IWMA Position Paper on CFD and Water Mist Firefighting

23rd International Water Mist Conference

Antwerp, Belgium, 18th and 19th September 2024

BACKGROUND

- **IWMA** recognized that the use of **CFD** (computational fluid dynamics) is increased:
  - CFD is generally getting more accepted tool
  - The codes have improved (used friendly interfaces)
  - CPU power has increased
  - PBD (performance based design) method is getting more popular

=> CFD is a powerful tool, if correctly used!

BACKGROUND

- **IWMA** recognized a risk that **CFD** would be misused in combination with water mist systems:
    - **Design justification** without experimental validation
    - **Limitations of CFD** would not be recognised
    - **No** guidance (CFD manuals) for **best practice**

=> A risk that some water mist system will fail (blame for whole industry)

TASK

- **Task**:
    - Produce a "position paper" on CFD and water mist systems

- **Objective**:
    - Provide insights into the application of CFD for water mist systems

- **Scope**:
    - Outline advantages, limitations, and best practices
    - **Not a technical guide or standard**

PROCESS

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PROCESS

- Editor:
  - **Max Lakkonen**
- Contributors:
  - Alex Palle, Ann Micheli, Bogdan Raciega, Dirk Laibach, Jonathan Carpenter, **Kati Laakkonen**, Kemal Arsava, Luciano Nigro, Markku Vuori-salo, Ning Ren, Rüdiger Kopp,   Siaka Dembele
- Language check:
  - **Ann Micheli**

POSITION PAPER

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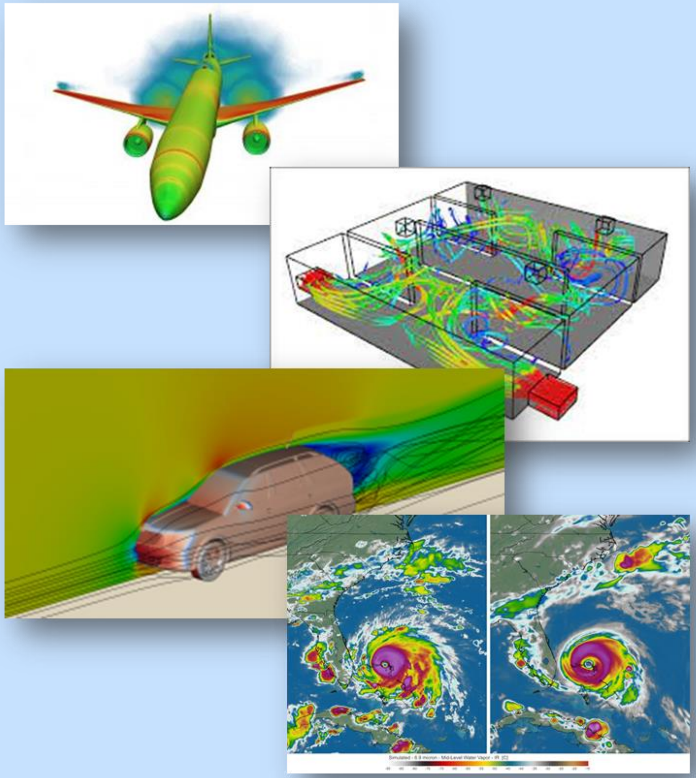
CFD IN GENERAL

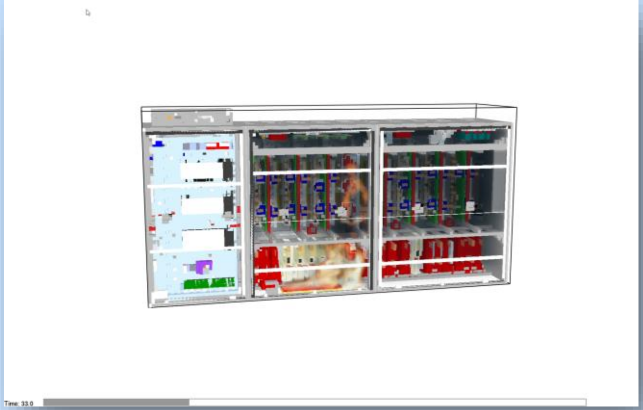
- **CFD Fundamentals**:
  - Solves Navier-Stokes equations for fluid flow

- **Key applications**:
  - Fluid dynamics
  - Aviation
  - Automobile
  - Weather forecast
  - HVAC

