COUPLING THE BIONIC SURFACE FRICTION CONTACT PERFORMANCE AND WEAR RESISTANCE ANALYSIS

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Abstract

This article is mainly to study the frictional contact performance of biomimetic flexible pits surface of different structure under the preload using the coupled bionic technology. And using finite element analysis software to conduct the contact analysis of bionic pit surface of different sizes, establish bionic flexible pit surface and rigid surface friction contact, discussion force and deformation of the surface of a flexible pit when bionic flexible pit surface and the rigid surface contact, and analyze the wear resistance. The results showed that the model of 1mm radius of pit has minimum equivalent stress, longest life and best wear resistance.

Index Terms: *finite element analysis, bionic, rigid -flexible contact, frictional contact, wear-resistant*

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1. INTRODUCTION

As well know in all areas of daily life and industrial production, and everywhere there is friction which derive from the contact between the surfaces such as the adhesive, sliding, separation process between the friction surfaces. However tribological and life science cross make research areas and scientific basis of tribology more extensive. Currently coupling bionic based on bioconjugation function is the latest advances in the field of engineering bionic, it can effectively realize the functional requirements of bionic design, resulting in better performance of bionic.

Recently domestic and foreign scholars have conducted a lot of research on the shape of the foot structure for climbing animals which has increased friction performance, and the results show that the shape of animals can be divided into flexible flat-contact manner and bristle contact and microscopic surface structure is convex, concave shape, diamond shape. Climbing increasing friction mechanism of different animal is not completely the same; more is two or more than two kinds of coupling bionics interaction.

At present Joseph Marrocco[1],Dai zhen dong[2],Han zhi wu[3]and Wang chao fei[4] analyze the abrasion resistance, erosion resistance of different bionic structure using the coupling bionic technology, but the methods used are static bionic and finite element analysis is not friction contact. In addition Wang Zaizhou and Zhang Chunxiang [5] analyze modeling method and sliding friction of single bionic non-smooth surface.

In this paper, using finite element analysis software ANSYS, establish frictional contact pairs between coupled bionic surface and rigid surface, carry on contact analysis of frictional contact about the different dimensions of the flexible bionics concave surface - rigid surface, study stress and deformation of the bionic flexible concave surface when the bionic flexible concave surface and rigid surface contact and explore the wear resistance of the three pits radius through fatigue life analysis.

2. COUPLED BIONIC STRUCTURE AND THE ESTABLISHMENT OF THE FINITE ELEMENT MODEL

Domestic and international studies have shown that the tree frog, which forelimb paws have 4 fingers which all have oval sucker and transparent is slightly texture, has a strong climbing ability that can stick its body tightly relying on the toes and hanging upside down from the branches. The long diameter of a single elliptical foot pad is about 3.5mm, and the short diameter is about 2mm, the area is 5.5mm2.The microscopic surface morphology of sucker foot pad which is observed by VHX-600 optical three-dimensional microscope is shown in Figure 1 (c) and (d).

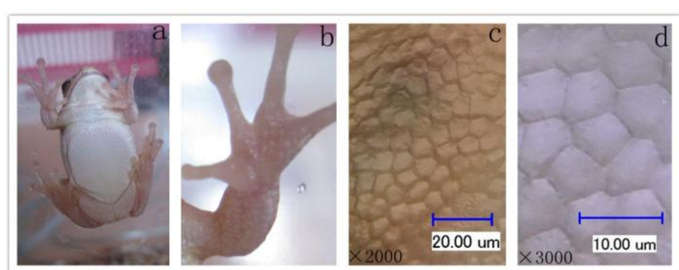

Fig. 1 the forelimb paws structure of tree frog

So the tree frog with sucker structure has very excellent climbing ability. Based on the flexible characteristics of the sucker and surface structure, make the coupling bionic about it’s flexible and structure and analyze the coupling structure frictional contact performance. Design three different coupling biomimetic function surface, such as shown in Table 1.

