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Evidence of friction reduction in laterally graded materials

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Full Research Paper

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Abstract

In many biological structures, optimized mechanical properties are obtained through complex structural organization involving multiple constituents, functional grading and hierarchical organization. In the case of biological surfaces, the possibility to modify the frictional and adhesive behaviour can also be achieved by exploiting a grading of the material properties. In this paper, we investigate this possibility by considering the frictional sliding of elastic surfaces in the presence of a spatial variation of the Young's modulus and the local friction coefficients. Using finite-element simulations and a two-dimensional spring-block model, we investigate how graded material properties affect the macroscopic frictional behaviour, in particular, static friction values and the transition from static to dynamic friction. The results suggest that the graded material properties can be exploited to reduce static friction with respect to the corresponding non-graded material and to tune it to desired values, opening possibilities for the design of bio-inspired surfaces with tailor-made tribological properties.

Introduction

Materials with a gradient in their physical or elastic properties are widely found in nature. Several known biological systems have developed specialized functionalities due to stiffness, density or composition gradients. Beetles, for instance, display setae with a graded stiffness that optimises the adhesive performance on rough surfaces [1]. Hardness and stiffness gradients are of fundamental importance in the biomechanics of contacts, since they allow increased resistance against wear, impact, penetration and crack propagation [2-7]. Bio-inspired solutions have thus been proposed for the design of advanced materials that mimic the hierarchical and graded structures found in nature, for use in engineering applications [8,9].