Case Study on achieving Customer Focus:

'Best in Class' Driveability & CO2/FE on XUV500

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Overview of Mahindra Group

US$ 14.4 Billion (FY 2011-12)

Conglomerate with diversified interests

144,000 employees in over 100 countries

Global excellence at dramatically lower costs

Sustained leadership across the sectors

A very strong corporate brand

Mahindra – A microcosm of India


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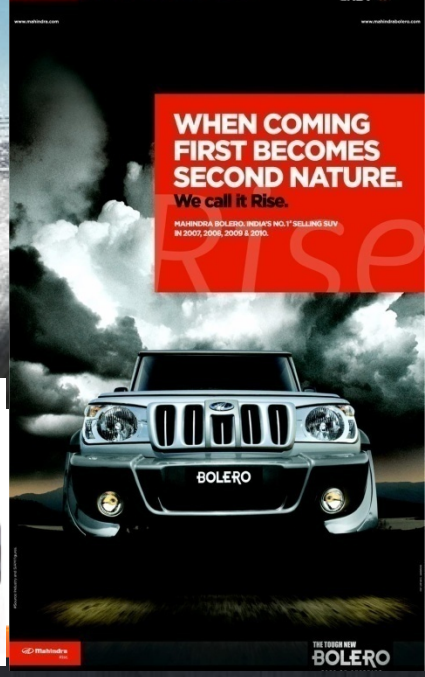
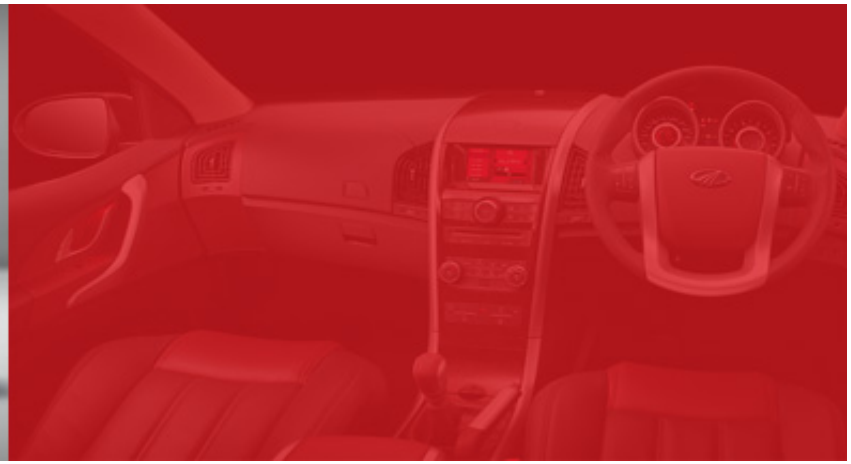
A MAHINDRA IS BORN.
We call it Rise.
THE ONLY COMPANY HERE TO MAKE EVERYTHING FROM 2-WHEELERS TO TRUCKS.
Rise
Mahindra
Rise.

Moving Force In India's Progress…



Mahindra & Mahindra XUV 500



Customer Focus :

