



INSTITUTE OF  
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# Hydrodynamics of Red Blood Cells

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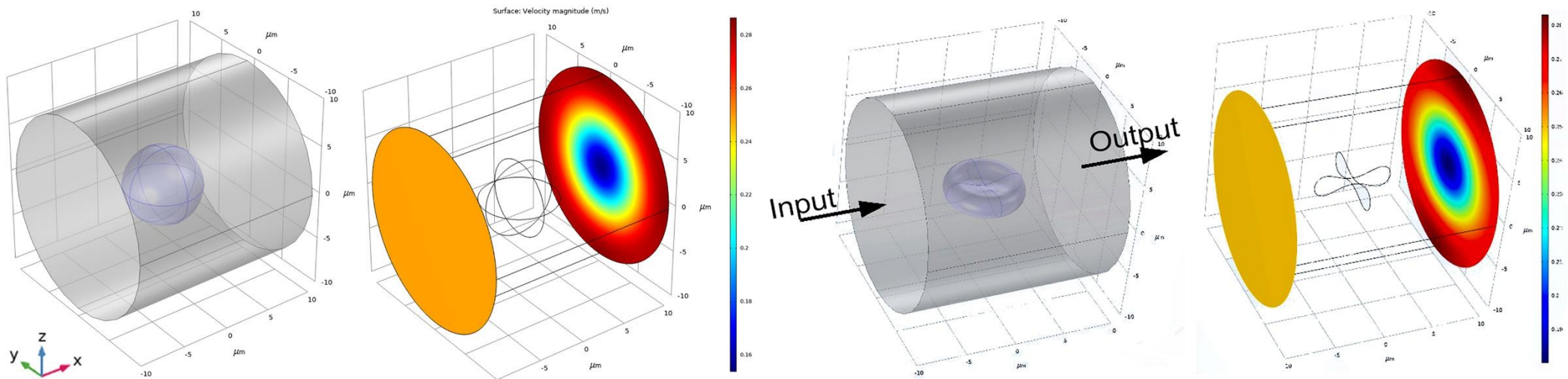
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# Introduction

