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The Study and Predict on the Surface Structure and the Characteristics of Pincers of Crawfish (Procambarus Clarkii)*

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Abstract: Based on the introduction of biological non-smooth surface and the characteristics of drag reduction and wear resistance, a series of macroscopic and microcosmic observation and analysis on the surface structure of pincers of crawfish (Procambarus clarkii) were finished with the OLYMPUS stereo microscope and LSCM (Laser Scanning Confocal Microscope). The results indicate that the surface of pincers of crawfish is mainly constituted by small pits, small semicircle bumps and small stripe-type groove, and there are clusters of bristles which have a lot of spinules in their surface within the pit and around the small bump. It shows the surface of pincers of crawfish is non-smooth and has typical non-smooth surface characteristics. In addition, by analyzing the variation rules of small haplonts(pits and bumps) in the non-smooth surface of pincers of crawfish, authors get the conclusion that the keystone and direction of the non-smooth surface study should be focused on the quantitative analysis to the changes(size, form, and the distribution) of the small haplonts influence on the characteristics of the drag reduction and wear resistance, and its engineering application.
Key words: Non-Smooth Surface; Pincers of Crawfish; Drag Reduction; Wear Resistance

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INTRODUCTION

1.1 Biological non-smooth Surface

Biological non-smooth surface widely exists in the living creatures of the nature, no matter in the land, sea or sky, and the different forms of surface to meet different environmental needs of the life are from the different evolving process (Ren Luquan et al., 2005). According to the differences of non-smooth structure, the biological non-smooth surface morphology can be divided into scale type, pit type, bump type, ripple type, and bristle type and so on (Ren Luquan et al.,2002).The effect of biological non-smooth surface mainly embody the characteristics of the drag reduction and wear resistance.

The drag reduction characteristics of the biological non-smooth surface morphology mainly lies in the effect of biological non-smooth surface, it means that the geometric structure of biological non-smooth surface will change the resistance which is produced by the relative motion materials and the biological surface.

According to the “use and disuse theory” of creatures, if some surface parts are often repeatedly stimulated by something else, it will probably produce some non-smooth wear-resistant structure (like pits, bumps, scale or groove and so on), finally they will evolve into different forms of non-smooth surface. So the biological non-smooth wear-resistance surface should be the results of these creatures long-term undergo unbalanced external force stimulation or function in their survival natural environment.

1.2 The Introduction of Related Research of this Paper

After billions of years of evolution, the natural creature formed a special surface structure with excellent characteristics. Therefore, it has the extremely vital significance that to do research on the structure of biological surface and its characteristics for the bionic design of surface morphology (Wang Liduo et al., 1996). Crawfish which belongs to phylum arthropoda and class crustacea, has strong ability to adapt to the environment. Fig. 1 shows the overall view of the crawfish. The pincers of crawfish play an important role in their life: the external resistance load and high-speed fled when fighting or prey, require it has good mechanical properties; furthermore, digging holes and water erosion, also require its surface has strong special characteristics. In addition，the crawfish enjoys digging holes, and is good at it, and most of the depth of the holes in 50-80 centimeters, some part over 1 meter, the longest can reach 2.1 meters. In the process of digging, undergoing the huge resistance and abrasion which are produced by sand, stone, and the flow etc, so the pincers of crawfish should have strong drag-reduction and wear-resistance ability.

Figure 1
Overall View of the Crawfish

Recently, Raabe group (Raabe D et al., 2005a, 2005b; Sachs C et al., 2006; Raabe D et al., 2006; Romano P et al., 2007; Raabe D et al., 2007) studied the material composition structure of the pincers of lobster of American sea, but did not analyze the structure of surface morphology and its properties. Compared with Raabe group, this paper replaced the lobster in American sea with the crawfish with the characteristics of smaller and lighter quality as the research object, meanwhile, it is cheap and easy to get, foremost, the pincers of crawfish have remarkable surface morphology for our observation and analysis. In addition, so far the study of crawfish at home and abroad are mainly concentrated in chitin purification, medicine, food feed and other areas of application, however there are very few researches on the surface structure and its related characteristics of the pincers of crawfish. So we focus on it, and discover some valuable information.

