International Water Mist Conference

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The Influence of Droplet Size of Water Mist on Extinguishment Fire Plume

Dr.Hemdan Shalaby
Institute of Fire Protection
Heyrothsberge, Germany

Hemdan.Shalaby@idf.uni-magdeburg.de

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Water mist and Sprinkler

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Water mist:

Consists of droplets where 90% (on mass basis) has a diameter less than1000 µm

Sprinkler droplets:

It is believed that the droplets are larger than water mist droplets.

Evaporating or not?

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- When droplets evaporate inside the combustion zone, the water utilises the maximum heat absorbing capacity, about 6 times the heat needed to increase the temperature from 10 -100 °C.

- By evaporation, water vapour (steam) is created. This process leads to expansion (about 1700 times), and the steam dilutes the gaseous fuel, the oxygen and the combustion products.

- Steam is invisible, water droplets are visible.

Water mist Fire Suppression

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- Water mist has been identified as a potential alternative to Halons
- Smaller than 150 µm water mist droplets have been shown to be effective in fire suppression

Advantages of water mist over sprinkler systems

- Water damage reduction
- Weight considerations, aircarft applications
- Facilities where water vapor or run-off could cause higher damage

Water mist applications

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•Widely used in maritime sector, both in machinery spaces and in cabins, corridors, public spaces, sales-and storage areas on passenger ships.

•Turbine hoods, emergency generator rooms, transformers etc on offshore oil and gas production platforms.

•Heritage buildings, museums, collections where water use is limited due to possible damage.

•Cable tunnels

•Aircraft hangars (fighter airplane local protection)

Background on Fire Modeling

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Must be capable of approximating:

- heat transfer physics
- flow physics
- combustion processes

FDS represents the leading edge of fire simulation tools.

Warning!!! Uninformed use of this tool is DANGEROUS!!!!

FDS GENERAL MODEL STRUCTURE

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- Hydrodynamics Model, Including Navier-Stokes Approximation Differencing Equations and Turbulence:
  - **Large Eddy Simulation (LES)** – Coarse Grids
  - **Direct Numerical Simulation (DNS)** – Fine Grids
- Combustion Model, Based on Scalar Quantity **Mixture Fraction**
- Radiation Transport Model, Based on **Finite Volume Method (FVM)** Including 100 Discrete Transport Angles
- Geometry (Gridding) Model for One or More **Rectilinear Grids**
- Boundary Condition Definitions, Assessed as Thermal as well as Physical Boundaries for Controlling **Heat and Mass Transfer**
- Fire Target Response Models, Including **Sprinkler and Detectors, and Water Sprays (Lagrangian Droplets)**

FDS APPLICATIONS

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- Low-Speed Transport of Heat and Combustion Products from Fires
- Radiative and Convective Heat Transfer Between Gas and Solid Surfaces
- Flame Spread and Fire Growth
- Interactions with Fire Suppression and Detection Systems