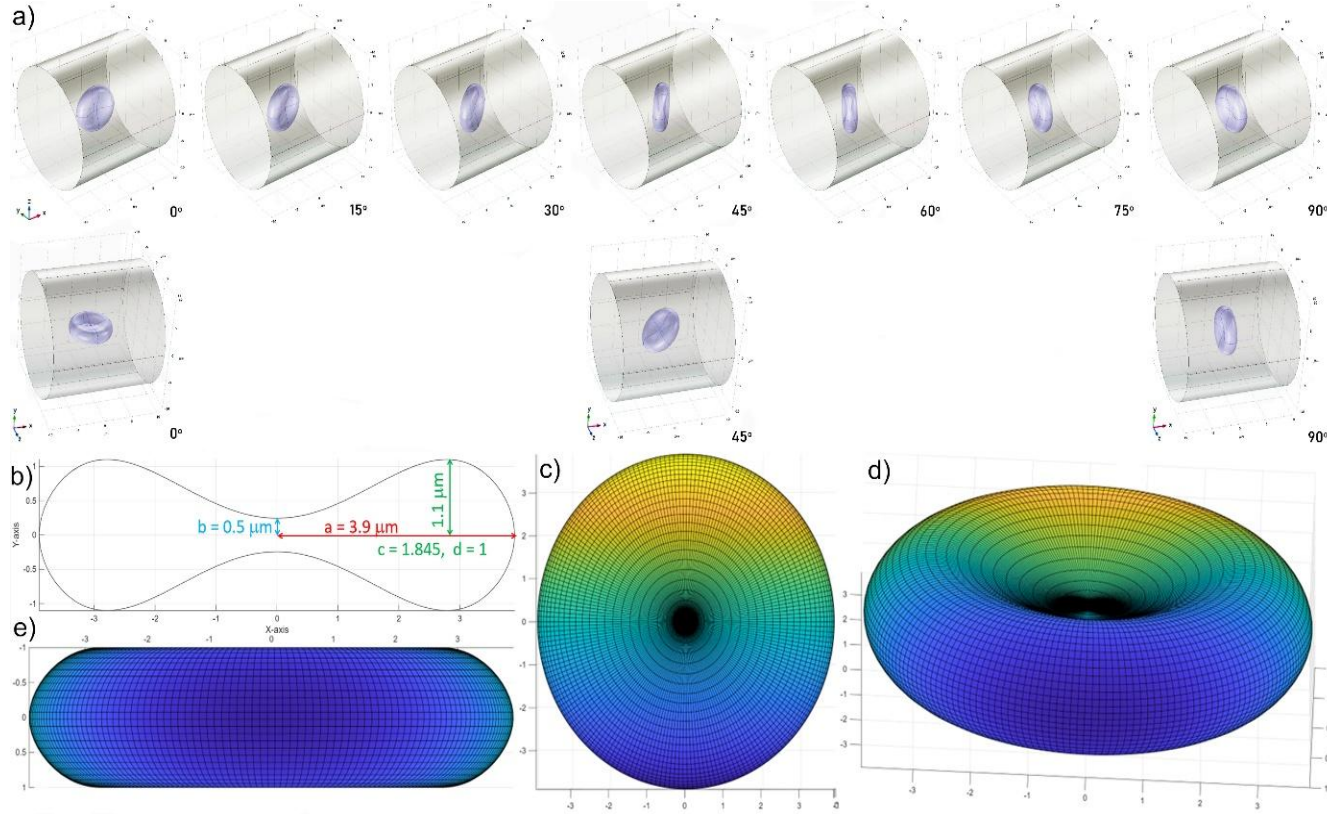


Cardiovascular disease is the leading cause of morbidity and mortality worldwide, and the majority of cases are vascular-based. Red blood cell shape is relevant mainly because it is a visible consequence of more profound **biophysical changes, e.g.**, hemoglobin polymerization, reduced deformability, dehydration, and adhesiveness. The improper build of RBCs can be a cause of multiple cardiovascular diseases, e.g., **sickle cell disease**.

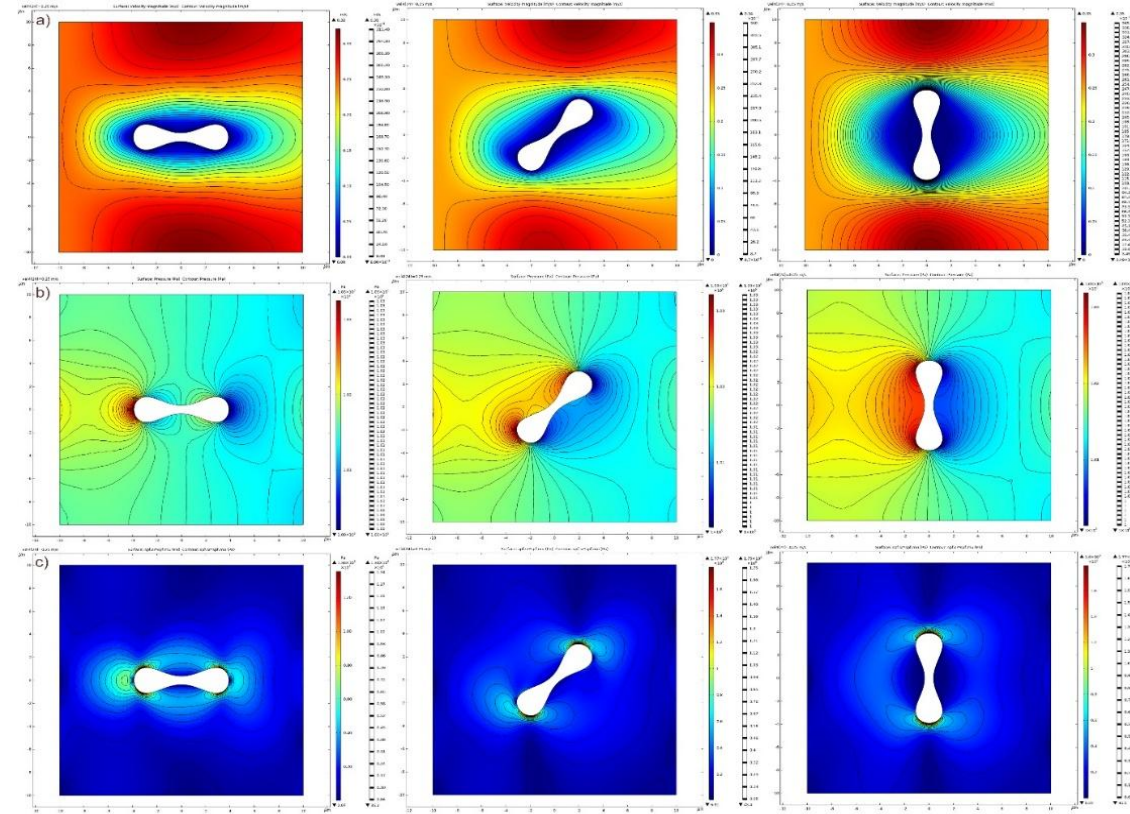
The study focuses on the solid-fluid interactions of a correctly built red blood cell (RBC). The forces acting on the surface of RBC are evaluated using the COMSOL Multiphysics Microfluidic module in the creeping-flow approximation. RBCs' geometry was estimated as a biconcave disc. The forces, pressures, velocities, and shear stresses acting on an RBC at various angles relative to the fluid flow were estimated for a rigid RBC in a tubular blood-vessel model.



