Vehicle Seat Bottom Cushion Clip Force Study for FMVSS No. 207 Requirements

Jaehyuk Jang
CAE Body Structure Systems
General Motors

GENERAL MOTORS

Abstract

Federal Motor Vehicle Safety Standard (FMVSS) No. 207, "Seating Systems," establishes requirements for seats, their attachment assemblies, and their installation, to support robust design for seat attachment to Body under vehicle impact. General Motors has been continuously improving the CAE procedure for this Safety Standard. This presentation introduces a CAE simulation method that was specifically developed to accurately simulate a deformational behavior of the plastic clip that is installed at seat bottom cushion attachments to the vehicle floor.

*The focus of this study was on how to precisely predict the separation point in load, if it occurs, so that the design of the attachment can be updated to ensure the success of the respective test. This paper discusses a customized model setup for the clip removal force measurement using *DATABASE_JNTFORC with separation criteria at the latch that successfully enables the model results to match the empirical force data at separation. In this newly developed method, an interface management between three-dimensional seat foam and one-dimensional wireframe elements embedded inside the foam without depending on rigid links is introduced. This method uses *CONSTRAINED_LAGRANGE_IN_SOLID keyword that is primarily intended for modeling Fluid-Structure Interaction (FSI).*

Its CAE simulation process flow from benchmarking up to a proof run to demonstrate a correlation to its empirical data is also introduced.

Introduction

Standard No. 207 establishes requirements for seats, attachment assemblies, and installation, to minimize the possibility of structural issues as a result of forces acting on the seat in vehicle impact

Standard No. 210 establishes requirements for seat belt assembly anchorages to ensure proper location for effective occupant restraint and to reduce the likelihood of structural issues. The requirements apply to any component, other than the webbing or straps, involved in transferring seat belt loads to the vehicle structure.

This paper discusses a CAE simulation methodology with process strategy that facilitates accurate analytical prediction in displacements and removal forces of the FMVSS 207 seat bottom cushion clip application that resides at the interface between the vehicle body and seat (Interior) structures. The performance objective of this Clip application is to withstand the FMVSS 207 specified load with appropriate safety margin that is transferred to the seat cushion foam and then to the Clip. The Clip is in the critical load path between the seat structure and body regarding the FMVSS load.

