Coupled Heat Transfer Processes during Fires – A New Model and its Application to Nuclear Facilities

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- Development of the heat transfer model
  - Model for convective heat transfer between gas phase and solid phase
  - Model for multidimensional heat conduction
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- Conclusion and outlook

Problems and aims

- consideration of the heat transfer to as well as within the solid phase in numerical fire simulations only possible with strong limitations so far
- focus of further developments: specification of the gas phase as well as modeling of pyrolysis and combustion processes
- possibilities in the fields of convective heat transfer and heat conduction currently available not sufficient for a lot of tasks
- direct coupling of the gas phase and the solid phase with each other is an absolute necessary basis for both sub systems

Problems and aims

- Improvement of the modeling of convective heat transfer
  - ∇ amongst others to consider special situations in a fire scenario as they appear for example in the context of ventilation ducts
- Improvement of the modeling of heat conduction within the solid phase within numerical fire simulations
  - ∇ multidimensional consideration of complex objects
  - ∇ interaction of gas phase and solid phase in both directions, i. e. including the feedback on the fire event

Status of knowledge

- Convective heat transfer in numerical fire simulations
  - ∇ Zone Models: amongst other things no velocity fields
  - ∇ CFD Models: dependency on how the gas phase related values are determined (DNS, RANS, LES, ...)
    - ⇨ sub models for convective heat transfer necessary
    - ⇨ empirical correlations (e. g. Nusselt relations)
  - ∇ current modeling of the convective heat transfer in fire simulations is insufficient and even wrong in several areas
    - ⇨ model or a modus operandi is necessary to be able to represent convective heat transfer appropriately

Status of knowledge

- Heat conduction in numerical fire simulations
  - ∇ global energy considerations
  - ∇ one-dimensional heat conduction through a homogeneous or in thickness direction layered (“multi-layer”) solid phase
    - ⇨ model for multidimensional heat conduction (“multi-cuboid“) required
- currently
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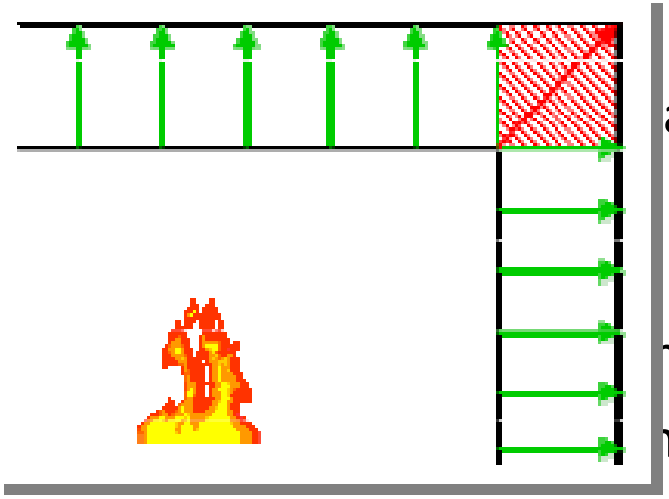
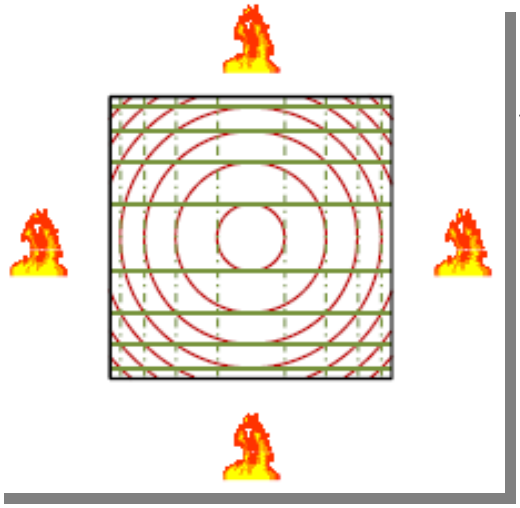




Development of the heat transfer model

- Model for convective heat transfer between gas phase and solid phase
- Model for multidimensional heat conduction

⇨ heat transfer model for coupled processes in fire simulations

- ∇ optimized both **physically** as well as **numerically** for the **integrated** usage within numerical fire simulations
- ∇ with a view to a parallelization of the model
- ∇ basis for upgrading with appropriate pyrolysis models
- ∇ Integration into the state-of-the-art fire simulation code “Fire Dynamics Simulator“ (FDS)