# Results

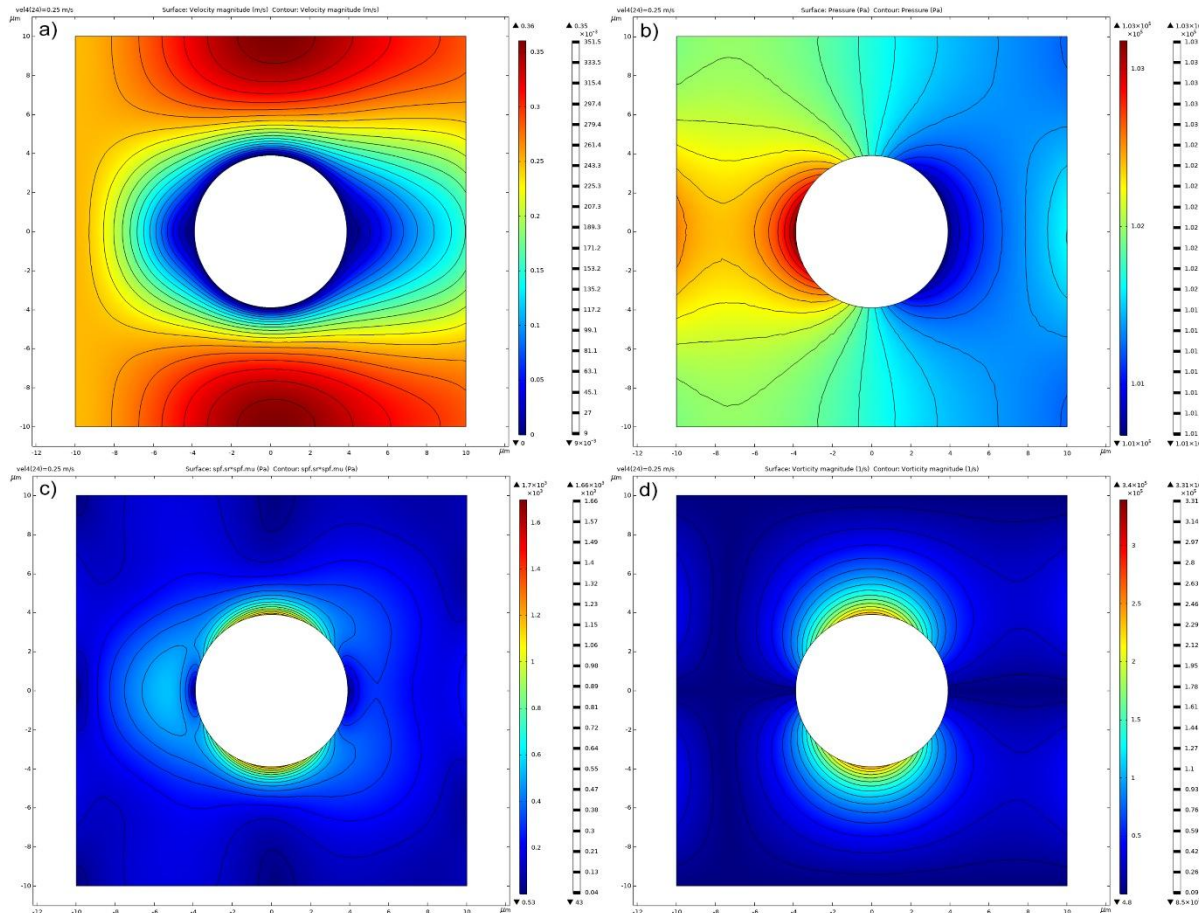


a) COMSOL model (roller) with a cell inside (parametric surface); different stages of rotation around the z-axis; b) cross-section with marked parameters; c-e) views at 3D cell surface.

