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Description of the research work proposed for a PhD

Title: Use of an image processing method to evaluate the unburnt gases in a flame impinging a ceiling in a confined enclosure.

Keywords: Image processing method; unburnt gases in an impinging flame, GC-MS analysis, under ventilated, CFD modelling.

Subjectif :

I- Context and goal

During a fire in a room, it is possible that a flame may spread along a ceiling and thus contribute to an increase in the heat flow and therefore the temperature [1] [2]. Under these conditions, the risk of fire spreading to another compartment increases and constitutes a threat to people and equipment: an unacceptable situation for fire safety [3]. In this context, the characterization of the behavior of flames impacting ceilings and thermal gradients observed in closed or semi-closed environments is of great interest for fire safety engineering. Moreover, it has been shown in scientific work [4] [5] that in a confined enclosure, unburnt gases have a major role in the risk of spreading a fire. Based on a flame impacting a ceiling, the production of unburnt gases can be done due to the under-ventilation of the room and by the pyrolysis of the ceiling impacted by the flame. To highlight the role of unburnt gases in the progression of a fire, it is necessary to put in place tools capable of properly mapping the field of unburnt gases throughout the fire enclosure. For this, use of an image processing method can be used by coupling to gas analyzes by GC-MS. In addition, the will to highlight the physical parameters which have a significant effect in the propagation of a fire are of particular interest to the scientific community [6] [7] [8] [9].
In this context, the objective of the thesis will be to set up a means to map the unburnt gas field using image processing. This will be compared at the same time by gas analyzes made by a GC-MS type gas analyzer. But also using numerical simulations carried out from a CFD code named FDS (Fire Dynamics Simulator) developed by the NIST [10].

II- Objective and Expected results

The objective of the thesis will be defining a method of image processing to highlight the field of unburnt gases in flame impinging a ceiling in an enclosure. From this tool, it will be possible to describe more the effects of confinement on a flame impinging a ceiling in a confined and semi-confined enclosure. To achieve this, gas measurements will be performed using a gas analyzer (GC-MS for example). From these gas measurements, it will be possible to make a comparison with the field of species get from image processing. It will be also possible to measure the inside and outside temperatures along the vertical and horizontal positions. In addition, from numerical modelling, a comparison between image processing field and numerical field of the unburnt gases will be carried out.

The experimental set up that will be used represents a 1:10 scale model of a student residence apartment with two possible openings: a door and a window. The design of the experimental device was carried out on the conservation of the Froude number based on the scaling law. To provide explanations in terms of fire safety on thermal accident that can occur during fires in closed environments, for example in a room of a university residence, five configurations of openings are used in this work with eight different heat release rates. These different configurations will be identified to a level of confinement varying from 0 to about 2.3 as equivalence ratio. The aim of the study will be to make a link between the field of unburnt gases with the level of confinement. From the field of unburnt gases, a comparison with the flammability domain will be performed to identify the ignition zones. From this, it will be possible to add explanations on the risk of spread fire from the fire compartment to another compartment due to a thermal accident such as backdraft.

The plan of the proposed thesis is outlined as follows:

1. Bibliographic study on the topic of impinging flame, fire science and image processing tools.
2. Selection Getting started with the image processing tool.
3. Experimental investigation on the characterization of unburnt gases in a flame impinging a ceiling in an enclosure.
4. Coupling of experiment data and image processing data.
5. Numerical modelling based on the FDS simulations with a validation from experiment data.

III- References

[1] G. Heskestad, T. Hamada, Ceiling jets of strong fire plumes, Fire Saf. J. 21 (1993) 69–82. doi:10.1016/0379-7112(93)90005-B.

[2] H.Z. and G.M.F. You, An investigation of fire impingement on a horizontal ceiling, 1979.

[3] R.L. Alpert, Calculation of response time of ceiling-mounted fire detectors, Fire Technol. 8 (1972) 181–195. doi:10.1007/BF02590543.

[4] P.L. Hinkley, H.G.H. Wraight, C.R. Theobald, The contribution of flames under ceilings to fire spread in compartments, Fire Saf. J. 7 (1984) 227–242. doi:10.1016/0379-7112(84)90022-5.

[5] B. Manescau, H. Y. Wang, B. Coudour, J. P. Garo, Influence of heat tightness of an enclosure fire on ignition risk of unburnt gases in a connected exhaust system – An experimental study, *Fire Safety Journal*, Vol. 109, 2019. doi.org/10.1016/j.firesaf.2019.102867

[6] A. Wang, B. Manescau, K. Chetehouna, Steve Rudz and Ludovic Lamoot, Experimental study on the flame extension and risk analysis of a diffusion impinging flame in confined compartment, Journal of Fire Sciences, 39(4), 285–308.

[7] B. Magnognou (Manescau), J. P. Garo, B. Coudour, H. Y. Wang, Risk Assessment of Unburnt Gas Ignition in an Exhaust System Connected to a Confined and Mechanically

Ventilated Enclosure Fire, *Fire Safety Journal*, Vol. 91, pp. 291-302, 2017. doi.org/10.1016/j.firesaf.2017.03.036

[8] B. Karlsson, J.G. Quintiere, Enclosure fire dynamics, 2000. doi:693.8′2--dc21.

[9] R.L. Alpert, Turbulent ceiling-jet induced by large-scale fires, Combust. Sci. Technol. 11 (1975) 197–213. doi :10.1080/00102207508946699.

[10] NIST. https://www.sabalcore.com/vertical-markets/engineering/fds-smv/

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