

Influence of Mild Hybridization on performance and emission in a 4 cylinder in-line Common Rail Diesel Engine

Maurizio Cisternino

Advanced Engineering-Hybrid Innovation Manager

General Motors Powertrain Europe

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Outline

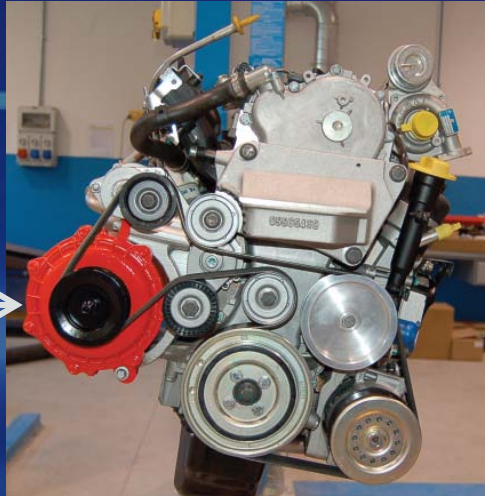
- ❑ Scope of the study
- ❑ Hybrid architecture
- ❑ Engine dyno test methodology
- ❑ FC and emission results
- ❑ Mule vehicle assessment
- ❑ Conclusions

Scope of the study

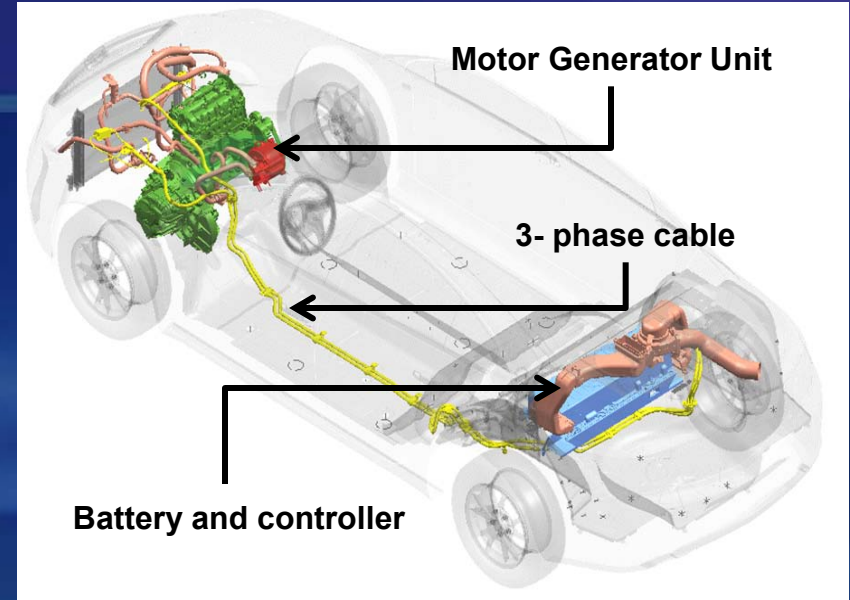
- Experimental assessment of an hybridized 4cyl in line Diesels MT powercube, leveraging the 2nd Gen GM Hybrid Architecture (High Voltage BAS)
- Emissions and performance assessment on:
 - High Dynamic engine test bed on 1.9L Diesel E4
 - Opel Corsa 1.3L Diesel E5 MT BAS Demo Vehicle

Mild Hybrid Architecture

Motor Generator Unit



1.3 SDE Engine Layout



Vehicle Layout

Coolant type	Water cooled
Operating voltage	~115V
Rated power (peak)	~15kW
Rated Torque	~65Nm
Engine-motor coupling ratio	2.4:1
Battery Capacity	~5.5Ah

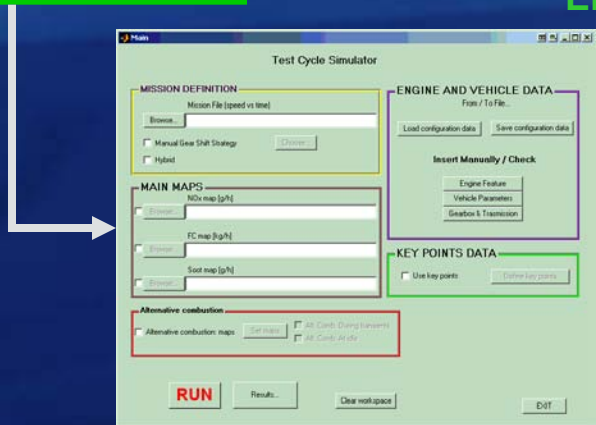
GM BAS gen 2 characteristics

The BAS (Belt Alternator Starter) architecture requires a specific FEAD layout, hybrid controller and battery

