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Influence of the normal force, abrasive slurry concentration and abrasive wear modes on the coefficient of friction in ball-cratering wear tests

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ABSTRACT

The purpose of this work is to study the influence of the normal force (N), abrasive slurry concentration (C) and abrasive wear modes on the coefficient of friction in ball-cratering wear tests. Experiments were conducted with balls of AISI 52100 steel, an AISI H10 tool-steel specimen and abrasive slurries prepared with black silicon carbide (SiC) particles + distilled water. The tangential (T) and normal loads were monitored throughout the tests and the results have shown that: (i) the coefficient of friction behavior was independent of the normal force and (ii) both the concentrations of abrasive slurries and the subsequent action of the abrasive wear modes, generally, did not affect the behavior or magnitude of the coefficient of friction.

1. Introduction

Recently, the micro-scale abrasive wear test has gained large acceptance at universities and research centers and is widely used in studies focusing on the abrasive wear of materials. Fig. 1a [1] presents a schematic diagram of the operating principles of the abrasive wear test, where a rotating ball is forced against the specimen being tested in the presence of an abrasive slurry. There are two main equipment configurations that can be used to conduct this type of test: the "free-ball" and "fixed-ball" configurations. Fig. 1b [2] and 1c [3,4] show examples of these equipment configurations.

The aim of the micro-abrasive wear test is to generate "wear craters" on the specimen being tested. Fig. 2 presents representative images of such craters, together with an indication of the crater diameter (b) [5] (Fig. 2a), the crater depth (h) (schematic illustration) (Fig. 2b) and the wear volume (V) [2] (Fig. 2c).

The diameter of the wear crater is commonly measured by optical microscopy, but other methods are available. For example, computer aided design (CAD) software [3] has been used for this purpose. The crater depth and the wear volume may be determined as a function of b, using Eqs. (1) and (2) [6], respectively, where R is the radius of the ball.

$$h \cong \frac{b^2}{8R} \quad \text{for } b \ll R \tag{1}$$

$$V \cong \frac{\pi b^4}{64R} \quad \text{for } b \ll R \tag{2}$$

Two abrasive wear modes are usually observed on the surface of the worn crater: "grooving abrasion" results when the abrasive particles slide on the specimen (Fig. 3a – [7]), while "rolling abrasion" is observed when the abrasive particles roll on the surface of the specimen (Fig. 3b – [7]). Depending on test conditions, "rolling abrasion" and "grooving abrasion" can occur simultaneously in a given crater [8]. Fig. 3c [1], 3d [8] and 3e [3] presents images of grooving abrasion, rolling abrasion and the simultaneous action of rolling and grooving abrasion, respectively. In a previous work [3], A_t was defined as the total projected area of the crater and A_g as the projected area with grooving abrasion. The projected area with rolling abrasion (A_r) may be defined as $A_r = A_t - A_g$ [9].

The micro-abrasive wear test has been applied toward studying the abrasive wear of metallic [2,3,8] and non-metallic [3,4,10] materials where, depending on the equipment configuration, it is possible to apply normal loads (N) from 0.01 N [11] to 10 N [12] and ball rotational speeds (n) up to 80 rpm [13].

The wear behavior of different materials can be analyzed based on the dimensions of the wear crater and/or on the wear mode.

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Nomenclature

A_g	projected area with grooving abrasion [mm^2]
A_r	projected area with rolling abrasion [mm^2]
A_t	total projected area of the wear crater [mm^2]
b	diameter of the wear crater [mm]
C	concentration of the abrasive slurry
CAD	Computer Aided Design
D	diameter of the ball [mm]
DSRW	Dry Sand Rubber Wheel
DW	distilled water
h	depth of the wear crater [mm]
k	wear coefficient [mm^3/(N m)]
n	ball rotational speed [rpm]
N	normal force [N]
R	radius of the ball [mm]
S	sliding distance [m]
t	test time [s]
T	tangential force (friction force) [N]
T_{AS}	tangential force (friction force) between abrasive particles and specimen [N]
T_{BA}	tangential force (friction force) between ball and abrasive particles [N]
v	tangential sliding velocity [m/s]
V	wear volume (volume of the wear crater) [mm^3]

