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## Ford Motors applies new simulation technology to solve challenge of balancing comfort and fuel efficiency

March 23, 2015 [Jennifer Calhoun](#) : 0 Comments

By Yijun Fan and Wulong Sun

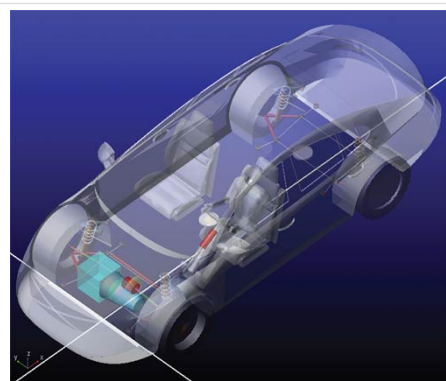
Lugging is a familiar—and unwelcome—challenge that symbolizes the tension between fuel economy and noise, vibration and harshness (NVH) in motor vehicle design today. Lugging occurs when a vehicle is operating at a high gear and a low engine speed—below 2,000 RPM—and the driver hits the accelerator.

The lack of torque in the high gear causes the drivetrain to vibrate as the engine struggles to move the load at a higher speed. The noise and vibrations travel through steering columns and seat tracks into the passenger compartment.

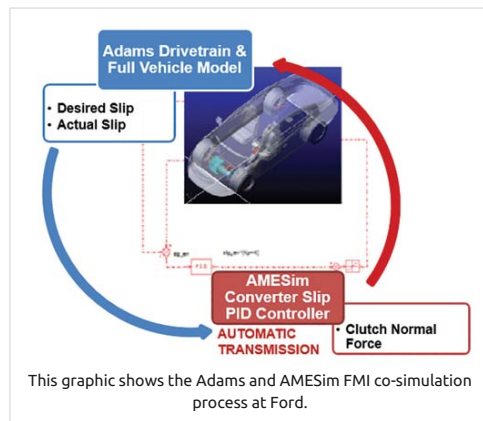
Engineers can adjust the vehicle's transmission to accelerate smoothly in high gear—a process called “slipping”—but doing so reduces the car's fuel economy. Therein lies the conflict. Consumers want the smoother rides that slipping the transmission yields, but automotive engineers are under enormous pressure to improve fuel efficiency to meet ever-stricter government mileage requirements.

In an environment where engineers measure weight savings in ounces, every bit of efficiency in the transmission is crucial. However, adjusting slip has been a largely trial-and-error process that seldom yields optimal results without substantial loss of time and money.

Ford Motor Company recently developed a method for adjusting the vehicle's transmission optimally without slowing down design or making it more expensive. Based on advanced simulation and modeling technology, Ford's method enables automotive engineers to adjust slip settings before the prototyping phase.



Using an advanced simulation and modeling technology, automotive engineers at Ford Motor Company recently developed a method that enables them to simulate the effects of different torque converter designs so engineers could make calculated tradeoffs between slip and lockup before the prototyping stage.



### Lugging and torque converters

A vehicle's engine and drivetrain deliver maximum fuel economy when a device called a lock-up clutch engages and provides a direct physical connection between the engine and the transmission. Lockup clutches are part of the



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Lockup clutches most often engage when a vehicle is cruising at a constant speed, usually on flat stretches of highway. Clutch lockup is the source of lugging; the locked-up clutch directly transmits engine torque fluctuation to the transmission, which causes it to vibrate and make noise.

“Slipping” the lockup clutch—or adjusting it to provide less than a 100% connection between the engine and the drivetrain—reduces vibration. Slipping, however, decreases the powertrain’s efficiency.

It causes energy loss from friction and “fluid coupling,” which is when the liquid in the transmission provides the connection between the engine and the drivetrain instead of the lock-up clutch providing a direct physical connection. Fluid coupling is less efficient than physical coupling, so it delivers lower fuel economy.

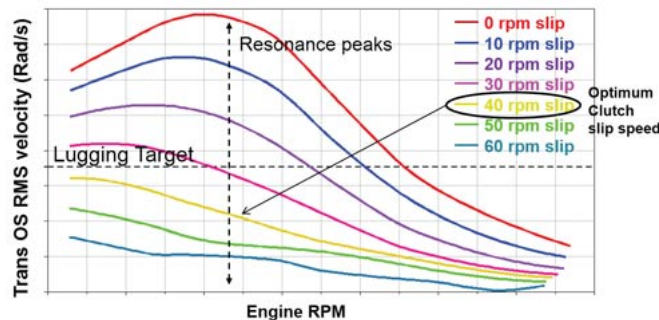
An accurate means of calculating slip has eluded automotive engineers for years. The only way to “test” slip was to commit to a setting in the prototype vehicle. If the engineers weren’t correct on their slip calculations on the first try—if the settings didn’t deliver the desired slip—it was nearly impossible to adjust them. A vehicle’s design is essentially frozen at the prototype stage, which makes changes expensive and potentially delays production. Only the most egregious problems are addressed during the prototyping phase.

#### Ford’s solution: virtual prototyping

Ford wanted to simulate the effects of different torque converter designs so engineers could make calculated tradeoffs between slip and lockup before the prototyping stage. The solution came through a combination of simulation and modeling technology and an open standard for co-simulation called Functional Mock-Up Interface (FMI).

FMI enables engineers to create a virtual product from a set of models of physical laws and control systems. It also enables model exchange and co-simulation between different simulation applications. Ford used FMI to combine simulations of a slip controller, a drivetrain and a full vehicle into a single simulation that enabled engineers to accurately anticipate how clutch slip settings would affect fuel economy and NVH.

Ford created detailed 3D models of the drivetrain and the entire vehicle in MSC Software’s Adams multi-body dynamics software. The drivetrain model included a turbocharged gasoline engine, a torque converter with a lockup clutch, a six-speed gearbox, and a front driveline with differential shafts, constant velocity joints and wheels.



The vehicle model included the chassis, suspension, steering, brake and wheel sub-systems. Ford engineers also created a separate 1D model of the torque converter with AMESim multi-domain simulation software. Both applications support the FMI standard, which enables their models to work together in one simulation.

The engineering staff ran the model for different values of desired slip. The AMESim model, working as the FMI co-simulation slave, simulated the force on the lockup clutch. The MSC Adams models, working as the FMI co-simulation master, simulated how much NVH different slip settings would create in the rest of the vehicle.

Simulation results showed that a slip of 30 rpm would fail to meet the NVH target while a slip of 40 rpm or greater would meet the target. The simulation demonstrated that 40 rpm slip was the optimal trade-off between NVH and fuel economy. Engineers also studied related assemblies to gauge the effects of slipping on passenger comfort. They compared vibration at the steering wheel and seat track at no slip and 40 rpm (the slip setting) and found a substantial improvement in NVH that justified slipping the clutch to 40 rpm.

In the future, Ford plans to validate the models with physical testing results, then integrate simulation into the design process so the torque converter design can be optimized early in the development cycle. The company also plans to build a more sophisticated torque converter model that depicts its hydraulic systems as well as the lockup clutch. The greater detail will help engineers develop vehicles that deliver the comfort and performance required to appeal to customers and the efficiency to meet increasingly stringent fuel economy standards.

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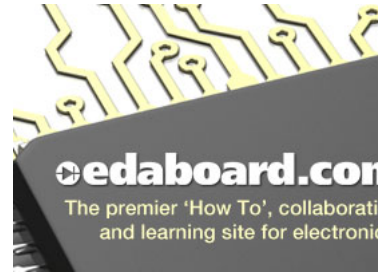
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