⇨ details of the model included in the paper

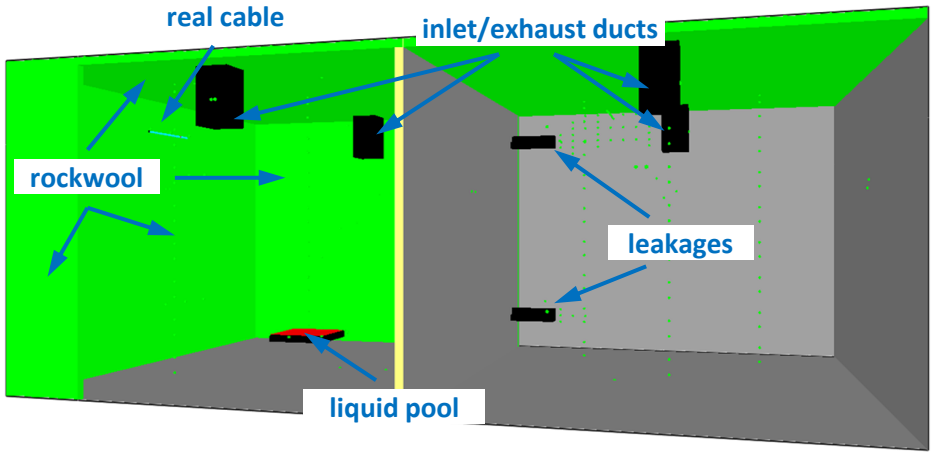
Verification and validation of the model

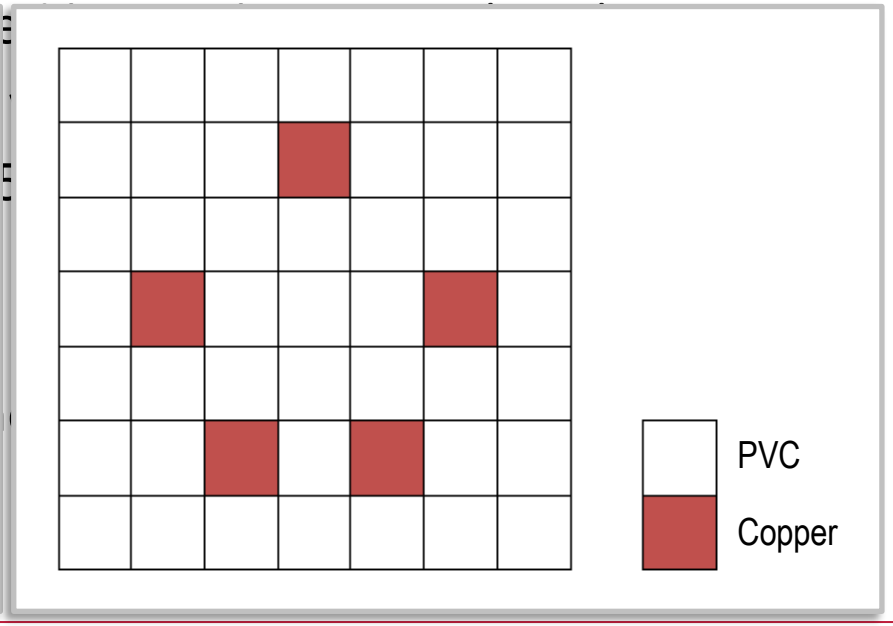
- Heat conduction including convective heat transfer
  ⇨ National Annex of Eurocode 1-1-2
- Transient multidimensional heat conduction with convective and radiative heat transfer
- Heat conduction with heat source/sink
- Convective heat transfer in tube/duct flows

