TRANSIENT MODELING USING MEAN VALUE ENGINE CYLINDER

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Overview

- Introduction to Mean Value Modeling
- Theory of Mean Value Modeling
- Recommended Methodology
- Comparisons with Detailed Engine Models

Intro to Mean Value Models

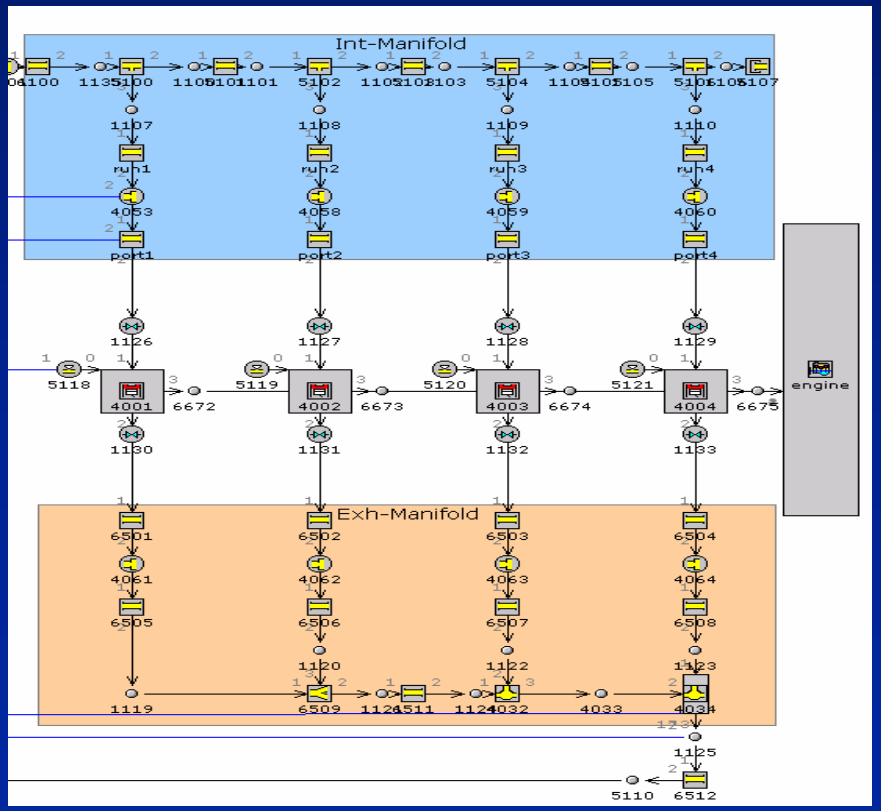
- **Simplified engine cylinder: maps define air flow and distribution of fuel energy**
  - **No combustion or breathing process modeled**
  - **Faster computations than 'EngCylinder'**
  - **Multiple cylinders combined into 1 mean value cylinder**
- **Modified Flow system**
  - **Parts combined into larger volumes**
  - **Further improves simulation time**
  - **Essentially "filling-emptying" models**
- **Useful when computation speed and "bulk flow" are important**
  - **Engine control system design**
  - **Transient vehicle simulations**

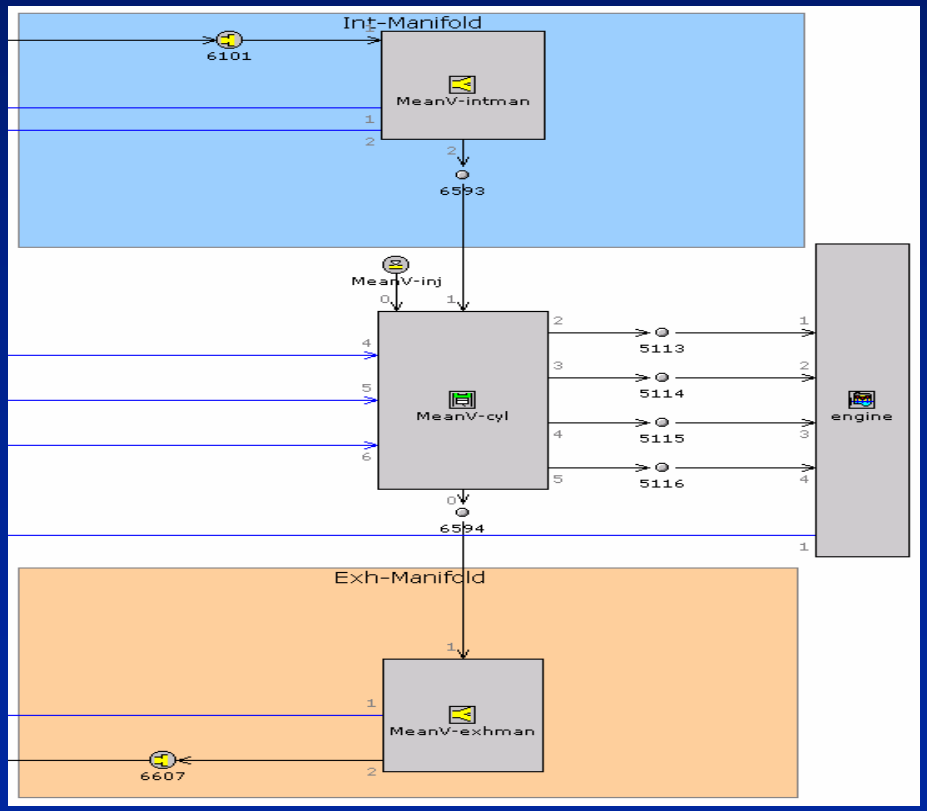
Mean Value Cylinder: Theory

- 'EngCylMeanV' defined by three maps
- Volumetric Efficiency
  - Air mass flow rate imposed at inlet and outlet of cylinder
- Indicated Efficiency
  - Percent of total fuel energy converted into work
- Exhaust Energy Fraction
  - Percent of total fuel energy converted into exhaust energy
  - All remaining fuel energy assumed lost to heat transfer
- Maps can be traditional or use Neural Network & controls

