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Study of wear mechanisms of UHMWPE/α-Al_2O_3/B_4C hybrid nanocomposites

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This work presents the dry sliding wear performance of polymeric nanocomposite materials, usingUHMWPE (ultrahigh molecular weight polyethylene) as the matrix, running against a metallic counterface under reciprocating ball-on-plate test configuration. The nanocomposites were prepared using α-Al_2O_3 and B_4C nanoparticles as nanofillers, considering their ability to improve polymer wear resistance. The obtained results have shown different wear mechanisms of the material involved in presence of each nanoparticle type, compared to the behavior of UHMWPE in the absence of nanofillers.

Keywords: tribology, nanocomposite, UHMWPE, boron carbide, aluminum oxide

1. Introduction

One of the most used polymers for tribological applications is UHMWPE due to its high mechanical properties and low coefficient of friction. Among the main uses of UHMWPE, there is the knee and hip implants in the sector of orthopedy, in which the soft material is used in one of the bearing parts of the joint prosthesis. In this case, the wear of the component releases particles inside the patient body, which disturbs the natural movements, resulting in pain, and also, may start inflammatory responses by the immune system acting against the foreign material [1]. Many published works show a reinforcement effect of polymeric materials by adding nanoparticles in their structure, improving mechanical and tribological properties. This work presents the effects of using α-Al_2O_3 (alpha aluminum oxide) and B_4C (boron carbide) nanoparticles as fillers, because of their intrinsic high hardness and wear resistance [2,3].

2. Methods

The materials, commercially obtained in powder,GUR 4150 UHMWPE matrix, and α-Al_2O_3(100 nm) and B_4C (50 nm)nanoparticles, were mixed in a planetary ball mill (370 rpm and 20 min) at defined ratios, and1%wt of vitamin E was incorporated in the powder mixture as an antioxidant agent(see Table 1). The mixtures were molded by hot pressing (483.15 K, 11 tons and 40 min). Reciprocating ball-on-flat dry friction tests were executed in a tribometer (TriboLab Bruker) with 10 mm wear track, 1 Hz frequency and 15 N normal load, in duplicates.Chrome steel AISI 52100 10 mm balls were used as counterfaces.

Table 1: Mass composition of the nanocomposites.

Sample	UHMWPE (%)	Al_2O_3 (%)	B_4C(%)	Vit. E(%)
UE	99	-	-	1
UEA	96	3	-	1
UE2A1B	96	2	1	1
UEAB	96	1,5	1,5	1
UE1A2B	96	1	2	1
UEB	96	-	3	1

3. Results and Concluding Remarks

Figure 1 shows optical microscopy images of the polymer surfaces after the tests; it is possible to observe differences in wear mechanisms to each composition. Two main morphologies are distinguished: scratch parallel to the motion, and permanent deformation aligned orthogonally to the motion.

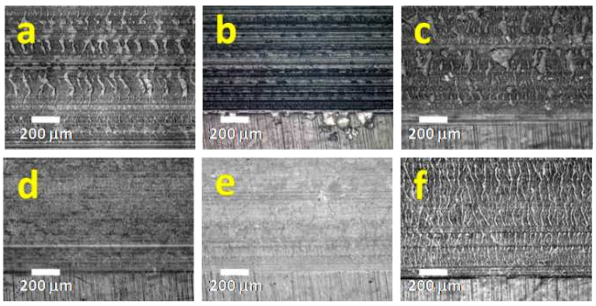

Figure 1: Optical microscopy images of polymer surfaces after test: (a) UE, (b) UEA, (c) UE2A1B, (d) UEAB, (e) UE1A2B and (f) UEB. Sliding direction (↔).

Without filler, the polymer clearly presents plastic deformation as predominant wear mechanism, related to the artifacts produced perpendicularly to the sliding direction (Fig. 1a). The presence of α-Al_2O_3 nanoparticles contributes to the predominance of abrasion mechanism, being evidenced by the scratches parallel to the sliding direction. Adding B_4C nanoparticles makes plastic deformation predominant besides the presence of α-Al_2O_3, however it becomes less severe, as the width of the orthogonal marks appears lower. Analyses of the wear track in the balls have shown the occurrence of adhesion wear mechanism.

4. References

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