Greek letters

μ	coefficient of friction
μ_{AS}	coefficient of friction between abrasive particles and specimen
μ_{BA}	coefficient of friction between ball and abrasive particles

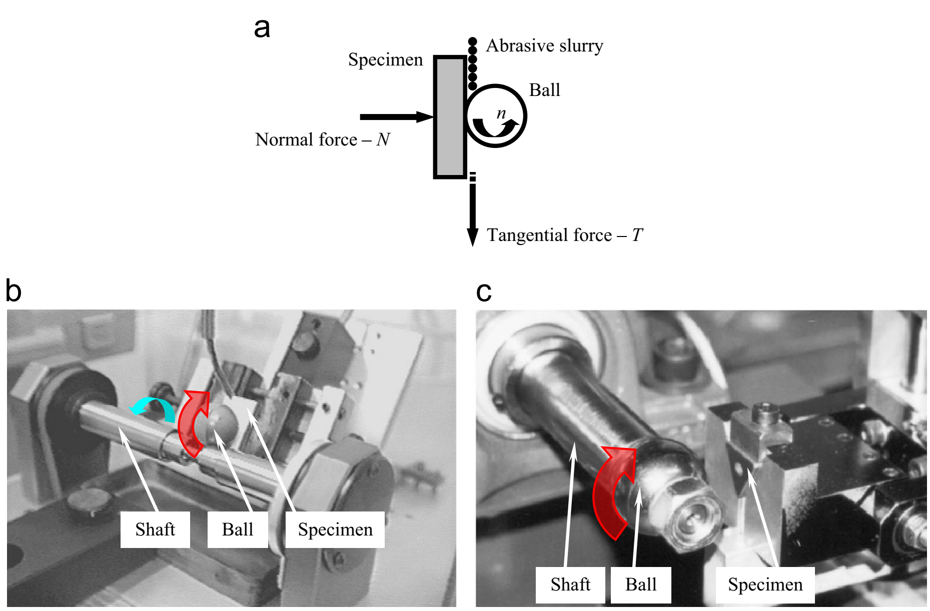

Fig. 1. Micro-abrasive wear testing using the rotating ball method: (a) schematic diagram of the operating principle [1], (b) “free-ball” configuration [2] and (c) “fixed-ball” configuration [3,4].

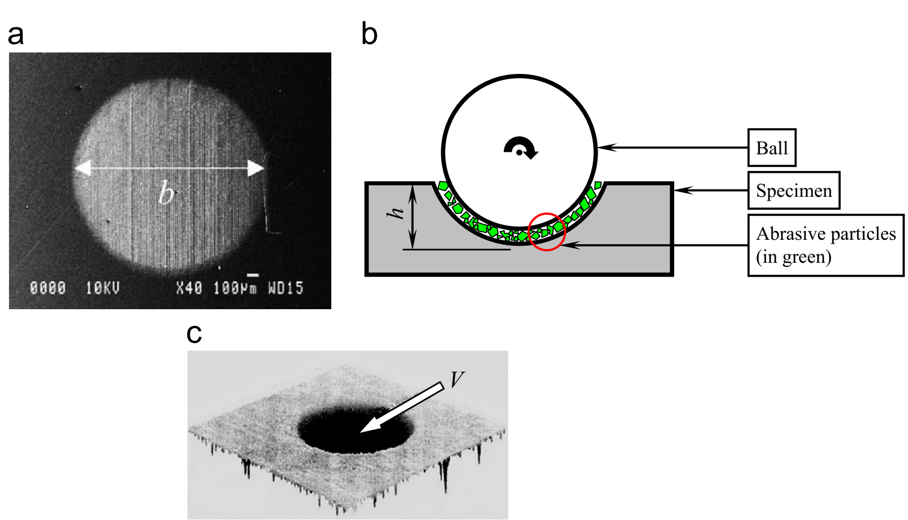

Fig. 2. Representative images of wear craters: (a) diameter – b [5], (b) crater depth – h (schematic illustration) and (c) wear volume – V [2].