Mean Value Engine: Flow System

- Intake and Exhaust Manifolds represented by single flowsplit
- Details of flow are in map of VE
- Remaining pipes have longer DX





Recommended Methodology

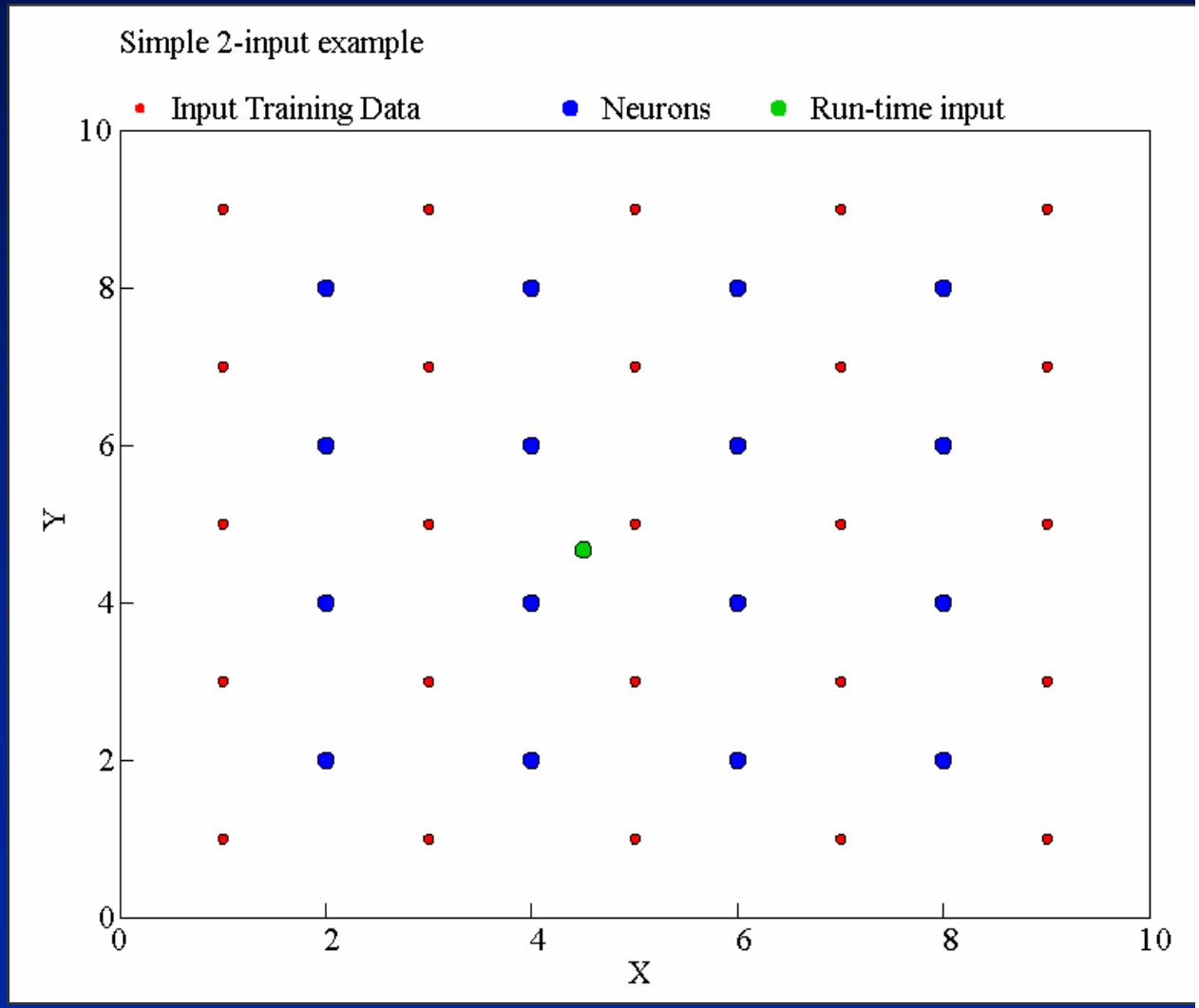
- **Select Independent Variables**
  - **Engineer must know important variables that affect engine and will be studied (RPM, load, manifold conditions, valve timing, etc.)**
- **Prepare model to run Sweeps**
  - **Remove TC, if applicable**
  - **Make independent variables parameters**
- **Run Sweeps**
  - **use DOE Setup**
  - **Distributed processing**
- **Create Neural Networks and Maps**
  - **New Neural Network training tool in GT-SUITE**
- **Build Model**

