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Spatiotemporal Mapping Analysis for Polymer/Metal Sliding

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This paper investigates the potential of spatiotemporal mapping (SMA) in visualising the temporal evolution of localised events during polymer/metal sliding. Two polymers were tested, namely polytetrafluoroethylene (PTFE) and polyimide (PI). The SMA of PTFE/AISI 304 sliding showed gradual movement of transfer materials due to poor adhesion which led to severe wear at low humidity. The SMA of PI/AISI 52100 indicated the presence of friction-reducing back-transfer films at low temperature and graphite content. Such phenomena have a large effect on the tribology of the system and could easily be overlooked without SMA.

Keywords: dry lubrication, polymer tribology, spatiotemporal mapping (SMA), transfer materials

1. Introduction

Spatiotemporal mapping (SMA) is a 3D visual representation of synchronised tribo-data as shown in Figure 1. Since 1992, this method has proven to be effective in capturing the temporal evolution of localised events in metal tribology, such as mutual transfer in adhesive wear and spalling of coating layers [1-2]. However, its application in polymer tribology has been limited and its effectiveness remains unclear. This research aims to explore the potential of SMA in the evolution of polymeric transfer films.

2. Methods

To illustrate the use of SMA, two highly different systems were investigated. Pin-on-disc unidirectional sliding tests were conducted under test conditions as listed in Table 1. Two polymer systems were studied, namely neat PTFE/AISI 304 and graphite-filled PI/AISI 52100. PTFE specimens were tested at 5, 50, and 95 % relative humidity (RH) at 20 °C. PI specimens with 15 and 40 wt% graphite-filler were tested at 100, 280, and 430 °C.

Table 1: Pin-on-disc test conditions

	PTFE/AISI 304	PI/AISI 52100
Contact mode	Ball-on-flat	Flat-on-flat
Disc roughness	0.02 µm	0.12 µm
Applied load	10 N/27 MPa	10 N/0.8 MPa
Sliding speed	0.063 m/s	0.25 m/s
Total distance	125.7 m	1257 m

3. Results and Discussion

3.1. PTFE/AISI 304 Sliding

Severe wear was found at 5 % RH while mild wear was found at 50 and 95 % RH. Severe wear was characterised by clean PTFE surfaces and transfer material-covered AISI 304 surfaces. Mild wear was characterised by iron oxide-covered PTFE surfaces and clean AISI 304 surfaces. Iron oxide forms on the pin due to the tribo-chemical reaction between PTFE and iron [3]. Figure 1 (a) shows the SMA for the severe wear case. Diagonal lines observed on the SMA signifies that the transfer materials moved gradually on the disc. This indicates that poor adhesion of the transfer materials led to continuous removal of PTFE, hence the high wear rate. At 50 and 95 % RH, the trace of gradual movement of transfer materials was only found on the SMA during the running-in period. This suggests that the sliding started with severe wear but later turned into mild wear as iron oxide formed on the pin surface, preventing further transfer of PTFE to the counterface and hence a low wear rate. The fact that the iron oxide formed on the pin surface was only found at high humidity sliding implies that adsorbed water is required to enhance the tribo-chemical reaction.

3.2. PI/AISI 52100 Sliding

Figure 1(b) shows the SMA of the 15 wt% graphite-filled PI/AISI 52100 sliding at 100 °C. Horizontal bands of low friction coefficient can be observed, which correspond to a 0.3 µm increase in pin displacement. The finding of 0.3 µm protrusion on the worn pin surface confirmed that the SMA bands were caused by the formation of so-called back-transfer films or secondary transfer films which detach from and reattach to the PI specimens instead of adhering to the metal counterface. This friction-reducing back-transfer film lasts for approximately 1000 revolutions. Further investigation will focus on methods that could improve the adhesion of the back-transfer film onto the pin surface.

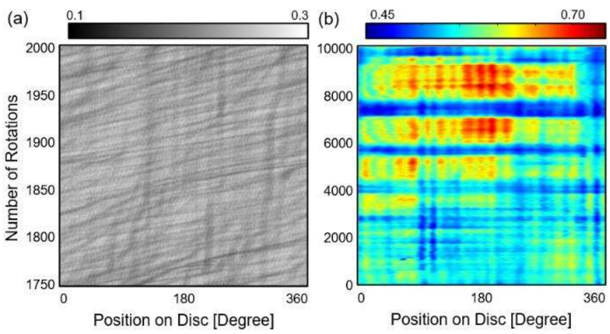

Figure 1: SMA of friction coefficient of (a) severe wear PTFE/AISI 304 sliding at 5 % RH and (b) 15 wt% graphite-filled PI/AISI 52100 sliding at 100 °C.

4. References

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