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Model Design and Processing of Bionic Non-smooth Surface of Fish-scale Concavity

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Abstract. Based on the basic methods of engineering bionics research, this paper is inspired by the desert surface morphology on the basis of the existing drag reduction microstructures, and extracts the characteristics of ecological surface drag reduction information, thereby establishing a fish-scale pit model. This paper designs and builds a diamond stamping platform to stamp and stamp copper sheets, and proposes a method that can effectively process the non-smooth surface of the fish-scale pits of the required size.

1. Introduction

In today's society, with the continuous development of science and technology and the continuous progress of society, a large amount of energy on the earth is rapidly consumed. With the declining non-renewable energy such as coal and natural gas, human society will face an energy crisis. Therefore, people need to develop new energy and save existing energy as an important mission at this stage. Among them, the development of new energy has been widely studied, and there is an extremely effective method for saving energy, which is to reduce the resistance of various vehicles during operation, so as to achieve the purpose of saving energy [1].my country has only conducted exploratory research on non-smooth surface drag reduction technology since the late 1980s. Many schools and research institutions, including Jilin University, Beihang University, etc., have conducted a large number of scientific researches and have achieved good results. The effect of [2]. But most of the researches are also based on V-shaped grooves. Moreover, most scholars only stay in the theoretical direction for drag reduction research on non-smooth surfaces, and there are only a handful of drag reduction models that can be effectively processed in practice [4].

At this stage, in fluid mechanics, automobile dynamics, soil mechanics and other disciplines, bionic non-smooth surfaces have been extensively studied and used [5]. Although their respective application scenarios and media may be different, the principles of selection are the same. In order to improve the existing drag reduction structure, this paper will propose a new non-smooth micro-structure unit based on the existing non-smooth unit body, combined with the principle of bionics, and process it to test its actual processing feasibility , To provide a reference for the application of non-smooth surfaces.

2. Design of fish scale pit bionic non-smooth surface model

There are many pits resembling fish scales in nature, and they often appear in arid areas such as deserts, beaches, and river beds. After long-term wind erosion, its appearance forms a structure similar to fish-scale pits. Therefore, the adaptive principle of nature can indirectly indicate that the fish-scale pit

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structure may be more conducive to the movement of fluid on the surface of the object. If it is applied to a non-smooth surface, it may achieve a good drag reduction effect.

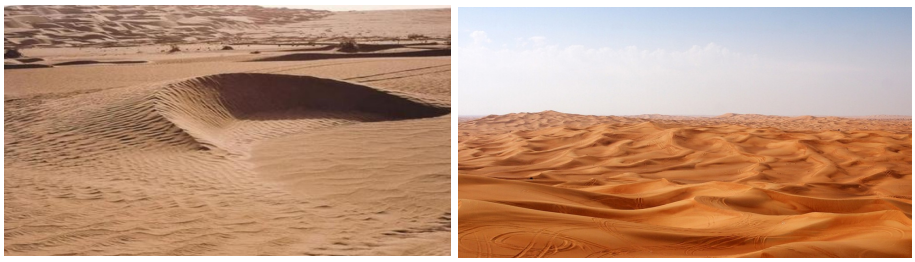


Figure 1 Desert surface morphology

Therefore, through the study of the surface morphology and characteristics of sand dunes, the main appearance characteristic parameters that affect drag reduction performance are analyzed and extracted, and a simplified model of fish-scale pits is established on this basis. The fish-scale pit is based on the shallow spherical pit. The deepest point is translated backwards along the direction of the fluid for a distance to the nearest edge with a length of S, and its onward surface is set as a slope with a slope of γ, and The bottom is smoothly transitioned. At the same time, in order to facilitate the establishment of the model, the projection of the scale-shaped pit on the plane is circular, the diameter is D, and the maximum depth of the pit is h. As shown in the figure, the cross-sectional view of the scale-shaped pit is shown.