Neural Networks & Mean Value Cylinder

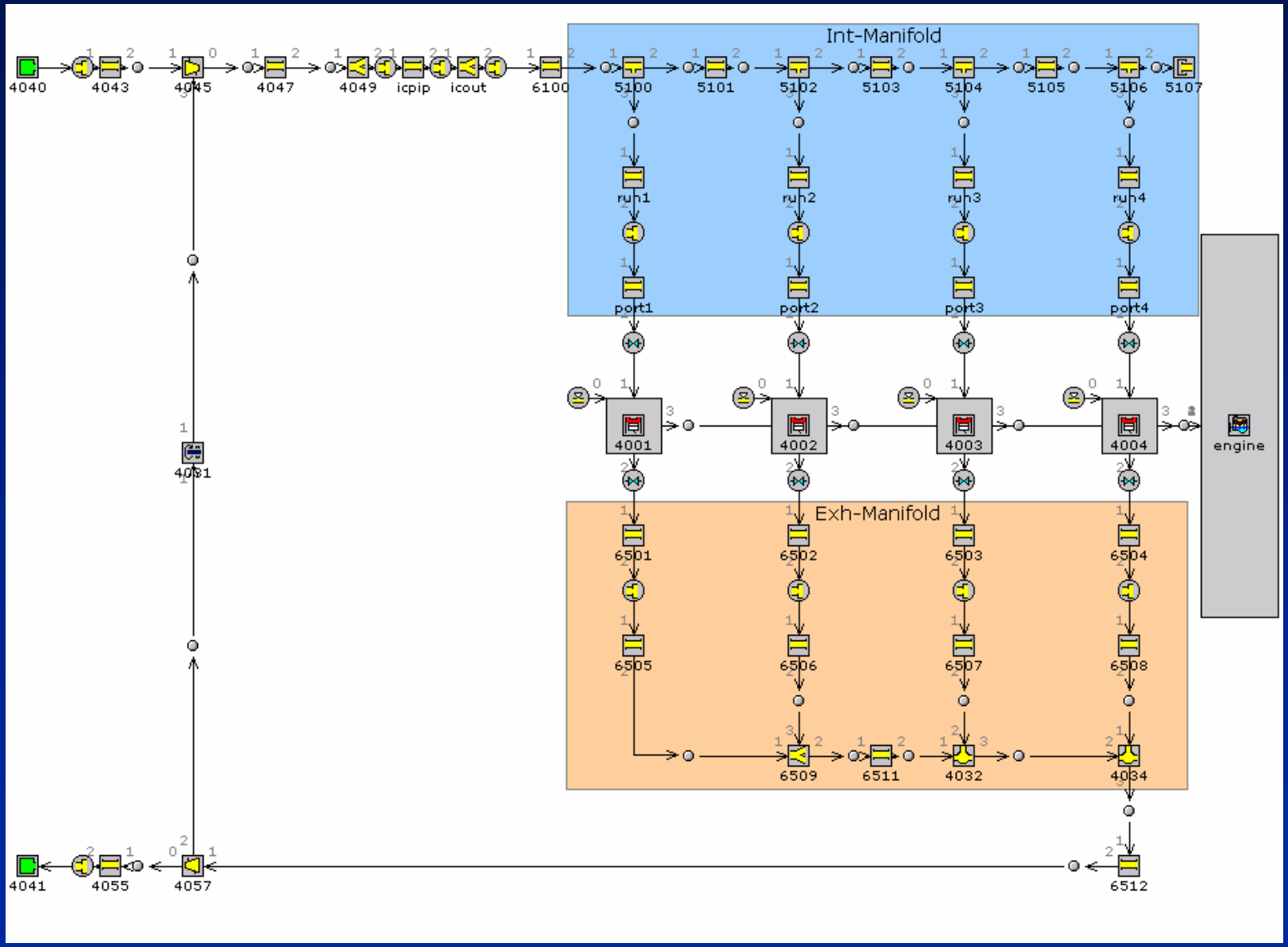
- Lookup tables are OK if variable is function of 1 or 2 RLT variables
- Defining more complex relationships requires the use of controls (dependence on 3 or more variables)
- Mean Value Cylinder require more than 2 inputs
- Neural Networks can be trained to control the mean value cylinder with complex dependencies
  - Faster than simple lookups, typically
  - Can fit data better than linear interpolation
  - Can interpolate 3 or more input values better than lookups

