Key Messages from AMF Research

Annex 51

February 2020

Methane Emission Control

DTU, Denmark
VTT, Finland
LEVO, Japan
KATECH, Korea
STA, Sweden
EMPA, Switzerland

Political Relevance

The use of methane in transport is predicted to increase, especially in liquid form in heavy-duty road transport and in the marine sector. Methane reduces, e.g., particulate emissions, and holds a promise to reduce CO_2 emission up to 20…25 %. However, almost all methane fuelled engines have methane slip that could nullify the CO_2 benefit. AMF Annex 51 shows that technologies exist to mitigate this problem.

Major Conclusion

The most important mechanisms behind unburned methane emissions from natural gas engines have been identified. These include: misfire/bulk quenching, wall quenching, crevice volumes, post oxidation and valve timing/overlap. Particularly low-pressure dual fuel engines are associated with high values of methane emissions. Mixing of hydrogen into natural gas has shown emission and operation advantages. Different oxidation catalyst concepts have shown to be promising for exhaust after treatment. Finally, engine exhaust is found to be the major source of methane slip from NG vehicles.

Background

Methane is the most common hydrocarbon in the exhaust of a natural gas engine, but not found in large concentrations in gasoline engine exhaust, and the concentration is close to zero in diesel exhaust. For many years methane has not been considered as a public health concern. Therefore, emission regulations for hydrocarbons in many cases have been regulated as NMHC (Non Methane Hydro Carbons) or similar. In recent years, the attention to methane's high GHG potential has changed this situation. Annex 51 is based on the experience of Annex 39, with the goal of understanding and improving engine-out methane emissions, methane catalyst efficiency, and methane emissions from other parts of a vehicle.

Research Protocol

The Danish part of the study looked into the basic mechanism behind unburned methane emissions in NG engines. The Swiss part looked into the influence of addition of hydrogen on the emissions and performance of NG fueled Euro 4 vehicle. Danish, Korean and Finish experimental studies looked into the development of new catalytic converters for reducing methane emissions in the exhaust by testing catalytic converters in test benches, specially designed for these investigations. Finally, a Swedish part of the study looked into all kinds of methane slip from vehicles in leakage tests with 12 city busses.

Key Findings

- The key mechanisms behind unburned methane emissions have been identified as: misfire/bulk quenching, wall quenching, crevice volumes, post oxidation and valve timing/overlap. All of these mechanisms are important factors, but wall quenching becomes more important as the engine operation becomes leaner.
- The major problems with unburned methane formation are associated with medium speed 4-stroke dual fuel engines.
- Since the unburned methane emissions origin from areas near the combustion chamber walls, the sensible way forward is towards direct injection of natural gas/bio-methane in order to reduce emissions.
- Addition of hydrogen to natural gas in a test with a stoichiometric operated Euro 4 CNG vehicle showed significant reductions in THC and NOx emissions. Hydrogen blending could be an interesting option for processes with diluted mixture formation (lean or EGR operation).
- A series of Rh/zeolite catalyst designs for oxidation of exhaust CH4 were tested. 1 wt.% Rh/zeolite catalyst had higher activity compared with the commercial catalyst under the same operation condition. A more efficient regeneration method is still being sought.
- Another case investigated the Pd based catalyst performance. In this study, some key factors were found, which enhanced the activity and durability of current Pd-based CNG catalysts.
- Regeneration of the catalysts used is an important issue, and a regeneration method with hydrogen was studied. With a catalyst aged to a conversion efficiency of 37%, it was possible to maintain this level and even increase the efficiency after regeneration and ageing again applying regeneration gases containing 2,5% hydrogen.
- A number of vehicles were tested for tailpipe methane emissions as well as other methane emissions. The result of this investigation indicates that the major contribution of methane originates from slip during driving, i.e. tailpipe emissions.