The Mises Stress in the Contact Region of Materials with Soft and Hard Phases in Frictional Process

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Abstract. Composite polymers are a class of materials that have demonstrated superior performance in various applications and thus been widely used in many industries. By mimicking the soft and hard structure in natural materials, a kind of materials with soft and hard phases based on flexible rubber /high rigidity ABS has been designed. In this paper, the numerical simulation of frictional process of materials with soft and hard phases was performed to analyse the Mises stress state in the contact region. The results show that hard phase support more load than soft phase, thus influence the frictional property of materials with soft and hard phases.

1. Introduction

Natural materials such as nacre, bone or dentin, are biological composites in which soft and hard element arranged in series, and provide a range of interesting properties, such as prevention of crack propagation, flexibility and protection for biological armors, and even strain enhancement and signal filtering for mechanosensing. Brick and mortar structure has been proposed[1] in 2000 to describe materials such as nacre or the mineralized collagen fibril.[2] Such soft and hard structures exist at all scales in natural materials,[3] can afford a mechanical performance better than each of soft or hard element, and have huge potential capacity to enhance the mechanical performance of conventional pure or simple materials.[4] Since the 1980s, Ren et al. [5, 6] has been dedicating to the study of the cuticle morphologies and principles of soil animals such as dung beetles, black ants, and pangolins and found that there were generally five kinds of simple structures on the cuticles, including convex, concave, stria, bristle and squama. They are called non-smooth construction units, which have been found to provide excellent anti-wear properties against soil. In this paper, the frictional process of the materials with soft and hard phases was studied with a finite element analysis tool, and the Mises stress state in the contact region was studied to analyze the frictional property of materials with soft and hard phases.

2. Finite element model

To understand the frictional process of materials with soft and hard phases deeply, numerical simulation of frictional process of materials with soft and hard phases was performed under ABAQUS/Explicit environment. The finite element model of frictional process is shown in Figure 1.

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The dimension of the material is 6 mm × 5 mm with the thickness 5 mm, and the material was meshed by C3D8R element which is designed for large strains and deformations. The size of the element is 0.01 mm × 0.01 mm × 0.01 mm, and a total of 152001 elements were used to model the material.

Table 1. Material properties of soft phase and hard phase.

	E (MPa)	μ	f
Soft material	270	0.4	0.1
Hard material	700	0.4	0.2

To simulate the friction boundary conditions between the material and the rubbing, surface-to-surface contact mode was used, the friction coefficients (f) were 0.1 for soft phase and 0.2 for hard phase, the Young's model (E) is 270 MPa and 700 MPa for soft phase and hard phase respectively, and the Poisson ratio for both soft and hard phases are 0.4. The material properties of the soft phase and hard phase are listed in Table 1.

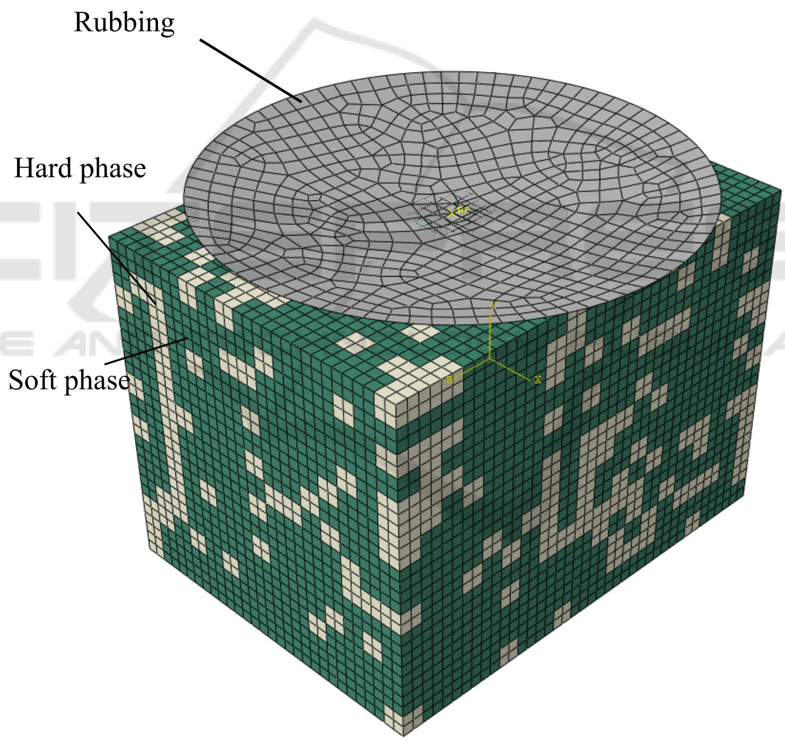

Figure 1. Numerical simulation of frictional process.

