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 Universite at 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

After the specification the catalyst compositions, durability and functionalities (report D3.2), the detailed AfterTreatment System (ATS) designs were finalized for 3 development engines operating partially or fully on natural gas (NG). The three engines on under investigation were a stoichiometric dedicated natural gas (FPT), lean operating natural gas (Ricardo based on FPT engine) and dual fuel Diesel and natural gas (MAN engine/idiada). The engine development was in an early stage and the final exhaust gas variables (flow rates, λ values, temperature, concentration, dual-fuel ratios) were not fully known when this deliverables report was finalized in June 2017. Therefore, the ATS designs were based on the existing data, inputs from WP3 and other work packages, as well as existing design knowledge. The aftertreatment system for the stoichiometric application (FPT) is most straight forward as these vehicles are already commercial. However, there is more space for variation in lean NG and dual-fuel exhaust gas variables, which might create a feedback loop requiring updates to the ATS.

Methane (CH_4) emission control is the main challenge related to NG fueled engines, even if the NG is environmentally friendly fuel has lower CO_2, particulates and heavy HC (polyaromatic hydrocarbons = PAH) emissions, in comparison to diesel. Methane is hard to be oxidized on catalysts with a high efficiency below 400-450°C and these methane catalysts are also very sensitive for deactivation.

Three way catalysts (TWCs) are applied for CO, THC (including CH_4) and NO_x removal from the exhaust gases of stoichiometric engines. Methane Oxidation Catalyst (MOC) for methane (and THC) oxidation in lean exhaust gases are required. SCR catalysts are applied for NO_x control in lean exhaust gases. The ATS in MAN/Idiada application will be based on existing diesel Euro VI ATS, where a MOC was added for methane removal in this research project. The TNO dual-fuel engine was the base for MOC accelerated thermal and chemical (sulfur) durability studies.

Due to the high temperature nature of the lean NG combustion, compared to diesel operation, a hybrid SCR system has been specified based on iron and copper catalysts. The hybrid system will consist of an upfront and downstream SCR catalysts with different formulations. For the dedicated lean burn application, the aftertreatment system has been supplied as a modular system, with each of the catalysts are prepared as single units. Therefore, all possible TWC/MOC and Fe-SCR/Cu-SCR combinations are possible to be examined in the Ricardo engine-bench experiments. It is assumed that a diesel particulate filter (DPF) is required only for NG-diesel dual fuel but not for lean NG applications. However, particle number (PN) emissions need to be followed to pass Euro VI limits.

The table below shows the summary of catalyst designs - WP3 applications and sub-projects.

Table 1-1: Summary of ATS designs with Dinex Ecocat substrates and coatings in WP3 in HD GAS project.

Sample nr	Application	Catalyst type	Substrate Dinex	Cells cpsi	Coating type Dinex	PGM Pt:Pd:Rh	Washcoat loafing g/l	PGM g/cft	Catalyst volume, Dimeter/Length
NP13255	FPT 13 litre λ =1	TWC	Brazed EC	500	NG-TWC K5.7	0:16:1	185	200	13,3 L D334 mm L152 mm
NP13346	Ricardo 13 litre lean	TWC	Brazed EC	500	NG-TWC K5.7	0:16:1	185	200	6,4 L x 2 D334 mm, L75 mm
NP13345	Ricardo 13 litre lean	MOC	Brazed EC	500	MOC-KGL4	1:4:0	165	200	6,4 L x 2 D334 mm, L75 mm
NP13348	Ricardo 13 litre lean	SCR	Brazed EC	500	Fe-SCR1	no	165	no	11,4 L x 2 D309 mm, L152 mm
NP13347	Ricardo 13 litre lean	SCR	Brazed EC	500	Cu-SCR1	no	165	no	11,4 L x 2 D309 mm, L152 mm
-	Ricardo 13 litre lean	ASC	Brazed EC	500	Pt-ASC	1:0:0		5	~2-3 L design later
NP13107	MAN/Idiada 12.4L, Dual-fuel	MOC	Brazed EC	500	MOC-KGL4	1:4:0	165	200	11,4 L x 1 D309 mm, L152 mm
NP12813	TNO 7.8L	MOC	Brazed EC	500	MOC-	1:4:0	200	200	8,7 L x 2

	Dual-fuel				KGL4				D270 mm, L152 mm
NP12814	TNO 7.8L Dual-fuel	SCR	Brazed EC	500	Cu-SCR1	no	125	no	9,0 L x 2 D309 mm, L120 mm
NP12815	TNO 7.8L Dual-fuel	DOC	EC	200	KDN1.4	4:1:0	100	35	4.9L x1 D229 mm, L 120 mm

The design drawings were created based on these dimensions for each samples for the preparation and assembly. The catalysts for methane control cause a high increase on ATS costs due to large TWC and MOC (~1x engine size) and high noble metal loadings (≥ 150 g/cft). Solely that noble metal amount for TWC or MOC will cost over 1000 € for a heavy-duty truck. Therefore, all the engine-out methane emission control, integration of catalytic units and possible thermal management are important to keep the size and cost reasonable.

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