BS VI Solutions for LD, LDD and HDD

Satoshi Sumiya
Johnson Matthey Japan GK
Gasoline
Gasoline
- Global Trend

1. TWC (Three Way Catalyst)
   - Still mainstream of aftertreatment system.
   - Continuous development is required to meet stringent emission legislations with optimized PGM usage.
   - Activities at low temperature, both light-off and steady state conversion, are needed.
   - Meeting tight OBD requirements is a key development target
   - TWC for HEV (Hybrid Electric Vehicle) is an interesting area and Japanese OEs prefer gasoline hybrid at this moment.
   - RDE (Real Driving Emission) will require high conversion efficiencies across a larger part of the engine map, so better systems will be needed – more TWC activity and amended calibrations

2. GPF (gasoline Particulate Filter)
   - The technology is required for EU and China from 2017 to meet the PN legislation, so the activities in customers are increasing. US market will follow because a stringent PM legislation will be implemented.
   - TWC advances can apply to GPF washcoats and lower backpressure is a key aim.
3. Lean burn engine after treatment
   • NSC (NOx Storage Catalyst) is a possible technology. But PGM cost is high and it has calibration complexity.
   • Reduction of N$_2$O emission and improvement of S tolerance are challenging.

4. Others
   • Hydrocarbon trap: Can be applied with advanced TWC technology.
   • Developing gCSC technology.
Gasoline
- BS VI solutions

Solution to control gasoline PN emissions

TWC + coated gasoline particulate filter

Three way filter + downstream TWC

- Development partnership with OEMs
- Some application to meet Euro 6c PN limit through improved engine technology or use of uncoated GPF
- Expect TWF™ / cGPF uptake to increase with RDE PN limit
Light Duty Diesel (LDD)
Widen NOx window (Real driving Emission)

Low Speed Emissions
- Low temperatures especially from CO₂ improvements

High Speed Emissions
- Higher engine-out NOx emissions
- High flow rates
Impact of Compliance Factors on System Choice

**Scenario 1 : Most demanding RDE conditions**
Compliance factors up to 1.5 (80 – 120 mg/km NOx)
- **NSC** : Challenging and low engine NOx at high load
- **Urea SCR** : NSC + SCRF® for low speed and high speed NOx
  - DOC + SCRF® is also available

**Scenario 2 : Less demanding RDE conditions**
Compliance factors > 1.5 (> 120 mg/km NOx)
- **NSC** : + passive SCR/F and low engine NOx at high load
- **Urea SCR** : DOC + SCRF® and low engine NOx at low load
  - NSC + SCRF®
Selective Catalytic Reduction (SCR)
- Metal-zeolite based catalyst
- Low PGM loading (slip catalyst only)
- Requires urea injection system, with tank, doser and injector systems
- Favoured on larger vehicles

NOx Storage Catalysts (NSC)
- PGM based catalyst
- Requires fuel addition, hence penalty on fuel consumption
- Favoured on smaller vehicles
Economical comparison between SCR and NSC based system

- Both system costs proportionally increase as a function of engine displacement.
- Cost estimates are almost equal for the engines with displacement around 2.4 L. (this cost balance point could be moved by costs of considered items.)

LDD
- BS VI Solutions

LDD After-Treatment System Road Map in Europe

- For Euro 6 b/c, either NSC or SCR are required
- For Euro 6d with RDE, both NSC and SCR function will be required in some applications
Heavy Duty Diesel (HDD)
HDD

- BS VI Expected to follow Euro VI : Requirement of Euro VI (PN first time required)

- Expected >96% NOx conversion required for most BSVI applications under WHTC transient cycle

Euro VI

- Particle Number regulated
- PM~ 0.01g/kw-hr
- NOx ~ 0.4-0.46g/kw-hr
HDD
- General Market Trends For Euro VI

• Euro VI regulates Particle Number, forcing to use high efficiency wall flow filters
• Global system trend:
  – JP’09: DOC + CSF + Fe-SCR + ASC
  – EPA10:
    ➢ DOC + CSF + Cu-SCR + ASC
    ➢ DOC + CSF + Fe-SCR + ASC
  – EU VI: DOC + CSF + SCR + ASC
    ➢ Filter effectively mandated at EU VI
    ➢ Mixed SCR technologies: V, Cu & Fe

• Key questions to address:
  – DPF/CSF regeneration strategy
    ➢ Active or passive?
  – SCR catalyst technology
    ➢ Cu or Fe or V?

Fully Integrated System : SCRT™
• Engines can have lower power ratings with large displacement (e.g., 6 L with 135 Hp)
  • This can result in cooler exhaust temperature
  • Further problem under WHTC testing
  • May require engine downsizing (use 4 L engine for 135 hp)

• Indian drive cycles can have prolonged low speed operation
  • Low speed operation can create exhaust temperature issue
  • Concern about real world emissions if temperature too low for SCR
  • May require thermal management
HDD
- Exhaust Temperatures BS IV (ETC) vs BS VI (WHTC) – Much Lower Temperature

*ETC allows for preconditioning (C100/20min);
*WHTC requires cold + hot (pre-soaking 20min), no preconditioning

Low Temperature, Hence about 20% of the cycle no urea injection (NH3) – significant challenge!!
HDD
- Expected systems for BS VI: Two Different Options

**DPF - Active Regeneration Design**

Periodic active regen re-sets the system
Increases fuel consumption and system durability requirement

**Key enablers**

**DOC/CSF with Fuel Light-off at low temperature**
Enables high level of active regeneration

**SCR with High Temperature Durability**
Two options: Fe and Cu SCR
- Fe is sulfur tolerant, but can be reversibly inhibited by HC/coke
- Cu is HC/coke tolerant, but is reversibly inhibited by sulfur

**ASC with high selectivity to N₂**

**DPF - Passive Regeneration Design**

DPF regeneration strategies largely passive
Some Assisted regen

**Key enablers**

**DOC/CSF with High NO₂ Make**
Provides limited added heat management
Enables passive regeneration
Provides more NO₂ for downstream SCR

**SCR with Poison Tolerance**
Ideally Sulfur and HC/coke tolerant
Use of V-SCR

**ASC with high selectivity to N₂**
SCR Selection for BS VI: Cu-SCR Outperforms V-SCR at Low Temperature

Performance gap in NO only; significantly less in application when NO$_2$ present
On Colder exhaust engines, Cu-SCR demonstrates improved performance, no difference on warmer engines.