Fuel Challenges for Modern (SI) Vehicles

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ICE DOWNSIZING AND ELECTRIFICATION

- Downsized boosted engines have significant potential for efficiency improvement.
  - Reduced throttling losses
  - Operation at higher average loads - lower friction
  - Higher torque at lower engine speed – downspeeding
  - Charge cooling benefits from DI

- Hybridisation (especially series hybrids) limits the speed load range so that the engine is more likely to operate in its most efficient region.

- Presentation will focus on fuel requirements for advanced SI Engines
FUEL OCTANE AND ENGINE KNOCK (1)

- Flame spreads across the combustion space
- Compressed and hot gasses in front of flame front can auto-ignite
- Knock Signal to EMS (Retard Ignition)
- Knock Sensor
FUEL OCTANE AND ENGINE KNOCK (2)

- Lower octane fuel makes the engine more prone to knock.

- For higher RON fuels the spark timing achieved is closer to optimum (MBT) with the highest torque.

- KLSA is the most advanced spark timing achievable without knock.

OCTANE AND REAL WORLD DRIVING (1)

- Measuring spark retard in vehicles typical of the European Market

Test fleet of 20 vehicles (representative of European markets in terms of coverage and vehicle technology)

50% of vehicles showed a power benefit (RON97 vs RON95)

95% of vehicles showed a power benefit (RON99 vs RON95)

MAXIMUM EFFICIENCY INCREASES WITH CR, BUT HIGH LOAD/LOW SPEED OPERATION RESTRICTED BY KNOCK

- Boosted single cylinder engine (up to 3 bar boost pressure)
- Fuel: RON = 92, S=10

\[ \eta_{\text{Max}} = 37.2\% \]

\[ \eta_{\text{Max}} = 37.8\% \]

\[ \eta_{\text{Max}} = 38.9\% \]

DOWNsIZED BOOSTED ENGINES OPERATE “BEYOND RON”

Extrapolate RON and MON via octane index (OI):

\[ OI = K \times MON + (1-K) \times RON \]

[OI = RON – K × S]

(Kalghatgi)

Cracknell et al MTZ worldwide June 2015, Volume 76, Issue 7-8, pp 4-7
The K-Value theory (Kalghatgi) can extrapolate RON & MON to apply to modern technology

Method: extrapolate RON and MON via octane index:

\[ OI = K \times MON + (1-K) \times RON \]
\[ OI = RON - K \times S \]

- The higher the OI, the more auto-ignition resistant the fuel (Sensitivity \( S = RON - MON \))

- **K-value**: engine and condition dependent scaling factor influenced by T, P history of in-cylinder end-gas

- Implications:
  - For \( K = 0 \); \( OI = RON \)
  - For \( K = 1 \); \( OI = MON \).
  - For \( K < 0 \); low MON fuels preferred (high sensitivity).

SINGLE CYLINDER ENGINE RESULTS (1)

SINGLE CYLINDER ENGINE RESULTS (1)

CLEANLINESS
INJECTOR FOULING: SPRAY CHARACTERISTICS AND PARTICULATE EMISSIONS

(University of Birmingham Collaboration)

Fouled injectors give:
• more distinct spray core
• larger droplets,
• more particulates

Higher injection pressure reduces PN

C Jiang et al; Applied Energy 203, 2017, 390-402
INJECTOR FOULING: SPRAY CHARACTERISTICS AND PARTICULATE EMISSIONS (IAV/ Imperial College Collaboration)

- Deposit control additive can mitigate injector fouling and PN drift

IVD BUILD-UP LEADS TO “SLUGGISH COMBUSTION”

- Uses Mercedes-Benz M111: CEC F-20-98
- Longer spark \(\Rightarrow\) CA50 observed during IVD build-up.
- Consistent with changes observed in NOx and Exhaust Gas Temperature.
- Changes in Air Flow due to IVDs measured.

IVDS CAN ACT AS A SPONGE TO SOAK UP FUEL
(University of Edinburgh Collaboration)

Valve deposits act as sponge

3000 x magnification

- Power loss
- Slow acceleration
- Poor drivability
- Poor cold start
- Increased emissions

The efficiency of today’s SI vehicles can be adversely impacted by knock in real world driving.

Downsizing, boosting, increasing CR and hybridisation all provide possible routes to increasing SI engine efficiency.

Increased CR leads to higher efficiency in some parts of the speed/load map but needs higher octane quality at low speed/high load.

Increased sensitivity (RON-MON) as well as increased RON can be beneficial in increasing efficiency.
SUMMARY - CLEANLINESS

- Injector deposits in DISI engines can impair the quality of the spray, leading to higher emissions and impaired combustion.

- Intake valve deposits in industry standard M111 engine shown to give “sluggish combustion” which can be linked to changes in air flow.

- Intake valve deposits have a well developed pore structure which can soak up fuel (in PFI engines).

- Deposit control additives can be shown to mitigate the adverse impact of fouling.
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