TRANSIENT MODELING
USING MEAN VALUE
ENGINE CYLINDER

Gamma Technologies and
J. Lennblad and S. Tabar – Volvo Cars

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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
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

2500 RPM Step Test - Ambient Temperature = 15°C

Detailed

Mean Value

Normalized Brake Torque

Time [sec]
Naturally Aspirated, SI-Engine

- Constant Speed Throttle Step Test

WOT Brake Torque - Ambient Temperature = 15°C
**Turbocharged, DI Engine**

- Indicated torque at steady state for different loads

![Graph of Indicated Torque, Steady State](image-url)
Turbocharged, DI Engine

- Steady state turbocharger speed

![Graph showing turbocharger speed vs. engine speed for different conditions and models.](image)
Comparision of indicated torque during a transient
**Turbocharged, DI Engine**

- Virtual Vehicle Simulation – Imposed Vehicle Speed

![Vehicle Speed Graph](image-url)
Turbocharged, DI Engine

- Predicted Brake Power

Brake Power (kW), Part engine

- Detailed
- Mean Value

Brake Power [kW]

Time [sec]

0.0 12.0 24.0 35.9 47.9 59.9
**Turbocharged, DI Engine**

- Comparison of Predicted BSFC