Dyno test methodology

- The instantaneous speed-torque trace determined by the hybrid simulation tool has been imposed as a target to the dynamic test bench allowing the test of different engine operating modes without need of hybrid HW
- Battery null balance strategy imposed on NEDC cycle (same SOC level at begin and end of cycle)

•NEDC
•PWT components
•Vehicle



Hybrid strategy

Engine torque, rpm



EM torque, rpm

•FC
•NOx
•CO
•HC
•PM

Engine type	1.9l EURO4
Displacement	1910 cm ³
Bore x stroke	82.0mm x 90.4mm
Stroke-to-bore ratio	1.10
Compression ratio	17.5:1
Valves per cylinder	4
Turbocharger	Single-stage with VGT
Fuel injection system	Common Rail 2nd gen. CRI2.2 – 1600bar – 7holes injector
Maximum power and torque	110kW @ 4000rpm 320Nm @ 2000rpm
Specific power and torque	57.6kW – 167Nm/l

Reference engine



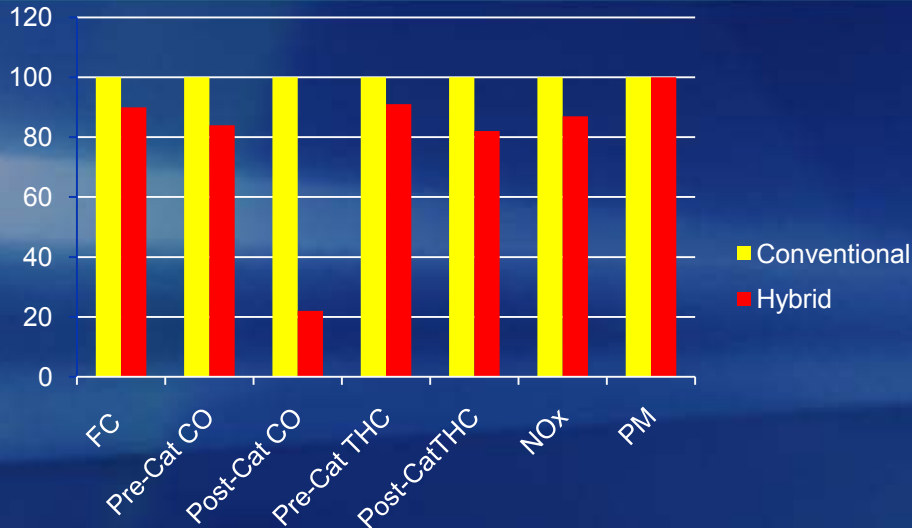
Mild-hybrid Operating strategy assumptions



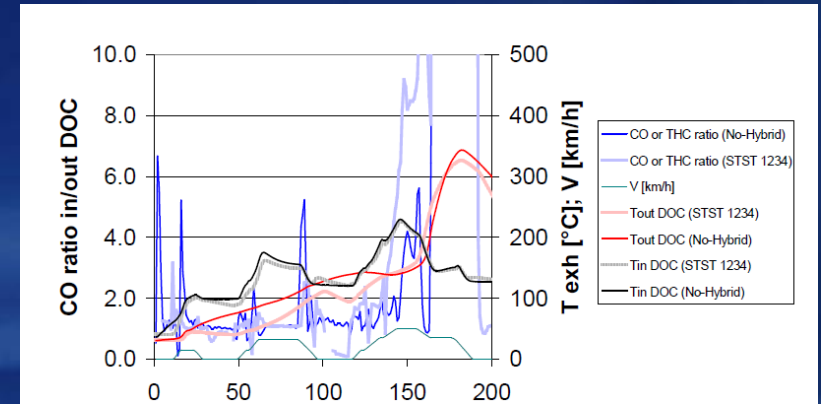
- Stop/Start from cycle ECE-2;
- Electric Assist in drive-away area and gear shift for reduced NOx production and noise;
- Energy recuperation at deceleration/coasting
- Opportunity charging during stationary 2nd and 3rd gear operation;

FC and emission results

Emission percentage reduction in hybridized Diesel (normalized vs conventional operation)



Time history of CO ratio and gas temperatures upstream and downstream DOC in ECE1 of cold NEDC cycle



FE benefits of about 10%

CO and THC emission show improvement due to Start Stop functionality

Both engine out and tailpipe emissions reduced due to lower generation and quicker DOC light off (caused by higher gas temperature by suppressing idling)

Electric assist during transients contributing to moderate NOx decrease

PM not affected

Demo Vehicle tests



Reference vehicle: Opel CORSA 1.3L SDE Euro 5 Diesel with Manual Transmission M20/M32 - Hybridized with GM HV BAS 2nd Gen

Tests performed focused on assessment of:

- Autostart and autostop functionality (Time, NVH, consistency, activation strategy)
- Electric boost and elasticity improvement
- Driveability

S&S activation strategy with MT

Engine Stop



..approaching the stop.



