Post-doc

Simulation of droplet motion over a liquid layer

The post-doc in collaboration between IMFT and TotalEnergies aims at understanding the physics behind oil-water flows using direct numerical simulations. The Post-Doc is part of a long term collaboration between TotalEnergies and IMFT. The subject addressed in this Post-doc has been initiated in 2020.

The post-doc will take place at IMFT (Institut de Mécanique des Fluides de Toulouse), under the direct supervision of Pr. Dominique Legendre (INPT-IMFT) and Dr. Roel Belt (TotalEnergies).

At this point it is a one-year post-doc starting on early 2024 with potential extension to 2025.

In a pipe flow with crude oil and water, a dense packed layer of water droplets in oil can form at the interface (figure 1). We must predict the occurrence of the dense packed layer in 1D models since it strongly impacts pressure drop predictions, especially when the oil viscosity increases: the water in the dense packed layer reduces the amount of water in the free water layer and therefore the ratio between oil-wetted perimeter and water-wetted perimeter (and hence the wall friction).

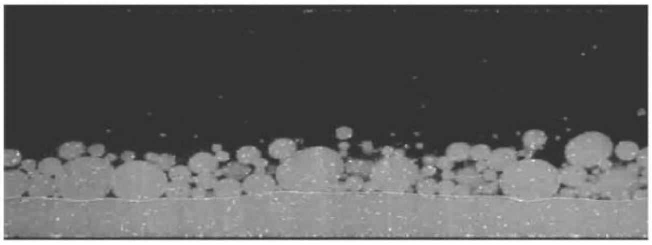

Figure 1: Dense packed layer of water droplets in oil in an oil-water pipe flow. Image from Voulgaropoulos (2017)

We have models for the stability of dense packed layers in separators. However, we have observed that the stability of a flowing dense packed layer differs from a static dense packed layer. A dense packed layer is complex and we can try first to simplify the situation by looking at one droplet in contact with a liquid layer. Dong et al. (2019) looked experimentally at this configuration and showed that the coalescence between a moving droplet and a liquid layer takes much longer than the coalescence between a static droplet and liquid layer. We can propose several explanations for this observation. One of them is that the external flow exerts a lift force on the droplet in the direction away from the liquid layer, similarly to the lift force expressed by Krishnan and Leighton (1995). The total force on the droplet is then smaller, leading to larger drainage time scales and larger coalescence time scales (Palermo, 1991; Basheva, 1999). Another explanation can be that the motion of the droplet induces a lubrification force pushing the droplet away from the liquid layer (see Reynolds' lubrification theory), similarly to a slider bearing. The objective of this work is to find the physical mechanism with the strongest impact.

For this purpose, simulations of a 2D droplet interacting with and interface and a shear flow have been performed and validated in order to check the accuracy of the JADIM code to manage such flow configuration. First simulations as reported in Fig. 2 clearly confirm the impact of the flow on the drainage between a droplet and a liquid film.

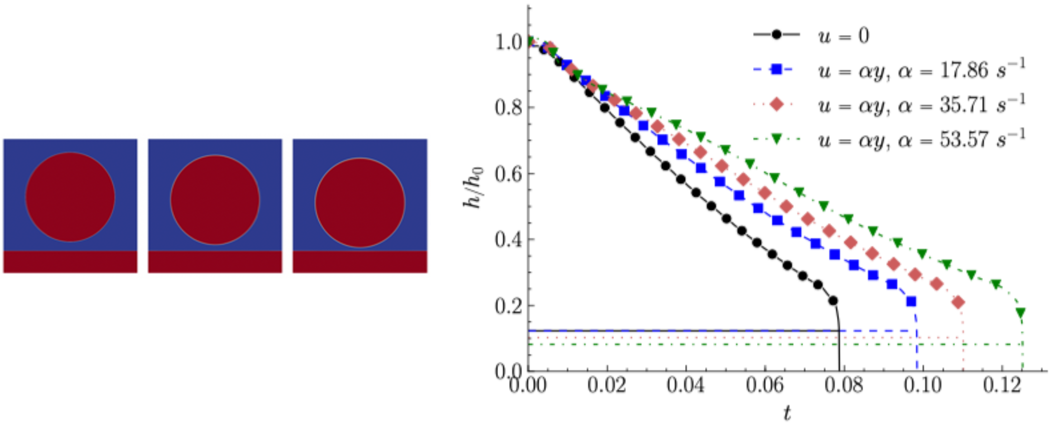

Figure 2: A droplet draining on a free surface and plot the time evolution of the gap h between the droplet and the free surface for different shear flows. The time to migrate to the liquid film is clearly impacted by the shear flow.

When refining the mesh, the simulations confirm that a droplet can stabilize at a fixed distance to the free surface, and the coalescence with the liquid layer expected due to the gravity is then avoided. This distance of stabilisation is observed to increase with the flow shear rate but also to be impacted by the droplet deformation (see Fig. 3) and the interaction with other droplets.

The objective of the proposed work is now to provide a deep physical investigation of the phenomenon involved in 2D and 3D and to provide relevant physical modeling. In particular the lift force applied to the droplet because of the linear shear flow will be discussed with regards to the induced pressure force in the lubrication film.

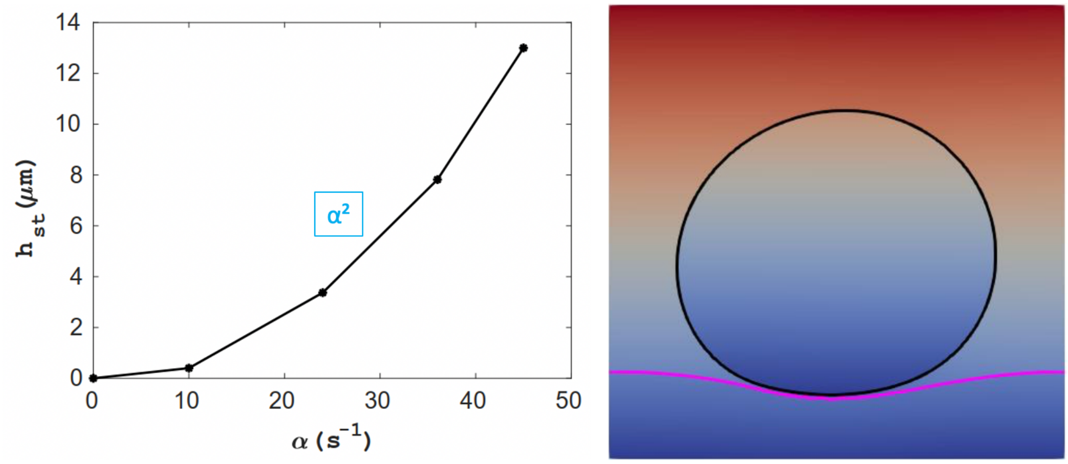

Figure 3: Levitating droplet on a liquid film. Left: effect of the shear on the stabilization distance to the liquid film. Right: A deformed droplet moving over a liquid film.