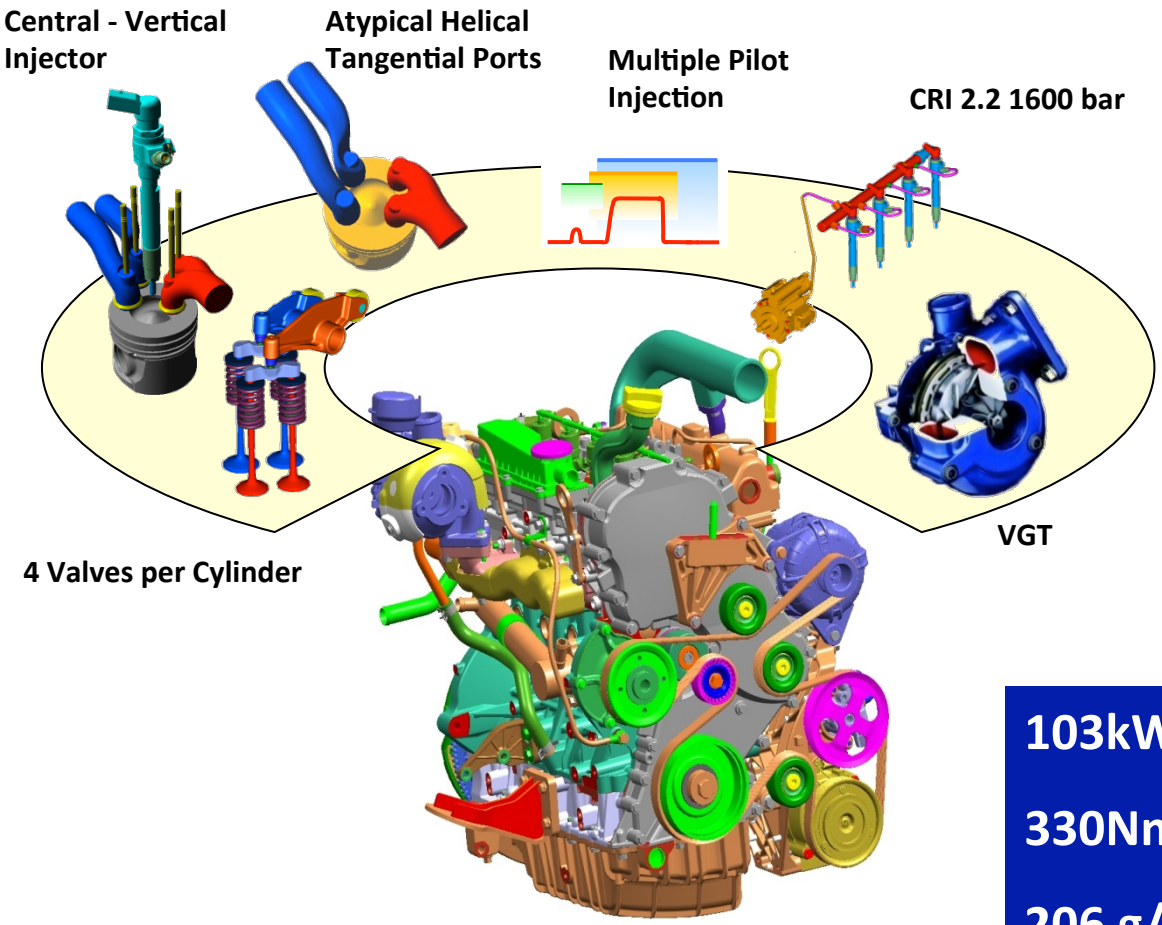
A) ‘Best in Class’ Driveability

B) ‘Best in Class’ CO2/FE

XUV 500

- 6 speed transaxle
- 4 Cyl, Inline, 2.2L engine
- BS4, EU4, EU5 compliant
- Kerb weight – 1900 kg
- 2WD & AWD

XUV 500 Engine – Heart is pumping good & real hard!!!

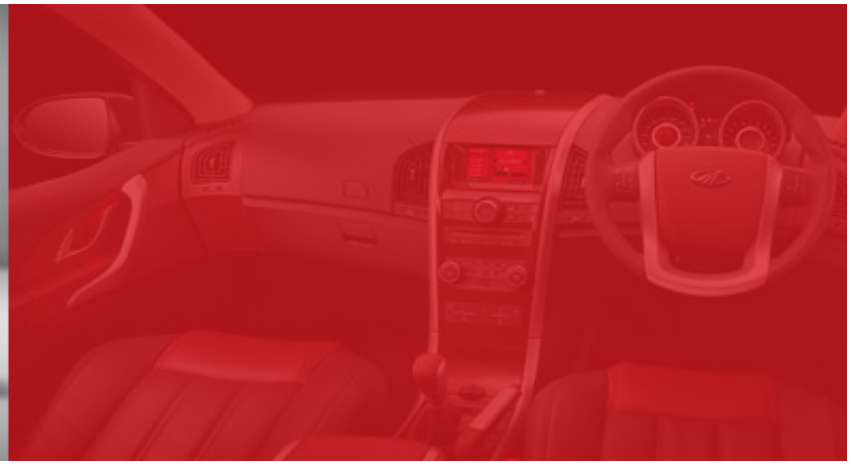


103kW @ 3750 rpm

330Nm @ 1600 – 2800 rpm

206 g/kW-h @ 2000 – 2250 rpm

Mahindra & Mahindra XUV 500



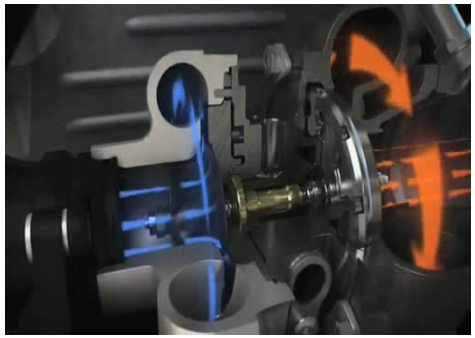
Customer Focus :

A) ‘Best in Class’ Driveability – Pleasurable Feel

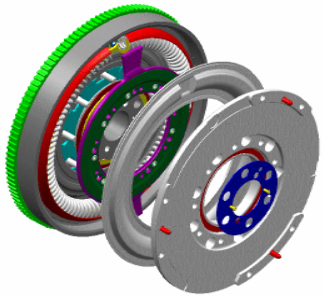
B) ‘Best in Class’ CO2/FE

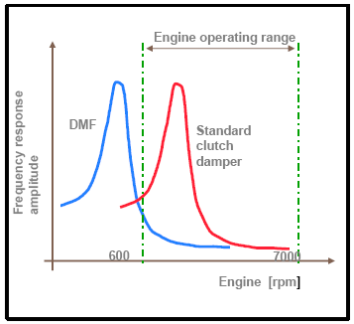
A) Driveability – Challenges to the Vehicle EMS Calibration

- Larger turbine for achieving power @ higher revs, results in poor boost build up during lower revs.

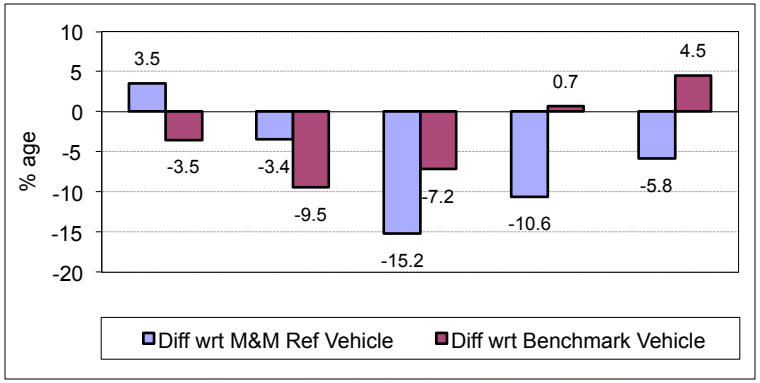


- Torsional flex b/w the primary & secondary flywheel of **D**ual **M**ass **F**lywheel (DMF) is deterrent to the transient response to the accelerator pedal.

