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MECH 493 project: Computational model for cryogenic fluid heat transfer

Background and research goal

Liquefied Natural Gas (LNG) is nowadays being introduced as a fuel in vehicles because it is cheap and causes fewer emissions than gasoline/diesel. For storage and transportation purposes, LNG must be kept below its boiling point (-161.5 °C at 1 atm). This is a "cryogenic" temperature range, meaning extremely low-temperature. In case of a breach of LNG tanks/pipes, cryogenic liquid is spilled on a surrounding structure, which is at ambient temperature. Consequentially, the structure is subjected to a thermal shock because of the spill. The thermal shock induces very high temperature gradient inside the structure. The structure very quickly warms up the LNG, which starts to evaporate and boil. To assess thermal stress accurately, it is necessary to understand the behavior of LNG and its phase transition. Small/moderate spills are of interest in this project that aims to provide design tools for a new generation of ships for Canadian commercial fleet.

Computational Fluid Dynamics (CFD) is a powerful tool to simulate behavior of fluids and model heat transfer in multi-physics problems. The current project focuses on the convective heat transfer between cryogenic fluid and a plate plus evaporation process within cryogenic fluid. The main goal is to understand and quantify thermal loading acting on the plate, by modeling the fluid evaporation characteristics with CFD and accounting for various modes of heat transfer between cryogenic fluid, plate and surrounding air.

Tasks to be performed by the student

1) Survey scientific literature to understand how heat transfers between cryogenic fluid and structure with the possibility to consider Fluid-Structure-Interaction (FSI)
2) Run CFD simulations using Star CCM+ or other commercial CFD packages
3) Validate the CFD solutions with existing literature
4) Discover and explore the physics behind cryogenic thermal loading on the material surface using CFD simulations
5) Modify the simulation to consider a different spill scenarios

You are expected to be a fast learner interested in numerical technique and should have experience in Heat Transfer and Fluid Mechanics. Previous knowledge in CFD modeling, FSI and coding/programming would be an asset.

Facilities and team:

You will periodically interact with Dr. Jelovica and his research group. You will need to do preliminary work and extend the problem setup using your own personal computer. If required, longer analyses could be run on a local cluster, with the help from the group.