SMOKE LAYER / WATER SPRAY INTERACTION: IMPACT ON VISIBILITY AND THERMAL CONDITIONS


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French strategy promotes **self-evacuation** of people. Then, it aims at making **fire-fighting** conditions better and limiting **fire propagation**.

French building standard allows sprinkler systems in some public buildings and in particular cases.

**What about water mist systems?**
Context

What about water mist systems?

French building standard is evolving: 
an article to be published soon

But many questions has been raised

- What is their performance?
- What are the conditions for people and fire-fighters?
- Same questions but integrated to other systems (ventilation systems)?
Objectives

Our research focuses on water spray/smoke layer interaction

- To question the notion of stratification
- To be able to measure opacity in extreme conditions
- To estimate and foresee visibility conditions and also,
  - To improve our understanding of the involved phenomena and to quantify them with different water spray systems
Our research focuses on **water spray/smoke layer interaction**

- To question the notion of stratification
- To be able to measure opacity in such conditions
- To estimate and foresee visibility conditions

Smoke with droplets in suspension is a participating medium with absorption AND scattering phenomena.
By focusing on water spray/smoke layer interaction

**Test campaign**
- Repetability
- Measurement uncertainties

**Input data**
- To assess its realism

**Development of a tool to render visibility conditions**

**Test campaign**

**Combustion**

**Input data**
- To provide a new visualisation of the results

**Computational reconstruction**
- To assess codes
- To quantify the phenomena
- To get certain quantities
- To evaluate sensitivity

**Input data**

**FDS developed by NIST and VTT**
**Description of the configuration**

**Configuration “room/corridor”**
- Room: 12 m² surface area and 2.15m high
- Corridor: 9m long and 2.35m high
- No mechanic ventilation system (until now)

To focus on water spray/smoke layer interaction
Description of the configuration

Fire load until now
- 0.09 m² heptane pool
- To limit uncertainties
- Surface = 0.09 m²
- HRR ≈ 275 kW

Water spray system : a HP until now
- Operating pressure around 110 bars
- $d_{32} = 23.5 \, \mu m$
- Flow rate = 27.5 l/min

To focus on water spray/smoke layer interaction
- **HRR** by monitoring MLR
- **Gas temperature** along 4 Tc trees
- **Opacity** along 2 trees

Transmissivity = $\frac{\Phi_{\text{received during test}}}{\Phi_{\text{received before test}}}$

**Problem!** Opacimeters cannot be used above 50°C

We are currently designing an opacimetry system which can work under high temperatures.
Main results

Test campaign
- Repetability
- Measurement uncertainties

2 tests:
- one without water mist
- one with a nozzle manually activated at 360 s

Development of a tool to render visibility conditions

Computational reconstruction
- To assess codes
- To quantify the phenomena
- To get certain quantities
- To evaluate sensitivity
Main results, without mist
Main results, without mist

\[
\tau = e^0 \int_0^L \kappa \, dy = e^i \sum_k \kappa_i \Delta y
\]

\[
\kappa = \frac{5.5 \times f_y}{\lambda}
\]

Solovjov and Webb
Main results, after mist activation

- **0.5m upstream the mist nozzle**
  - Measurement
  - FDS predictions

- **2.5m downstream the mist nozzle**
  - Measurement
  - FDS predictions

- **5.5m downstream the mist nozzle**
  - Measurement
  - FDS predictions
Main results, after mist activation

Mist act.
Main results

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Main results

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Mie theory:

\[ K = \sum_{i=1}^{N} \frac{d_i^2}{4} N_i Q_{i_{\text{abs}}}(d_i) \]
\[ \sigma = \sum_{i=1}^{N} \frac{d_i^2}{4 A} N_i Q_{i_{\text{diff}}}(d_i) \]
\[ P_{i_{\text{abs}}}(\Theta) = \frac{1}{\sigma} \sum_{i=1}^{N} \frac{d_i^2}{4} Q_{i_{\text{abs}}}(d_i) P_{i_{\text{abs}}}(d_i, \Theta) N_i \]
For an isolated point

$\lambda = 500 \text{ nm}$

Water volumetric concentration $1.10^{-3}$

Optical depth of $0.1 \text{ m}$

For a test pattern

Source

Its images

$\lambda = 500 \text{ nm}$

$f_v = 1.10^{-3}$

$d = 0.1 \text{ m}$

$\lambda = 500 \text{ nm}$

$f_v = 2.10^{-4}$

$d = 0.1 \text{ m}$
Before mist activation
Thermal and optical stratifications appear coupled

After mist activation
- Gas temperature become homogeneous downstream WM explained by mixing and cooling
- Whereas opacity is not homogeneous: its is even lower close to the floor than at mid-height

The tool currently developed appears promising

Test campaign
- Repetability
- Measurement uncertainties

Development of a tool to render visibility conditions

Computational reconstruction
- To quantify the phenomena
- To get certain quantities
- To assess sensitivity

FDS developed by NIST and VTT captured well the trends before and after mist activation
Design an instrumentation enabled to measure opacity in severe conditions (hot and wet gases with water droplets)

- Test other fuel loads, **water spray systems** by varying the number of activated nozzles, its(theri) position to their effect
- Quantify the involved phenomena: How much radiation attenuation represents compared to surface cooling with a WM?
- Add gas contribution within the visualization tool
- Find a way to assess this tool
Thank you for your attention!