

VIRTUAL ENGINE TEST BENCH v0.5 – PROGRESS REPORT

Overview

Version 0.5 marks a significant step forward from the baseline pipeline established in v0.1. While v0.1 acted primarily as a proof-of-concept “calculator,” v0.5 introduces fidelity improvements that begin to emulate the workflows of a real calibration engineer. The focus of this release is steady-state testing, enabling more realistic torque, power, and emissions estimation.

Major Additions

- **AFR Targeting:** Users can now specify AFR targets across RPM ranges. Interpolation between points allows flexible calibration, forming the foundation for multi-fuel support planned in v2.0.
- **Loss Models (FMEP & PMEP):** Empirical models for Friction Mean Effective Pressure (FMEP) and Pumping Mean Effective Pressure (PMEP) have been implemented to capture internal losses and more realistic torque behaviour, particularly at higher RPMs.
- **Volumetric Efficiency Map:** Instead of a fixed VE, the engine model now uses a VE map. Users can supply their own map or use the default map derived from the Nissan VQ35DE (3.5L NA, Nissan 350Z).
- **Emissions Model:** A simplified empirical emissions model has been added, producing estimates for CO₂, CO, NO_x, and THC. This expands the scope of the test bench beyond performance metrics into environmental considerations.
- **Enhanced Reporting & Plotting:** Results are no longer limited to CSV export. Torque and power curves are now plotted against RPM. WOT runs display combined torque and power curves. Full sweeps allow selection of throttle positions, with torque and power plotted separately. Emissions are plotted alongside performance metrics for a complete picture.

Fidelity Improvements

To track model development, results have been logged after each major upgrade. *Figure 1* illustrates WOT torque behaviour for a 2.0L NA engine, showing the effect of richer AFR calibration and the performance deterioration caused by FMEP & PMEP at high RPM.

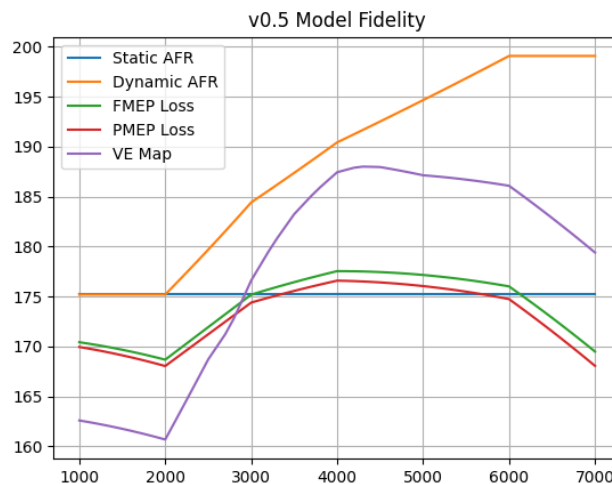


Figure 1: WOT torque results for a 2 Liter NA engine

Validation

For external validation, the model has been compared against dyno results of the Nissan VQ35DE engine, the same platform from which the default VE map is derived.

Agreement: The model shows strong alignment with measured torque and power curves.

Discrepancies: At low and high RPMs, torque is over-predicted. Causes include:

- Constant indicated thermal efficiency assumption (real engines see reduced efficiency due to mixture prep, burn duration, and combustion phasing away from MBT).
- Possible underestimation of frictional losses at higher speeds.

Figures 2 and 3 present the comparison. Despite limitations, the correlation demonstrates that the model is progressing toward realistic fidelity. v1.0 and v1.1 aims to address the combustion and spark timing which will increase the fidelity even further.

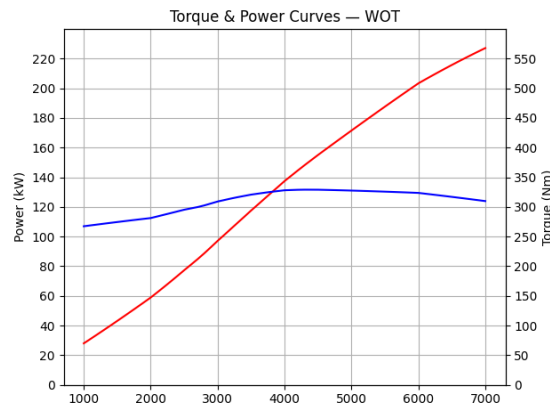


Figure 2: WOT torque and power results from the Virtual Engine Test Bench model for the Nissan VQ35DE (3.5L NA)

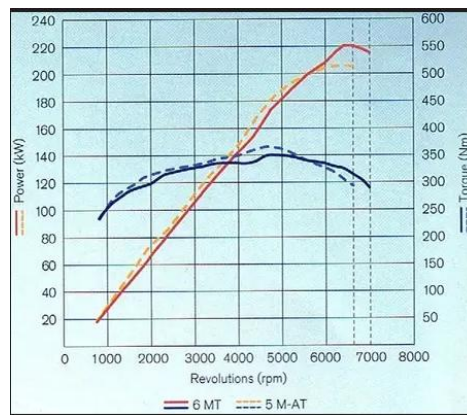


Figure 3: Measured WOT torque and power from dyno testing of the Nissan VQ35DE (3.5L NA), used for model validation

Next Steps

- **v1.0:** Semi-empirical combustion using Wiebe function, enabling more realistic demonstration of combustion.
- **v1.1:** Spark timing control, allowing users to advance/retard ignition and experience real-world calibration trade-offs.
- **v1.2:** Reverse Engine Simulation, enabling ingestion of OBD data for real-world analysis and back-calibration.
- **v1.5:** Transient Testing, introducing idle-speed control (PID), inertial & filling dynamics, and validation of transient response.
- **v2.0:** Multi-fuel & Emissions, adding fuel database, EGR & aftertreatment cycle simulation, and full emissions-cycle (WLTP).
- **v2.1:** Automated Reporting, integrating real-time dashboards (Dash/UI) and automated report generation.