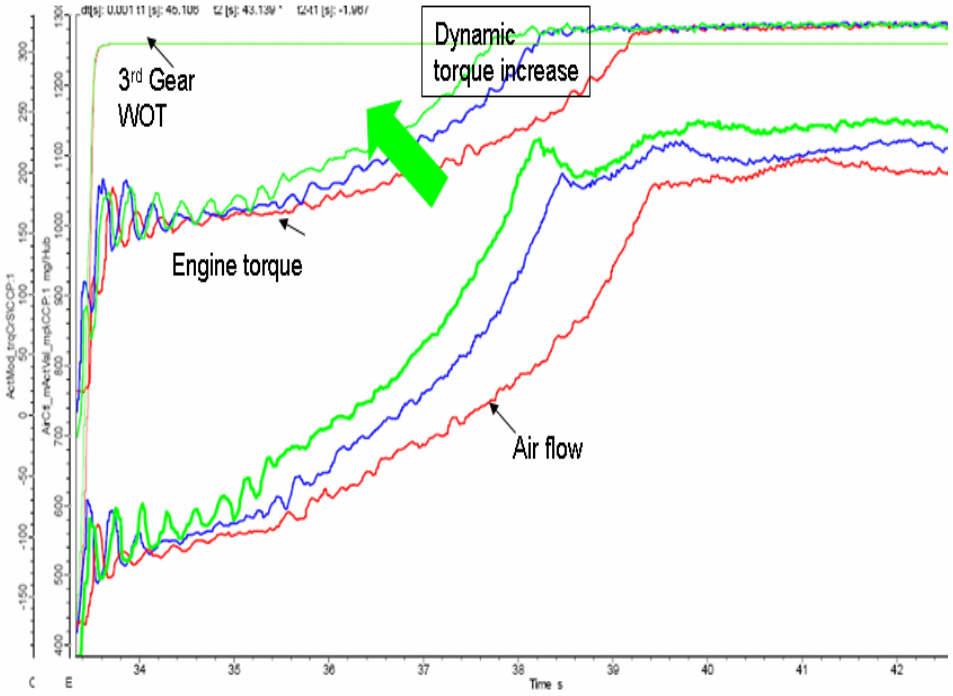


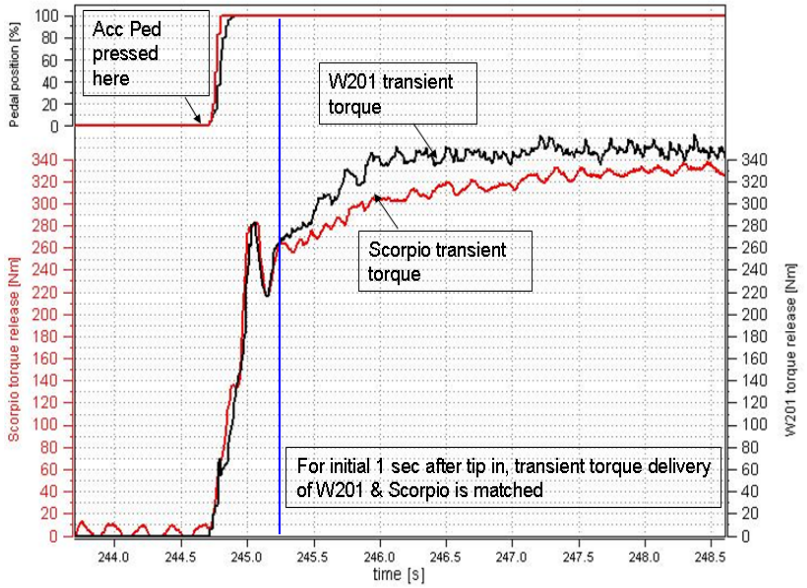


- Lower gear ratio selection for fuel economy & high revving performance in higher gears.