Neural Network

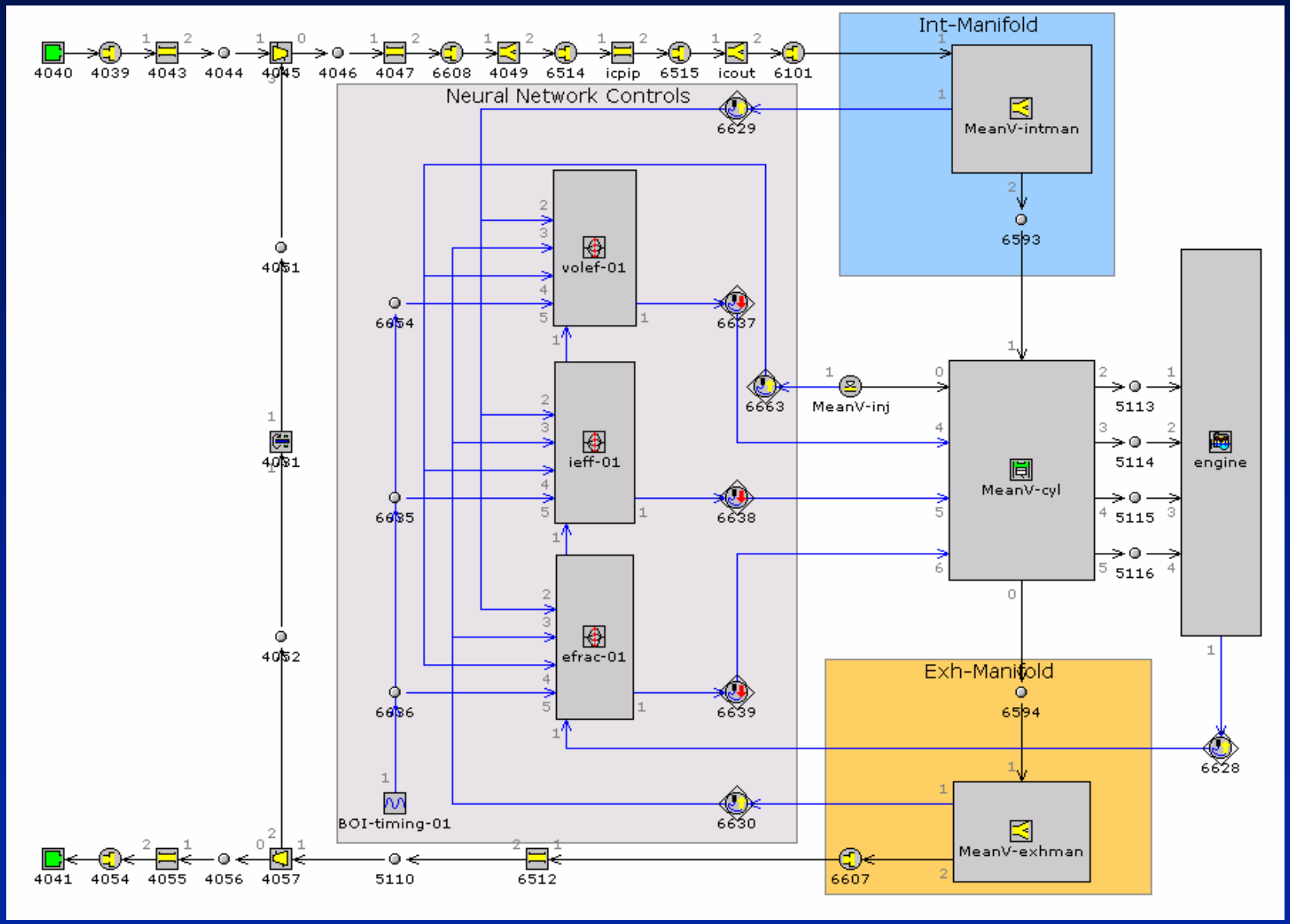
- "Black box"
- "Neurons" work in parallel
- "Taught" to produce output with inputs
- Best fit – not exact
- Neurons placed in domain of input data
- Each neuron assigned math operations
- Output from all neurons is combined to form output



