Attachment stability based on a combination of biomimetic microstructures of different shapes

David Badler[1)*], Yuri Kligerman[1)] and Haytam Kasem[1,2)]

[1)] Faculty of Mechanical Engineering, Technion - Israel Institute of Technology, Haifa, Israel
[2)] Department of Mechanical Engineering, Azrieli College of Engineering, Jerusalem, Israel
*Corresponding author: davidbadler@campus.technion.ac.il

Potential applications of engineering biomimetic adhesive solutions are various including, among others, climbing robotic systems, handling systems for wafers in nanofabrication facilities, mobile sensor platforms, and biomedical applications such as patch for external use. However, some critical issues still need to be addressed for the wide usage of the biomimetic adhesive microstructures as advanced biomedical platforms. In the present study, we show that combinations of different biomimetic adhesive microstructure shapes increase efficiency in different types of environments, leads to uniform and stable peeling, and enables the creation of long-term adhesive solutions. Our work sheds light on the various combinations and their effectiveness under different conditions.

Keywords: biomimetic, microstructures, adhesion, friction, peeling

1. Introduction

The ability to simultaneously maintain a high adhesion and adequate friction forces is not achievable with a single biomimetic micro-structure type [1], [2]. In the wild, males of different beetles use a unique combination of different microstructures developed to enhance friction and adhesion and create a firm grip during mating [3]. The Synergistic effect of simultaneously using different microstructures was investigated experimentally. It was found that combined models improve the frictional and adhesive performances compared to non-combined models [4]. Increased adhesion and friction capabilities are essential for a variety of engineering fields and can be reached by the integration of micro-structures inspired by nature.

2. Methods

A combined biomimetic adhesive model inspired by the dock beetle *Gastrophysa Viridula* (Coleoptera: Chrysomelidae) was used. It consists of mushroom-shaped adhesive microstructures (MSAMS) and wall shaped microstructure spatula (WSMSS). The samples were prepared in advance by casting a soft elastomer and performing integration of the various microstructures into a single model (figure 1, right). The tribological characterization of the combined samples was done using a custom test-rig, as shown in figure 1, left.

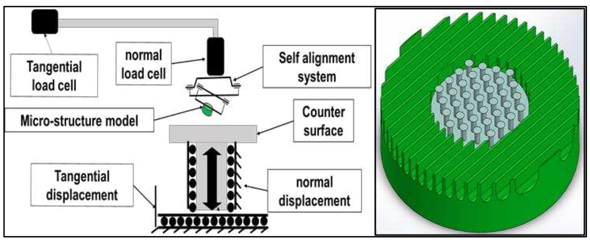

Figure 1: Left - schematic illustration of a two-axis linear tribometer. Right - schematic description of a combined biomimetic microstructures sample.

3. Discussion

Figure 2 shows the distribution of the different forces and how uniform and stable combined peeling force can be achieved for each possible peeling angle. Furthermore, the principle of using combined biomimetic micro-structures enhances long-term adhesive solutions and attachment capacity in different applications.

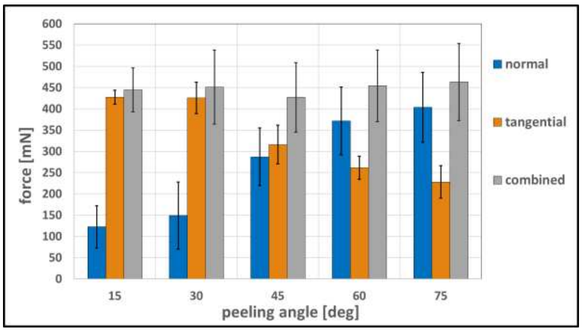

Figure 2: Peeling strength performances of the combined model that consisted of 60% (MSAMS) and 40% (WSMSS).

4. References

[1] H. Kasem et al., “Biomimetic wall-shaped hierarchical microstructure for gecko-like attachment,” Soft Matter, vol. 11, no. 15, pp. 2909–2915, 2015.

[2] M. Varenberg et al., “Close-up of mushroom-shaped fibrillar adhesive microstructure: Contact element behaviour,” J. R. Soc. Interface, vol. 5, no. 24, pp. 785–789, 2008.

[3] D. Voigt et al., “How tight are beetle hugs? Attachment in mating leaf beetles,” R. Soc. Open Sci., vol. 4, no. 9, 2017.

[4] D. Badler et al., “Synergetic effect of the simultaneous use of different biomimetic adhesive micro-structures on tribological performances,” Biotribology, vol. 22, Jun. 2020.