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Tribology International 39 (2006) 769–773

TRIBOLOGY INTERNATIONAL

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A methodology to determine surface durability in multifunctional coatings applied to soft substrates

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Available online 31 August 2005

Abstract

The tribological characterization, in particular the surface durability of multifunctional layers applied to soft, non-magnetic materials, due to their important differences in mechanical and tribological properties, constitutes, by itself, an important challenge to the tribologist.

These multifunctional layers consist of a solid lubricant coating on top of a hard, wear resistant and high load-supporting layer. The use of low severity conditions, which are necessary to discriminate between solid lubricants, induce unnecessary and unduly long test times. The use of high severity conditions, which are more adequate to analyse the hard, high load supporting layers, produce shorter tests but are not able to discriminate among the solid lubricant deposits.

In this paper, a new methodology allowing short test time with good discrimination between multifunctional layers is proposed. The test protocol is based on a method of incremental loading. By increasing the normal load in increments at a constant time interval the surface durability of both the hard layer and the solid lubricant coating was determined. The suitability, reliability and reproducibility of the proposed methodology were determined by testing commercially available solid lubricants (DLC, Teflon®, MoS_2 dispersed in an inorganic binder and MoS_2 dispersed in an organic binder) coated on commercial aluminium (as received and as anodised).

1. Introduction

In some special applications soft, non-magnetic materials should be used as components in poorly lubricated sliding contacts. Aluminium and its alloys, due to their excellent resistance to corrosion, their good thermal conductivity, their low density, and moderate cost [1] seems to be natural candidates for these applications.

However, Aluminium and its alloys are generally softer than the usual engineering materials and present low surface chemical inertia and hence are hard to lubricate [2,3]. Additionally they experience low threshold to severe wear in sliding contact [4].

Preventing surface damage as well as reducing friction for these energy-efficient applications present a significant design challenge. In spite of considerable research developments, through more than 2000 published papers from the past 25 years, there exists no single solid lubricant that can provide both low friction and wear over broad use conditions, temperatures and environments [5]. The current methods to enhance the wear resistance of these alloys range from cladding and anodising techniques to recently developed micro plasma deposited oxide coatings [6] and composite sol gel ceramic coatings [7] while the low friction is normally obtained by solid lubricant coatings (Teflon®, MoS_2, DLC) [8]. In order to achieve a combination of high wear resistance and load support associated with a low friction coefficient, a multi functional surface engineering process combining purpose-oriented layers can be applied to these soft materials.

The tribological characterization, in particular the surface durability of those multifunctional layers, due to their important differences in mechanical and tribological properties, constitutes, by itself, an important challenge to the tribologist.

Tribological bench testing in the laboratory can provide rapid and cost effective information, and is often used for screening or ranking purposes in the development of new

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doi:10.1016/j.triboint.2005.07.015

