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Influence of tribo-magnetization on wear debris trapping processes of textured dimples

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ABSTRACT

The mechanism of attachment of wear debris to textured dimples was investigated experimentally. Textured dimples were fabricated on the surface of medium carbon steel specimen with drilling method. Reciprocating ball on disc sliding wear experiments were carried out. The dimples trapped with wear debris and worn surfaces were observed with microscope. Tribo-magnetization of wear debris was employed to explain the attachment of debris in dimples. The size of wear debris and magnetic flux density of worn surfaces were measured. Wear experiments processes were also carried out under degaussing conditions. The experimental results show that tribo-magnetization causes the phenomena of attachment and bridging of wear debris to edge of textured dimples. By applying degaussing method, attachment of wear debris within textured dimples can be reduced. For comparison, coefficients of friction, wear mass loss of specimens and wear volume loss of mating balls were measured under both conditions of non-degaussing and degaussing. Degaussing can be beneficial to improve the capacity of trapping wear debris of textured dimples for ferromagnetic materials, and to improve the wear resistance of dimple textured specimen.

1. Introduction

Surface texture has been recognized as an effective approach to improve tribological performances of sliding surfaces [1–3]. A growing number of studies have demonstrated that surface texture can trap wear debris, reduce wear debris on frictional surface and prevent further abrasive wear [4–6] under dry frictional conditions. Different patterns of surface texture have been studied, such as dimples, grooves, meshes, and so on [7,8]. Researchers have studied the capacity of trapping wear debris of surface texture. For example, Pettersson et al. [9] fabricated rectangular texture and groove texture by photolithography and anisotropic etching of silicon wafers. They observed that the depressions and grooves were more or less filled with wear particles within the worn marks. Wang et al. [10] fabricated micro groove texture on stainless steel surface by femtosecond laser, and indicated that the micro groove texture can capture a certain amount of wear debris.

Circular dimple is convenient to be fabricated, and has been paid more attentions [11,12]. Some studies also have shown that the dimple texture has the ability of trapping wear debris. Volchok et al. [13] demonstrated that laser texture allowed wear debris easy to escape from the fretted zone into the micropores, and improved fretting fatigue resistance. He et al. [14] studied the effect of dimple density on wear resistance of specimens under dry friction, and Roy et al. [15] fabricated dimples on ceramic surface of hip replacement with drilling method. They all indicated that for the same diameter of dimples, with the increasing of dimple density, textured surface with higher dimple density could capture more wear debris effectively, which could enhance tribological performance of textured samples [14,15]. Borghi et al. [16] indicated that wear debris moved from contact region to fill dimples. Etsion [17] stated that micro-dimples usually functioned as micro-traps for wear debris. Gropper et al. [18] also stated that surface texture may entrap wear debris and minimize third-body abrasion.

At present, it is confirmed that dimples of textured surface have capacity of trapping wear debris. However, to the author's knowledge, little attention has been paid to the process and reason of wear debris trapped by dimples and the influence of debris trapping capacity of dimples on tribological properties of textured surface. In this study, medium carbon steel AISI1045 was taken for example. Wear experiments of dimple textured surfaces were carried out to observe wear debris trapped by textured dimples at regular intervals, and to measure coefficients of friction, wear mass loss of specimens and wear volume loss of mating balls. Two phenomena, attachment and bridging of wear debris within textured dimples were observed and analyzed based on tribo-magnetization behavior. In addition, degaussing method was applied to reduce the attachment of wear debris to dimple edges and improve the dimple's capacity of trapping wear debris.

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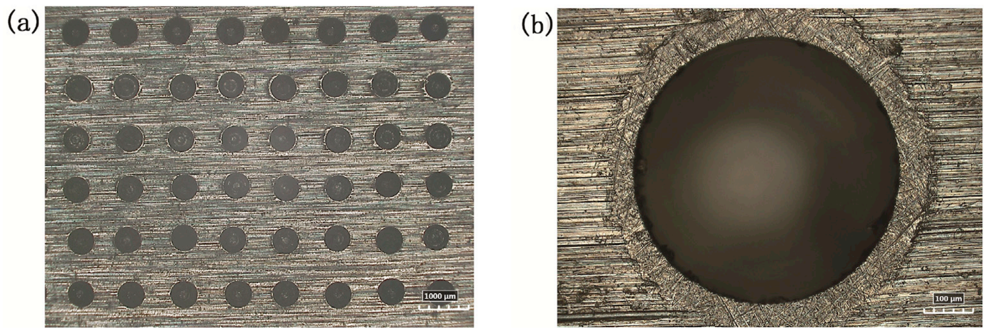

Fig. 1. Optical micrographs of dimple textured specimen (a) drilled dimples (b) single dimple.

