Heavy-Duty Gas Engines integrated into Vehicles

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Project partners:

1 - AVL - AVL List GmbH - AT
2 - BWR - Borgwarner Ludwigsburg GmbH - DE
3 - BOSCH - Robert Bosch GmbH - DE
4 - DAI - Daimler AG - DE
5 - DINEX - Dinex Ecocat OY - DK
6 - FPT - FPT Industrial S.p.A. - IT
7 - IDIADA - Idiada Automotive Technology S.A.- ES
8 - IVECO - Iveco Espana SL - ES
9 - MAN - MAN Truck & Bus AG - DE
10 - POLIMI - Politecnico di Milano - IT
11 - RCD - Ricardo UK Limited - UK
12 - SAG - SAG Motion GmbH - AT
13 - TNO - Nederlands organisatie voor toegepast natuurwetenschappelijk onderzoek - NL
14 - TUG - Technische Universiteat Graz - AT
15 - UEF - ITA-Suomen Ylipisto (University of Eastern Finland) - FI
16 - UASE - Hochschule Esslingen - DE
17 - UNR - Uniresearch BV - NL
18 - VOLVO - Volvo Technology AB - SE
19 - VIF - Virtual Vehicle Research Center - AT

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Executive summary

MAN and IDIADA are developing within the HDGAS project an advanced dual-fuel natural gas prototype engine and related LNG (liquefied natural gas) truck. This advanced truck will feature a low-pressure injection (indirect injection in the intake system) engine with a diesel-like targeted performance and drivability. The MAN engine will have the economical advantage of less complex injection system hardware compared to HPDI and spark-ignited engines (useful for the LNG trucks market which is still small and with around 30 to 50% extra-costs to the equivalent truck). Additionally, it will be able to revert to full diesel operation when required, thus allowing LNG dual-fuel MAN trucks to run solely on diesel whenever there is a lack of LNG stations (around 60 LNG stations are available in Europe at the moment in 2016) or in case of LNG is not available for any reason.

The engineered engine and vehicle are therefore key to the market development of alternative fuels, in this case LNG. The recent directive 2014/94/EC about Alternative Fuels Infrastructures (AFI) includes LNG as key fuel for Europe and is to be adopted in the coming years to reduce Europe's dependency on oil and mitigate climate change. However, a short term goal has not been detailed, as 2025 is the year defined as the milestone for all member states to establish an adequate network of LNG stations, stations at intervals of 400 km have been suggested. Finally, the member states decide upon the distance between their LNG stations, and given the current economic crisis, this 400 km distance is not expected to be achievable. However, a more realistic interval of 600-700 km between stations is to be implemented. Until now, dedicated 100% LNG trucks or even HPDI trucks have a restricted range of action due to the lack of infrastructure, and thus are limited in providing a viable business case for today's fleet operators' needs. The fact that the TGX LNG, using a dual-fuel engine, is able to operate using both fuels at the same time and if required by the circumstances operated only in diesel, gives fleet operators the opportunity to run their trucks everywhere in Europe without any limitation, to have a good TCO (Total Cost of Ownership) and still maintain a similar residual value of the truck (in comparison to the current residual value reduction of a 100% LNG truck in Europe).

Deliverable 5.4 condenses the results of task 5.3, "Development of dual-fuel engine", where a completely new engine management system has been tailored and calibrated following an engine concept based on simplicity and robustness. Integrating the functionalities of the engine independent of the fuel used, substitution ratios of up to 90% have been calibrated for the entire engine operating range, except at full load where ratios are reduced in order to guarantee the correct combustion process, providing the same performances of the baseline diesel engine and meeting Euro VI emissions compliance. The new engine has been optimized for dual-fuel mode operation and if no gas is available, it is also able to run on diesel - in the same way as it was possible before with the baseline Bosch EDC17 unit.

The D26 engine, which was previously used for tasks 5.1, "Development of initial dual-fuel engine assessment", has been upgraded with a new tailored control unit which integrates all the functions to run the engine either in pure diesel mode or dual-fuel mode. These functions, algorithms and strategies have been developed from scratch by IDIADA and integrated on a Pi Innovo M670 control unit for rapid prototyping, including the functions of the SCR and DPF system. Therefore, the original D26 Bosch EDC17 is not used anymore, while the same hardware of the engine is kept, including the wiring harness, pistons, cylinder head, turbochargers and aftertreatment.