1. RESEARCH ON SURFACE STRUCTURE OF PINCERS OF CRAWFISH

1.1 Macroscopic observation and research on the pincer

In order to have a complete understand and study, the author did a series of macroscopic observations and researches on the pincers of crawfish, with the high magnification digital camera of Kodak Z1012, then found that the central surface of the pincer arranges many convex hull shape structure, with the characteristics of different sizes and the arrangement all accord with the direction of growth of the pincers; in addition, there are the same structure in the root surface with the central part, but this arrangement all rotating around the root, extending outward. Fig. 2 was the macroscopic observation on the pincers of crawfish.

Figure 2
Macroscopic Observation on the Pincers of Crawfish

2.2 Microcosmic experiment research with stereo microscope

In order to clearly know the surface structure and its properties of the pincer, the author respectively did a great deal of researches on the three parts of clamp, central and the root surface of the pincer with OLYMPUS stereo microscope (SZX12) in Fig. 3.

Figure 3

OLYMPUS Stereo Microscope (SZX12)

2.2.1 Sample pretreatment

Remove the pincer from the crawfish, and clean its surface with water. Then put the pincer into alcohol solution of 75%, in case the surface of the pincer would go bad in the long time experiment.

2.2.2 Observation research on pincer with stereo microscope

Put the sample on the center of consoles of the stereo microscope and adjust light to moderate brightness. Then we should put the objective lens to the minimum place then gradually adjust it upward with the coarse quasi focal spiral in case of the objective lens contacts with the sample. When we roughly observed the image, should replace the coarse quasi focal spiral with the fine quasi focal spiral to zooming, so that we could observe clear images. Finally, take a picture and storage for study and analysis.

After the different multiples observation serial research on the clamp surface of pincers of crawfish from a to d with stereo microscope in Fig. 4, we could discover the clamp surface is non-smooth surface (Ren Luquan et al., 2001): there are a great deal of small pits with the characteristics of regular arrangement, similar shape and different sizes in the surface. Meanwhile, there are clusters of bristles within every small pit; and when the sizes of small pits change bigger or smaller, the clusters of bristles will also have the same change discipline. In addition, there are some small semicircle bumps arranging in line on the internal of clamp surface.