Water Mist Simulation Parameters

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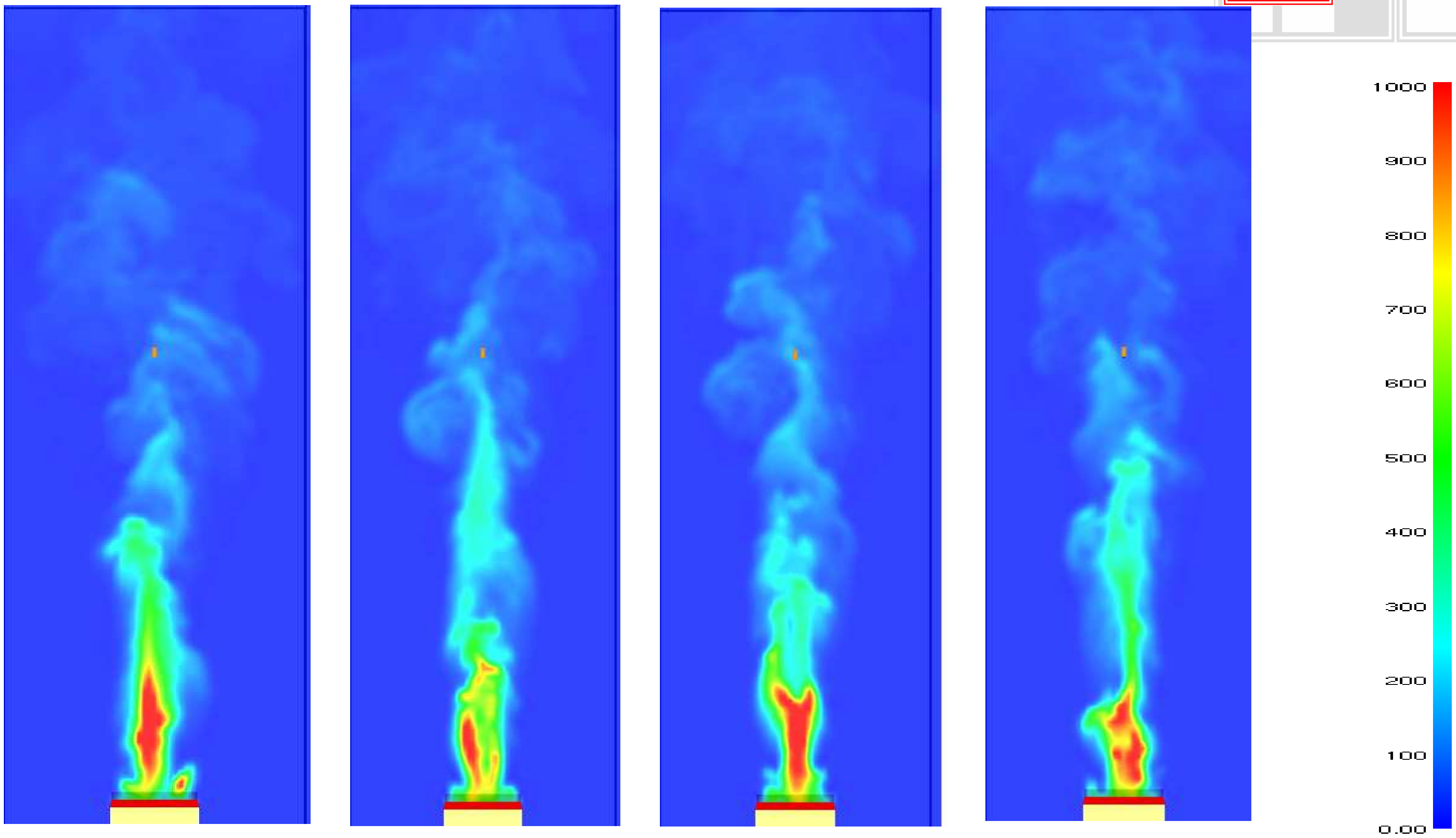
- The computational domain plan area of 1.08m x 1.08m and height of 3.6 m
- Except the ground, all other boundaries are set open
- Cells in the center of the fire were stretched to give a finer resolution of 1 cm
- Around two million cells resolution of 1.3 cm outside the center of fire region
- Methane burner with diameter of 30.0 cm and HR of 22 kW is used
- Droplet size to be considered were 50 and 300 μm
- The pulsation period of the fire depending on burner diamter is 0.33 s
- Simulated time = 20 s to reach fully developed stage

Results and Discussions



Temporal temperature distribution (FDS)

