Development and Characterisation of Nanoparticle Filled Polytetrafluoroethylene for Tribological Applications

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Motivation

Polytetrafluoroethylene (PTFE) is a widely used material in tribology, as it has good chemical resistance, broad service temperature range, low coefficient of friction and self-lubrication nature. In industry, PTFE composites are widely used as sliding bearings, seals, guideways and linear slides if the requested mechanical load is low. PTFE provides a maintenance-free product due to its self-lubricating behaviour. At the same time, its low coefficient of friction can decrease the operational costs (if the low coefficient of friction meets an improved wear resistance). This material is also considered in specific requirements (e.g. strong need for chemical resistance and/or high thermal stability).

A remarkable challenge with PTFE is the relatively high wear rate which is a relevant drawback compared to other thermoplastics. The aim of this research work is to significantly improve the wear resistance of PTFE, making it a real competitor of some other semi-crystalline thermoplastics in the aspect of the wear behaviour. The addition of appropriate fillers can reduce the wear rate of PTFE. These fillers can decrease the wear rate and reduce the maintenance costs and increase the lifetime of the product. Graphene and alumina (Al_2O_3) nanofillers can enhance the wear resistance of PTFE by 2 to 3 orders of magnitude. The background for this significant improvement is still an open question.

Objectives

The purpose of this project is to design and develop nanoparticle filled PTFE materials with ultra-low wear rate. PTFE is an appropriate material to promote the transfer layer formation between the contact surfaces. Although the general idea is known, many uncertainties remain about the precise functioning of the transfer layer and the precise use of adequate fillers to increase more efficiently the wear resistance. The proposed fillers are graphene, alumina, aluminium oxide hydroxide (boehmite alumina) and hydrotalcite. Due to the functional groups of boehmite alumina and hydrotalcite, a better understanding of the tribo-chemical reactions during the wear process is possible. The friction and wear decreasing effect of the fillers, the physical and chemical underlying knowledge and the mechanism of transfer layer formation are analysed to build up fundamental insight and understanding.

Three objectives are addressed in this research:

1. Develop a proper method for the blending, and the production of high-quality nanoparticle filled PTFE.
2. Analyse and compare the developed neat PTFE and PTFE composites regarding their physical, mechanical, thermal, chemical and tribological behaviour.
3. Fundamental understanding of the wear mechanism and transfer layer formation. Explain how the applied fillers affect the friction and wear mechanism.

Approach

After a comprehensive literature survey, the first step is to develop a protocol for producing the PTFE composites. A widely used production technique for PTFE is the so-called room temperature pressing – free sintering method, which is preceded by a dry or solvent blending procedure when PTFE contains fillers. The quality of the final products depends on the applied blending efficiency, which affects the particle dispersion. The final material properties also highly depend on the protocol of the sintering process. Critical parameters of the sintering cycles are the heating rate, the maximal temperature, dwelling time at maximal

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temperature and the cooling rate. The maximum sintering temperature range of PTFE is between 360 and 380°C; the thermal profile of the sintering cycle depends on the shape and volume of the material.

The second step is the material characterisation of the developed PTFE composites. Some material properties such as density (porosity), thermal conductivity, crystallinity, viscoelastic behaviour, hardness, compressive/shear/tensile strength and modulus can influence polymers' friction and wear behaviour. In this way, a well detailed tribological characterisation has to include the investigations of these material features for the fundamental understanding of friction and wear influencing factors.

As a third step, the tribological properties are investigated. Filler materials can significantly change the tribological behaviour of polymers, and in this way, the friction and wear properties of PTFE. The type of the filler has a dominant (primary) role in the friction and wear mechanism of filled materials. These fillers also affect the friction and wear stability, the transfer layer and debris formation, the homogeneity and uniformity of the transfer layer, the size and the amount of the formed debris. The chemical composition of the steel counterfaces can also influence the tribological performance. The tribological properties are determined using pin-on-disc configuration with rotating cylindrical polymer pin and stationary steel disc counterface (Figure 1).

The fourth step includes the parametric tribological characterisation. Four different contact pressures and five different sliding speeds are chosen. The sliding speeds and contact pressures are 0.5/1.0/1.5/2.0/3.0 m/s (at track centreline) and 1/3/5/7 MPa, respectively.

The developed filled PTFE can be the base material of, e.g. sliding bearings, guideways and linear slides.

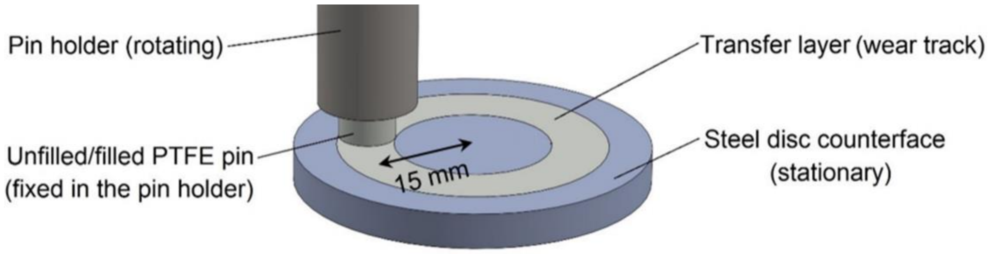

Figure 1: pin-on-disc configuration

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