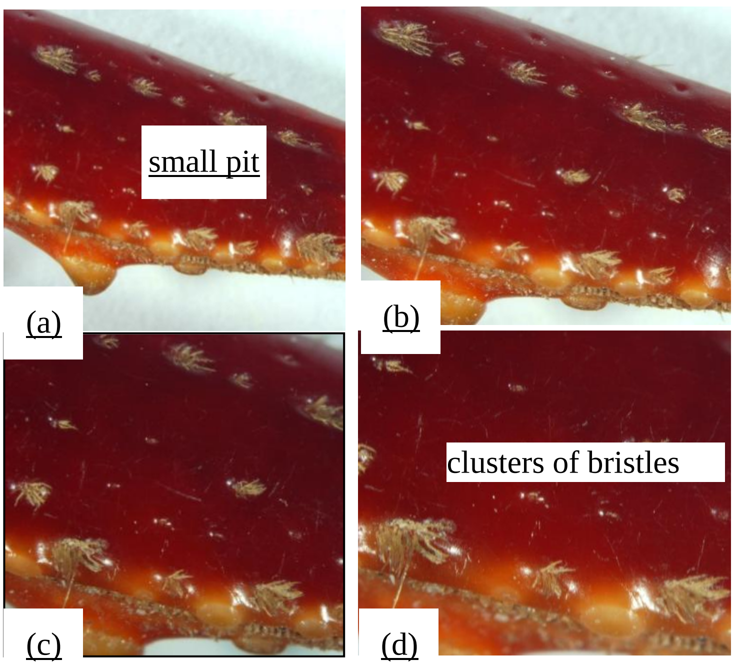

Figure 4
Research on the Clamp Surface of Pincer with Stereo Microscope

After the different multiples observation serial research on the central surface of pincers of crawfish from a to d with stereo microscope in Fig. 5, we could discover there are a great deal of small semicircle bumps with the characteristics of regular arrangement, similar shape and different sizes in the surface. And the arrangement rule of small bumps accord with the direction of growth rule of the pincers, at the same time, these small bumps gradually change bigger from the root to the clamp of pincer of crawfish. Furthermore, there are clusters of bristles around one side surface of small bump which towards the clamp of the pincer and the direction of growth of the bristle is also same with the clamp. When the sizes of small bumps change big or small the clusters of bristles will also have the same change discipline. The structural feature of the small semicircle bumps and the clusters of bristles indicate that the central surface of pincer has obviously non-smooth surface.

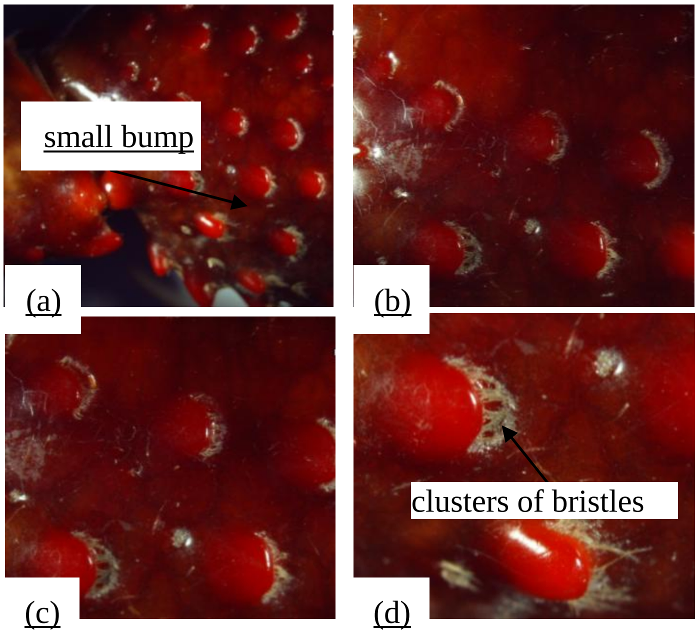

Figure 5

Research on the Central Surface of Pincer with Stereo Microscope

After the different multiples observation serial research on the root surface of pincers of crawfish from a to d with stereo microscope in Fig. 6, we could discover there are a great deal of small semicircle bumps with the characteristics of similar shape, irregular arrangement, and different sizes around the surface, but there are not clusters of bristles around each bump. In addition, there are a few bigger size cone-shape bumps around the surface, and accompany with the clusters of bristles around one side surface of cone-shape bump which also towards the clamp of the pincer, and the direction of growth of the bristle is same with the pincer too. Meanwhile, there are many small pits of pinhole sort with the characteristics of irregular arrangement, and different sizes in the root surface.