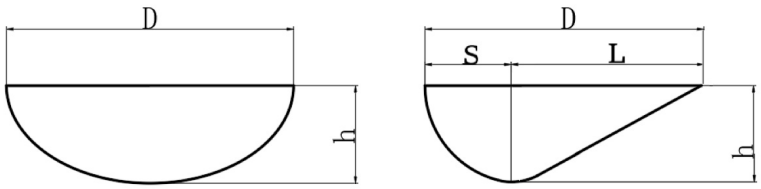


Figure 2 Profile of fish scale - shaped pit

3. Development of stamping device and processing and inspection of non-smooth surface of fish-scale pits

3.1. Drafting of the overall plan for press equipment

The purpose of the design of the diamond imprinting microstructure device is to process fish-scale pits on the pure copper workpiece by using a diamond indenter. In the design phase of the scheme, firstly, a comprehensive analysis of the functional requirements of the imprinting device must be carried out. The device should meet the following requirements:

1) The diamond indenter should have precise drive control, which can accurately control the pressing in and out of the diamond indenter;

2) The diamond indenter can be moved and adjusted horizontally X, Y;

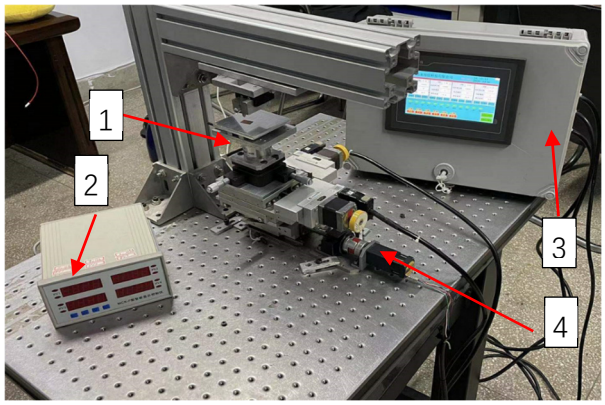
3) The indenter can be accurately deflected at a small angle.

4) The load of the diamond indenter can be detected to confirm the indentation stroke.

Contact According to the analysis of the above motion functions, the overall printing and pressing device can be divided into the following parts: gantry support device, bottom plate connection mechanism, horizontal micro-adjustment device, Z-axis precision drive device, small angle table, and detection module.

The stamping experiment instrument adopts the self-built experiment platform as shown in the figure. This device adopts a more stable vertical gantry structure, which effectively avoids processing errors

caused by device chatter during processing. The workpiece in the processing area is fixed by a screw-press plate combination clamping and fixing form. The workpiece is completely attached to the substrate, which not only restricts the workpiece The degree of freedom in the XYZ direction reduces the machining error caused by the micro-movement in the machining process, and has good self-locking performance and a large clamping stroke adjustment range. The micro-video microscope in the monitoring area realizes the accurate and damage-free contact between the indenter and the surface of the workpiece, and the displacement control box realizes the precise control of the tool lift displacement under different printing speeds to ensure the small error processing of the pits of the specified size.



1- Stamping processing area 2- Force sensor 3- Displacement control box 4-XYZ three-way motor
Figure 3 Imprinting experimental device