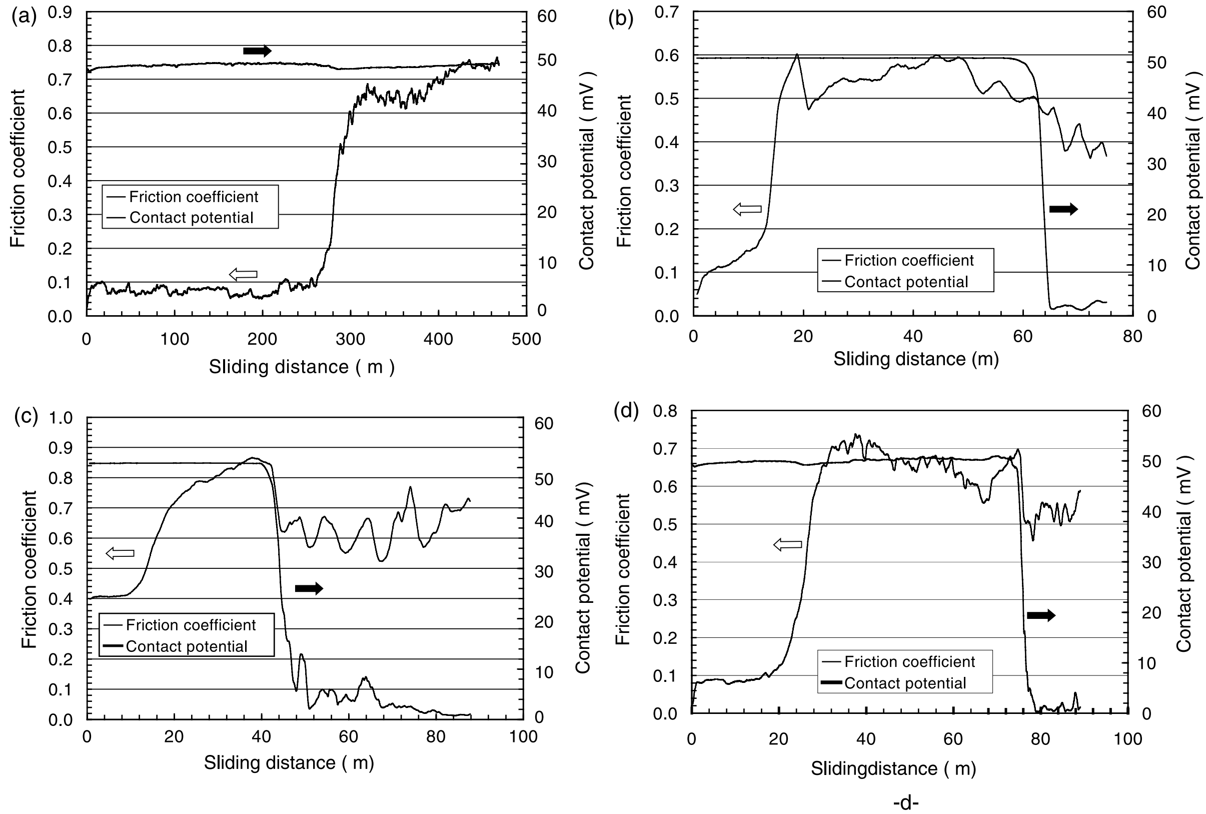

Fig. 1. Effect of tribological parameters on the surface durability of anodised MoS_2 dispersed in an inorganic binder. (Preliminary tests-Frequency: 2 Hz). (a) Ball diameter: 10 mm, stroke: 8 mm, Normal load: 22.40 N. (b) Ball diameter: 10 mm, stroke: 8 mm, Normal load: 42.8 N. (c) Ball diameter: 10 mm, stroke: 8 mm, Normal load: 32.60 N. (d) Ball diameter: 5 mm, stroke: 3 mm, Normal load: 42.8 N.

materials and lubricants. Several tribological configurations are in common use for friction and wear evaluation.

Standard rotary bench devices include pin-on-disk, block-on-ring, cross cylinders, and four ball tests. While these tests can be designed for unidirectional, or rotary motion, they all involve a non-conformal contact geometry. In general, the main disadvantage of rotary bench test methods is that real components cannot be tested; hence, eventually the conformal contact geometry is not preserved, and representative surface finishes cannot be evaluated by using this standard test method. The main advantage of friction and wear tester providing a reciprocating motion is that real components can be tested and representative surface finishes can be meaningfully evaluated [9]. Experimental tribological studies are generally performed with sphere or cylinder on flat contact geometry because these contact configurations are very easy to use and stresses can be determined with analytical calculations [10].

De Mello and co-workers [11–13] successfully applied an unlubricated reciprocating wear test, in which the electrical contact resistance between the sliding surfaces was continually monitored to determine the surface durability of steam treated sintered iron.

Preliminary tests applied to the present multifunctional layers showed that the use of low severity conditions illustrated by Fig. 1a, which are necessary to discriminate between solid lubricants, induces unnecessary and unduly long test times. The use of high severity conditions, Fig. 1b and c, which are more adequate to analyse the hard, high load supporting layers, produces shorter tests but is not able to discriminate between the solid lubricant deposits. Finally Fig. 1d presents an ideal severity condition which is fortuitously characteristic of the present tribological system (MoS_2 dispersed in an inorganic binder coating applied to anodised aluminium alloy, reciprocating dry test, ball diameter: 5 mm, stroke: 3 mm, normal load: 42.8 N). Although all tribological systems have their optimal severity condition, they cannot be compared to the ideal condition of other tribological systems.

In this paper, a new methodology allowing short test time with good discrimination among multifunctional layers is proposed. The test protocol is based on a method of incremental loading. By increasing the normal load in increments at a constant time interval, the surface durability of both the hard layer and the solid lubricant coating was determined. The suitability, reliability and reproducibility of the proposed methodology were determined by testing commercially available solid lubricants (DLC, Teflon®, MoS_2 dispersed in an inorganic binder and MoS_2 dispersed in an organic binder) coated on commercial aluminium (as received and as anodised).