Original Detailed Model



Mean Value Cylinder Model

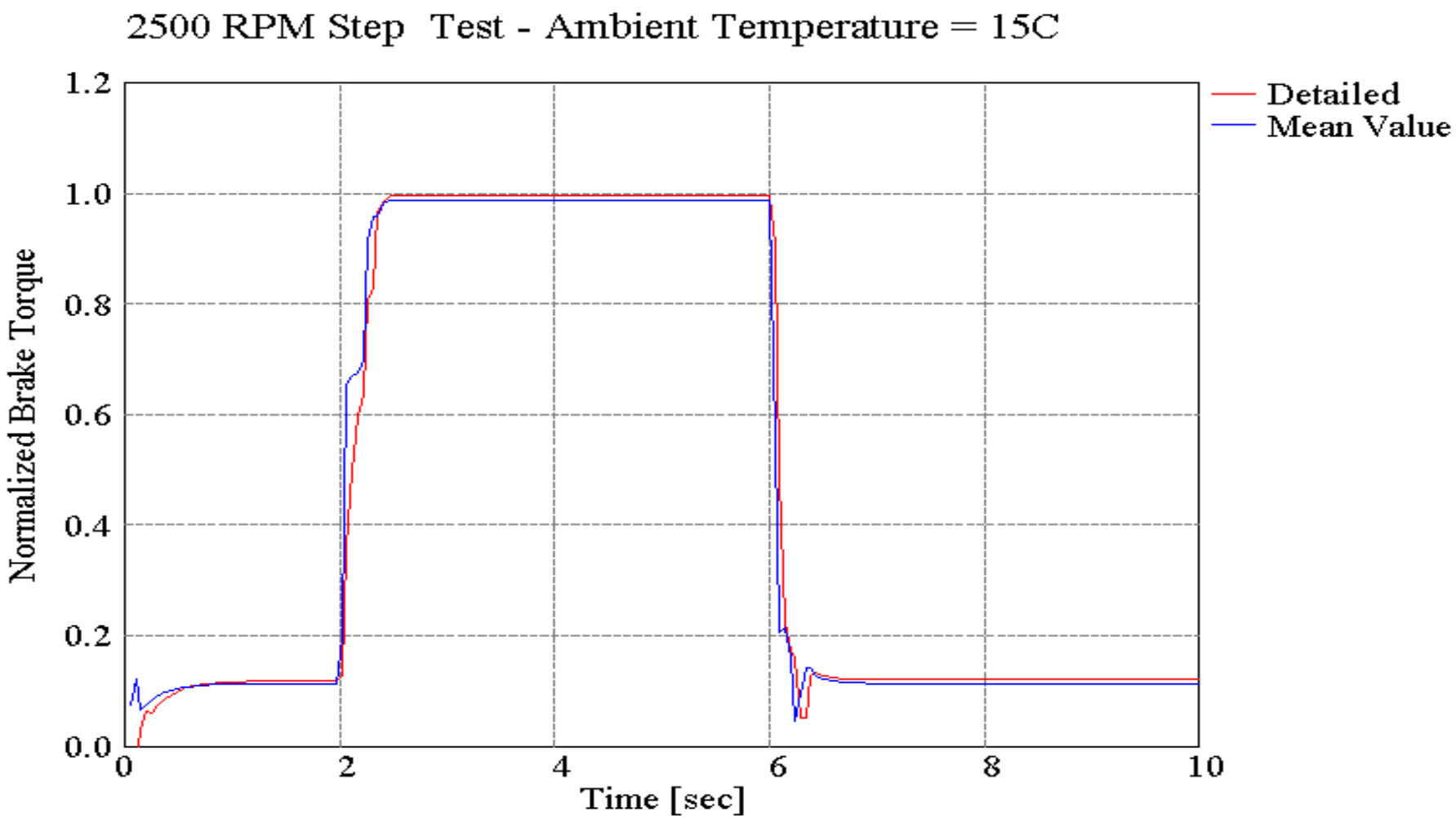


Comparison with Detailed Models

- **Naturally aspirated, 6-cylinder, SI engine**
  - **VVT**
  - **Wide open throttle test**
  - **Constant speed throttle test**
  - **Model provided courtesy of Volvo Cars**
- **Turbocharged, 4-cylinder, 2.0L, DI engine**
  - **Steady State comparison**
  - **Transient comparison**
  - **Coupled engine-vehicle comparison**
  - **Made from example ‘injmap’**

