Future directions in natural gas injection: Is CNG an alternative to gasoline or Diesel for passenger cars?

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Bascharage, 6. November 2014
Delphi’s global team
At the center of automotive technology innovation

19,000 engineers and scientists
$16.5B 2013 revenue
126 manufacturing sites
15 major global technical centers
$1.7 B in Research & Development
more than 160,000 people in 32 countries

Delphi Powertrain Headquarter in Bascharage, Luxemburg
Megatrends drive DELPHI technology portfolio

- Active Safety Systems
- Driver State Alerts
- Safety Electronics
- Battery Disconnects
- Human Machine Interface
- Occupant Classification Systems

- Gasoline Direct Injection
- Diesel Fuel Injection Systems
- Fuel Economy & Performance Technologies
- Next Generation Energy Efficient AC
- Hybrid & Electric Vehicle Technologies

- Vehicle Infrastructure Interface (VII) & Vehicle-to-Vehicle Interface
- Telematics
- Digital Receivers
- Connected Vehicle
- Satellite, Audio, Video & Data Systems

CNG injector for direct injection developed at the Delphi Technical Center of Bascharage
Introduction

• Carbon dioxide (CO2) emissions from vehicles are now regulated in major automotive markets.

• CNG offers approximately 25% lower CO2 emissions level than gasoline.

• Large proven natural gas reserves worldwide.

• Current CNG injection technologies challenged by low end torque causing reduced drivability compared to current technologies (Diesel and gasoline).

• Delphi developing an injector which will improve performance of natural gas vehicles. The project is supported by LIFE+.

• The objective of the presentation:
  • Show the benefit of natural gas as an alternative to fossil fuels.
  • Share the status of the technology, next development plan.

Demonstrate that CNG is an alternative to gasoline or Diesel for passenger cars
Agenda

• Introduction of the supporting European Funding Program Life+.

• Benefit of natural gas as an alternative to fossil fuels.

• Delphi injector technology : status and next development.

• Summary and Outlook.
LIFE+ program and principles

• The DI-CNG (*) injector industrialization development is supported by LIFE+.
• LIFE+
  • Is a Europe’s funding instrument for environment aiming to contribute to nature conservation, climate change and development of EU environmental policy and legislation.
  • Finances the testing, prototyping and demonstration phases, meaning the development and validation of a technology at pre-industrial stage
  • The project must be innovative and have a significant impact on environment on European level

(*) : DI-CNG = Direct Injection- Compressed Natural Gas
Global legislation driving emissions reductions

Significant CO₂ Reductions globally

Emerging countries adopting European regulations

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Global regulations become more stringent for CO2 and toxic emissions.

- **Tier II**: CA LEV III Phase-in (thru 2025)
- **Tier III**: TBD

- **09EM Equiv. CA ULEV+NMOG Fleet Avg Sys.**: EURO5Diesel EURO6 Diesel
- **Beijing Feb 2013**: Euro 5 (Shanghai, Nationwide, TBD)
Why CNG for automotive applications?
Benefits and challenges of CNG vs alternative fuels

• Benefits
  • Very similar fuel injection equipment and technology than for gasoline injection
  • CNG offers highest hydrogen to carbon ratio (CH₄) of all fossil fuels (including LPG)
  • CNG powered cars offers lowest CO₂ emissions of fossil fuels
  • Lowest cost fuel
  • Gas reserves will survive oil reserves
  • Safe storage and handling of CNG with large end-user acceptance

• Challenges
  • Competitive driving comfort (Improve torque at low rpm)
  • Currently low CNG vehicle range
  • Infrastructure of fuel stations
  • Regional tax regulations

Excellent conditions to position CNG as alternative fuel for transportation
Why CNG for end-customer?

Natural Gas Price

How many kilometers can you drive with 10 €?
Natural gas (CNG) as fuel for economical driving

- PETROL 97 km
- DIESEL 148 km
- LPG 169 km
- CNG 201 km

Reference: Opel Zafira Tourer (comparable motorisation, 130 - 150 HP), average fuel consumption and range, status: January 2013.

Source: 8th conference gaseous fuel powered vehicles,

CNG is competitive in terms of fueling cost, refueling infrastructure remains a challenge.
CNG challenge
Filling station footprint

CNG filling stations in Luxembourg

CNG filling stations European footprint

Source: http://www.ngvaeurope.eu/
Why DI-CNG for end-customer?

Drivability

[Graph showing the comparison of Torque vs. Engine Speed for Manifold injection and Direct injection]

Mercedes-Benz M270 2.0 litre four-cylinder engine

Source: (Daimler, 7th IAV Conference: Gas-Powered Vehicles, 2012)

Increase of volumetric efficiency

→ Low end torque considerably improved via direct injection!
Why DI-CNG for OEM?
Benefits and concerns

• DI-CNG Benefits
  • High value technology for reduced CO2 to meet fleet average mandates
  • Low carbon fuel
  • Higher octane allows increased compression ratio
  • Continue with conventional internal combustion technology - easy conversion from GDi engine
  • Improved torque characteristic

• DI-CNG Concerns
  • Limited market size – regional differences
  • Competition to Hybrid / EV(*) technologies

(*) EV : Electrical Vehicles
Delphi injector development
Project description and objectives

- Develop production-intent DI-CNG injectors for equal or better low-end torque than comparable DI gasoline and Diesel engines, leading to improved driving performance and end consumer acceptance.

- Develop pre-industrial manufacturing capability for small scale production of injectors, ensuring marketability at project end.

