Sorbonne Université - Paris6

Institut Jean le Rond d'Alembert (CNRS UMR 7190)

2, place de la gare de ceinture

78210 Saint Cyr-l'Ecole, France

Internship opportunity

Title: Characterizing smoke in microgravity: microscopic measurements of morphological dispersion

Terms: Applicants should be motivated individuals with previous experience in combustion science, and pursue a graduate degree in Mechanical Engineering and/or Physics. The position is expected to start from Spring 2021 and will last 3/6 months.

The monthly allowance is 550€ (M1/M2 student).

Contacts: Yutao Li, PhD Student, Sorbonne Université (contact)
email : yutao.li@sorbonne-universite.fr

Guillaume Legros, Maître de Conférences – Sorbonne Université

web: http://www.dalembert.upmc.fr/home/legros

Augustin Guibaud, Lecturer – University College London
email : a.guibaud@ucl.ac.uk

Jean-Marie Citerne, engineer, Sorbonne Université

Topic context: The current projects deal with fire safety for spacecraft and lunar habitats. As new ambitions are set for manned space exploration, past incidents have stressed the need for a comprehensive understanding of the specifics of fire safety in such environment. Yet, in reduced gravity, the physics of a fire are still poorly understood. To face this challenge, a topical team gathering experts from NASA, CNES, JAXA, ESA, and ROSCOSMOS is working on a series of demonstration and validation experiments[1] which must capture fundamental aspects of ignition, spread, and extinction of a flame in various gravitational fields. Investigations are carried out in orbit and on the ground, using a wide range of facilities such as drop towers, parabolic flights, sounding rockets, the International Space Station, and Cygnus resupply modules. Such experiments have lately investigated the effects of scale, geometry, and ambient conditions, and continue to explore new configurations. Eventually, efficient fire sensing and growth prediction tools will be developed along with the project.

Scientific objectives: An experimental rig has been developed at Sorbonne Université for parabolic flight investigations[2]. Probing flames spreading over electrical wires under various oxygen contents, flow velocities, and ambient pressures, it has been central in the evaluation of the impact of gravity on flammability limits, smoke emission, and flame spread rate. Recent findings tend to show that the characteristic dimensions of soot particles in the smoke are intimately linked to gravity, and ambient conditions which is problematic as most fire detectors rely on the knowledge of the soot particles collected on the ground. To detect the fire correctly, it is important to perform morphological analysis of soot particles sampled from a flame spreading in reduced gravity and better understand what optical properties to expect in the smoke.

Expected progress: The student will join a team of experimentalists at Institut Jean le Rond d'Alembert (Sorbonne Université - Paris 6, Saint Cyr l'Ecole campus). The experimental core of this work is a rig that has been developed at Institut d'Alembert.[3] It especially enables the study of flame spread over cylindrical wires both on the ground and onboard the Airbus ZeroG. The student will carry out experiments on the ground to sample the soot particles from a spreading flame in order to compare the particles obtained in microgravity, and will analyze the morphology of the soot particles collected from both gravity levels with Transmission Electron Microscope (TEM) images in using a program developed in matlab[4]. This internship will combine experimental and theoretical investigations, and will be supervised by a team of experts in the different fields of knowledge at stake.

References:

[1] O. Fujita, Solid combustion research in microgravity as a basis of fire safety in space, *Proc. Combust. Inst.* **35**, p.2487-2502, 2015. https://doi.org/10.1016/j.proci.2014.08.010.

[2] J.-M. Citerne, H. Dutilleul, K. Kizawa, M. Nagachi, O. Fujita, M. Kikuchi, G. Jomaas, S. Rouvreau, J.L. Torero, and G. Legros, Fire safety in space - Investigating flame spread interaction over wires, *Acta Astronautica* **126**, p.500-509, 2016.

[3] See the interview perfomed in October 2018: https://www.youtube.com/watch?v=Vh7rBj4PBnQ

[4] P.M. Anderson, H. Guo, P.B. Sunderland. Repeatability and reproducibility of TEM soot primary particle size measurements and comparison of automated methods. *J. Aerosol Sci.*, 114: 317-326, 2017. https://doi.org/10.1016/j.jaerosci.2017.10.002.