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Fictional mechanism of materials with soft & hard phases

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Fictional mechanism of materials with soft & hard phases

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Abstract. Materials with soft & hard phases, showing excellent mechanical properties, are ubiquitous in nature. Herein this paper is proposed to investigate the frictional properties of materials with soft & hard phases by numerical simulation. The processes of a range of materials with soft & hard phases with different values of Young's modulus will be examined and their fictional mechanism will be discussed. It can be found that the maximum value of Mises stress is happened in the contact zone, and Mises stress gradually decrease with the distance from the contact zone increasing. The hard phase layer has the maximum Mises stress, and the soft phase layer has relatively small Mises stresses, which show the frictional property of materials with soft & hard phases.

1. Introduction

Bio-inspired materials with soft & hard phases provide exceptional mechanical and other properties beyond those of pure soft or hard phases [1, 2]. Indeed, many structural biological materials such as seashells, bone, and teeth exhibit a remarkable balance of high stiffness, high strength, fracture toughness, and energy dissipation [3-10]. Rather than discussing mechanical properties in an exhaustive way, in this paper we will focus on researching frictional properties. For low friction and extensive wear reduction, nature provides an abundance of solutions. Shark skin consisting of stiff surface denticles embedded in a flexible collagenous supportive layer [11, 12], exhibits a similar combination of hard elements and relatively soft connecting layers [13]. Nacre is a two-phase material with soft phase (aragonite platelets) and hard phase (polymer film) and has tensile strength 78-130 MPa (wet) and 90-167 MPa (dry) [14], Young's modulus 58-70 GPa (wet) and 68-90 GPa (dry) with a work of fracture 1240 J m⁻¹ which is much higher than monolithic CaCO₃ [15].

Materials with soft & hard phases have a structural motif that involves periodic soft & hard elements arranged in series (Figure 1) [13], which alters the frictional properties of macroscopic materials. Friction coefficient is a tribological feature often related to the hardness of a material and has important implications for a range of applications [16]. Here, we present and interpret the dry sliding process of the materials with soft & hard phases through the simulation.



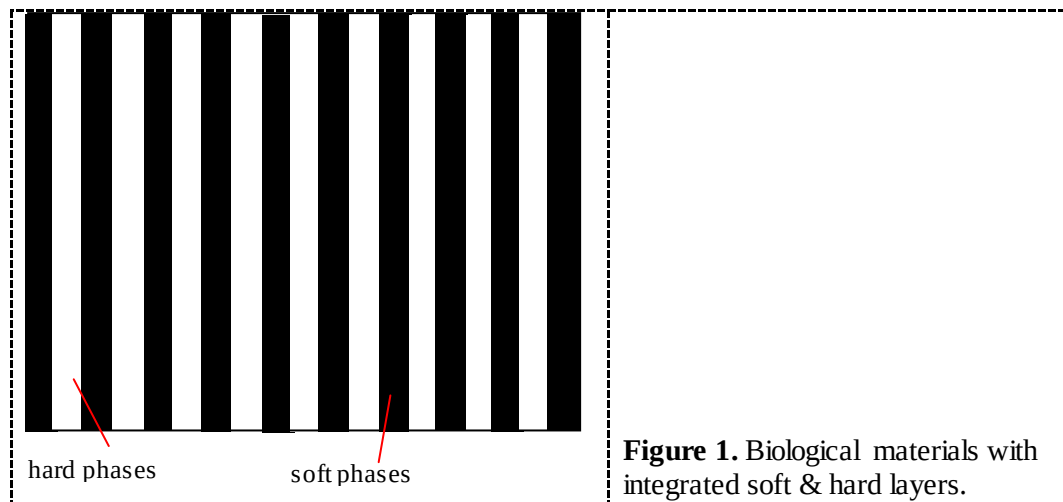


Figure 1. Biological materials with integrated soft & hard layers.

2. Simulation

2.1. Finite element model

In order to provide more insights into the frictional property in materials with soft & hard phases, finite element models of sliding process of materials with soft & hard phases with different values of Young's modulus were established. Surface roughness has an impact on the sliding process but in simulation we are not concerned with such roughness, we assume that the surface profiles of the two solids have geometrically simple and smooth shapes. Figure 2 is the finite element model of the sliding process of materials with soft & hard phases based on ABAQUS/explicit. In finite element model, surface-to-surface contact was used to model the friction boundary condition between materials with soft & hard phases and friction tool. The thickness of soft & hard phase layer is 0.2 mm with basic parameters shown in Table 1.