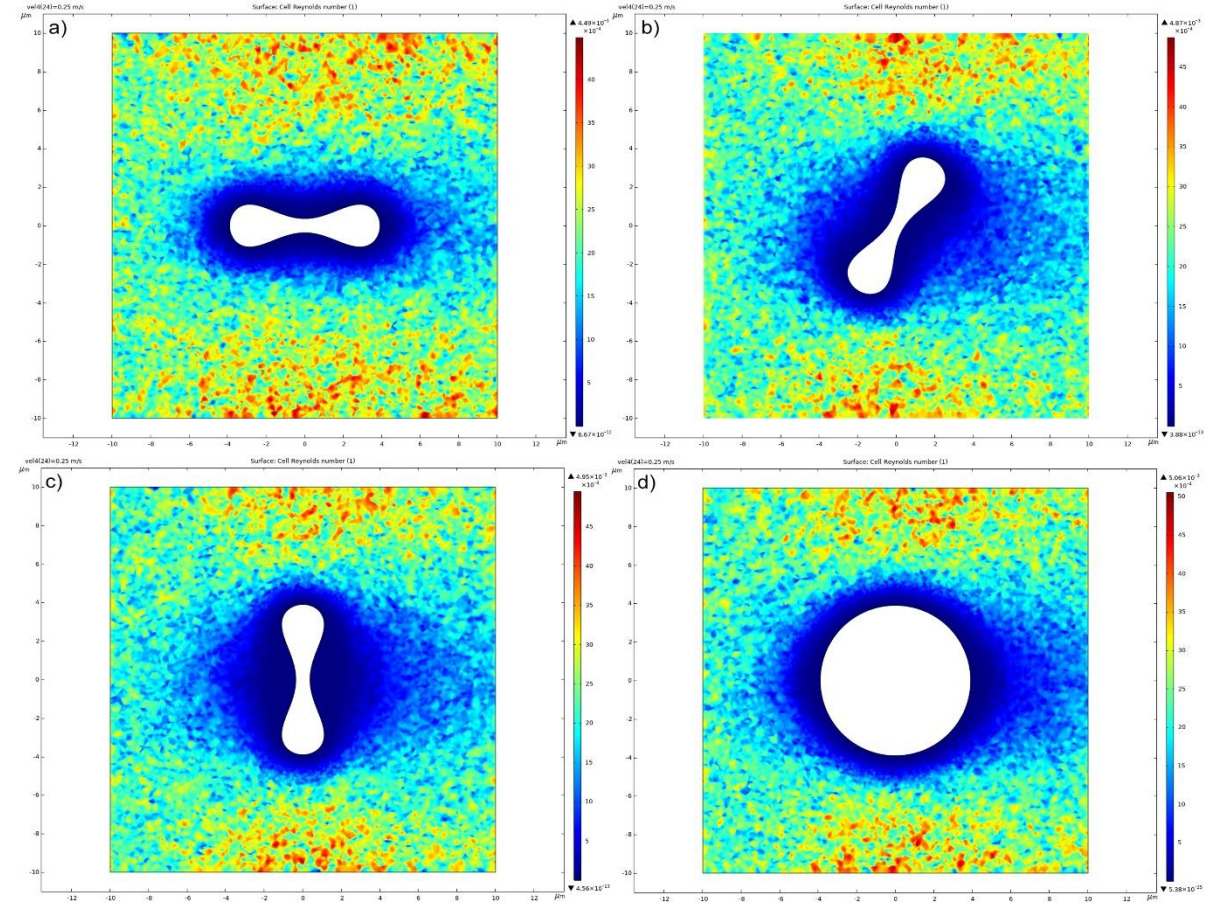


Maps of a) velocity magnitude; b) pressure; c) shear stress in xy plane for cell rotated around the z-axis,  $0^\circ$ ,  $45^\circ$ ,  $90^\circ$  (inlet velocity 0.25 m/s).

