Accelerating the Development of a 2500bar Common Rail Fuel System for a Locomotive Application by using GT-SUITE

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Woodward Inc.
Overview

- Who is Woodward?
- What is the EMD 1010J engine?
- Woodward HPCR1 Pump
- Woodward 1010 CRI
- System Architecture Optimization
- Conclusions / On-Going Work
Woodward on a page

What we do...
We design and manufacture control system solutions and components for the aerospace and industrial markets

Our Technology...
Innovative flow, combustion, electrical, and motion control systems help our customers offer cleaner, more reliable, and more efficient equipment

Our Customers...
Our customers are leading original equipment manufacturers and end users of their products

We are Global...
Woodward is a global company with over 30 offices in 14 countries and over 7,000 members
What we do—Industrial Control Systems

Reciprocating Engine Controls

Steam & Compressor Controls

Gas Turbine Controls

Wind Turbine Controls
EMD 1010J engine

- Combined development by Progress Rail and Caterpillar
- 265mm Bore; 16.6l displacement (1010in³); 4,500 BHP
- World-class fuel efficiency
- Meets EPA Tier 4 standards without urea after-treatment
- Double-Walled Fuel Injection System provides increased safety and simplified maintenance
- Two-Staged Turbocharging
- EMD turbos are custom designed to optimize locomotive performance across operating environments
Woodward HPCR1 Pump

- Designed for Tier IV Common Rail applications
- Rated pressure 2500Bar
- Flow up to 24l/min
- Based on previous 1800Bar Tier II design
- Currently used in multiple applications across several customers
Woodward HPCR1 Pump

- 1D model including complete bottom-end and oil circuit
- Individual elements are published as compound templates for modular use (2-, 3- and 4-element versions exist)
- Whole pump published as a compound template for easy integration into system level models
Woodward 1010 CR Injector
Woodward 1010 CR Injector

- Rated pressure 2500Bar
- Maximum delivery 2400mm³/cycle with up to five events
- Hydraulic control mechanism
- Zero static leakage
- Based on existing smaller lower flow injector (<1000mm³/injection)
Woodward 1010 CR Injector

- 1D model includes all relevant features.
- Broken up into subassemblies to improve model maintenance
- Published as a compound template for easier integration into system level models
Correlation

- Analysis matches delivery very well
- Slightly worse correlation at lower pressure
Correlation

- The injection behavior is matched very well by the simulation.
- Thus 1D could be used for optimizing the responsiveness of the injector.
Design simplification – RFCV removal

- Original design included a reverse flow control valve to dampen pressure waves but early testing showed structural problems
- 1D analysis suggested that removal would not affect injection behavior
- Thus the valve could be removed which reduced the number of parts and cost
Accumulator Volume and HP-Line Diameter

- Pressure drop during injection is impacted by HP-line Diameter and Accumulator Volume
- 1D analysis was used to select the optimum values within the existing design restrictions
System Architecture Optimization
Investigations into system architecture

- Initial system architecture had the injectors arranged in two separate banks fed by the same pump via a junction block
- GEM3D was used to extract the piping geometry
- Pressures were measured at four different locations on early prototype engine
Investigations into system architecture

- Measured data was used to calibrate the GT-SUITE system level model
- Overall agreement is acceptable but a perfect match at all conditions was not possible
- Different methods were investigated to improve uniformity but some were not as beneficial as initially expected
Investigations into system architecture

- At high pressures and flows all injectors within +/-0.5% of the average injection
- At lower pressures and flows this increases to a maximum of +/-3%
- Small post injections vary up to +/-5%
- Difference between the banks is below 1% for most cases
Conclusions / Next steps

- 1D analysis in GT-SUITE helped with quickly iterating different design options
- 1D analysis also lead to design simplification and helped optimizing the system architecture
- Currently continuous improvement projects are ongoing and are also supported by 1D analysis
Thank you!

Questions?