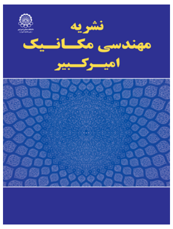

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Experimental Studies On The Tribology Behavior Of UHMWPE/Zeolite Nanocomposite

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ABSTRACT: In this research article, the effect of zeolite nanoparticles on the tribological properties of ultra-high molecular weight polyethylene, which are widely used in orthopedic implants, and its nanocomposites has been studied. Improving the tribological properties of this polymer is one of the medical industry challenges which has an important effect on the life-time of orthopedic implants. Nanocomposites based on ultra-high molecular weight polyethylene blend, containing 2 to 6 wt. % of nano-zeolite, were prepared via melt compounding followed by injection molding. The morphology was studied using scanning electron microscopy. The wear rate and contact temperature of specimens as well as friction coefficient were characterized by employing a pin on disk wear test under 50 N and sliding velocity of 0.5 m/s. The wear rates, contact temperature and friction coefficient of nanocomposite containing 4 wt. % of nano-zeolite, were 56, 32 and 26%, respectively, lower than those of neat ultra-high molecular weight polyethylene. In contrast, the application of 6 wt. % of nano-zeolite, led to agglomeration and increased wear, temperature and coefficient of friction compared to nanocomposite samples. In addition, the morphology of nanocomposite samples, after testing, revealed a smoother surface with the mild abrasion marks than that of pure ultra-high molecular weight polyethylene sample.

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1. INTRODUCTION

Ultra-High Molecular Weight Polyethylene (UHMWPE) is an engineering thermoplastic that is widely employed in advanced engineering application due to its outstanding properties such as high impact resistance [1], self-lubricating, chemical inertness and the highest wear resistance as compared to other thermoplastics [2]. One of the applications of this polymer is in the field of orthopedic implants. For decades, the increasing demand of artificial joint implant from the global market has made UHMWPE to become one of the major research interests among researchers and industries. Despite its exceptional properties, the long-term wear problem occurs after certain service period still remained as the challenge.

In some other studies, the effect of mineral particles on the wear properties of polyethylene has been investigated. Mineral particles have been considered as a reinforcement in polymeric matrix due to their properties such as high mechanical properties, low cost and nucleating effect. Zeolite is one of the minerals used in medical, agricultural and other fields to improve mechanical and wear properties. Aksoy et al. [3] reported the mechanical properties of polyurethane films can be enhanced by adding zeolite beta particles. Zeolite-filled epoxy composites resulted significant improvements on the mechanical properties have been reported by Lee et al. [4]. In particular, zeolite possesses the potential as nucleating agent in promoting nucleation in polymer [5, 6].

In the present research, the wear behavior of UHMWPE/nano-zeolite nanocomposites in terms of wear and failure are studied. UHMWPE is chosen as polymer matrix because of its relatively desirable properties in terms of heat and wear resistances. Nano-zeolite nanoparticle was employed because of its isotropic geometry and ease of dispersion in polymer matrix. The incorporation of nano-zeolite nanoparticle into polymers can also enhance the heat resistance, rigidity, toughness and tribological performances

2. . MATERIALS AND METHODS

UHMWPE was supplied by BASF. Nano-sized zeolite (Z4A-005-R) with average particle size of 50 nm was supplied by Tsuruta-cho. Different composites containing 0, 2, 4 and 6 wt.% of nano-zeolite were prepared by employing a twin-screw extruder. The nanocomposite wear test samples produced using an injection molding machine at melt temperature of 160°C and mold temperature of 60°C. Prior to extrusion and injection molding, all mixtures were dried at 80°C for 4 hours. The morphology was studied using Scanning Electron Microscopy (SEM). The wear rate and contact temperature of specimens as well as friction coefficient were characterized by employing a pin on disk wear test under 50 N and sliding velocity of 0.5 m/s.

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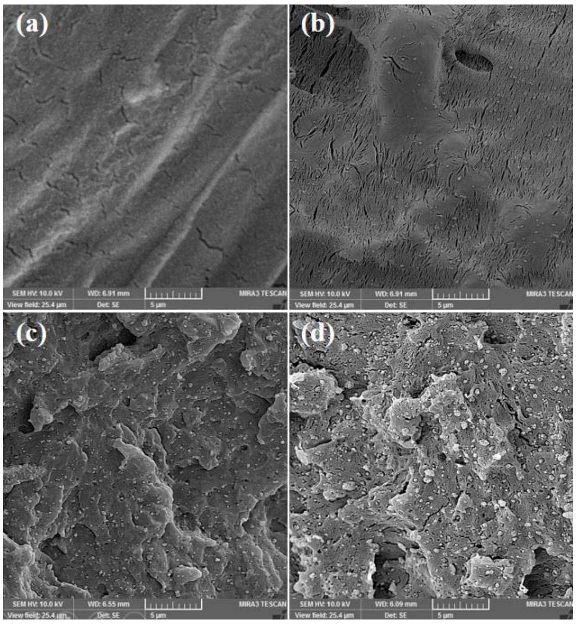

Fig. 1. Scanning electron microscopy micrograph for (a) UHMWPE, (b) UHMWPE/2z, (c) UHMWPE/4z and (d) UHMWPE/6z samples

