Proceedings of Asia International Conference on Tribology 2018, pp. 13-14, September 2018

Development of tribological polymeric coatings

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Keywords: Epoxy; UHMWPE; MoS_2

ABSTRACT - Different types of coatings are used in tribological applications for reducing friction and increasing scratch and wear resistance. Recently, polymer-based coatings have been developed for the protection of many bulk materials such as Si, steel, aluminium etc. In this presentation, we will review the works carried out by our and several other research groups in the world in this field. Important polymers and composites, methodology of coating process and the tribological performances of these polymeric coatings will be presented.

1. INTRODUCTION

Though polymer coatings have been used for several decades now for decorative, aesthetic or corrosion protection purposes, their tribological applications have been only recent. For example, in our previous works we have shown the efficacy of ultra-high molecular weight polyethylene (UHMWPE) coatings, both in its pure form and as composites [1,2]. Several studies were carried out for producing tribologically durable UHMWPE coatings on substrates such as Si and steel. UHMWPE is a biocompatible material and such novel coatings will have applications in medical devices and implants, in addition to more traditional industrial application. Research by [3,4] was carried out on PTFE, PEEK and aromatic thermosetting polyester (ATP) and their composites. They found that ATP/PTFE composite coating performed better in comparison to PTFE and PEEK based composite coatings under starved boundary lubrication by ISO46 grade mineral oil. Low friction and presence of micro-reservoir helping oil retention were claimed to be the reasons for this improved tribological performance. It was noted that compared to bare metal substrate all three polymer coatings showed excellent performance in titling pad thrust bearing simulated tests under boundary lubrication.

Our recent efforts were focused on the development of epoxy-based composite coatings for application on steel and other metallic substrates [3]. It was found that epoxy, with its thermal resistance property, was a very useful matrix for some novel fillers such as graphene, talc and base oil SN150. It was also found that an intermediate coating of DLC is most suitable between steel substrate and the polymeric coatings such that the load bearing capacity of the dual-layer composite coating is drastically enhanced.

In this talk we will summarize our UHMWPE and epoxy-based coatings' results in relation to some other similar research works taking place in the world.

2. METHODOLOGY

UHMWPE coatings were applied by the dip-coating methods [1]. Prior to dip-coating, the polymer powder was dissolved in Decalin solvent at elevated temperature of 170 ºC. Continuous magnetic stirring was carried out to obtain complete dissolution. Planar substrate of Si or metallic specimen were then dipped and withdrawn at a certain rate to obtain uniform coating of the polymer solution. This specimen was then heat-treated to evaporate the solvent from the polymer. Similar procedure was also used for the epoxy-based composite coatings on steel substrates. Further details on the coating method for epoxy-based composites can be found in reference [5]. Tribological tests were conducted on coated substrates by sliding steel or silicon nitride balls against the flat coated substrates at given normal loads and sliding speed on a ball-on-disk tribometer.

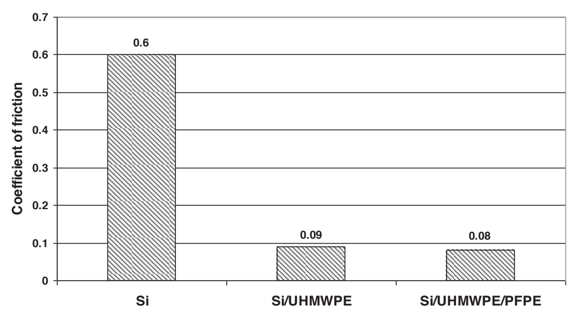

Figure 1 Coefficient of friction of bare Si, Si/UHMWPE and Si/UHMWPE/PFPE samples. Tests were conducted at 70 mN load with calculated contact stress of 370 MPa and sliding speed of 0.042 m/s and the counterface was a 4 mm diameter silicon nitride ball [1].

3. RESULTS AND DISCUSSION

Figure 1 provides coefficient of friction data for the substrate and the coatings. It is seen that there is drastic reduction in the coefficient of friction for the polymeric coatings. This reduction in the coefficient of friction also resulted in much longer wear life for the coated substrate when compared with the bare substrate (Figure 2). There were five orders of increase in the wear life for the dual coating of UHMWPE with top layer of perfluoropolyether (PFPE).

Similar kind of tribological studies on epoxy-based composites with liquid lubricant filler has shown drastic improvements in the wear life and reduction in the coefficient of friction. Liquid lubricants such as PFPE and base oil, even in small quantity, provide *in situ* lubrication in the mixed lubrication mode.

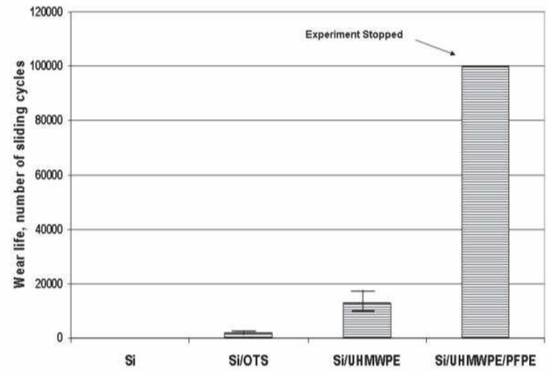

Figure 1 Wear life as the number of cycles of sliding before the coefficient of friction reach the level of 0.3 of bare Si, Si/UHMWPE and Si/UHMWPE/PFPE samples. Tests were conducted at 70 mN load with calculated contact stress of 370 MPa and sliding speed of 0.042 m/s and the counterface was a 4 mm diameter silicon nitride ball [1].

4. CONCLUSION

It is concluded that polymer coatings show highly improved performance in protecting metal and other substrates again wear mainly by reducing the coefficient of friction. Better coating adhesion to the substrate also has beneficial effects on the coating life. These polymeric coatings can be used for bearings of different types where tradition lubrication is not desirable. Some coatings can also work in addition to the external liquid lubrication and thus enhancing the wear life by several orders.

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