...clutch being disengaged...



...rpm gauge indicates „AUTOSTOP“ active.



..neutral engaged (optional)..



..clutch engaged (optional)..

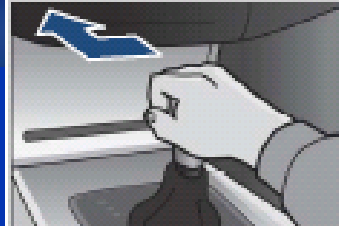
Engine Start



Driver wants to drive off...



...presses the clutch pedal...



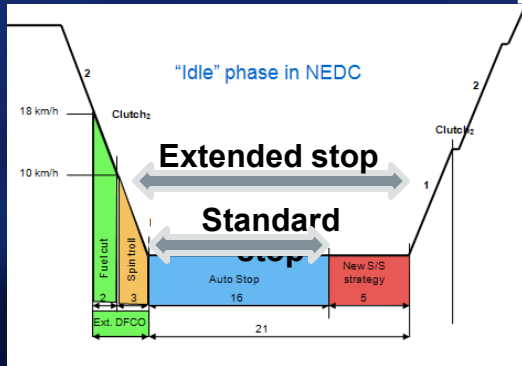
...the driver engage the first gear...



..releases the clutch pedal...

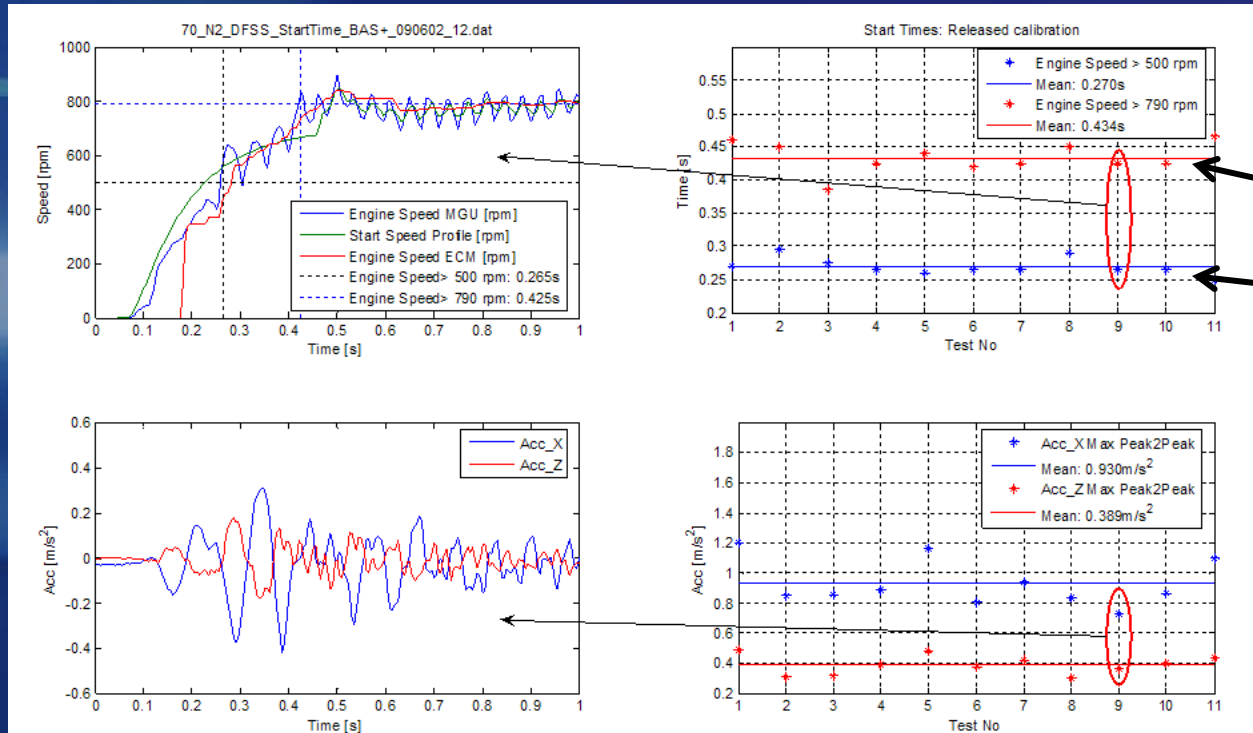


...the engine is started and the vehicle drives off.



