WP8: Engine Integrated SCR and combined SCR and DPF

Objectives

Engine Integrated SCR

- Investigation of High Pressure SCR process; injection, mixing, decomposition and flow distribution with the aim of making the SCR components compact while still maintaining the same high performance as best available technology today
- Designing of engine integrated High Pressure SCR with system with unaffected engine footprint and only slightly affected gallery arrangement around the engine
- Testing of compact High Pressure SCR component performance on 4T50ME-X test engine

Combined SCR and DPF

- 80% PM reduction with after-treatment system (based on IMO Tier II engine out emissions)
- 80 % NOx reduction with after-treatment system to reach IMO Tier III limits
- Reduce the necessary installation space for after-treatment system SCR on DPF within IMO Tier III (SCR only) system
- Adaption and integration of the after-treatment system (SCR on DPF) on a marine Diesel engine

WP8: Engine Integrated SCR and combined SCR and DPF

WP Leader
Lone Mønsted Schmidt , Ph.D.
MAN Energy Solutions SE

Deputy
Manuel Kleinhenz
MAN Energy Solutions SE

Partners

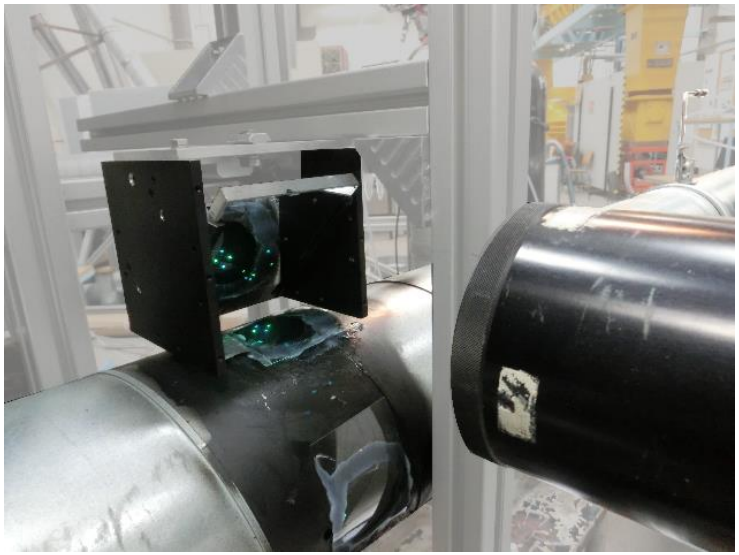
- LUH: Leibniz University Hannover (Hannover)
- DTU: Technical University of Denmark (Copenhagen)
- MAN: MAN Energy Solutions

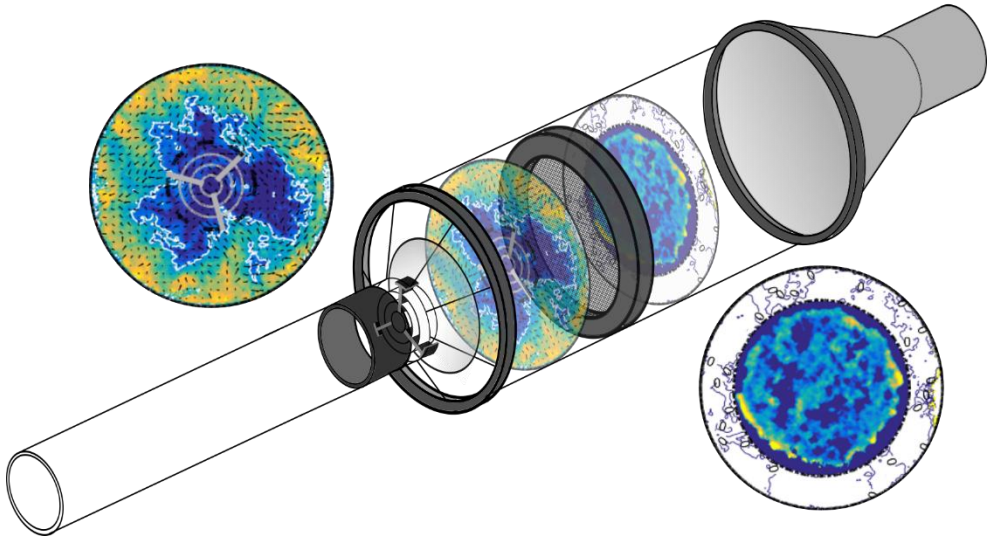
Roles

- LUH: Test rig for investigation of urea injection and decomposition
- DTU: Investigations of SCR mixing and flow distribution
  Development of mechanism for NH_3 measurements
- MAN-CPH: Compact mixer, Integrated SCR design and NH_3-slip investigation
- MAN-Aug: Catalyst coating and filter test bed. Selection & design of SCR on DPF prototype. Modelling of urea injection and decomposition

