DOI 10.5162/SMSI2020/P1.1

# Multi-sensor system for selective methane measurements in harsh environments

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**Summary:**
We present a multi-sensor system for the detection of methane in crankcases of large dual fuel or gas engines to prevent exceedance of the lower explosion limit (LEL). It contains a total of four sensors each based on a different detection principle. To test the approach two systems were installed at a stationary power plant with a large dual fuel engine for long-term test with an online GC as reference system.

**Keywords:** sensor array, methane detection, LEL, crankcase, harsh environment

## Motivation

Continuously increasing emission regulations in shipping [1] also increase the need for a more environmentally friendly fuel source than marine diesel oil (MDO) or heavy fuel oil (HFO). One solution is to use liquefied natural gas (LNG) as alternative fuel [2]. This is possible in dual fuel engines enabled for methane usage in emission control areas (ECAs) and MDO usage otherwise or in a purely gas driven engine as used in power plant applications. During the operation of these large 4-stroke engines a significant amount of unburned methane can be pushed alongside the piston into the crankcase as so-called blow-by. Continuous operation therefore might lead to an accumulation of unburned methane in the crankcase up to the lower explosive level (LEL) at its worst [3]. Therefore, a device is needed to monitor the methane concentration in the crankcase during the operation of these engines.

## Hardware

The system consists of three different parts which can be described as follows.

(1) The sensor block contains the various gas sensors placed sequentially inside a sensor chamber. This sensor array consists of a metal oxide semiconductor (MOS) sensor (Figaro TGS8410), a pellistor (SGX VQ546M), a digital humidity and temperature sensor (Sensirion SHT35) and an electrochemical cell (Alpha-Sense O2-A2). The EC cell is operated at constant voltage, while both the MOS sensor and pellistor are operated dynamically (temperature-cycled operation, TCO).

(2) The filter and pump systems are placed at the inlet and outlet of the sensor chamber, respectively. The filter is used to prevent particles and lubrication oil from entering the sensor chamber whereas the pump is used to continuously extract atmosphere from the crankcase.

(3) The controller handles the dynamic sensor operation and online methane concentration calculation.

## Experimental Setup

The field test systems were installed on a modified 18-cylinder V-engine Pielstick PC 2-5V DFC with 8 MW power. The dual fuel engine is capable of running on MDO or HFO as well as on natural gas. In natural gas operation, the methane concentration in the fuel supply is approx. 98%. Analytical probing revealed a crankcase atmospheric composition as presented in Table 1.

*Tab. 1: Crankcase atmosphere composition*

| | |
|---|---|
| Carbon monoxide | < 10 ppm |
| Carbon dioxide | < 0.1 % |
| Ethane | < 1 ppm |
| Propane | < 1 ppm |
| Butane | < 1 ppm |
| Formaldehyde | < 1 ppm |
| Total VOC | < 1 ppm |

In the crankcase, a relative humidity of 55 – 60 %r.H. was measured during the test

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campaign in combination with a permanent oil mist atmosphere. Two test devices (001, 002) were connected to the crankcase, where one of the systems was installed in line with an online gas chromatograph (GC, type I-GRAPHX S) via PTFE hoses. A flame arrester was used as safety device between test system and crankcase. The test system and the GC were permanently installed to monitor the methane concentration over time and to compare the signals. In order to check the system status and to account for possible signal offsets, fresh air balancing was used every 24 h and a test gas mixture with 3.8 Vol.% methane in synthetic air was applied every 7 days.

## Results & Discussion

Fig. 1 shows the methane concentrations as determined by the two independent GasMOS systems plus the GC reference measurement.

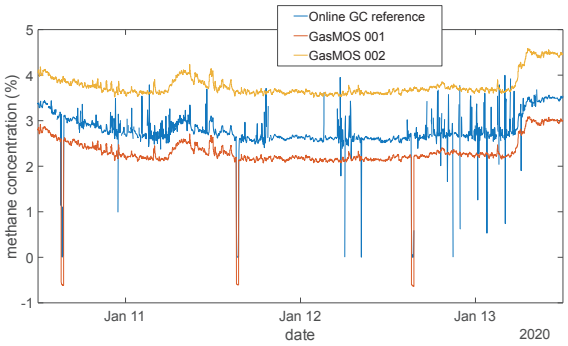


*Fig 1: 3-day section of a long-term test at the 8 MW test engine. Both sensor systems follow the reference concentration closely, except an offset, which can easily be compensated.*

Both sensor systems follow the shape of the GC reference with a constant offset. One shows a constant higher concentration (1% methane) whereas the other always shows a slightly lower concentration (0,5% methane). Both offsets can be corrected by subtracting a constant offset, as shown in Fig. 2.

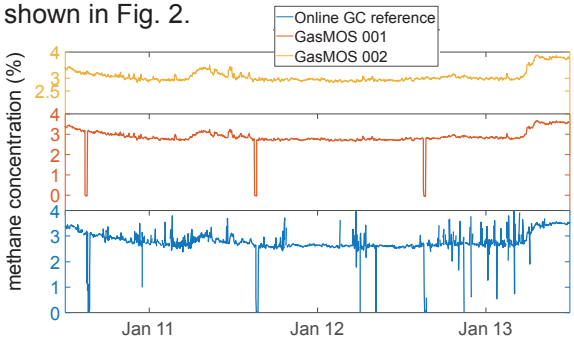


*Fig 2: offset compensated long-term test.*

The 001 system (red line) as well as the reference from the GC (blue line) show a methane concentration of 0 % every 24 hours, whereas the 002 system (yellow line) shows a methane concentration of 3.8 %. This is caused by the self- fresh air balancing where the intake is periodically switched to fresh air without any methane. Since the 001 system and the GC are connected in series, the reference air is applied to both, whereas the 002 system is connected in parallel to the others and therefore air is never applied to this system. Nevertheless, both systems show the same trend as the reference. Even small concentration changes (0.05% change in methane concentration) can be detected with all three systems. Therefore, the multi gas sensor system shows a high precision comparable to a commercially available GC but a low accuracy between the systems still exists, due to the offset from the reference. To increase the accuracy, it is possible to subtract the offset with a base line correction where the system intake is periodically switched to an atmosphere without methane [4]. To increase the accuracy even further, it is possible to perform a two-point online recalibration where the system is also periodically exposed to a defined methane concentration.

## Conclusion

We have shown that this multi sensor approach yields a promising selective methane determination in harsh environments such as a gas engine. It is possible to determine the methane concentration with a resolution and precision comparable to a commercial reference GC, even with an unknown amount of interfering gases produced by the combustion process of the engine. To eliminate the still existing offset between system and reference, an automated recalibration procedure must be developed and implemented.

## Acknowledgements

Part of this research was performed within the project “GasMOS” funded by the European Regional Development Fund (ERDF).

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