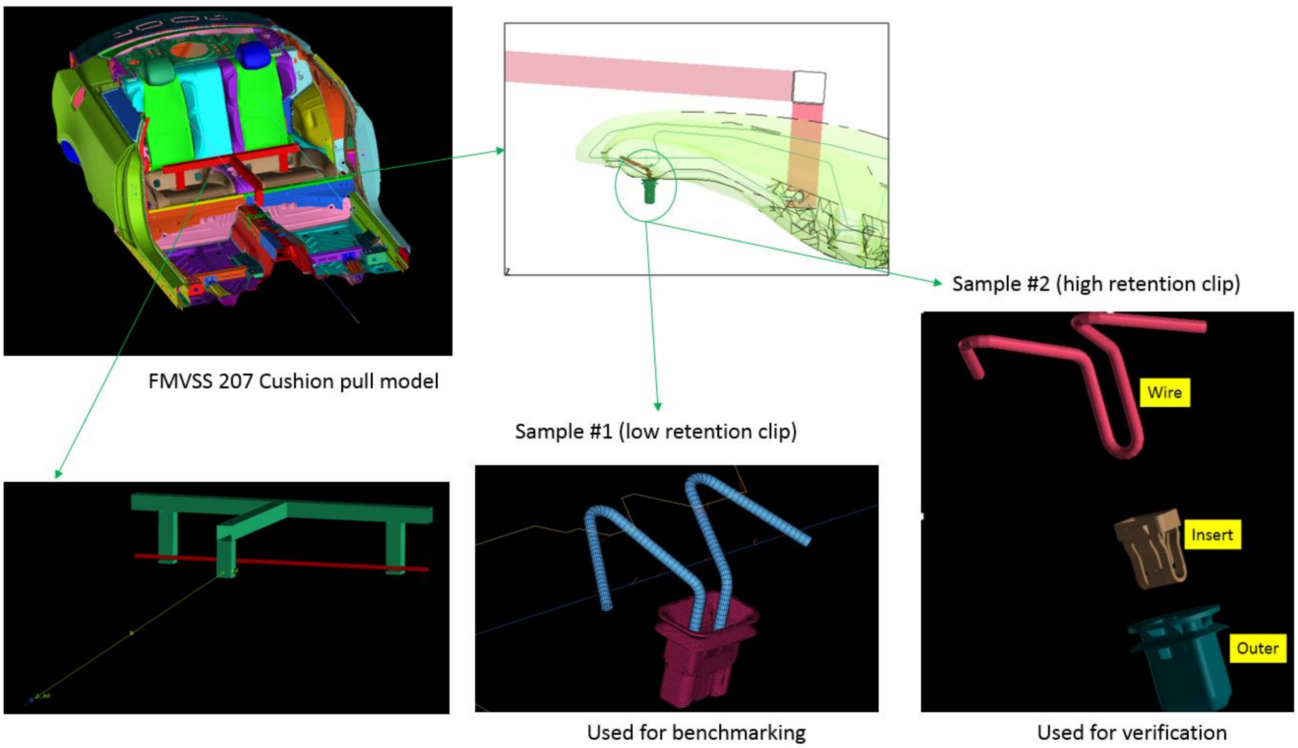

Figure 1

Two sets of test data from FMVSS 207 seat cushion pull tests (vehicle level tests) with two different Clips (Sample #1 and Sample #2) and a set of component level test data from Sample #2 were used to set up the inputs and to validate. The vehicle level test data with Sample #1 was used to establish a benchmark and then the vehicle level test data with Sample #2 was used to validate the established CAE method using the data from Sample #1 component level test data. This proven CAE method was to include the interface management between the seat cushion and parts imbedded in the seat cushion foam using FSI option in LS-DYNA®, modeling technique for Clip removal force measurements, and introduction of the FMVSS 207 Cushion pull device CAE model.

A proper load path establishment was the key to successful duplication of the Clip behavior in the vehicle level test CAE simulation. The following are major elements required to result in a good CAE prediction:

1. FMVSS 207 vehicle level test data with Sample #1
2. Clip model setup with separation criteria and joint force request

3. Interface management between seat cushion foam and parts within (wireframe – 1D beam elements, and test pull rod, 3D solid elements) using FSI option in LS-DYNA®.
4. Clip retention removal force information from the component level test.

CAE Simulation Process of FMVSS 207 Seat Bottom Cushion Pull with Clip Application

A progressive CAE simulation process flow (Figure 2) was developed for the FMVSS 207 Seat Cushion Clip application.

