Quantifying Open Parameter Effects in Cone Calorimetry Using Optical Techniques

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Introduction

The cone calorimeter is a standard device for evaluating material fire behavior. While general test setups follow standards (e.g., ISO 5660 [1], ASTM E1354 [2]), key operational parameters – like sensor placement, ventilation, and ambient airflow – can vary.
These flexible parameters can significantly influence calibration and key measurements like heat release rate (HRR), yet their effects are not well documented. This lack of clarity can lead to inconsistent or non-comparable results across measurements.
In this study, we systematically investigate how variations in the vertical placement of sample and cone, as well as ventilation (influenced by door configuration) affect critical outputs including HRR, smoke production, and flow field dynamics.
By quantifying these influences, we aim to enhance the reliability and reproducibility of cone calorimeter experiments. Additionally, this research aims to improve the scientific validation of the cone calorimeter as a reliable tool for academic and research-based fire testing applications.

Methodology

Controlled cone calorimeter experiments are conducted with systematically varied open parameters.

To assess temperature and flow fields, we apply advanced optical diagnostics:

- Infrared imaging (IR)
- Particle image velocimetry (PIV)
- Background-oriented Schlieren (BOS)

Comparative analyses are performed for:

- Measurement positions: keeping sample and cone at varying distances from the hood (1)
- Ventilation conditions: open vs. closed doors
- External influences: with vs. without draft