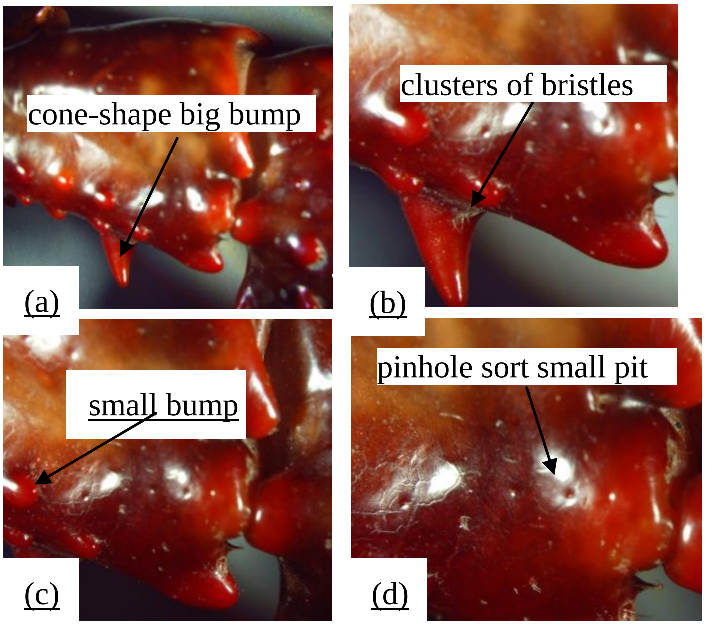

Figure 6

Research on the Root Surface of Pincer with Stereo Microscope

Through the above observing and analyzing, we could know the surface structure of pincer of crawfish is mainly constituted by small pits, small semicircle bumps, the clusters of bristles and theirs combination, and they all have the common characteristics that the size and the arrangement are associated with the direction of growth of pincers of crawfish: the direction of them all point to the clamp of pincer, and the size is gradually changing bigger. The pits, small bumps, and the bristles and theirs combination of biological surface formed remarkable non-smooth structure, so it further indicates the surface structure of pincers of crawfish is non-smooth.

2.3 Microcosmic Experiment Research with LSCM

In order to study the surface structure and its characteristics of pincers of crawfish in detail, the author did a further research on the pits, small bumps, and the clusters of bristles with the LSCE (Laser Scanning Confocal Microscope) in Fig. 7.

Figure 7
Laser Scanning Confocal Microscope

2.3.1 Sample pretreatment

Take the sample(pincer) out of the alcohol solution, and respectively cut the three parts of clamp, central and the root of pincer into some tiny chips to adapt the range of observation of the LSCE.

2.3.2 Observation research on pincers with LSCE

From the different multiples observation research on the small bump of root surface of pincers of crawfish from a to b with LSCE in Fig. 8, we could discover the small bump of the conical shape surface is relatively smooth, and there are not clusters of bristles around it; meanwhile, the direction of growth still points to the clamp of pincer. In addition, there are some tiny stripe-type groove with the characteristics of irregular arrangement and different sizes near around the small bump, and the surface area of tiny stripe-type groove is non-smooth and rough.

