Popular Scientific Abstract

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Analysis of Heated Urea Water Solution Droplets for Selective Catalytic Reduction Systems

Selective Catalytic Reduction (SCR) is a promising technique to meet the increasing emission regulations regrading NOx emissions of diesel engines. The approach requires injection of urea water solution (UWS) injected directly into exhaust gas where the droplets decompose to produce ammonia, which acts as a reducing agent in the SCR catalyst. Understanding the whole process requires a combination of significant amount of experimental and numerical work to ensure the development of an efficient SCR system.

In the early stage of PhD, a measurement system was decided to be designed and built specifically for SCR spray investigations. This was subsequently built and installed at the facilities of Dinex A/S located in Middelfart, Denmark. Spray investigations were performed using Phase Doppler Anemometry (PDA) in various scenarios and this data was then used for developing methodologies that may be useful for reducing NOx emissions from the diesel engine exhaust. Measurement and post processing of droplet data was a time consuming task and required a strategy to avoid any kind of biasness. In order to address this issue, post processing scripts were implemented in python to make sure that the data was presented in high statistical resolution with the consideration of all the possible factors to eliminate any biasness. This dissertation includes an overview of the whole measurement setup, experimental campaigns and simulations, while addressing different post processing techniques as well as contributes to different strategies that can be involved in the development of SCR systems.

Data from three different commercial spray nozzles was recorded under quiescent and heated cross flow conditions and was used to understand the differences in spray dynamics of water and UWS. The study clearly indicated that the atomization process for both the liquids was very similar indicating a very good correlation near the nozzle. The differences start to become more prominent further downstream, linking directly to a difference in evaporation rates. It was also concluded that nozzle operating principle drastically affects the values of Sauter Mean Diameters (SMD). To further understand the evaporation process, a simulation was setup using a commercial Computational Fluid Dynamics (CFD) solver, ANSYS Fluent using Euler-Lagrangian approach. The study found that initial momentum of the droplets drastically affects the diameter and velocity distribution trend. It was observed that splitting the spray into segments of diameter and velocity distributions and then initializing the spray validates the velocity distributions very well with the experimental data. For instance, in terms of velocity distribution trends, where using a single velocity and diameter distribution had an average difference of around 32%, the spray initiated with 10 different diameter and velocity distributions, had an average difference of around 8% with the actual measurement data. It was also seen that Eulerian-Lagrangian approach over predicts the diameter distribution near the nozzle and the distribution starts to correlate better further downstream. It was also observed that the droplets enter solidification region at around 77% of urea concentration.

UWS droplet concentration and temperature are known to influence the refractive index which is used as an input for particle diameter estimation by PDA in refraction mode as the dominant scattering mode. Pairing the correct urea concentration with the refractive index is essential for UWS measurements conducted in heated cross flow environments as the urea concentration of droplets increases when the water starts to evaporate. The CFD work was further extended where urea concentration estimates were derived from numerical simulation and the phase difference was recalculated to obtain a correction factor. This correction factor was then used to recalculate the diameter statistics. It was seen that where the plane averaged urea concentration was 43% and 79% the maximum deviation in the droplet diameters was around 0.42% and 3.85% respectively. Thus, it was deduced that although the refractive index increases linearly with an increase in urea concentration, the deviation in droplet diameters was not linear.

Spray-wall impingement regimes were also touched upon briefly both experimentally and numerically. It was determined that the kinetic properties of the impinging droplets as well as the surface temperature play a major role in determining the impingement regime and thus the determination of deposits formation.