A Simulational and Experimental Attempt for a High Temperature Condensed Nuclei Magnifier Using Organic Working Fluids

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Introduction

Condensation particle counters (CPC) are widely used in science and industry for measuring particle number concentrations. The condensation nuclei magnifier (CNM) is the part of the CPC where the actual particle growth happens. This work deals with an approach for a CNM operating at around 150 - 200 °C (HT-CNM) using an organic working fluid.

This concept prevents formation of artefacts in the aerosol stream caused by dilution and heating and minimizes the effort of aerosol preconditioning [1]. The main application field is defiled aerosols, in particular automotive exhaust gases, but such devices are also of interest for interference-free measurement of aerosols e.g. in highly humid environments.

To prove the feasibility of an HT-CNM, two embodiments were designed, built and characterized: a T-shaped (Fig. 1) and a L-shaped geometry. The design was supported by extensive computational fluid dynamics (CFD) simulations of the flow and the (super-)saturation behavior.

Simulation Results

The CFD simulations of the HT-CNM geometries using Ansys Fluent was aiding the design of the functional demonstrators and indicates (Fig. 1 for T-Type and Fig. 2 for L-Type) very good gas saturation in the saturator and negligible aerosol particle losses due to wall contacts in both geometries. The cut-off size can be adapted by controlling the relative temperatures in the system. This ability to discriminate between differently sized particles was found to be extremely sensitive for the L-type (which provides a low detection limit) and very stable for the T-type.

Fig. 1 shows the results for a simulation of the T-Type with a temperature difference of 20 °C. In this case the cut-off should be at particles with a size of 10 nm. Because of the bidirectional inlet the flow at the elbow is still very laminar and does not influence negatively the functionality of the CNM.