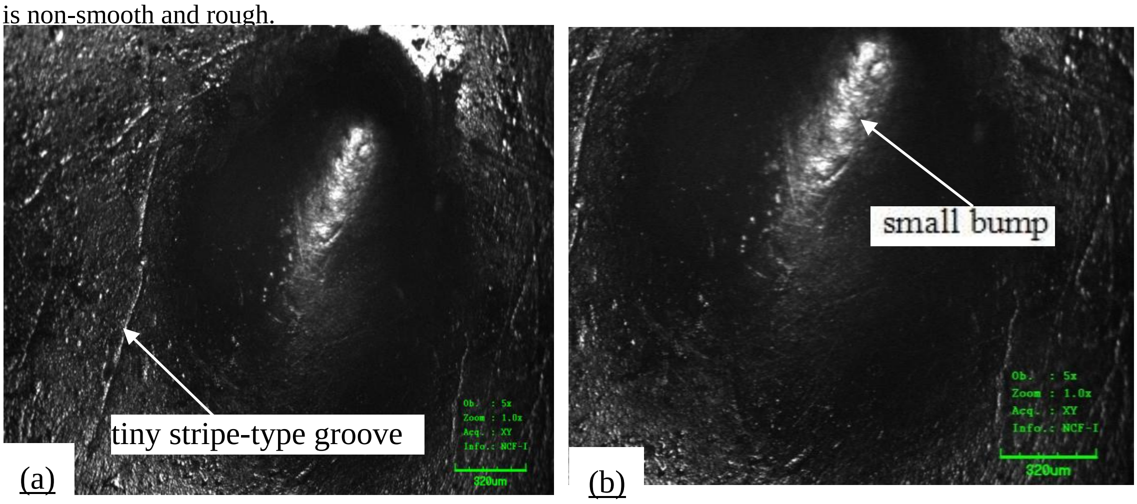

Figure 8
Research on the Small Bump of Root Surface of Pincer with LSCE

In order to detailed research on the bump and bristles of the central surface of pincer, the author did a further studied from a to b with LSCE in Fig. 9, then found the bump are still semi-circular and its surface is relatively smooth too, and there are some clusters of bristles on one side of the bump. Further amplification observation from a to b in Fig. 10, we could discover there are lots of acicular spinules extending outward at the edge of each bristle; and the longer of the bristle, the more and more intensive of these spinules.

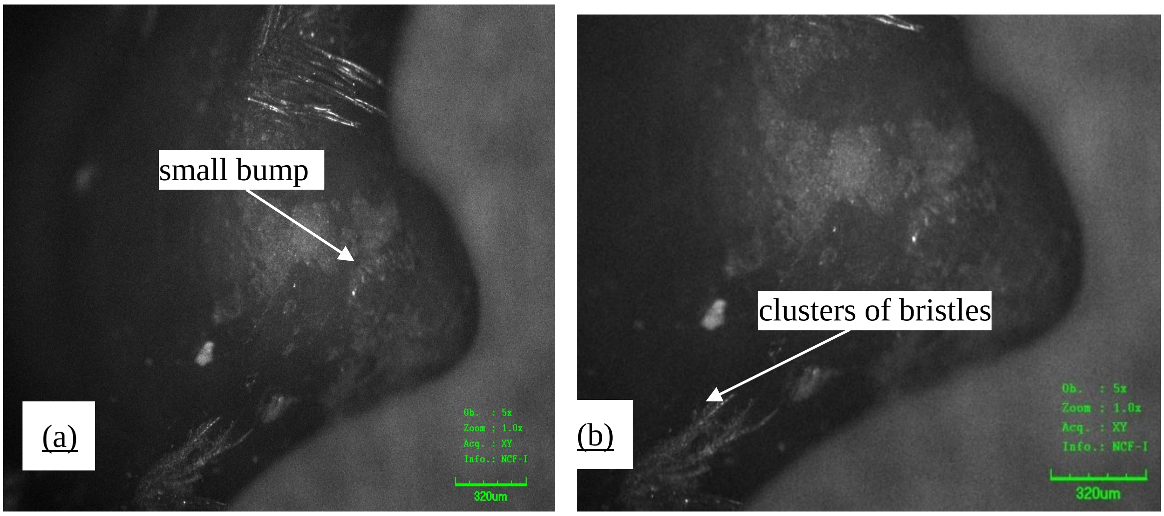

Figure 9
Research on the Bump and Bristles of the Central Surface of Pincer with LSCE

