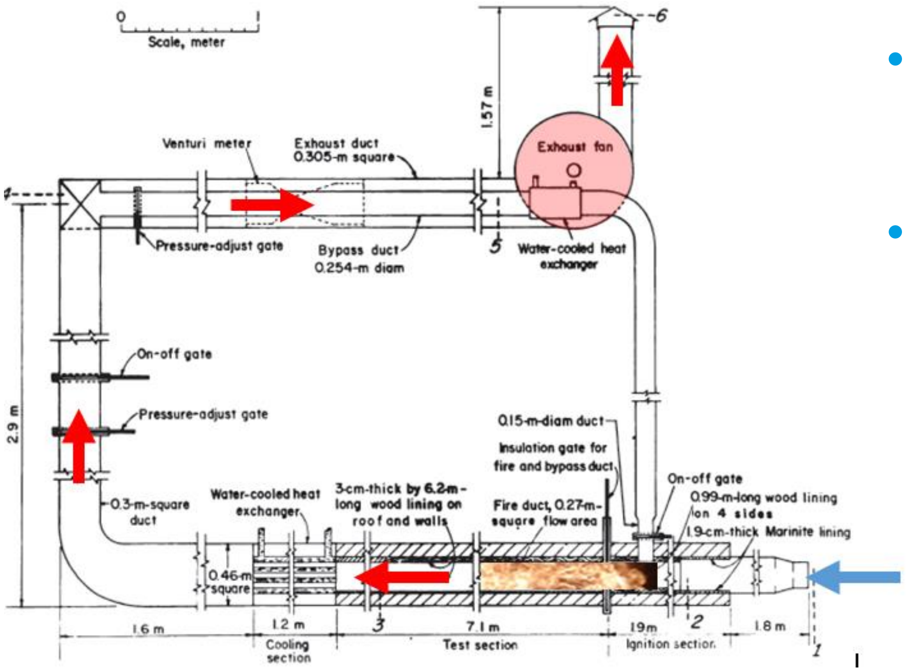
Ingo Riess, Daniel Weber, Michael Steck

On the air-flow resistance of tunnel fires in longitudinal ventilation – the “Throttling Effect”

Introduction



- Chaiken, Singer et al. (1976-80)
- «changes in pressure drop [...] indicate the presence of an additional pressure drop [...] that throttled the ventilation air flow.»

Previous Studies

- Studies based on 1d and 3d CFD simulation
- General consensus: the throttling effect depends on
  - heat release rate,
  - upstream flow velocity, and
  - tunnel cross section (D_h or A_T)
- No consensus on the formulation

Assumptions

- The flow resistance of a tunnel fire consists of several effects (Chaiken & Singer)
  - Reduction of static pressure at the fire location (expansion and acceleration),
  - Increased wall friction downstream of the fire (increased air-flow velocity),
  - Increase of static pressure (cooling at the tunnel wall and deceleration),

  } pen & paper

  - And 3d effects not included in the above. → CFD

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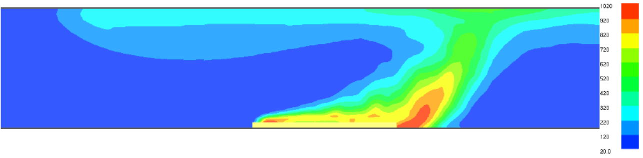
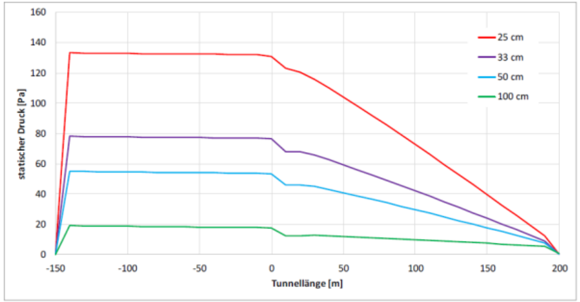
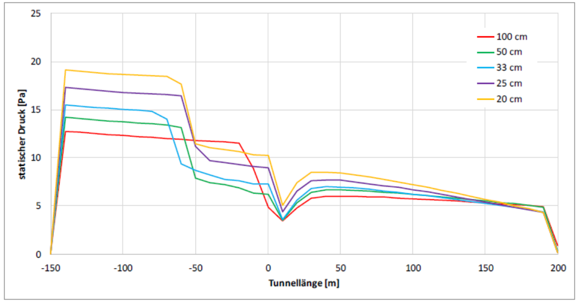
CFD – Fire Dynamic Simulator





