Steady-State and Transient Simulation of SuperTruck Waste Heat Recovery System in GT-Suite

Milan Visaria
Cummins Inc.
Outline

- Background
- System Architecture
- Model Development
- Steady-State Calibration
- Steady-State Performance Comparison of Different Working Fluids
- Transient Testing
- Transient FTP75 Cycle Performance Comparison of Different Working Fluids
- Real-Time WHR Model link to Simulink models
Background

- SuperTruck – DoE funded program
- Engine system demonstration of 50% or greater BTE in a test cell
- 50% improvement in Class 8 freight efficiency
- Waste Heat Recovery is one of the many technologies considered
  - Organic Rankine Cycle
  - Suitable for long-haul, high-load applications (trucks, inter-city buses)
  - Sources of “waste” energy for recovery: Exhaust & EGR stream
  - Mechanical power output to crankshaft through gearbox
Energy Balance and WHR Sources

Fuel Energy (100%)

- Brake Power (42%)
- Friction/Misc Losses (8%)

Heat Transfer (24%)

Exhaust Energy (26%)

Cooled EGR

200-750°C

Tailpipe Exhaust

200-600°C

Engine Cooling

80-100°C

Charge Air Cooling

20-60°C

Waste Heat Quality High

Waste Heat Quality Low

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CMI WHR System Overview

- Ram Airflow
- WHR Condenser
- CAC
- Radiator
- Intake Manifold
- Turbo Heat Exchanger
- EGR/Exhaust Gas
- Recuperator
- Turbine Expander
- Power Out
- Aftertreatment
- Tailpipe
- Working Fluid
Purpose of Model Development

- Compare steady-state and transient performances of different working fluids
- Optimize and predict the most efficient system operating point (Engine + WHR)
- Perform OBD and controls development
- Ability to replace component(s) and study its effect on the system
- Ease of linking WHR model to GT-Power engine model and study the integrated system performance
Model Building Procedure

Heat exchanger physical specs from supplier

GT-Suite WHR System Model

Combine all calibrated components and plumbing and retune the model

Calculate relevant parameters e.g. Hydraulic diameter, flow area, heat transfer area, dimensions, etc.

Compare model results against data/specs

Select heat transfer and pressure drop correlations

Heat exchanger performance specs/test data

Calibrate each component against performance data
GT-Suite WHR System Model

Model Inputs:
- Exhaust inlet flow rate and temperature
- EGR inlet flow rate and temperature
- Condenser and subcooler sfr flow rate and temperature
- Pump and turbine expander speed
- Target EGR gas outlet temperature
Steady-State Model Calibration

- Model calibrated using test data at 12 different steady-state speed and load points
- Figures compare the system flow rates, turbine inlet pressure and turbine inlet temperature
- The mean error in all quantities between model and test data was less than 3%
Steady-state performance of three different working fluids compared at 12 different operating points.
Transient Model Test – Inputs

- Transient profiles (using steady-state test data) of relevant parameters was input to the model.

- The idea behind the testing was to test the model controls and ensure that the model can handle receiver draining and filling.
Transient Model Test – Results

- Temperature
- Target Turbine Inlet Temp
- Turbine Inlet Temp
- Valve Command

- Receiver Liquid Level
- Net System Power

- Pump Subcool
  - Ideal Max Limit
  - Ideal Min Limit
FTP75 Simulation

- Engine test data from FTP75 cycle was input to the WHR model
- Transient profiles of feed pump speed (engine driven), EGR and exhaust gas flow rates, EGR and exhaust gas inlet temperatures, etc. are input to the model
- Performance of three different working fluids over FTP75 cycle is then compared
FTP75 Simulation – Results

System Mass Flow

Turbine Pressure Ratio

Time (sec)
FTP75 Simulation – Results

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Net System Power

Receiver Liquid Level

Time (sec)
Thank You!