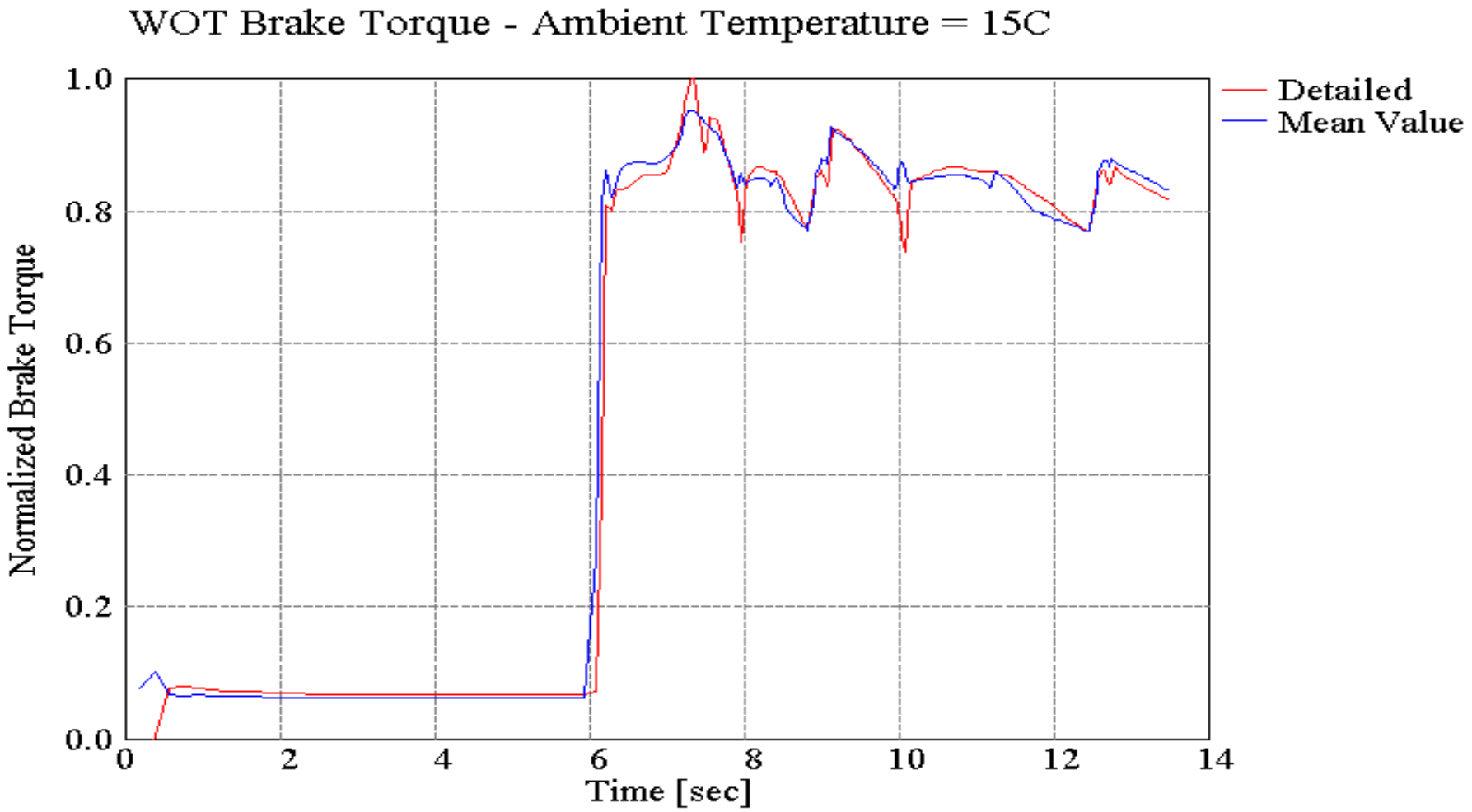
Naturally Aspirated, SI-Engine

- Wide open throttle test



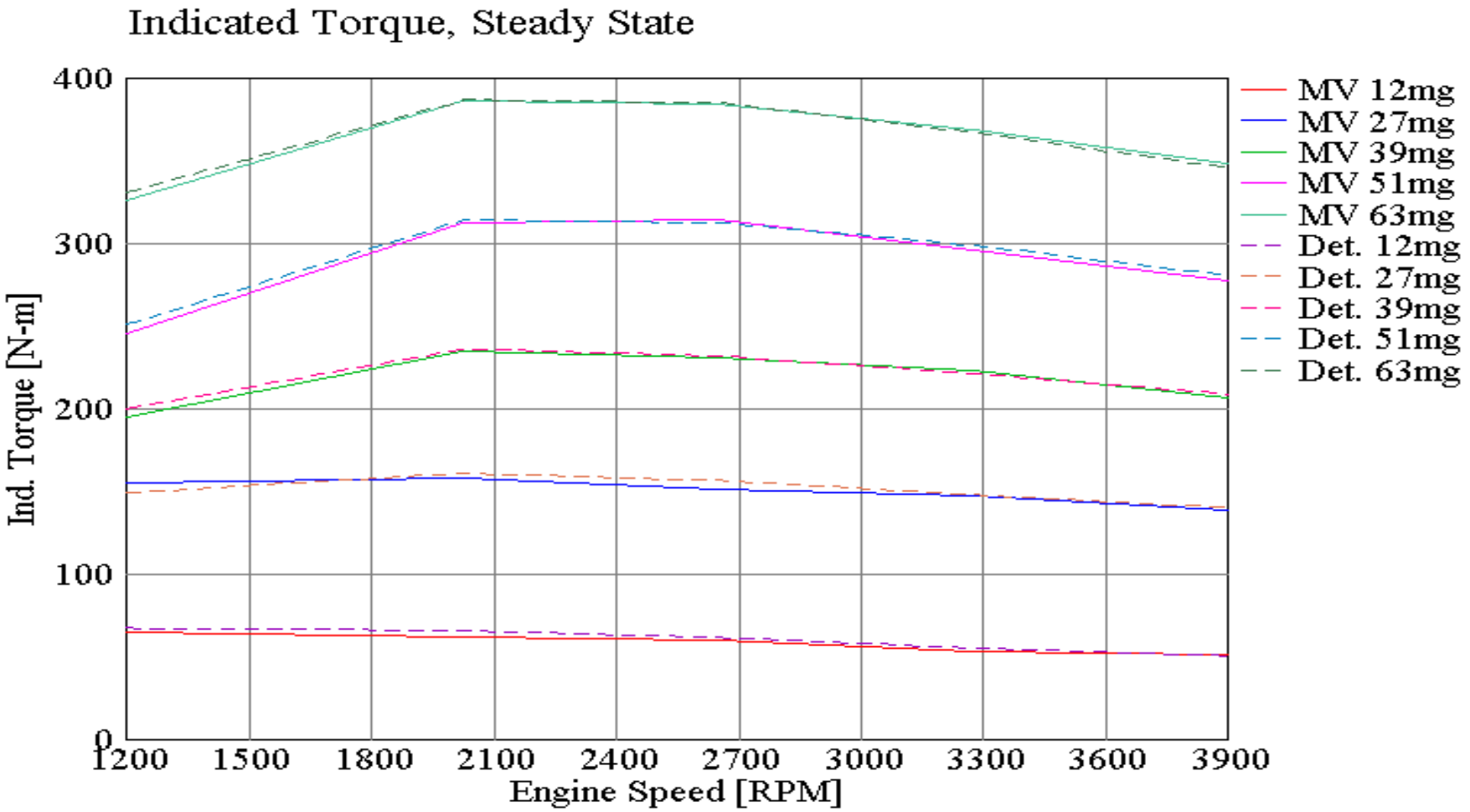
Naturally Aspirated, SI-Engine

- Constant Speed Throttle Step Test



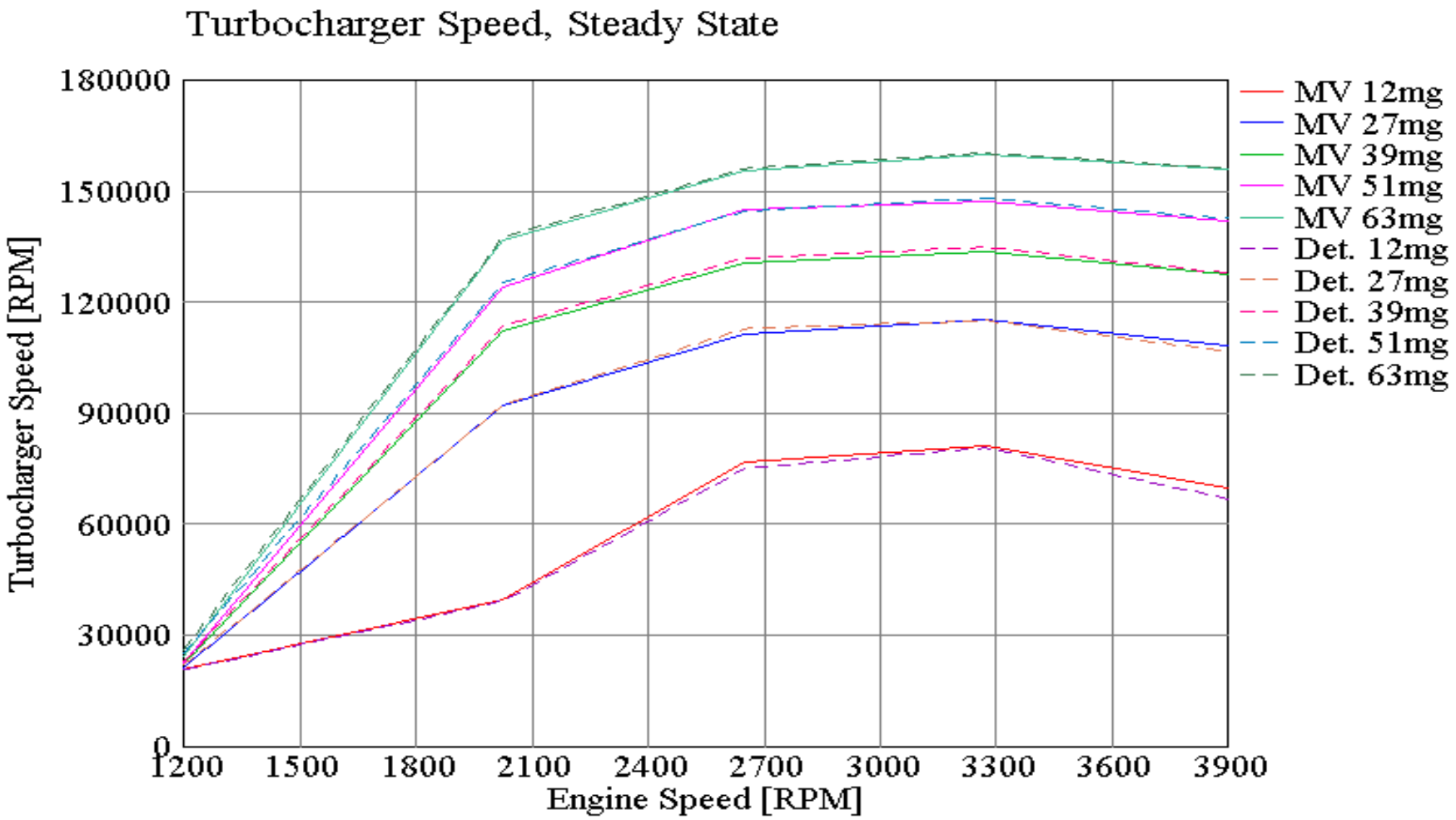
