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 CO_2 emissions. As a matter of fact, the CO_2 emission targets set by EU (95 g/km in 2020 and 75 g/km in 2025) are extremely demanding.

In order to reach the 2020 CO_2 emission target with a spark ignition engine, solutions need to be developed (e.g. hybridization) or reinforced (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 CO_2 emissions compared to a state of the art Diesel engine without compromising fun to drive.

Target

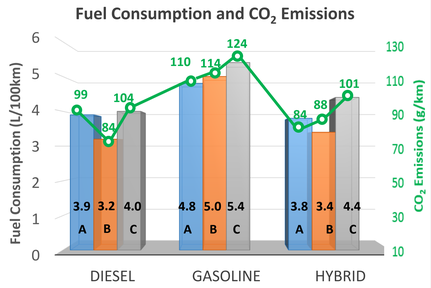
- Baseline: Golf VII 1.6L TDI, a state-of-the-art conventional diesel vehicle.

Curb Weight (kg)	Power (hp)	Torque (Nm)	Maximum speed (km/h)	80-120 km/h (s)	30-60 km/h (s)	NEDC FC (L/100km)	CO2 (g/km)
1295	105	250	192	11.6	6.7	3.9	99

- Target those kind of CO_2 figures with a mild-hybrid vehicle (48 Volt) 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).

Benchmark (C-segment)

	Diesel	Gasoline	Hybrid
A	Golf VII 1.6 TDI	Peugeot 308 II 1.2 THP	Toyota Auris 136h
B	Peugeot 308 Blue HDI 120	Ford Focus III 1.0 Ecoboost	Peugeot 3008 Hybrid4
C	Alpha Romeo Giullietta 1.6 JTDM-2 105	Renault Mégane Energy TCe 130	Honda Insight II



Engine Selection & Optimization

IC Engine	1.6L 4 cylinders Turbocharged
Max Torque [Nm/L]	170.9
Max Power [kW/L]	67.3

Specific Torque → Engine Downsized to 1.2L → ✓ Improving Fuel Consumption → Heat losses proportional to the available surface area → 3 cylinders implementation → 9.15 % reduction in heat transfer area → ✓ 2.75% gain in fuel consumption

$$\dot{Q} = h * A * (Tg - Twall)$$

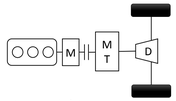
3-cyclinders Implementation

Assumptions:

- S/B ratio for conventional gasoline engines = 0.8
- Exhaust gas losses = 30 % of the fuel energy
- Constant mean wall temperature
- BMEP unchanged

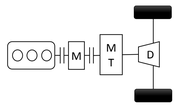
Hybrid Architecture Selection

P1



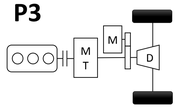
Pros: Limited extra-weight.
Cons: No regenerative braking when clutch disengaged, Undergoes engine resistive torque when running Full Electric or regenerating during braking.

P2

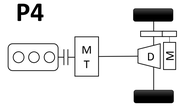


Pros: E-Machine can be totally decoupled from engine.
Cons: Additional clutch (limited space for transverse engine).

P3

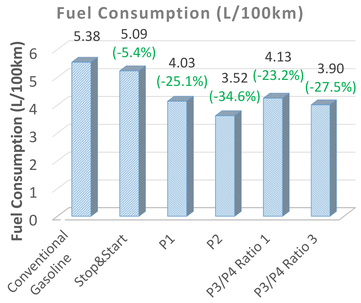


P4



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

Assumptions: Imposed gear shifting, ideal Stop & Start, E-Machine (15 kW) not used for cranking and all the braking torque can be recovered by the E-Machine.



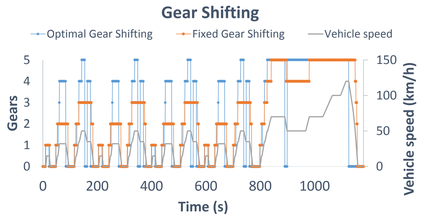
As the C-segment cars usually adopt a transverse engine, the P3 architecture has been preferred with a gear ratio of 3 to ensure the CO_2 target.

Gear Selection Optimization

Assumptions: Stop & Start disabled during the first 150s to warm up the engine.

