and PTFE; 50 wt.% PEEK/PTFE exhibited the lowest friction coefficient, whereas 32 wt.% PEEK/PTFE showed the lowest wear rate.

The filler morphology also plays an important role in the wear rate and friction coefficient. The effects of graphite-filled polymeric materials on tribological properties have been investigated [17–20] hexagonal boron nitride (h-BN). Known as white graphite, h-BN is one of the crystalline forms of boron nitride (BN) known with a crystal structure similar to graphite and MoS_2. In a single h-BN layer, boron and nitrogen atoms are joined with strong covalent bonds, while a stack of h-BN layers is bonded by weak van der Waals forces, resulting in crystal structures that shear easily [21,22]. Thus, h-BN provides excellent solid lubrication ability. Besides its superior lubricating properties, h-BN has relatively high thermal conductivity, good chemical inertness and high thermal stability [23,24]. h-BN is generally used as a solid lubricant for high-temperature applications, such as metalworking processes and sealing materials in aircraft engines [25]. Due to the poor sinterability of h-BN, h-BN bulk components are fabricated at high temperature and long sintering time, which causes high production costs [26]. Furthermore, h-BN has also been used as an inorganic filler in lubricant additives [27,28], composite applications [21,29] and coatings [23,30–33]. Based on

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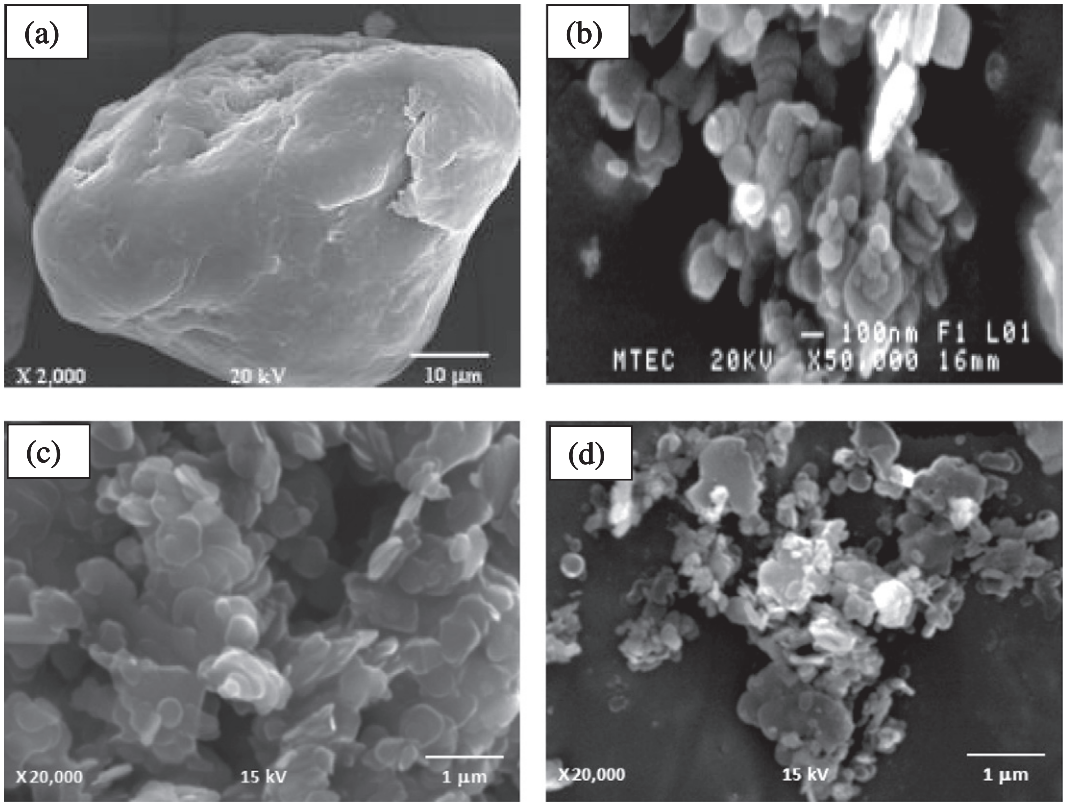

Fig. 1. SEM images of raw powders: (a) neat PEEK, (b) h-BN of 0.1 μm, (c) h-BN of 0.5 μm and (d) h-BN of 1.5 μm.

literature reviews, most studies have been referred to as the tribological properties of h-BN/metal based composites. Very few published papers [21,29] have reported the effect of h-BN addition on friction and wear properties of polymer matrix composite, especially where the particle characteristics (size and size distributions) of h-BN have mattered. Therefore, the main purpose of this work was to investigate the effects

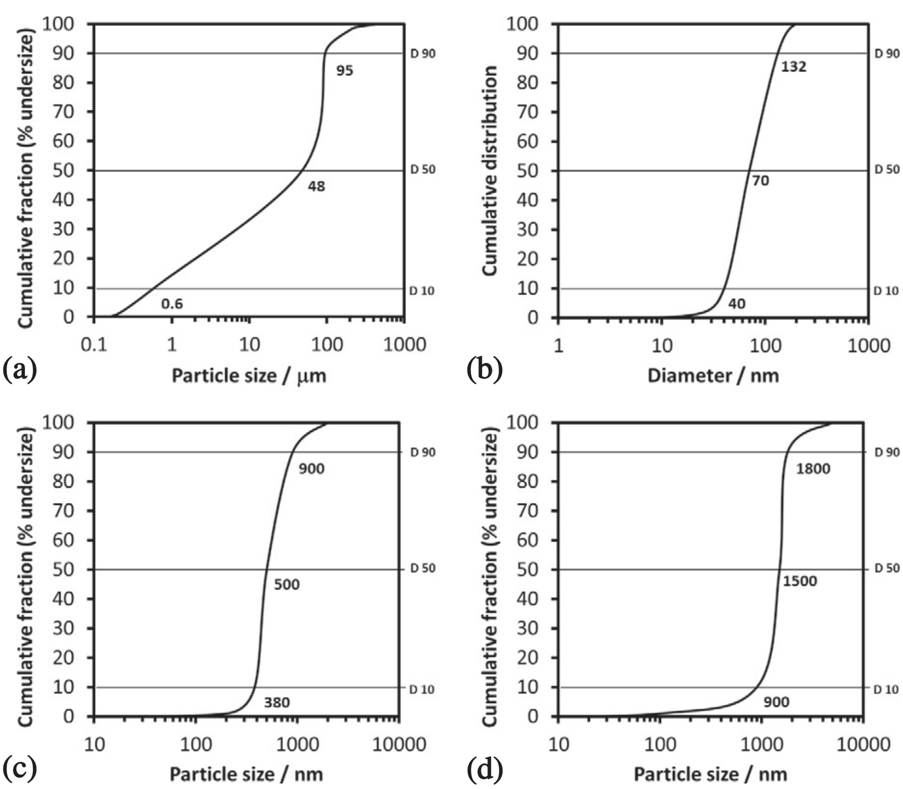

Fig. 2. Particle size distributions of (a) PEEK, (b) h-BN of 0.1 μm, (b) h-BN of 0.5 μm and (d) h-BN of 1.5 μm.