

## DESIGN AND 3D CFD ANALYSIS OF BIO-INSPIRED GROOVES AND PILLARS MICRO-STRUCTURES FOR ENHANCED DRAG REDUCTION OF THIN FILMS

Nikolaos Rogkas <sup>a\*</sup>, Georgios Adamopoulos <sup>a</sup>, Dimitrios Skondras-Gousios <sup>b</sup>, Panagiotis Karmiris-Obratański <sup>b,c</sup>, Vasilios Spitas <sup>a</sup>

\*nrogkas@mail.ntua.gr

<sup>a</sup>Laboratory of Machine Design and Dynamics, School of Mechanical Engineering, National Technical University of Athens, 9 Heron Polytechniou Str., 15780 Zografou, Athens, Greece

<sup>a</sup>Laboratory of Manufacturing Technology, School of Mechanical Engineering, National Technical University of Athens, 9 Heron Polytechniou Str., 15780 Athens, Greece

<sup>c</sup>Department of Manufacturing Systems, Faculty of Mechanical Engineering and Robotics, AGH University of Krakow, 30–059 Cracow, Poland

### KEYWORDS

*Texturation; Fluid lubrication; Hydrodynamic Lubrication, bio-inspired texture*

### ABSTRACT

In recent years, advancements in the field of tribology have been crucial for ensuring the sustainability and optimal performance of mechanically moving systems [1]. The study of principles governing relative motion between two or more independent systems in contact has been a long-standing focus, with the overarching goal of minimizing energy loss while maximizing efficiency. Within this framework, bio-inspiration emerges as a promising avenue, offering innovative solutions in the design of tribological features.

This paper delves into the design of bio-inspired grooves and pillars micro-structures, focusing on evaluating their impact on reducing drag torque in the thin film flow between rotating disks through computational methods [2]. The study involves an extensive examination and analysis of patterns observed in the animal, aiming to integrate these influences into tribological systems. The focus is directed toward comprehending how these natural grooves and pillars micro-structures influence hydrodynamic lubrication and contribute to drag torque reduction, showcasing practical applications in the design of tribological features. The findings underscore the pivotal role of micro-geometry in enhancing tribological performance, presenting novel perspectives for the integration of biomimetic design.

The computational evaluation is conducted by developing a 3D periodic CFD model using the commercial code ANSYS Fluent. The model comprises two discs separated by a fluid film with a thickness of 150  $\mu\text{m}$ . One disc remains stationary, while the other rotates at speeds ranging from 100 rpm to 1500 rpm. Additionally, a constant inflow rate of 300 ml/min to the gap is considered. A comparative assessment was conducted across all parametrizations for the examined patterns. The aim was to identify the structurally most efficient configuration, emphasizing the reduction of losses. Figure 1 displays the drag torque results per contact surface using a box plot for seven analyzed patterns: shark skin (SS), dung beetle (DB), geckos' leg (GK), lotus leaf (LL), pitcher plant (PP), desert scorpion

(DS), and dragonfly (PD). The patterns yielding the smallest ratio values are indicative of superior performance in minimizing drag torque. Additionally, shorter error bar lengths correspond to a more pronounced influence of the pattern shape on the results.

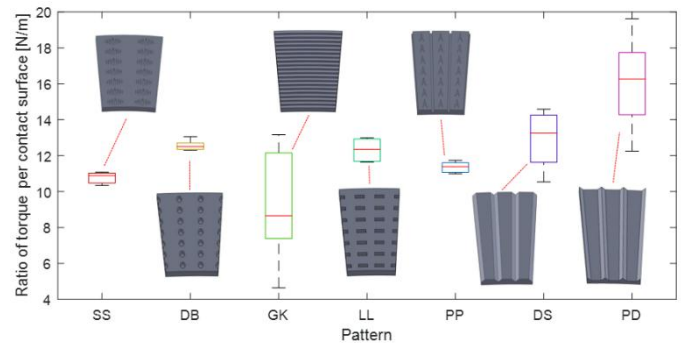


Fig.1 Results on the ratio of drag torque per contact surface for the examined patterns in the form of a box plot.

In summary, the results of this work emphasize the importance of micro-scale texturing for improved tribological performance through drag torque reduction in thin films applications, showcasing the transformative potential of biomimetic design in enhancing the efficiency of tribological structures.

### ACKNOWLEDGMENTS

This research has received funding from the Basic Research program of National Technical University of Athens under the project titled "WetSURF: From micro to macro scale—nature-inspired hierarchical surfaces for tribology."

### REFERENCES

- [1] Popov, V. L. (2018). Is tribology approaching its golden age? Grand challenges in engineering education and tribological research. *Frontiers in Mechanical Engineering*, 4, 16.
- [2] Rogkas, N., Vasilopoulos, L., & Spitas, V. (2023). A hybrid transient/quasi-static model for wet clutch engagement. *International Journal of Mechanical Sciences*, 108507

