VIRTUAL ENGINE TEST BENCH v1.0 – PROGRESS REPORT

Executive Summary

Version 1.0 introduces a physics-based combustion core using the Wiebe heat-release model and a modular solver that closes the thermodynamic loop from intake valve closure (IVC) to exhaust valve opening (IVO). Test modes have been refactored to operate on the new solver. The tool now produces:

- Physically consistent p–V diagrams
- IMEP, BMEP, FMEP, PMEP
- CA10/50/90 burn duration markers
- A spec-driven engine database with volumetric efficiency (VE) sourced from maps

Changes from v0.5

Combustion & Thermodynamics

- Single-zone Wiebe combustion model (SOC → EOC) with tuneable parameters (a, m) and duration.
- First Law applied stepwise: dU = dQchem − p·dV
- Heat capacity is temperature-dependent, blending unburned and burned gases.
- Expansion treated polytropically with n ≈ 1.26–1.34.
- Exhaust blowdown modelled as an adiabatic control-volume process, bleeding to ~1.05 bar / ~1150 K at IVO.

Solver Architecture & Data Model

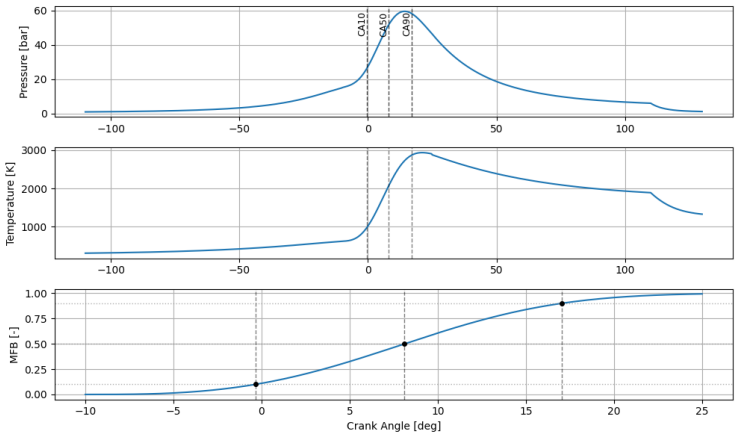
- Engine Database: stores geometry (cylinders, bore, stroke, rod, CR) and VE maps. Enables repeatable tests and future optimisation.
- VE Tables Only: constant-VE path removed. Engines are bounded by intake manifold maps.
- RunPoint API: returns torque, power, IMEP, BMEP, FMEP, PMEP, BSFC, air/fuel flows, AFR, emissions, CA10/50/90, Pmax, and Tmax.
- Custom Engine Setup: geometry + VE CSV import. Tables loaded and sanitised on creation.

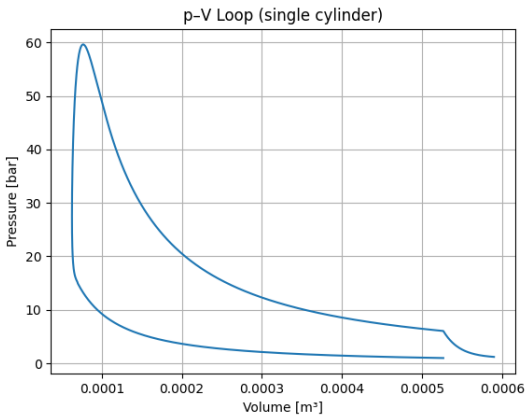
Reporting & Analysis

- p–V diagrams for each operating point.
- CA10/50/90 markers displayed on pressure, temperature, and MFB plots.
- Brake-specific fuel consumption (BSFC) and emission intensities reported in g/kWh.
- CSV export and plotting outputs aligned with the new solver workflow.

Single-Point Result

Configuration: VQ35DE geometry, VE from 350z(VQ35DE) map, 3000 rpm at WOT.