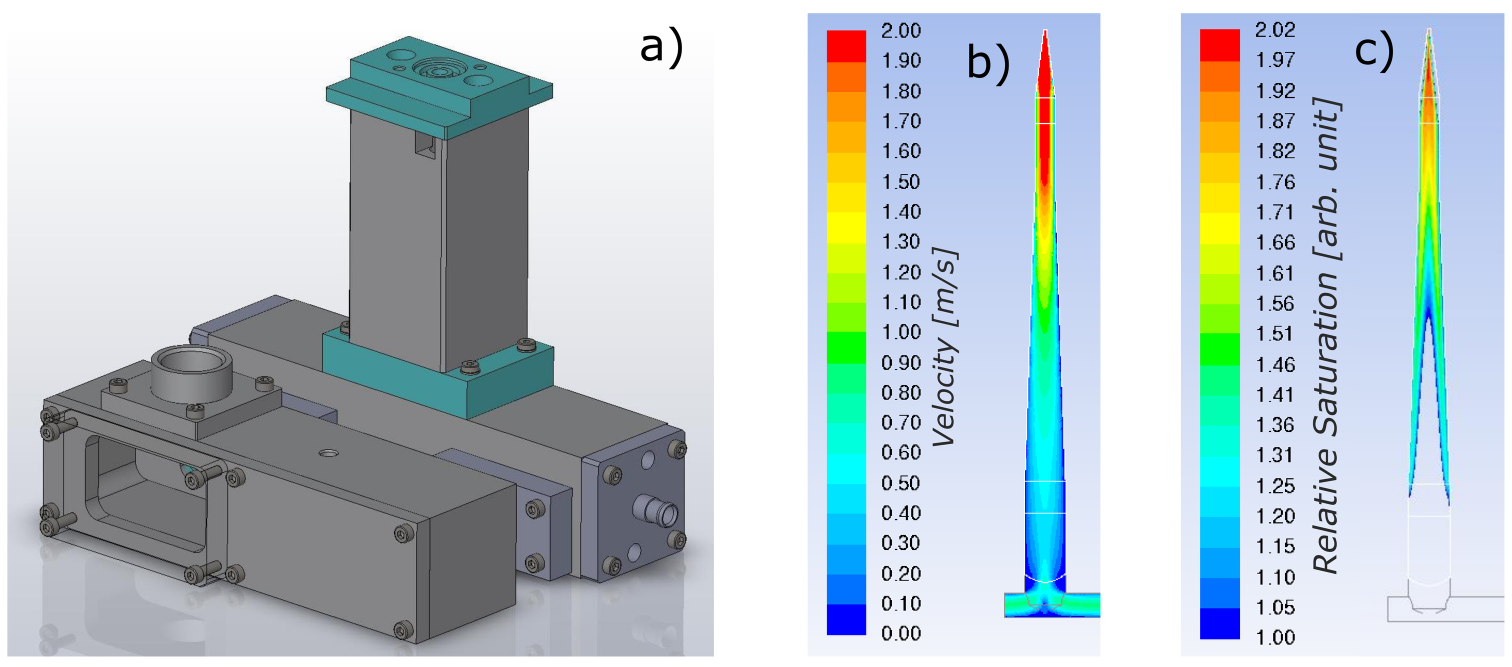

Figure 1: Results of simulations of the Type-T HTCNM with Ansys Fluent

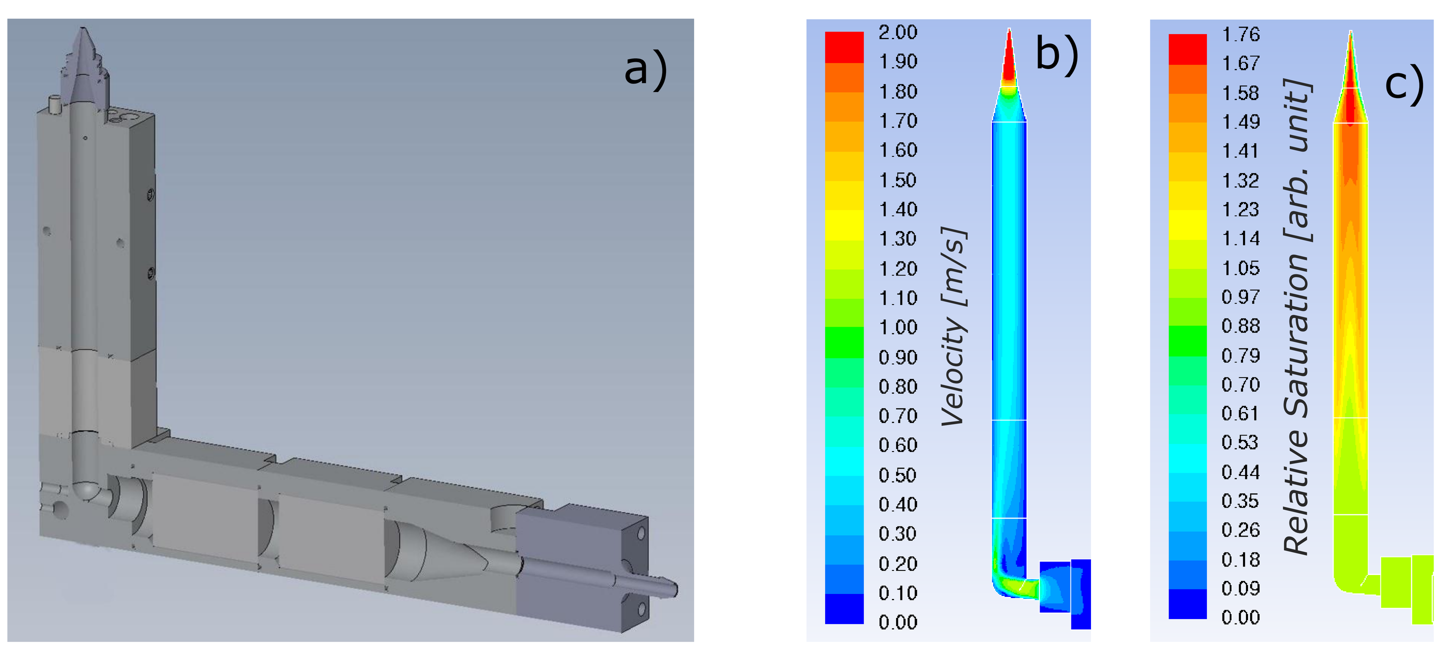

Figure 2: Results of simulations of the Type-L HTCNM with Ansys Fluent

For the L-Type clearly a flow separation is happening in the elbow (Fig. 2b). Nevertheless with this CNM geometry a cut-off at 10 nm particle size is possible with a temperature difference of 10 °C according to our simulations shown in Fig. 2b and 2c. Particle losses due to the flow separation have to be examined experimentally.

This different behavior of T- and L-Type is mainly due to the different (super-)saturation of the embodiments because of the chosen geometry of the wicking elements. The L-Type uses a porous honeycomb structure whereas for the T-Type a metal foam was considered.

Experimental Results

The experiments with the realized functional demonstrators showed clearly a reproducible and stable heterogeneous nucleation with the chosen materials and therefore prove the functionality of our approach for a HT-CNM. Scattering of a Laser ray on the grown droplets can be seen without optical aids (see Fig. 3a). One proof for the heterogeneous nucleation was that the scattering event vanished if the particles were filtered from the air fed into the CNM.

