Contact Behaviours of Biomimetic Spatula-Shaped Adhesive Microstructures on Rough Surfaces Using Finite Element Simulations

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Abstract

During biological evolution, numerous organisms have developed hair-like attachment structures to achieve stable adhesion on diverse surfaces. This inspired researchers to explore biomimetic adhesive microstructures, wherein mushroom-shaped structures have received extensive attention, but comparatively little on spatula-shaped ones better suited for adhesion on rough surfaces. Here, we present two bio-inspired adhesive prototypes, both featuring an inclined seta and spatulate tip. One prototype incorporates a variable cross-section cylinder with a leaflike thin plate, while the other comprises a uniform cross-section square column and a wedge thick plate, exhibiting geometric transition at the seta-tip joint. Finite element analysis is utilized to investigate the adhesive contact behaviours of these prototypes under vertical displacement on surfaces with varying roughness, specifically asperity radii of 30 nm, 1 μm and infinity (flat surface). The results reveal that compared to the surface with a 30 nm radius asperity, the spatula could adapt relatively well to the single asperity with a 1 μm radius due to such asymmetric structures, which also lead to a leverage phenomenon that will compete with adhesive forces and tend the contact surfaces to separate. Although the thicker spatula tip exhibits poor flexibility, resulting in reduced effective contact area and adhesion, it allows to regulate attachment under unidirectional loading. This study contributes novel insights into the contact behaviour of spatula-shaped adhesive structures and provides valuable inspiration for the future development of artificial adhesives.

Keywords: Biomimetics; Spatula-shaped adhesive microstructures; Surfaces roughness; Finite element simulations