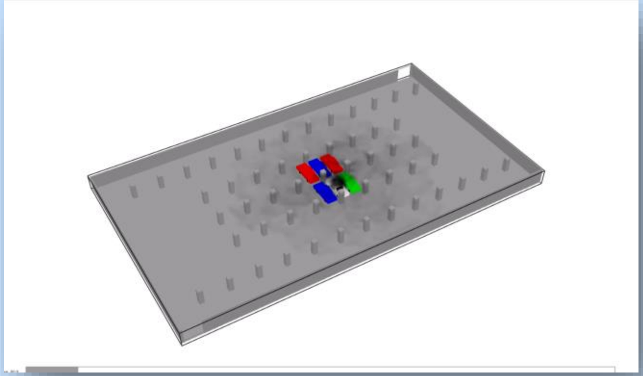


CFD IN FIRE ENGINEERING

- Challenges:
  - **Heat release rate / combustion**
  - **Flame sheet modelling**: Inadequate resolution limits accuracy
  - **Radiation modelling**: Complex and resource intensive
  - **Computational resources**: Requires powerful systems for large-scale simulations



- Typical **codes**:
  - FDS (Fire Dynamics Simulator)
  - FireFoam (Open Foam)
  - Commercial codes (universal)



CFD AND WATER MIST

- Modelling with mist:
  - **Input parameters**: Droplet size, distribution, spray angle, and velocity are derived from experimental data due to limitations in atomization modelling.
  - **Activation modelling**: Heat activation of automatic nozzles is modelled using differential equations and parameters (RTI and C) based on experimental data from nozzle manufacturers.
  - **Effects on fire**: Water mist impacts fire through cooling (flame/gas/surface), radiation attenuation, and oxygen depletion, all simulated by accounting for droplet heating, evaporation, and vapor formation.

CFD AND WATER MIST

- Key challenges:
    - **Modelling & combustion**: High computational demands due to small droplets; accuracy depends on grid resolution and turbulence models. ***Combustion processes are not fully understood, limiting precise modelling***.
    - **Geometry & validation**: Complex geometries lose detail in certain CFD codes. Fire validation is difficult due to fire's nonlinear nature; CFD models require extensive experimental validation.
    - Cost, time, **& user expertise**: Water mist simulations are resource-intensive. ***Experienced users*** and access to reliable data are essential for accurate simulation results.

BEST PRACTICE

- Applications:
    - CFD for **design & optimization**:
        - Help fire engineers model water mist dispersion and interaction with fire-induced airflow, ***leading to optimized nozzle replacement and system design within approved tolerances.***
    - **Assessing** installations:
        - CFD can demonstrate improvements in cases where ***real installations deviate from fire test specifications, subject to authority approval.***
        - Deeper insight to temperature distribution, thermal radiation, cooling etc.

BEST PRACTICE

- Key limitations:
  - **Combustion**: Limited CFD capabilities and semi-empirical modelling are recommended.
  - **Computational**: High resource demand, especially for water mist systems, requiring advanced techniques like mesh size variation and cluster simulations.
  - **User experience: Lack of experience can lead to inaccurate results.**
  - **Reliability & validation**: Validation with ***experimental data is essential*** for ensuring accuracy, with iterative improvements based on empirical findings. Validation should be included in all reports, and mesh independence studies are recommended.

BEST PRACTICE

- **What is needed from USERs**:
    - **Expertise**: Fire engineers using CFD must have specialized knowledge in fire dynamics, turbulence models, and numerical methods to ensure accurate results.
        - Inexperienced users risk producing false or misleading outcomes. Proper understanding of the modelling process is crucial for credible simulations.
    - **Detailed reporting**: Ensuring transparency in the CFD process through comprehensive reporting enables better understanding and validation of the model.

CONCLUSIONS

- **CFD is a tool that give benefits for fire engineering**

- CFD can be used with certain limitations also to model water mist systems

- CFD does not replace need of experimental tests, but it's rather for the design, assessment and optimization

- Main limitations are combustion modelling (semi-empirical models), micro/macro scale (resolution) and USER EXPERTISE

- CFD (CPU power + codes) are improving continuously

Q&A

Q1: Can CFD used for providing the design basis for water mist system?

A1: Whether CFD can be utilised to establish the design basis for water mist systems depends on the local Authority Having Jurisdiction (AHJ). However, IWMA does not endorse this practice. The acceptable design basis should be derived from full-scale fire tests in accordance with respected hazard classifications. CFD may be used as an additional tool for further optimisation and assessment, depending upon the availability of validation data.

Q&A

Q3: How can the results of CFD simulations be validated to ensure their accuracy and reliability in predicting the performance of water mist systems?

A3: The accuracy and reliability of CFD simulations for water mist systems can be validated by comparing the results with experimental data from full-scale fire tests or laboratory experiments. Sensitivity analysis (or parameter study), which assesses the impact of different input parameters on the simulation outcomes, can also be done provide insights into model robustness. Some validation data is publicly available, but manufacturers have lots of data from the approval fire tests.

Q&A

Q6: What are the potential cost savings and benefits of using CFD in conjunction with water mist systems compared to traditional design methods?

A6: Using CFD with water mist systems offers potential cost savings and benefits as it allows for more accurate analysis of fire scenarios, helping optimise system parameters like nozzle placement and protection concept (within approvals). CFD can provide additional data which identifies design flaws early, reducing the need for costly modifications later. CFD can also help in the development of the fire test protocols e.g. when ad-hoc testing is used.

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