Rapid Exhaust Catalyst Heat-up Strategies Evaluated by Using Integrated GT-SUITE Models

M. Sedat Çevirgen

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Sancaktepe R&D Center - 2015
- Vehicle and Powertrain Development, Design Studio, CAVE (Virtual Reality) Software Development (HIL)

Gölcük R&D Center - 2009
- Vehicle and Powertrain Test Facilities, Exhaust Aftertreatment System Test Laboratory, Powertrain Development for MCV and LCV

İnönü R&D Center - 2016
- Engine Test Center, Prototype Shop, Cargo Special Vehicle Engineering, Cargo Manufacturing
Long Haul Tractor Unit

2019 Truck of the Year

Ecotorq 13L 500PS EU6 Heavy-Duty Engine

MT – AMT Heavy-Duty Transmission

Virtual Vehicle Simulation Platform is main target to cover most of the fuel economy engineering problems.
OUTLINE

PROBLEM DEFINITION

TECNOLOGIES

SOLUTION METHOD

GT-SUITE TOOLS

RESULTS

CONCLUSION & DISCUSSION
Engine Operating Modes (EOM)

EOM 4: Catalyst Heat Up Mode

• Fuel Economy trade off
• Heating up the catalyst to run it its most efficient point
• Treshold temperature is defined to go up to economy mode

EOM 0: Fuel Economy Mode

• Fuel economy optimized
• Catalyst runs at its most efficient point
• Treshold temperature is defined to go down to Heat up mode

Problem:
→ At the first minutes of vehicle operation, as the catalyst is not hot, some of the fuel is consumed to heat up the catalyst.

Solution Idea:
→ Already available technologies such as EGR Cooler – Charge Air Cooler by pass and Exhaust Back Pressure valve usage and re-calibration of the critical operating points.
• The already available, above technologies are considered in engine and drive cycle simulations if they have any positive effect on heating up the exhaust aftertreatment catalyst quicker.

• Main physical phenomenon behind the strategies 1 & 2 is to increase the engine inlet temperature, hence targeting increased exhaust temperature before and after turbine.

• For strategy 3, it is considered that running turbine at its less efficiency point will increase the outlet temperature.
- VECTO Long Haul Drive Cycle Fuel Consumption Residencies

- Lower loads are more sensitive for heat-up strategies as the heat required for catalyst almost at threshold

- Lower engine loads between 400 – 800 Nm selected for brake torque levels.

- 1000 – 1200 rpm also represents the vehicle cruise speeds between 75 – 90 km/h
Turbine

Exhaust Back Pressure Valve

- DoE study has been performed for calibration set points in GT-suite engine model.
- Each technology has been evaluated with the DoE.
- To find best SFC (min), T4(max) (Turbine out temperature) point.
- Exhaust back pressure valve is the best tool among the others for max T4 with min SFC penalty.
Selection of Operation Points

Sweep analyses for CAL set points

Best SFC – ExhTemp trade-off

Modifying CAL Maps

Running integrated model at drive cycle to see combined temperature and fuel consumption effect on vehicle level.

Replacing CAL Maps in the GT-SUITE Virtual Vehicle Model
Engine FRM: used for virtual calibration studies. Also within the integrated model environment as main element

Engine Friction Model: Used primarily integrated with engine model. It is the function for Indicated torque and brake torque calculation. All calibration maps in integrated model are dependent on indicated torque at their Y axis

Vehicle & Driveline Model: Used mainly within integrated model to run drive cycle. Driver element uses accelerator pedal which determined the Y axis of all engine calibration maps

Cooling Model: Used mainly within integrated model to predict the coolant and oil temperatures

Oil Cooler Model: Predicts the oil temperature

Underhood Model: Used mainly within integrated model to predict Boost, EGR Cooler outlet, coolant and oil temperatures

Exhaust Aftertreatment Model: Predicts the exhaust catalyst temperature and performs chemical reactions to predict urea consumption
Abbreviations

• EBPV → the model with exhaust back pressure valve applied

• Reference → the base model

• T4 → Exhaust catalyst temperature

Purpose

• The purpose is to observe T4 increase with and without the exhaust back pressure valve technology

• If the T4 exceeds the threshold value then the engine goes to fuel economy mode.

• The model with technology is expected to increase T4 faster than the base model so the residency at fuel economy engine mode to be increased, hence fuel economy to be improved

• Drive cycle VECTO – LH and constant cruise speeds have been analysed in the simulations
VECTO LH cycle with gradients. Driving vehicle with greater loads at which Heat up mode and economy mode make no difference in calibration maps.

No differentiating T4 increase behaviour for this cycle.

Even though the cycle is with constant speeds, the ever changing gradient effects the engine load to stay at higher levels.

No difference at average fuel economy at the end of cycle.
75 km/h 0% grade at top gear (1:1)

Simulation of starting vehicle cold and running at constant cruise speed at flat road.

The simulation time is 500 seconds corresponds to around 10 km of range.

EBPV technology and re-mapped engine gives slight benefit at selected 10 km. with quicker heat-up.

Fuel economy is ~1.6% improved at the first 10 km.

It will obviously get smaller and zero after several more kilometers.
90 km/h 0% grade at top gear (1:1)

Simulation of starting vehicle cold and running at constant cruise speed at flat road.

The simulation time is 500 seconds corresponds to around 12.5 km of range

EBPV technology and re-mapped engine gives slight benefit at selected 12.5 km. with quicker heat-up

Fuel economy is ~1% improved at the first 10 km.

It will obviously get smaller and zero after several more kilometers.
• Already available technologies such as EGR cooler by-pass, Charge air cooler by-pass and Exhaust back pressure valve have been studied for exhaust catalysy rapid heat up

• Exhaust back pressure valve is the best solution among others.

• All simulation were done with ambient temperature (20degC) initial temperature.

• Exhaust heat up strategies make no difference at drive cycles such frequently high load residencies.

• Whereas, constant cruise speed at 0% gradient road conditions are more suitable for technology comparison.

• The selected exhaust back pressure valve technology has got slight advantage only at flat road cruise speed conditions.

• GT-SUITE integrated model platform is applicable for all kind of simulations to represent multi-circuit affected conditions.