Recent Applications of Abaqus/Explicit in GM Chassis CAE

Robert L. Geisler, Ravindra Patil, Dr. Joseph Schudt, Dr. Sung-Ling Twu

General Motors Global Product Development – Chassis CAE

Abstract: GM Chassis CAE has used ABAQUS successfully for many years. In the past most problems examined were more traditional durability and strength analyses of metallic structural components. Recently we have used ABAQUS/Explicit to great advantage to assess and solve for a wider range of component materials and loadings such as elastomers, sealing and impact. This presentation highlights some recent examples of these types of analyses, as well as sharing some general conclusions and lessons learned from these studies.

Keywords: Automotive, Dynamics, Experimental Verification, Hyperelasticity, Impact, Plasticity, Polymer, Rubber, Rubber Bushing, Sealing, Suspension

Introduction

General Motors Chassis CAE has used Abaqus/Standard successfully for over 20 years. However, until recently this use has typically been traditional strength & durability analyses of metallic components. Examples included both linear and non-linear, static and dynamic, structural analyses. More compute intensive, highly non-linear and/or dynamic analyses were done only on an as-needed method, and usually to diagnose and solve a very specific known problem.

As CAE tools have improved and computing power has increased, it is now possible to incorporate these types of analyses using Abaqus/Explicit into mainstream product design. Examples include analysis and design of elastomers, sealing analyses, and impact analyses.

This paper presents some recent examples of Abaqus/Explicit analyses performed at GM Chassis CAE.

Example #1 – Strut Mount

Recent GM vehicles have employed a new front suspension Macpherson strut mount. (See Figure 1.) During the development of this design, an unexpected noise was detected originating from the strut mount. Substituting multiple samples of the same design into the test vehicle confirmed that the source of the noise was local to the strut mount. It was also discovered that prototype samples of the mount had the rate plate shifted forward in the vehicle position by 2.5 mm. (see Figure 2.)

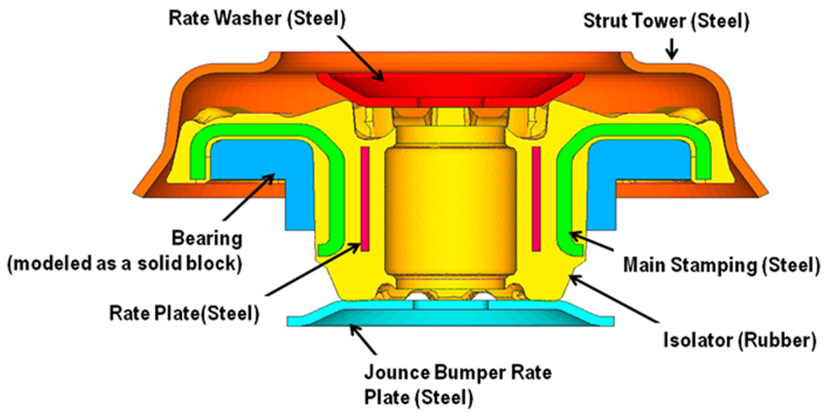


Figure 1. Strut mount cross section view & model content

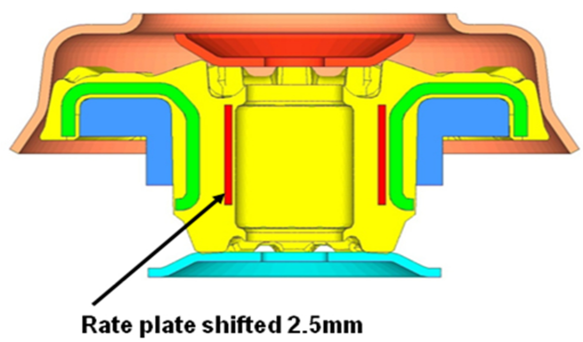


Figure 2. Strut mount cross section showing shifted rate plate.

The Chassis CAE group was asked to assist in diagnosing the source of the noise in the mount. Initial models of the design as intended had already been done the SIMULIA/Great Lakes Office as part of an engineering contract. A new model was built by GM with the rate plate in the shifted position. Abaqus/Explicit analysis of the both version of the strut mount was performed. This analysis had the following objectives:

1. Check the static rate of both versions of strut mount versus design specifications
2. Review strut mount performance of both versions in detail, including internal interactions as well as interaction with the body structure.