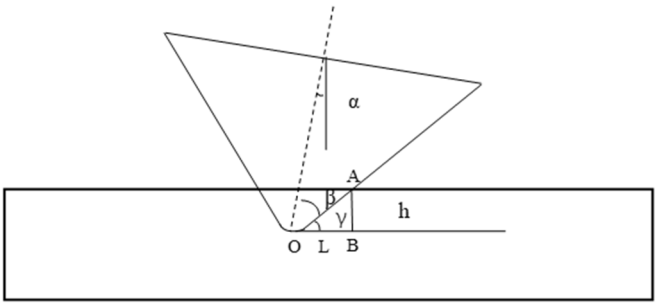


Figure 4 Mathematical Model Diagram of Inpresser Inclined into Workpiece

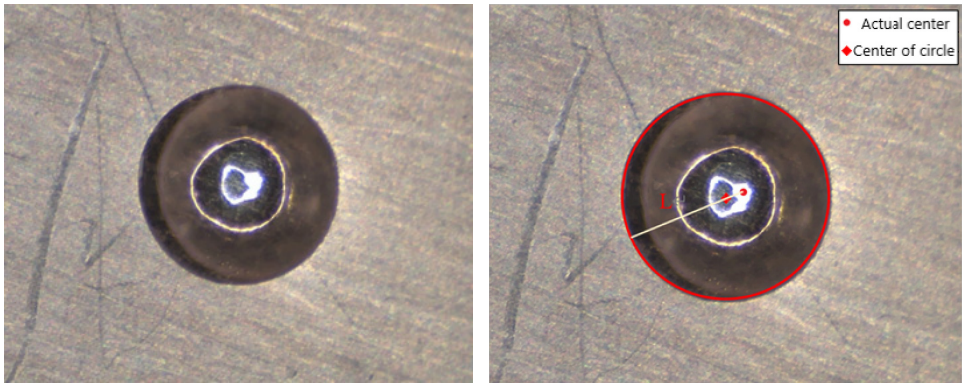
According to the numerical relationship in the model, the inclination angle α of the indenter can be calculated as:

$$\alpha = 90° - \beta - \gamma \tag{1}$$

$$\gamma = arctan\frac{h}{L} \tag{2}$$

In the formula: γ is the minimum included angle between the indenter and the lower surface of the workpiece; h is the indentation depth of the indenter; L is the maximum projection length from the bottom vertex of the pit to the edge of the pit. Therefore, as long as the sizes of h and L are known, the indenter angle to be adjusted can be calculated, and then the indenter angle can be adjusted by the angle adjusting device to achieve the initial state setting of the indenter.

Also according to the above formula, the inclination angle of the cutter head before processing can be corrected to ensure the accuracy of angle adjustment. The depth h of the indenter is a known amount. As long as the length of L is measured, the value of the inclination angle α can be obtained, and then the angle of the diamond indenter can be adjusted by the angle adjustment device to realize the inclination correction of the indenter.



(a) (b)

Figure 5 Initial vertical printing pressure map
(a) Vertical press-in graph (b) Image fitting graph

3.2. Processing and testing of the microstructure of fish scale pits

In the experiment, a diamond rolling knife with a blunt circle radius of 0.5mm and a cone angle of 90° was selected as the indenter for embossing. At the same time, according to the research results of the unilateral ultra-micro hole forming in this subject, the pure copper material has high plasticity, strength and The hardness is low, which is conducive to the formation of pits. Therefore, in this experiment, T2 pure copper is used as the experimental material, and the initial specification of the material is 30×10×0.5mm.

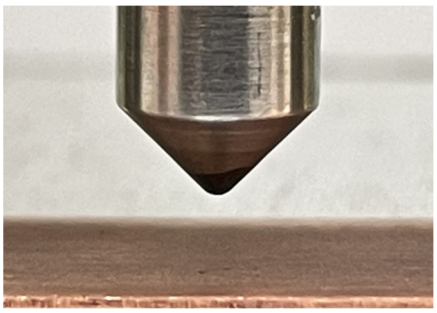
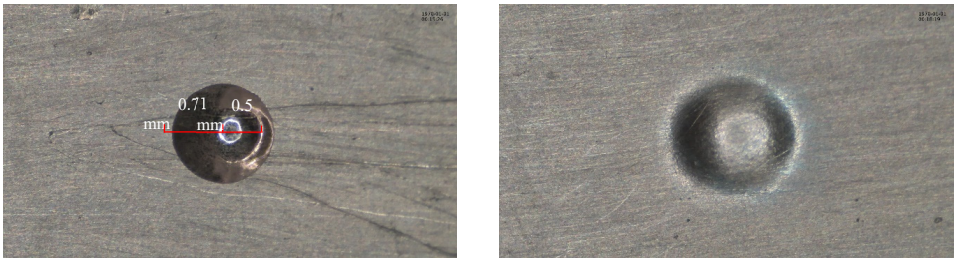


