48V Hybridization Of A Mid Size Vehicle Using Electric Motor And Electric Assisted Supercharger

Team Members: Thomas REDLINGER, Shixiong ZHAO, Aggelos ZOUFIOS, Stanish GUNASEKARAN

Abstract

In a context of growing demand for sustainable transportation worldwide, different technical solutions for hybrid vehicles are nowadays investigated as effective ways to improve efficiency of the driveline and thus to reduce CO₂ emissions. As a matter of fact, the CO₂ emission targets set by EU (95 g/km in 2020 and 75 g/km in 2030) are extremely demanding.

In order to reach the 2020 CO₂ emission target with a spark ignition engine, solutions need to be developed (e.g., hybridization) or refined (e.g., downsizing). At the same time, no compromise should be done between fuel consumption and fun-to-drive. While turbocharged engines exhibit poor transient performance (“turbo lag”), an electric supercharger allows improving fuel consumption, turbo lag and increasing engine torque at low speed.

The subject of this study is to present a cost effective solution package with a gasoline engine, achieving lower CO₂ emissions compared to a state of the art Diesel engine without compromising fun-to-drive.

Target

- Baseline: Golf VII 1.6L TDI, a state-of-the-art conventional diesel vehicle.
- Target those kind of CO₂ figures with a mid-size hybrid vehicle (48V) powered by a turbocharged gasoline engine and equipped with a manual transmission.
- Provide better driving performance (fun-to-drive) by adopting an electric-assisted supercharger (eSC).

Hybrid Architecture Selection

P1: Assumptions: Stop & Start disabled during the first 15s to warm up the engine.

Pros: Limited extra-weight.
Cons: No regenerative braking when clutch disengaged, engine driven by electric motor during starting.

P2: E-Machine can be totally decoupled from engine.
Cons: Additional clutch (limited space for transverse engine).

P3: Double shaft suitable with transverse engine, Regenerative braking with engine totally decoupled.
Cons: Additional transmission ratio (weight).

As the C-segment cars usually adopt a transverse engine, the P3 architecture has been preferred with a gear ratio of 3 to ensure the CO₂ target.

Benchmark (C-segment)

Diesel Gasoline Hybrid
A Golf 7 V 1.6 TDI Peugeot 308 1.6 THP Toyota Aqua
Power [hp] 110 125 126
Torque [Nm] 275 350 275
Maximum speed [km/h] 192 196 196
B Peugeot 308 Blue HDI 130 Ford Focus III 1.0 EcoBoost Peugeot 308 THP
Power [hp] 130 130 156
Torque [Nm] 360 275 275
C Alpha Romeo Giulietta 1.6 JTDM-2 105 Renault Megane Energy TCe 1.5 Blue dCi
Power [hp] 110 110 115
Torque [Nm] 250 275 275

Engine Selection & Optimization

- IC Engine L4 4 cylinders Turbocharged Specific Torque 170.0
- Max Torque [Nm/L] 100.0
- Max Power [kW/l] 67.3

3-cylinders Implementation

Assumptions:
- 5:1/8 ratio for conventional gasoline engines + 0.8
- Exhaust gas losses = 30 % of the fuel energy
- Constant mean wall temperature
- BMEP unchanged

Heat losses proportional to the available surface area

2.75% gain in fuel consumption

9.55% reduction in heat transfer area

Engine operating point evolution of 60-100km/h acceleration

Fuel Consumption (L/100km)

Gear Selection Optimization

Assumptions: Stop & Start disabled during the first 15s to warm up the engine.

Pros: Fuel Consumption & CO₂ Emission

Gear Shifting Strategy (Manual Transmission):
- When vehicle speed is constant or increases a gear has to be engaged (safety).
- When decelerating shift to neutral to recover the max energy.
- E-machine (15kW) ensures take off.
- A fuel penalty is added to gear shifting.

Fuel Consumption NEDC 3.72/L/100km (2.8% Fuel Saving)

e-Supercharger Implementation

- Electric-assisted supercharger is able to considerably reduce the time to torque, thus increasing the fun-to-drive of a vehicle. Improvement could reach more than 10%.
- E-motor is another good enabler of better acceleration performance, but requires rapid depletion of the battery capacity.

Cost Calculation

Gas Hybrid Diesel Insurance (€/year) 385 550
Maintenance (€/year) 900 1000
Fuel consumption (€/year) 605 560
Total cost (€/years) 9450 10550

Conclusion

- Through Mild Hybridization (48V) it has been possible to achieve considerable CO₂ benefit regarding both conventional gasoline and state-of-the-art diesel vehicle and meet the 95 gCO₂/km target.
- Thanks to the E-Machine (15kW) and electric supercharger (4kW) (especially at low and mid load) the fuel improvement is not at the expense of the fun-to-drive.

Acknowledgement

Special thanks go to Mr Sebastien Potreau from Valeo and Mr Prakash Desawar from IFP School for their continuous support and availability.