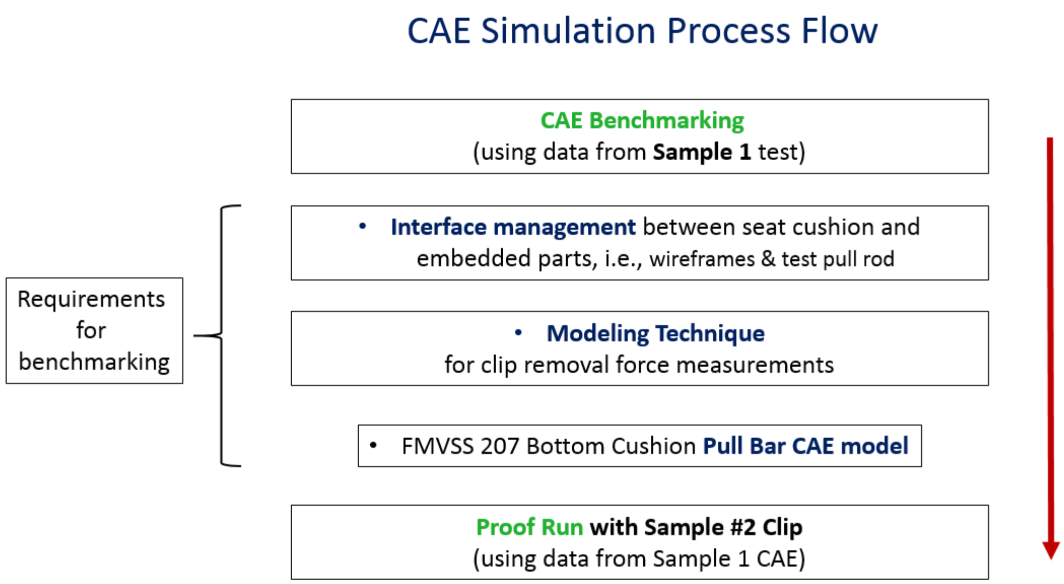

Figure 2

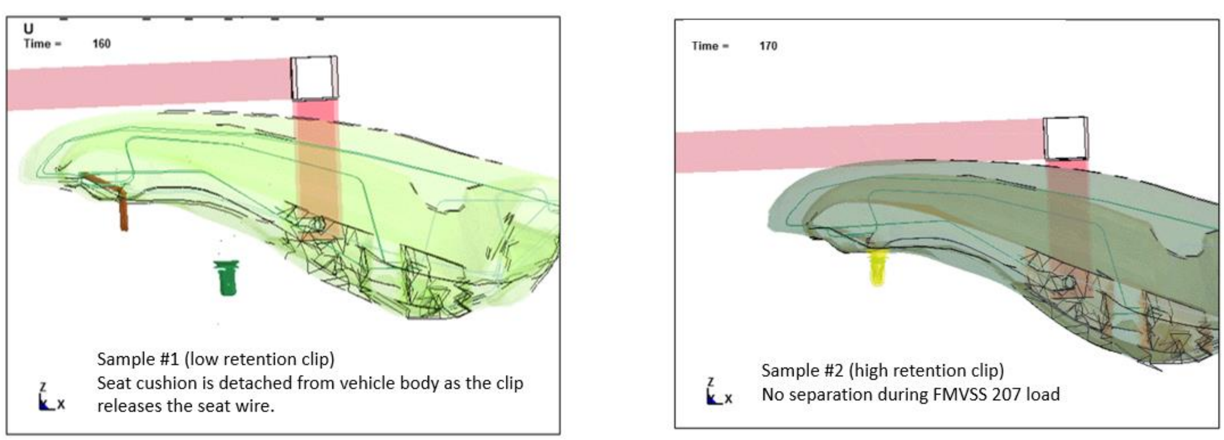

Figure 3 - Performance comparison Sample #1 vs. Sample #2

Interface Management between Seat Cushion Foam and Internal Parts (wireframes & test pull rod)

An FSI option was successfully utilized to properly handle the components inside the seat cushion, even though its application was for an interface between solid parts without fluids included in the model. The wireframe and a steel rod realistically deformed during loading without passing through the soft foam model; one-dimensional wireframe model could have easily passed through without the use of *CONSTRAINED_NODAL_RIGID_BODY (CNRB). The traditional best practice was to use multiple nodal rigid links that would be sporadically located over the wireframe in its entirety. These rigid-links were removed and replaced with a single Arbitrary Lagrangian-Eulerian (ALE) option in LS-DYNA to observe no penetration, while showing a nice and smooth load transfer from the internal parts to the foam. Such an interface management was made possible by using *CONSTRAINED_LAGRANGE_IN_SOLID, that is primarily used to provide the coupling mechanism for modeling FSI. This option was used to impose the interpolation functions that are to apply weighted forces to nodes. The beam type wireframe and the steel pull rod models (3D) fall into slave or Lagrangian structure and seat cushion foams are treated as ALE or master elements. Even though the seat foam does not have a fluid material embedded to make it an ALE, the slave and master can interact using the above mentioned option card for a good retention forces prediction for the FMVSS 207 specified load in the time domain. The above described traditional way of constraining the wireframe into the foam will overly rigidify the foam, which can easily lead to much stiffer responses than reality.