⇨ included in the paper and further cases in literature mentioned there

Application of the model

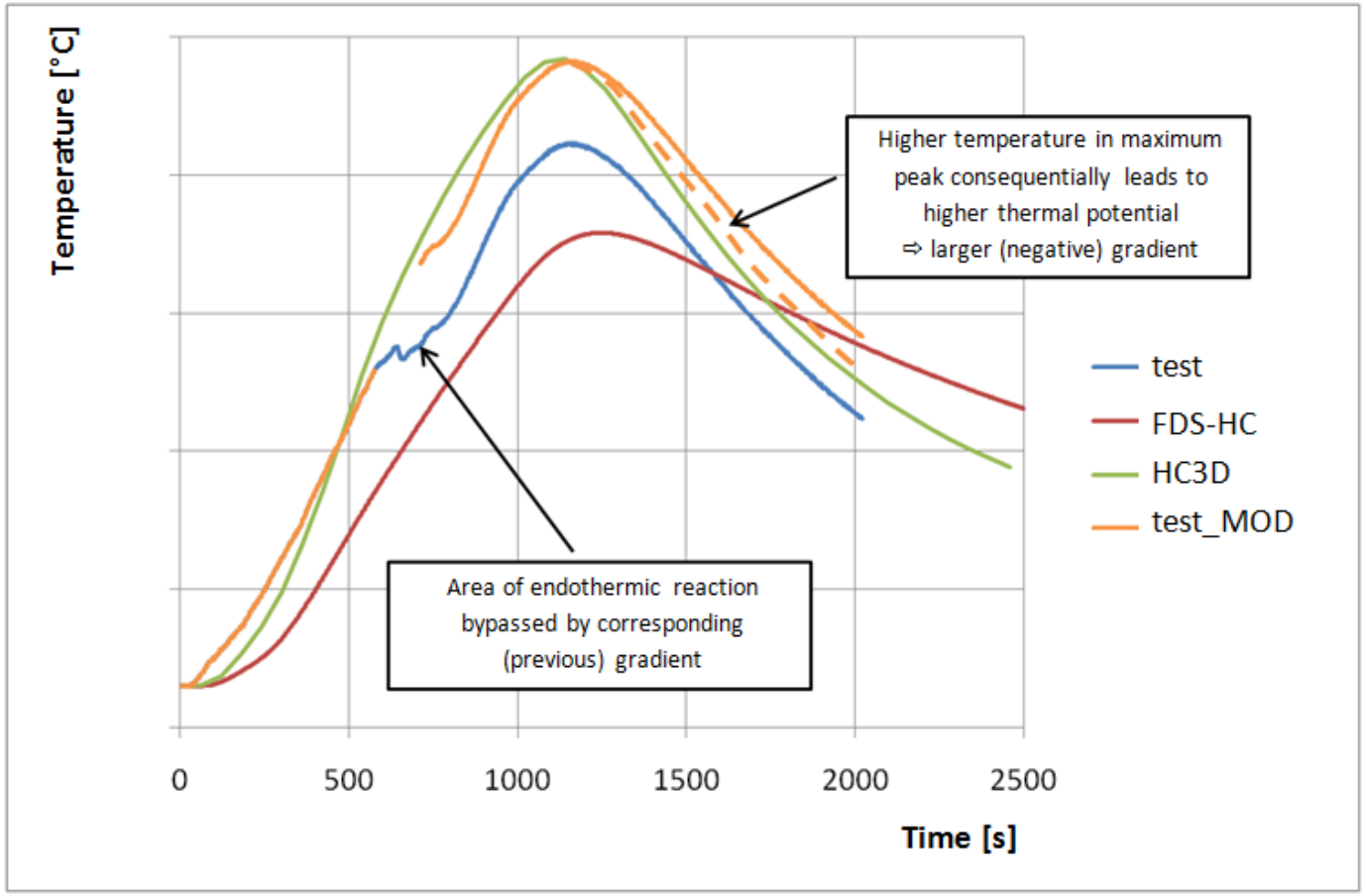
- model for experiment
  - ∇ Fire and target room
  - ∇ Leakages
  - ∇ Target: real cable
- basic input parameters
  - ∇ Fire source
  - ∇ Ventilation
  - ∇ Mesh [cm]
  - ∇ Initial tem
  - ∇ Cable
    - PVC: λ an
    - Copper: λ
    - Cable des





Application of the model

- Temperature inside the cable



Conclusion

- Heat transfer model for coupled processes in fire simulations developed
  - ∇ Improvement of the modeling of convective heat transfer between gas phase and solid phase
  - ∇ Improvement of the modeling of heat conduction within the solid phase
  - ∇ Basis for pyrolysis models
- Integration into state-of-the-art fire simulation code
- Extensive verification and validation of the model
- Successful application to practical fire scenarios, amongst others in the context of nuclear facilities

Outlook

- Combination of multidimensional heat conduction with pyrolysis
- Analysis and formulations for the boundary layer (in the gas phase at the surface of the solid phase) when pyrolysis occurs and affects the flow
- Integration into state-of-the-art fire simulation code
- Application to practical fire scenarios, especially in the context of nuclear facilities

Contact

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