Turbo Charging Improvements

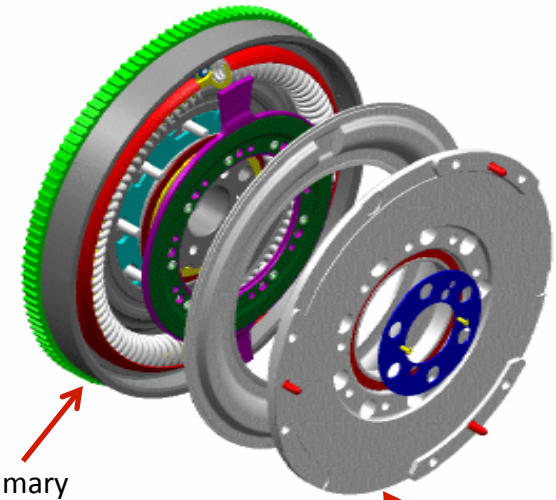


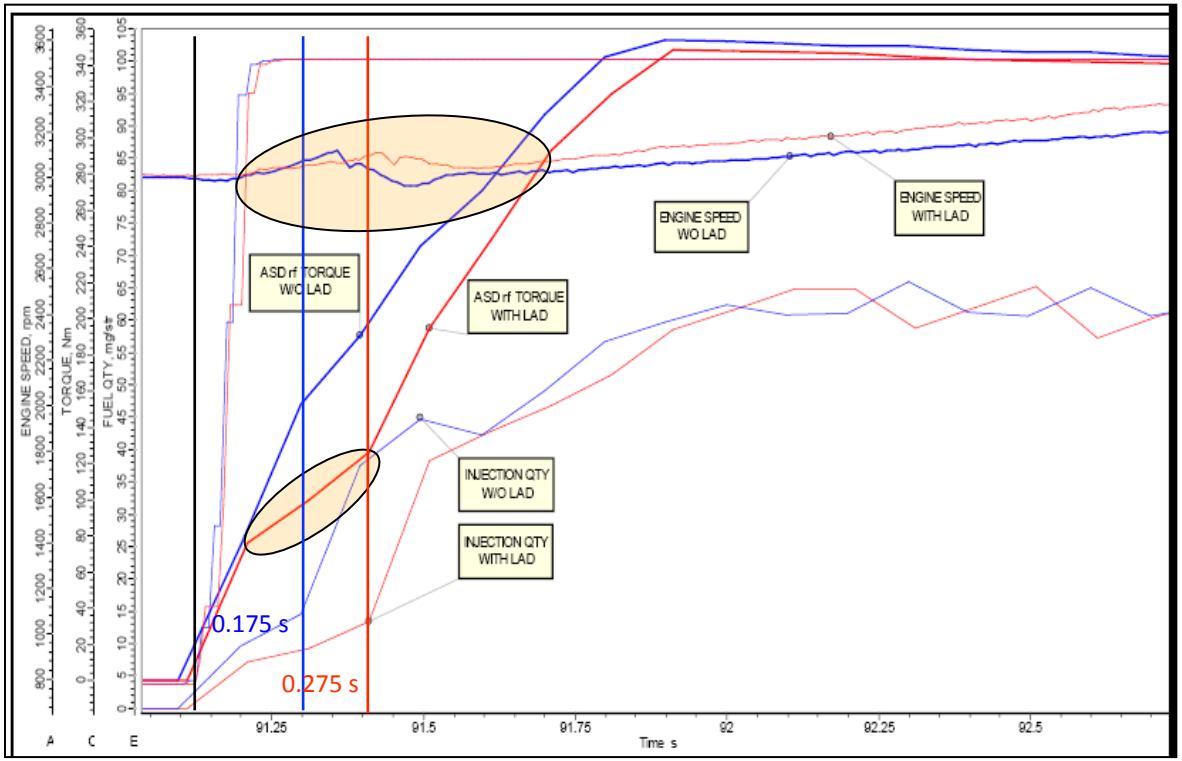


- Flow optimized design of turbine – **'S' Vane** Concept
- **Higher efficiency** operation in entire range
- Hardware improvements – **Minimum Flow** Optimisation

VGT Governor – Minimum TC vane position concept was implemented to achieve better transient response. This resulted in **better boost build up** behavior & **better transient torque response.**

Torsional Flex from DMF – ASD Calibration





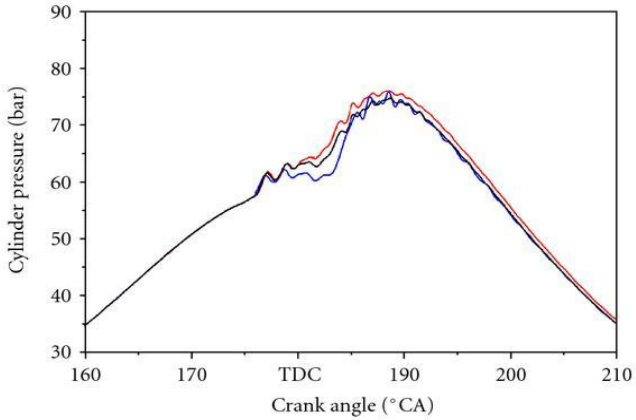
LAD OFF **LAD ON**

Active Surge Damper along with **Load Alteration Damper (LAD)** Concept was integrated in the EMS Software. With LAD, we could remove the dual acceleration feel & achieve **LINEAR TORQUE DELIVERY** for every driving pattern.

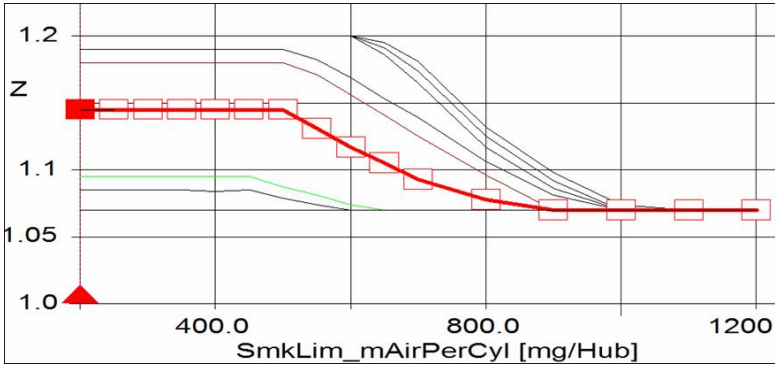
Lower Gear Ratios – Multiple Injection & Gear Based Calibration

• For Lower revs, **better turbo charging** characteristics resulted in a **better boost build up** & hence better torque delivery.

• For lower air charge intake, **multiple split pilot injection** strategy with higher pilot separation/qty helps to utilize the air available in the combustion chamber resulting in higher torque buildup. (Refer the picture for effect of pilot qty)



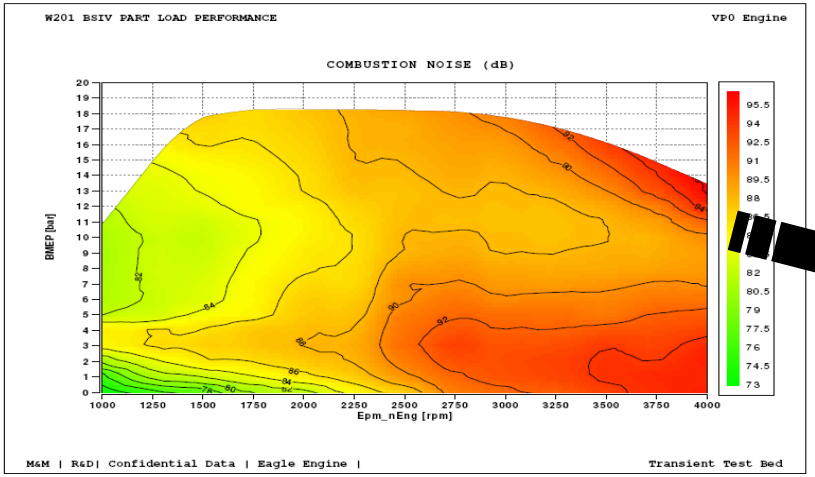
• **Gear based c**alibration for **driver demanded torque & smoke map** calibration resulted in best trade off b/w driveability & fuel economy.



