Particle Reduced, Efficient Gasoline Engines

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Summary

The Particle Reduced Efficient Gasoline Engine (PaREGEn) project is a European Horizon 2020 project that has been created with a view to demonstrating a new generation of Gasoline Direct Injection (GDI) engines achieving a reduction in CO_2 emissions of 15% compared to the best equivalent engines in the market in 2016 and control of particle size down to 10nm in size through the adoption of new technologies. Jaguar Land Rover (JLR), in conjunction with Bosch (BOSCH), Johnson Matthey (JM), Ricardo (RIC) and Honeywell (HON) are to deliver a Jaguar XE vehicle in 2019 that will adopt dilute combustion (excess air, external Exhaust Gas Recirculation (EGR), internal exhaust residuals or a combination of all three) with a view to realising the fuel consumption saving equivalent to the CO_2 reduction mentioned above as well as ensuring the vehicle and engine they are applied to is compliant with EU6c emissions regulations with particulate control down to 10nm.

The engine controller, currently being developed by Jaguar Land Rover, controls the air and combustion systems centred around dilute combustion. This includes combinations of excess air, external EGR and exhaust residuals. To support this, low-pressure EGR, Continuously Variable Valve Lift (CVVL) and Variable Nozzle Turbocharging (VNT) systems have been employed. This is supplemented by an electric compressor (e-compressor), supplied by Honeywell, to facilitate rapid stoichiometric-to-lean transitions. The combustion system utilises a high energy ignition system coupled with optimised fuel injectors suitable for lean operation and reduced particle formation, both supplied by Bosch. Combustion control is enhanced with the adoption of cylinder pressure feedback control, allowing improved combustion phasing as well as Indicated Mean Effective Pressure (IMEP) control. A 48V system architecture is also configured to drive the e-compressor and Electrically Heated Catalyst (EHC). Smooth coordination of all these systems is critical to achieving a good trade-off between transient performance, fuel consumption and emissions.

The Engine Control Unit (ECU) platform adopted to run the engine controller is a Schaeffler PROtroniC ECU. Key elements of the control system have been implemented and tested successfully at Jaguar Land Rover on a Jaguar XE equipped with an Ingenium 2.0 litre, 4 cylinder, turbocharged gasoline engine. The PROtroniC ECU was also wired to communicate with the vehicle network, in order to enable the car to be driven in all operating conditions. A number of control features were tested covering basic engine control and the CVVL was tested through to combustion feedback control. This work was in preparation for the implementation on the PaREGEn engine at Ricardo, where the engine controller development will be carried forward.

The aftertreatment controller, being developed by Ricardo, is designed to operate under both lean and stoichiometric conditions. Lean NOx reduction is facilitated by a Lean NOx Trap (LNT) in combination with a downstream active Selective Catalytic Reduction (SCR) system. A Gasoline Particulate Filter (GPF) has been selected allowing particle reduction down to 10nm. Both LNT and GPF have been coated to facilitate Three-Way (NOx, CO and HC) catalytic converter capability under stoichiometric conditions. All three catalysts have been supplied by Johnson Matthey as part of WP2.

A supervisory controller (Supervisor) coordinates the various subsystems of the aftertreatment system controller. These include purging of the NOx stored in the LNT, based on both opportunistic and forced events, where the former utilises the normal purging of the TWC following overrun. The Supervisor also manages the heating of the aftertreatment system, enabling the EHC or switching to stoichiometric operation based on the battery as well as the engine operating conditions. Furthermore, the Supervisor coordinates the various functions related to the SCR controller.

The SCR controller is advanced technology (developed by Ricardo on past projects) that is well suited to the PaREGEn concept. Urea is injected upstream of the SCR and is converted immediately into ammonia, which is stored on the catalyst surface to reduce the incoming NOx. A simplified chemical kinetic observer model, developed within a Kalman Filter framework, estimates the level of ammonia storage. This is fed into a PID

controller that controls the quantity of urea sufficient to track a predefined storage set-point which is based on the current catalyst operating conditions. A Reference Governor (RG) predictive controller adjusts this set-point dynamically to ensure the SCR operates within system constraints, including minimal ammonia slippage from the catalyst.

The aftertreatment system controller has been successfully tested in Model-in-the-Loop (MiL) simulations. The SCR observer model was initially characterised using synthetic gas reactor data provided by Johnson Matthey. The controller has also undergone initial testing on the Schaeffler PROtroniC ECU for tool-chain compatibility. The next step is further characterisation and testing on an engine testbed followed by validation on the PaREGEn demonstrator vehicle.

Appendix A – Acknowledgement

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Project partners:

#	Partner	Partner Full Name
1	RIC	RICARDO UK LIMITED
2	DAI	DAIMLER AG
3	JLR	JAGUAR LAND ROVER LIMITED
4	BOSCH	ROBERT BOSCH GMBH
5	FEV	FEV EUROPE GMBH
6	JM	JOHNSON MATTHEY PLC
7	HON	HONEYWELL, SPOL. S.R.O
8	JRC	JOINT RESEARCH CENTRE – EUROPEAN COMMISSION
9	UNR	UNIRESEARCH BV
10	IDIADA	IDIADA AUTOMOTIVE TECHNOLOGY SA
11	SIEMENS	SIEMENS INDUSTRY SOFTWARE SAS
12	LOGE	LUND COMBUSTION ENGINEERING LOGE AB
13	ETH	EIDGENOESSISCHE TECHNISCHE HOCHSCHULE ZUERICH
14	UDE	UNIVERSITAET DUISBURG-ESSEN
15	RWTH	RWTH AACHEN UNIVERSITY
16	UFI	UFI FILTERS SPA

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