WP7: On-engine aftertreatment systems

Objectives

WP Leader: Jukka Leinonen

- Integration of SCR (Selective Catalytic Reduction) with the existing strong Miller cycle 4-stroke diesel engine and combining it with particulate emission (PM) abatement technology would enable to achieve more than 80% NOx emission reduction and 25% reduction in PM. Also a combination of integrated SCR and EGR (Exhaust Gas Recirculation) is to be developed. Feasible solutions of combining the above mentioned technologies having as a target the near zero emission engine are also studied.

- Integrating methane and ethane abatement technology into lean burn 4-stroke gas engines will enable compact solutions to reduce methane and ethane slip. The objective is a catalytic system working with the engine and optimization of the engine performance. Also the knowledge on deactivation & regeneration strategies for integrated catalyst solutions and methane formation and location in the engine exhaust system should increase. Target is a greenhouse gas emission decrease up to 15% and fuel savings up to 5%.

Partners: WÄRTSILÄ VTT Vaasan yliopisto UNIVERSITY OF VAASA PAUL SCHERRER INSTITUT PSI

Subprojects

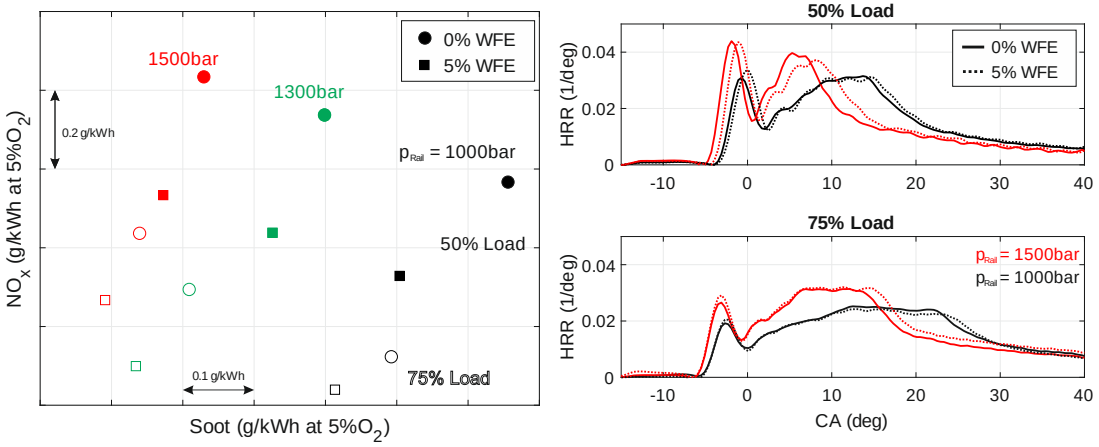
- 7.1 Combined on-engine aftertreatment solutions for 4-stroke diesel engines
- 7.2 SCR reduction agent injection solutions
- 7.3 Integration of methane and ethane abatement technology with gas engines
- 7.4 Emission measurement systems for integrated after treatment technologies

Final results 1/2

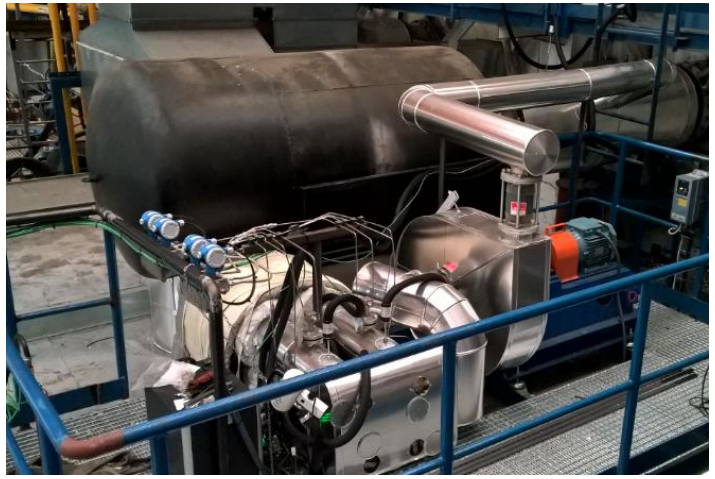
- PSI, All the work finalized due to plan. Comprehensive measurement campaign performed with detailed data analysis (performance information, in-cylinder pressure analysis, emission measurements) and potential of the combined application of EGR and WFE on the simultaneous abatement of NOx and soot has been successfully investigated.