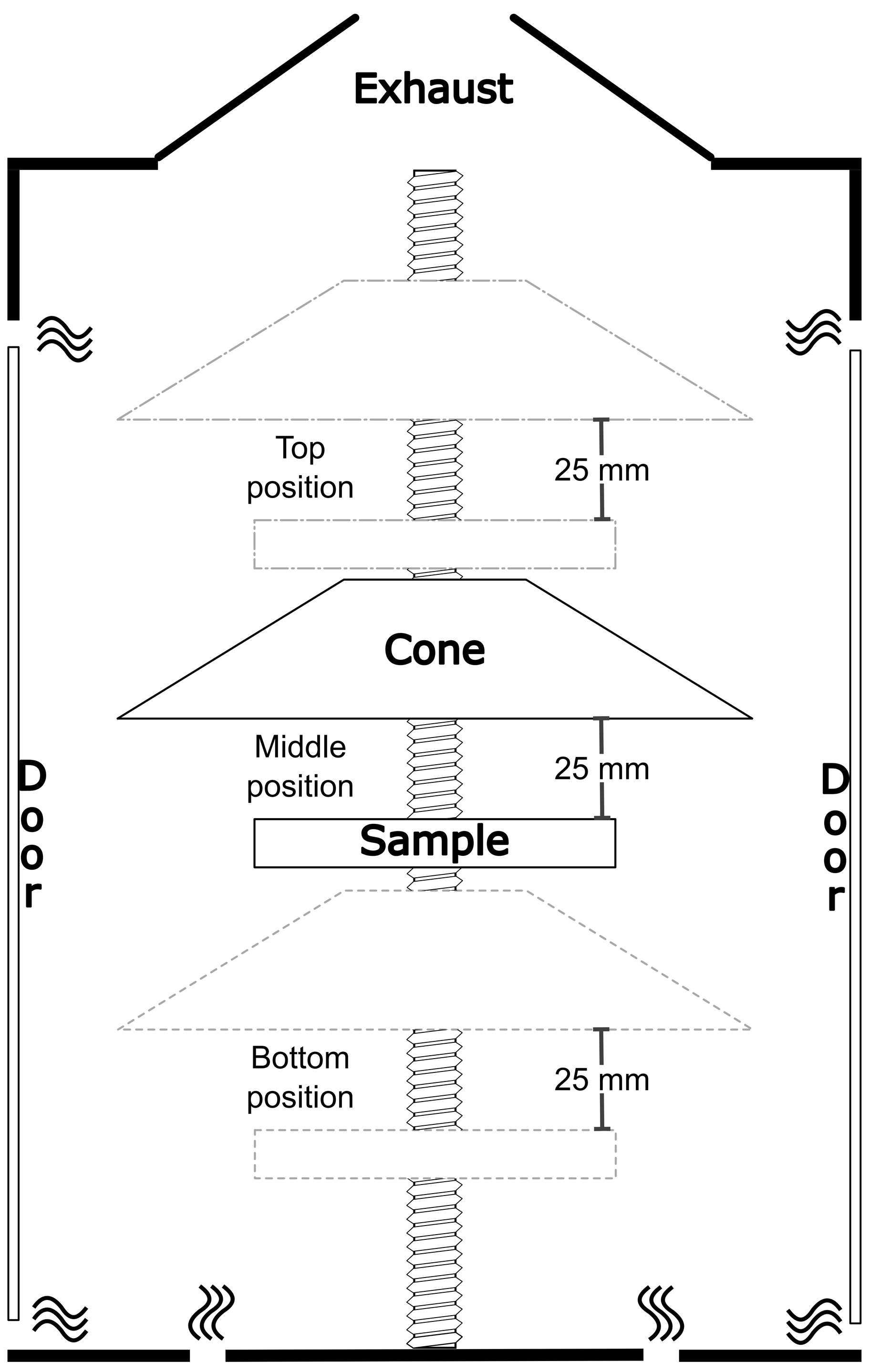

Figure 1: *Schematic of the different measurement positions during a cone experiment. Solid lines represent a typical experiment whereas dotted lines show other possible positions. Wavy lines indicate inlets for ambient air*

Preliminary results

Preliminary experiments were performed to assess the initial heat distribution that the cone (heat flux of 50 kW m^{-2}) imposes on the sample, using an infrared camera. The resulting data for distances of 25 mm and 75 mm are shown in Figure 2. The measurement was repeated for different distances between sample and cone.

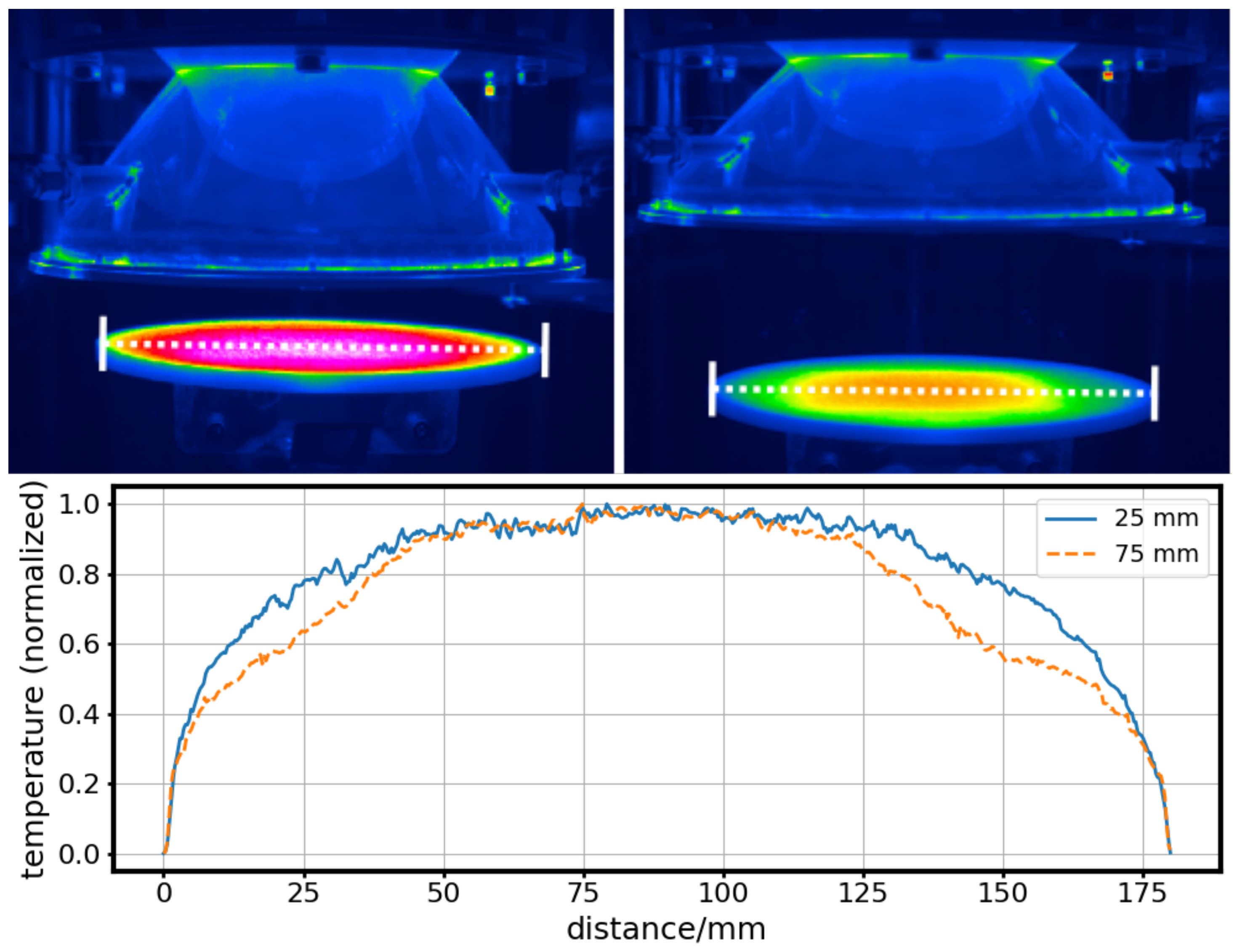

Figure 2: *IR image of heat imposed by cone heater at* 25 mm *and* 75 mm. *The images show the surface temperature distribution, with horizontal white bars indicating the measurement region. Temperature profiles show higher peak and uniformity at* 25 mm.