Turbocharged, DI Engine

- **Indicated torque at steady state for different loads**



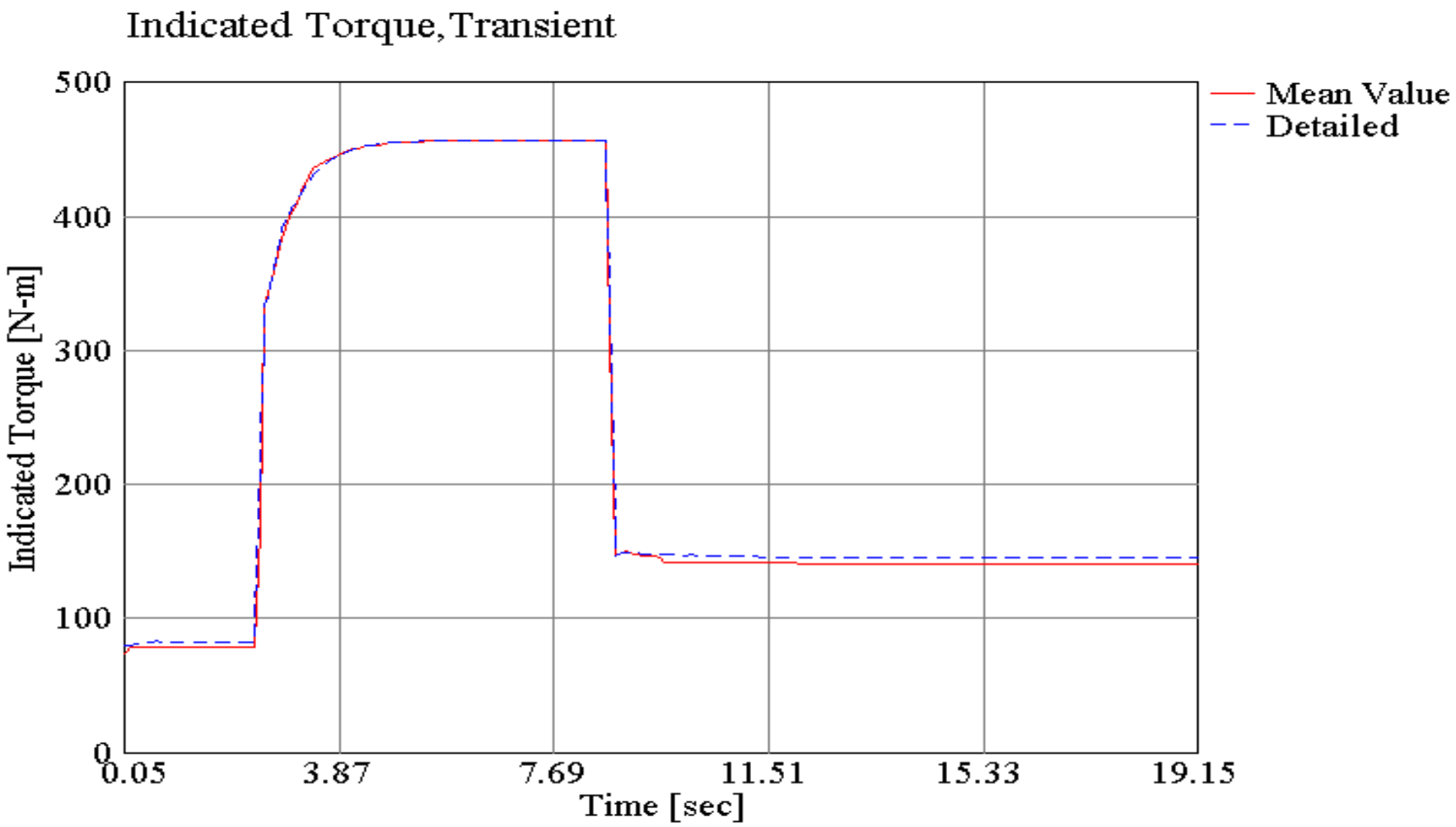
Turbocharged, DI Engine

- Steady state turbocharger speed



Turbocharged, DI Engine

- Comparison of indicated torque during a transient