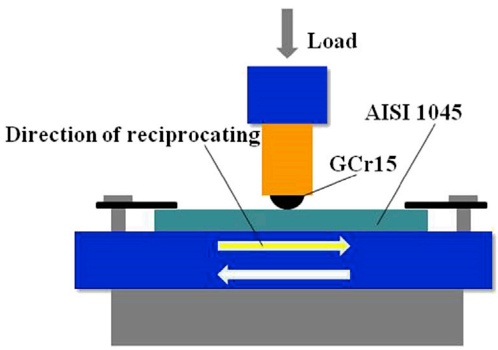

Fig. 2. Schematic of pin-on disc test rig.

2. Experimental procedures

2.1. Materials preparation

Some components made of medium carbon steels, such as shaft, gear, piston, are subjected to tribological processes. Medium carbon steel AISI 1045 was chosen as specimen. The size of specimen after wire EDM and surface grinding was 45 mm in length, 35 mm in width and 5 mm in thickness. The surface roughness of specimen was Ra1.251 μm and surface hardness was 205.14 H V. The textured dimples of specimen surfaces were fabricated with bench driller. The spindle speed of driller was 8000 r/min without cooling. Diameter of high speed steel drill bit was 0.5 mm. The dimple size was diameter of 500 μm, depth of 500 μm and center distance between dimples of 1 mm, as shown in Fig. 1 (a). After drilling process, specimen surfaces were polished with abrasive paper to remove drilled burrs. Fig. 1 (b) shows the micrograph of single dimple before wear test. Another 304 stainless steel specimen was fabricated and tested for further experiments.

2.2. Tribological evaluation

Reciprocating wear tests were carried out with HSR-2M type tribotester, as shown in Fig. 2. The tests were conducted at room temperature under dry sliding condition with a test load of 15 N, reciprocating speed of 200 t/min and a stroke length of 10 mm. Six wear time of duration was 10 min, 20 min, 30 min, 40 min, 50 min and 60 min,

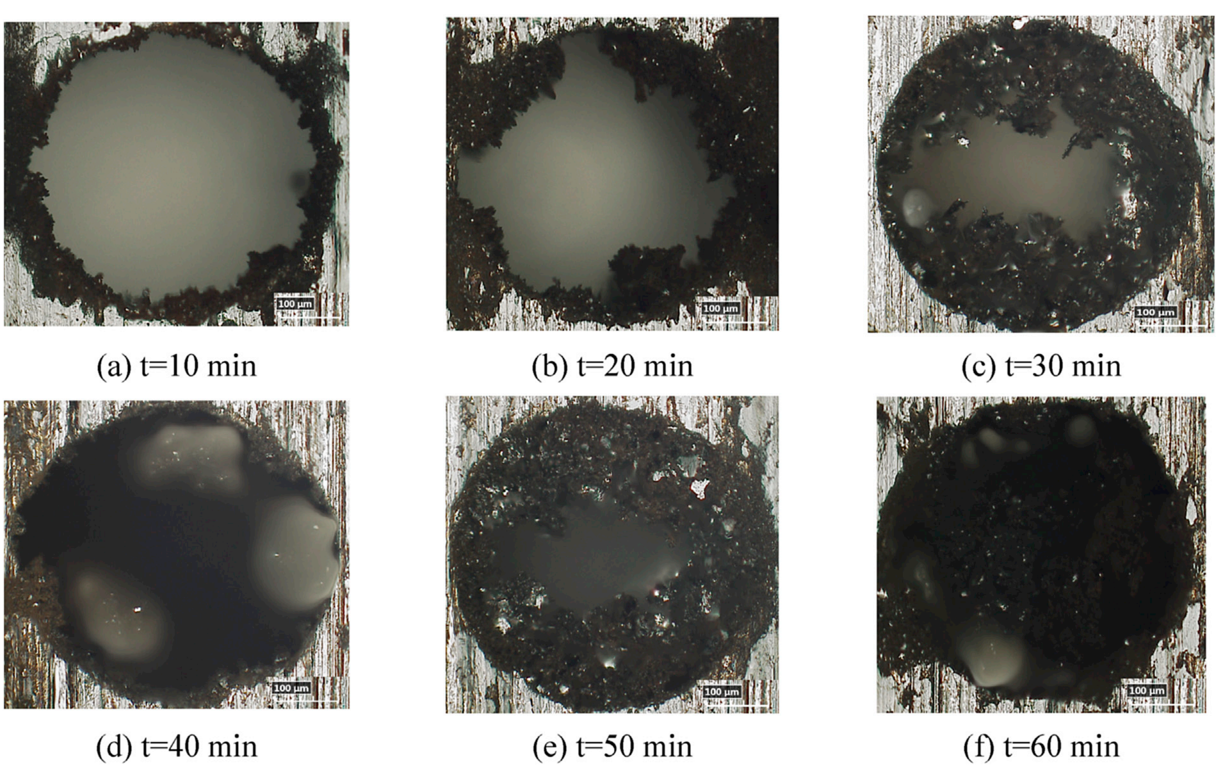

Fig. 3. Optical micrographs of dimples with trapped wear debris.