**RESEARCH TOPIC FOR THE PARISTECH/CSC PHD PROGRAM**

***Field: Materials Science, Mechanics, Fluids***

***Subfield***: Mechanical Engineering

***Title***: Numerical modeling of solidification and high-pressure die casting process.

***ParisTech School***: Arts et Métiers Sciences et Technologies

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***Short description of possible research topics for a PhD***:

Approximately half of the world's production of light metal castings is obtained by High-Pressure Die Casting (HPDC). Mastering this technology is a crucial issue for the industry because of its high productivity and its ability to produce thin and solid parts.

Numerical modeling of the process is complex. This is a multi-physical problem involving fluid flows, heat transfers, chemical species transfers, phase changes, free surface flows as well as moving parts. The complex geometry of the molds and the high injection speeds lead to turbulent flows, highly three-dimensional and with very large fragments of the free surface. These high speeds and pressures are sought for good filling of the mold and for reducing the porosity of the parts produced. Solidification modeling is in itself complex because it is necessary to take into account the microstructures which greatly influence the properties of materials at the macroscopic scale. To account for these microscopic effects, the macroscopic solidification models are generally multiscale and the mushy zone is modeled by several additional phases. These methods however rely on very approximate relationships to model the interactions between grains. The so-called mesoscopic and multiscale approaches that we have developed aim to improve these relationships.

The aim of this thesis is to develop models and numerical solvers specifically optimized for the High-Pressure Die Casting process using Open-Source frameworks.

***Required background of the student***: PDEs applied to physics (fluid mechanics preferably), discretization methods (Finite-Volume), scientific computing (with Python/C++)

***A list of 5 (max.) representative publications of the group:***

1. A. Viardin, Y. Souhar, M. Cisternas Fernández, M. Apel, M. Založnik, "Mesoscopic modeling of equiaxed and columnar solidification microstructures under forced flow and buoyancy-driven flow in hypergravity: Envelope versus phase-field model", Acta Materialia, 2020, vol. 199, pp. 680-694. doi:10.1016/j.actamat.2020.07.069
2. M. Torabi Rad, M. Založnik, H. Combeau, C. Beckermann, "Upscaling mesoscopic simulation results to develop constitutive relations for macroscopic modeling of equiaxed dendritic solidification", Materialia, 2019, vol. 5, pp. 100231. doi:10.1016/j.mtla.2019.100231
3. A. Viardin, M. Založnik, Y. Souhar, M. Apel, H. Combeau, "Mesoscopic modeling of spacing and grain selection in columnar dendritic solidification: Envelope versus phase-field model", Acta Materialia, 2017, vol. 122, pp. 386-399. doi:10.1016/j.actamat.2016.10.004
4. Y. Souhar, V. F. De Felice, C. Beckermann, H. Combeau, M. Založnik, "Three-dimensional mesoscopic modeling of equiaxed dendritic solidification of a binary alloy", Computational Materials Science, 2016, vol. 112, pp. 304-317. doi:10.1016/j.commatsci.2015.10.028