Contents lists available at ScienceDirect

Tribology International

journal homepage: www.elsevier.com/locate/triboint

Investigation of material transfer in sliding friction-topography or surface chemistry?

V. Westlund [a], J. Heinrichs [a], M. Olsson [a,b], S. Jacobson [a]

[a] Ångström Tribomaterials Group, Uppsala University, Box 534, 751 21 Uppsala, Sweden
[b] Materials Science, Dalarna University, 791 88 Falun, Sweden

ARTICLE INFO

Article history:
Received 30 July 2015
Received in revised form
23 November 2015
Accepted 11 January 2016

Keywords:
Sliding
Topography
Coating
Transfer

ABSTRACT

To differentiate between the roles of surface topography and chemical composition on influencing friction and transfer in sliding contact, a series of tests were performed in situ in an SEM. The initial sliding during metal forming was investigated, using an aluminum tip representing the work material, put into sliding contact with a polished flat tool material. Both DLC-coated and uncoated tool steel was used. By varying the final polishing step of the tool material, different surface topographies were obtained.

The study demonstrates the strong influence from nano topography of an unpolished DLC coated surface on both coefficient of friction and material transfer. The influence of tool surface chemistry is also discussed.

1. Introduction

The objective of the present study is to increase the understanding about the roles of roughness and chemical composition, respectively, in determining the friction and material transfer between a soft metal (aluminum) and a harder tool material (tool steel and DLC coated tool steel). In cold metal forming, a lubricant is always used to reduce the friction and the tendency to material transfer to the tool surface [1]. But even with lubrication, the surfaces will occasionally come in contact [2]. Here, the focus has been on the very initial stages of the worst-case scenario of total (local) loss of lubricant, i.e. what happens during the first few millimeters of sliding in completely dry sliding.

In unlubricated sliding contacts, the friction has a tendency to vary significantly and quickly, especially during the running in period. This results in unstable friction curves with seemingly random peaks. To interpret these variations, only parameters that can change considerably over time and shift very locally over the surfaces should be considered. This turns the focus to topography and local surface composition.

However, when analyzing the friction behavior, it proves complicated to separate the contributions from these two parameters. Since it is impossible to produce a perfectly smooth surface, there will always be a contribution from the topography to the friction. By producing surfaces with very similar topography, but with different chemistry, this problem can potentially be avoided.

In previous research the topography has been reported to have a strong impact on the material transfer [3–5] and the transferred material will in its turn have a big impact on the friction. Typically, abundant material transfer is coupled to a high friction level and vice versa, but there are some exceptions. For example it has been shown when dealing with titanium the friction can remain low despite significant transfer to the counter surface [6].

This very intriguing interaction between friction and material transfer is important in many industrial forming and cutting applications. A well-known problem in metal forming is the transfer of work material to the tool, i.e. galling. The transferred material affects the surface quality of the following pieces to be formed as well as increases the forming forces. In this study, a deeper understanding of the initial material transfer is gained, by investigating the influence of the topography and the chemistry.

2. Experimental

2.1. In situ scratch testing in the SEM

The friction force and material transfer were studied in sliding tests performed in situ in a Scanning Electron Microscope (SEM). This technique facilitates observation of the events that cause a particular friction response, and has been employed in several recent articles [6–10]. In this test, the work material is represented by a relatively sharp tip, which under a normal load is sliding against

---

E-mail address: viktoria.westlund@angstrom.uu.se (V. Westlund).

http://dx.doi.org/10.1016/j.triboint.2016.01.022
0301-679X/

Please cite this article as: Westlund V, et al. Investigation of material transfer in sliding friction-topography or surface chemistry? Tribology International (2016), http://dx.doi.org/10.1016/j.triboint.2016.01.022

