New multiscale polymer composites for water lubricated tribological contacts

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Ultra High Molecular Weight Poly Ethylene is a promising candidate to be used in environmentally friendly tribological systems. Currently, various grades of UHMWPE are available with a range of particle size and molecular weight distribution (MWD). This study aims to address the following questions: Does the particle size and MWD of UHMWPE affects its thermomechanical properties and tribological performance? Can the properties and performance be improved by the addition of carbon-based reinforcements, namely Nano Diamonds, Short Carbon Fibres, and Graphene Oxide? How do resulting composites perform post hygrothermal aging tests? What is the influence of the lubricant used? Promising results are uncovered.

Keywords: UHMWPE, Viscoelasticity, Friction, Wear, Lubrication

1. Introduction

Traditionally, only specific grades of UHMWPE, with a narrow particle size and molecular weight distribution, have been deemed suitable for tribological applications. Now, various grades of UHMWPE are available that differ from each other based on their particle size and molecular weight distribution. The present study attempts to address the question of whether the particle size of UHMWPE affects its performance and properties. Additionally, the effect of processing of the UHMWPE is studied. Furthermore, based on the information gathered from studying the UHMWPE viscoelastic properties, various UHMPE composites containing carbon-based reinforcements such as Nano diamonds, Graphene oxide and Short Carbon Fibers are manufactured and characterized for their tribological and physical and other properties.

2. Methods

Various UHMWPE were selected as listed in table 1

Table 1: UHMWE grades

Particle size	Molecular weight ($\times 10^4$)[g/mol]	Density [kg/m^3]
10µm	180	0.94
30µm	200	0.94
120µm	200	0.94
140µm	350	0.93
160µm	240	0.935

2.1. Thermomechanical and thermal analysis
DMA tests were carried out in amplitude and frequency sweep modes after determining the linear viscoelastic region of the various UHMWE. Temperature ramp tests in 3-point bending mode were also carried out. The thermomechanical analysis was supported by purely thermal analysis in the form of DSC and TGA tests.

2.2. Tribological tests
Tests in Pin on Disk configuration were carried out at different velocities and loads. A variety of lubricants including sea water and DI water were used.

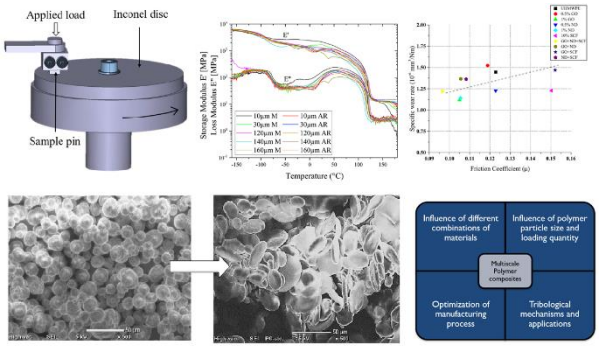

Figure 1: Summary of some results and Pin on disk setup.

2.3. Hygrothermal aging
The UHMWPE composites were immersed in water for the duration of 120 days at 80°C to study the effect of aging on performance and properties.

3. Discussion

It was observed through dynamic mechanical analysis and 3-point bending tests that the particle size and molecular weight distribution did not affect the thermomechanical properties and tribological performance of UHMWPE. At a frequency of 1Hz in DMA freq. sweep, the difference in G' and G" values between 10µm and 160µm is approximately 31\% and 11\%. Similarly, processing had no effect on the performance of various UHMWPE. Composites performed better than neat UHMWPE in tribological tests. Friction and wear are reduced as much as 21% and 15% respectively in DI water. Friction and wear are observed to be affected by the quality of the lubricating water. It was also observed that the tribological performance of the composites were not significantly affected by the hygrothermal aging, due to the excellent structural integrity of the newly developed UHMWPE based hybrid composites.

4. References

[1] Vadivel, H.S. et al., " Tribological behavior of carbon filled hybrid UHMWPE composites in water." Tribology International, 124:169-177, 2018.