Improved Dynamic Torque Predictive modeling using ECU logics and transient vehicle phenomena for Diesel vehicle applications with GT FRM model

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**Aim:** To improve dynamic torque modelling for diesel vehicle applications to obtain the best correlation with tested data and hence be able to predict it for future engines in the concept phase.

**Introduction:**

- Dynamic torque for each gear is the torque obtained from low idle to high idle speed when acc pedal is completely pressed within 0.2s in that gear.

- Factors affecting: Turbocharger lag, active surge damping, Low-idle governing, intercooler efficiency, smoke limitation ECU logics etc.

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2. [www.wikihow.com](http://www.wikihow.com)
Simulation Methodology

1. Engine model creation and validation for steady state performance
2. FRM Conversion
3. Vehicle modelling and integration with engine model
4. Conversion to transient model and addition of driver inputs
5. Implementation of ECU logics
6. Dynamic torque simulation for all gears and correlation analysis
Engine model created in GT-Suite for steady state points and validated.

Acceptable level of correlation was obtained for torque and air flow rate between tested and simulated data.

Calibrated steady state model for integration with vehicle
- Detailed calibrated steady state model was converted to a fast running model to achieve faster run time.
- The model was converted to obtain the results with a real time factor change from x14 to x8.
- Accuracy was maintained within 2%.
Integration of engine model with the vehicle

- Transient-capable Engine model
- Transmission control (Gear ratios, in-gear efficiency etc.)
- Clutch inputs (mode, max torque, radius, friction model etc.)
- ECU inputs (start/shut off speed, idle control, fuel cut etc.)
- Vehicle inputs (Aero dynamics, Coast Down, Rolling radius, Brake map, Axle inputs, road details etc.)
- Driver inputs (acc pedal behavior, braking event, launch control, declutching speed etc.)
- Over speeding control
Conversion to transient model

- FRM conversion

- Integration of ECU maps (acc pedal to torque conversion, fueling and boost pressure maps, FTP limitation).

- Integration of vehicle and engine model.

- Driver Acc pedal inputs included.

- Change in Intercooler effectiveness

- Inclusion of active surge damping

- Fueling limitation to keep smoke in control.

- Calculated port wall temperatures.

- Addition of engine and turbocharger inertias.
Port Temperature Modelling

- For steady state model calibration, constant wall temperature modelling can be utilized since sufficient time is available for the model to achieve the temperatures in steady state.

- In transient operation, since temperature changes rapidly, predicting it at the exhaust side becomes essential in achieving the desired boost pressure.

- To achieve this, wall temperature method was modified for exhaust runners and collector volumes from a constant imposed value to calculated wall temperature.

- Exhaust manifold material properties and external convection heat transfer coefficients were modified for this purpose.

- For exhaust ports, a port temperature dependence object based on the Engine BMEP was given which imposed wall temperatures based on the engine load.
Turbocharger modelling

- Achieving the desired boost pressure forms the foundation of predicting dynamic torque.
- For adapting to transient modelling, accurate shaft moment of inertia was obtained and turbocharger inertia multipliers were removed.
- For turbocharger controller, minimum and maximum closing rates were adjusted to achieve the desired response for an available set of gear data.
- These were carried forward for prediction for other gears.

Low idle governing

- Idling speed has been defined for each gear for better idle control.
Integration of ECU logics

Acc pedal map
- Gear dependent conversion of pedal position to engine torque

ASD map
- Adjustment of the engine torque to dampen the surge in boost pressure development

FMTC map
- Conversion of the desired engine torque to the required fueling

Smoke limitation map
- Limiting the fueling from FMTC map to control engine smoke

Boost Pressure map
- Estimation of the required boost pressure from the injected fueling for the desired A/F ratio

Final output of torque, fueling and boost pressure is also limited by FTP steady state performance

Smoke limited fueling

Full throttle performance limited fueling

FMTC map

ASD map

Desired torque
Intercooler effectiveness is usually higher in test bed conditions as compared to actual vehicle conditions.
Effect of Smoke limitation

- Limiting the injected fueling to keep the smoke under limit.
- Gear-wise upper limit applied to fueling based on the incoming air flow rate at the operating RPM.
- This reduces the torque in the initial ramp-up phase.
Active surge damping (ASD) is deployed to prevent any abrupt rise of torque.

It results in a reduced demand in fueling and consequently a slower rise in torque.
Accuracy boost pressure prediction is the primary step for dynamic torque simulations. Good turbocharger and temperature modelling along with accurate gear-wise desired boost pressure maps result in good prediction. Acceptable level of boost pressure correlation was thus obtained initially and then fueling match was attempted.
Gear-wise Fueling correlation

Fueling correlation obtained through ECU logic implementation
Good correlation for air flow and fueling obtained from simulation which is an indicator of good correlation of dynamic torque.
Gear-wise Torque correlation

Note: In the absence of vehicle testing torque data, tested_torque depicted here is a calculation from engine RPM and gear ratios.
Transient Speed ramp up

Gear 2

RPM vs Time(s)

Testing speed vs Simulated speed

Gear 3

RPM vs Time(s)

Tested speed vs Simulated speed

Ramp up time @ 100% pedal position

Time(s)

Gear

Simulated vs Tested
Applications

- The model has been utilized for predicting the dynamic performance of different turbochargers and based on this, a comparison between VGT and wastegate turbochargers were made for final turbocharger selection.

- The model was also utilized to predict temperatures on RDE cycles at the inlet of the exhaust systems for selection of aftertreatment solutions.

- Transient BSFC prediction was done for different TC applications.

Conclusions and Way forward

- Dynamic torque can be predicted in GT-SUITE with a high level of accuracy

- ECU logics can be implemented fairly accurately and results correlate between testing and simulation.

- Further modeling will be attempted for predicting drivability for cycles such as NEDC.