LES MOTEURS PSA EURO 6
DE DEUXIEME GENERATION ET LES
PERSPECTIVES AU DELA DE 2020

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Powertrain System Senior Expert

QUALITY AND ENGINEERING DIVISION

Arts et Métiers - 3 novembre 2017
1. CHALLENGES PRINCIPAUX

2. NOUVELLES FAMILLES MOTEURS ESSENCE

3. NOUVELLES FAMILLES MOTEURS DIESEL

4. PERSPECTIVES AU DELA DE 2020
CO₂ REDUCTION

- Clean mobility is a major target for automotive industry
- CO₂ reduction drives important technical evolutions in vehicles and powertrains. Middle term roadmaps are still moving taking in account “reasonable” overcost
- Groupe PSA has developed for many years solutions to make consistent progress in fuel economy and emissions reduction
1 - CHALLENGES PRINCIPAUX

- **ÉLECTRIQUE**
  - 1995

- **DIÉSEL HDI**
  - 1998

- **DPF**
  - 2000

- **STOP & START**
  - 2004

- **GAZOLINE THP**
  - 2006

- **HYBRID4**
  - 2012
For emissions, progress has been made in all major customer usages and RDE with new test cycles will contribute to measure progress.

For fuel consumption (and in next future, NOx emission) Groupe PSA, NGOs T&E and FNE, and Bureau Veritas set up a protocol for measuring real world fuel consumption. Until now, Groupe PSA has published results for more than 58 vehicles.

Challenge for “out of Europe”: to carry technical improvements with lower quality fuels and lubs with more difficult usage conditions.
CO₂

- 2020: CO₂ emissions target is, for Groupe PSA, less than 95 g/km
- Groupe PSA will release PHEV on mid/upper platform and BEV on future new small platform
- But in 2020, in Europe
  - BEV: 4% to 5% of the market
  - MHEV and PHEV: 12% of the market

⇒ Conventional thermal engine = more than 80% of the sales
⇒ More than 95% of the sold vehicles = at least one thermal engine

Further improvement of conventional engines is necessary
2.1 – Headlines of new PSA gasoline engine line up

### PURETECH 3 CYLINDERS 1.2l
- PURETECH 82: 60kW / 118 N.m (N.A.)
- PURETECH 110: 81kW / 205 N.m
- PURETECH 130: 96kW / 230 N.m

### PURETECH 4 CYLINDERS 1.6l
- PURETECH 180: 133kW / 250 N.m
- PURETECH 225: 165kW / 300 N.m
2.2 – New 1.2l Puretech engines

Launch date: 1st application in Europe: December 2017
Launch date: 1st application in China: March 2019

Main objectives

- Improve fuel consumption on the engine itself and on powertrain with new manual (6 speed) and new AT (8 speed) gearbox
- Improve packaging for installation in all existing and future vehicle platforms
- Meet most of worldwide emissions with in particular:
  - Euro 6d anticipated with RDE conformity factor of 1.5 (WLTP)
  - China 6b (and China 6a)
- Ability to be deployed worldwide
- Robustness to fuel quality
2.2 – New 1,2l Puretech engines

Main features

- Cylinder head evolution with compact packaging
- Combustion system upgrade with new turbocharger
- Improved protection strategies and mechanical reinforcement to cope with environmental requirements and improve robustness to abnormal combustion with low quality fuels and/or extreme usage conditions
- Gasoline particulate filter (GPF)
- Reduction of friction losses
- Proportional A/F sensor
- Volumetric ratio: 10,5 (same for Europe and China)
- Same core calibration settings for Europe and China
Main characteristics of the new EB PureTech engine

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<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Number of cylinder</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>Displacement</td>
<td>cm³</td>
<td>1199</td>
</tr>
<tr>
<td>Stroke</td>
<td>mm</td>
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<tr>
<td>Bore</td>
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<tr>
<td>Cylinder spacing</td>
<td>mm</td>
<td>82</td>
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<tr>
<td>Main bearing diameter</td>
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<tr>
<td>Conrod bearing diameter</td>
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<td>42</td>
</tr>
<tr>
<td>Conrod length</td>
<td>mm</td>
<td>143</td>
</tr>
<tr>
<td>Compression ratio</td>
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<td>10,5</td>
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<tr>
<td>Power output</td>
<td>kW</td>
<td>96</td>
</tr>
<tr>
<td>Specific power output</td>
<td>kW/l</td>
<td>80</td>
</tr>
<tr>
<td>Max torque</td>
<td>Nm</td>
<td>230</td>
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<tr>
<td>Specific max torque</td>
<td>Nm/l</td>
<td>192</td>
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<tr>
<td>Fuel type (European version)</td>
<td>RON</td>
<td>91 - 98</td>
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</table>
NEW 1.2L PURE TECH PSA ENGINE: A CHAMPION IN FUEL CONSUMPTION!