Final results & achievements

- Experimental investigation of flow phenomena in a simplified SCR setup for optimization of the flow conditions in the catalyst
- Successful comparison of numerical and experimental concentration and velocity profiles at different development stages of flow turbulence





Velocity measurements with laser doppler anemometry

WP8.1: Engine integrated high pressure SCR

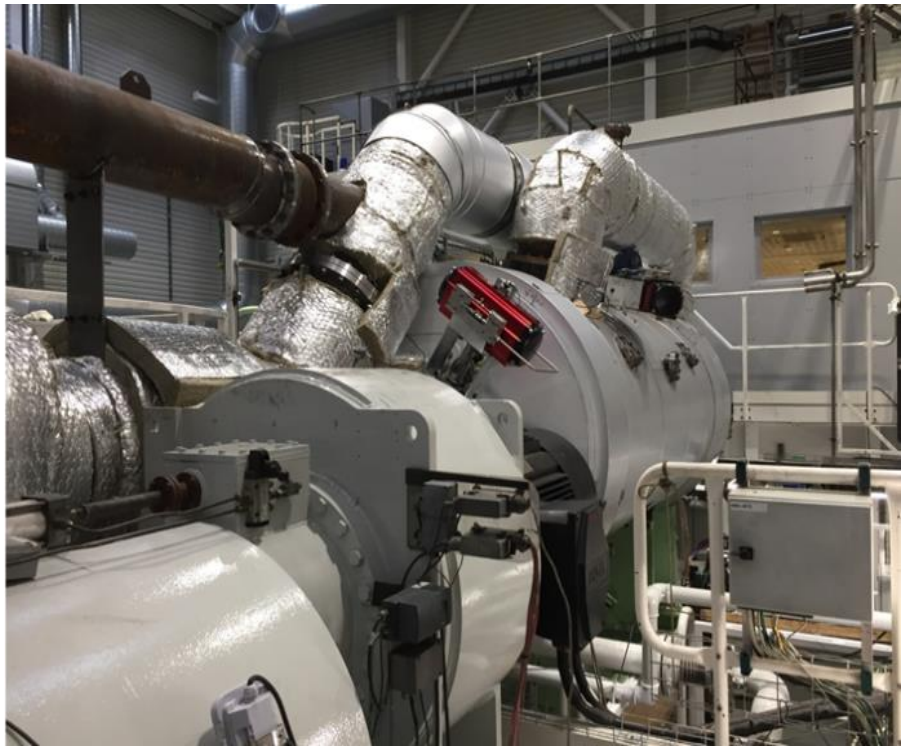
Final results & achievements

- Development of mechanism for gas probing locally at catalyst in and outlet in a full size high pressure SCR system
- Successful 12 hour test of developed mechanism with a range of 2 meters
- Method of using purge air for sealing, cooling and cleaning

WP8.1: Engine integrated high pressure SCR

Final results & achievements

- Design, installation and test of an engine-integrated HP SCR system on the 4T50ME-X R&D engine in Copenhagen
- Replacement of the exhaust gas receiver by a larger receiver with the catalyst elements located inside

