

Various regimes of two-phase turbulent flow in corrugated channels

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Corrugated plate heat exchangers are commonly used for a wide variety of processes, and their range of use in terms of Re typically extends from a few hundred to a few hundred thousand. The flows that occur in these exchangers are typically two-phase (oil transported by a dense gas), turbulent and have complex structures due to the geometry of the channels. The exchangers considered are made of a superposition of plates (see the schematic representation of Fig. 1), each characterized by the angle, β , between the direction of corrugation and the streamwise direction. As the angle β is opposite from one plate to another, this creates a periodic pattern of successive channels and contact points between two plates. This work presents experimental characterization of turbulent two-phase flow within corrugated plates. The experimental setup, composed of transparent corrugated plates, allows to characterize, thanks to high-speed shadowgraphy, the various flow patterns encountered in corrugated plate heat exchangers. By varying the gas flow rate as well as the liquid flow rate a wide range of flow conditions, including turbulent and non-turbulent regimes, are studied with a specific focus on the clogging limit, in which the air flow rate is too small to drag water all along the setup, and give rise to intermittent bursting of gas pockets. We consider upward air/water flows with a wide range of void fractions (typically from 75% to 100%) with air flow rate ranging from 1 to 20 m/s (corresponding to a Reynolds number, based on the half maximum channel width, from 500 to 10 000). Different plate configurations are tested with a low β ($< 45^\circ$). Fig. 1 gives a schematic view of our experimental setup. These visualizations, coupled with the numerical results of single-phase flows obtained using Large Eddies Simulations, give us an overview and a better understanding of the physical phenomena in place for the flow regimes and configurations studied. In canonical geometries several flows patterns are reported (bubbly, slug, churn, annular and mist flows), however, it remains largely unknown how such complex geometry could influence the transition between these regimes. We observe that the various turns that lead to the creation of strong vortical structures in the flows enhance the film formation, and that the many contact points between the two plates can act as anchors for these films. As illustrated by the visualization of Fig. 1, in these situations bursting pocket of gas can form and significantly alter the clogging limit. In the latter regimes, occurring at a small enough gas flow rate, is important from an industrial point of view.

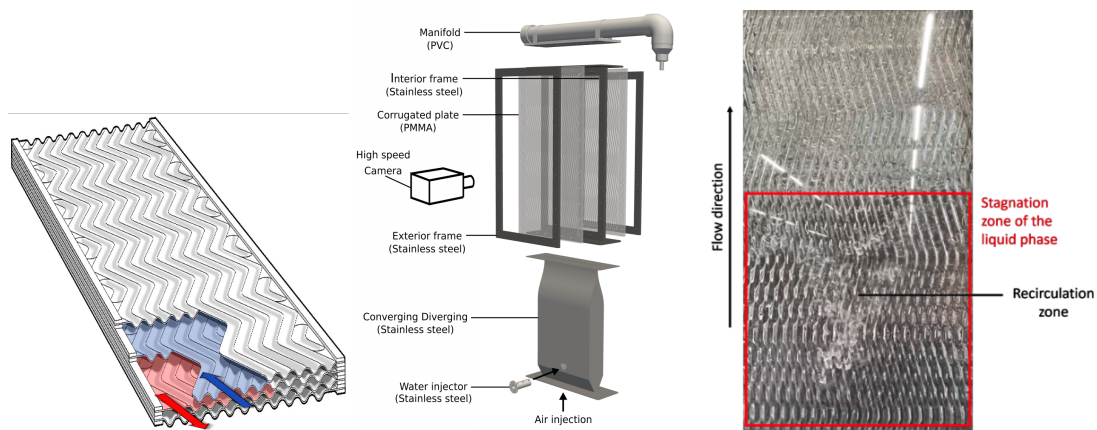


Figure 1: Left : Schematic representation of a stack of corrugated plates in which the two-phase mixture flows. Center : Schematic view of experimental setup. Right : Photo of a flow pattern at the clogging transition. The liquid phase is concentrated at the bottom half of the channel. The flow of the gaseous phase produces a vortex which agitates the liquid and ejects it sporadically towards the top of the channel.

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