Large range BSFC <240g/Kw/h

Minimal BSFC: 234g/kWh

Performance: 96kw / 230 mN
2.2 – New 1,2l Puretech engines

**Combustion system upgrade**

- Full use of double VVT to optimise BSFC, gaseous and PN emissions and comply with RDE requirements
2.2 – New 1.2l Puretech engines

Combustion system upgrade

- Increase of injection pressure from 200 to 250 bars which gives 20 to 30% PN reduction (raw emissions upstream aftertreatment system)

<table>
<thead>
<tr>
<th>Operating point : 3000 - 8bar BMEP</th>
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<tbody>
<tr>
<td>Fuel pressure</td>
</tr>
<tr>
<td>Particulate Number</td>
</tr>
<tr>
<td>Gap</td>
</tr>
</tbody>
</table>

Combustion system with 5 holes injector with 50° spray angle offers best compromise between PN, oil dilution issues and pre-ignition occurrence
Engine dynamic performances improved by turbocharger evolutions

- Global evolution of the turbocharger performance through
  - Reduction by 20 % of the inertia with the use of a mix-flow technology for the turbine
  - Compressor stage was also redesigned for a significant step in terms of efficiency
  - Reduced shaft diameter (less friction losses)
  - Improvement of the sealing between wastegate valve and seat. An axial prepositioning was added by a ring welded in the bushing
  - Integration of the dump valve
  - Electric wastegate actuator instead of pneumatic
2.2 – New 1,2l Puretech engines

**Engine dynamic performance improved by turbocharger evolutions**

- Inertia benefit (-20%) in comparison with previous turbocharger
- Turbine wheel efficiency increased at equal flow capacity
- Enhancement of the turbocharger bearing system
2.2 – New 1,2l Puretech engines

- Improved protection strategies and mechanical reinforcement to cope with environmental requirements and improve robustness to abnormal combustion with low quality fuels and/or extreme usage conditions.

- Several steps of improvement:
  - Lube oil specification
  - Oil consumption limitation (most important improvement is in oil ring tuning)
  - Ring carrier on pistons
  - Pre ignition protection strategies
  - Cylinder head cooling
2.2 – New 1,2l Puretech engines

- Groupe PSA will generalize GPF in all TGDi PURETECH engines
- The « one-can » module with
  - a 3 ways catalyst (1,25l)
  - a cordierite GPF (1,16l)
- Filtering efficiency of 75%
- Specific strategies to manage all driving conditions which could generate GPF overload
FRICTION LOSSES

- Main features of current engine are unchanged:
  - Crankshaft offset
  - Main and conrod bearings diameter

- Regulated oil pump
- DLC coating on tappets
- Timing belt in oil
FRICITION LOSSES

- Introduction of new improvements regarding friction losses:
  - 0W20 oil: reduced viscosity and new additives
  - Optimized ring pack: very low tangential load
  & DLC coating on 1st and 3rd ring:
  - Superfinishing on cams: better compromise cost / friction than DLC coating

⇒ - 6.8% friction losses on new engine compared to the current
2.2 – New 1,2l Puretech engines

Frictions losses: Synthesis

- Friction improvement between previous and new generation Puretech engines: up to 6,8% gain in WLTC

![Friction losses optimization graph]

- New oil 0W20: 1,6%
- Superfinishing on cams: 3,4%
- Oil ring with DLC: 0,4%
- Camshaft bearing geometry: 1,4%
- €6.2 engine: 6,8%
2.3 – Global powertrain Puretech 3 cylinders attributes improvement with new transmission

- Steady state performances are unchanged:
  230 N.m @ 1750 rpm and 96 kW
- Transient response improved

<table>
<thead>
<tr>
<th>EUROPE (WLTP)</th>
<th>MT</th>
<th>4%</th>
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<tbody>
<tr>
<td></td>
<td>AT</td>
<td>3 to 4%</td>
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<table>
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<tr>
<th>CHINA (China 6b)</th>
<th>MT</th>
<th>2%</th>
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<tbody>
<tr>
<td></td>
<td>AT(*)</td>
<td>Up to 9%</td>
</tr>
</tbody>
</table>

* DCT in China

- Emissions results
  - Euro 6d with RDE ≤ 1,5 achieved
  - China 6b achieved
3.1 – Headlines of PSA Diesel engine line up

