2022 PhD:

Study of boiling flow in rocket engine cooling systems

Space system engines are cooled via channels in which cryogenic fluids (oxygen, hydrogen, methane) circulate at very low temperatures (100 K or less). Under subcritical conditions, the walls of these channels, which are subjected to extremely intense heat fluxes, can cause the cryogenic liquid to vaporize and the flow becomes multiphase. Even at low speed, the appearance of vapor requires the consideration of the compressibility of the fluid which modifies the flow conditions: the heat exchanges can be improved via the latent heat of vaporization of the fluid, but they can also dramatically decrease if the topology of the flow becomes unfavorable to heat transfers (vapor flow in the wall causing an insulating zone) Similarly, the speed of sound changes abruptly and can even lead to choked flows that limit the mass flow rates (appearance of steam that can affect the flow rates).

Modeling and numerical simulation of these multiphase flows require the consideration of many effects: compressibility, intense heat transfers that can lead to mass transfers (vaporization, condensation), cavitation - all within various geometries (long pipes, singularities in the pipes). The physics of cryogenic fluids itself also brings many questions. For example, which Equation of Stage (EOS) to use to correctly represent these fluids in the supercritical domain as well as during a phase change. This physics will have to be modeled correctly to ensure essential properties of mathematical models such as conservation of mass, momentum and energy or hyperbolicity to garanty correct wave propagation.

Mathematical models dealing with multiphase flows and vaporization in such situations exist at IUSTI ([1], [2] and [3]). IUSTI also develops the openSource tool ECOGEN which allows the solution of such flows.

This thesis will be carried out in a context of development of models, algorithms and computational codes to address this issue:

- Heat and mass transfers in multiphase flows and thermal coupling with walls.
- Determination of exchange coefficients by model reduction.
- Effects of physical parameters: viscosity, surface tension.
- Improvement of EOS: these EOS could be analytical or tabulated.

The corresponding algorithms will be fully developed and introduced in the ECOGEN tool. Improvements will be made to the numerical scheme by testing and implementing robust and fast space-time integration algorithms.

PhD applicant :

The applicant will ideally be a mechanical engineer/numerical engineer who has completed a research master's degree in the field of fluid mechanics and liquid/vapor phase change. At ease in the various fields of fluid mechanics (essentially compressible), he/she will also have knowledge of numerical simulations of single-phase or multi-phase flows. The applicant must be comfortable with computer tools and be sensitive to sequential and parallel algorithmic development. Good knowledge of C/C++ is a plus.

The thesis will take place at IUSTI in Marseille.

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References :

[1] F. Petitpas, J. Massoni, R. Saurel, E. Lapebie and L. Munier (2009) Diffuse interface model for high speed cavitating underwater systems. *International Journal of Multiphase Flow, vol. 35(8), pp. 747-759.*

[2] Petitpas, F., & Le Martelot, S. (2014). A discrete method to treat heat conduction in compressible two-phase flows. *Computational Thermal Sciences: An International Journal*, *6*(3).

[3] Schmidmayer, K., Petitpas, F., Daniel, E., Favrie, N., & Gavrilyuk, S. (2017). A model and numerical method for compressible flows with capillary effects. *Journal of Computational Physics, 334, 468-496.*

[4] Schmidmayer, K., Petitpas, F., Le Martelot, S., & Daniel, É. (2020). ECOGEN: An open-source tool for multiphase, compressible, multiphysics flows. *Computer Physics Communications, 251, 107093.*