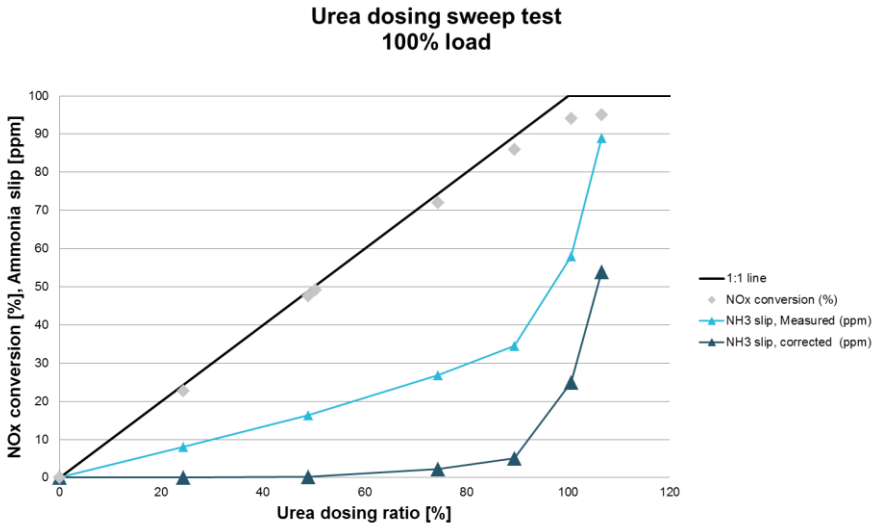


WP8.1: Engine integrated high pressure SCR

Final results & achievements

- Reduction of the required installation space for the engine integrated HP SCR design by more than 90 % compared to traditional HP SCR systems

- Verification of the engine integrated HP SCR concept by fulfilment of IMO Tier III NO_X limits



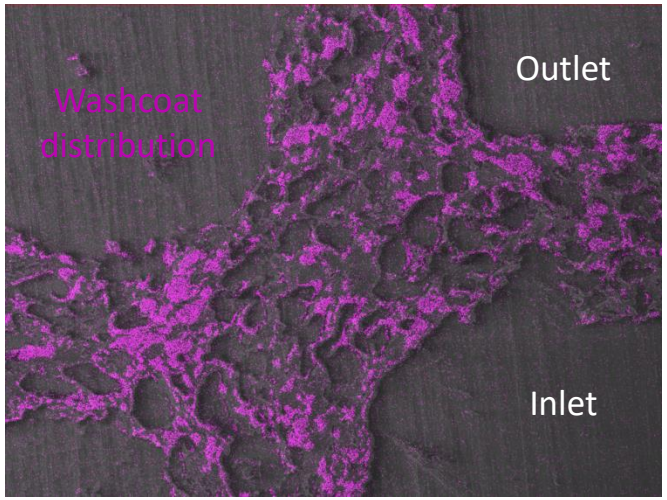
Engine load	NO_X conversion
25%	81%
50%	82%
75%	82%
100%	86%

NO_X conversion with acceptable corrected ammonia slip while using low sulphur fuel oil

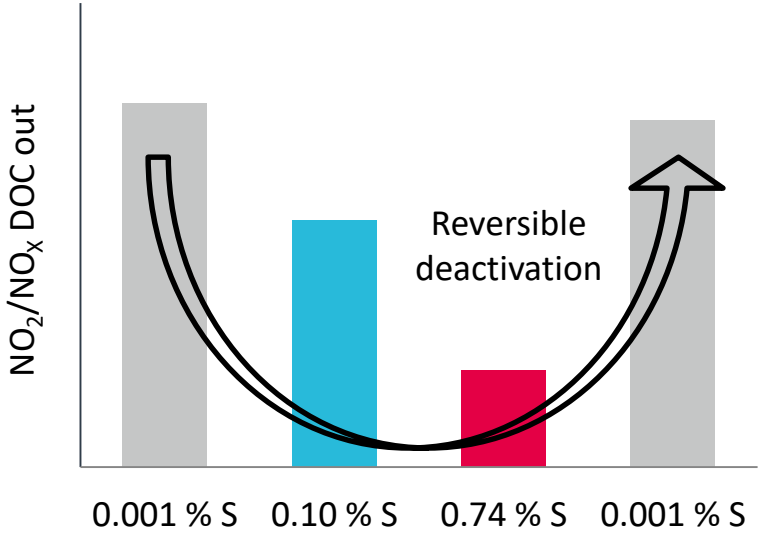
WP8.2: Combined SCR and DPF

Final results & achievements

- Design and installation of a synthetic gas ted bed including particulate matter generation for filter testing
- Benchmark of SCR coated DPF in laboratory scale based on measurements in a synthetic gas test bed as well as BET and SEM/EDX investigations successfully completed
- Endurance test of Diesel oxidation catalysts on engine test bed using marine fuels with different sulphur contents showing the sulphur resistance of the DOC technology