- WFI, All Deliverables submitted due to plan and other activities were finalized within schedule. Test platform for particulate reduction research with real engine exhaust has been built and testing was done. Results have shown test setup feasible and the potential for the particulate reduction. Work on improved SCR reagent injection systems has also done, as has support for the measurements conducted at Wärtsilä Spain in the subproject: “Integration of methane and ethane abatement technology with gas engines”.

- WSP, Feasibility and demonstration of integrated methane and ethane abatement with gas engine testing was ended due to plan.



50/75% Load, 22% EGR, SOI 10/11°CA bTDC

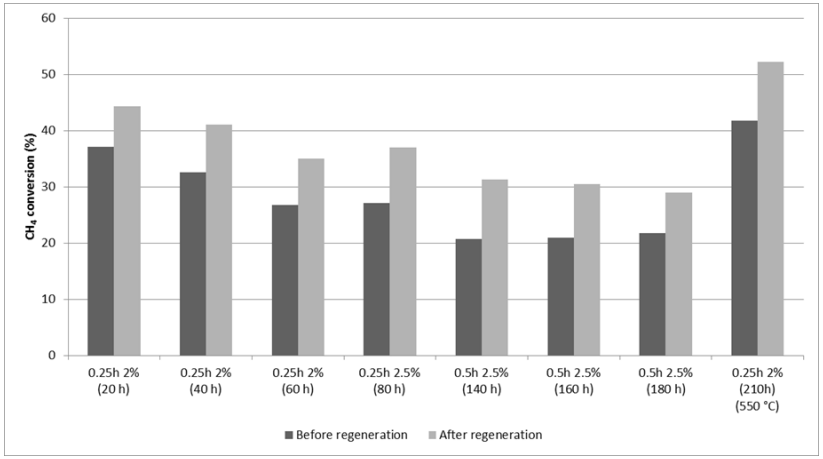


Small scale test bench at the roof of engine test cell

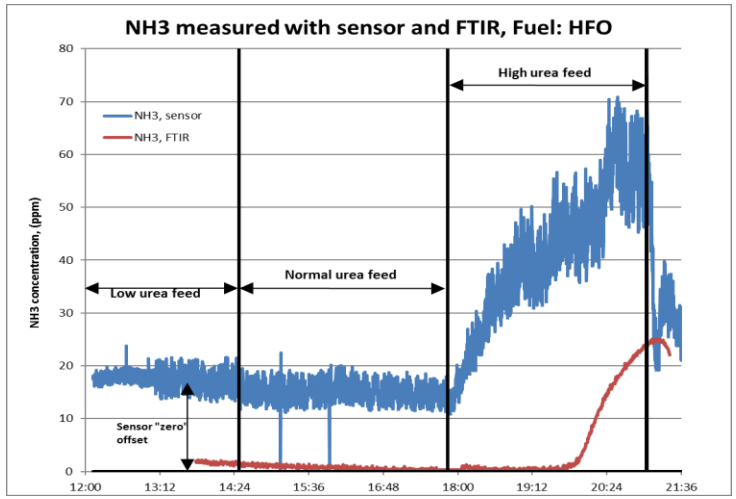
Final results 2/2

- UV, All Deliverables submitted due to plan. Literature review regarding SCR engine integration and particulate abatement and Feasibility and demonstration of methane catalyst element regeneration method study and experimental study has completed due to plan. Feasibility study about catalyst rig testing showed that technically suitable engine can be found and that the VEBIC laboratory in Vaasa would be cost efficient possible location for the rig. The experimental study about Methane slip abatement by hydrogen addition was completed at two different temperatures.