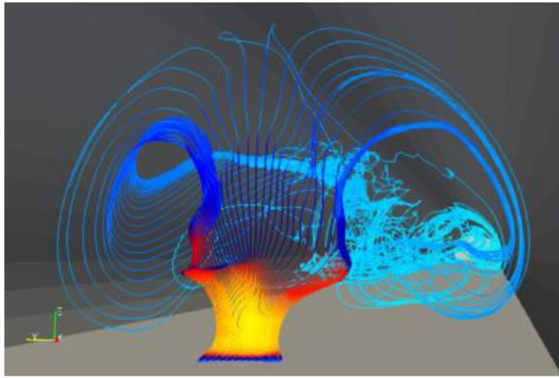


rmcdermo commented on 16 Jan — Author — Contributor

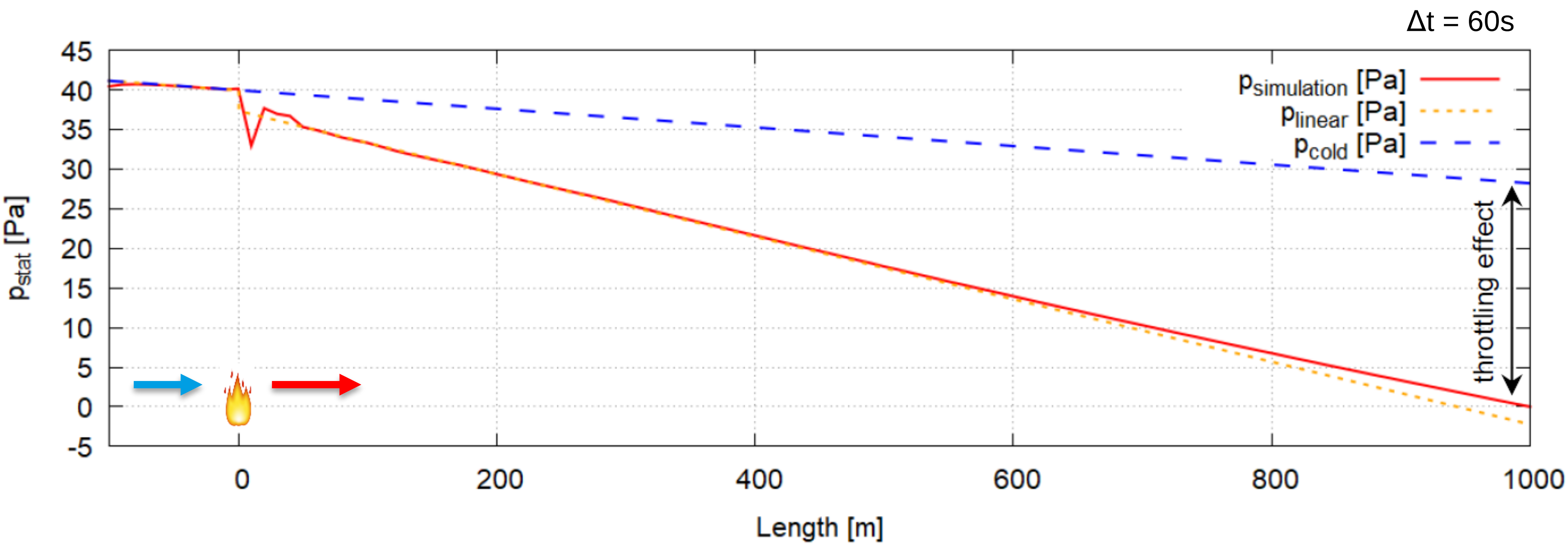
@ [redacted] Fluctuations don't bother me. The flow is quasi-transient, as are all LES calculations. What bothers me is (1) that the solution does not converge and (2) that CP(T) gives drastically different results from CP even though CP(T) is nominally constant. This is a problem, which, if we do not understand, means we cannot hope to have reliable tunnel simulations.

