FLAME ANGLE, SMOKE AND CFD SIMULATION

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Introduction

Based on the plume experiments of McCaffrey and Heskestad, a test series of fires by a propane burner conducted in the year 2010 showed some differences between the measured temperatures and the predicted ones by the plume, see in Tab. 1. The axial symmetric temperatures of the experiments are not the highest ones, because the flame and plume were declined. This was caused by the inflow of the supply air through a door (1m x 2.1m) into the test room with an area of 96 m².

Tab. 1: Compare of Measured and Plume Temperatures (°C) of 100 kW fire

Burning Area	0.09m²			0.81m²		
Measuring heigh (m)	0.5	2.0	3.5	0.5	2.0	3.5
Experiment in 2010	489	80	51	274	65	52
The Ideal Plume		108	52		108	52
Heskestad		169	72		107	58
McCaffrey	857	163	74	857	164	74

The inflow velocity of the supply air, that depends on the geometry of the surroundings as well as on the dimension of the fire (HRR, Area) specifies the smoke production and the temperature distribution in the plume and also flame development based on the resultant flame angle [1]. Further research on the flame spread and exhaust flow done by Steckler, Drysdale...etc. associates the influence of the flame angle to the smoke production, which could be three times higher as predicted by the plume equations due to the different plume behavior [2].

Methodology

To investigate systematically the relationship between the smoke production and the flame angle, together with the inclination of the plume, CFD simulations were carried out. The experiments of the Steckler compartment are the initial and reference scenario to validate the CFD program FDS 5.5.3 for this use (Fig. 1).