Gear Shifting Strategy (Manual Transmission) :

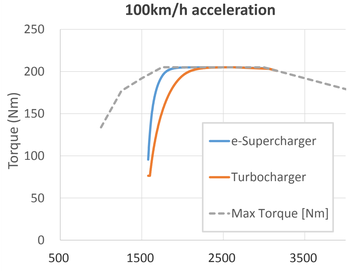
- When vehicle speed is constant or increases a gear has to be engaged (safety).
- When decelerating shift to neutral to recover the max energy.
- E-machine (15kW) ensures take off.
- A fuel penalty is added to gear shifting.

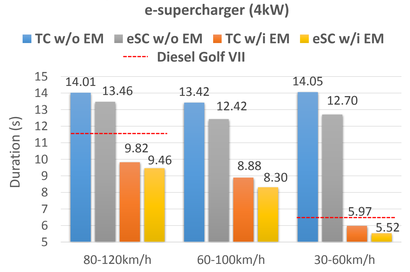


Fuel Consumption NEDC: 3.72L/100km
(2.8% Fuel Saving)

e-Supercharger Implementation

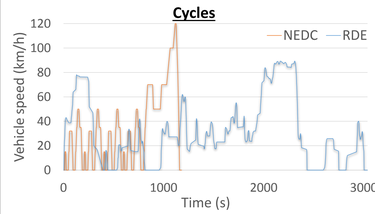
- Electric-assisted supercharger is able to considerably reduce the time to torque, thus increases the fun-to-drive of a vehicle. Improvement could reach more than 10%.
- This improvement is especially interesting when the engine is running at low RPM.
- E-motor is another good enabler of better acceleration performance, but requires rapid depletion of the battery capacity.

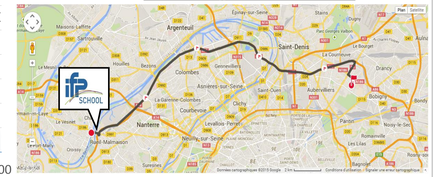




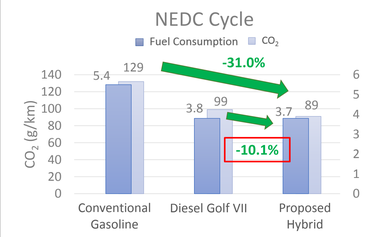
Results

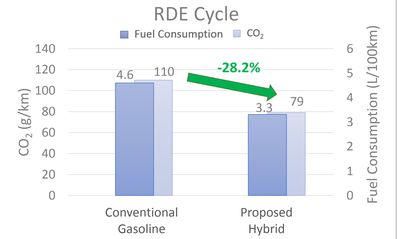
Cycle Definition





Fuel Consumption & CO_2 Emission

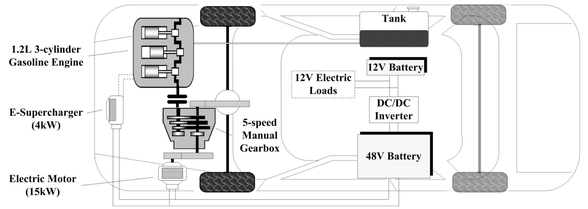




System Overview

Additional components:

- E-Supercharger (4kW)
- E-motor (15 kW)
- Battery pack (48V)
- DC/DC converter
- Cables



Additional Weight and Cost Estimation

Comparison: Proposed Hybrid	vs. Conventional Gasoline	vs. State of Art Diesel (Golf VII 1.6TDI)
Weight Increase	+ 43 kg	+ 3 kg
Additional Cost	+ 1285 € (*)	+ 285 € (*)
CO_2 Benefit	40 g/km	10 g/km
CO_2 Reduction Cost	32.1 €/gCO_2/km	28.5 €/gCO_2/km

(*) : Indicative Market Price for 2020 for mass production (> 200 000 pieces / year)

Total Cost of Ownership Estimation

Assumptions	Gas Hybrid	Diesel
Mean distance (km/year)	12 700	12 700
Ownership duration (year)	5	5
Fuel rate (€/L)	(Super 98) 1.28	1.17
Fuel consumption (L/100km)	3.72	3.9

Cost Calculation	Gas Hybrid	Diesel
Insurance (€/year)	385	550
Maintenance (€/year)	900	1000
Fuel consumption (€/year)	605	560
Total cost (€/5years)	9 450	10 550
	(1100€/5years Savings)	

Conclusion

- Through Mild Hybridization (48V) it has been possible to achieve considerable CO_2 benefit regarding both conventional gasoline and state-of-the-art diesel vehicle and meet the 95 gCO_2/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 Potteau from Valeo and Mr Prakash Dewangan from IFP School for their continuous support and availability.