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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 a impinging flame, GC-MS analysis, Under ventilated, CFD modelling.

Subject:

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 flux 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. In order 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, an image processing method can be used [6] and coupled to gas analyzes made by GC-MS [7]. And thus, from the overall data, it will be possible to highlight physical parameters which have a significant effect in the propagation of a fire are of interest to the scientific community [8] [9]. Among these parameters, there is ignition or auto-ignition of unburnt gases mixed with outside air conducting to a thermal accident such as backdraft and flashover.

In this context, the objective of this PhD thesis will be to set up a tool to map the unburnt gas field using image processing technique. The obtained results from this tool will be compared at the same time to gas analyzes made by a GC-MS device. But also using numerical simulations carried out from a CFD code named Fire Dynamics Simulator [10][11].

II. Objective and expected results

The objective of the PhD thesis will be defining a method of image processing in order 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). 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. In order 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 in order 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 and 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] S Rudz, K Chetehouna, O Séro-Guillaume, E Pastor and E Planas., Comparison of two methods for estimating fire positions and the rate of spread of linear flame fronts", Measurement Science Technology, 20(2009) 115501 (10pp).

[7] K.Chetehouna, N.Grange, N.Gascoin, L.Lemée, I.Reynaud, S.Senave, Release and flammability evaluation of pyrolysis gases from carbon-based composite materials undergoing fire conditions,Journal of Analytical and Applied Pyrolysis,Volume 134, September 2018, Pages 136-142

[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] A. Wang, B. Manescau, Q. Serra, K. Chetehouna, E. Florentin, C. De Izarra, Sensitivity analysis on numerical results dealing with outdoor wind effects on smoke spreading along a corridor, International Journal of Thermal Sciences, Vol. 142, pp. 332-347, 2019.

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

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