USER STORY

Rose-Hulman Institute of Technology Students Design Hybrid Vehicle Powertrain with Simulink® and SimDriveline

Often, undergraduate engineering students spend their college years immersed in math and theory, with little opportunity to apply their knowledge and gain practical, real-world experience. That is not the case for students at the Rose-Hulman Institute of Technology participating in the Challenge X competition.

As part of the competition, Rose-Hulman engineering students will spend as many as three years using MathWorks tools for Model-Based Design to develop and build a hybrid vehicle powertrain. By applying the same tools as many of their industry counterparts on a real-world project, the students are acquiring engineering experience not easily found in a classroom.

"With MathWorks tools, our students can focus on design and engineering tradeoffs, instead of spending all their time on linear algebra and differential equations," says Zac Chambers, faculty coadviser of Rose-Hulman's Challenge X team. "Students on our Challenge X team will gain years of vehicle development experience using MathWorks tools."

THE CHALLENGE

Sponsored by General Motors and the U.S. Department of Energy, the Challenge X competition presents students with many challenges found in the automotive industry. The students are designing a vehicle that will reduce energy consumption and emissions production while maintaining acceptable levels of consumer satisfaction, performance, utility, and safety.

In addition to the technical challenge, the competition has a broader objective. "Our goal is to provide our undergraduate students with up to three years of experience

Rose-Hulman team for Challenge X.

in the design of fuel-efficient vehicles," says Marc Herniter, associate professor at Rose-Hulman. "This technology–and these students–will likely drive the market for cars, trucks, and offroad equipment for the next twenty years."

THE SOLUTION

In the first year of the competition, Rose-Hulman engineering students used MathWorks tools for Model-Based Design to model and simulate electrical, mechanical, and control systems of the hybrid vehicle.

After choosing a power-split architecture, the team began using Simulink, SimDriveline, and Stateflow® to develop models of their supervisory control system and a plant that included models of the engine, motors, batteries, brakes, and powertrain.

"By modeling the plant and the controller in the same environment, we quickly fixed an unstable mode in our vehicle controller by adding a second feedback loop," says Herniter. "I don't know how we would have done this without Simulink and SimDriveline."

Students used Simulink and SimDriveline to create the initial model, which included

THE CHALLENGE

To design a hybrid vehicle powertrain and gain real-world engineering experience

THE SOLUTION

Use MathWorks tools for Model-Based Design to model and simulate the vehicle's electrical, mechanical, and control systems

THE RESULTS

- Powertrain development time cut by 80%
- Practical experience acquired
- Focus on engineering maintained

a Planetary Gear Set (PGS) and a constant torque for the engine and both motors. The model helped them understand how the PGS interacts with the three power sources in the vehicle and the remainder of the driveline. Students added detail to each component to model nonlinearities and actual components.

"Simulink and SimDriveline helped us to teach a design philosophy, develop an understanding of the vehicle's physics, design the vehicle, and choose components," explains Herniter. "With this approach, we gained confidence in our model and chose and verified the operation of the components based on vendor-supplied data."

Using Stateflow, they designed the entire supervisory controller for the vehicle, which incorporates vehicle speed, battery state of charge, and driver torque request. By analyzing results from Stateflow simulations, students simplified their design by eliminating unnecessary states as well as hazards in the control logic that could damage vehicle components.

"In the competition, we were among the first to get our vehicle to move because we used Stateflow to put together a control strategy," explains Chambers. "With Stateflow, we spent our time improving the logic, not trying to code it."

The students then used Real-Time Workshop® to automatically generate DLLs for the supervisory controller and for the plant model, including the vehicle and powertrain. The DLLs were downloaded to hardware for real-time testing.

In the next two years, the students will continue to calibrate and optimize their design as they conduct hardware-in-the-loop testing of all the components, assemble the powertrain, and install the system into a vehicle for onroad testing.

> *"For our initial model, we began by writing differential equations and incorporating the kinematic constraints. It was a very difficult six-week process to develop a very simple model. With Simulink and SimDriveline, we built that same model in 20 minutes."*
>
> Zac Chambers, Rose-Hulman Institute of Technology

THE RESULTS

- **Powertrain development time cut by 80%.** "Without SimDriveline, we would have spent four or five times the amount of effort and time on developing our powertrain. SimDriveline enables us to fully understand how the power is split from the engine and the motors to get to the rear wheels and how all the components interact in the power flow," notes Herniter.
- **Practical experience acquired.** "We have a large group of students graduating from Rose-Hulman with significant experience in vehicle modeling using MathWorks tools," says Chambers. "Two of our recent graduates now work at General Electric and Caterpillar, and they are both using Simulink in their jobs."
- **Focus on engineering maintained.** "We have courses where students develop differential equations to describe systems, but there is a point where it is just too ugly," explains Herniter. "SimDriveline allows us to concentrate on the motors, the engine, the control systems, and the engineering."

To learn more about the Rose-Hulman Institute of Technology, visit **www.rose-hulman.edu**

APPLICATION AREAS

- Academia
- Automotive
- Model-Based Design
- Simulation

PRODUCTS USED

- Simulink
- SimDriveline
- Stateflow
- Real-Time Workshop

www.mathworks.com

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