Tribology International ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Tribology International

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

Experimental investigation of plastic contact between a rough steel surface and a flat sintered carbide surface

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ARTICLE INFO

Article history:
Received 1 August 2015
Received in revised form
8 December 2015
Accepted 10 December 2015

Keywords:
Plastic contact
Surface topography
Two-process surfaces

ABSTRACT

Experiments were performed in this study using a modified hardness tester. A hard flat specimen made of sintered carbide contacted a flat surface made of 42CrMo4 with a hardness of 2.15 GPa and different topographies after vapour blasting and/or lapping. Nine types of one-process surfaces were created on the steel samples with standard deviations of heights (i.e., Sq parameters) between 0.3 and 6 μm. Six types of two-process textures were characterized by Sq parameters between 1.5 and 3.1 μm, and the standard deviations of the plateau heights, represented by the Spq parameter, were between 0.5 and 1.8 μm. The normal loads in the compression tests were 150, 550 and 950 N. Before and after loading, the steel samples were measured using a white light Talysurf CCI Lite interferometer. A special relocation procedure was used to analyse the topographies in the same location on a given sample before and after loading. Based on surfaces changes, plastic deformations were identified and compared with those obtained using the elastic–plastic contact model at various sampling intervals. It was found that both plastic and calculated elastic–plastic deformations were highly correlated with the plasticity index. Plastic deformations were found to be marginally smaller than the elastic–plastic deformations that were computed at a sampling interval of 12 μm.

1. Introduction

The accurate characterization of contact between rough surfaces is important when analysing tribological problems such as friction and wear. The contact of rough surfaces has been studied by many researchers; the pioneering contribution was made by Greenwood and Williamson (GW) [1], who developed a basic elastic contact model. Supplementing the GW model, elastic–plastic asperity contact models have been devised [2–6], and contact models typically consider surfaces of Gaussian ordinate distribution, which is different from stratified surfaces.

A few experimental investigations concerning the contact of rough surfaces have been reported. Jamari et al. [7,8] studied the contact of a ceramic sphere with a rough flat surface made of aluminium using a device from earlier studies [9,10].

Todorovic et al. [11] analysed the contact between flat surfaces with textures: a hard metal surface and a rough aluminium surface with an initial roughness height characterized by the Rq parameter of 2.15 μm. Normal loads were between 600 N and 15.3 kN, and nominal pressures were in the range of 40.1 –944.8 MPa. A decrease in the roughness height of the aluminium sample was observed.

Powierza et al. [12] and Polijaniuk [13] experimentally analysed the normal contact between a smooth rigid flat surface and a rough surface using a device based on a hydraulic press. Displacements were measured using an inductive sensor. Powierza et al. [12] confirmed the accuracy of the GW model with regard to the elastic deformation of quasi-isotropic surfaces. For larger loads, interference were found to be higher than that resulting from the GW model. Polijaniuk [13] measured real contact areas in situ using a modified version of the device described in Refs. [12–14]. Because plastic deformation of the peaks on a material's surface and the elastic deformation of the system were both measured, the plastic deformation of surface asperities was determined by the difference in the displacements during loading and unloading. The maximum pressure used was 800 MPa, and the roughness height of the flat surface (i.e., the Ra parameter) was 0.06 μm. This equipment was used also in the study described in Ref. [15].

It is evident that in most studies of the contact of rough surfaces, one-process textures were investigated; however, the tribological properties of two-process surfaces are usually better than those of one-process textures under lubricated conditions [16–18]. Only a few studies have investigated dry friction

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http://dx.doi.org/10.1016/j.triboint.2015.12.015
0301-679X/

conditions [19,20], and the contact of two-process surfaces was analysed theoretically in Refs. [21–23].

2. Experimental details

Experiments were performed using a modified hardness tester. A normal force was applied using a bolted joint with a 65-mm diameter and a 0.5-mm pitch. A hard flat specimen made of sintered carbide was placed in contact with flat surfaces made of 42CrMo4 steel that exhibited different topographies after vapour blasting and/or lapping. The roughness height of the flat sample, which was characterized by the Rq parameter, was 0.2 μm. In the set-up shown in Fig. 1, the displacement was measured by a 1-WI/2MMT-type contact sensor, and the normal load was measured using a sensor with a force range and an accuracy of $\pm$0.1 N.

