Postdoctoral position – 18 months
Heat transfer characterization in cryogenic environments

Context and research topic :

Liquid hydrogen is characterized by several important limitations and challenges that restrict its current use. One of them is the cryogenic boiling losses associated with storing, transporting and handling of liquid hydrogen and which can consume up to 40% of its available combustion energy. Molecular hydrogen exists in two allotropic (spin isomers) forms, ortho-hydrogen and para-hydrogen, differentiated by the nuclear spin state of the protons in each hydrogen atom. For a given temperature, the equilibrium ratio of ortho- to para-hydrogen concentrations: $[\boldsymbol{H_{2,\,para}}]_{eq}$ and $[\boldsymbol{H_{2,\,ortho}}]_{eq}$ can be calculated [1], but the kinetics of the exothermic conversion can take weeks when the temperature is rapidly dropped. Therefore, reliable in situ measurement's method of this concentration is important for the hydrogen industrial sector.
One way to measure these concentrations consists in using the thermal properties of hydrogen, such as the enthalpy difference [2] or the difference of thermal conductivity [3] between ortho and para hydrogen. Transport of heat in a fluid is usually assumed to be determined together by advection and diffusion phenomena. In some specific cases, transport of heat relies upon complex processes at molecular scale that can potentially deviate from conventional transport by heat diffusion. In these conditions, the thermal conductivity is no longer a constant parameter but varies in time and space, leading either to faster or slower heat transport. Fluids close to super-critical conditions like dihydrogen in cryogenic conditions exhibit for instance a super diffusivity of heat with a transport much faster than expected by normal diffusion [4]. A solid understanding of the anomalous transport properties of heat in unconventional conditions [5] opens the way for more robust and faster concentration estimates based on thermal conductivity measurements.

The postdoctoral applicant will be asked to help design a cryostat with engineers of Institut Néel prior to perform the development and fabrication of an innovative sensor for assessment of chemical composition of a gaseous mixture based on a heat transfer at various temperatures at LGF in Mines Saint-Etienne. A knowledge modeling of the sensor, based on physical first principles, as well as a behavior modeling based on the experimental sensor's responses to various excitations is also planned to validate measurements in laboratory conditions.

Host laboratories and supervision :

The project is a collaboration between Institut Néel (https://neel.cnrs.fr/) and Laboratory George Friedel (LGF – UMR 5307 – Mines Saint-Etienne https://www.mines-stetienne.fr/lgf/) within the PARACHUTE project, funded by the ANR. The position will be based at Mines Saint-Etienne with regular meeting and travels to NEEL institute in Grenoble.

Supervisors: Dr. Patricia Derango (CNRS Researcher), Riadh Lakhmi (EC-LGF), Mathilde Rieu (EC-LGF) and Guillaume Dumazer (EC-LGF), Gaetan Becker (Fives CRYO).

Application :

Candidate profile sought: PhD in Physics of transport processes, Thermodynamics, Condensed-Matter Physics or a closely related discipline. The project's subject includes different disciplines (fluid mechanics, transfers, engineering, automatics) and involves also digital and experimental development. Therefore, strong versatility is expected from the candidate. Excellent written and oral communication skills.

Contract and remuneration: The candidate will be employed by Neel institute with a fixed-term post-doctoral contract for a duration of 18 months.

Post-doc start date: Between 1st September 2025 and 1st October 2025.

Post-doc application deadline: 31 Mai 2025.

Application: Please send CV, cover letter, latest transcripts, and contact details for two references to Riadh LAKHMI (riadh.lakhmi@emse.fr)

References :

[1] L. Barrón-Palos, R. Alarcon, S. Balascuta et. al., Determination of the parahydrogen fraction in a liquid hydrogen target using energy-dependent slow neutron transmission, Nuclear Instruments and Methods in Physics Research, 2011, 659, 579-586.

[2] J. Essler, C. Haberstroh, Performance of an ortho-para concentration measurement cryostat for hydrogen, AIP Conf. Proc., 2012, 1434 (1), 1865–1872.

[3] D. Zhou, G.G. Ihas and N.S. Sullivan, Determination of the Ortho-Para Ratio in Gaseous Hydrogen Mixtures, Journal of Low Temperature Physics, 2004, 134, 401–406.

[4] B. Zappoli, D. Bailly, Y. Garrabos et al., Anomalous heat transport by the piston effect in supercritical fluids under zero gravity, Phys. Rev. A, 1990, 41(4), 2264.

[5] A. Lemarchand, B. Nowakowski, G. Dumazer, and C. Antoine, Microscopic simulations of supersonic and subsonic exothermic chemical wave fronts and transition to detonation, Journal of Chemical Physics, 2011, 134, 034121.