CFD - OpenFOAM

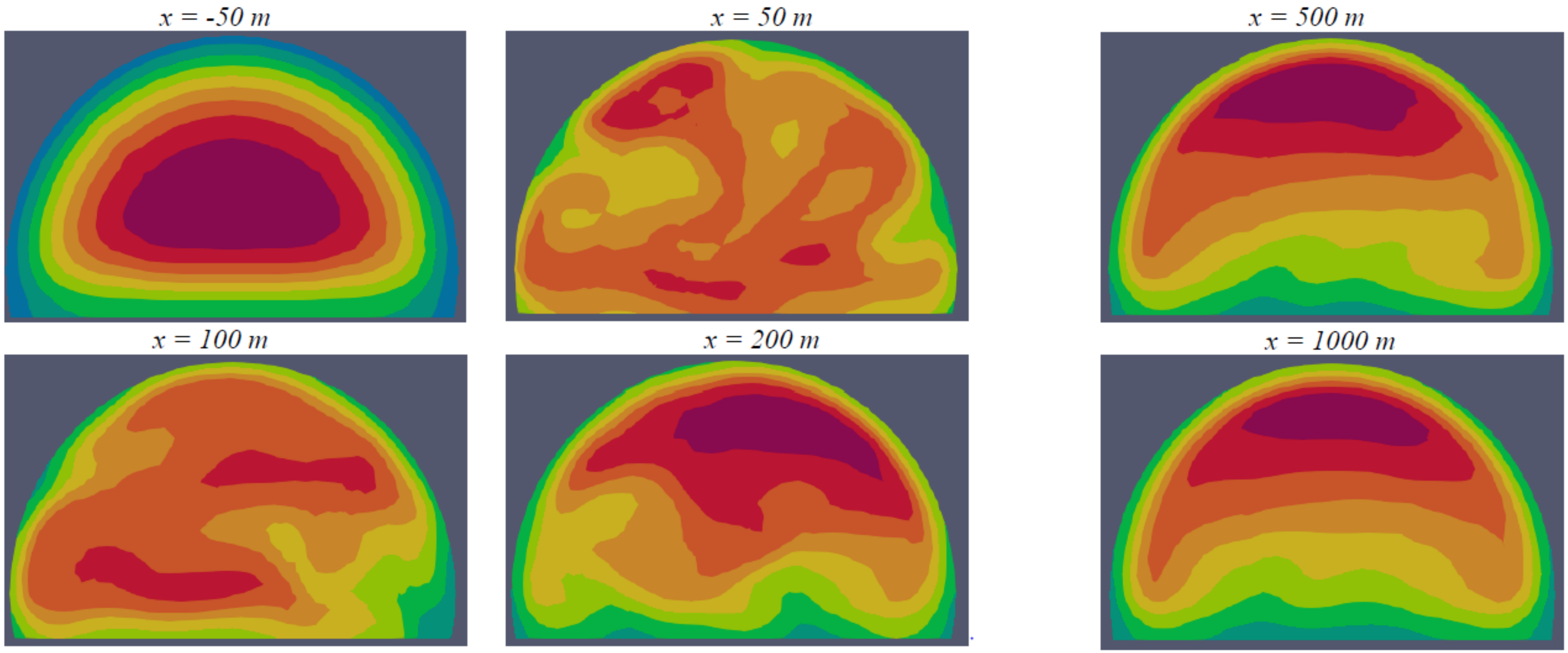
- OpenFOAM Version 1812, FireFoam
- For details, see → proceedings or → report (German)
- Parameter variation:
  - Heat release rate from 2 MW to 34 MW,
  - Upstream velocity from 1 m/s to 4 m/s,
  - Tunnel cross-section from 52 m^2 to 136 m^2, and
  - Height of the tunnel profile from 5.2 m to 9.0 m.