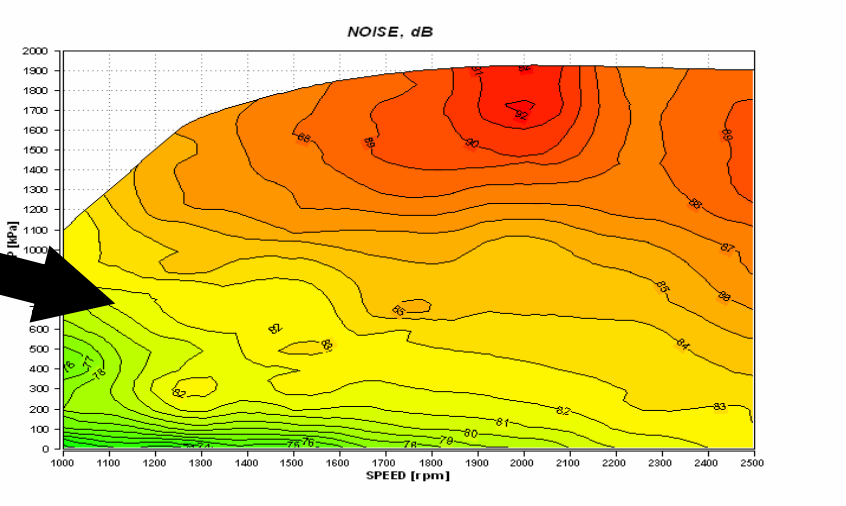
• **Low end torque @ full load – 330Nm** achieved for as low as **1600 rpm** – helped to improve low speed driveability

NVH Improvement

Single Pilot



Double Pilot

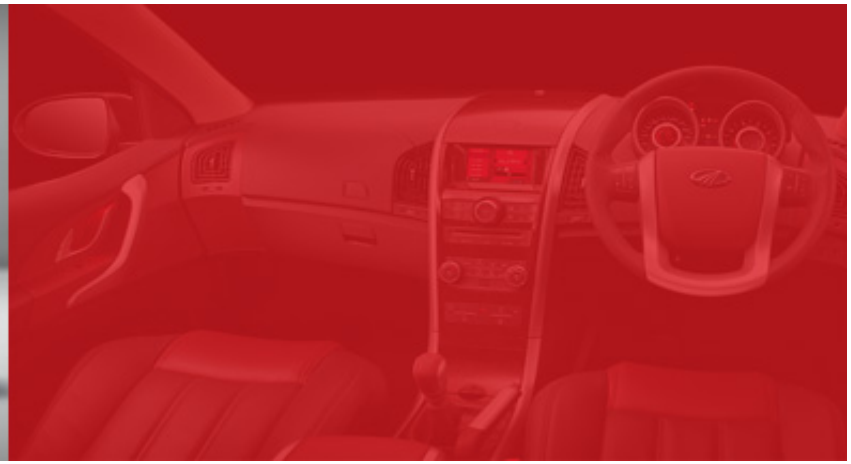


- **Multiple pilot injection strategy** & **optimum rail pressure** selection led to **combustion noise improvement by ~ 2-3 dB** & engine NVH levels achieved similar to benchmark vehicles.

- **Incremental map for rail pressure rise** applicated for smoother combustion during acceleration maneuvers.

- **Main injection timing correction** based on **boost pressure deviation** was applicated for noise harshness modulation for harsh maneuvers.

Mahindra & Mahindra XUV 500



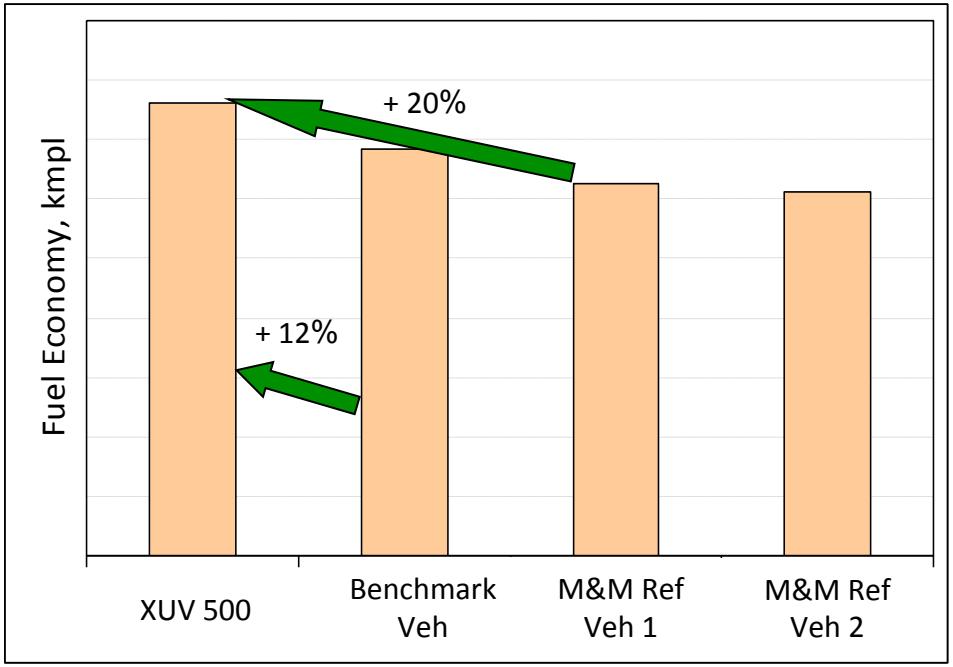
Customer Focus :

