

Study on quantitative relation between characteristics of striature bionic coupling unit and wear resistance of gray cast iron



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ABSTRACT

In order to improve the wear resistance of gray cast iron guide rail, striature bionic coupling units of different characteristics were manufactured by laser surface remelting. Wear behavior of gray cast iron with striature bionic coupling units has been studied under dry sliding condition at room temperature using a homemade linear reciprocating wear testing machine. The wear resistance was evaluated by means of weight loss measurement and wear morphology. The results indicated that there is a relationship between weight loss and the area of striature bionic coupling units and α : $\Delta m = \Delta m_0 - 0.0212S \times \cos \alpha - 0.0241S \times \sin \alpha$.

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1. Introduction

Bionics is a new science borrowing design ideas from nature [1]. Nature has its perfect designs through billions of years' evolution, the biological structures have gradually develop to best adapt to the environment [2]. These designs often give us some inspiration. After studying the cuticle morphologies of some soil animals such as dung beetles, Ren et al. [3–5] found that some structures on cuticles called 'non-smooth construction units' could provide excellent abrasion resistance against soil. By mimicking the cuticles of soil animals (Fig. 1), bionic coupling units were obtained by laser remelting. These units will play the role of a hard phase because of its superior hardness and strength. On the contrary, base metal plays the part of the soft phase. It forms a soft and hard alternative non-smooth surface, which likes the nacreous layer of shell (Fig. 2) [6]. In our previous researches [7–13], this structure will not only improve the wear resistance and thermal fatigue of materials, but also greatly extend the life of work pieces. However, it also shows that different characteristics of units would increase the thermal fatigue of samples at different degree [11–13].

Due to the low melting point, good damping property, and low cost, gray cast iron is widely used in the machine tool guide-ways [14]. The wear resistance of gray cast iron guide way is an important index in judging the precision degree of lathe cutting, which affected the life of the machine. Many researchers worked on the theoretical and experimental study on improving the wear resistance of gray cast iron by laser processing [15–17]. Most of these experiments were directly tested on pin-on-disk wear-test machine, which still has some differences in the form of gray cast iron guide rail movement. Meanwhile, it is also difficult for them to give us a clear quantitative relationship. Therefore, it is very necessary to study on line reciprocating wear of gray cast iron guide rail, and give a positive quantitative relation between characteristics of striature bionic coupling unit and wear resistance of gray cast. It will give us huge help for the workpiece' designing and machining, which will meet the wear resistance that we need.

Through the observation of the scales of pangolin as Fig. 3, we found that the distance between adjacent edges is not the same; and there exists an angle that the edges at the margin of scale. When the pangolin is moving through rocks and sands, the wear of different scales is different. The striature bionic coupling samples were obtained by laser remelting, through mimicking the scales of pangolin. The quantitative relation between characteristics of striature bionic coupling unit (the units' area and the wear angle) and wear resistance of gray cast was studied by wear test by homemade linear reciprocating wear testing machine.

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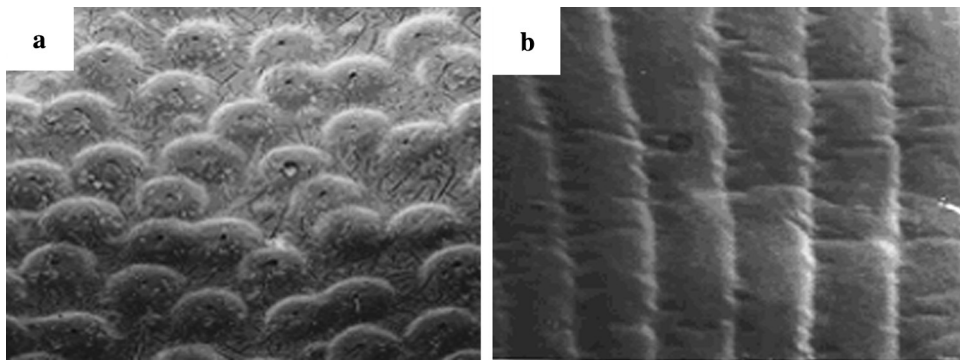


Fig. 1. Various coupling surfaces of dung beetle (a) punctuate coupling surface on the head of dung beetle; (b) striate coupling surface on the backing deals of dung beetle.