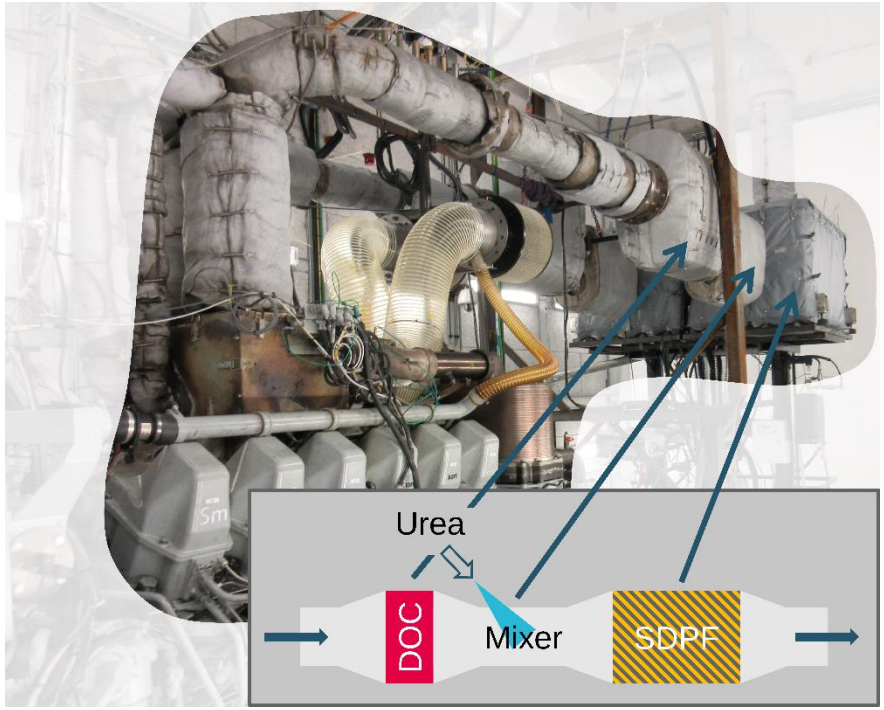
SEM/EDX image of SCR coated DPF

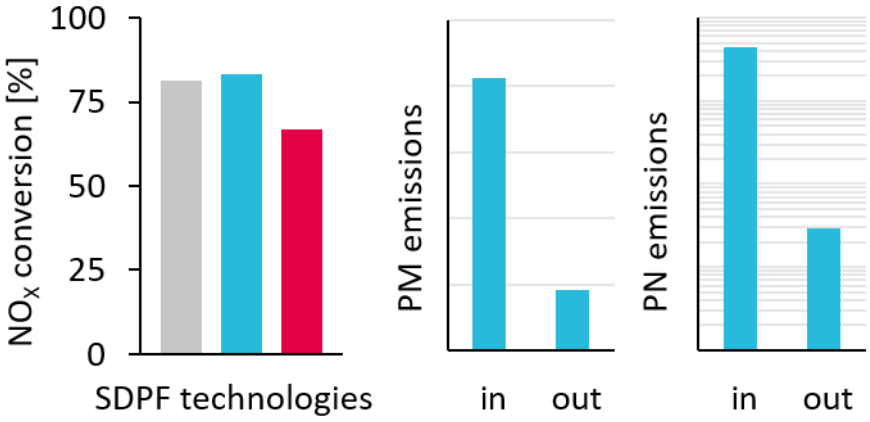


WP8.2: Combined SCR and DPF

Final results & achievements

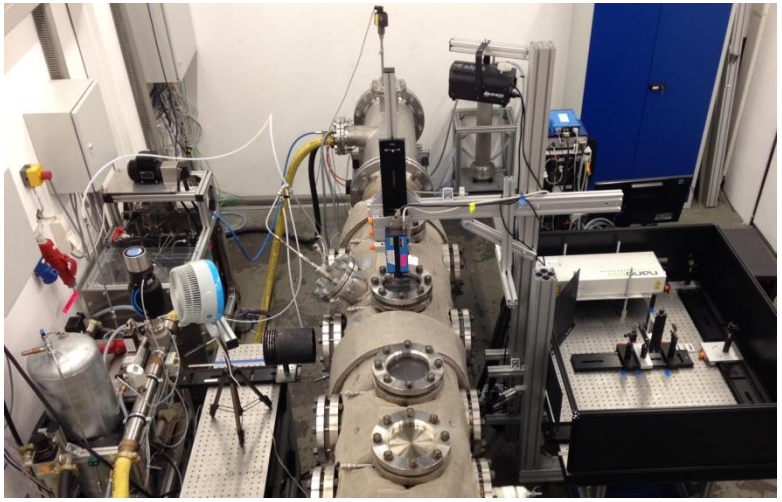
- Adaption and investigation of a full-scale EAT system comprising SCR coated DPFs and a sulphur resistant DOC in combination with the 12V175D R&D marine distillate engine
- Compact design based on the mixing unit and the canisters of the standard SCR system for the SDPF system
- Fulfilment of the required NO_X reduction of 80 % by two of three SDPF technologies tested in full-scale
- Fulfilment of the required PM and PN reduction in full-scale