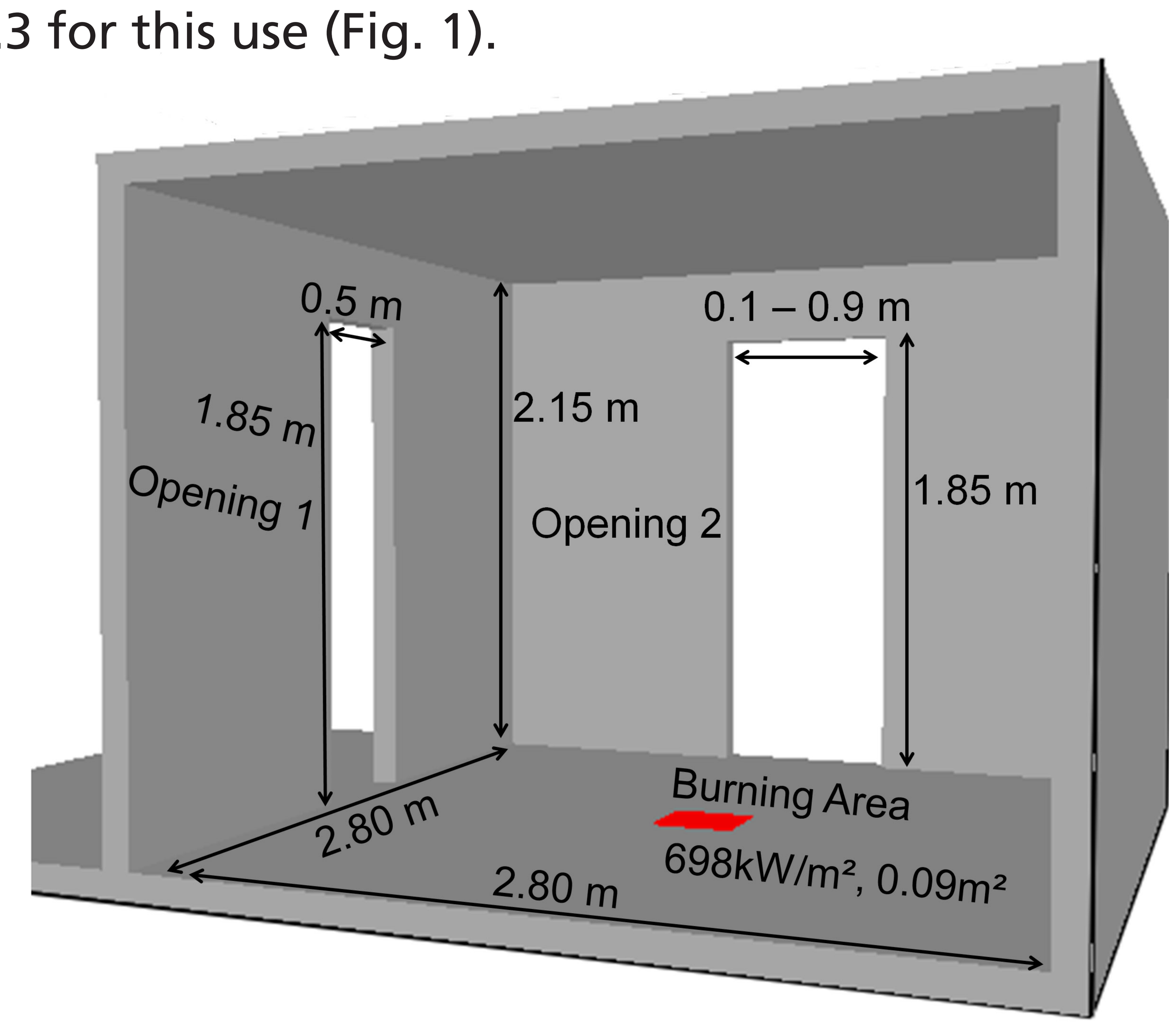

Fig. 1: Geometry of FDS based on [1]

The original experimental geometry of Steckler is extended in terms of an additional opening with varied width, to enable a higher inflow of fresh air into the room from different directions. The flame angle is determined by the highest temperatures from the center of the burning area by following the temperatures for every level of thermocouples (Fig. 3). It is distinguished in the angle at the bottom without regarding the thermal buoyancy β and the inclination of the flame α. The correlation between the mass flow rate of the exhaust gases throw the first opening and the flame angle is shown in Fig. 2 and 4.

