Success Story
COMET

ASSIC
AUSTRIAN SMART SYSTEMS INTEGRATION RESEARCH CENTER

ASSIC
Austrian Smart Systems Integration Research Center
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High-Accuracy Exhaust Analysis for Automobiles

Amongst all the “fine dust”, in particular nanoparticles emitted by combustion processes pose serious health concerns. In a joint effort, researchers of the competence centre ASSIC developed a new, highly accurate optical sensor for such ultra-small pollutants. Using a dedicated, simulation-aided integrative design process, the resulting particle sensor features a three-fold increased dynamic range as well as significantly enhanced system stability and controllability. A resulting product line is now being manufactured and marketed by Austrian company partner AVL for the key application field “automotive exhaust analysis”.

Challenge

Among the various airborne pollutants, in particular respirable nanoparticles < 0.2 µm are regarded with increasing concern. Internal combustion engines in general, and Diesel engines in particular, are relevant sources of these particles, requiring accurate and reliable sensors to verify the actual particle emissions. An additional challenge are legally mandated measurement conditions, in this case an individual counting of the nanoparticles in the air or exhaust, rather than some sum parameter. This precludes a number of sensor principles that are used e.g. in environmental monitoring.

Since nanoparticles are way too small for a direct, individual detection, e.g. by optical means, one way is to pass them through a super-saturated atmosphere where they act as condensation nuclei, creating a kind of fog, which’s droplets can be individually counted. While such systems exist, they depend on carefully balanced, interacting thermal, physical and chemical processes to warrant reliable and reproducible operation and thus particle detection.

Integrative System Modelling and Co-Design

Given the complexity and various interdependencies in the sensor system, a comprehensive, highly detailed computer simulation model was established and validated against experimental data. The model takes into account flows, multiphase heat transport and transfer, particle and vapour concentrations, evaporation cooling, particle losses, and many more parameters and functions. The model enables a unique all-in-one simulation of the actual behaviour of the entire sensor (see Fig. 1 and Fig. 2), down to accurate predictions of the size-dependent response function (Fig. 2).

Using this computer model as a tool, the competence centre’s joint team around Dr. Alexander Bergmann and Tristan Reinisch, M.Sc. (both AVL) and Dr. Martin Kraft (CTR) devised and evaluated a range of possible improvements and fundamentally new approaches “*in-silico*” on the computer, rather than building and testing various prototypes. These efforts yielded a number of important insights into the exact functioning of

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the sensor, and allowed identifying key design parameters for optimal performance:

- a possible homogeneous, highly laminar flow of the particle-laden aerosol stream,
- high surface/volume ratios in the saturator and the "fog chamber" sections, and
- an optimised heat transfer.

Together with practical considerations for a later implementation, the teams succeeded in developing a fundamentally new, vertically oriented annular system design. Innovative features include an optimised aerosol flow path, chemically, thermally and mechanically co-optimised micro-porous evaporator elements and a high efficiency optical fog droplet counter. This new design (which has been filed for patent, together with a number of other related innovations) saturates the aerosol stream almost perfectly with working fluid vapours (< ± 0.3% deviation from the mean, see Fig. 1), providing an essential precondition for achieving extremely precise size discrimination functions, as shown in Fig 2.

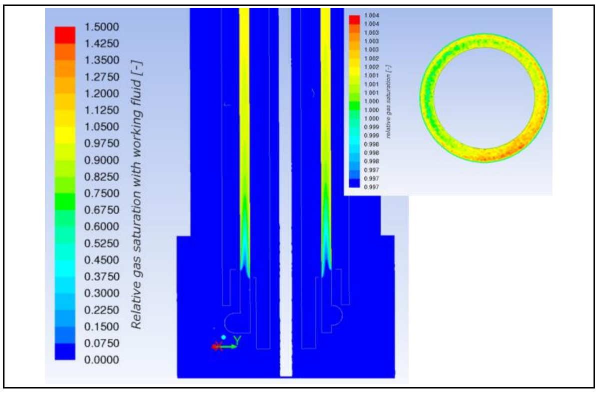

Fig. 1: Simulated gas saturation of the aerosol stream in the sensor © CTR AG

Impact and Effects

Following the simulation-aided design phase, the most promising approaches were realised as first functional demonstrators. Highlighting the accuracy of the models, the optimal experimental working point was found to be less than 0.5°C off the value predicted in the simulation.

A key advantage of the annular design is a much sharper size-discrimination function (Fig. 2) and higher particle transmission, both of which have been experimentally validated.

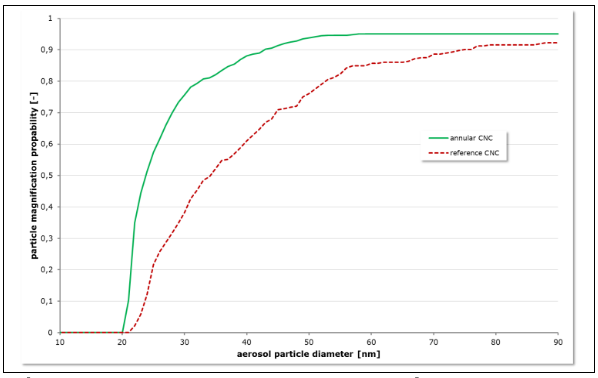

Fig. 2: Sensor response curve vs. size; AVL particle sensor shown in comparison to standard device © CTR AG

Based on the results of this research, AVL has developed a product line (AVL CPC, see Fig. 3) that is now being marketed for the exhausts analysis of automotive engine and after-treatment systems. Besides technical innovation – unparalleled precise control of the sensor sensitivity, enhanced system stability and controllability, significantly reduced warm-up times and a 3-times higher sensor concentration range of 0 – 30.000 particles/cm³, the COMET programme thus resulted in manufacturing a key sensor element in Austria, rather than importing it from outside the EU.

Fig. 3: AVL CPC Nanoparticle Sensor System © AVL List GmbH

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