- VTT, All Deliverables submitted due to plan. A commercial NH3 sensor designed for automotive applications using high quality diesel fuel was tested in laboratory and in ship campaigns. The sensor´s response was compared to results obtained by FTIR and LDS methods. With Sulphur free (S< 10 ppm) diesel the methods gave equal results. However, the on-board tests clearly demonstrated the difficulties of NH3 measurements with extractive sampling from exhaust gas in the presence of SO2. The long-term campaigns showed that NH3 sensor has potential for monitoring of NH3 in harsh conditions if precautions are taken for protecting the sensor against particle matter.



Average CH_4 conversions during the experiment at 500 °C and at 550 °C.



Deliverables and Completed work

- Literature review regarding SCR engine integration and particulate abatement.
- Emission measurement systems for SO3, NH3 and PM emissions to support integrated after-treatment technologies
- Experimental assessment of integration of methane and ethane abatement technology into gas engine structure
- Experimental assessment of SCR reduction agent injection systems with sensors for feedback control

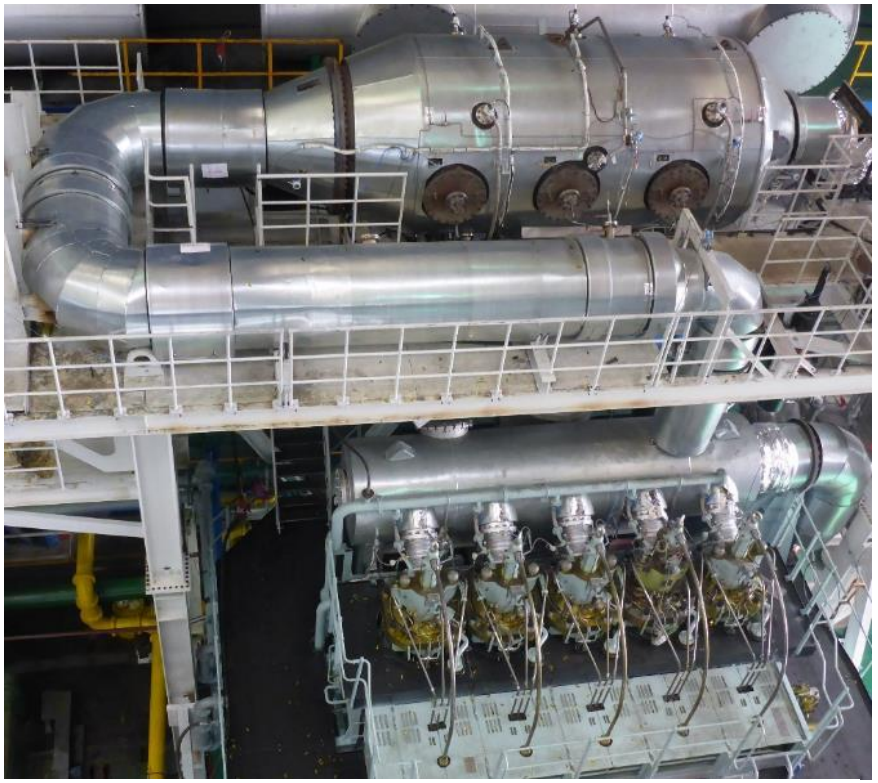
WP deputy: Flavio Soppelsa

Subproject

- 7.5 Robust catalysts for pre-turbo SCR

Objective

Evaluation of components allowing the integration of aftertreatment devices into existing engine structure. SCR catalyst need to cope with challenging physical operation condition. Therefore, vibration resistance an PM load will be investigated so a suitable catalyst design can be developed and tested. Main route of catalyst deactivation will be analyzed by laboratory experiments and quantified in order to adapt the exchange of catalyst elements and the dimensioning of catalysts with known operating conditions for optimum conversion efficiency.