The long-term stability of the used materials (e.g. working fluid, wick) was tested and shown separately for each material. Operation of the CNMs showed so far a degradation of the used organic working fluid at the cordierite wicking element (Fig. 3b) after a few hours. Surprisingly first it was not noticed while examining the light scattering at the nucleated droplets, an influence on that was seen after more than 10 hours of operation. Further investigation is ongoing.

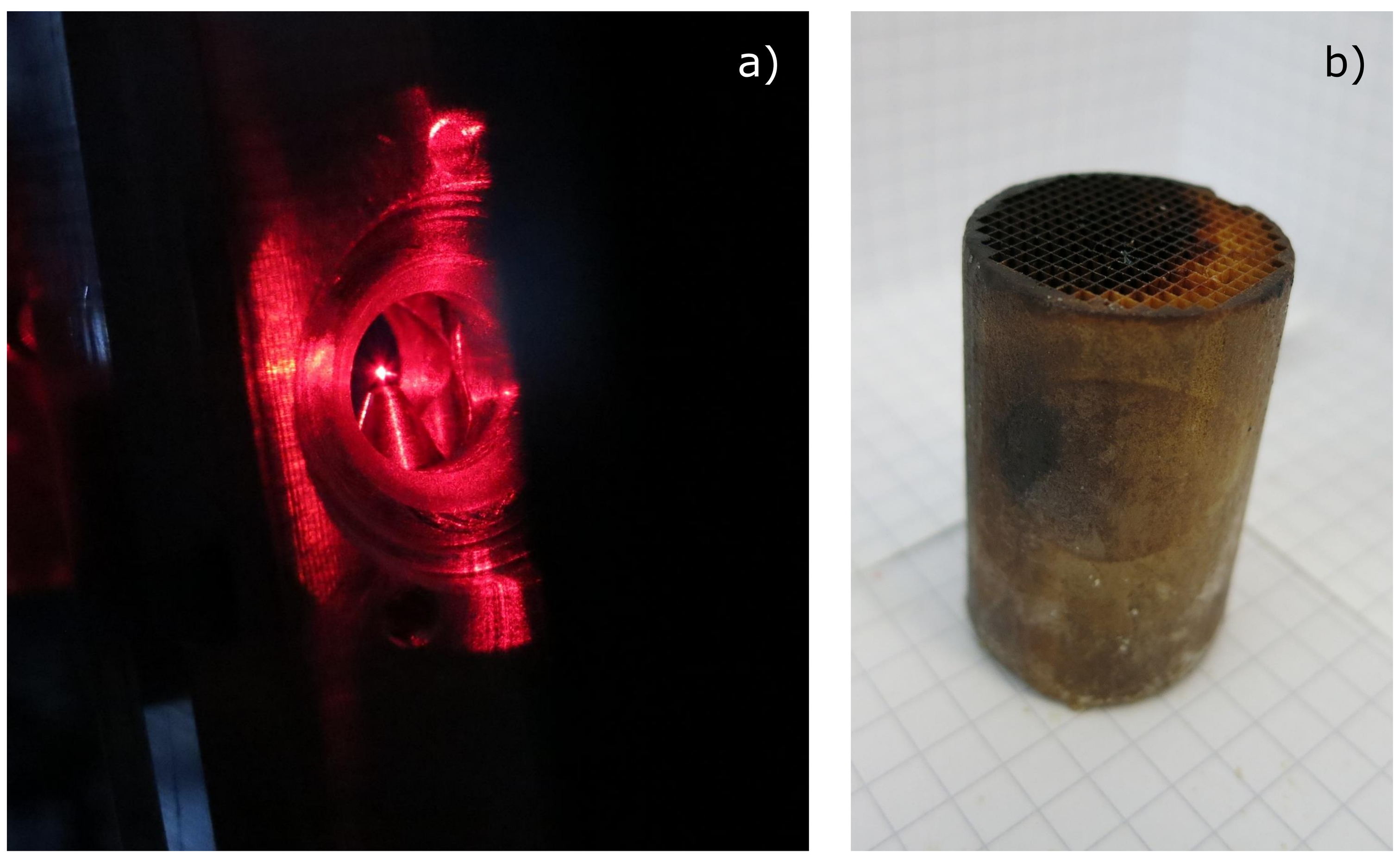

Figure 3: a) Photo of light scattering at nucleated droplets above the nozzle of the L-Type HTCNM
b) Photo of a used cordierite wick (~ 7 h) with degraded working fluid

A detailed experimental characterization of the nucleated droplets has still to be done. First attempts of examination using static light scattering failed because of distortion by reflections.

Reference

[1] Collings, N., Rongchai, K. & Symonds, J. P. R., A condensation particle counter insensitive to volatile particles J. Aerosol Sci. 73, 27–38 (2014)

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