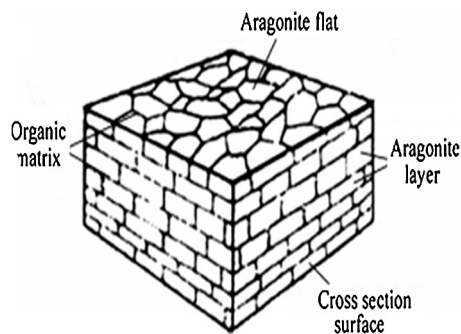


Fig. 2. The structure in the nacreous layer.

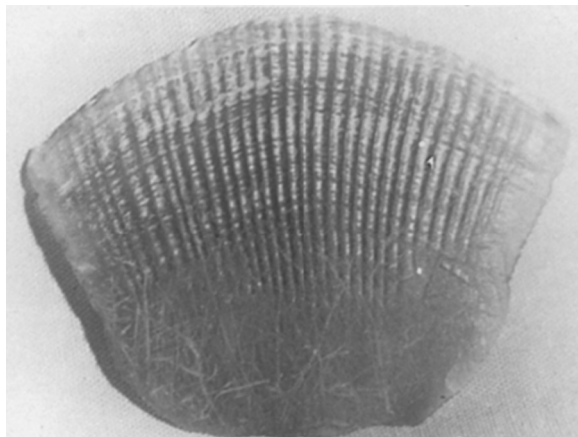


Fig. 3. The scales of pangolin.

2. Experimental

2.1. Material

Gray cast iron used in the experiment is from the guide rail part of a lathe. Fig. 4 shows the microstructure of the test material, which is composed of flak graphite (G) and pearlite (P). The chemical compositions in weight percentage of gray cast iron are given in Table 1.

Table 1
Chemical composition of compact gray cast iron.

Element	C	Si	Mn	P	S	Fe
Composition (wt%)	3.25	1.82	0.94	0.15	0.98	Balance

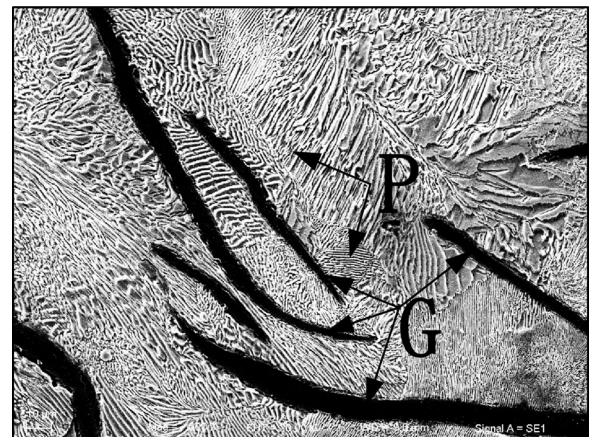


Fig. 4. Microstructure of gray cast iron.

2.2. Sample preparation

The sample was made the geometrical size of 30 mm × 20 mm × 6 mm by an electric spark machine; then remove cutting trace and oil on the surface of the specimen by sand papers to obtain a smooth and clean surface.

A solid state Nd-YAG laser of 1.06 μm and maximum 300 W was used to fabricate the bionic coupling surface on the specimens. The bionic coupling sample was shown in Fig. 5. The acute angle between striature units and wear direction is defined as wear angle α . The laser processing parameters were pulse energy 12 J, pulse duration 8 ms, frequency 5 Hz, defocusing size 5.5 mm, scanning speed 0.5 mm/s. Argon gas was used as shielding gas with constant flow rate of 10 L/min. The biominetic samples acquired before the wear experiment were ground by sand papers to meet the roughness requirement.

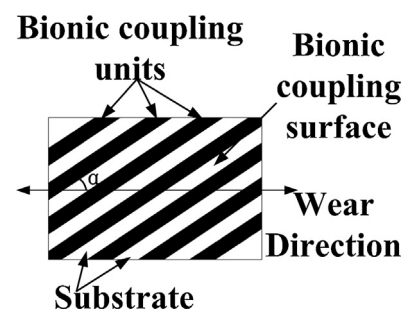


Fig. 5. The sketch of bionic coupling sample.

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