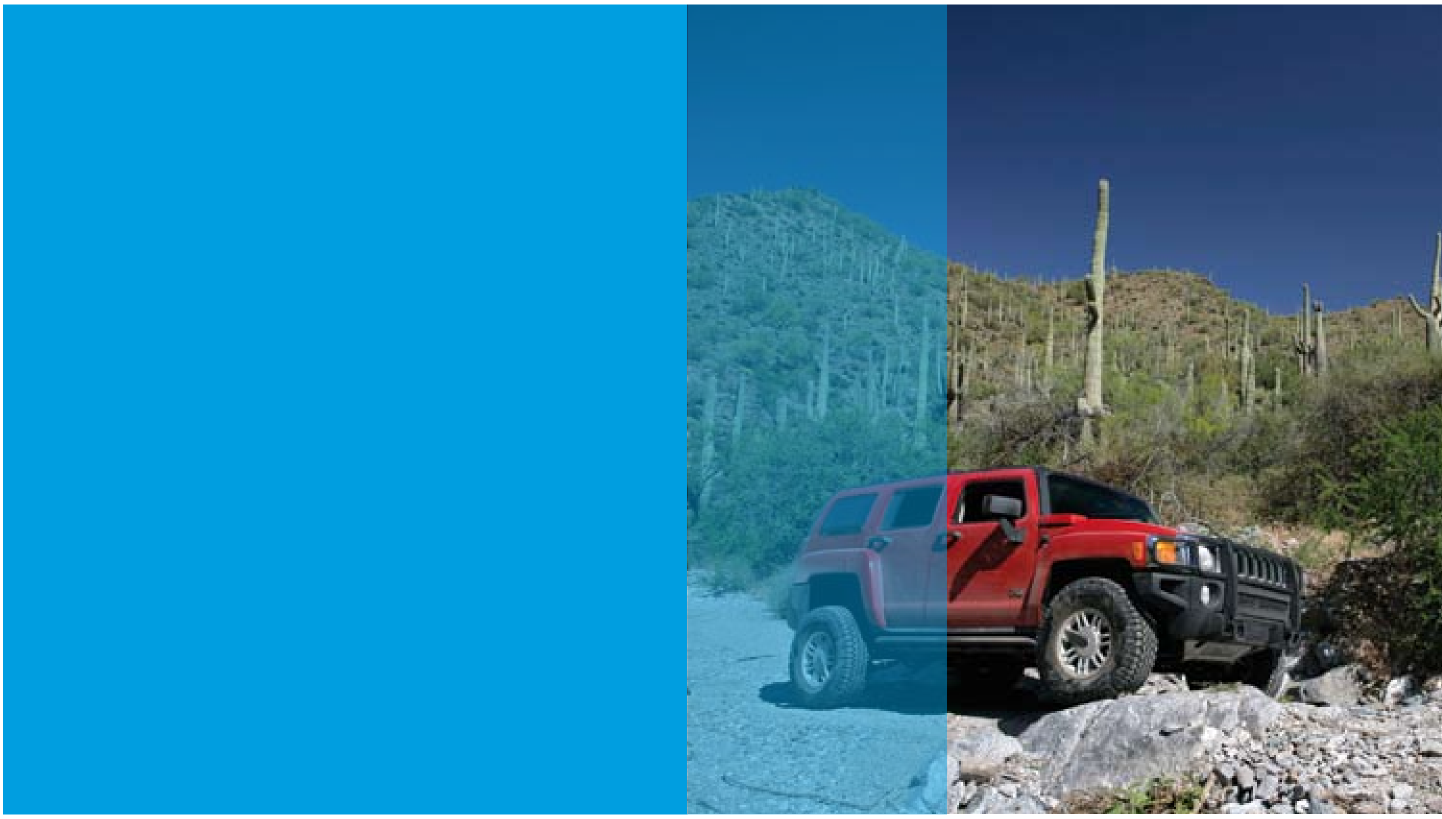
GM replaces driveline tests with simulation

LMS Multibody Simulation accurately matches test cell results while sweeping from 0 to 7,000 rpm