WinGD pre-turbocharger SCR system

Partners - roles

Johnson Matthey / Dinex Finland

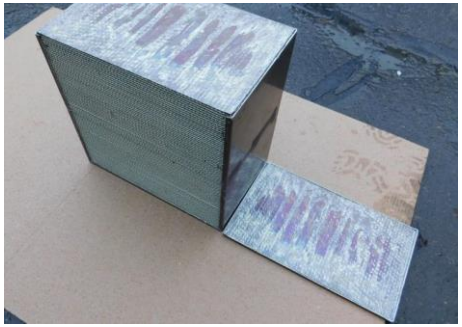
- Development of a vibration resistant SCR catalyst for the use in a pre-TC SCR application integrated in the engine.

WinGD – Testing activities

- Field testing of newly developed SCR catalyst, with focus on vibration resistance.
- Catalyst aging by SCR-operation in a vessel installation, with focus on catalyst lifetime prediction.

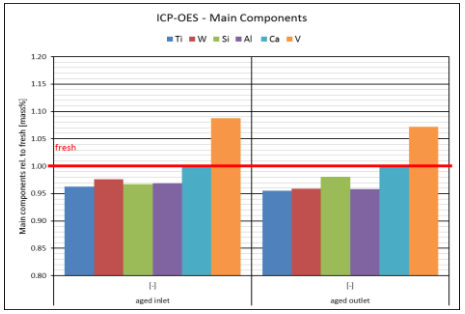
PSI – Catalyst analysis

- Catalyst DeNOx characterisation on the model exhaust gas test bench.
- Catalyst element analysis in fresh and in aged condition.



Condition analysis after hot shaker test

SCR-installation on WinGD field test vessel



Catalyst Post Mortem Analysis

Performed work and result

Johnson Matthey

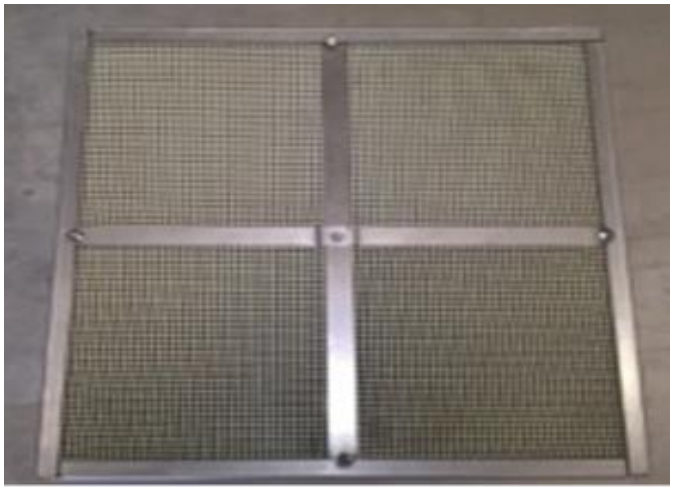
- Re-design of standard element frame for ceramic catalyst by implementing vibration damping and stiffening materials.