Table 1 Imitation tree frog foot pad biomimetic surface structure parameter table

Pit shape	Diameter（mm）	Depth (mm)	Lateral spacing (mm)	vertical spacing（mm）	Arrangement
Hemispherical	0.5	0.25	4.5	3.5	Neat distribution
Hemispherical	1	0.5	4.5	3.5	Neat distribution
Hemispherical	2	1	4.5	3.5	Neat distribution

Following the model designed with Pro/e is imported into ANSYS software, as shown in Figure 2 is the digitized model of the three different coupling bionic functional surfaces.

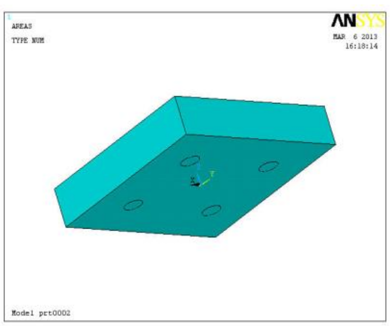

Figure 2 three digital model of different coupling bionic functional surface

3. FINITE ELEMENT ANALYSIS

Firstly, define unit type and material parameters. The rigid surface selection SOLID186 unit, the elastic modulus of the rigid body E = 2.1×105Mpa, Poisson's ratio of the material γ =0.33; Flexible rubber material used HYPER86 unit, the elastic modulus E = 7.84 MPa, Poisson's ratio γ = 0.47; The coefficient of friction between the material μ =0.3; Then draw a face and the same rectangular size in ANSYS as a rigid surface.

Secondly, create a contact pair. In accordance with the principle of rigid - flexible, flexible body only (rectangular) mesh. Contact type selection surface contact mode[6-11]that rigid surface for the target surface thatTARGE170 unit used, and cuboid with hemisphere for contact surface that CONTA174 unit used. The contact pair is shown in Figure 3.
Finally, constraints is a rigid surface full constraint, the rectangular horizontal surface x direction constraint and vertical surface y direction constraint. Then applied 100N force to the cuboid upper surface. Solving results shown in Figure 4and Figure 5.