ENGINEERING INNOVATION

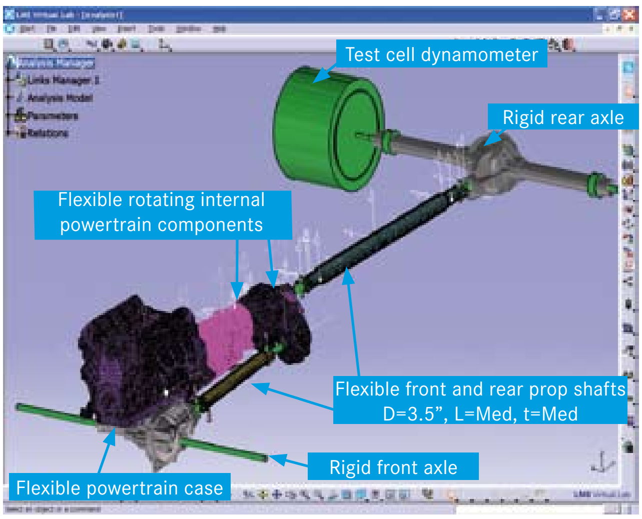
Among the most challenging tasks in developing a new 4-Wheel Drive (4WD) vehicle are validating the durability and Noise, Vibration and Harshness (NVH) performance of the driveline. Performing this task under the full range of operating speeds, while also taking manufacturing variation into account, makes it even more difficult. Yet today, physical testing cannot occur until prototypes become available rather late in the design and development process, making design changes highly expensive and time-consuming. General Motors implemented an alternative approach, using LMS multibody simulation software, to evaluate driveline performance using virtual prototypes with a high level of accuracy. "We already succeeded in eliminating 25 tests per year for our 4WD sport utility vehicles and pickup trucks, saving significant costs in material and testing," said Chandra Shah, Computer Aided Engineering Engineer at General Motors in Detroit, Michigan.

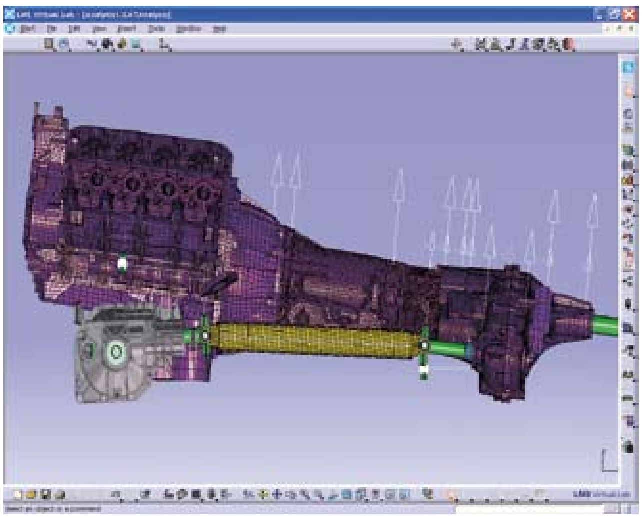
Before General Motors releases a new 4WD vehicle, every rotating component from engine to wheels must be validated as part of the overall system. The main reason is that all these components have inherent manufacturing variations that cause out-of-balance conditions, which in turn, generate centrifugal forces. These forces increase as vehicle speed rises and generate stress in all driveline components. The adapter, which connects the transmission to the transfer case, is often the most sensitive component because it is very short in length. In the test cell, the worst out-of-balance conditions are evaluated by adding weights to the components. The driveline is instrumented by placing strain gauges at the critical locations to measure stress and vibration. The engine is then typically run from 0 to 7,000 rpm in order to identify excitations that may come into play at specific speeds. The test is designed to identify vibration and bending that could create durability problems or generate excessive noise.