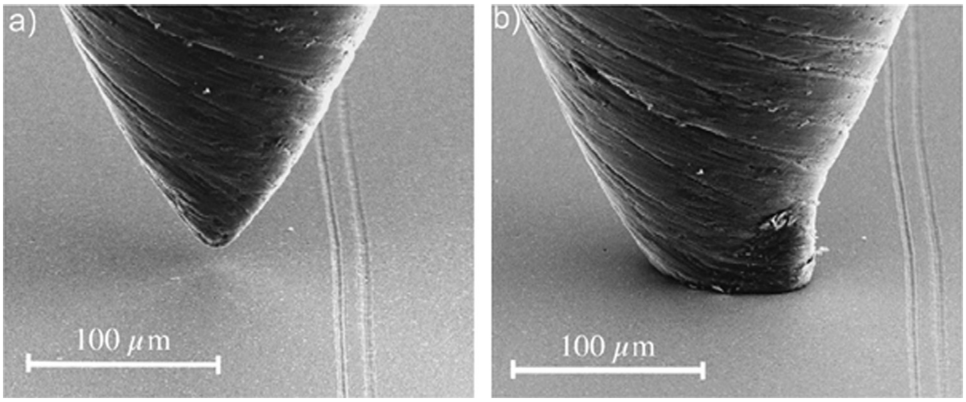

Fig. 1. [10] Example of an aluminum tip before and during contact against the tool material flat. At first contact with the flat, the tip deforms, resulting in a contact area with a diameter of 100–200 μm.

Table 1
The included tool material samples. The preparation techniques and resulting roughness values (measured by AFM, 10 μm × 10 μm) are given. The sample designations refer to tool material, resulting Ra value and preparation, *pp* designates polishing post coating deposition. Ra is the arithmetic average of the profile height deviation from the mean line. Rz is the average distance between the five highest peaks and the five deepest valleys of the profile.

Substrate prep.	**Coating prep.**	**Ra value [nm]**	**Rz value [nm]**	**Name**
Steel, Diamond pol 2 min	–	7	100	V10
Steel, SiO_2 pol 1 min	–	32	210	V30
Steel, SiO_2 pol 10 min	–	44	240	V40
Steel, SiO_2 pol 1 min	DLC, as deposited	27	220	DLC30
Steel, SiO_2 pol 10 min	DLC, as deposited	40	320	DLC40
Steel, Diamond pol 2 min	DLC, post polished	2	45	DLC2pp
Steel, Diamond pol 2 min	DLC, rough post polished	8	90	DLC10rpp
Steel, SiO_2 pol 1 min	DLC, post polished	8	80	DLC10pp
Steel, SiO_2 pol 10 min	DLC, post polished	24	150	DLC30pp

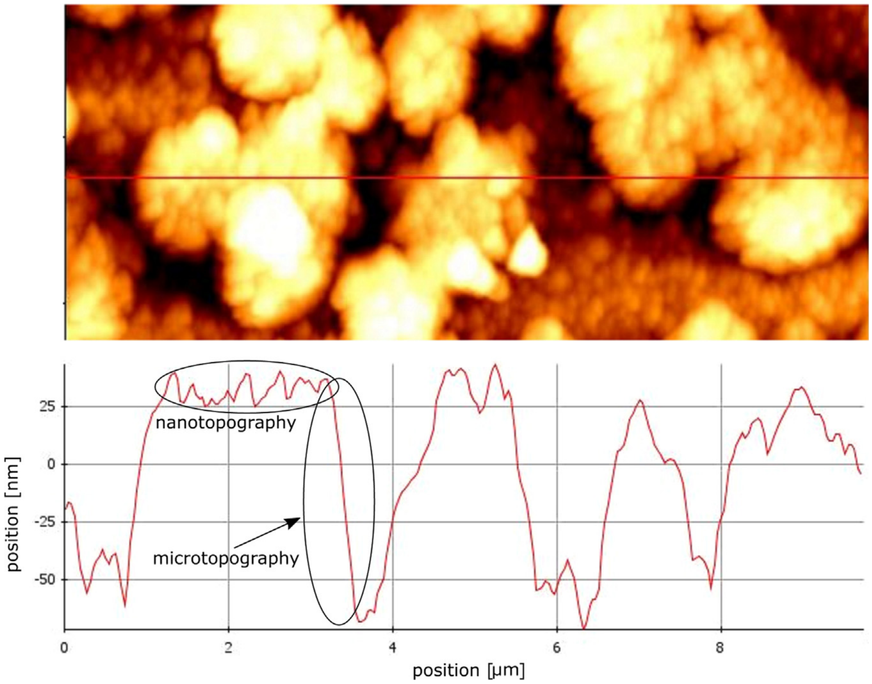

Fig. 2. A line profile on the DLC30 surface illustrating the size relation between the nano and the micro topographies. (AFM).

Please cite this article as: Westlund V, et al. Investigation of material transfer in sliding friction-topography or surface chemistry? Tribology International (2016), http://dx.doi.org/10.1016/j.triboint.2016.01.022