In addition to checking rate, a combined radial + coning load was also applied to more closely represent on-car conditions under normal operation.

Analysis of the two versions showed very different results, as shown in Figures 3 & 4.

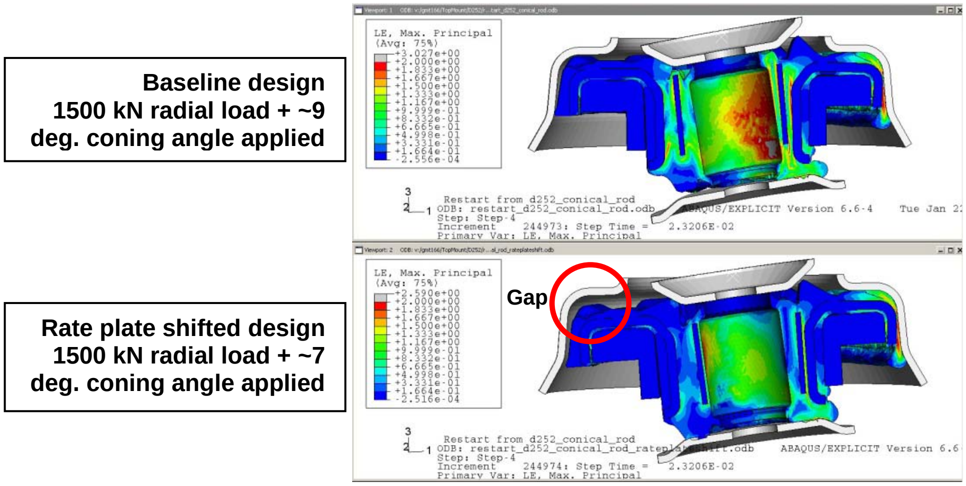


Figure 3. Strut mount analysis results; deformed shape

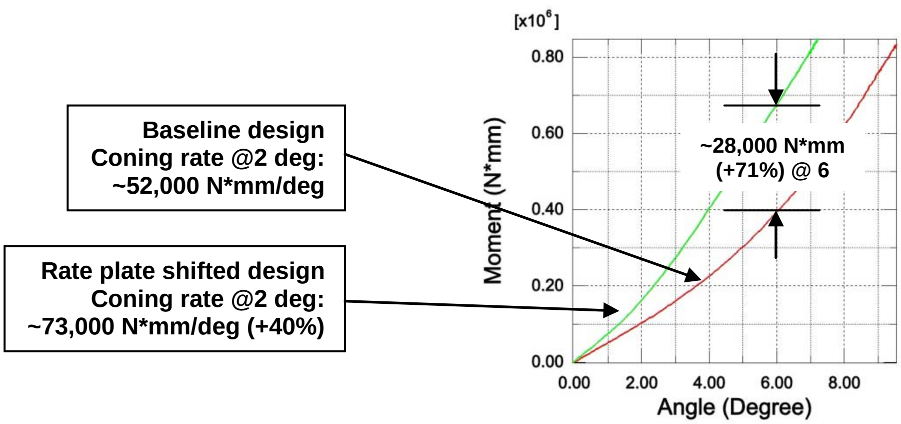


Figure 4. Strut mount analysis results; coning rate

The analysis results showed that the separation from body structure that was shown in the shifted rate plate design was most likely the cause of the noise. This was confirmed when properly made parts did not show the same noise. This analysis also clearly illustrated the importance of the position of the rate plate relative to the main stamping to the performance of the mount.

Now that confidence in the analysis was established, the model was used to evaluate & determine rates for further design proposals.

Example #2 – Hydraulic Sealing Port

One of our vehicles was found to be leaking hydraulic fluid during the assembly process. The leak was traced to a pressurized hydraulic port in the steering gear housing. The port was sealed with a pressed-in steel ball.

In order to quickly solve this problem, it was decided to add a sealing plug to this port. Use of the plug required increasing the diameter of the port. This lead to concern that the hoop stress caused by pressing the plug into the port would be enough to either prevent proper sealing or cause other structural concerns such as fatigue cracking. See Figure 5 for an overview of the affected area and sealing plug. (For more details on the KVT Koening EXPANDER® sealing plug, please www.kvtkoenig.com/2320/produkte.jsp)

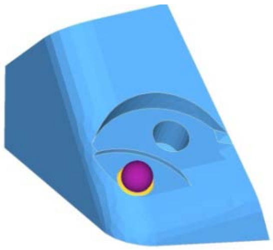


Figure 5. Sealed hydraulic port; Koenig EXPANDER® sealing plug.

