RWTH AACHEN UNIVERSITY

HP0967

A Fast Laser Optical Method for the Evaluation of the Ventilation Effectiveness

Introduction

For large rooms and sufficiently large nominal time constants the tracer gas method is well established and documented. However, as the nominal time constant becomes smaller, as in highly ventilated storage rooms or passenger cabins, for example, the validity of the method is limited due to

(I) the limited response time of the tracer gas sensors

(II) measurement errors caused by diffusive mixing during the transport time between the sampling location and the analyzing device.

Research methods

Instead of a tracer gas an aerosol is used for concentration decay measurements. Laser Doppler velocimetry (LDV) instrumentation is used to determine the concentration of particles at a local measurement volume. Due to the high temporal resolution of the measurement system, every particle of the aerosol crossing the measurement volume can be detected. Thus, the number of detected particles in a defined period of time corresponds to a time average particle concentration of the aerosol.

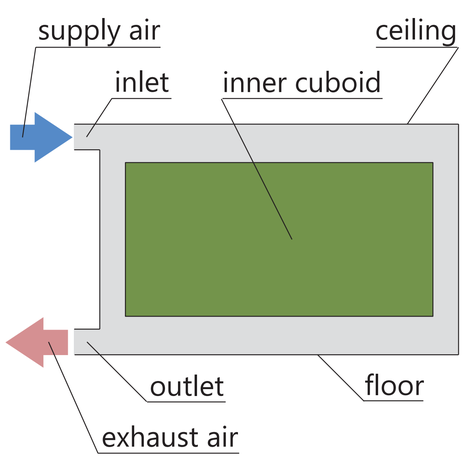

Fig. 1: Schematic cross section of the experimental setup (side view)

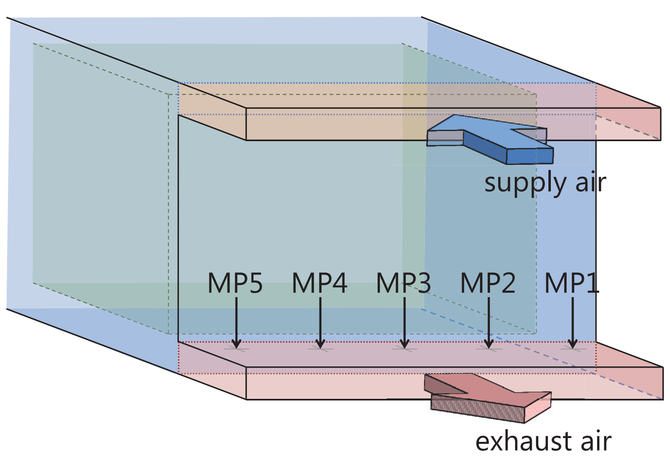

Fig. 2: Measurement positions (MP1…5) at the exhaust (isometric front view)

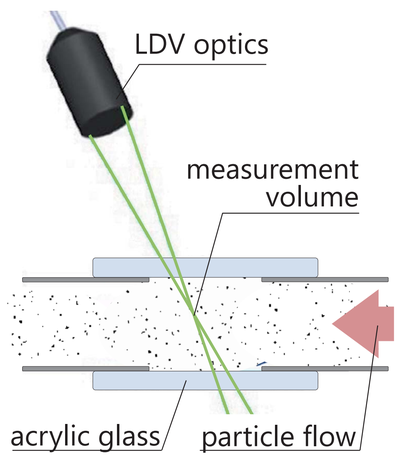

Fig. 3: Measurement position of the LDV focus (cross section)

Theoretical background

In general, the air inside a room needs to be exchanged in order to maintain the desired air quality. If the air exchange is realized by a mechanical ventilation system, it is reasonable to optimize the system with regard to both the comfort in the occupied zone and the overall energy efficiency. This is described by the

Ventilation Effectiveness. The term is used to express how well the air is exchanged and how well contaminants carried by the air are removed from a room by a particular ventilation system. Under certain circumstances it can also be used to determine the energy demand for the removal or the supply of a heat flow inside a room. Utilizing the concept of the age of air and comparing the shortest possible air exchange time (τ_n, nominal time constant) to the actual time leads to the

Air Change Efficiency ε^{α}. The highest possible air change efficiency (100%) is achieved by ideal piston flow. Lower air change efficiencies occur for non-ideal flow patterns. Usually, the ventilation effectiveness is evaluated by measuring the concentration of a tracer gas in the room air at discrete times. In this time study, the so-called step-down method was used, in which the concentration decay min the exhaust air $c_e(t)$ is recorded in order to determine the room mean age of air and, thus, the air change efficiency.