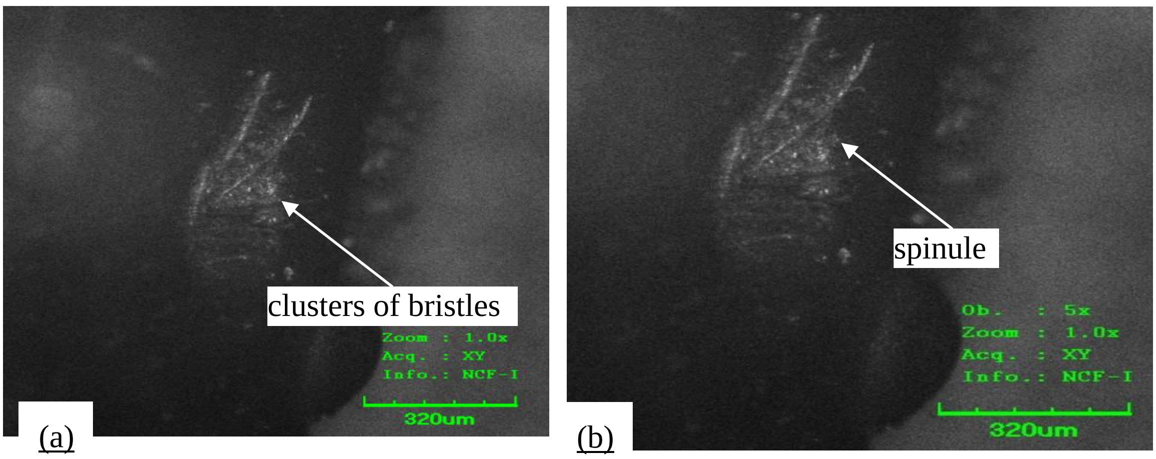

Figure 10
Detailed Research on the clusters of Bristle with LSCE

When researching on the clamp surface of pincer from a to b with LSCE in Fig. 11, we could found there are plenty of small pits with the characteristics of regular arrangement, different size; meanwhile, there are clusters of bristles which are the same with the fig. 10 within every small pit. In addition, there are also some tiny stripe-type groove with the characteristics of intersection and rendezvous near around each small pit. And others surface area of the clamp is relatively smooth and bright.

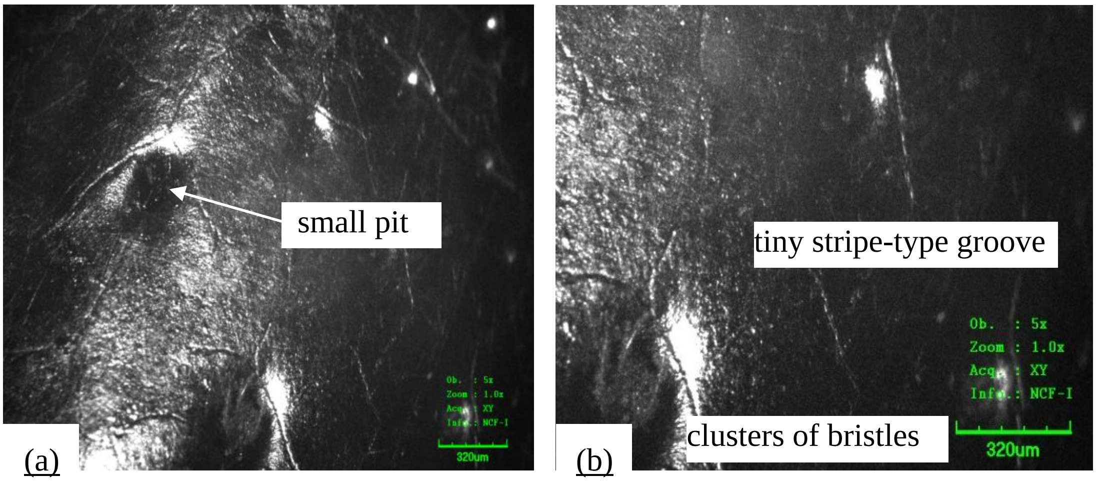

Figure 11
Research on Clamp Surface of Pincer with LSCE

Through the above observing and analyzing, we could further discover there are some tiny stripe-type groove, with the characteristics of the arrangement around near each pit and bump, on the surface structure of pincers besides the small pits, small bumps, and the clusters of bristles. Meanwhile, there are lots of acicular spinules, extending outward, at the edge of each bristle. These researches further indicated the pincer of crawfish has significant non-smooth surface structure.

3. RESULTS AND DISSCUSSION

From the above experimental observation analysis, we could know the surface structure of pincer of crawfish has obviously non-smooth surface structure.