Dinex Finland

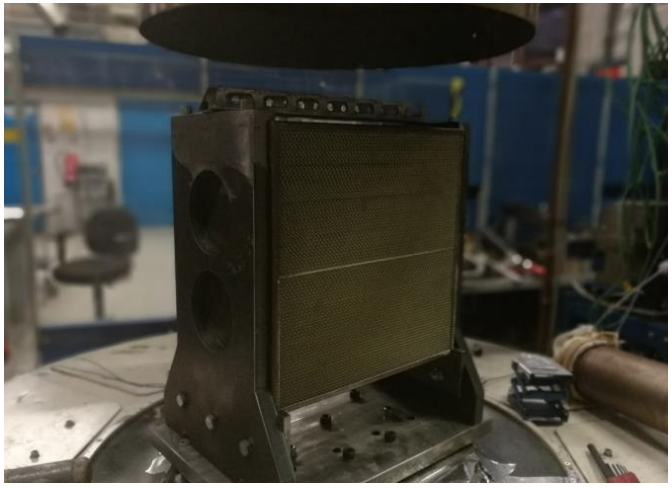
- Re-design of the stack size of the metallic substrate in order to improve vibration resistance.
- Adaptations of the coating sequence of the metallic substrate against wash coat loss.
- Adjustment of the wash coat thickness against wash coat loss.

Both

- Several concepts were tested on hot shaker test bench.
- The most promising concepts were prepared for field test
- Condition analysis after field test executed without significant findings in terms of mechanical damage and wash coat loss



Johnson Matthey - Reference element frame



Dinex Finland - Test setup on the hot shaker test bench

Performed work and result

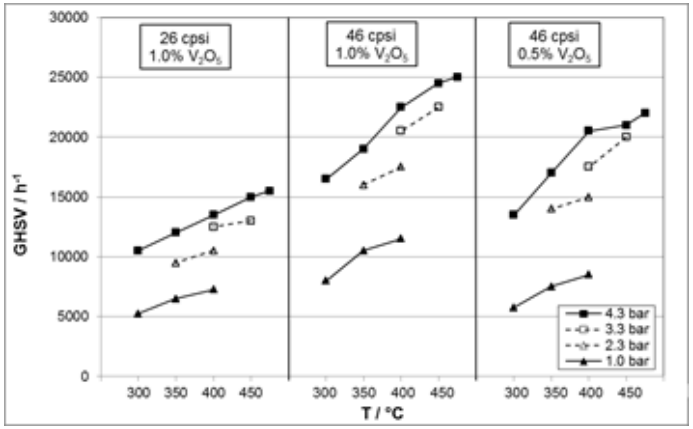
WinGD

- Definition of a vibration test cycle based on on-board vibration measurements.
- Field testing of newly developed SCR catalyst, with focus on vibration resistance. Installation in the exhaust manifold of an engine in a vessel.
  - ➢ No mechanical damage found
- Catalyst operation installed in an SCR-system on a vessel, with focus on catalyst lifetime prediction.
- Laboratory experiments about SCR reliability focussing on temperature management, when operating on high sulphur fuels.

Vibration test in exhaust manifold

PSI

- Investigation of SCR reaction kinetics under elevated pressure for catalyst characterisation
- Post Mortem Analysis of 900h field aged catalysts
  - ➢ No significant amount of catalyst poisons
  - ➢ Increased DeNOx-performance
  - ➢ No catalyst lifetime predictable, due to short operating periode



Graph SCR reaction kinetics

Final results & Achievements

D7.4 - Experimental assessment of newly developed vibration resistant SCR catalyst in field

- The deliverable was successfully completed by all Partners.
- The new design of the element frame for ceramic catalyst as well as the improvement on the substrate and coating method for metal catalyst seems to enable both catalyst technologies to cope with the requirements of an integrated SCR system.

D7.5 - Concept about catalyst aging from in-field monitoring and laboratory experiments

- The deliverable was successfully completed by all Partners.
- The field aged samples have shown higher DeNOx-activity compared to the fresh one, presumably due to vanadium uptake from the flue gas.
- The elemental analysis of the samples regarding poisons causing catalyst de-activation did not reveal any significant uptake of catalyst poisons.
- Within the framework of the project it would not have been meaningful to perform laboratory experiments to simulate field ageing as basis for the development of regeneration strategies, since no de-activation was detected after 900h field installation.

Conclusion

The outcome of the Work package 7.5, contributes to the development of the SCR exhaust aftertreatment technology integrated into engine structure.