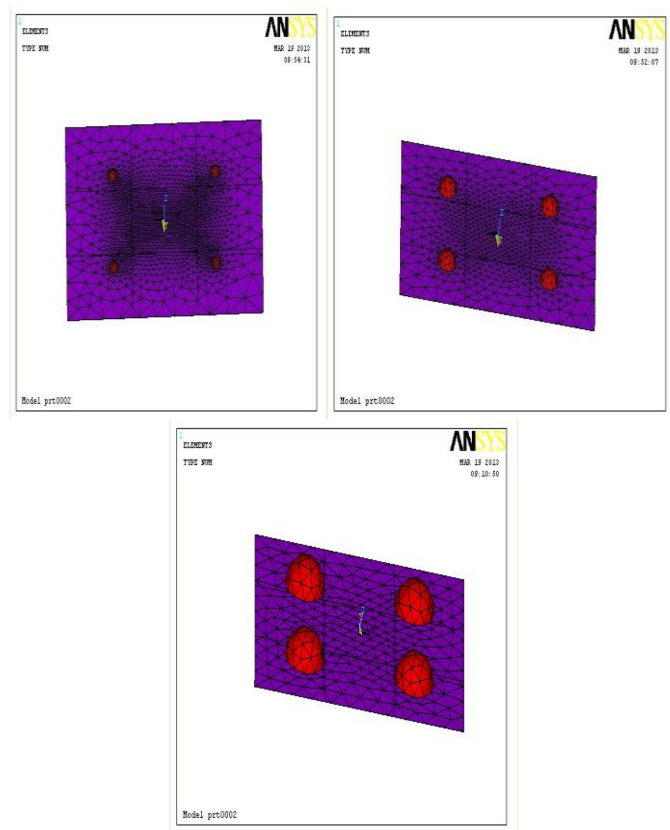

Figure 3 Contact pair of models which radius is 0.5mm ,1mm and 2mm

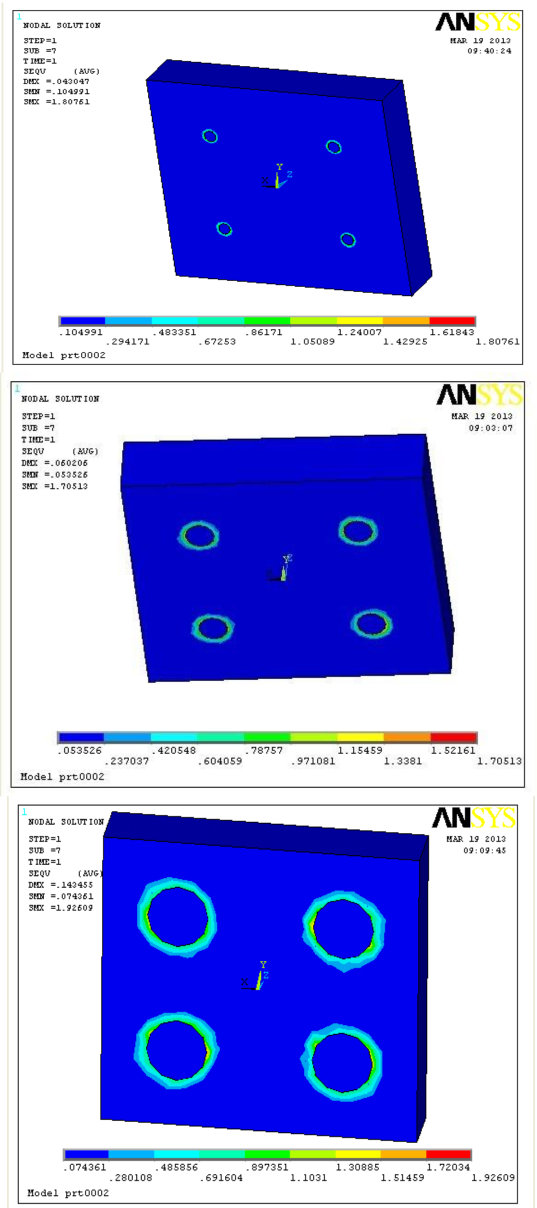

Figure4 Dimple radius of 0.5mm 1mm 2mm model's von Mises stress

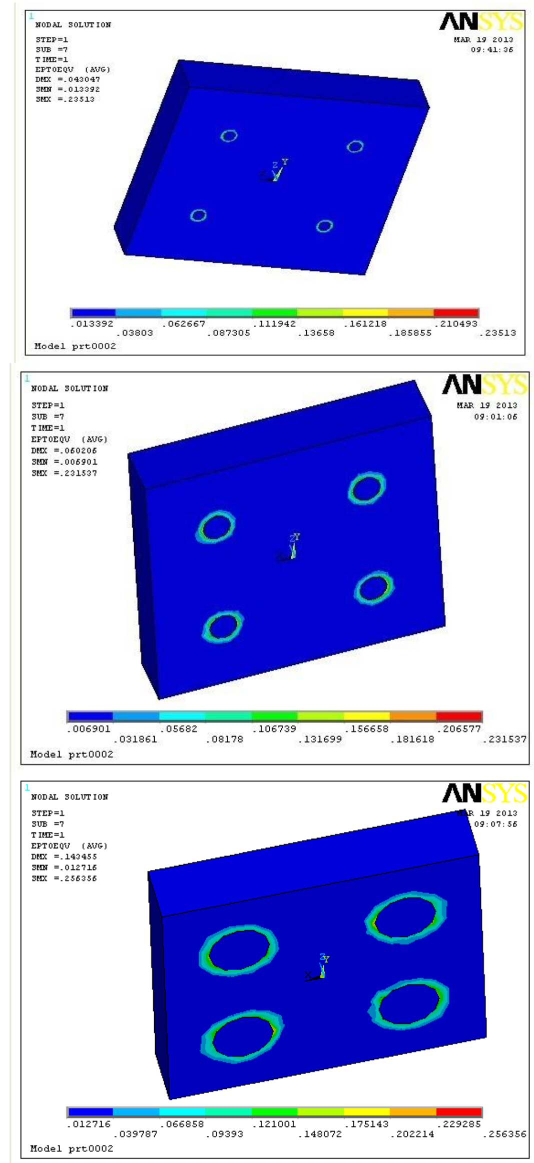

Figure5 Dimple radius of 0.5mm 1mm 2mm model's strain determine the stress position and define the stress concentration factor[12].