S&S activation strategy enabled by quickness of BAS restart allows extended engine off time at NEDC idle phase compared to starter based S&S system (+50% idle time)

Autostart results



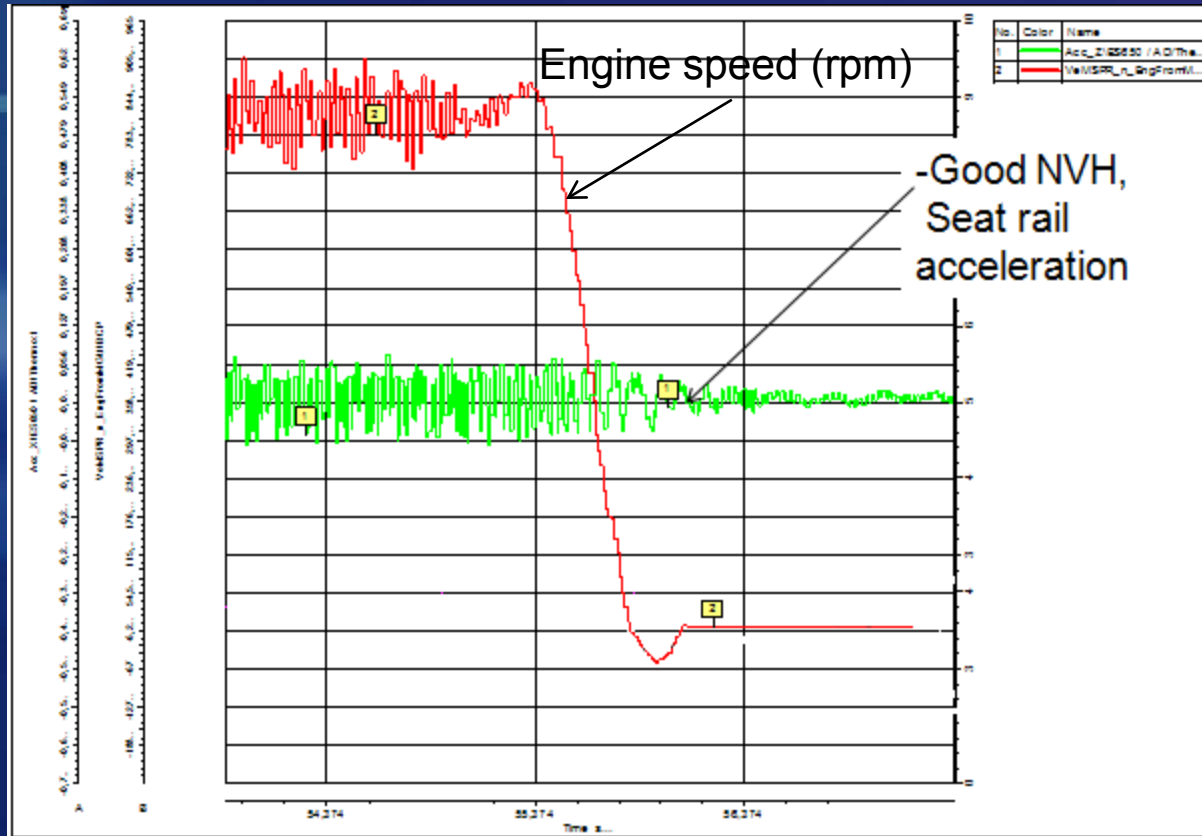
Start time 0->800 rpm

Start time 0->500 rpm

➤ Average start time 435ms (0 to idle) and 270ms (0 to 500 rpm) with max spread of 55ms depending on engine stop position

➤ Smooth start with low NVH (seat acceleration <0.5m/s/s)

