Spray/Wall-Interaction in Urea-SCR systems

Background: Selective Catalytic Reduction (SCR) is the most promising technical aftertreatment solution to decrease nitric oxide emissions of vehicles propelled with diesel engines. The reducing agent ammonia is added to the exhaust gas by injecting urea-water solution, which is gradually converted to ammonia by evaporation, thermolysis and hydrolysis. The highly transient conditions in the exhaust line can result in incomplete evaporation and spray impact on the tailpipe wall leading to film formation. Depending on gas temperature and residence time, solid deposits can be formed by decomposition of the liquid film. Solid deposits in the tailpipe can lead to a failure of the dosing strategy, reduction of the NOx conversion and, in serious cases, to a blockage of the whole SCR system.

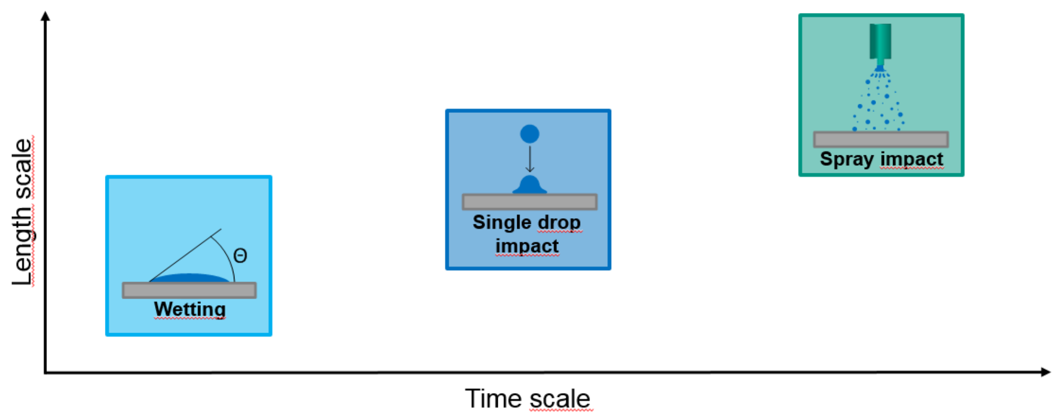


Figure 1 Phenomena of spray/wall interaction at different scales

Project: Both spray/wall-interaction and heat transfer of urea-water solution in SCR context are studied to provide valuable data for suitable submodels of the process. Multiscale experiments, ranging from single droplet impact to spray impingement in a model tailpipe, give insight to spray impingement phenomena, film formation and evaporative cooling, which lead to solid formation. High-speed and thermal imaging techniques are used together with image analysis and numerical methods.

Wetting phenomena and spreading behavior of impinging droplets control the extent of liquid film formation in the tailpipe. Experimental investigations on single droplet impact gives insight into spreading dynamics, which are well predictable by a numerical model developed in OpenFOAM, see Fig. 2.

The outcome of droplet impingement on the heated tailpipe wall is dependent on temperature and impact dynamics. Experimental investigation of single droplets on heated substrates enables the definition of a regime map describing impact behavior by four characteristic regimes (Fig. 3).

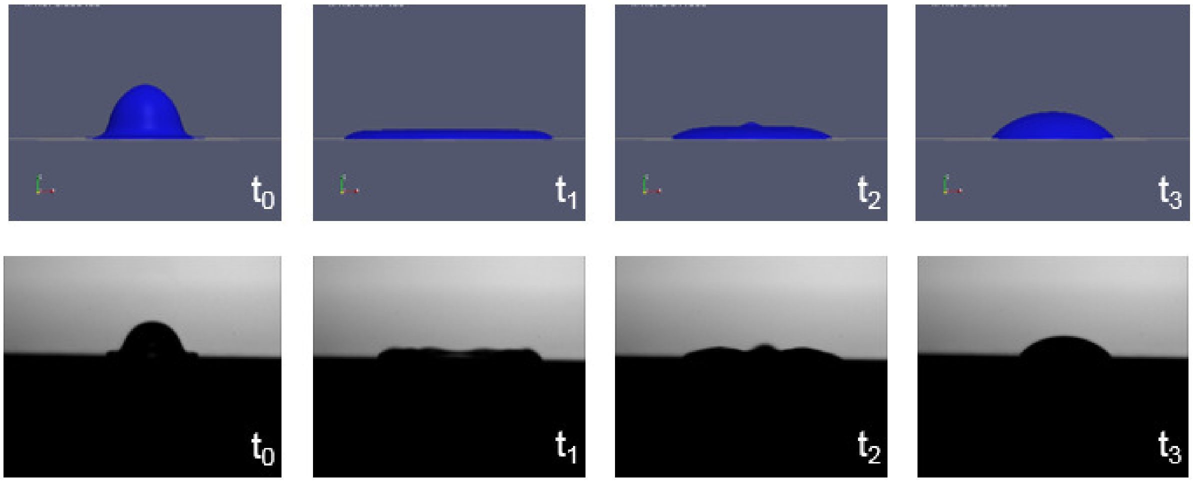
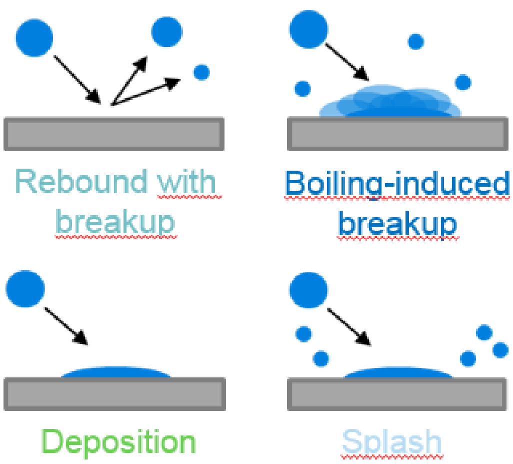
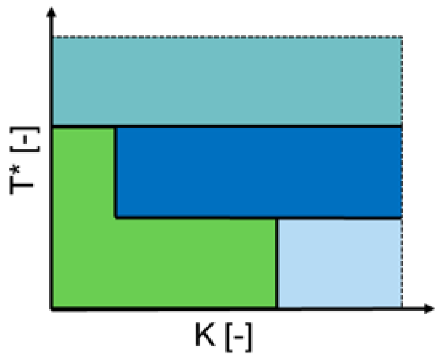


Figure 2 Numerical (upper row) and experimental (lower row) results of a single urea-water droplet wetting a metallic substrate





$$K = \frac{(\rho D)^{3/4} u^{5/4}}{\sigma^{1/2} \mu^{1/4}} = We^{1/2}\,\mathrm{Re}^{1/4} \qquad T^* = \frac{T_W}{T_{sat}}$$

Figure 3 Regime map characterizing single droplet impact regimes

High-speed recordings of different single droplet impact regimes are available at http://www.itcp.kit.edu/deutschmann/english/1951.php.

Further studies focus on heat transfer during spray impingement on hot walls and the resulting film and deposit formation in a real-scale laboratory test rig.

Understanding the processes of spray impingement, film formation and evaporation of urea-water solution is crucial for evaluating the risk of deposit formation and optimizing system performance.

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