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Effect of distribution of striated laser hardening tracks on dry sliding wear resistance of biomimetic surface

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ABSTRACT

Some biological surfaces were proved to have excellent anti-wear performance. Being inspired, Nd:YAG pulsed laser was used to create striated biomimetic laser hardening tracks on medium carbon steel samples. Dry sliding wear tests biomimetic samples were performed to investigate specific influence of distribution of laser hardening tracks on sliding wear resistance of biomimetic samples. After comparing wear weight loss of biomimetic samples, quenched sample and untreated sample, it can be suggested that the sample covered with dense laser tracks (3.5 mm spacing) has lower wear weight loss than the one covered with sparse laser tracks (4.5 mm spacing); samples distributed with only dense laser tracks or sparse laser tracks (even distribution) were proved to have better wear resistance than samples distributed with both dense and sparse tracks (uneven distribution). Wear mechanisms indicate that laser track and exposed substrate of biomimetic sample can be regarded as hard zone and soft zone respectively. Inconsecutive striated hard regions, on the one hand, can disperse load into small branches, on the other hand, will hinder sliding abrasives during wear. Soft regions with small range are beneficial in consuming mechanical energy and storing lubricative oxides, however, soft zone with large width (>0.5 mm) will be harmful to abrasion resistance of biomimetic sample because damages and material loss are more obvious on surface of soft phase. As for the reason why samples with even distributed bionic laser tracks have better wear resistance, it can be explained by the fact that even distributed laser hardening tracks can inhibit severe worn of local regions, thus sliding process can be more stable and wear extent can be alleviated as well.

1. Introduction

Brake shoe is an important mechanical part in drum brake system of trailer. The most significant problem of brake shoe is severe abrasion between rolling pin and tribological loaded surface (Fig. 1). In order to improve dry sliding wear resistance of such mechanical parts, medium frequency quenching, which can form a hardened layer with average hardness above 40 HRC is widely used. However, this traditional technique is generally accompanied by energy waste and at the cost of rising expense of production. Another kind of technique used for enhancing surface hardness for components is laser surface hardening. As mentioned by G. Tami et al., laser surface heat treatment is particularly competitive with respect to induction hardening, mainly because higher overall process efficiency and lower electrical power requirements are achievable [1]. However, when scanning area is greater than laser spot, multi-track overlapping for laser hardening trajectories is necessary. The major problem in this case is back-tempering among overlapped laser tracks, which may limit abrasion resistance of components severely. Therefore, it is necessary to design a new method to replace above two methods.

Biologically inspired design, adaptation, or derivation from nature is referred to as "biomimetics" [2]. Living creatures from hundreds of million years of evolution are usually granted with several special capabilities so as to adapt to external surroundings [3]. Fig. 2 presents some biological surfaces with excellent anti-wear properties. It can be seen from Fig. 2(a) that surface of a mollusk shell is generally covered with dense ridges and sparse ridges, which will play different roles in resisting changeable outer natural friction force. Additionally, radically distributed hard ridges of shell can play important role in hindering ploughing of small stones and erosion of sea water while soft substrate can release lateral stress converted between hard ridges and prevent the propagation of cracks. Similar soft-hard alternate structures can be observed in scale of pangolin and abdomen of ground beetle as shown in Fig. 2(c) and (d), and these natural non-smooth biological surfaces had been proved to have excellent anti-wear properties.

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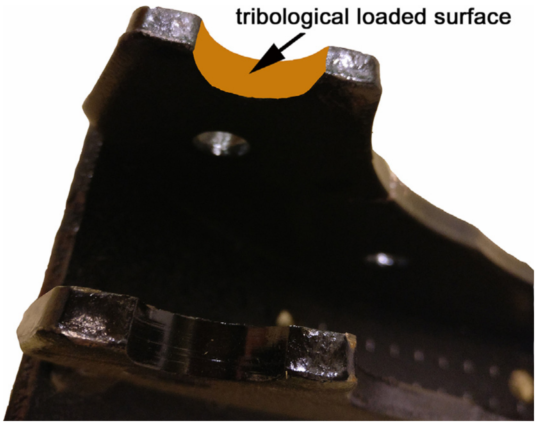

Fig. 1. The tribological loaded surface of brake shoe.

In previous studies [6–8], by imitating these natural surfaces, spot-shaped, net-shaped or stripe bionic units fabricated by laser remelting or laser cladding were created on mechanical components such as die steels and railway guides. Anti-wear properties of these mechanical parts with bionic units were proved to be better than that of untreated counterparts. However, these biomimetic methods are at the cost of enhancing surface roughness of components and cannot be applied in treating tribological loaded surface of brake shoe with strict surface roughness requirements.