The biological non-smooth surface morphology can reduce the interface contact area and destroy the continuity of water film thus has a great effect upon decreasing adhesion and reducing friction resistance (Cong Qian et al., 1992). The wear-resistance of the biological non-smooth surface and the adhesion and drag reduction of the bionic non-smooth bulldozing plates was studied by Ren Luquan etc (Cong Qian et al.,1992; Ren Luquan et al.,1997; Ren Luquan et al.,2003) , meanwhile, Cheng Hong etc (Cheng Hong et al.,2002) studied the relationship between the body wall surface structure of smelly dung beetle and the function of adhesion and drag reduction, which pointed out the structure of small pits and bumps have certain function of friction reduction and wear-resistance. For example, based on the surface modification and topography reform by bionics, plow moldboards with reducing soil adhesion and plowing resistance function were developed, according to the working conditions of the tractor-drawn plow moldboard. Results showed that, compared with conventional plow moldboard, the bionic plow moldboard could save the oil consumption to 5.6%~12.6%, and reduce the plowing resistance to 15%~18% both in the soil bin and in the field. Meanwhile, after the whole farming, the non-smooth bumps did not obviously wear, so it indicated the bionic plow moldboard possesses better properties of friction reduction and abrasion resistance (Li Jianqiao et al., 1996). Through the above introduction, we can deduce the surface of pincer of crawfish also possesses strong non-smooth surface characteristics which are benefit to the drag reduction and wear resistance.

After further analysis those experiment, we could get two points:

The first point, in the width-ways of clamp surface of pincers: when near the medial and lateral edge of clamp, the pits would change bigger, and the clusters of bristles within the pits would also change more and bigger; but when in the central of the clamp, the pits and the clusters of bristles would obviously change smaller and fewer; when in the lateral edge of the clamp, we only can some tiny pits without any bristles. In the lengthways of clamp surface of pincers: the size of the pits and the clusters of bristles have a tendency to change big and more, when the distance becomes closer between them and the clamp tip.

Another point, there is not obvious change about the bumps and the clusters of bristles in the width-ways of central and root surface of pincers, but in the lengthways of central and root surface of pincers, the size of the bumps and the clusters of bristles have a tendency to change big and more, along with the distance become closer between them and the clamp tip. At the same time, the clusters of bristles around one side surface of small bump which towards the clamp of the pincer, and the direction of growth of the bristle is also same with the clamp.

We know when the crawfish digs a hole with its pincers, the clamp of the pincers will first touch the sand, stone, and the flow etc; when the depth of digging increase, the part of the central and root of the pincers will also begin to have the interaction with the sand, stone etc; in the process, the resistance and the worn degree of different part of the pincers will also gradually increase. Meanwhile, it will have different contact area between the different part of the pincers and the sand, stone etc, so it also will suffer different resistance and the worn degree in the different part of the pincers. In this case, we can deduce the change-rule of the size and the arrangement of the pits, bumps, and the bristles of the pincers is largely related to the ability of drag reduction and wear resistance, which means the change-rule of the surface of pincers will enhance the non-smooth characteristics. In a word, the non-smooth surface of pincers of crawfish and its change-rule of the surface of small haplonts give us a thought for researching on the non-smooth surface and its engineering application.

4. CONCULSION AND PROSPECT

The surface structure of pincers of crawfish is mainly constituted by small pits, small semicircle bumps, the clusters of bristles and some tiny stripe-type groove, and there are lots of acicular spinules at the edge of each bristle. These typical structures indicate the surface of pincers of crawfish possesses significantly non-smooth characteristics and the ability of drag reduction and wear resistance. In addition, the change-rule of the size and the arrangement of the pits, bumps, and the bristles of the pincers give us a thought for researching on the non-smooth surface and its engineering application. So we should do some systematic research on the following two points in the future.

(1) Quantitative research on the influence which the non-smooth surface characteristics of pincers of crawfish and the size, form, and the distribution of non-smooth small haplonts will produce on the drag reduction and wear resistance; then further study the variation rules of small haplonts using series of simulation experiments, so that we can find the variation rules of the drag reduction and wear resistance.

(2) Detailed research on the engineering application with the non-smooth surface characteristics of pincers of crawfish and the variation rules of small haplonts, then discuss the feasibility and industry value of this bionic design.

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