- Achieve significant reduction in engine emissions
  - CO2 : 25%; CO : 80% (vs. gasoline)
  - Particulates : >90%; NOx : 35-60% (vs. Diesel)

- Project Duration: June 2014 – May 2018
Delphi test and validation equipment
Performance and durability benches

Performance Bench
- Pintle Motion + Flow Curve
- Leak Test
- Spray Visualization

Supply Stand
- N2 Tank
- Evaporators

Test Stand
- Injector Holders

Nitrogen Durability (Delphi CTC Luxembourg)

CNG Durability (Delphi TC Rochester)
Injector realization

- (4) Generations of DI CNG Injector Design

- Sealing Interface to Fuel Rail
- Extension Tube
- Solenoid Actuator
- Valve Group

Entire flow path optimized for high gas flow rates
Special materials and interfaces designed for robust durability.
High-flow nozzle with no leakage
DI-CNG validation test results:
Injector performance

Low leakage and low flow shift at full cycle life
CNG manifold injection vehicle market
Small passenger cars

**Fiat Panda 0.9 Twin Air Natural Power**

- Power: 59 kW/80 PS; High speed: 168 km/h
- CNG tank volume: 12 kg; Gasoline tank: 35 l
- CNG consumption: 3.1 kg/100km; CNG range: 380 km
- CO\(_2\) Emissions: **86 g/km for CNG**; 107 g/km for gasoline

**Skoda Citigo 1.0 G-Tec**

- Power: 50 kW/68 PS; High speed: 164 km/h
- CNG tank volume: 11 kg; Gasoline tank: 10 l
- CNG consumption: 2.9 kg/100km; CNG range: 410 km
- CO\(_2\) Emissions: **79 g/km for CNG**

**Fiat 500L 0.9 Twin Air Natural Power**

- Power: 59 kW/80 PS; High speed: 163 km/h
- CNG tank volume: 14 kg; Gasoline tank: 50 l
- CNG consumption: 3.9 kg/100km; CNG range: 350 km
- CO\(_2\) Emissions: **105 g/km for CNG**; 137 g/km for gasoline

**VW eco up**

- Power: 50 kW/68 PS; High speed: 164 km/h
- CNG tank volume: 11 kg; Gasoline tank: 10 l
- CNG consumption: 2.9 kg/100km; CNG range: 410 km
- CO\(_2\) Emissions: **79 g/km for CNG**
Automotive Day 2014: Green Automotive Future

CNG manifold injection vehicle market
Passenger cars, compact + vans

**Audi A3 Sportback 1.4 g-tron**
- Power: 81 kW/110 PS; High speed: 197 km/h
- CNG tank volume: 14.4 kg; Gasoline tank: 50 l
- CNG consumption: 3.3 kg/100km; CNG range: 400 km
- CO₂ Emissions: 92 g/km for CNG; 120 g/km for gasoline

**VW Passat TSI EcoFuel**
- Power: 110 kW/150 PS; High speed: 214 km/h
- CNG tank volume: 21 kg; Gasoline tank: 31 l
- CNG consumption: 4.3 kg/100km; CNG range: 480 km
- CO₂ Emissions: 117 g/km for CNG; 157 g/km for gasoline

**Opel Zafira 1.6 CNG Turbo ecoFlex**
- Power: 110 kW/150 PS; High speed: 200 km/h
- CNG tank volume: 25 kg; Gasoline tank: 15 l
- CNG consumption: 4.7 kg/100km; CNG range: 530 km
- Emissions: 129 g/km for CNG; 154 g/km for gasoline

**Mercedes-Benz B200 NGD**
- Power: 115 kW/156 PS; High speed: 200 km/h
- CNG tank volume: 21 kg; Gasoline tank: 12 l
- CNG consumption: 4.3 kg/100km; CNG range: 500 km
- Emissions: 117 g/km
Delphi DI CNG
Vehicle experience

• Daimler – B-Class

Results published at the 23rd Aachen Colloquium, October 6-8, 2014

• Identical engine power output achieved with DELPHI DI-CNG R&D prototype injector on 1.6L DI-CNG engine as 2,0 L PFI engine (Max. Power : 115 kW)

• CO₂ Emissions: 117 g/km

• Demonstrated low-end torque increase and benefit on emission of Particulate Matters.

• TU-Wien/ Magna Steyr – (CULT project)

• Car concept equipped with Delphi DICNG R&D injectors

• Awarded the bmvi (*) Staatspreis Mobilität 2013 (category „Forschen. Entwickeln. Neue Wege weisen.“)

(*) Bundesministerium für Verkehr, Innovation und Technologie

The DICNG Mercedes B-class in the Delphi Bascharage parking lot

THE CULT CAR (TU-Wien/ Magna), equipped with Delphi injectors
DI-CNG injection

Summary and Outlook

• Several European strategy papers foster the growth of CNG vehicles as strong contributor for its environmental policy, climate change & crude oil independence.

• CNG direct injection technology is competitive to state-of-the art gasoline or Diesel engines and will increase drastically the end user acceptance.

• Delphi successfully developed R&D injectors, used by partnering OEMs to demonstrate the potential of the technology at the engine and vehicle level.

• The future will depend on factors such as filling station footprint and tax regulations at a European and regional level.

• In its next development phase, Delphi will transition from R&D to production-intended solutions, enabling the technology to be marketable at the project end.

➔ Yes, CNG is an alternative to gasoline or Diesel for passenger cars!