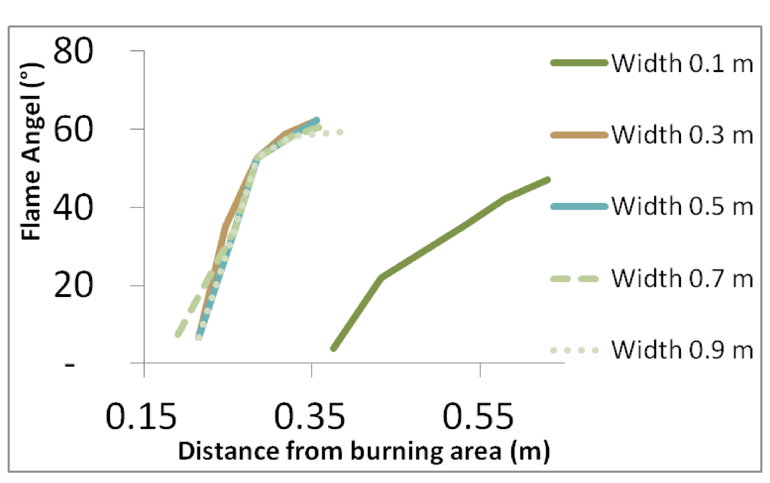

Fig. 2: Flame Angle α

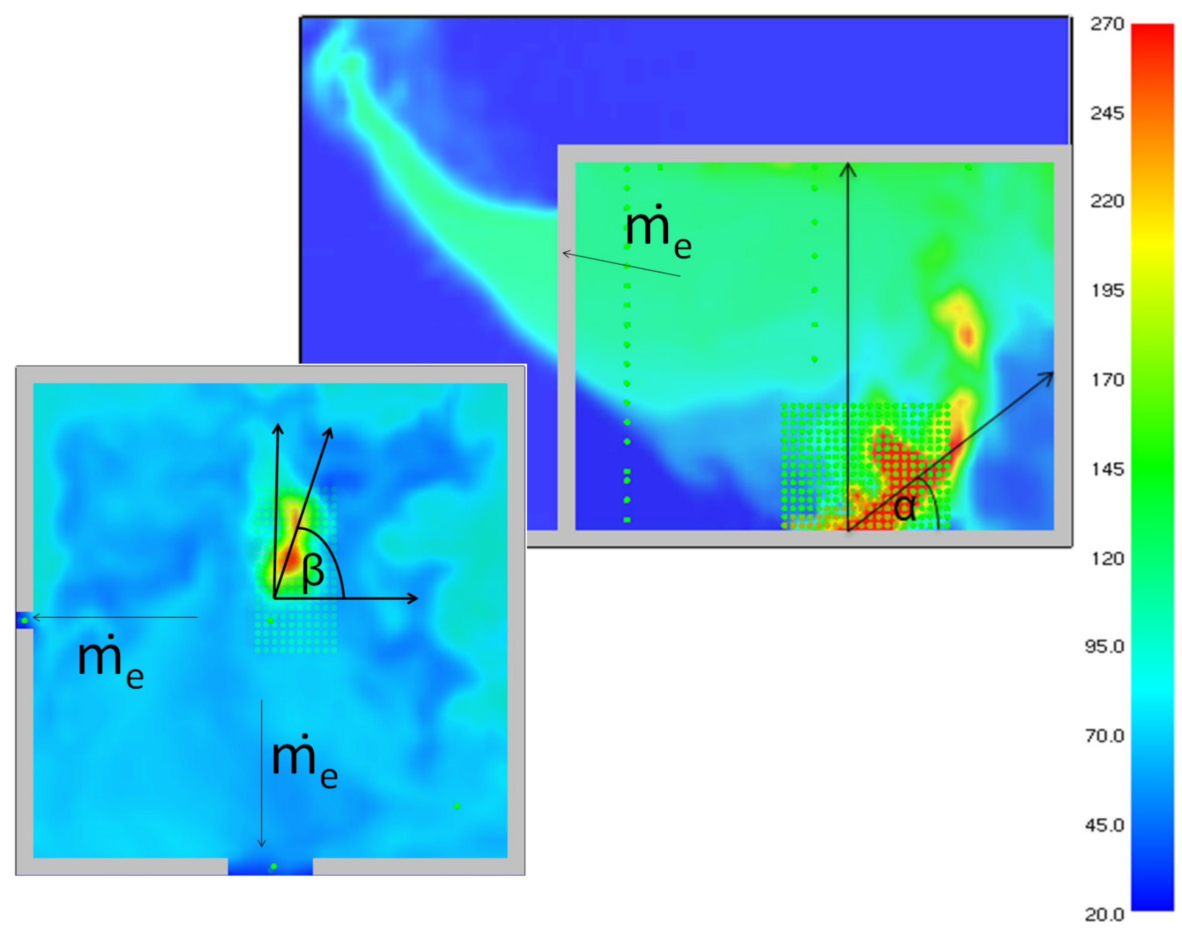

Fig. 3: Determination of Flame Angel by Temperature

Results

- The additional opening (No.2) larger ≥ 0.3 m dominates the bottom angel β and the flame moves horizontally.
- For an opening (No.2) of 0.1 m the influence on the flame angel α is maximal, because of the inflow velocity of opening No. 1.
- The mass flow rate m_e through the first opening decreases with an increase of the dimension of the second opening.
- Because of the decreasing velocity through a larger opening the inclination of the flame angel is reduced, as well as the the mass flow rate m_e.

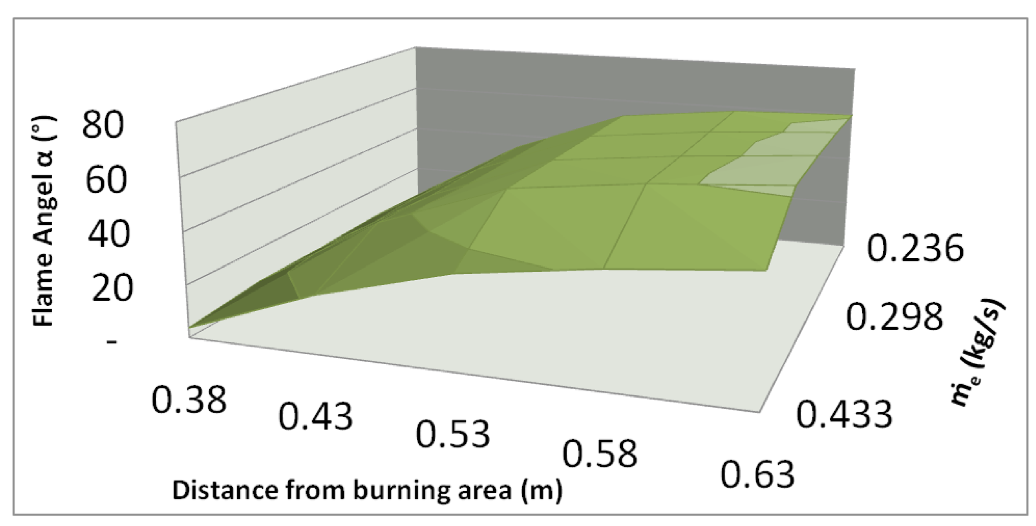

Fig. 4: Correlation between Flame Angle and m_e

Conclusion

- For profound knowledge further simulations with varied influences like the heat release rate and the arrangements of the opening are necessary.
- As a result the limitations of the plume equations can be shown for room fires.

References

- [1] Steckler, K.D.; Quintiere, J.G.; Rinkinen, W.J.: NBSIR 82-2520, Flow induced by a Fire in an Compartment. September 1982, US Department of Commerce; Washington, DC., 1982
- [2] Quintiere, J.G.: Rinkinen, W.J.; Jones, W.W.:The Effect of Room Openings on Fire Plume Entrainment. Combustion Science and Technology, Volume 26, Page 193-201, Gordon and Breach Science Publishers Inc., Great Britain, 1981

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