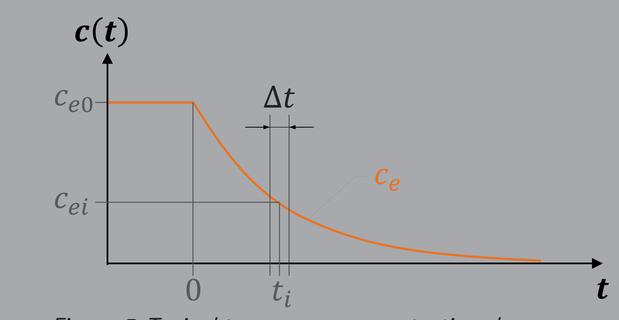

Figure 5: Typical tracer gas concentration decay curve measured in the exhaust air of an ideally mixed flow; according to: Mundt et al (2004)

Results

Measurement results of three single measurements at measurement point MP5 under identical boundary conditions are shown in figure 4. A nominal time constant of 2.46 s was set in this ventilation configuration. The averaged local air change efficiencies ($\varepsilon^{\alpha}_{MP1}$ to $\varepsilon^{\alpha}_{MP5}$) are used to calculate a global value for the air change efficiency of the room.

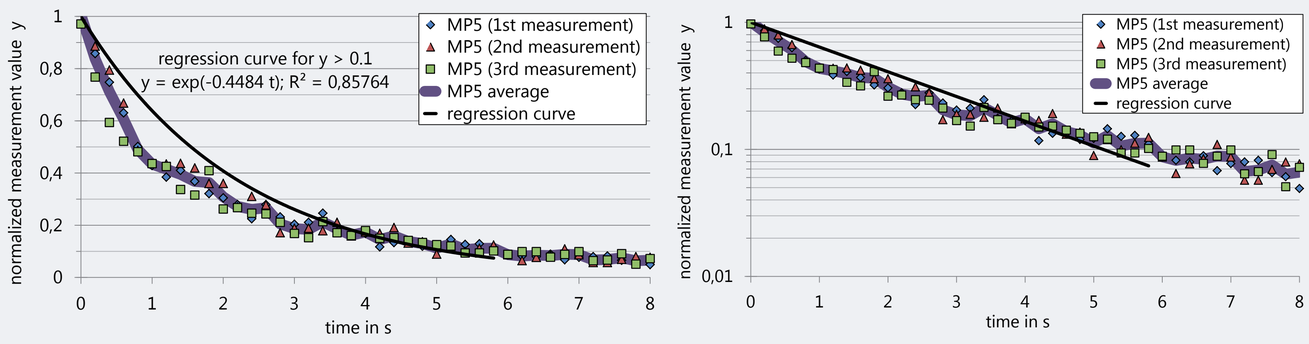

Fig. 4: Linear (left) and single logarithmic (right) diagram of the concentration decay at measurement point MP5 for τ_n = 2,46 s.

Conclusions

The measurement approach presented in this paper showed to be capable of determining the ventilation effectiveness for small nominal time constants. It can be stated that this novel method features very fast response times due to the superior temporal resolution of the LDV instrumentation. Thus, it can be applied in cases where measurement ranges are usually limited due to the slow response time of conventional tracer gas sensors. Furthermore, it is a non-intrusive method making air sampling equipment unnecessary.

References

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About the author

Henning Freitag is a research associate at the Institute for Energy Efficient Buildings and Indoor Climate at RWTH Aachen University in Aachen, Germany.

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