Figure 3 illustrates the parts embedded inside of the cushion staying there within and being able to receive the load from the foam in a realistic fashion.

In the card *CONSTRAINED_LAGRANGE_IN_SOLID, a different option than the usual CTYPE was specified to constrain the acceleration and velocity. This condition of the card causes MCOUP option to be deactivated so that only the Lagrangian portion of the ALE can be treated, while the Eulerian portion is left out. This is a major difference from the typical ALE option in the same keyword option card. With this setting, the beam element (wireframes) and solid elements (steel pull rod and solid portion of wire at latch) were coupled to the solid elements (seat cushion foam). Such a fine-tuning of the usual setting of the card enabled the code to properly constrain the parts at the interface and the nodes in contact inside of the seat cushion foam, without having to reply on the multiple rigid-links.

Figure 4 is to show the wireframe before and after the updates with the ALE option applied to the seat cushion and all parts within. An optimized settings for *CONSTRAINED_LAGRANGE_IN_SOLID card also introduced in Figure 4.

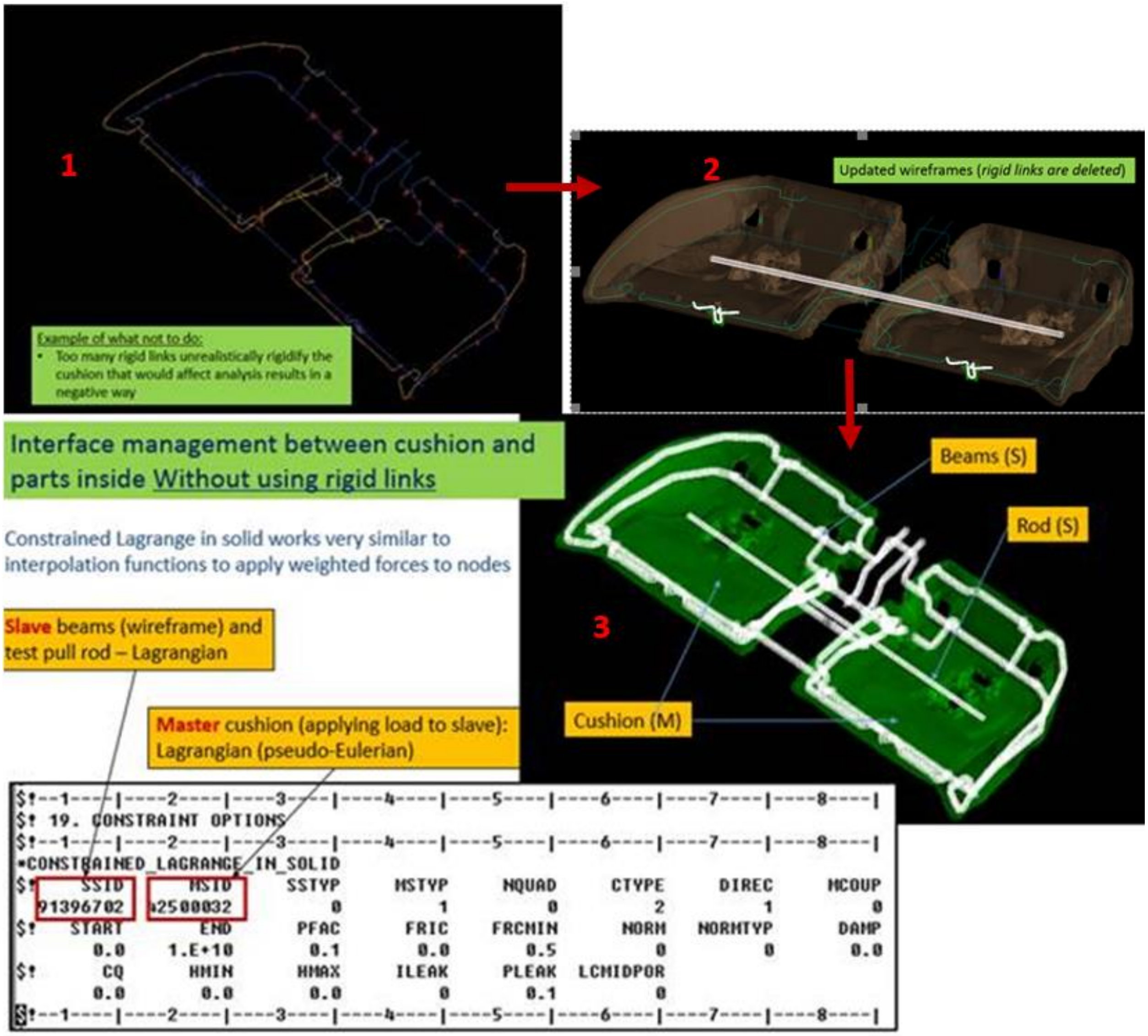

Figure 4

Modeling Technique for Clip Removal Measurement