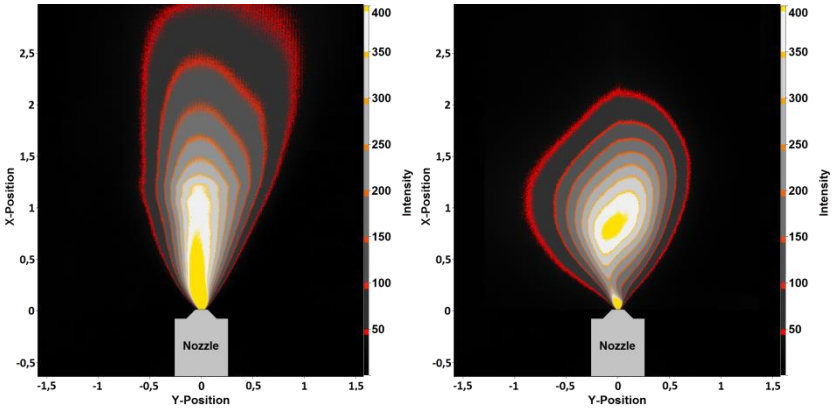


Final results & achievements

- Investigation of urea decomposition by means of the hot gas test rig at different temperature and pressure conditions
- Characterization of the influence of mixing elements to enhance urea decomposition
- Developing a calibration method for application of PDA at the hot gas test rig
- PDA measurements for reliable droplet spectra of urea sprays as validation data for numerical simulations



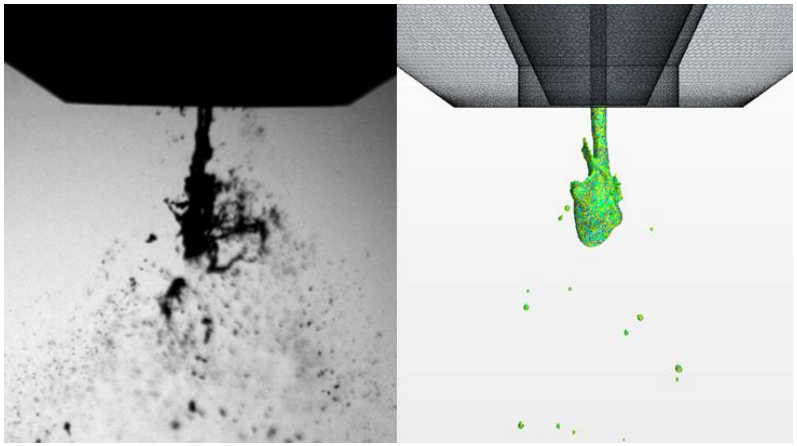
Hot gas test rig with measurement setup



Spray propagation without (left) and with mixing element (right)

Final results & achievements

- Experimental study of urea spray breakup for various settings and different operating conditions
  - Improved nozzle configuration
  - Validation data for simulations
- Good agreement of experimental results and numerical simulations
- Setup of an optically accessible prototype of an ammonia generator as compact device for urea decomposition
- Investigation and depiction of ways to minimize risk of deposits



Experimental (left) and simulated spray break-up (right)

Optically accessible prototype of ammonia generator

Conclusions based on objectives

Engine Integrated SCR

- Design, installation and test of an engine-integrated HP SCR system on the 4T50ME-X R&D engine to fulfil IMO Tier III NO_X limits while reducing the required installation space by more than 90 % compared to traditional HP SCR systems
- Results showed a large overall $DeNO_X$ potential of the downsized SCR system and pointed out the potential areas of additional improvement

Combined SCR and DPF

- Adaption of a compact EAT system to the 12V175D R&D marine distillate engine to fulfil upcoming emission legislations by using the mixing unit and the canisters of the standard SCR system
- Fulfilment of 80% PM and NO_X reduction with a full-scale EAT system comprising SCR coated DPFs and a sulphur resistant DOC to provide the required NO_2 for the passive soot regeneration

Additional conclusions

- Validation data for urea decomposition from extensive studies at hot gas test rig, showing that the pressure influence on the spray breakup and the urea decomposition has to be considered

- Successful comparison of numerical and experimental concentration and velocity profiles in a simplified SCR setup at different development stages of flow turbulence to optimize the flow conditions in the catalyst