1,5 BLUE HDi

1,5 BLUE HDi 130: 96kW / 300 N.m
1,5 BLUE HDi 100: 75kW / 250 N.m

2,0 BLUE HDi

2,0 BLUE HDi 180: 130kW / 400 N.m
Main objectives

- Improve fuel consumption on the engine itself and on powertrain with new gearboxes
- Improve packaging of the engine and aftertreatment system for installation in all existing and future vehicle platforms
- Meet key emissions target
  - Euro 6d anticipated with RDE conformity factor of 1.5 (WLTP)
  - Japan and Korea
- Improve digital design (and reduce experimental phases)
3.2 – New 1,5l Blue HDi engines

Main features

- New design of the cylinderhead with better packaging and 4 valves by cylinder
- New combustion system
- New EGR system
- New “one-can” aftertreatment system (with SCR on filter trap)
- Reduction of friction losses

Remarks

- Derived versions for commercial applications
- Development in collaboration with Ford
NEW 1,5L BLUE HDI PSA ENGINE: A CHAMPION IN FUEL CONSUMPTION!

Large range BSFC < 220g/Kw/h
Minimal BSFC: 210g/kWh
Performance: 96kw / 300 mN
3.2 – New 1.5l Blue HDi engines

From 2013, PSA extended the SCR use on all its applications

Efficient NOx aftertreatment technology allows combustion system optimization for global vehicle NOx and CO2 reduction

- Compression ratio increase
- Injector nozzle optimization
- Adapted and optimized injection pattern and calibration

Euro 6

Euro 5
3.2 – New 1,5l Blue HDi engines

- Objectives for new engine generation
  - Further CO₂ and NOx emission reduction on the whole range of vehicle utilization
  - Improvement of specific performances and NVH
  - Keep downsizing benefits and fun to drive

→ New combustion system set up to fulfill these requirements

- Full load combustion analysis
  - Increased heat release rate when combustion reaches squish area
  - Reduced combustion duration
  - Improved efficiency

→ This new combustion system offers
  - An increased thermal efficiency without pollutants emissions penalties
  - Further CO₂ and NOx reduction combined with aftertreatment system
3.2 – New 1,5l Blue HDi engines

THE NEW BLUE HDi AFTERTREATMENT SYSTEM:
A COMPACT INNOVATIVE « ONE-CAN » SYSTEM

DOC / NOx ADSORBER:
- CO, HC REDUCTION
- NOx STORAGE AT LOW TEMPERATURE

EXHAUST:
H2O, N2, CO2

POLLUTANTS:
PARTICULATE MATTER, CO, HC, NOx

ADBLUE® OPTIMISED INJECTION

OPTIMISED NOx CONVERSION
THANKS TO SCR CATALYST
AND ONE SCR ON DPF
- UP TO 95% NOx REDUCTION
- 99% PM REDUCTION AND 99.9% PN REDUCTION
3 – NOUVELLES FAMILLE MOTEURS DIESEL

3.2 – New 1,5l Blue HDi engines

**Fuel consumption reduction: main drivers**

- **Combustion system** with new 16V cylinder head / 2000 bar injection pressure and high efficiency cooled EGR

- **Friction losses reduction**
  - Oil viscosity: 0W20 instead of 0W30
  - 1 ball bearing on inlet camshaft on timing belt side
  - Low friction coating on piston and rings
  - Ring pack tuning (dimension and tangential load)
  - Significant reduction of crankshaft’s, connecting rod’s and piston’s masses
    - -15% for alternative mass
    - -35% for connecting rod’s rotating mass
3.3 – Global 1,5 BLUE HDi powertrain attribute improvement with new transmission

- Emissions results
  - Euro 6d with RDE CF < 1,5 achieved

- Fuel consumption

<table>
<thead>
<tr>
<th>EUROPE (WLTP)</th>
<th>1,5 Blue HDi 130</th>
<th>MT</th>
<th>5 to 6%</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>AT</td>
<td>7 to 9%</td>
</tr>
<tr>
<td>1,5 Blue HDi 100</td>
<td>MT</td>
<td>4 to 6%</td>
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REAL WORLD FUEL CONSUMPTION

- Thanks to measurements handled with T&E FNE, it is now possible to evaluate the consumption in real world driving conditions for more than 1000 versions of Peugeot, Citroën and DS vehicles. For each model, estimations have been made at same powertrain plus 3 variants: body type, trim level and tires dimensions.