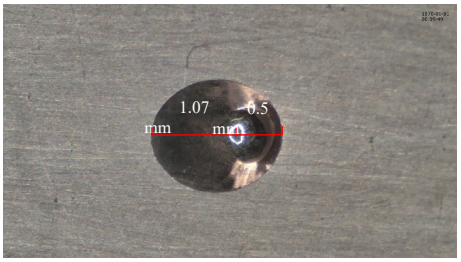
Figure 6 Diamond indenter and copper sheet

On the basis of the completion of the diamond indenter proofreading, the indenter angles of 10°, 20°, and 30° were selected to imprint the copper sheet with 0.5mm inclination angles. The results of the fish-scale pits are shown in the following figure:

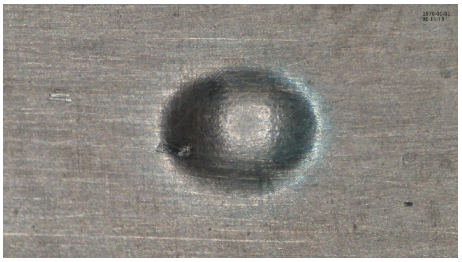


The upper surface of fish-scale pits The lower surface of fish-scale pits

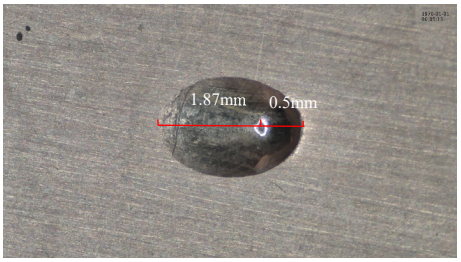
(a)



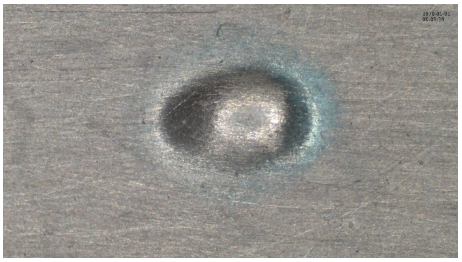
The upper surface of fish-scale pits


The lower surface of fish-scale pits

(b)



The upper surface of fish-scale pits

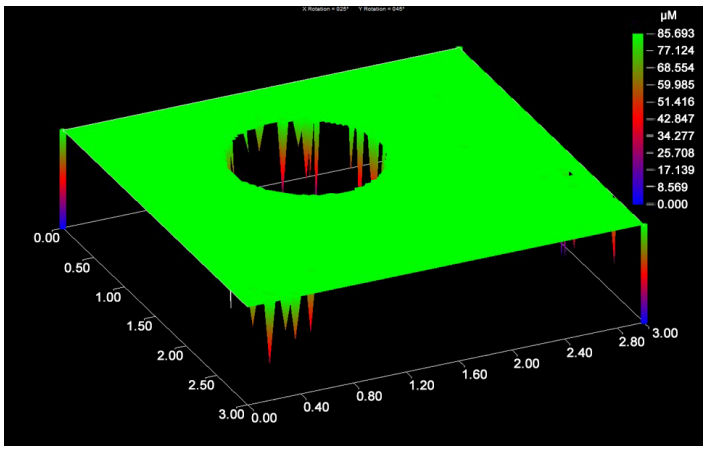

The lower surface of fish-scale pits

(c)