A 2-D cyclosymmetric model of the steering gear around the hydraulic port and appropriate EXPANDER® plug was built. The steering gear portion was modeled using the minimum section around the port. Abaqus/Explicit was used to model pressing the EXPANDER® plug into the port. Stress and strain during after the press-in was monitored. The entire tolerance range of port diameter was also evaluated. This entire sequence was completed overnight, in order to minimize assembly plant downtime.

Analysis results are shown in Figure 6. Stress and strain around the port was not considered excessive relative to the capability of the steering gear. Push-in forces throughout the entire range were considered adequate to properly seal the port.

The push-in forces from the Abaqus/Explicit analysis were compared to push-out forces recorded on actual parts. The analysis results closely matched the hardware measurements.

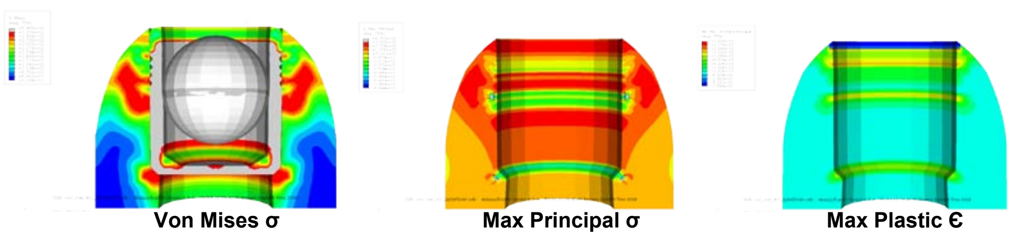


Figure 6. Analysis results; plug press-in to steering gear hydraulic port

Example #3 – Impact Energy Absorber

Cadillac introduced the 2nd generation CTS for 2008 model year. At the time of introduction, the largest wheel and tire combination was an 18” package. All design work for the body and chassis had been done using the impact loads generated with this tire & wheel package.

For the 2009 model year, Cadillac introduced the CTS-*V*. Cadillac had specified the use of a 19” run-flat tire as well as a 10 mm reduction in trim height. This tire has a stiffer and shorter sidewall compared to the previous 18” tire. There was concern that the higher shock tower forces under impact road events like potholes & bumps due to stiffer tires & reduced jounce travel may drive the need for changes in the body and suspension. Chassis CAE was asked to develop a suspension package that would maintain or reduce peak shock tower loads for the CTS-V at the same levels as the base CTS.

Chassis CAE had previously developed a device that is in use on the Chevrolet Cobalt rear suspension. (See Figure 7; see Reference 1 for more details on this device.) However, the fact that in the CTS the jounce bumpers are coaxial with the shock absorber for both front and rear suspension prevented the use of this type of device.

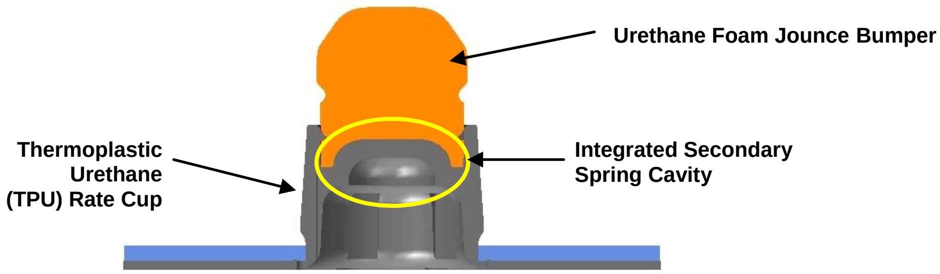


Figure 7. Chevrolet Cobalt dual-rate rear jounce bumper

Instead, Chassis CAE developed a **L**oad **M**anagement **S**triker **C**ap, or LMSC. The LMSC is pressed onto the top of all four shock absorbers. This part presses onto the top of each shock absorber and acts as another spring in line with the jounce bumper to absorb additional energy under impact loading. (See Figure 8.)