Calibration has been supported by engineering expertise on engines, including simulation. IDIADA has performed both 1D and 3D simulations. 1D Gt-Power and 3D-CFD AVL Fire tools were used by IDIADA, however in both cases new and tailored combustion models had to be developed since baseline tools did not predict correctly the dual-fuel combustion phenomena for this kind of engine (type 2 B).

Under R49.06 emission cycle the engineered solution demonstrates that the engine is able to meet Euro VI for methane and NMHC pollutants, providing an average substitution ratio of more than 70% of diesel by natural gas on WHTC warm cycle, and more than 80% on typical long-haul operation with more stable speeds and loads. The engine has been limited in terms of diesel replacement to 90% in stationary operation; however, it has been observed that even higher substitution ratios are technically possible.

With WHTC_GER exceeding 70%, regulation 49.06 defines 0.5 g/kWh of CH4 emissions for a type 2B dual-fuel engine, which has been achieved and demonstrated at IDIADA's engine test bed using regular natural gas (IDIADA has its own LNG station, supplied with commercial LNG, the same as IVECO and SCANIA LNG trucks use in daily

operation in Europe). To meet the more stringent Euro VI emissions limits, as no one has been able to demonstrate it before, IDIADA features the new integrated management system and a methane oxidation catalyst installed in front of the baseline aftertreatment SCR+DPF+NH3 slip. The target aftertreatment, has been tailor-made by IDIADA in cooperation with DINEX.

The baseline Bosch EDC17 engine Control Unit (ECU) has been removed and replaced by an IDIADA tailored control unit which is used to manage all the engine systems, including diesel, natural gas, vehicle functions and aftertreatment at once. The new control unit interfaces by CAN with other systems such as aftertreatment and vehicle PTM (MAN's vehicle control module), which has been created in cooperation between teams in Spain (Tarragona, IDIADA Headquarters), UK (IDIADA Cambridge) and Germany (MAN Munich and Nuremberg).

Work on the engine test bed focused on the optimization of the dual-fuel operation taking advantage of an accurate management of all the engine systems (EGR, throttle, WG, common-rail pump, diesel injectors) in combination with the gas systems (gas rail, gas injectors, gas pressure regulator, etc.) as well as the aftertreatment system, whose components come from the diesel aftertreatment system (DOC, SCR, DPF, NH3 catalyst) and an additional methane oxidation catalyst for the specific need of the dual-fuel natural gas. PPCI (Partially-Premixed Compression Ignition) injection process has been used at low loads, to improve the burn quality of the natural gas at very low turbulence conditions.

Work has mainly focused on a balanced performance (energy consumed) vs emissions (achievement of Euro VI), both in stationary conditions (mapping, WHSC) and transient (T90%, WHTC_warm). At the moment, emissions below 0.36 g/kWh CH4 have been measured at the WHTC_warm following R49.06, with WHTC_Ger exceeding 70%. At the WHSC cycle, the engine is able to meet R49.06 emissions for dual-fuel 2B engines, with Energy Ratios above 80% in all modes, except in idle, which is performed solely on diesel.

Considering the results of the Deliverable 5.1, "Development of initial dual-fuel engine assessment", and Deliverable 5.2, "2013 dual-fuels performance evaluation", and 5.3, "MPI low-pressure dual-fuel functional operation", it becomes clear that the most important challenge to achieve Euro VI compliance for an indirect-injection dual-fuel engine is unburned methane, and this challenge has been overcome by a correct injection strategy applied by IDIADA on the engine and the correct operation of the aftertreatment system supplied by DINEX.

Now that the engine functional and emissions operation has been demonstrated, the engine calibration and configuration will be further optimized in the next months to meet the diesel and dual-fuel Euro VI CO_2 reduction targeted, while the demonstration at the IDIADA Headquarters test bed, supervised by a TÜV witness, will be executed by October 2017.

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