A) ‘Best in Class’ Driveability

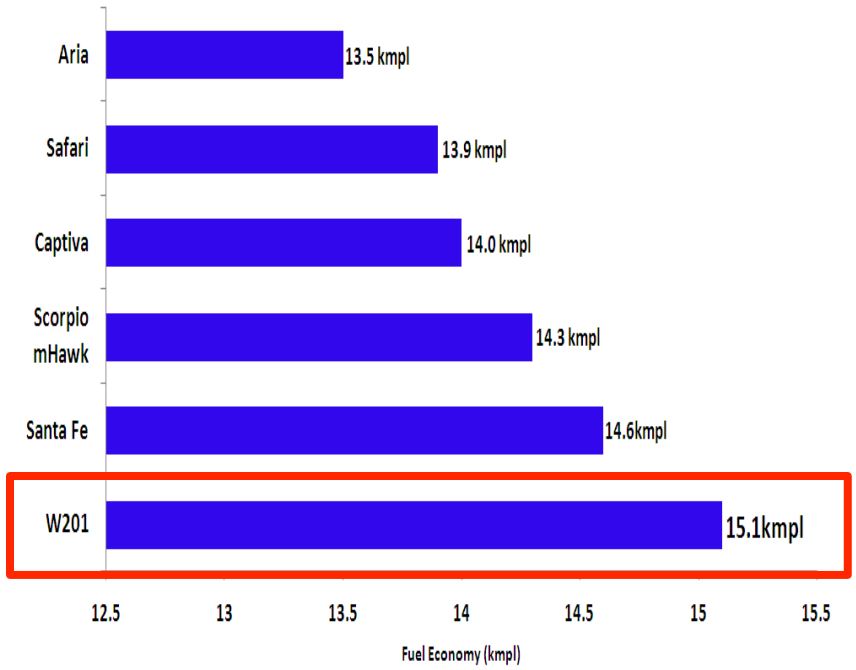
B) ‘Best in Class’ CO2/FE – Greener Environment & less $ $ $!!!

B) Fuel Economy – Best In Class

Good Power/Drive-ability is appreciated more if it leaves a lesser dent in the pocket of the **CUSTOMER**. Hence tag of **"BEST IN CLASS" FE** was necessary to beat the competition.



(FE data collected on road for a given City + Highway Route)

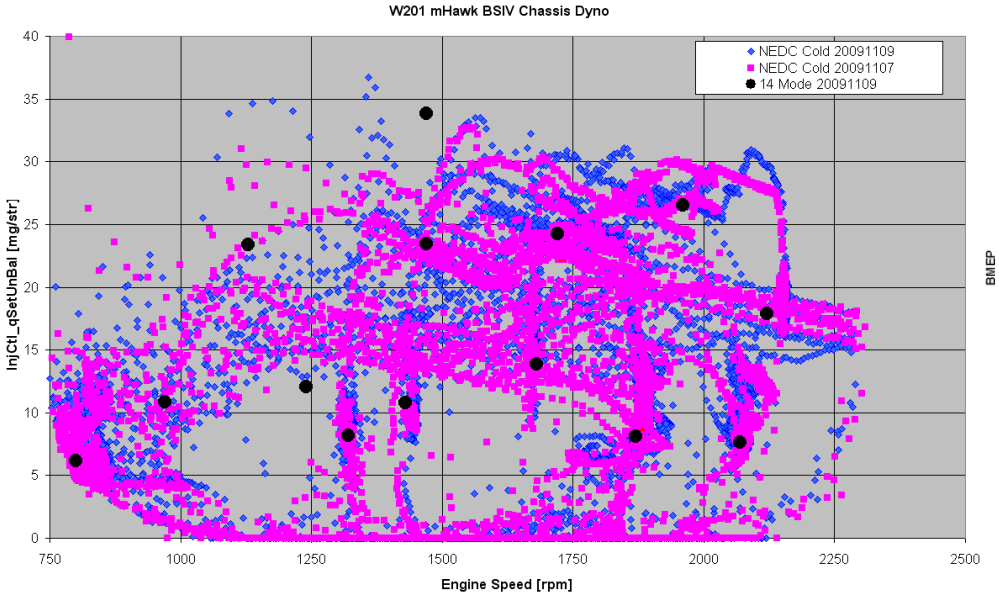


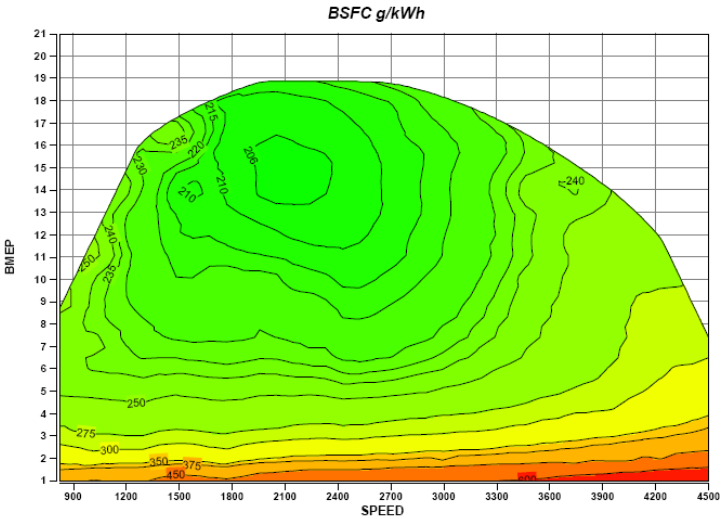
Under cold NEDC_90KPH Emission cycle (certified by ARAI)

We achieved **20%** better FE than M&M Reference Vehicle & **12%** better than benchmark vehicle.

Engine Mapping – Steady State optimisation

Across entire engine operation, DOE method was adopted for **selection of boost pressures, main injection, multiple pilot injection parameters & EGR rates f**or lowest BSFC & engine out emissions.