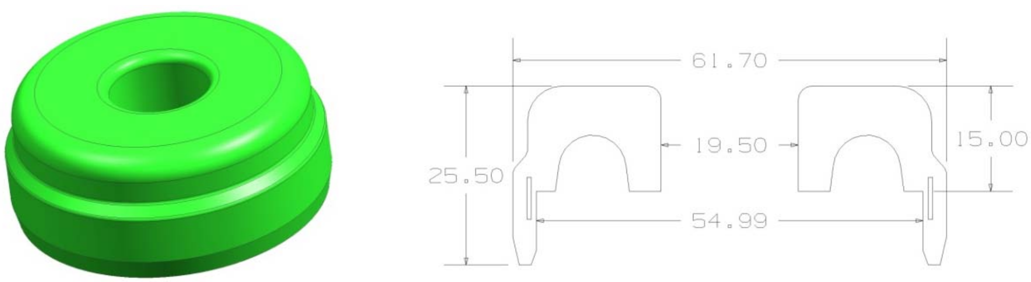
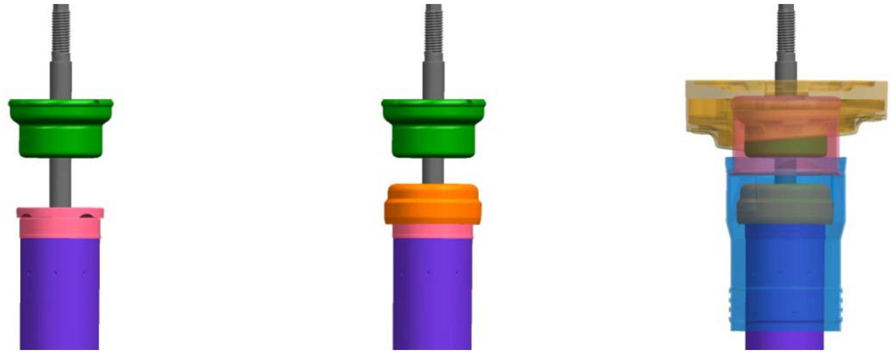


Figure 8. Cadillac CTS-*V* front suspension LMSC

The LMSC is fabricated from thermoplastic urethane supplied by BASF. (The specific material is Elastollan 1564D.) The LMSC presses on to the jounce bumper striker cap in the same assembly station where the striker cap is pressed on to the shock tube. (See Figure 9.) Each LMSC also includes an internal steel band for improved retention to the shock absorber top cap.

Abaqus/Explicit was used to determine the shape of the LMSC that would result in maximum energy absorption. Again, a cyclosymmetric 2-D model was used. The TPU and urethane foam jounce bumper were modeled as hyperelastic materials. The shape of the LMSC was iterated until the desired energy absorption was achieved. (See Figure 10 for model content.) Analysis was performed as a dynamic drop test to closely simulate the impact of a bump or pothole.



Typically, striker cap (rose) contacts jounce bumper (green)