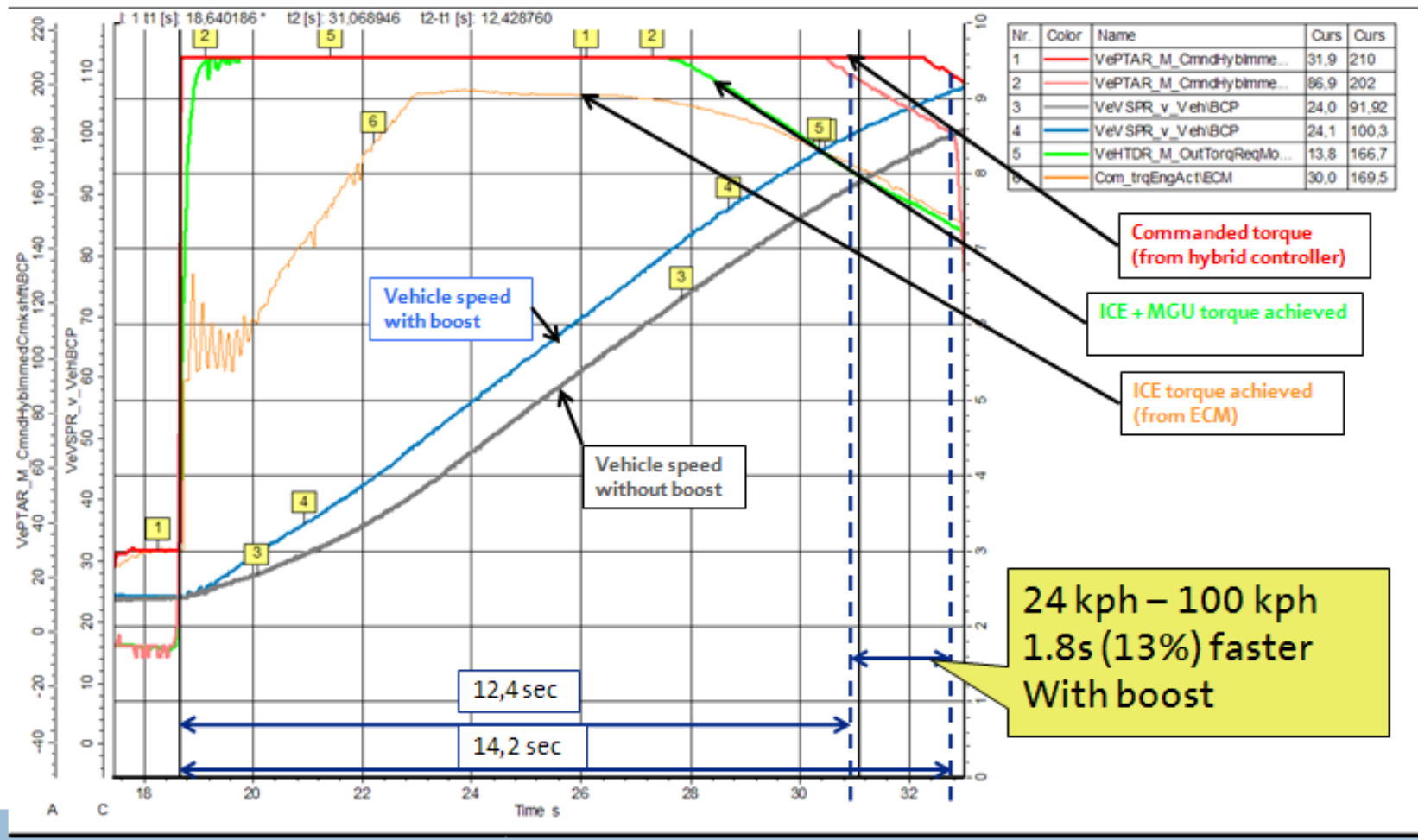
Autostop results



- Average stop time of about 400ms with ICE compression compensation
- Very fast and smooth stop with unnoticeable vibration and noise

Electric assist & elasticity

in



WOT in 3rd gear manouver

Conclusions

- Mild-hybridization of Diesels has been experimentally assessed showing a general improvement of both FE and emissions.
- Benefits driven by suppressions of engine idling time have been observed in CO and THC emissions also due to an accelerated DOC light-off
- NOx emission has also showed improvements due to the electrical assist in transients, while PM engine out emission is unaffected by mild hybrid operations.
- Vehicle tests have showed consistent, smooth and fast autostart and autostop with very low NVH and a perceivable elasticity improvement due to mild hybrid torque assist capability. Positive overall subjective assessment of driveability
- Additional activities planned to investigate synergies of mild hybrid technology with turbocharger for optimal turbo-matching, valves deactivation for optimal regeneration and impact on Euro 6 after-treatment (SCR, LNT) and DPF regeneration

Thank you for the attention

