Experimental and numerical studies to assess the benefits of water mist system in Mont-Blanc tunnel

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Presentation outline

1. Overview
2. Experimental campaign
3. Numerical study
4. Results
5. Conclusion
Use of water mist in Mont-Blanc tunnel

- Bibliographic review of existing fixed fire-fighting systems (FFS)
- Experimental performance assessment of several types of FFS at scale 0.8
- Numerical simulations to evaluate the interaction of water mist system with existing safety equipment and procedures

What are the benefits of using water mist in the Mont-Blanc tunnel in its existing state?
Mont-Blanc tunnel current high-end safety equipments

- Fire localisation and longitudinal velocity control (in less than 3 min)
- 156 m$^3$/s smoke extraction (7 dampers opened in the fire zone)
- Reduced air blowing during smoke extraction
- Emergency shelter every 300 m
- Road barrier every 600 m to prevent people from driving close to the fire
- 3 fire stations (at both portals + in the middle) : first fire crew on site in less than 7 min
Experimental campaign

15 fire tests carried out in the TST tunnel tests facility (San Pedro, Spain)
Experimental campaign

- 3 FFS technologies: SPK, low-pressure & high-pressure water mist
- 2 fire load compositions (using electric cables, tyres, hidden surfaces)
  - 30 MW wood
  - 50 MW wood and gasoil
- Generate steady longitudinal flow (with extraction) then start the fire
- 2 activation strategies
  - At fire detection (heat sensor cable)
  - At t = 7 min (firefighters arrival)
- Monitoring of temperature, velocity, gas composition, heat flux, etc.
Experimental campaign main findings

- High-pressure water mist system provides the global best performance (gas cooling and fire suppression), especially when activated at 7 min.
- High-pressure water mist and sprinkler give similar results when activated early (at fire detection).
- Significant reduction of visibility has been observed in the flooding zone with water mist (smoke de-stratification and water droplets).
- Carbon monoxyde yield is clearly affected by water flooding on the fire, but at the same time HRR is reduced.
Numerical study: overview

**Working approach**

- CFD modeling using FDS (NIST, USA)
- Numerical parameters tuning by simulating 6 experimental tests
- Extensive use of FDS to simulate realistic fire scenarios

![Experimental campaign](image)

**Experimental campaign**

Mont-Blanc tunnel

[Image of Mont-Blanc tunnel with equipment]
Numerical study: parameters tuning

Fitting the Rosin-Rammler/log-normal droplets size distribution

\[ F(D) = \begin{cases} \frac{1}{\sqrt{2\pi}} \int_{0}^{d} \frac{1}{\sigma d'} \exp \left( -\frac{[\ln(d'/d_m)]^2}{2\sigma^2} \right) dd' \quad (d \leq d_m) \\ 1 - \exp \left( -0.693 \left( \frac{d}{d_m} \right)^\gamma \right) \quad (d > d_m) \end{cases} \]
Acceptable agreement to use FDS to simulate water mist effect in the real tunnel.
Numerical study: fire scenarios

Numerical simulation of 36 fire scenarios (3’000 hours of calculation)

- 4 fire intensities
  - 15 MW (big light vehicle fire, common serious fire case)
  - 30 MW (design HGV fire for ventilation system)
  - 50 MW (big HGV fire)
  - 100 MW (huge HGV fire - dangerous goods are forbidden)

- 3 initial natural draught conditions due to meteorological effects (quickly vanished thanks to longitudinal velocity control system)
  - $\Delta p = 100$ Pa $\Rightarrow$ initial 1.9 m/s
  - $\Delta p = 300$ Pa $\Rightarrow$ initial 3.4 m/s
  - $\Delta p = 500$ Pa $\Rightarrow$ initial 4.3 m/s

- 3 FFS activation strategies
  - no activation (current configuration)
  - activation at 2 min (as fire is detected)
  - activation at 7 min (firemen arrival on site)
Numerical study: assumptions

Simplified HRR curves

- Presumed
- From experimental campaign
- Based on SOLIT results

Graphs showing HRR (MW) over time (min) for different power levels and activation scenarios.
**Results analysis methodology**

- Tenability conditions for people: FED calculation (heat and toxicity)
- Walking speed affected by visibility

- Reduced visibility within water mist taken into account
Results analysis methodology

- Firemen intervention conditions (temperature and radiative heat fluxes)
- Firemen traveling speed affected by visibility

![Traveling speed vs visibility distance](image-url)
Results analysis: types of representation

- Water mist interaction with fire and damages to the structure

- Evacuation conditions
Results analysis: effect on visibility
Results analysis: effect on visibility
Results analysis: effect on temperature
Results analysis: effect on temperature
Conclusion

- Early activation leads to significant degradation of visibility and temperature in the flooding area, that may disturb evacuation.
- No significant asset for safety of users up to medium fires (15 MW, 30 MW) because the existing smoke management system is very effective in Mont-Blanc tunnel.
- Aspersion can help firemen with their progression to the fire, by reducing smoke generation.
- But firemen operating conditions can be deteriorated (reduced visibility near the fire and temperature increase with water vapor).
- Very good results to protect structure and equipments when facing big fires (50 MW, 100 MW).
- The technical feasibility has not been studied here.
Thank you for your attention