PROPOSITION DE STAGE – MASTER 2 DET

Dynamique des fluides, Energétique et transferts

Université Toulouse 3 Paul Sabatier - Toulouse INP - INSA Toulouse - ISAE SUPAERO – IMT Mines Albi

Title/Titre : Dynamics of a Gas-Liquid Hourglass / Dynamique d'un Sablier Gaz-Liquide

Responsable(s) : Olivier Praud, enseignant chercheur Toulouse INP, IMFT, olivier.praud@imft.fr ;
Véronique Roig, enseignant chercheur Toulouse INP, IMFT, tél. 05 34 32 28 20, veronique.roig@imft.fr

Lieu du stage : Institut de Mécanique des Fluides de Toulouse (IMFT) / Dublin City University

Durée / période : 6 months, from February-March to July-August 2024

Candidature [CV, lettre de motivation, références] à envoyer à : O. Praud and V. Roig

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Topic / Sujet

Context, motivation:

Gas-liquid flows are present in many industry processes. Related to the study that we propose, prediction of transient gravity-driven exchange flows between tanks is important for safety issues of pressurized water nuclear reactors. Indeed, accurate prediction of the rates of fluids exchanges can, for example, help the decision for a transfer process to be used during corrective operations in nuclear reactors such as draining of the pressurizer coolant water through the surge line during severe accidents.
In our team we have already studied experimentally or numerically the emptying of a bottle and its glug-glug behavior as well as the filling of a cylinder (Mer *et al*., 2018 & 2019). Both configurations relate two tanks, one of them being at constant atmospheric pressure. In the present study we want to investigate a closed system consisting in a gas-liquid hourglass.
We want to study the oscillatory behavior of the transient counter-current gas-liquid flow that develops during the gravity-driven exchange of liquid between two closed cylindrical tanks aligned in the vertical direction and connected by a vertical tube (Fig. 1). The upper tank is initially filled of liquid while the bottom one is initially empty. When the valve between them opens, the transient exchange of liquid and gas starts with a complex flow that develops in the connecting tube. This flow varies depending on the geometrical dimensions (lengths L and l, diameters D and d on Fig. 1) and on the physical properties of the fluids.

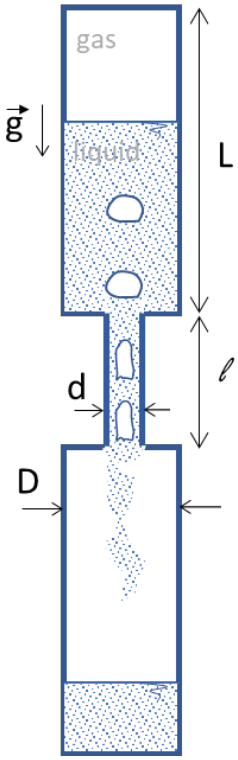

Figure 1: Scheme of the flow during the exchange.

Goal and research program:
During this internship, the student will
- perform an experimental investigation of this hourglass flow for different geometrical parameters
- analyze the acquired data and compare the results to those obtained in previous works
- contribute to the elaboration of one-dimensional model that aim to predict the pressure oscillations in both tanks
- synthesize his work in a scientific report.

The experimental set-up is under construction and will be available for experiments at the beginning of the training period. It will allow to vary parameters d and l as well as the initial filling ratio of the upper tank. Using pressure probes located at the top and the bottom of the hourglass and high-speed imaging, we will characterize the total time of exchange, the period of both pressure oscillations as well as their respective amplitudes and phases. Image processing will be used to carefully characterize the alternation of gas and liquid phases in the connecting tube in order to build a

model of the two-phase flow coupling the pressures in both tanks. We will build a map of the types of flows observed in the tube and will try to measure sizes of gas bubbles or gas volume fractions present in this tube. Depending on the control parameters of the problem, we expect that the flow can deviate from a periodic one, and we will investigate a map of the regimes that may appear.
The one-dimensional model we want to develop is inspired from literature on emptying or filling of bottles where a single tank is connected to atmospheric pressure. Representations of such flow as an equivalent mass-spring oscillator or as an Helmoltz resonator have proved to reproduce accurately the frequency of the oscillations for short necks of the bottles (Clanet & Searby, 2004). To predict the amplitudes of the oscillations we will work to extend and improve the model developed by Clanet & Searby (2004) or the one-dimensional two-fluid model developed by Dougall & Khatiresan (1981) or Tehrani *et al*. (1992) which takes into account the specific two-phase flow through long connecting tubes. We anticipate that a key-problem could be the clever representation of the boundary conditions exerted at both ends of the connecting tube that will exert a strong coupling across the system.

Expected skills of the candidates:
The candidate, having studied Fluid Mechanics, should be able to manage experimental measurements, to develop signal and image processing and to solve numerically differential equations (Runge-Kutta method, Newton's method for non-linear equations).

Working conditions:
Salary will be of 600€/month.
This program of research will develop in the context of a starting collaboration with Corné Muilwijk, assistant professor at Dublin City University. It implies a visit to Dublin City University (~ 2 weeks)

References:
Clanet, C. & Seaby, G., 2004, On the glug-glug of ideal bottles, Journal of Fluid Mechanics, Vol. 510, pp. 145-168
Mer, S., Praud, O., Neau, H., Merigoux, N., Magnaudet, J. and Roig, V., 2018, The emptying of a bottle as a test case for assessing interfacial momentum exchange models for Euler–Euler simulations of multi-scale gas-liquid flows, International Journal of Multiphase Flow, vol. 106. pp. 109-124.
Mer, S., Praud, O., Magnaudet, J., Roig, V., 2019, Emptying of a bottle: How a robust pressure-driven oscillator coexists with complex two-phase flow dynamics, International Journal of Multiphase Flow, Vol. 118, pp. 23-36
Tehrani, A.A.K., Patrick, M.A., Wragg, A.A., 1992, Dynamic fluid flow behaviour of a tank draining through a vertical tube, International Journal of Multiphase Flow, Vol. 18, Issue 6, pp. 977-988
Dougall, R.S. & Kathiresan, M., 1981, Dynamic behavior of fluid flow through a vertical tube into a sealed tank filled with gas, Chemical Engineering Communications, Vol.8:4-6, pp. 289-304