Mouad DAOUDI

Will publicly defend his PhD entitled:

Development of optical and chemical diagnostics to characterize and control particulate and gaseous emissions from combustion systems

On December 7, 2022, at 2 PM at IFPEN (1 et 4 avenue de Bois-Préau, 92852 Rueil-Malmaison) in Amphi Séquoia (SE-052)

The PhD defense can be followed by videoconference*

Before the jury:

Jérôme YON	Professeur, INSA-Rouen, CORIA	RAPPORTEUR
Barbara D'ANNA	Directrice de Recherche, CNRS, LCE, Univ. Marseille	RAPPORTRICE
Georgios KELESIDIS	Research Associate, ETH-Zürich	EXAMINATEUR
Cornelia IRIMIEA	Ingénieure de recherche, ONERA-Palaiseau	EXAMINATRICE
Cristian FOCSA	Professeur, Univ. Lille, PhLam	EXAMINATEUR
Pascale DESGROUX	Directrice de Recherche, CNRS, PC2A, Univ. Lille	DIRECTRICE DE THÈSE
Philipp SCHIFFMANN	Ingénieure de recherche, IFP Energies nouvelles	CO-ENCADRANT DE THÈSE
Alessandro FACCINETTO	Chargé de Recherche, CNRS, PC2A, Univ. Lille	CO-ENCADRANT DE THÈSE
Arnaud FROBERT	Chef de Projet Innovation, IFP Energies nouvelles	MEMBRE INVITÉ

Abstract : Combustion is one of the main contributors to both particulate matter (PM) and several gaseous pollutants which may have harmful effects on human health, environment, and climate. The main goal of this PhD is to develop a measurement procedure based on optical extinction to monitor PM and/or some gaseous pollutants emissions produced by a combustion system (e.g., internal combustion engine, turbine, or industrial burner). This work also aims to shed the light on the relationship between the chemical composition and the optical extinction coefficient measured for these emissions. To succeed in this measurement challenge and avoid the complexity of a real powertrain setup, a modular combustion bench has been built in which gaseous pollutants and PM can be monitored independently. This experimental setup was equipped with a version of the miniCAST soot generator that has the ability to burn liquid fuels, thus allowing the study of the impact of the chemical composition of the fuel on the physico-chemical properties of PM. A total of 34 operating points were characterized, spanning a wide range of flame overall equivalence ratio (i.e., 0.104 - 1.673) using two different fuels (diesel B7 and dodecane). The soot particles produced by this burner were characterized in terms of morphological key parameters, size distributions, mass concentrations, and optical extinction coefficients. All these data were then used to evaluate and intercompare the soot volume fraction using three different methods: granulometric (combining size measurement and morphology), mass, and optical. Furthermore, the chemical composition of the combustion products of the miniCAST was studied in order to characterize the organic content of the gas phase and the particulate phases. This study was carried out by combining gas chromatography (GC), to examine low mass polycyclic aromatic hydrocarbons (PAHs) in the gas phase, and time-of-flight secondary ion mass spectrometry (ToF-SIMS), to characterize the heavy PAHs in both the gas and particulate phase. These experiments allowed to identify the operating points associated with the highest content of organic compounds. Then, a correlation was observed between the presence of that organic content (mostly attributed to organic PAHs) and the optical extinction coefficient. The use of an oxidation catalyst (catalytic stripper) on the burner exhaust gases allowed to evaluate the impact of this thermal treatment at 350 °C on the chemical composition of the exhaust gases, on the size and morphology characteristics of soot aggregates, and consequently on the measurement of the optical extinction coefficient. Finally, the measurement of the optical extinction coefficient for PM and gaseous pollutants such as NO, NO_2, and/or NH_3 injected first separately and then simultaneously was performed to evaluate the interference of gaseous pollutants with PM and to propose a procedure allowing their simultaneous control. In conclusion, this thesis provides for a soot generator's PM emissions a detailed description of soot particles sizes, morphologies, soot volume fractions and optical extinction coefficients, as well as a detailed characterization of the chemical composition of the gas- and particulate-phase produced by this generator, under different operating conditions. Thanks to the experimental database obtained, this thesis proposes a methodology of measurement and analysis for optical extinction coefficients and for ToF-SIMS mass spectra which can be transposed to the study of biofuels or synthetic fuels (e-fuels) in the near future.

Keywords : Optical extinction, chemical composition, morphology, volume fraction, soot particles, gaseous pollutants, PN, PM, ToF-SIMS, miniCAST ;

*** Access link to the videoconference broadcast of the PhD defense:**

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