In the present work, for the purpose of replacing induction hardening and multi-track laser hardening in improving dry sliding wear resistance of steel made components like brake shoe's tribological loaded surface, a comparison of anti-wear performance among biomimetic samples, quenched sample and untreated sample was made. Because distribution of striated laser tracks has significant influence on abrasion resistance of biomimetic samples, in this article, the effect of distribution way of laser tracks on abrasion of biomimetic samples was specifically investigated. The technique used in generating biomimetic laser tracks can be named as biomimetic laser texturing or biomimetic laser hardening. A solid state Nd:YAG pulsed laser machine was used in processing striated laser tracks, which are featured with 2.6 mm maximal width and 160 μm maximal depth. Medium carbon steel samples covered with only dense striated laser tracks (3.5 mm macroscopic spacing) or sparse striated laser tracks (4.5 mm macroscopic spacing) were classified as even distributed samples, while samples covered with both sparse and dense striated laser tracks were defined as uneven distributed samples. Microstructures and microhardness of cross section of laser hardening tracks were examined by optical microscope and SEM. Dry sliding wear experiments were performed on a self-designed reciprocating wear test machine. The wear mechanism and possible wear process were concluded after experiments. Additionally, it should be noted that besides sliding abrasion, there still have cycling load when applying biomimetic surface into actual use of brake shoe. Therefore, the investigation of fatigue wear behavior of biomimetic samples during dry sliding is necessary and will be conducted in future work.

2. Experimental

2.1. Material

Experimental material is medium carbon steel. Table 1 lists main chemical compositions of this material.

2.2. Sample preparation

Blank samples with dimensions of 20 mm × 30 mm × 6 mm were cut from an as-received brake shoe by electric spark cutting machine. Before laser processing, all samples were ground by sandpapers to obtain the same surface roughness about 0.16 μm. The laser beam with wavelength of 1.064 μm was from a solid state Nd:YAG pulsed laser machine (YASKAWA, Japan) with Gaussian output mode and 400 W maximal power. For laser hardening

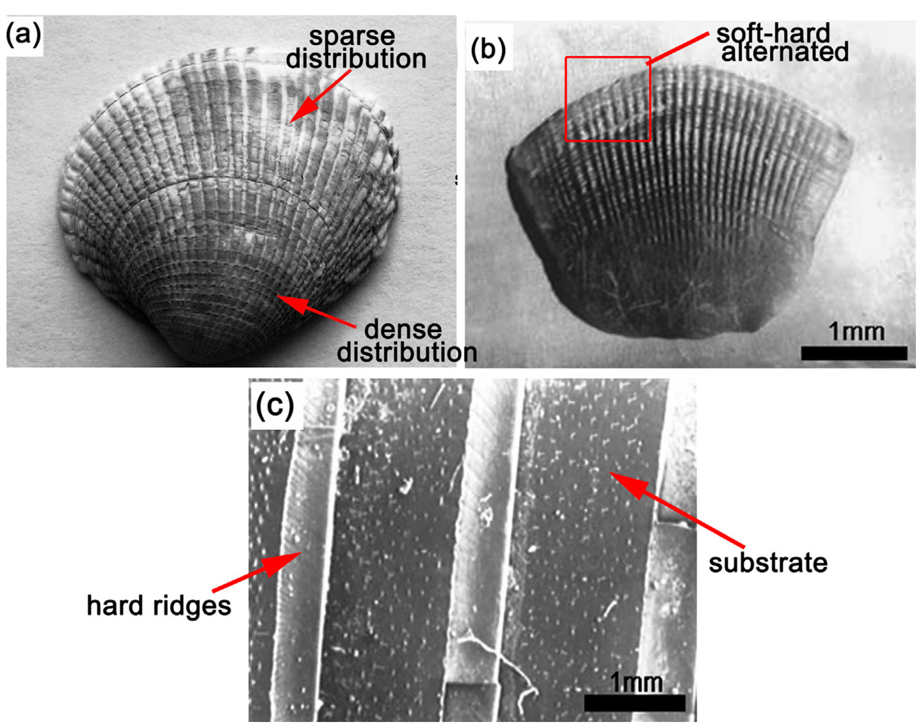

Fig. 2. Examples of biological surfaces with excellent anti-wear properties. (a) Radically distributed ridges of shell surface [5]; (b) striated ridges of a scale of pangolin; (c) ridged abdomen of ground beetle [4].