A second experiment examined the influence of the position of sample and cone. The distance between sample and cone was fixed to 25 mm according to the ASTM regulation. The setup was positioned sequentially at the top, bottom, and midpoint of the apparatus (Figure 1). Samples of black PMMA with a thickness of 10 mm were burned with an incident heat flux of 50 kW m^{-2}. The resulting heat release rates are plotted in Figure 3.
In the plot, one can already observe a change in the HRR decay time for the setup with closed doors. Here, the HRR drops to zero approximately 20 s earlier compared to the open-door configuration. When comparing the area under the curves, it becomes evident that it is approximately 3.6 % smaller in the closed-door case.

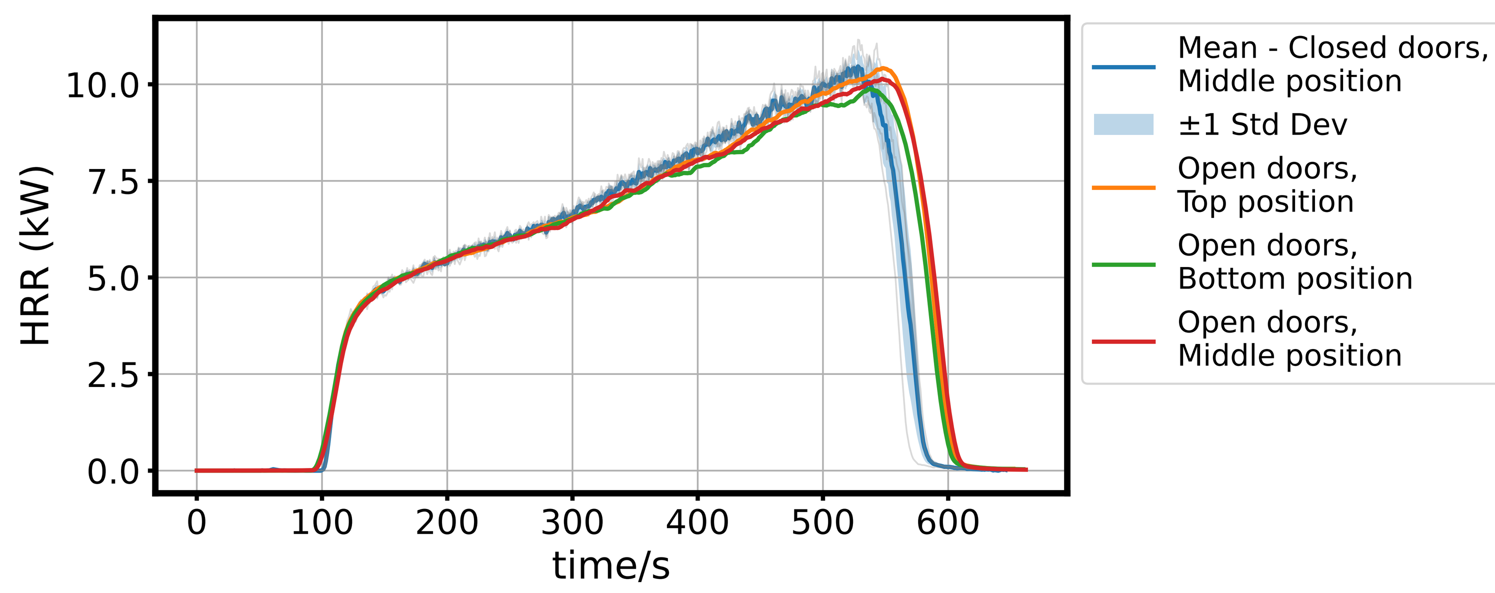

Figure 3: *Heat release rate with open calorimeter doors compared to measurements with closed doors*

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GEFÖRDERT VOM Bundesministerium für Bildung und Forschung

References

[1] *ISO 5660-1:2015. Reaction-to-fire tests — Heat release, smoke production and mass loss rate - Part 1: Heat release rate (cone calorimeter method) and smoke production rate (dynamic measurement).* Standard. Geneva, Switzerland: International Organization for Standardization, 2016.

[2] *ASTM E1354-23 Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter.* Standard. ASTM International, 2024.