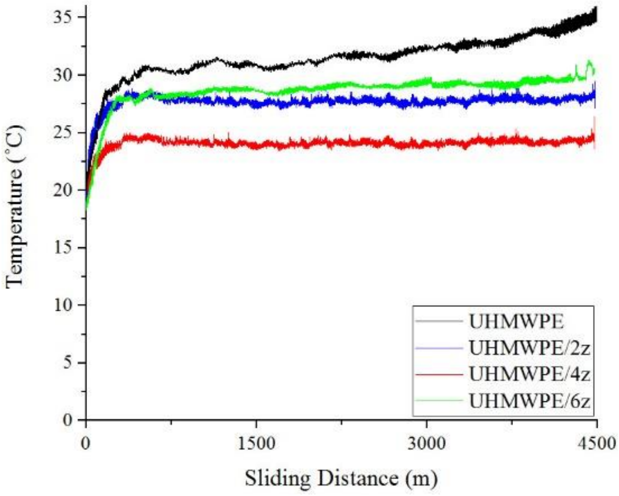

Fig. 3. Comparison of surface temperature variation of samples in wear test

3. RESULTS AND DISCUSSION

Fig. 1 illustrates SEM images of fractured surfaces of wear samples for pure UHWMPE and UHWMPE nanocomposites with 2, 4 and 6 wt. % of nano-zeolite concentrations. For 4 wt. % nano-zeolite inclusion, a relatively uniform dispersion of nanoparticles is achieved as compared to that of 6 wt. % nano-zeolite contents. However, relatively more agglomerates are found in nanocomposites containing high nano-zeolite (6 wt. %).

The values of the coefficients of friction obtained from the wear test for pure polyethylene and its nanocomposites under 50 N load and constant velocity of 0.5 m/s are shown

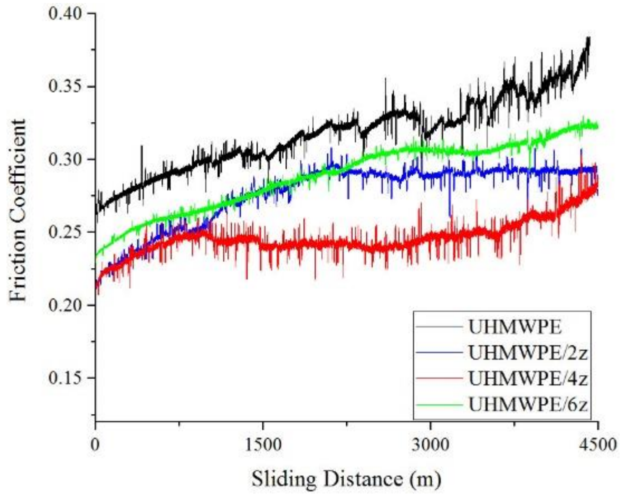

Fig. 2. Comparison of the coefficient of friction in terms of test duration for pure and nanocomposite samples

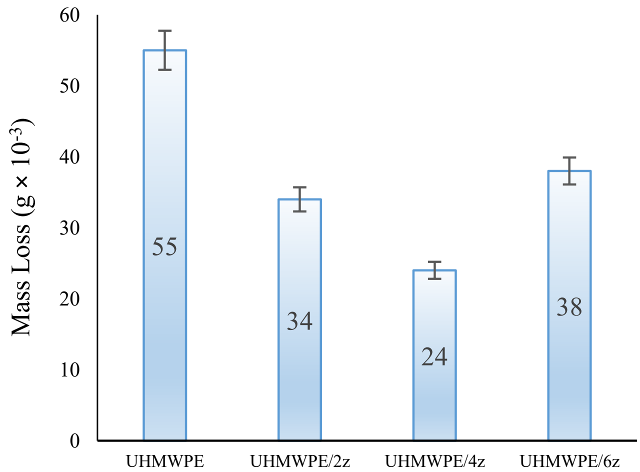

Fig. 4. Mass reduction of samples in wear test

in and Fig. 2. according to the Fig. 2, the addition of zeolite nanoparticles has reduced the coefficient of friction. The lowest coefficient of friction is related to the sample containing 4 wt. % of zeolite nanoparticles. Zeolite nanoparticles with quasi-spherical geometry reduce the direct contact of the polymer in the wear zone and act as a solid lubricant in the contact zone of two surfaces, which leads to a reduction in the contact surface and thus a reduction in the coefficient of friction.

Fig.s 3 and 4 compare the surface temperatures and wear of samples for different compounds, respectively. Under similar working conditions, the teeth temperatures and wear amount of UHMWPE nanocomposites gears are less than UHMWPE. The temperature reduction via addition of the nano-zeolite can be explained by the fact that the nano-zeolite has a higher thermal conductivity coefficient than pure UHMWPE and hence superior heat dissipation occurs for nanocomposite.

Fig. 5 shows SEM images of the worn surface of pure UHMWPE and nanocomposite samples. The morphology of nanocomposite samples, after testing, revealed a smoother surface with the mild abrasion marks than that of pure UHMWPE sample.

4. CONCLUSIONS

UHMWPE/nano-zeolite nanocomposite samples containing 2 to 6 wt. % of zeolite nanoparticles were produced by injection molding and subjected to a pin on disk test. The incorporation of zeolite nanoparticles significantly reduced the samples temperature and wear. In addition, the morphology of nanocomposite samples, after testing, revealed a smoother surface than that of pure UHMWPE sample.

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