Modeling of a Combine through Tight Coupling of GT-SUITE and 3D MBD Software

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David Holt – Presenter
Dr. Marian Gofron – Contributor
Product Engineering, Combines
Hesston, Kansas
AGCO Corporation Overview

- U.S. company based in Duluth, GA
- 2013 Global Sales = $10.8B
- 22,000 Global Employees

Sales by Geographic Region:
- EAME: 51%
- North America: 26%
- South America: 19%
- Asia/Pacific: 4%

AGCO Corporation (AGCO) is a manufacturer and distributor of agricultural equipment and related replacement parts globally. The Company sells a range of agricultural equipment, including tractors, combines, self-propelled sprayers, hay tools, forage equipment and implements. It also manufactures and distributes grain storage and handling equipment systems, as well as protein production systems. Its products are recognized in the agricultural equipment industry and are marketed under a range of brands, including: Challenger, Fendt, Massey Ferguson and Valtra.
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Project Background and Objectives

- What is Header Height Control?
Project Background and Objectives

- Reduce the need for costly physical testing by modeling header height control in the GT-SUITE simulation environment
  - Multiple iterations (headers, tires, tracks)

- Identify problems with components or system behavior further upstream in the design process

- Provide controls group and analysis group a common simulation tool
Create a co-simulation environment between GT-SUITE and pre-existing tools at AGCO
- Matlab/Simulink for control
- Virtual.Lab for 3D Multi-body Dynamics (MBD)
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Plumbing model easily created from CAD
- GT-SPACECLAIM: “Volume Extract” feature to quickly get “negative” CAD
- GEM3D: Convert CAD data to GT flow elements
Model created from supplier data sheets, test data, and CAD
- Plumbing lines for hydraulic system
- Load sensing pump
- Cartridge valves for the header lift and lower operation
- Check valves
- Lift cylinders

A mix of templates used to construct the model
- Standard GT-SUITE templates (majority of model)
- User-created compound templates for unique/custom valves
GT-SUITE Model

Lowering Valve Characteristics

Flow Rate

- dP 1
- dP 2
- dP 3

Current

Lift Valve Characteristics

Flow Rate

Current

*Bolded labels indicate external interfaces

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A special co-simulation interface, MBDInterface, was developed by Gamma Technologies (V7.4 Build 4)
- Allows linking GT-SUITE to 3D MBD codes such as Virtual.Lab Motion
- Flexible number of inputs and outputs
- Advanced algorithm for maintaining stability under transient conditions
  - Eliminates the need to reduce \( \Delta t \) for stability in co-simulation

Virtual.Lab Motion calculates cylinder displacement based upon GT-SUITE calculated hydraulic forces, exchanged at every communication interval
- Simulink controller was compiled into a .dll
- Targets header height by controlling PWM current for lift/lower valves
- User can still control factors such as sensitivity dynamically from GT-SUITE
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**Scenario Description**

- Constant speed over representative terrain from Hesston test track
- Constant set-point for header height – 150 mm above ground
Simulation Results

- Combine Co-Simulation over Hesston Track
Simulation Results

Pump Results

Pump Displacement

Load Sense Pressure

Time [s]

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Simulation Results

Lift Valve Results

Controller Current

Valve Flow Rate

Time [s]
Improvements in Response

- It was also desirable to determine the sensitivity of header response to different designs and control strategies ("what-if studies")
  - Increase inlet fitting diameters
  - Increase hydraulic line diameters
  - Change lift and lower valves

- A virtual tool allows for quick iteration in testing different designs and control strategies
Improvements in Response

- New design in front with old design behind
Comparing old designs to new designs shows significant improvements in header response time.
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Conclusions

- Simulations through GT-SUITE can
  - Reduce physical testing
  - Find issues early in development cycle
  - Optimize designs

- Very positive experience working with GTI development and support during the project