THIRD BODY EFFECTS IN THE WEAR OF POLYAMIDES MATERIALS.

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ABSTRACT

This study deals with the micro-wear mechanisms of polyamide materials under reciprocating sliding conditions. Using the resources of in situ contact visualisation through transparent sapphire counterfaces, third body formation and flow processes have been monitored as a function of the sliding amplitude. Under confined contact conditions, the stabilization of coherent third body compacts with distinct microstructural properties was found to have a profound effect on the displacement of wear debris from the contact and on the ultimate wear resistance of the polyamide materials.

1. INTRODUCTION

Interface tribology has demonstrated that third bodies can substantially affect the development of wear processes by generating a load carrying capacity (like a lubricant does) and by providing additional velocity accommodation mechanisms (shearing, rolling…) between the rubbing surfaces. Such third body effects are likely to be especially relevant in tribological applications involving conformal contact conditions and/or reduced sliding amplitudes (bearings, gears, hip joints replacements…), which limit the ability of debris to flow out from the contacts. However, the mechanisms for polymer third body formation and their implications on the ultimate wear resistance of tribological systems still need further clarification.

Within the context of this study, the contribution of third body to polymer wear processes has been investigated within macroscopic contacts between polyamide substrates and a sapphire counterface. Wear processes were induced under reciprocating sliding micro-motions. In order to vary third body formation mechanisms, contact conditions were selected which were characterized by various overlap ratios, \( \Delta = \delta / 2a \), where \( \delta \) and \( 2a \) are the displacement amplitude and the contact diameter, respectively. For low values of \( \Delta \), the confinement of the contact zone was expected to enhance wear particles accumulation within the contact, as opposed to large amplitude (i.e. high \( \Delta \) ratios) conditions. A dynamic analysis of third body formation and flow was carried out using in situ contact visualization through the transparent sapphire counterface.

2. RESULTS AND DISCUSSION

The in situ analysis of the tribological damage of different polyamide grades (PA6, PA66, PA46) has been carried out under moderate sliding velocities (≤ 2mm.s⁻¹) which prevented any substantial heating of the contact zone during the course of wear processes. The nature and the extent of the wear degradation were observed to rely largely on the generation and the stabilization of third body agglomerates at the contact interface. The latter processes were found to be critically dependent on the magnitude of the relative displacement between the rubbing counterfaces.

For low \( \Delta \) values, contact damage was dominated by the accumulation and compaction of the polyamide wear debris into corrugations which were oriented perpendicularly to the sliding direction (Fig. 1). During the course of the tests, steady-state conditions were achieved where the wear rate controlling process appeared to be the protrusion of fibril-like wear debris from the extremities of the third body corrugations. In situ observation indicated that these mechanisms were related to
changes in the contact zone kinematics which resulted from the load-carrying capacity of the third body compacts. The main features of third body formation were found to be essentially preserved when the normal load or the sliding velocity were changed. They are also relatively independent on the nature of the Polyamide grade.

D.S.C. (Differential Scanning Calorimetry, Fig.2) and polarized optical microscopy indicated that the microstructure of the fibril-like debris was substantially different from that of the polymer surface where they originate from.

![Image](image1.png)

Figure 1. In situ observation of third body generation during the course of a small amplitude reciprocating sliding experiment. (PA66 substrate, sliding velocity 400 µm.s⁻¹, sliding amplitude : 200 µm, normal load : 200 N).

On the other hand, no significant third body accumulation was observed for high Δ values: In situ and ex situ observations of the wear scars indicated the disappearance of distinct third body corrugations when the sliding ratio exceeded about 0.3. In such situations, pellets-like debris instead of fibrils were extensively displaced from the extremities of the wear track. The associated wear volumes were found to be much increased as compared to wear situations with extensive third body accumulation. This increase in the extent of wear damage at high sliding ratios was not correlated with any significant change in the coefficient of friction, whose values remained nearly independent on the magnitude of the relative displacement.

An examination of the tangential force/displacement loops provided some insight into the associated mechanisms. As extensive wear damage proceeded under more and more conformal contact conditions, some increase in the frictional force was observed at the end of the wear tracks just before the sliding direction was reversed. This increase was attributed to some ploughing of the extremities of the semi-ellipsoidal wear tracks by the rigid spherical counterface. The formation of flake-like debris within this region could therefore be attributed to the repeated unidirectional shearing of the PA surface by the sapphire counterface at the ends of the wear tracks.

A direct comparison of wear volumes associated with the various overlap ratios is, however, invalidated by the different sliding distances (tests were carried out at constant number of sliding cycles). These effects were accounted for by an energy analysis which takes into account the cumulative value of the frictional energy dissipated at the contact interface.

![Image](image2.png)

Figure 2. DSC analysis of a virgin PA6 surface and of PA6 fibrils generated under small amplitude cyclic micro-motions (2°C/min).

This approach clearly indicated the beneficial effects of third body accumulation on the resistance of the investigated polyamide systems to frictional energy dissipation. Under confined contact conditions, the dissipation of a substantial part of the frictional energy by a third body shearing process reduces the amount of available mechanical energy for particle detachment from the polyamide substrates.