Replacing tests with simulation

The process of building and instrumenting the prototype and running test programs involves significant engineering time and expense. Another drawback of physical testing is that it can only be performed relatively late in the development process, when fixing potential problems require lengthy and costly multi-attribute testing efforts. For these reasons, General Motors started several years ago to simulate the driveline up to a level of accuracy that would make it possible to identify problems long before prototypes become available. "Physical testing will always be necessary to verify the accuracy of simulation, particularly when developing new vehicle designs," Shah said. "In addition to testing, simulation provides substantial time and cost savings by offering the means to identify problems in the early design stages and to evaluate performance differences between new and existing designs. The early insights acquired in this way enable engineers to eliminate all major weak spots in a new design and substantially reduce the number of physical tests required."

While multibody simulation technology has successfully been applied to simulate drivetrain assemblies in the past, this application may be the most challenging ever in this area. In order to reliably assess a drivetrain's dynamic performance, most of the components, including the powertrain case, rotating internal transmission and transfer case components, adapter, and front and rear propshafts must be modeled as





To reliably assess the dynamic motion performance of a drivetrain assembly, the powertrain case, rotating internal transmission and transfer case components, adapter, and front and rear propshafts must be modeled as flexible bodies.

LMS multibody simulation helps eliminate expensive late-stage design changes and optimize designs for durability and NVH up to a level that was not feasible in the past.

flexible bodies, which, as a consequence, increase computational simulation requirements considerably. Further adding to the computational challenge is the need to sweep the simulation over the full range of vehicle operating speeds.

Developing the multibody simulation model

GM driveline engineers Jennifer Bagley, Venu Gowducheruvu, and Chandra Shah experienced that LMS DADS offers the robustness required to meet the computational challenges of this application. Using the LMS dynamic motion simulation software, GM engineers model complete assemblies by importing solid models of driveline components, which they converted from Unigraphics CAD systems into MSC. NASTRAN Finite-Element (FE) analysis models. LMS DADS integrates the FE analysis results by using component modal synthesis to simulate flexible bodies and track vibration frequencies. Mass properties update automatically in response to changes in center of gravity location and inertia due to structural deformation. Joints, constraints, and forces are directly defined in LMS DADS. On the basis of Statistical Quality Control (SQC) data received from component suppliers, the GM engineers were able to calculate maximum variation within a 95% level of confidence as well as six sigma limits. Then they evaluated system performance by adding additional weights that are needed to simulate these worst-case conditions. In order to keep the computational load manageable, they use a first-order unbalance forcing function for the main components. The powertrain contribution is simplified due to memory limitations and by defining the subsystem damping magnitude on the basis of an empirical estimate. The simulation model is configured to sweep through the driving range, typically between 0 to 7,000 rpm, at 80 rpm per second ramp rate.

LMS dynamic motion simulations automatically solve the non-linear equations of motion and reports loads, positions, velocities, and accelerations at each time step of the simulation. Results are presented in graphs and photo-realistic 3D animations that enable engineers to visualize the flexible deformation of the driveline components. From the early stages of the project, GM engineers found they were able to duplicate the results of the test to a high level of accuracy. The standard deviation of test cell results is typically 10%, due to the impossibility of precisely duplicating the conditions in any two tests. When this variation is considered, the ability of GM engineers to consistently perform simulations that match test results within 15% is considered very good.

Validating a program without additional testing

In a typical example, the GM engineers used the results from driveline program A, which had previously been validated with physical testing, to validate driveline program B. The main differences between the two programs are the propshaft and liner. Engineers first configured a multibody simulation model to match vehicle program A and verified that the simulation results matched the previous physical tests. Then they changed the propshaft and made other adjustments to the model to convert it to program B. The simulation showed that the propshaft, transfer case and adapter case stresses are all lower for program B than for program A, so its validation can be derived from testing performed for case A.

In the second example, a design change was made to a transfer case in program C. The modified transfer case was integrated into a previously correlated LMS DADS driveline system model and the effects of the design change were studied. The results showed that under the worst possible driveline bending conditions, the center bearing support never comes into contact with the transfer case housing. Simulations also showed that the center bearing support appears to have no dynamic effect on driveline bending integrity. The prop shaft, adapter and transfer case all tested below the "no-test–is-required" level for the given axle ratio at the limiting vehicle speed. The conclusion was that no hardware testing was needed to validate this design change.

