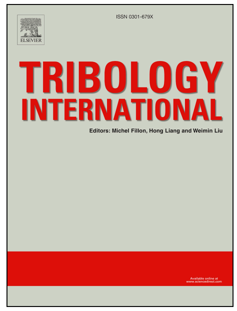

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Tribolayer formation during macro- and microscale cyclic contact

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Abstract

The formation of tribological surface layers is essential for ultra-mild wear. These surface layers form during machine operation in lubricated conditions with additives. Zinc-dialkyldithiophosphates (ZDDP) are frequently used anti-wear additives, but their future use is limited due to environmental concerns. The design of next-generation additives requires a thorough understanding of the tribolayer formation mechanisms of current additives. The present work describes novel macro- and microscale experiments at room temperature that have a limited number of parameters and that use cyclic contact to form tribological surface layers. The new setup allows focusing on the influence of the mechanical stresses, which are very localized in this setup. This study shows that compression creates surface layers even with limited shear driven lubricant flow.

Keywords: Tribology, Surface layers, Testing

1. Introduction

Additives are added to lubricants to improve their performance. Zinc-dialkyldithiophosphates $Zn-(SSP(RO)_2)_2$ (ZDDPs) are of special importance because of their extensive use in current lubricants because they considerably decrease the wear rate. Originally developed as anti-oxidant and extreme pressures additive, the beneficial anti-wear properties of ZDDP were discovered in the 1950s [1]. It is understood that during tribological loading, ZDDP results in the formation of protective thin layers, e.g. [2, 3], which prevent metal-metal contact and which result in contact stress reduction, the latter of which is considered a self-limiting mechanism for ZDDP layer growth [4]. Tribofilms form irrespective of the substrate chemistry: tribolayer formation was observed on steel, tungsten carbide [5, 6], glasses [7]. On graphene, the interaction of mechanical load and temperature was studied by atomic force microscopy (AFM) [8]. Since tribolayers form on a number of elements, tribolayer formation cannot be connected to a specific reaction: e.g. the exchange of Zn^{2+} with Fe^{3+} cations during a static absorption reaction [9]. However, ZDDP also increase the surface micropitting because ZDDP reduces the run-in efficiency [10]. This detrimental behavior can be compensated by employing additional additives [11]. Moreover, modern requirements on the environmental protection and exhaust catalysts severely limit the use of P and S in lubricants [12]. In order to replace both elements in lubricants, a thorough understanding of the beneficial effects and formation mechanisms of the ZDDP tribolayer is required.

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