Pressure Profile



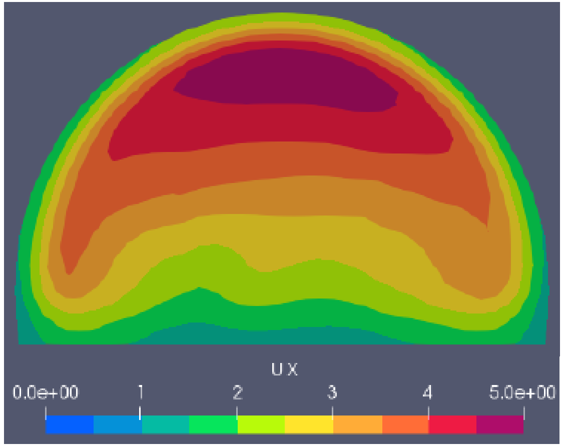
Flow Profiles



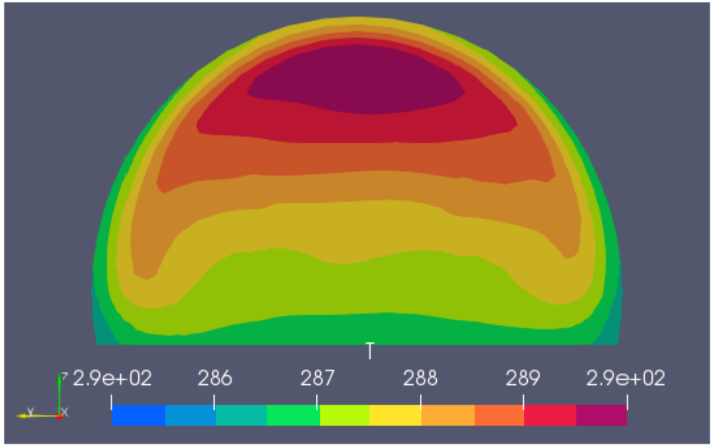
Flow vs. Temperature

Flow Velocity

$x = 1000\ m$



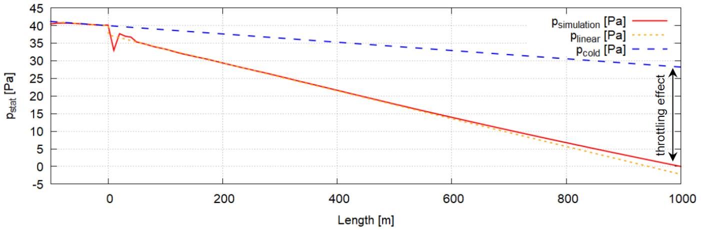
Temperature

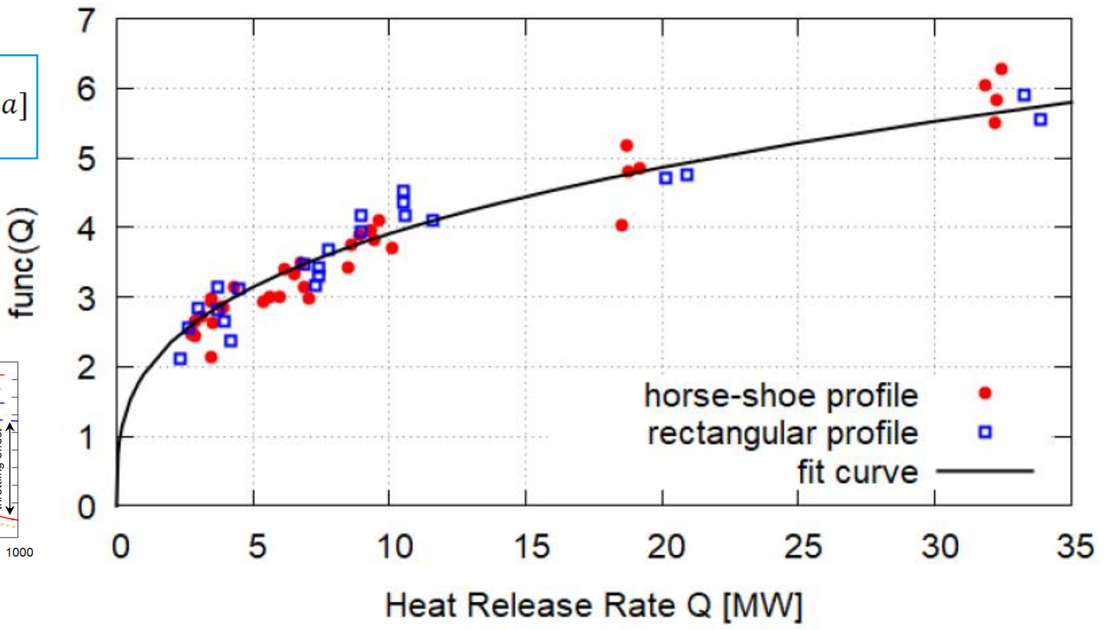


