A HARDWARE-IN-THE-LOOP (HIL) BENCH TEST OF A GT-POWER FAST RUNNING MODEL (FRM) FOR RAPID CONTROL PROTOTYPING (RCP) VERIFICATION

Hai Wu, Meng-Feng Li, General Motors

Key Words:
FRM - Fast Running Model
H I L - Hardware-in-the-loop
RCP - Rapid Control Prototyping
Outline

• Objective
• Hard/Soft-ware Setup
• Model Conversion
• Co-Simulation
• Test Results
• Conclusion
Engine System Models for HIL Test
- PDE Model, Mean Value model, ODE Model
- GT-POWER is a PDE based 1D modeling tool
- Availability and reusability from the upstream

Challenges in HIL Simulation
- Reusing the available models
- Tuning parameters
- Keeping consistency
- Having real-time capability
Mean Value, Map Based, ODE Model

• No breathing or combustion predictions
• Air flow, piston work, and exhaust energy imposed via neural networks

Advantages of GT-POWER Model

• Fidelity, availability, tailoring flexibility, extendibility
• Co-simulation verification

Fast Running Model (FRM)

• It is a speed-tuned version of a standard, detailed GT-POWER model
• Time-step level of detail can be adjusted by user
• Easy to convert (Combine Volume Wizard, FRM Converter)
• Fully predictive solution

Advantages of FRM

- Fidelity, availability, tailoring flexibility, extendibility
- Co-simulation verification

Fast Running Model (FRM)

- It is a speed-tuned version of a standard, detailed GT-POWER model
- Time-step level of detail can be adjusted by user
- Easy to convert (Combine Volume Wizard, FRM Converter)
- Fully predictive solution
Process and Setup

Procedure
- Convert GT detailed model into FRM
- Test FRM on HIL for real-time capability
- Comparison results of HIL and GT model

GT-POWER Model Conversion
- Volume size and discretization
- Optimization and parameterization
- Simulation comparisons by steps

Co-simulation with Matlab/Simulink
- Simulink S-function
- Controller designed and verified within Simulink

Hardware
- FRM on dSPACE Simulator (DS1006)
- RCP HIL for real-time capability test
- Comparison with GT model results
GT-POWER Detailed

5-10 times of RT
Detailed Model to FRM
Consider:
Highest fluctuations in velocities causes restrictions to the time step
• Reduce Volume number,
• Discretization size,

Procedure:
Starting from the Exhaust Ports/Runners, then move outward

Combine volumes:
• Exhaust Ports and Runners (not including Manifold)
• Exhaust Ports, Runners, and Manifold (depending on the Accuracy vs. Run Time goal)
• Exhaust Pipes after Turbine
• Intake Pipes before Compressor

Perform calibration:
Calibrating an Orifice Diameter is the most common way to calibrate pressure loss
Calibrating the Heat Transfer Multiplier is the most common way to calibrate Temperature in a certain location (e.g. Turbine Inlet Temperature)

Completion:
when the desired compromise of Run Time and Accuracy is achieved.
FRM Converter Tool

Key Variables
- BMEP
- BSFC
- Vol-eff
- etc.

Parameter Tuning
- Optimize pressure and Temp for data

Different Steps
- Management
- Comparison

HIL Goal
- Reduce run-time
- Keep accuracy
FRM – Fast Running Model
Results Comparison
Replace Feedback Controllers
• Turbo Changer control
• A/F Ratio
• BMEP/Torque Control

GT-POWER S-function
• Sensors (signal Input )
• Actuators (signal Output )

Control Design in Simulink
• PID
• Model based Control
HIL Simulator with DS1006

Real-time solver

Offline solver

Controller
Test Results: BMEP
Test Results: BMEP and Throttle

Graphs showing BMEP and throttle dynamics over time, with metrics such as MAF, Wastegate, and time intervals.
Test Results: Spark Timing on P_cyl
Test Results: 20 deg ATDC
• The Advantages: align HIL with R&P
  Model is available and reusable
• Conversion Process and Tool
  Easy in conversion and tuning with optimization
• Control Design and verification with Co-simulation
  Be capable of Engine and ECU simulation
• HIL tests
  FRM runs on dSPACE DS 1006 successfully
• Comparison with GT-POWER Simulation
  Agree well both in steady and transient
• GT-POWER-FRM-HIL is applicable & extendable
  Inherit models, convert seamlessly, and run in real-time
The authors would like to express their appreciations to

- Gamma Technology
  Iakovos Papadimitriou
  Miles Melka
  Kevin Roggendorf

- General Motors R&D
  Orgun A Guralp
  Jonathan Dawson
  Xiaofeng Yang
Thank you for your attention!

Published in SAE: 2016-01-0549