- Torque: ~311 Nm
- Power: ~98 kW
- IMEP: ~12.3bar, BMEP: ~11.2bar, FMEP: ~0.97 bar, PMEP: ~0.13 bar, BSFC: ~217 g/kWh
- Pmax: ~60 bar; Tmax: ~2936 K

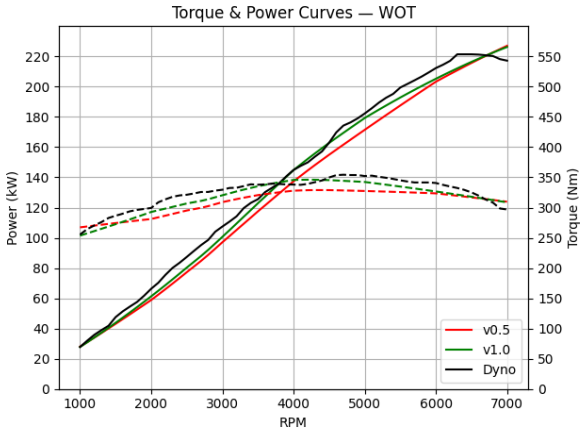
Validation

Comparison of v0.5, v1.0, and dyno results (Nissan VQ35DE):

- Accuracy improved by ~2% in v1.0.
- Main discrepancy near 4500 rpm due to VVT/VVL activation in the real engine, not yet modelled.
- Current PMEP correlation is linear; does not capture torque recovery from valve phasing.

Observed trends:

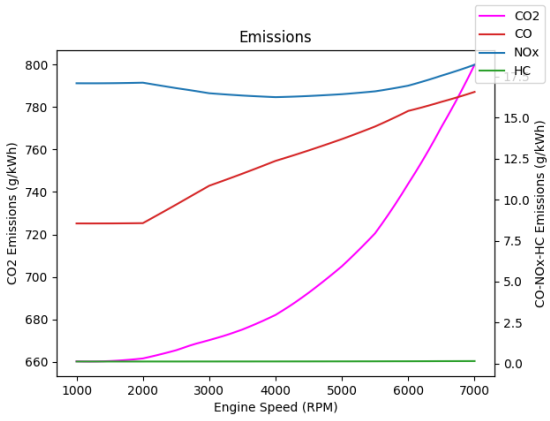
- WOT torque and power trends match expected shapes for the VQ35DE.
- Expansion and blowdown reduce cylinder pressure and temperature appropriately after EOC.
- CA50 aligns with typical SI phasing for current Wiebe inputs.
- Peak Tmax remains an upper bound due to no heat transfer or dissociation modelling.



Emissions

Validation not yet conducted. Future validation and aftertreatment integration planned for v2.0. Current behaviour aligns with physical expectations:

- CO_2 increases proportionally with fuel mass burned.
- CO rises under rich AFR conditions.
- NOx decreases under rich mixtures but increases at high rpm due to temperature rise.



Known Limitations (v1.0 Scope)

- No spark timing map (MBT/knock not yet implemented).
- Heat transfer and detailed species thermodynamics omitted; cv(T) approximate.
- Blowdown phase simplified.
- FMEP/PMEP remain empirical.

Conclusion

v1.0 establishes a thermodynamically closed, VE-driven foundation. The solver supports credible p–V, IMEP, and BMEP outputs, providing a robust base for spark timing and knock modelling in v1.1.

Next Steps

- **v1.1 – Spark Timing**
  - Ignition advance/retard control
  - CA50 targeting, MBT/knock phasing limits
  - Heat-transfer refinements for improved Tmax and IMEP
  - Engine-specific loss model tuning
- **v1.5 – Transient Testing**
  - Idle-speed PID control
  - Inertial and filling dynamics
  - Step/ramp load tests
- **v2.0 – Multi-Fuel & Emissions**
  - Fuel database
  - EGR & aftertreatment simulation
  - WLTP/NEDC cycle emissions
- **v2.1 – Automated Reporting**
  - Dash/UI dashboards
  - Automated PDF/HTML report generation
- **v2.5 – Reverse Engine Simulation**
  - OBD data ingestion
  - Back-calibration workflow

Demo video for WOT Test