# Results

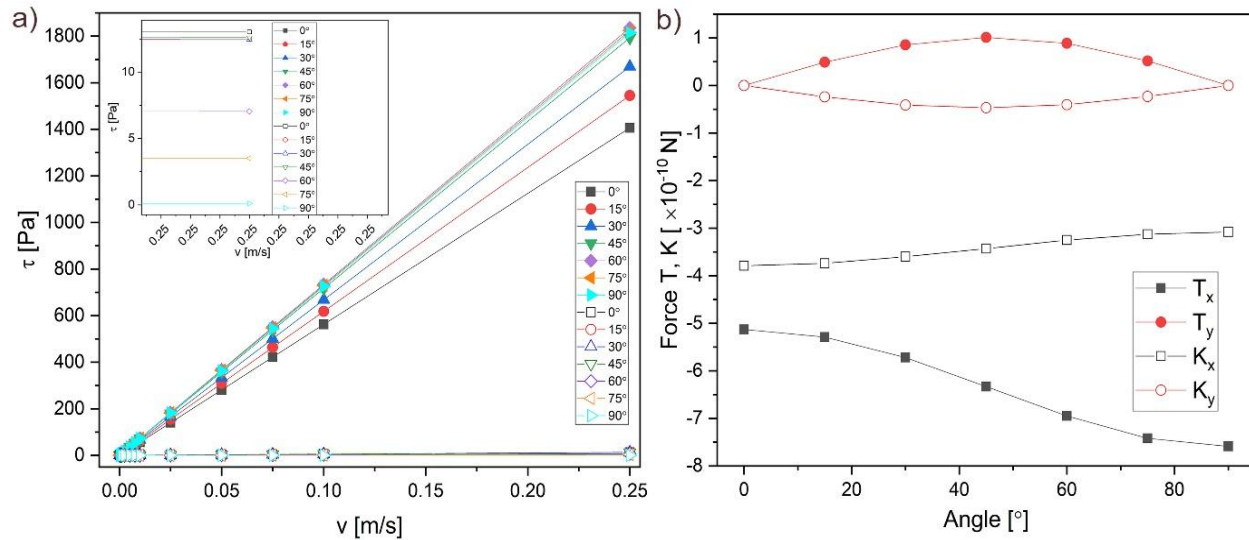


xy-plane maps of a cell in the shape of a sphere of  $3.9 \mu\text{m}$  radius ( $v = 0.25 \text{ m/s}$ ); a) velocity magnitude [m/s]; b) pressure [Pa]; c) shear stress [Pa]; d) vorticity [1/s].