<table>
<thead>
<tr>
<th>6 DS MODELS</th>
<th>Protocole l/100km</th>
<th>Homologation l/100km</th>
<th>Ecart l/100km</th>
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<tbody>
<tr>
<td>DS 3 PureTech 110 S&amp;S BVM pneu 16&quot; TBRR</td>
<td>6</td>
<td>4.3</td>
<td>1.7</td>
</tr>
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<td>5</td>
<td>3.6</td>
<td>1.4</td>
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<tr>
<td>DS3 cabrio BlueHDI 100 S&amp;S BVM pneu 16&quot; TBRR</td>
<td>5</td>
<td>3.5</td>
<td>1.5</td>
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<td>DS4 PureTech 130 S&amp;S BVM6 pneu 17&quot; TBRR</td>
<td>6,8</td>
<td>4.9</td>
<td>1.9</td>
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<td>1.6</td>
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<td>6,7</td>
<td>4.5</td>
<td>2.2</td>
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REAL WORLD FUEL CONSUMPTION

- Vehicles equipped with Diesel powertrains are in better position compared to gasoline engines with less deviation.
- Diesel is still a strong way to secure the CO2 route but there is a need to offer, complementary to Diesel, new alternative and reasonable solutions.
- Gasoline engines and electrification have still wide ways of improvements to be explored.
Challenge: How to proceed keeping reasonable overcost?

→ Need to consider other attributes

- CO₂ / Tank to wheel
- CO₂ / Well to wheel
- Refueling, charging time
- Weight
- Low speed performance
- Impact of fuel quality
- TCO
- …
Challenge: How to proceed keeping reasonable overcost?

→ SEVERAL POSSIBLE ROUTES
→ INTERESTING CHALLENGE FOR CAR MAKER COMMUNITY
Future for thermal engines

- **Diesel**
  - Strong emissions pressure
  - Still a good solutions for CO₂ and fuel consumption
  - Cost?
  - Solution for LCV, MDT and HDT

- **Gasoline**
  - Progress made recently with downsized TGDi engines
  - What reasonable technology to secure CO₂ route?
    - Electrification ?
    - Electrification + new features ?
Gasoline engines challenges: fuel consumption

- Fuel economy and GHG
- Emission Standards RDE Social responsibility
- TCO Development Investment Industrialisation
- Fun to drive Robustness Quality
- Cost
- Performance
- Standards Fuel & oil Local integration
- World deployment
- Hybridization
- Transmission
- Manual Automatic Intelligent
- Mild Full Plug in

Gasoline engine
Gasoline engine challenges: possible solutions

- World engine
- VCR
- Miller Cycle
- Efficient boosting
- Water injection
- Cylinder deactivation
- Go with hybrid deployment
- Higher CR
- EGR
- B/S > 1.2
- Best compromise performance / fuel eco / cost
Gasoline engine challenges: tentative technical portfolio

- **Emissions CAFE**
  - Optimised Homogeneous GDI (High injection pressure / increased tumble /EGR …)
    - ~ 1-2% CO2
  - Deep Miller-Atkinson Cycle (Higher CR incl.)
    - ~ 1-2% CO2
  - Long stroke (Higher CR incl.)
    - ~ 1-2% CO2
  - Water injection (Higher CR incl.)
    - ~ 2-4% CO2
  - Variable Compression Ratio / 2-stage
    - ~ 2-5% CO2
  - Lean Burn / Advanced ignition
    - ~ 5-7% CO2

Approx CO2 values given for TGDI engines

- **Combustion concepts & technologies**
Solutions for Groupe PSA

- "Clean car" is a strategical axis in the global R&D Groupe PSA program
- For 10 years, Groupe PSA is leading or among “top 3” carmakers with lowest CO₂ emissions in Europe
- New generation Diesel and gasoline powertrains will contribute to maintain this position
- To perform further progress, in addition to theses new powertrain families, Groupe PSA will launch from 2019 to 2021
  - 7 gasoline PHEV for C/D class cars on mid / upper platform
  - 4 BEV for B/C class cars on our future new small platform
- Groupe PSA will deliver a large “efficient and clean” offer for all customers
CONCLUSION

- Lot of possible combinations to progress on CO₂ route
- Lot of features have to be considered: well to wheel, tank to wheel, TCO, …
- Reasonable overcost is a strategical key (€ / g CO₂)
- Potential good synergy between combustion engine and electrification

A fantastic coming period for engineers!
MERCI DE VOTRE ATTENTION!

- Car-sharing services
- Smart services
- Leasing
- B2B services for business fleets
- B2B Fleet management