NUMERICAL SIMULATION OF RADIATION PROPAGATION THROUGH WATER MIST

9TH International Water Mist Conference

Élizabeth BLANCHARD[1,2], Pascal BOULET[1], Éric CESMAT[2] and Sylvain DESANGHERE[2]

(1) LEMTA, Nancy Université, CNRS, Faculté des Sciences et Techniques, BP 70239 - 54506 Vandoeuvre Cedex – France
(2) CSTB, 84 avenue Jean Jaurès, Champs-sur-Marne, 77447 Marne-la-Vallée Cedex 2 - France

CONTEXT & OBJECTIVE

In the event of fire, thermal radiation represents an additional amount of heat which could increase the heat release rate of the fire and could be a threat to human life and structures. Water mist systems, used as protection device against fire, can attenuate radiation by absorption and scattering effects due to the water droplets.

Our group from LEMTA and CSTB works on the comparison of two numerical tools dealing with radiative heat transfer through a layer of water spray : BERGAMOTE, a laboratory code developed by LEMTA and FDS, developed at NIST in co-operation with VTT.

The objective is to evaluate FDS radiative model in order to investigate some possible improvements and to use FDS for more realistic configurations of water mist systems.

RADIATIVE MODELS

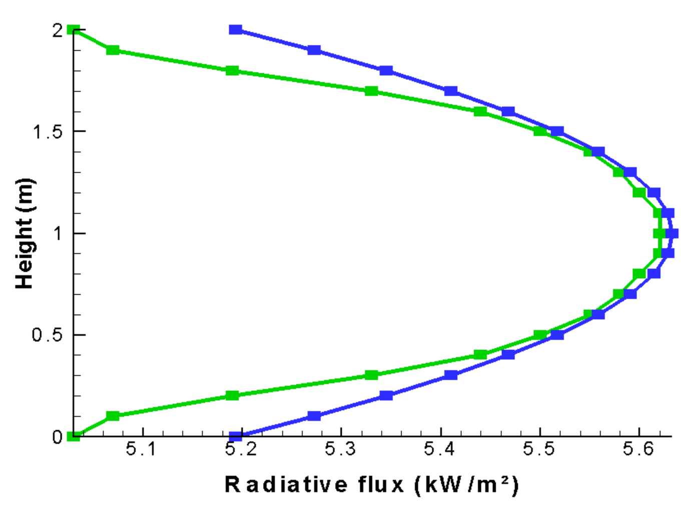
The differences between the radiative models of these two codes are :

• in BERGAMOTE, a Monte-Carlo method is combined with a fine spectral approach (43 to 367 bands). The Mie theory yields the radiative properties of the droplets including the phase function handled in its most complex form. A C-K model provides the characteristics of the gas taking into account H_2O and CO_2 contributions.

• FDS is based on a finite volume method applied on a wide band model (1 to 9 bands) ; it approximates the single-droplet phase function with a sum of forward and isotropic components and the characteristics of the gas are computed using a RadCal narrow-band model. It takes into account H_2O, CO, O_2 and CO_2 contributions.

VERIFICATION STUDY

The preliminary study consists in simulating with FDS the radiative energy transfer between two parallel infinitely-long panels in a nonparticipating media : one panel, heated at 800 K, emits radiation and the other receives it. The horizontal distance from the radiation panel to the target panel is 4 m.



Radiative heat flux versus to the vertical position

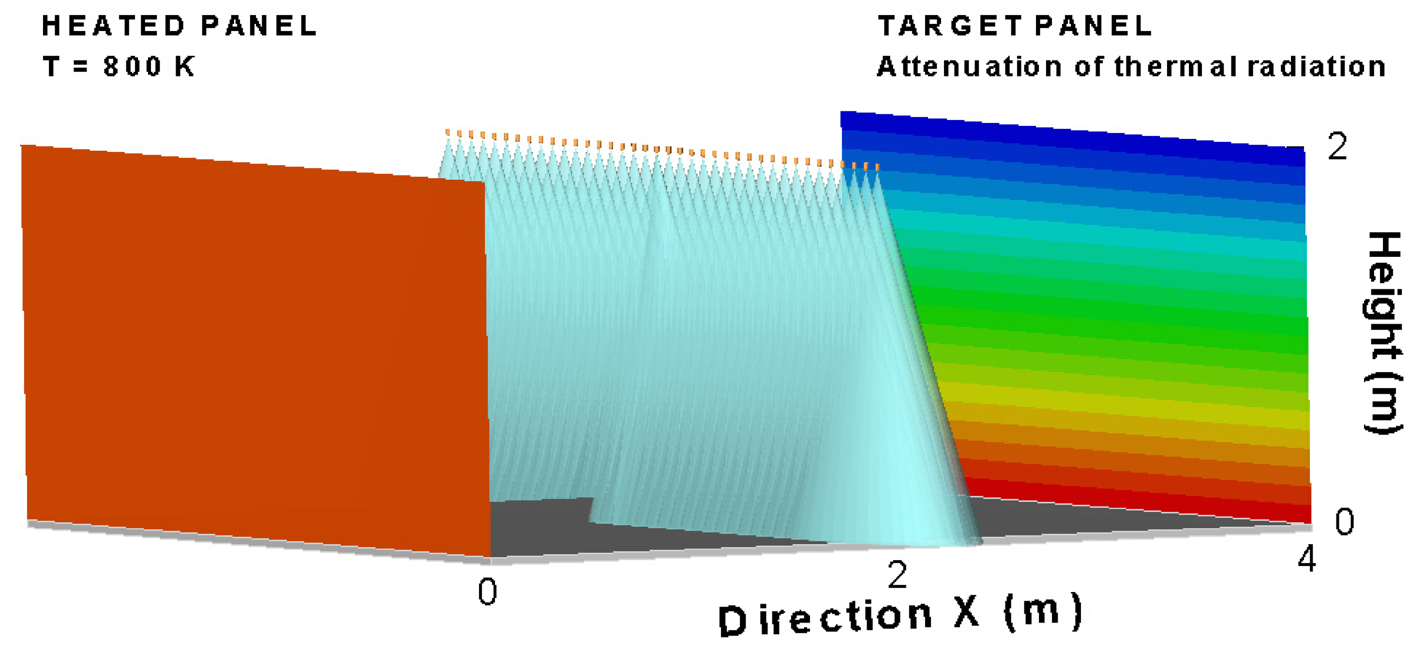
The numerical radiative heat flux are very close to analytical values obtained with view factors.