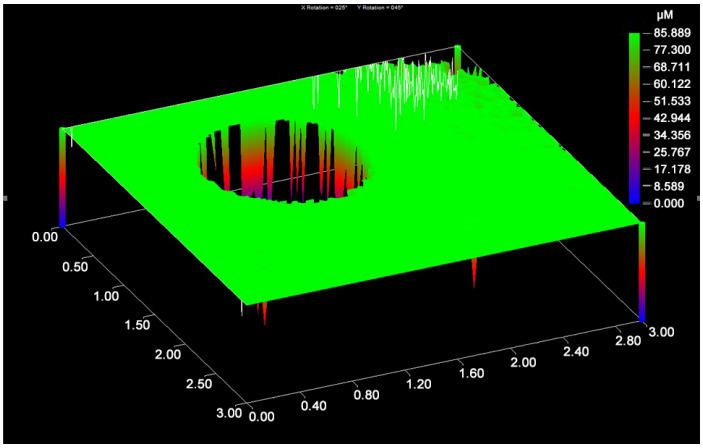
Figure 7 Surface profile of fish-scale pits
(a) Indenter tilt angle 10° (b) Indenter tilt angle 20° (c) Indenter tilt angle 30°

Through the ratio of the indentation depth h to the length of the maximum distance L between the deepest point of the scale-shaped pit and the edge of the contour obtained by the measurement, the slope angles γ are respectively 15°, 25°, and 35°, which are consistent with the theoretical results. It is proved that by adjusting the indenter depth and the indenter angle, the fish-scale pit model of the required size can be processed.

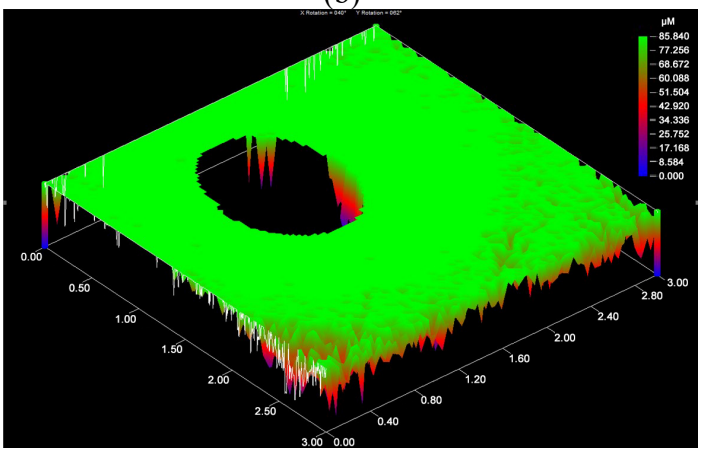
At the same time, the picture is the scan image of the upper surface of the copper sheet with different indentation angles. It can be observed that the surface of the copper sheet with different indentation angles is not obvious, indicating that this processing technology has an excellent grasp of the edge contour of the fish scale pit. The microstructure of fish-scale pits consistent with the theoretical model can be processed.



(a)



(b)



(c)

Figure 8 Scanned images of the upper surface of the copper sheet with different pressing angles. (a)Indenter tilt angle 10° (b) Indenter tilt angle 20° (c) Indenter tilt angle 30°

4. Conclusion

In this chapter, based on the principle of bionics, the morphological selection principle of the fish-scale pit non-smooth surface studied in this paper is described, and a new type of bionic non-smooth drag-reducing microstructure surface is proposed.

At the same time, the diamond imprint microstructure platform was designed and built according to the experimental processing requirements, and the angle adjustment device and the key components of the precision drive spindle were analyzed and designed in detail. A mathematical model is established for the eccentricity phenomenon in the printing process, and the expression of the indentation angle of the indenter is calculated. In addition, the dimensional accuracy of the scale-shaped pit microstructure and the surface profile of the non-smooth surface are tested. The results show that the non-smooth surface of the scale-shaped pit that can be obtained by this processing method is consistent with the theoretical model.

Acknowledgements

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