Data Processing

$$\Delta p_{2-3C} = A \cdot Q^B \cdot u^C \cdot A_T^D \cdot H_T^E$$

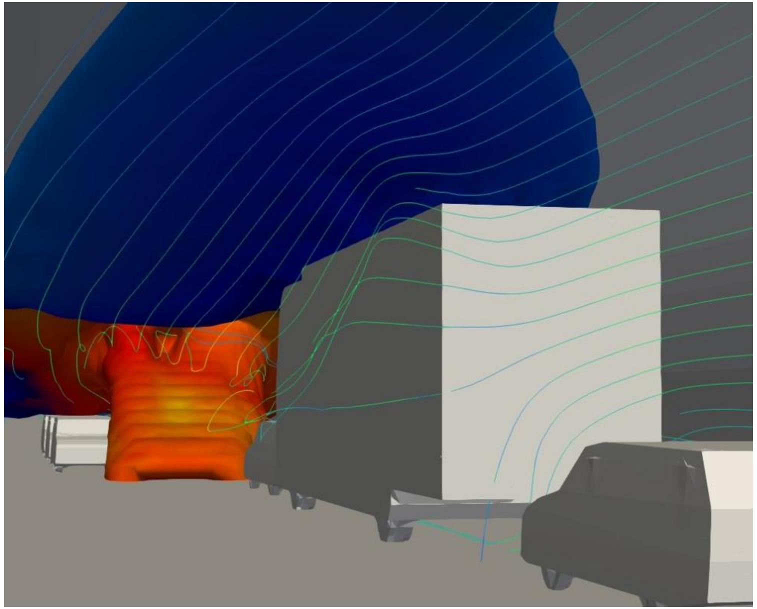
$$\Delta p_{2-3C} = -1.894 \cdot \frac{Q^{0.315}\, u^{1.136}\, H_T^{0.608}}{A_T^{1.295}} \cdot \frac{L_3}{500m}\ [Pa]$$