TEST CASE

The comparison test deals with the attenuation of thermal radiation passing through a water curtain, simulating the use of a water spray as radiative shield against a strong radiation source.

The radiation is produced by a heated panel at 800 K. Then, it crosses a water curtain and it is received by a target panel, 4.0 m behind.

Schematic of the comparison test



The numerical results have been compared between the two models studying the attenuation of thermal radiation at the target panel.

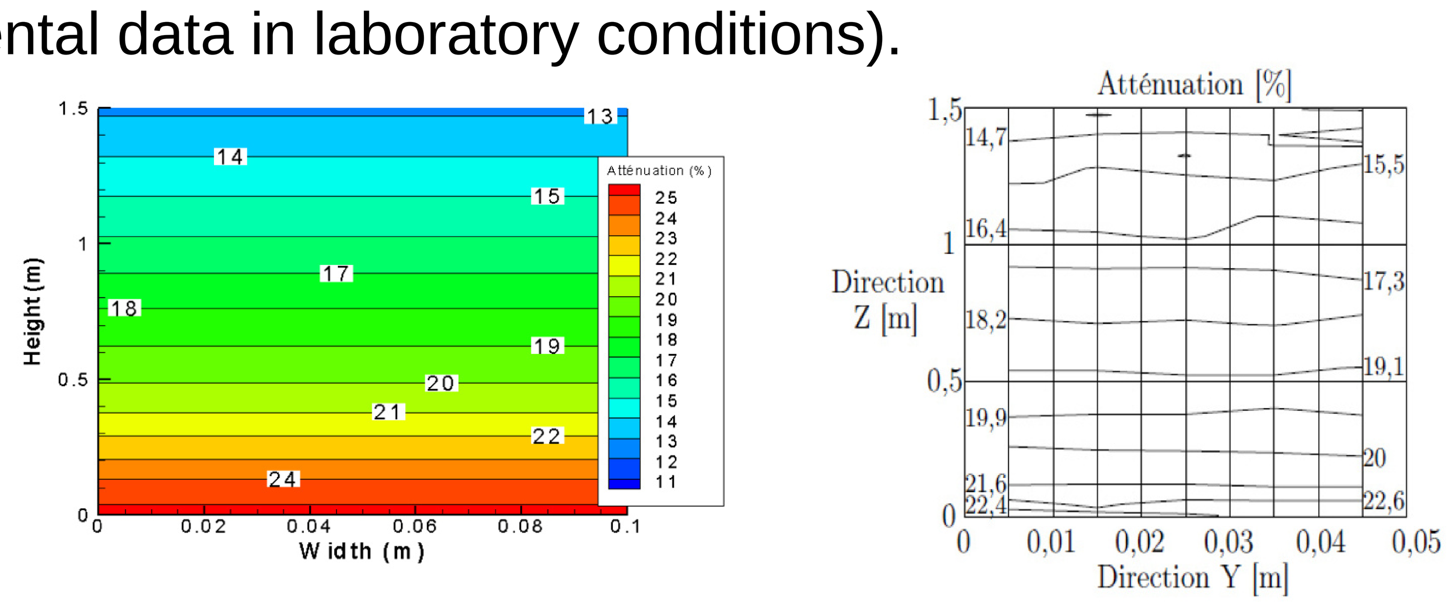
TEST RESULTS

Good general agreement has been found for the results obtained with BERGAMOTE and FDS using only one spectral band (gray gas assumption) :

– the attenuation of thermal radiation only depends on the vertical location of the measurement point on the target panel ;

– the attenuation increases near the floor as a consequence of the spray dynamics : the droplets deceleration results in an increase in their residence time when moving away from the injection area ;

– the attenuation values range from 13 to 26% (currently involving moderate flow rates in the simulations in order to allow a possible comparison with experimental data in laboratory conditions).



FDS BERGAMOTE

Attenuation of thermal radiation on the target panel, predicted by FDS and BERGAMOTE

CONCLUSION

The attenuation of thermal radiation predicted by the two codes FDS and BERGAMOTE appears to be in fairly good agreement, even if the radiative models used are rather different. This ensures that radiation predicted by FDS is sufficiently accurate, with a reduced computational cost using the gray medium assumption.

Moreover, the non uniformity of the attenuation through a simple undisturbed water mist curtain clearly illustrates the notable effect of the variation of water droplets distribution due to the falling droplets dynamics. This observation highlights the importance of being able to accurately predict the dynamics of the water mist itself.

Complementary work will be conducted in order to couple radiative effect with phenomena encountered in case of fire, especially heat release and related consequences on droplets evaporation and mist dynamics.