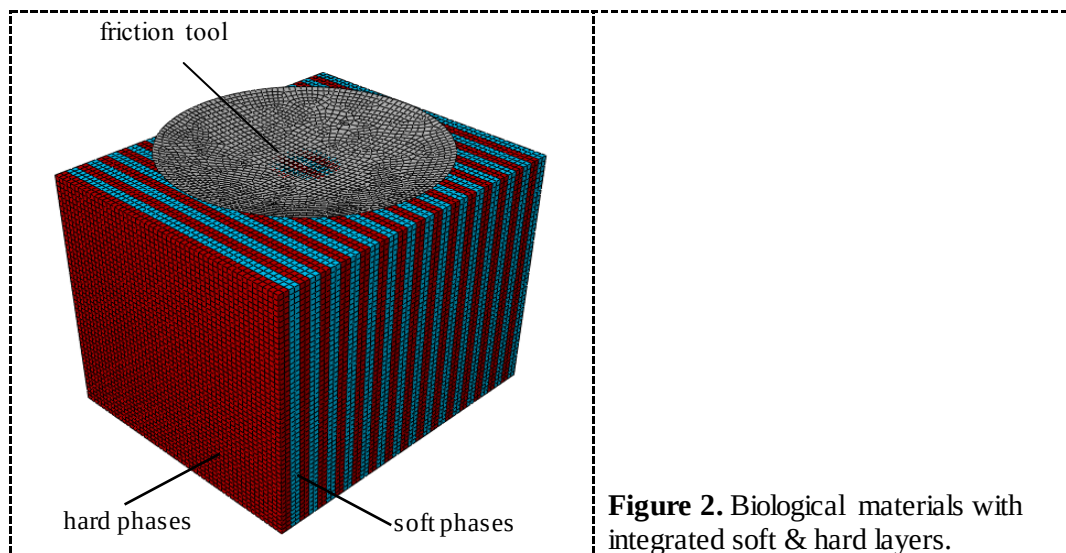


Figure 2. Biological materials with integrated soft & hard layers.

Table 1. Basic parameters of materials

	μ	ρ (g/cm ³)	f
soft phase	0.4	1.5	0.1
hard phase	0.4	1.5	0.2

2.2. Simulation results

The Mises stress nephogram of materials with soft & hard phases with difference values of Young's modulus (400 MPa, 700 MPa, 1000 MPa, 1300 MPa) are shown in Figure 3. It can be observed that the contact zone is the location where has the maximum Mises stress, and Mises stress decrease beyond the contact zone. With the Young's modulus of the hard phase increasing from 400 MPa to 1300 MPa, Mises stress at the hard phase layer increases and that at the soft phase layer decreases, which shows the redistribution of normal load in sliding process, thus gives the reason for the change of friction properties.

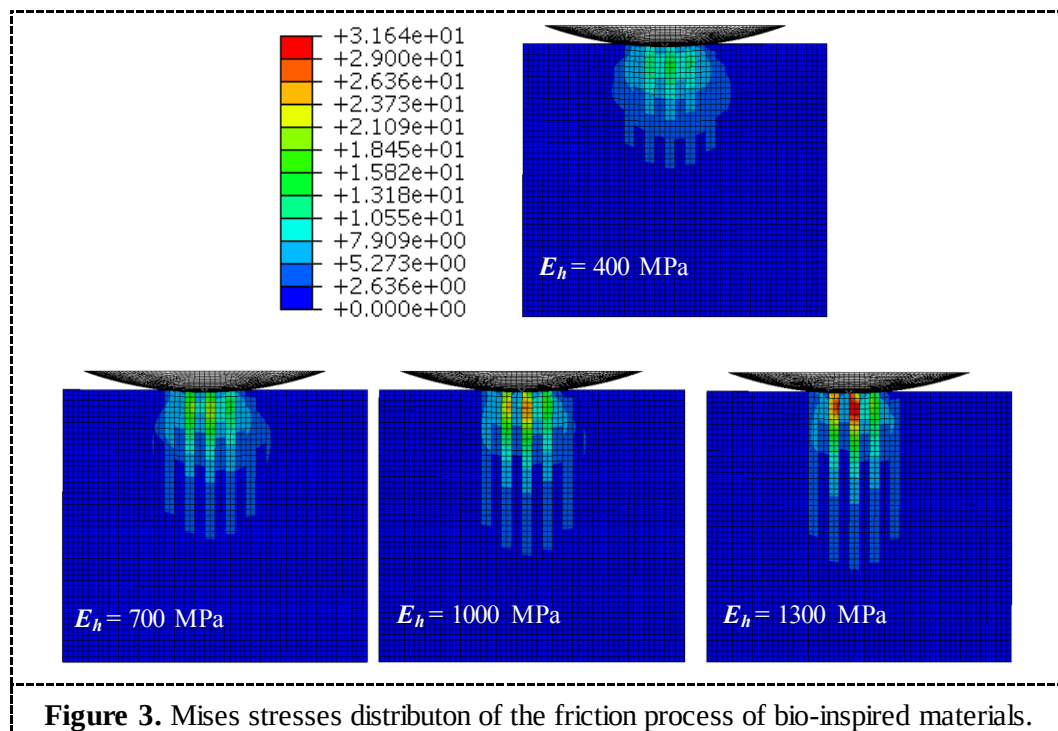


Figure 3. Mises stresses distributon of the friction process of bio-inspired materials.

3. Conclusions

By mimicking the soft and hard phases, material with soft & hard phases has been successfully proposed. In this paper, we study the frictional process of material with soft & hard phases through simulation. The results show that Mises stress is large in the contact zone and decreased with the distance from the contact zoon increasing. The maximum Mises stress occurs at the hard phase layer, and relatively small Mises stresses appear at the soft phase layer. This is due to the remarkable load carrying potential of the hard phase layer, and can give strong evidence for the change of friction properties of material with soft & hard phases.

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