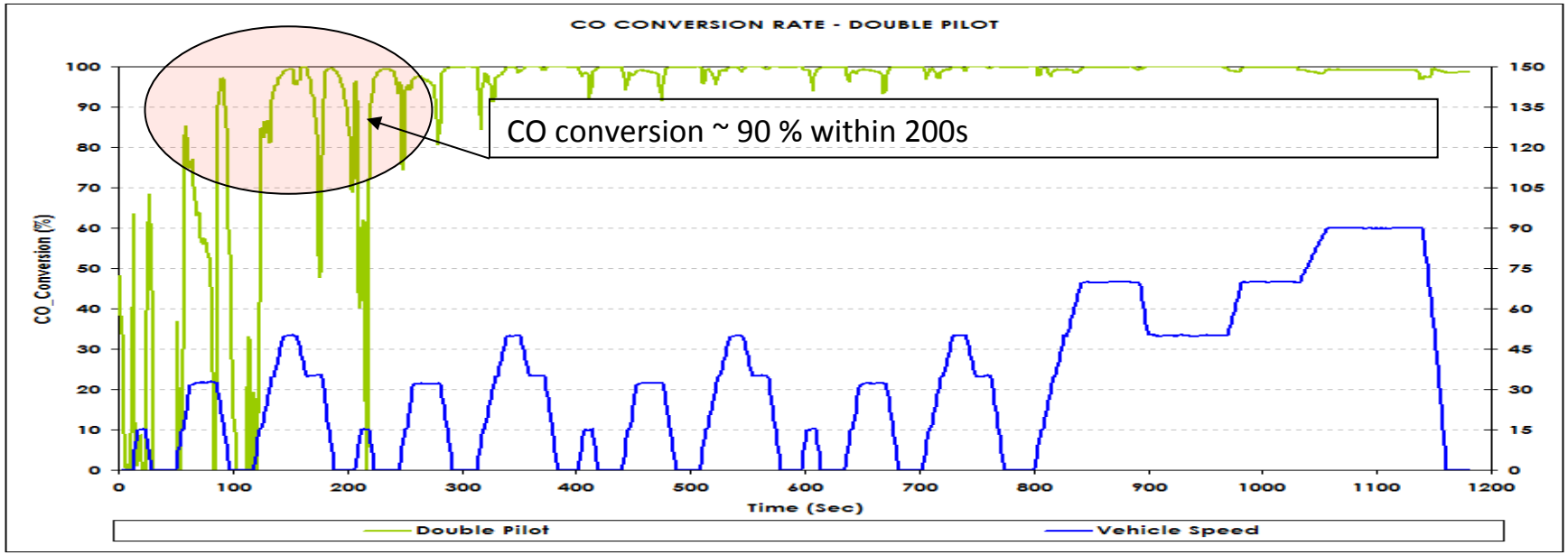
Reduced boost pressure results in lower back pressure & **optimum EGR rates** helped to achieve **better NOx-PM trade off**. This methodology helped us to **achieve lower fuel consumption** in NEDC 90/120 cycle.

Emission optimisation without Under Floor Catalyst & No DPF

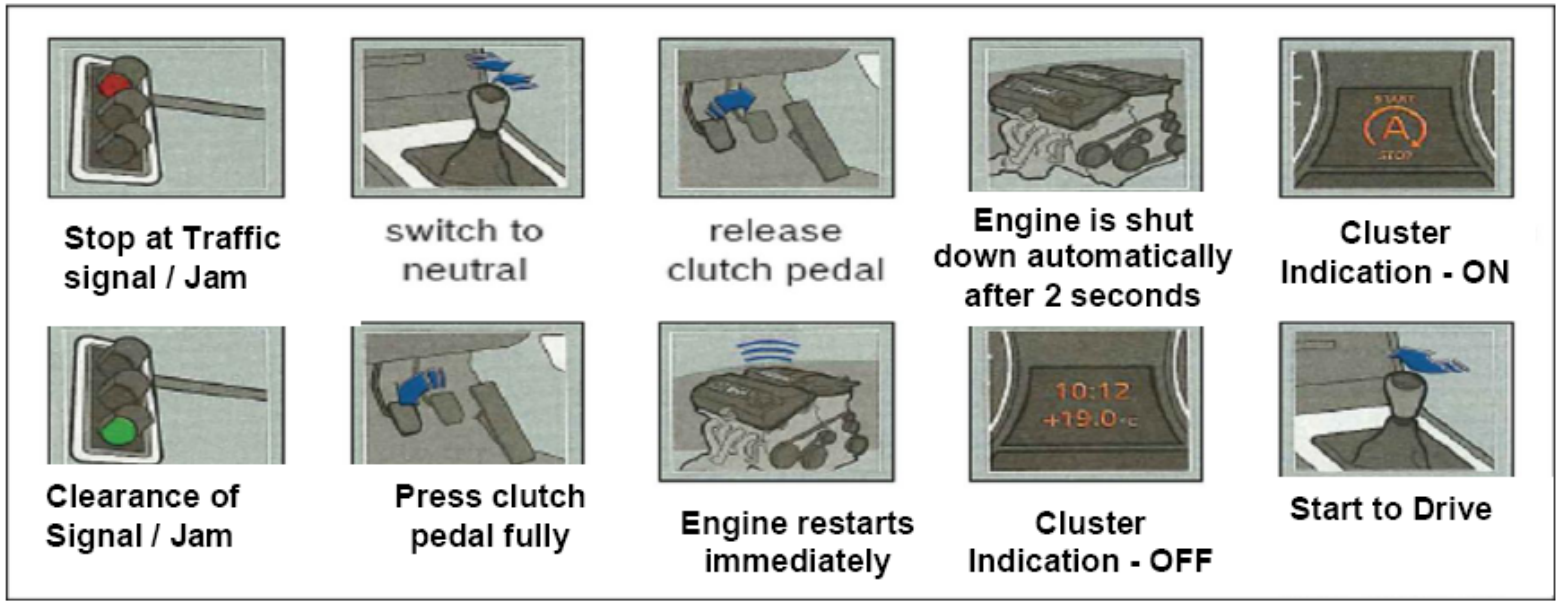
Double pilot injection strategy was implemented to improve engine NVH. However, with multiple pilot injections, **optimum pilot quantity improved catalyst light off temperatures** & resulted in CO/HC improvements.

