Simulation of AWD Performance with Multi-body Chassis Model and Hardware in the Loop System (HILS)

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Background/Scope

Current Environment:

• Computer controls are expanding into every major vehicle system.
• OEM and supplier resources are constrained to maintain costs and development schedule.
• Simulation tools have improved so that simulation speed and model fidelity are no longer mutually exclusive

Opportunity and Challenge:

Couple High-Fidelity Simulation Tools (Simpack) with computer controls hardware in order to create a new workspace for control-prototyping
Goals of Activity

- Construct a Real-Time Simpack model that has the correct interfaces to the powertrain models and AWD HILS bench and represents the performance of the base chassis.
- Construct a HILS bench in order to capture the actual AWD ECU control and servo-hydraulic actuator response.
- Construct a co-simulation environment in order to integrate the Simpack model and HILS bench.
- Demonstrate the ability of the co-simulation model to respond to control algorithm changes.
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AWD System Overview

Key Specifications:
- Power take-off torque transfer
- Dual rear clutches for independent torque control
- Active control for longitudinal slip and lateral torque-vectoring

Control Objective:
- Minimize Front Wheel Slip
- Throttle Line-Trace Ability
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Model Architecture Overview

- Engine Model
- TM Model
- EPS Model
- Brake Model
- Engine Controller
- TM Controller
- EPS Controller
- Brake/VSA Controller

HONDA

MATLAB SIMULINK

dSPACE

SIM PACK
Simpack Validation (Indoor)

Simpack base-chassis model was constructed and validated with laboratory test results in order to verify basic hard-points, mass properties, and compliances.
The basic chassis system can be validated by laboratory test, so the Tire + Proving Ground Effect can be isolated.
HILS Bench Design

From Vehicle Model
- Engine Torque
- Gear Position
- Wheel Speeds
- Steer Angle
- G-sensor

To Vehicle Model
- Left Clutch Pressure
- Right Clutch Pressure

Co-Simulation BUS

12V Power Supply

CAN BUS

Left Clutch Pressure

Right Clutch Pressure

AWD Harness
Real-Time Model Integration

All models are coupled in the Concurrent Real-Time environment with internal I/O (Simpack-Simulink) and external I/O (Simpack-dSPACE).
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A simple drive maneuver was designed to activate longitudinal slip and active yaw control in order to demonstrate the coupling of Simpack and HILS in Real-time.
Results (No AWD Control)

Driver Inputs

- **Steer Angle**
- **Throttle PCT**
- **Wheel RPM**
- **Wheel TRQ N-m**
- **Vehicle Yaw Rate deg/s**

- **Rear Diff Response**

- **Launch**
- **Accelerate in Turn**
- **Rev Limiter**
- **FR Wheel Slip**
- **No HILS Command**

Legend:
- FL
- FR
- RL
- RR
- RL Command (HILS)
- RR Command (HILS)
- RL Shaft TRQ
- RR Shaft TRQ
Results (Slip Control Only)

Driver Inputs

Steer Angle

Throttle PCT

Wheel RPM

Wheel TRQ

Vehicle Yaw Rate

Launch

Accelerate in Turn

Eliminate Slip

HILS Slip Control Active
Results (Slip Control + Torque Vectoring)

Driver Inputs

Steer Angle

Throttle PCT

Launch

Accelerate in Turn

Wheel Speeds

Wheel RPM

Rear Diff Response

HILS Torque-Vectoring Control Active

Wheel TRQ N-m

Vehicle Yaw Rate

Yaw Rate deg/s

More Yaw-Rate (tighter turn radius)
The combined Simpack and HILS simulation produced the expected result when combined with different AWD control algorithms.
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• A Real-Time Simpack model and AWD HILS bench were integrated using Concurrent and dSPACE.
• A driving scenario was simulated in order to demonstrate the coupling between the virtual model and the hardware controller.
• The vehicle model responded to changes in the control code deployed on the HILS bench.