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PROPOSITION DE SUJET DE THESE

Intitulé : Photoluminescence thermal imaging applied to composites interacting with a fire

Référence : MFE-DMPE-2025-42
(à rappeler dans toute correspondance)

Début de la thèse : 10/2025	**Date limite de candidature :** 05/2025

Mots clés

Thermal imaging, experimental techniques, composite materials, optics,high temperature, combustion (Imagerie thermométrique, techniques expérimentales, matériaux composites, optique, hautes températures, combustion)

Profil et compétences recherchées

The ideal candidate for this position should have a strong affinity for experimental work and be willing to engage in technical tasks. He/she will need to demonstrate initiative and creativity, which are essential qualities for successful experimental work. Candidates should also be able to read theoretical literature and apply relevant concepts to their own research. The ability to work as part of a team made up of members with diverse profiles, such as experimental technicians and research engineers, is also required. At least B2 level English and knowledge of Python are required. Previous laboratory and/or experimental research experience would be an asset.

Présentation du projet doctoral, contexte et objectif

International aeronautic standards require a fire certification for aircraft elements such as structures and engines. It is mandatory to anticipate this certification step as early as possible in the development process while taking into account the evolution of materials and additional risks due to the use of new fuels as so-called Sustainable Aircraft Fuels (SAF) and hydrogen. Indeed, composite materials are currently replacing some metallic alloys to provide efficient and resilient structural components such as fuselage and engine carters. However, such materials may not withstand significant thermal stresses generated by a fuel-induced fire. As the flame-wall interaction is already complex on metallic or ceramic walls, on composites, outgassing and delamination add further coupling between flame and wall. In order to better model these physics, experimental data are required [1]. A key quantity is the temperature of the wall interacting with the flame. It plays a key role in the degradation of the composite as well as in the flame propagation near the wall but also drives the heat transfer level from the flame. Moreover, the absence of a non-intrusive technique to measure the temperature of composite walls impinged by a flame remains a major obstacle to the development of accurate numerical models. Thermocouples have to be integrated directly into the composite, which can change the structural behavior. Infrared thermography suffers not only from the interference of flame radiation, but also from the change in emissivity of the wall as the resin degrades.

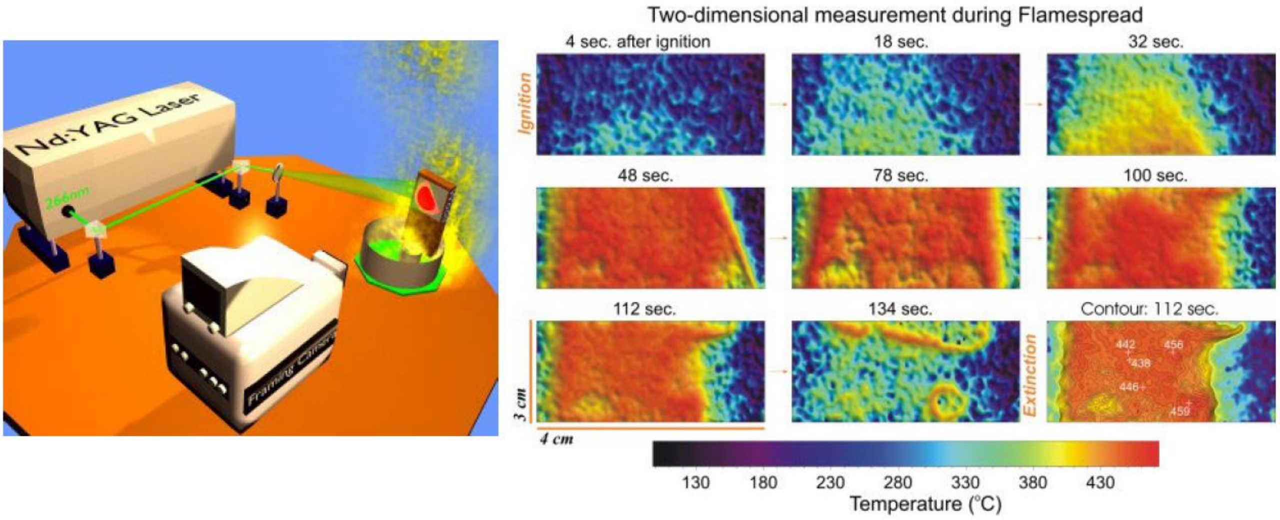

Figure 1: Experimental setup for 2D thermometry on a burning fireboard using phosphor thermometry (gauche), and obtained temperature fields (right), reproduced from Ref. [3]

This thesis will evaluate the use temperature-sensitive inorganic luminescent particles [2], also known as "thermographic phosphors", as a potential solution. When illuminated by an excitation source, such as a laser or an LED, these particles emit luminescence, which can be detected and analyzed temporally or spectrally to infer the particle temperature. The particles are highly thermochemically stable, and therefore do not degrade during flame attack. They also enable measurements over a wide temperature range (100-1400 K). Spectral and temporal filtering can also be used to eliminate flame emission. These luminescent particles have been applied to temperature measurement on reactive surfaces (a burning firebrand in [3], also shown in Fig. 1 and a burning coke particle in [4]).

This thesis will focus on the interaction of a flame with carbon-fiber composites. The aim of this thesis will be to identify suitable particles and implement a luminescence detection strategy for temperature measurement, offering sufficient signal for accurate and robust measurements in a reactive environment. It will also study whether the presence of the particles may affect the flame – wall interaction, i.e. that the measurements remain non-intrusive. Iterations in terms of luminescent particles and thermometric approach may be necessary. Samples of materials treated with these particles will be tested in laboratory conditions, then with more intense flame conditions (propane/air premixed flame and hydrogen flame). The effectiveness of this innovative technique will be validated through comparisons with mature techniques, or alternative techniques from other laboratories.

References :
[1] Dellinger, Donjat, Laroche and Reulet, Fire Safety Journal, 2023
[2] Abram, Fond and Beyrau, Progress in Energy and combustion science, 64, 93-156 (2018)
[3] Omrane, Ossler and Aldén, Proceedings of the Combustion Institute, 29, 2653-2659 (2002)
[4] Cai, Khodsiani et al., Proceedings of the Combustion Institute, 38, 4225-4232 (2021)

Collaborations envisagées

Polytech Montreal – thermométrie sur composite avec cameras IR multispectrales – Pr. Etienne Robert

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