Hence we could manage BS4/EU4 emissions with Closed Couple Catalyst only & Under Floor Catalyst (cost saving of Rs 3500/-) was deleted from the exhaust system layout.

Reduced exhaust back pressure in the emission cycle helped us to **reduce fuel consumption.**



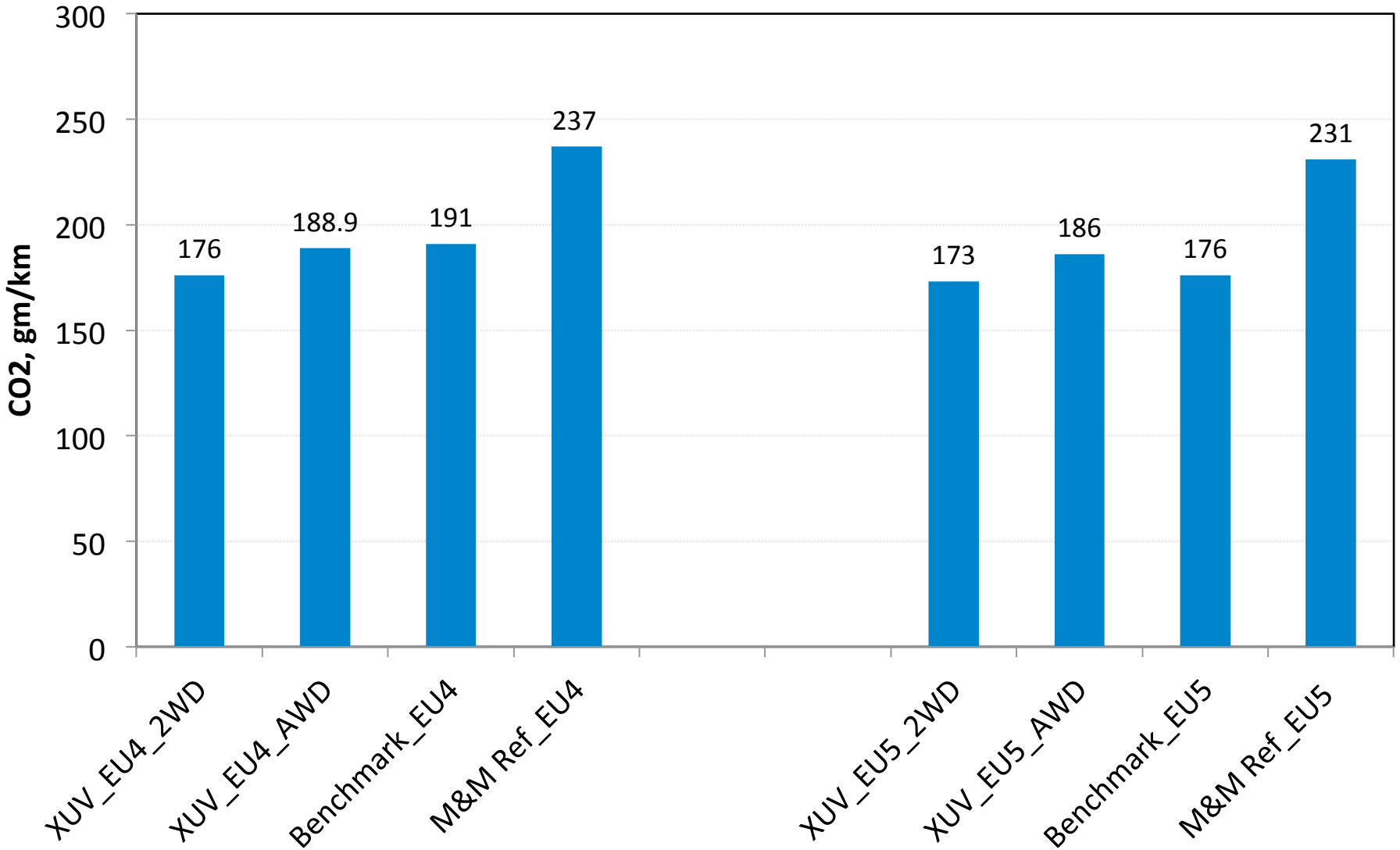
Engine Start Stop Technology



(Schematic Representation of Start Stop System)

Engine Start Stop resulted in improvement in FE by ~ 3.5%

CO2 Spread Up



Conclusion

• For driveability improvement, turbocharger minimum flow optimisation & minimum VGT governor position calibration improved the low end torque delivery on the vehicle.

• ASD – Load Alteration Damper calibration resulted in overcoming the torsional flex from the Dual Mass Flywheel – linear torque delivery.

• Multiple split pilot injection with higher pilot quantities, gear based calibration & low end full load torque helped us overcome the driveability issues in 2^{nd} & 3^{rd} gear for lower revs.

• NVH improvement from multiple pilot injection with optimum rail pressure selection helped us to reduce combustion noise by ~ 2dB.

Conclusion continued…..

• For FE improvement, optimisation of boost pressure / egr rates & injection parameters helped us achieve good bsfc values with desired emission levels.

• With DOE approach, reduced boost pressures & optimum egr rates resulted in better NOx – PM trade off & hence bsfc improvement.

• Double pilot injection strategy with optimized pilot injection quantities helped us achieve higher exhaust temperatures in NEDC cycle & hence better light off temperatures for the catalyst. With this approach under floor catalyst was not required for BS4/EU4 emissions. Reduced back pressure again helps in FE improvement on road.

• Start Stop technology was also implemented & this resulted in ~ 3.5% improvement in Fuel Economy.

Thank You