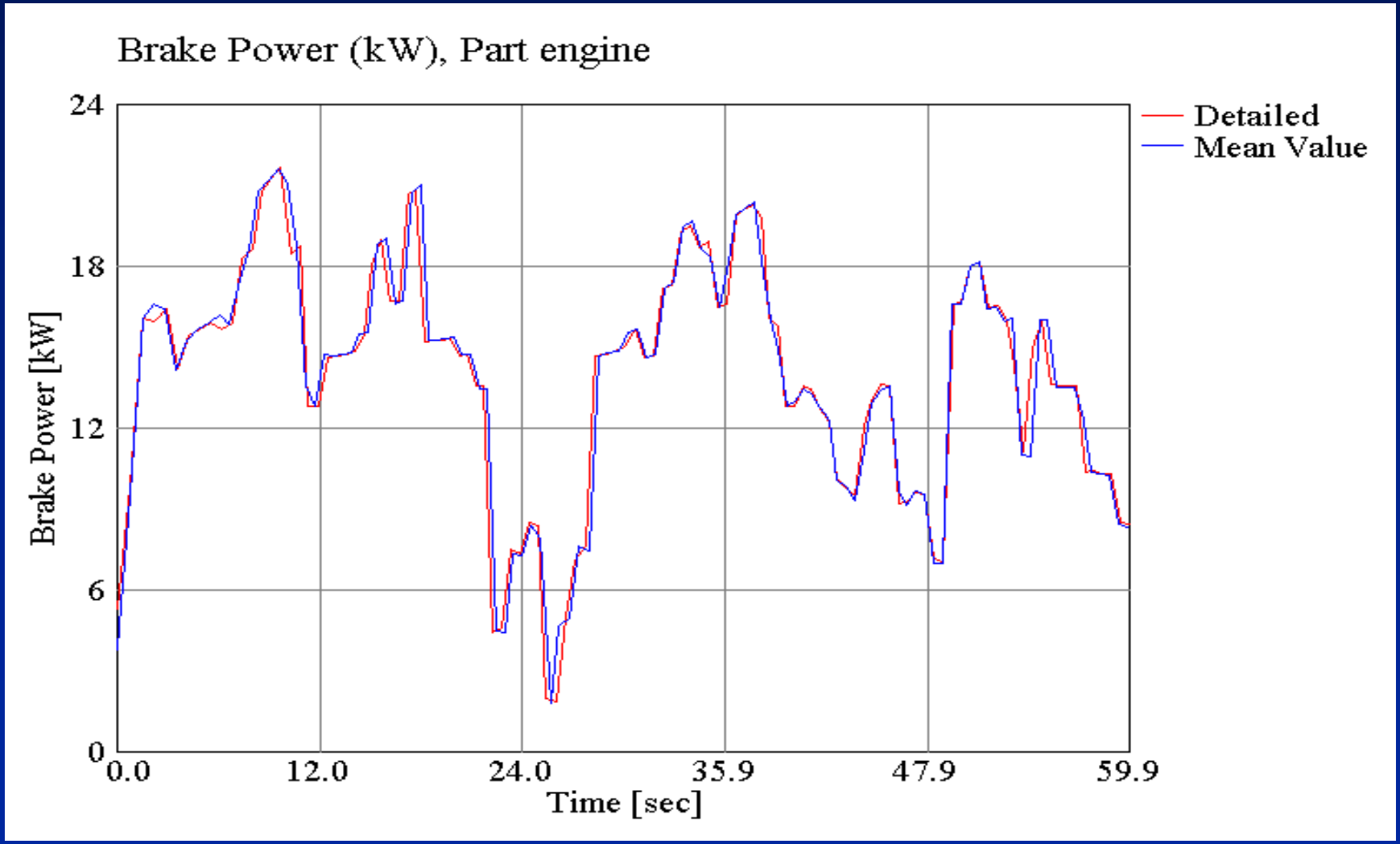


Turbocharged, DI Engine

- **Virtual Vehicle Simulation – Imposed Vehicle Speed**

Turbocharged, DI Engine

- **Predicted Brake Power**



Turbocharged, DI Engine

- Comparison of Predicted BSFC