Post-doc: simulation of oil-water flows

The post-doc in collaboration between IMFT and Total aims at understanding the physics behind in two different oil-water flows configurations using direct numerical simulations.

The post-doc will take place at IMFT (Institut de Mécanique des Fluides de Toulouse), under the direct supervision of Dominique Legendre. There will be regular (monthly) progress/brainstorming meetings in order to transfer the knowledge obtained in the post-doc to the 1D modelling activities in Total. People (co-supervisors) involved in the meetings are: Alain Liné (INSA Toulouse), Roel Belt and Thierry Palermo (Total).

At this point it is a one-year post-doc starting on October 1st 2020, with possible 1-year renewal.

Configuration 1: "lubrification" of oil-water pipe flow with a viscous oil

When a viscous oil and water flow in a horizontal pipe, it is possible to form a core-annular flow: the viscous oil is centred in the core of the pipe while water forms a film around it (figure 1-left). This flow regime is particularly interesting for the oil industry, since it allows to transport a viscous oil at a small pressure drop because the wall friction is small when the wall is in contact with water compared to a viscous oil.

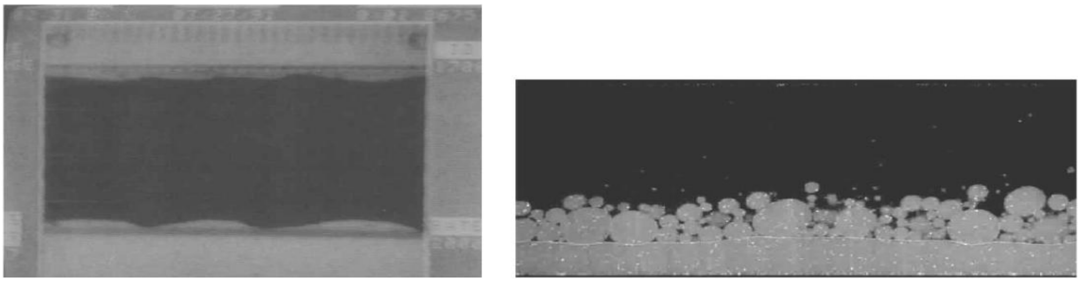

Figure 1: (left) First configuration: horizontal core-annular flow with the oil in the centre (in black) and water around, (right) second configuration: dense packed layer of water droplets in oil in an oil-water pipe flow. Image from Voulgaropoulos (2017)

There are several explanations in the literature for why the water film in the top of the cross-section does not drain and why the viscous oil core is pushed away from the top wall. However, they do not provide an explanation for the physical mechanism transporting water from the bottom to the top of the cross-section. The objective is to understand the mechanism pushing a water film upwards along the wall, and once it is understood, to propose a 1D model for its extent as a function of the viscosity ratio.

Configuration 2: drainage of the film between a droplet and a liquid layer with a lateral external flow and surfactants

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-right). 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).

We have models for the stability of dense packed layers in separators. However, we have observed that a flowing dense packed layer is more stable than 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 package is to find the physical mechanism with the strongest impact.

Considering the same configuration, we will try to simulate a number (to be defined) of packed droplets that allow reasonable computation times and highlight some physics associated to dense packed layers. The objective is to understand the stability of a flowing dense packed layers due to the lateral pressure gradient (in figure 1, the axial pressure gradient is the same over the entire cross-section, thus it also applies on the dense packed layer) and how the flow through the packed network limits the drainage compared to a single droplet.

The effect of surfactants can be added as well into the simulations for single and multiple droplets.