"The described simulation-driven design methods have now been implemented on a large scale at General Motors. The result is that many vehicle programs have been validated using prior simulation and test correlation from an existing vehicle program that shares the same powertrain components," Shah concluded. At any given time, General Motor typically has 100 driveline programs underway. In the past, these programs used to require about 40 tests per year. Today, the number of tests has been reduced to 15 and this number is expected to be further reduced to 10. The company has already eliminated several test cells that are very expensive to operate. Even more important is that simulations provide design guidance up-front in the program cycle when no hardware is available yet. This helps eliminate expensive late-stage design changes and also offers the opportunity to optimize designs for durability and NVH up to a level that was not feasible in the past. ■

LMS INTERNATIONAL
Researchpark Z1, Interleuvenlaan 68
B-3001 Leuven [Belgium]
T +32 16 384 200 | F +32 16 384 350
info@lms.be | www.lmsintl.com

LMS FRANCE	**Paris** | T +33 1 69 35 19 20 | info@lmsfrance.fr **Lyon** | T +33 4 37 49 13 25
LMS DEUTSCHLAND	**Leonberg** | T +49 7152 97 97 90 | info@lms-gmbh.de **Munich** | T +49 8954 03 43 21
LMS ITALIANA	**Novara** | T +39 0321 445 011 | info@lms.it
LMS UK	**Coventry** | T +44 2476 408120 | info@lms-uk.co.uk
LMS N. AMERICA	**Detroit** | T +1 248 952-5664 | info@lmsna.com **Los Angeles** | T +1 714 891-4205 **Washington D.C. / Baltimore** | T +1 410 203-1200
LMS JAPAN	**Yokohama** | T +81 45-478-4800 | info@lms-ja.co.jp
LMS KOREA	**Seoul** | T +82 2-571-7246 | info@lmskorea.com
LMS CHINA	**Beijing** | T +86 10 8497 6463 | info@lmschina.com **Shangai** | T +86 21 5888 8882
LMS INDIA	**CAE - Bangalore** | T +91 80 511 51 512 | info.lmsindia@lms.be **Test - Chennai** | T +91 44 281 73 711| info.lmsindia@lms.be
LMS RUSSIA	**Moscow** | T +7 095 937 84 93 | info.lmsrussia@lms.be
LMS SINGAPORE	**Singapore** | T +65 6777 3609 | info.lmssingapore@lms.be
LMS Test Division	**Leuven [Belgium]** | T +32 16 384 200 | info@lms.be **Breda [The Netherlands]** | T +31 76 573 6363 **Göttingen [Germany]** | T +49 551 50 48 50 **Brasov [Romania]** | T +40 268 414200
LMS CAE Division	**Leuven [Belgium]** | T +32 16 384 200 | info@lms.be **Kaiserslautern [Germany]** | T +49 631 30322 100 **Coralville, IA [United States]** | T +1 319 626 6700 **Brasov [Romania]** | T +40 268 414200
LMS Engineering Services Division	**Leuven [Belgium]** | T +32 16 384 200 | info@lms.be **Kaiserslautern [Germany]** | T +49 631 30322 100 **Detroit, MI [United States]** | T +1 248 952 5664 **Torino [Italy]** | T +39 011 6671 615
Worldwide	For the address of your local representative, please visit www.lmsintl.com/lmsworldwide

LMS is an engineering innovation partner for companies in the automotive, aerospace and other advanced manufacturing industries. LMS enables its customers to get better products faster to market, and to turn superior process efficiency to their strategic competitive advantage. LMS offers a unique combination of virtual simulation software, testing systems and engineering services.

LMS is focused on the mission critical performance attributes in key manufacturing industries, including structural integrity, system dynamics, handling, safety, reliability, comfort and sound quality. Through our technology, people and over 25 years of experience, LMS has become the partner of choice for most of the leading discrete manufacturing companies worldwide.

LMS is certified to ISO9001:2000 quality standards and operates through a network of subsidiaries and representatives in key locations around the world.

LMS®
ENGINEERING INNOVATION