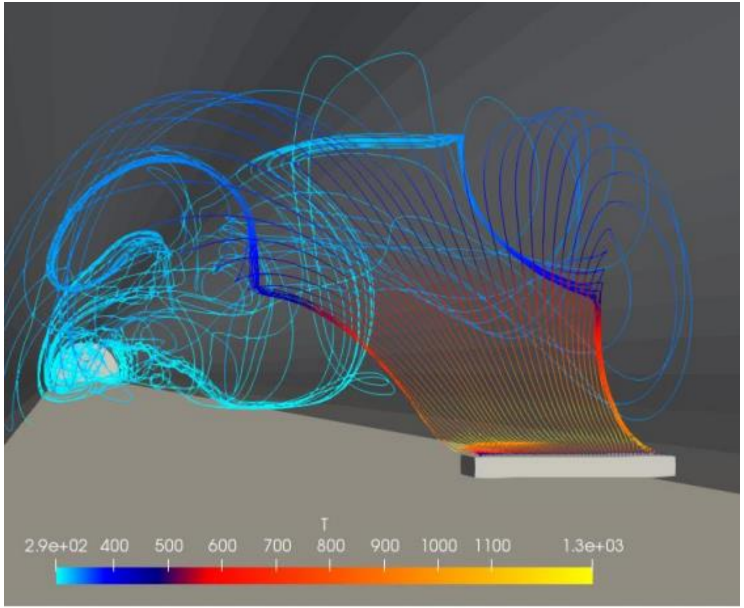


Other Scenarios

- Vehicles

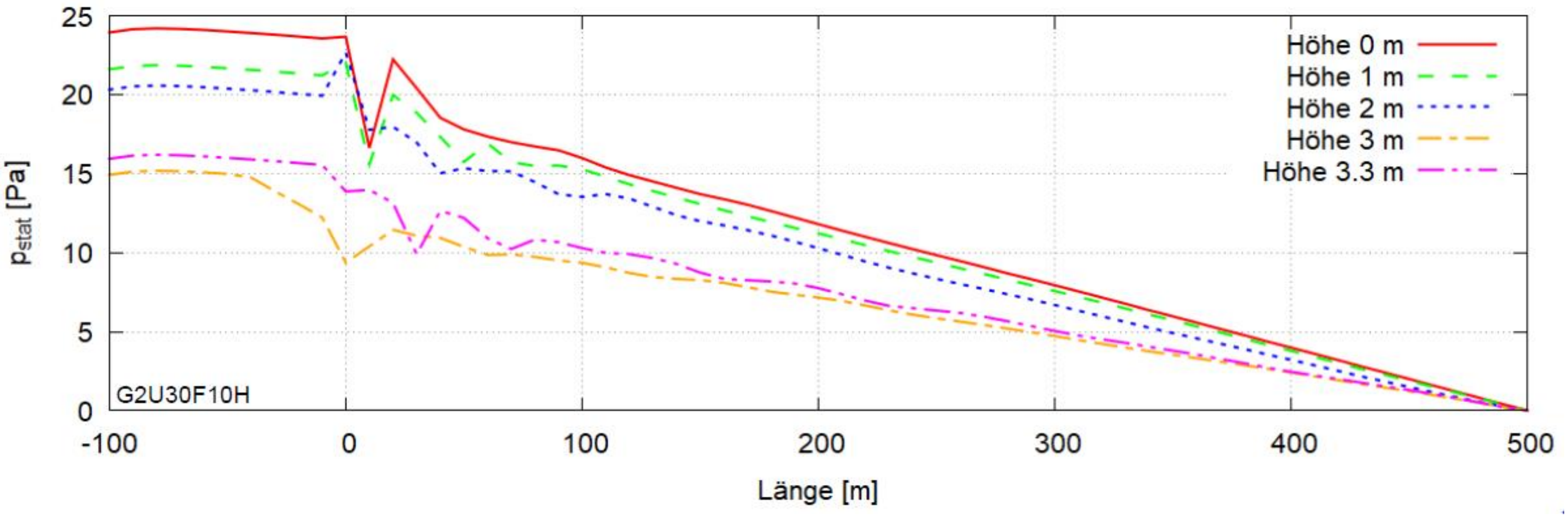


- Fire Height



Variation of Fire Height

- The selected pan fire on the road surface is a worst case assumption for the pressure drop.



Conclusions

- The study confirms the observation of a pressure drop due to a tunnel fire in longitudinal ventilation. The “Throttling Effect” is described as the sum of several contributions.
- Temperature stratification contributes to the pressure drop even far beyond the extent of the fire.
- The CFD simulations shown in the paper should be supported by further experimental evidence.

Thank you!

- The study is available as PDF: https://lnkd.in/dcYK3-i
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