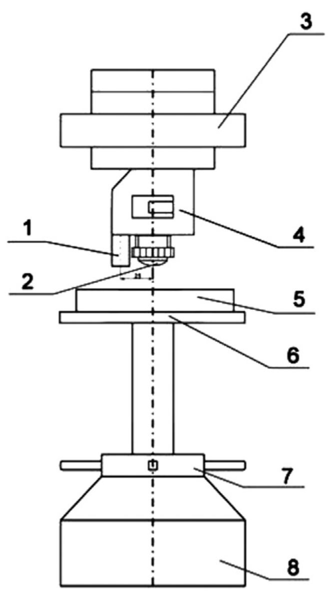

Fig. 1. Schematic of the experimental stand used in this study: 1 – contact displacement sensor, 2 – hemisphere, 3 – place of loading, 4 – extensometer, 5 – hard flat specimen, 6 – table, 7 – adjustment of table height, and 8 – frame.

Steel hemispheres with radii of 3.175 mm were truncated by grinding at 35 m/s with a cut depth of 0.005 mm to circles with radii of 2.5 mm. Then, the truncated hemispheres were subjected to abrasive machining.

Nine types of one-process surfaces were created on the steel samples, and the resulting standard deviation in height (i.e., the Sq parameter) was 0.3–6 μm. Six types of two-process textures were vapour blasted or lapped. Aloxite with 100- and 120-μm granulations was used during vapour blasting; the air pressure used was in the range of 0.2–0.6 MPa; and the machining time was between 60 and 120 s. Lapping was performed with P800–P2000 abrasive papers. Six types of two-process surfaces were machined via vapour blasting followed by lapping. A total of 12–14 surfaces with similar topographies were produced. The normal loads in the compression tests of this study were 150, 550 and 950 N, and the number of repetitions for each load was four or five. In the compression tests, a load was applied for 30 s and then removed. Before and after compression, the steel samples were measured using a white light Talysurf CCI Lite interferometer. A special relocation procedure was used to analyse the surfaces in the same locations before and after loading. Initially, the truncated hemispheres were similarly positioned on the measurement table before and after compression (i.e., mechanical relocation). Then, a more precise digital relocation was used with the aid of TalyMap, version 6, software. After measurements were made, both measured textures should be levelled; one was then rotated. The details of similar and comparatively large rectangular areas could be determined. These topographies should be again levelled with a possible rotation, as before. For the final textures, surface subtraction was used and the surfaces were matched by translating

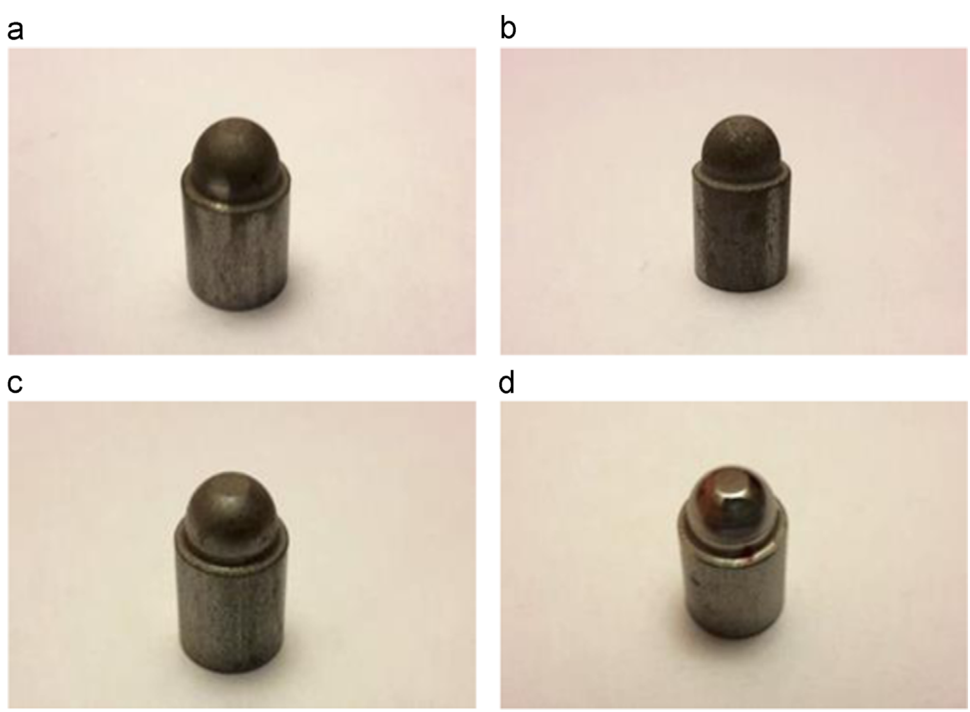

Fig. 2. Photos of rough steel surfaces: two-process after vapour blasting following by lapping (a), one-process after vapour blasting with a high roughness (b), one-process after vapour blasting with a medium roughness (c), one-process after lapping with a small roughness.