Water mist & Fire plume Interactions

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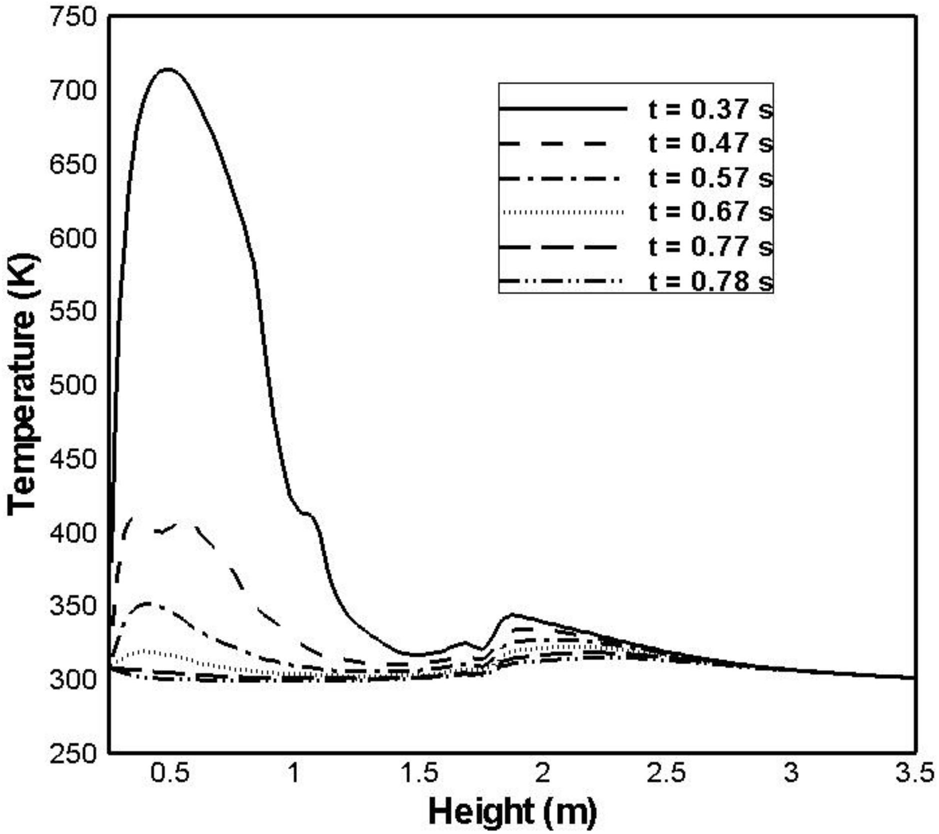
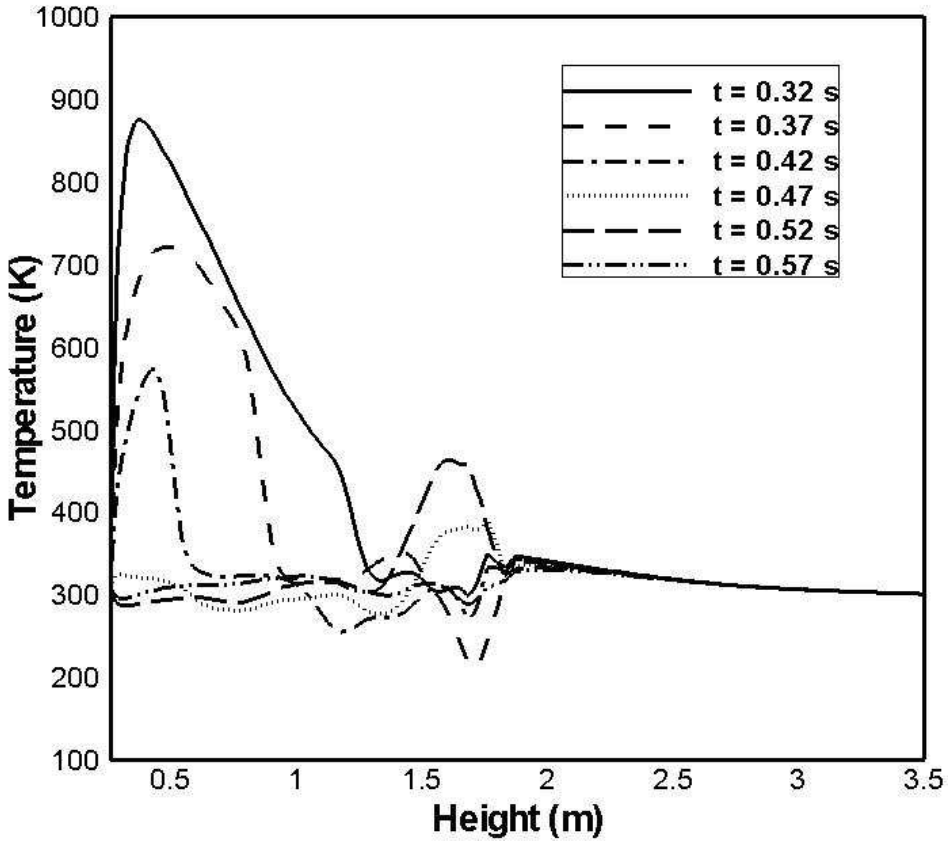
1. Momentum interaction: the injection of a water mist can change the gas flow pattern in the fire plume, which turn affect the flame structure and its heat and mass transfer characteristic
2. Thermal interaction: the evaporation of water droplet will cool the fire plume
3. Chemical reaction interaction: the chemical reaction rate in the fire plume is reduced due to lowered reaction temperature caused by the heat absorption of the evaporating water droplets