4 .THE FATIGUE LIFE ANALYSIS

Because fatigue life is relate to wear resistance and the cycle times of objects, therefore more cycle times, longer life and more wear-resistant, so after contact analysis and get the von mises, we can analysis the fatigue life about coupling bionic surface.

According to the fatigue life curve of rubber(Figure 6), analysis fatigue life about the same node of three cases which need establish the location, event and the number of loading,

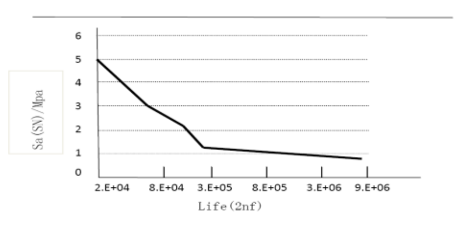

Figure6 The fatigue life curve of rubber

By Figure 6, define material fatigue properties such as the number of node is 1,the number of event is 1,the load step of each event is 2[13]. After solving will appear a dialog box shown in Figure 7.

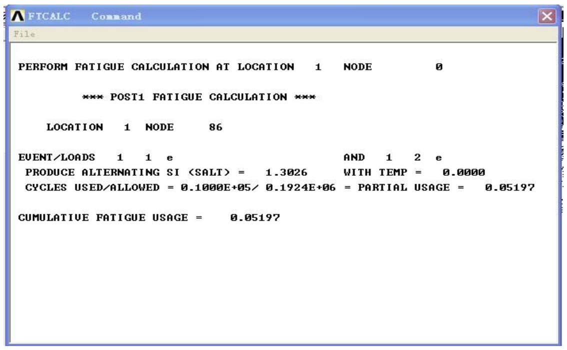

Figure 7 The results of fatigue life analysis

After the fatigue life analysis of three cases, results will show in table 2.

Table 2 The analysis results of fatigue life of three cases

location	stress amplitude /Mpa	cycles used	fatigue usage factor	Cycles allowed /number
Node86（0.5mm）	1.3026	100000	0.05197	192400
Node86（1mm）	1.2163	100000	0.05032	198700
Node86 (2mm)	1.4582	100000	0.05482	182400

5. DISCUSSION

It can be seen from Figure 4 and Figure 5 that the stress and deformation is mainly concentrated in the pits which stress is much larger than the surrounding areas and the deformation is larger. 1mm radius has minimum stress value, followed of 0.5 mm and 2mm has maximum stress value. From fatigue life analysis on the same node of the edge of the pit and compare the wear resistance of the three cases know that the model of radius of 1mm node has minimum stress amplitude minimum, lowest coefficient of fatigue and largest number of cycles which see from the table 2.

For concave bionic flexible body model which with the rigid body from the initial contact about the surface into a common contact about the pits and the rigid surface has a certain amount of elastic deformation under pressure. Therefore, stress is mainly concentrated in the edge of the pit, and the pit deformation is the biggest.

While pits increasing the frictional driving force have chuck effect, so that the model has a better abrasion resistance. As can be seen from table 2 the smaller stress, the more cycles, the better wear resistance and by von mises picture, the stress value of dimple radius 1mm in all regions of the model is smaller than the dimple radius of 0.5mm and 2mm model. So the above analysis shows that the model which radius is 1mm has best wear resistance.

CONCLUSIONS

According to the above analysis of ANSYS contact, when biomimetic flexible dimple surface and the rigid surface are contact with friction, the stress at pit is much larger than the stress of its surrounding area and the deformation of pits is largest. The model which dimple radius is 1mm has minimum von mises stress value.

Under the fatigue life analysis, we know that the smaller node stress value, the more cycles, longer life and better wear resistance. So the three cases, wear resistance of dimple radius 1mm model is preferably

ACKNOWLEDGEMENTS

We are very thankful to The Natural Science Foundation of Shandong Province (Grant No.ZR2012EEM004) for sponsoring to publish this paper.

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