3. Results

The frictional process for materials with soft and hard phases is more complicated than the material with only hard or soft material. The materials with integrated hard and soft phases will lead to the redistribution of the loads, and change the frictional property of the material. Figure 2a shows the contact region of materials with soft and hard phases in frictional process, in which blue is for hard region and yellow for soft region. It can be found in figure 2b that the Mises stress in the contact region is larger than the other region, and the Mises stress is large in the region with hard phase (blue region) and small in the region with soft phase (yellow region). This phenomenon shows the redistribution of load, the hard phase support more load than soft phase, thus influence the frictional property of the material with soft and hard phases.

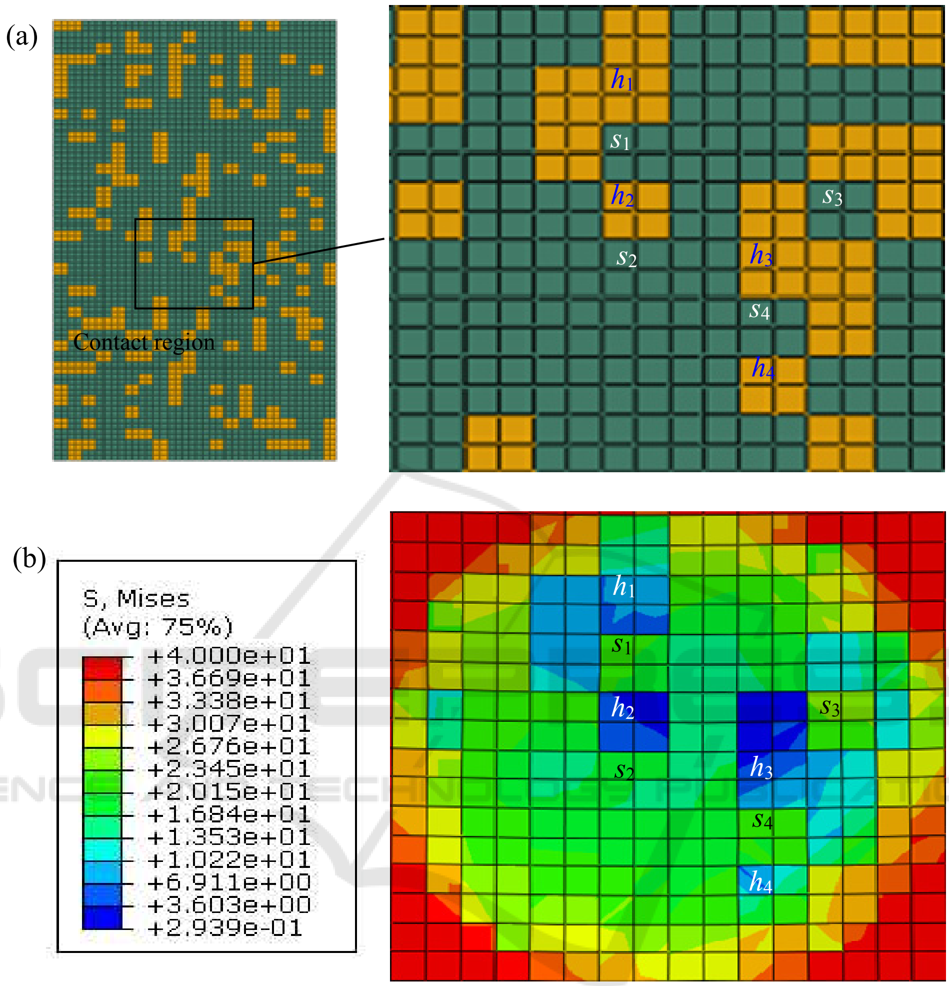

Figure 2. Contact region of materials with soft and hard phases in frictional process.

4. Conclusions

Soft and hard structure which contains polymers with hardness differential can afford a mechanical performance better than each of the composing polymers. The contact region of materials with soft and hard phases in frictional process was present in this paper. It is obvious that the more load is applied in the hard phase than the soft phase, and the redistribution of the load will influence the contact state of two contact surface, thus change the frictional property of the materials with soft and hard phases.

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References

[1] Jäger I and Fratzl P 2000 Mineralized collagen fibrils: a mechanical model with a staggered arrangement of mineral particles *Biophysical Journal* **79** 1737-46

[2] Gao H, Ji B, Jager IL, Arzt E and Fratzl P 2003 Materials become insensitive to flaws at nanoscale: lessons from nature *Proceedings of the National Academy of Sciences of the United States of America* **100** 5597-600

[3] Browning A, Ortiz C and Boyce M C 2013 Mechanics of composite elasmoid fish scale assemblies and their bioinspired analogues *Journal of the Mechanical Behavior of Biomedical Materials* **19** 75-86

[4] Fratzl P, Kolednik O, Fischer F D and Dean M N 2015 The mechanics of tessellations - bioinspired strategies for fracture resistance *Chemical Society Reviews*

[5] Ren L, Deng S, Wang J and Han Z 2004 Design Principles of the Non-smooth Surface of Bionic Plow Moldboard *Journal of Bionic Engineering* **1** 9-19

[6] Zhang Z H, Zhou H, Ren L Q and Tong X 2007 Tensile property of H13 die steel with convex-shaped biomimetic surface *Applied Surface Science* **253** 8939-44