Platelet-aggregation in blood-on-chip devices through CFD-DEM methods

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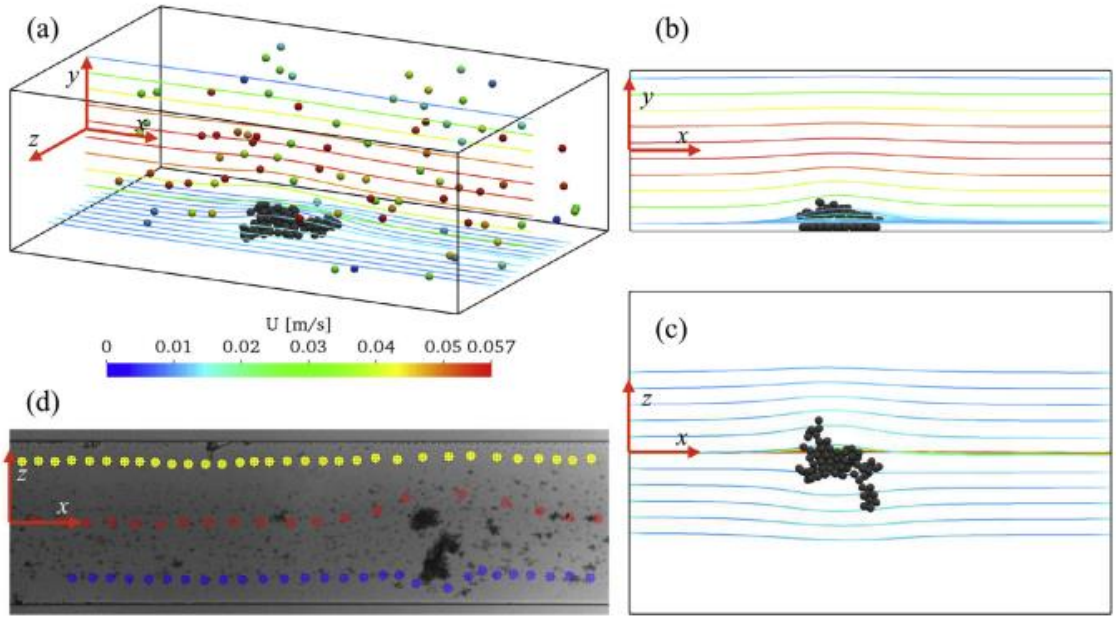
When particles are suspended and forced to flow through a microfluidic device, fouling occurs because the suspended particles stick to the surface of the channel. Fouling may cause clusters to grow over time and completely block the channel. The process of platelets in the blood clumping together is known as platelet aggregation, and it plays an essential role for hemostasis (blood clotting) in order to stop excessive bleeding. To examine the initial growth of clusters, we combine the discrete element approach with computational fluid dynamics. The advantages of both CFD and DEM are combined in CFD-DEM methods. While DEM is used to simulate the discrete motion of individual particles, in this case, platelets, CFD is utilized to model the fluid flow behavior. Researchers may examine the intricate relationships between platelets, fluid flow, and the environment in blood-on-chip devices by combining the two techniques. A comparison with some experimental data is done to demonstrate that the model we use exhibits experimental aspects of the fouling process, such as Cluster Morphology, possibility of break up and resuspension and linear growth rate of cluster project area on to channel wall.

Here's a general overview of how CFD-DEM methods can be applied to study platelet aggregation in blood-on-chip devices:

1) Geometry and Mesh Generation: The geometry of the blood-on-chip device is constructed, including the microfluidic channels and any relevant structures or surfaces. A computational mesh is generated to discretize the geometry, allowing for numerical calculations.
2) Fluid Flow Simulation (CFD): CFD techniques are used to model the fluid flow within the blood-on-chip device. The Navier-Stokes equations, supplemented by appropriate boundary conditions, are solved numerically to determine the velocity, pressure, and shear stress distributions within the fluid.
3) Particle Motion Simulation (DEM): Platelets are treated as discrete particles in the DEM framework. Each platelet is represented by a sphere or a more complex shape, and its motion is governed by Newton's laws of motion. Interactions between platelets, such as adhesion, aggregation, and repulsion, are modeled based on experimental data and theoretical models.
4) Fluid-Particle Coupling: The effects of fluid flow on platelet behavior and vice versa are considered. The fluid flow exerts forces on the platelets, influencing their motion and aggregation. Simultaneously, the presence of aggregated platelets alters the local flow conditions, affecting the fluid dynamics.
5) Platelet Aggregation Analysis: Various metrics can be employed to assess platelet aggregation, such as the size and structure of aggregates, the percentage of platelets involved in aggregation, and the time evolution of aggregation under different flow conditions or drug treatments.
6) Validation and Optimization: The simulation results can be compared with experimental data to validate the CFD-DEM model. Sensitivity analyses and optimization techniques may be applied to refine the model parameters and improve its accuracy.

The main objective of this project is the implementation of a CFD-DEM code to investigate hard-gel microparticle suspension dynamics in microfluidic channels, including aggregation and wall deposition, under conditions mimicking the ones found in microvascular thrombosis. The so developed code can be used for the design and optimization of blood-on-chip devices for the diagnostics and prevention of thrombosis response.



A typical snapshot of the particle distribution in the channel and of the fluid streamline (the colors of the flowing particles represent their velocity magnitude).

References:

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