Add the LMSC (orange), to act as another spring to absorb energy

This shows how the LMSC and jounce bumper fit inside the mount & dust tube

Figure 9. Cadillac CTS-*V* front suspension LMSC/shock absorber assembly

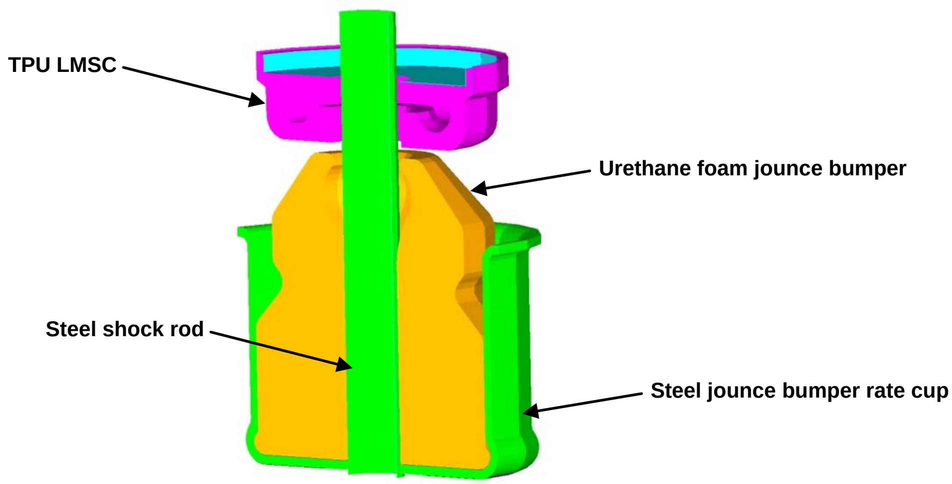


Figure 10. LMSC + jounce bumper model

Figure 11 shows the analysis results. There is 4 to 5 mm less free travel in the LMSC configuration compared to the baseline. However, the rate build up with the LMSC + jounce bumper is more progressive, and the end of travel is less harsh. Both of these behaviors result in a higher level of energy absorption for the LMSC + jounce bumper as compared to the jounce bumper alone. Overall, the LMSC + jounce bumper absorbs 74% more energy than the jounce bumper alone. (These analysis results were duplicated in physical testing of prototype parts.)

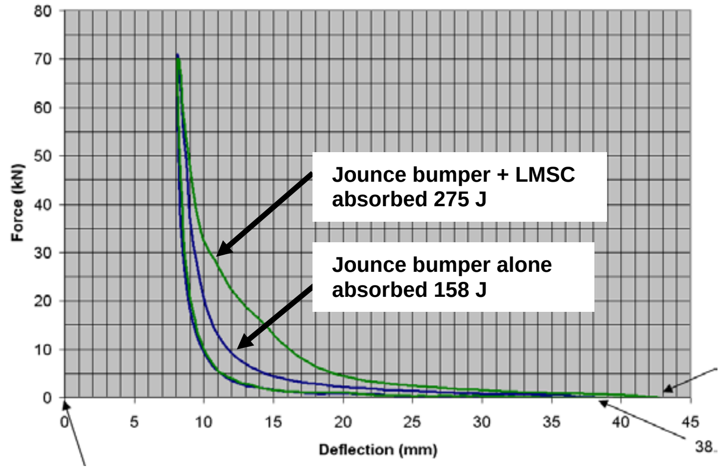


Figure 11. Analysis results; LMSC + jounce bumper vs. jounce bumper alone

Next, the effect of the LMSC was included in full-vehicle ADAMS road load data predictions. Figure 12 shows these results. Inclusion of the LMSC resulted in a 14% peak shock tower load reduction in the front suspension, and a 12% peak shock tower load reduction in the rear suspension. These reductions were sufficient that no other body or chassis structural design modifications were necessary for the CTS-*V* compared to the base CTS.

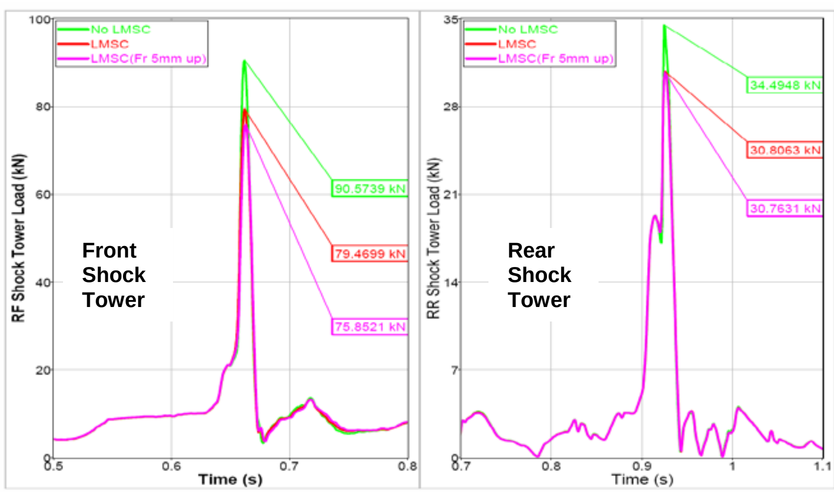


Figure 12. Cadillac CTS-*V* front & rear suspension peak shock tower loads

References

1. Patil, R. & Geisler, R. "Jounce Bumper Design using ABAQUS/Explicit", presented at the 2006 Great lakes Abaqus RUM, November 2006.