Laboratoire d'Energétique Moléculaire & Macroscopique, Combustion – EM2C – UPR288

Avis de Soutenance

M. Yi DING

Soutiendra publiquement ses travaux de thèse intitulés

Use of flame chemiluminescence and ionization current for the combustion state monitoring of a domestic gas boiler

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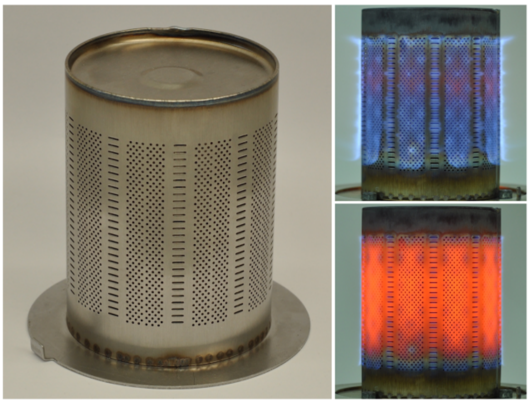

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ÉCOLE DOCTORALE
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Abstract:

The current control strategy of domestic gas boilers optimizes the heating efficiency and pollutant gas emissions assuming a fixed fuel composition. However, larger variations of gas composition are expected in the European natural gas network. A new control system capable of monitoring and regulating the flame status in real time is therefore necessary. The present thesis addresses two potential low-cost techniques, i.e. the use of flame chemiluminescence and ionization current, for the monitoring of flame equivalence ratio, a key parameter for the optimization of boiler performances.

The possibility of equivalence ratio sensing by analyzing the flame chemiluminescence signal is first investigated. An equivalence ratio indicator is determined from flame spectra from binary fuel blends with methane and one of the secondary components N_2, CO_2, H_2, C_2H_6 and C_3H_8. It is found that the commonly used indicator of CH^*/OH^* intensity ratio yields considerable errors with the natural gas contains C_2H_6 or C_3H_8. The intensity of OH^* alone is then proposed as an alternative indicator.

An analysis is then carried out to understand the effects of several disturbing factors on the flame chemiluminescence signal with emphasis on the burner used in a domestic gas boiler. One important feature is the strong heat exchange taking place between the flame and the burner surface at low operating power when the burner works under the so-called radiation mode. The chemiluminescence intensities of OH^*, CH^* and CO_2^* are found to be no longer proportional to the gas flow rate, when the gas velocity drops below the adiabatic laminar flame speed. Also, a higher inlet gas temperature is seen to enhance the chemiluminescence intensity for freely-propagating flames while it has no effects on the burner-stabilized flames. These phenomena are then studied with a 1-D burner-stabilized flame model and the numerical results are in good agreement with the experiments.

The study then continues with the flame ionization current. Its application to flame monitoring is already emerging in domestic gas boilers. Experiments are carried out on a conical flame burner to understand the evolution of the ionization current intensity with various parameters including the probe position, flame power, fuel composition and equivalence ratio. The dead space between the conical flame base and the burner rim is suggested as the major factor limiting the ionization current. The changes of the current intensity are then attributed to modifications of the flame standoff distance

A control loop is developed at the end with LabVIEW to demonstrate the feasibility of equivalence ratio self-regulation by real time analysis of the flame chemiluminescence signal. After a comparison of several sensing strategies, the OH^* signal from a photomultiplier tube is selected as an indicator for the equivalence ratio. The control loop is shown to respond correctly and with a good precision to changes of fuel composition and equivalence ratio set value.

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