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Hierarchical Spring-Block Model for Multiscale Friction Problems

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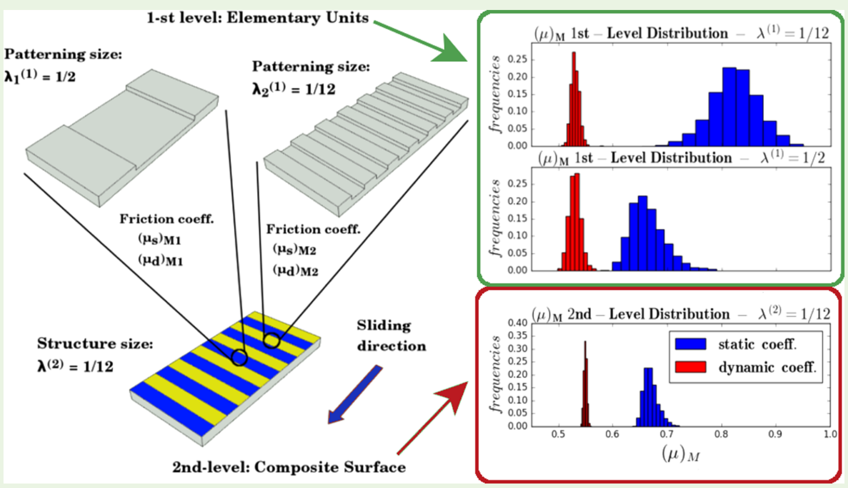

ABSTRACT: A primary issue in biomaterials science is to design materials with *ad hoc* properties, depending on the specific application. Among these properties, friction is recognized as a fundamental aspect characterizing materials for many practical purposes. Recently, new and unexpected frictional properties have been obtained by exploiting hierarchical multiscale structures, inspired by those observed in many biological systems. In order to understand the emergent frictional behavior of these materials at the macroscale, it is fundamental to investigate their hierarchical structure, spanning across different length scales. In this article, we introduce a statistical multiscale approach, based on a one-dimensional formulation of the spring-block model, in which friction is modeled at each hierarchical scale through the classical Amontons−Coulomb force with statistical dispersion on the friction coefficients of the microscopic components. By means of numerical simulations, we deduce the global statistical distributions of the elementary structure at micrometric scale and use them as input distributions for the simulations at the next scale levels. We thus study the influence of microscopic artificial patterning on macroscopic friction coefficients. We show that it is possible to tune the friction properties of a hierarchical surface and provide some insight on the mechanisms involved at different length scales.

KEYWORDS: *friction, multiscale modeling, statistical properties, hierarchy, microscale structures*

1. INTRODUCTION

Many biological systems commonly observed in Nature are organized according to a hierarchical multiscale structure, e.g., gecko paws,[1−3] insect legs,[4,5] lotus leaves,[6−8] or many tissues like bone, tendons, skin, etc.[9−12] These types of structures exhibit remarkable mechanical properties, which have attracted much interest in the quest to understand their underlying mechanisms and to design artificial materials with improved properties through complex multiscale structural organization of microscopic components.[13−17] This issue is inherently linked to research on biomaterials, in which it is essential to be able to tune the mechanical properties as desired. In particular, friction of biomaterial surfaces is an important aspect that requires accurate characterization before a material can be practically employed for specific applications.[18−22]

In bioinspired materials research, new properties have been obtained by mimicking the structure observed in biological systems, suggesting that the key factor lies in the hierarchical

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