the performance of a water mist fire suppression may be affected by any combination of the above interactions.

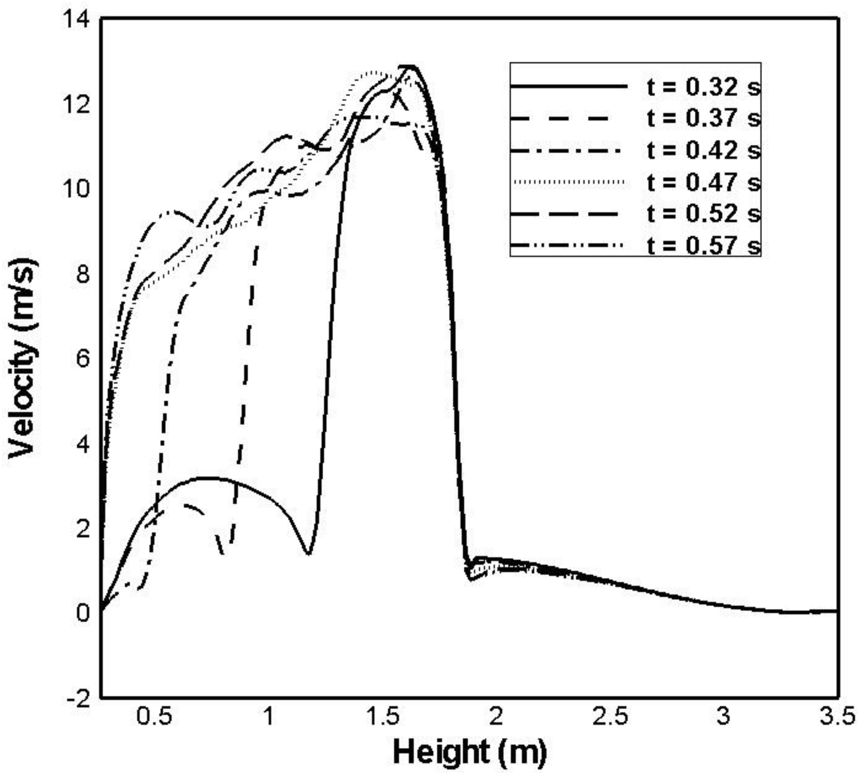
Gas Phase Temperature

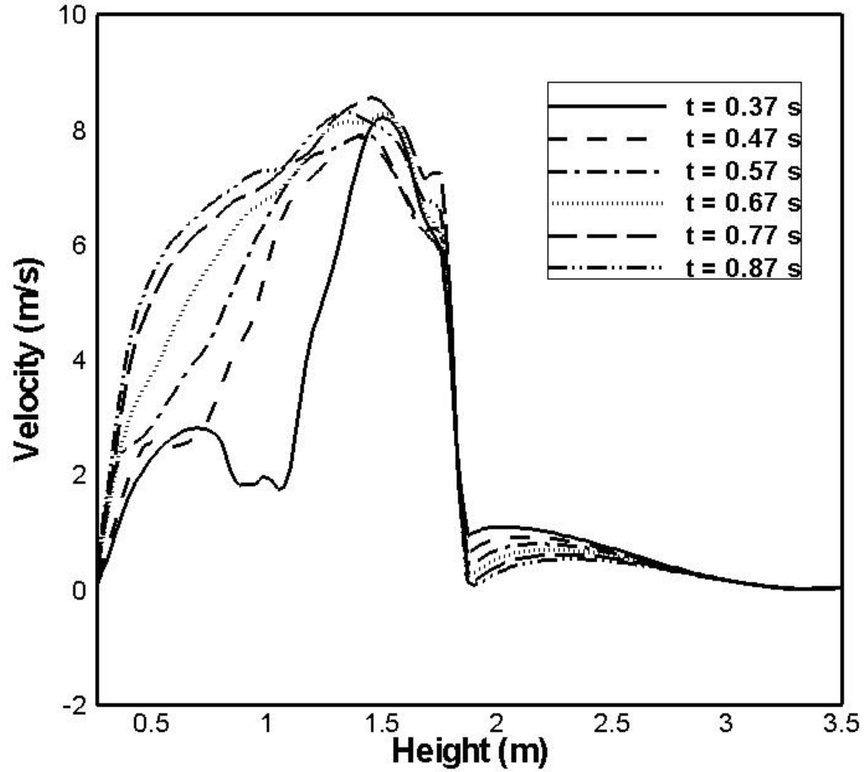




The temporal distribution of gas phase temperature along the vertical central line for different water mist size: (left) 50 μm and (right) 300 μm (FDS)

Gas Phase Velocity





The temporal distribution of gas phase velocity along the vertical central line for different water mist size: (left) 50 μm and (right) 300 μm (FDS)

Water spray modelling

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For forced convection, the heat transfer coefficient is normally correlated in terms of the Nusselt number, Nu, the Reynold number, Re, and the Prandtl number, Pr.

$$Nu = 2 + 0.6\,\mathrm{Re}^{1/2}\,\mathrm{Pr}^{1/3}$$

(Ranz and Marshall, 1952)

stagnant fluid

$$Nu = 2$$

high Re and the boundary layer is laminar

$$Nu = 0.6\,\mathrm{Re}^{1/2}\,\mathrm{Pr}^{1/3}$$

Water spray modelling cont.

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Since the heat and mass transfer correlations are analogous:

$$Nu = 2 + 0.6\,\mathrm{Re}^{1/2}\,\mathrm{Pr}^{1/3}$$

(Ranz and Marshall, 1952)

$$Sh = 2 + 0.6\,\mathrm{Re}^{1/2}\,\mathrm{Sc}^{1/3}$$

(Frössling, 1938)

Sh: the Sherwood number

Sc: the Schmidt number

Open discussions

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For forced convection heat transfer correlations

$$Nu = 2 + 0.6\,\mathrm{Re}^{1/2}\,\mathrm{Pr}^{1/3}$$

For forced convection mass transfer correlations

$$Sh = 2 + 0.6\,\mathrm{Re}^{1/2}\,\mathrm{Sc}^{1/3}$$

Is it feasible using the above correlations at nanscale???

Conclusions

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- Numerical simulation has been performed using FDS to investigate the interaction betwen the fire plume and water mist.
- The droplets size of 50 and 300 µm have been considered.
- The finer water mist led to higher water evaporation rate cooling the fire plume and hence reducing the buoyancy effect.
- The finer water mist was then able to penetrate and suppress the fire plume more effectively.

Thanks for your attention

Dr. Hemdan Shalaby
Hemdan.Shalaby@idf.uni-magdeburg.de