System-level design of electrohydraulic and mechatronic systems

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Key Points

1. Testing different actuator designs in one environment saves time and encourages innovation.

2. Optimizing systems with respect to design requirements leads to optimal design choices.

3. Simulating at different levels of fidelity is required throughout the development process.
Agenda

- Trends in the automotive industry 10 min
  - Industry trends
  - Strategies for improvement
  - How simulation can help
- Example: Power steering system 15 min
  - Model explanation
  - Tradeoff study
  - System optimization
  - Assess implementation effects
- Conclusions
Industry Trends

- System needs
  - Vehicles must produce less pollution
  - Vehicles must be more efficient

- Energy losses in vehicles
  - Friction and accessories reduce efficiency significantly

- Strategies include advancing technology, vehicle-level design
Strategies for Improved Vehicle Design

- Technology: Electrical actuation
  - Fewer losses than hydraulic actuation
  - Only needs to be turned on when in use
  - Tend to be more reliable, cleaner, and safer

- Vehicle-level design and optimization
  - Integration with other systems
  - Optimization of integrated systems

- Simulation can help with each of these strategies
How Simulation Can Help

1. Tradeoff studies to test electrical and hydraulic systems
   - Determine actuator requirements
   - Test hydraulic and electrical actuator designs

2. System-level models
   - Required to test system integration
   - Few key parameters and quick simulation

3. Simulating at different levels of fidelity
   - Enable rapid iteration and test impact of design implementation
   - Reuse work done at system level (Model-Based Design)
Example: Power Steering System

- System

- Simulation goals
  1. Determine requirements for actuation systems
  2. Test performance with electrical or hydraulic actuation
  3. Optimize the actuation system
  4. Assess effects of system implementation
Determining Actuator Requirements

**Problem:** Determine the requirements for hydraulic and electric power steering actuators.

**Solution:** Use SimMechanics™ to model the steering system and Simscape™ for an ideal actuator.
Test Electrical and Hydraulic Designs

Model:
- Hydraulic
- Electro-mechanical

Problem: Test different actuator designs in the system

Solution: Use SimHydraulics™ and SimElectronics™ to model the actuators, and configurable subsystems to exchange them
Actuator System-Level Designs

- Hydraulic
  - Valve position controller
  - Directional valve
  - Double-acting hydraulic cylinder
  - Fixed-displacement pump
  - Pressure-relief valves

- Electric
  - DC Motor
  - Current sensor and current controller
  - Hall effect sensor and speed controller
  - PWM and H-bridge driver
Optimize System Performance

**Model:**

![Diagram of a control system with Speed and Current blocks connected]

**Problem:** Optimize the speed controller to meet system requirements.

**Solution:** Use Simulink Response Optimization™ to tune the controller parameters.

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Assess Implementation Effects

**Model:**

- Speed Control
- Current Control
- Simulink
- Circuit
- Averaged
- PWM

**Problem:** Assess the effects of design implementation on system performance

**Solution:** Use SimElectronics™ to add a PWM signal and analog circuit implementation
Conclusion

1. Testing different actuator designs in one environment saves time and encourages innovation.

2. Optimizing systems with respect to design requirements leads to optimal design choices.

3. Simulating at different levels of fidelity is required throughout the development process.
MathWorks Products Used

- Simscape™
  - Multidomain physical systems
- SimMechanics™
  - 3-D mechanical systems
- SimHydraulics®
  - Hydraulic (fluid power) systems
- SimElectronics™ (new)
  - Electronic and electromechanical systems
- Simulink Parameter Estimation
- Simulink® Response Optimization™
Physical Modeling Master Class (4:00 – 5:30PM)

- Build up pieces of power steering system (electric, hydraulic)
- Tune parameters using measurement data
- Build custom components (valves, etc.)

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