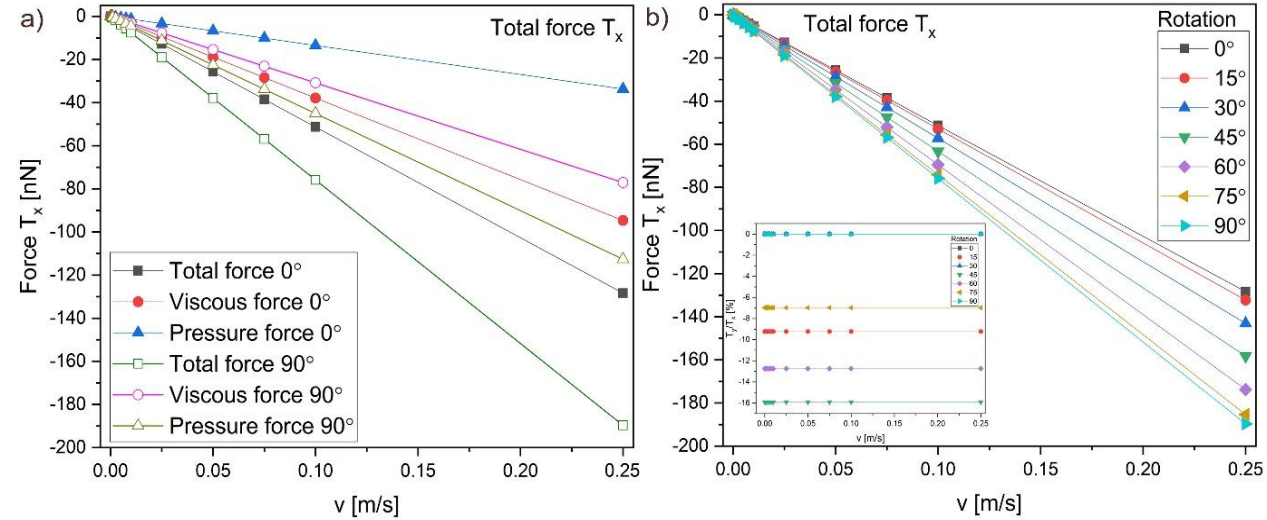


Reynolds numbers in the plane xy, a) RBC  $0^\circ$  rotation; b) RBC  $60^\circ$  rotation; c) RBC  $90^\circ$  rotation; d) sphere for  $v = 0.25 \text{ m/s}$ .

# Results



a) Maximal (full symbols) and minimal (open symbols) shear stress on the cell's surface vs. inflow velocity for various angles of rotation around the z-axis; inset shows closeup on minimal shear stress values for velocity 0.25 m/s; b) Drag – total force  $T_x$  and viscous part of total force  $K_x$  acting on cell's surface, and Lift  $T_y$  – total force acting in "y" direction and its contribution - viscous force  $K_y$ .



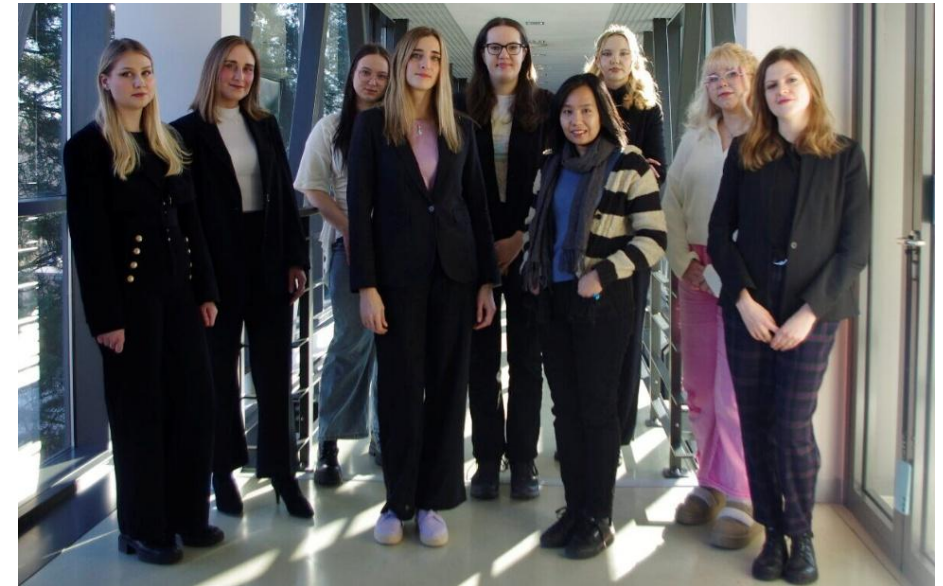
a) Forces acting on the cell's surface ( $0^\circ$  and  $90^\circ$ ), divided into pressure, viscous force, and the sum of both, marked as total force; b) Total force  $T_x$  (drag) vs. inflow velocity for selected rotation angles around z-axis; inset shows the ratio of Lift to Drag ( $T_y/T_x$  in %) vs. inflow velocity.

For a flow velocity 1 mm/s the total force acting on the cell is 0.51-0.76 nN, but for 250 mm/s, it increases to 128-190 nN for  $0^\circ$  and  $90^\circ$ , respectively.

# Acknowledgement



We acknowledge financial support from the joint project of the Polish National Science Centre (UMO2024/55/I/ST5/02185) and the Czech Science Foundation (26-19849L), under the title “Engineering Biocompatible and Bioactive Stents for Improved Endothelial Integration in Cardiovascular Applications”.



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