Another major contributor to the correlation is the solid wire modeling technique implemented at the clip interface for accurate clip removal force measurement. A diagram shown in Figure 5 is a blueprint for the actual CAE model setup. It shows a multi-nodes rigid link, partial vehicle floor sheet metal, solid wire at latch extended from the seat cushion wireframe, a spherical joint with the separation criterion, and a rigid beam that connects the solid wire to the clip at the latch. A multi-nodes CNRB was used to retain the installed clip model in the design slot of the vehicle floor. This method was found to accurately duplicate the Clip behavior and the removal forces.

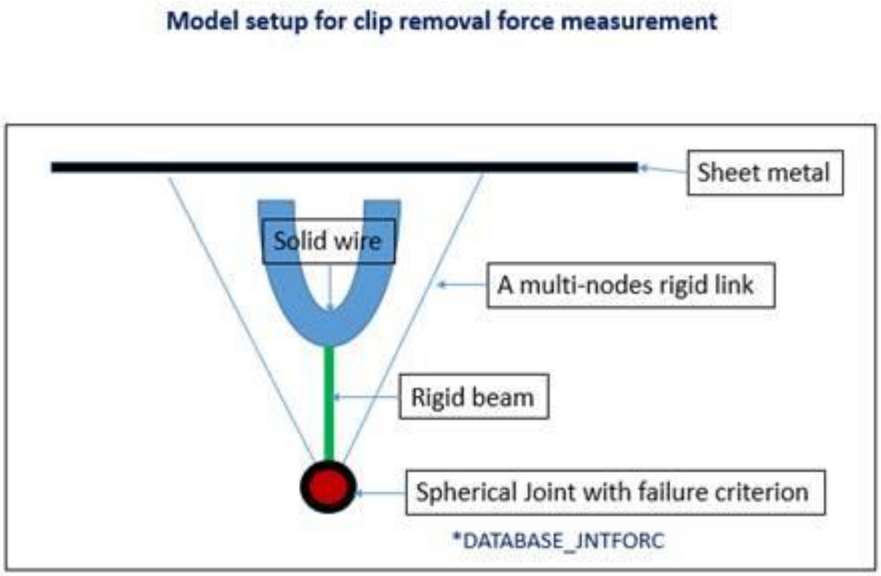

Figure 5

The following are recommended steps to take for a modeling approach in the area of the Clip:

1. Create a node directly below the center of the solid wire.
2. Using the plan view, draw a circle close to the slot of the vehicle floor with respect to the center of the circle using the node that is created in the above step.
3. Select nodes on the vehicle body parts in the vicinity of circumference of the circle.
4. Establish a multi-nodes CNRB using the selected nodes and the node in the Step 1 as an independent node.
5. Create a rigid beam between the center of the multi-nodes CNRB and the center of the solid wire.
6. Create a spherical joint feature with a separation criterion at the juncture between the multi-nodes CNRB center and the rigid beam.

Figure 5 illustrates a simple diagram to explain the content and Figure 6 shows all modeling details using images of the actual model in the plan and side views.

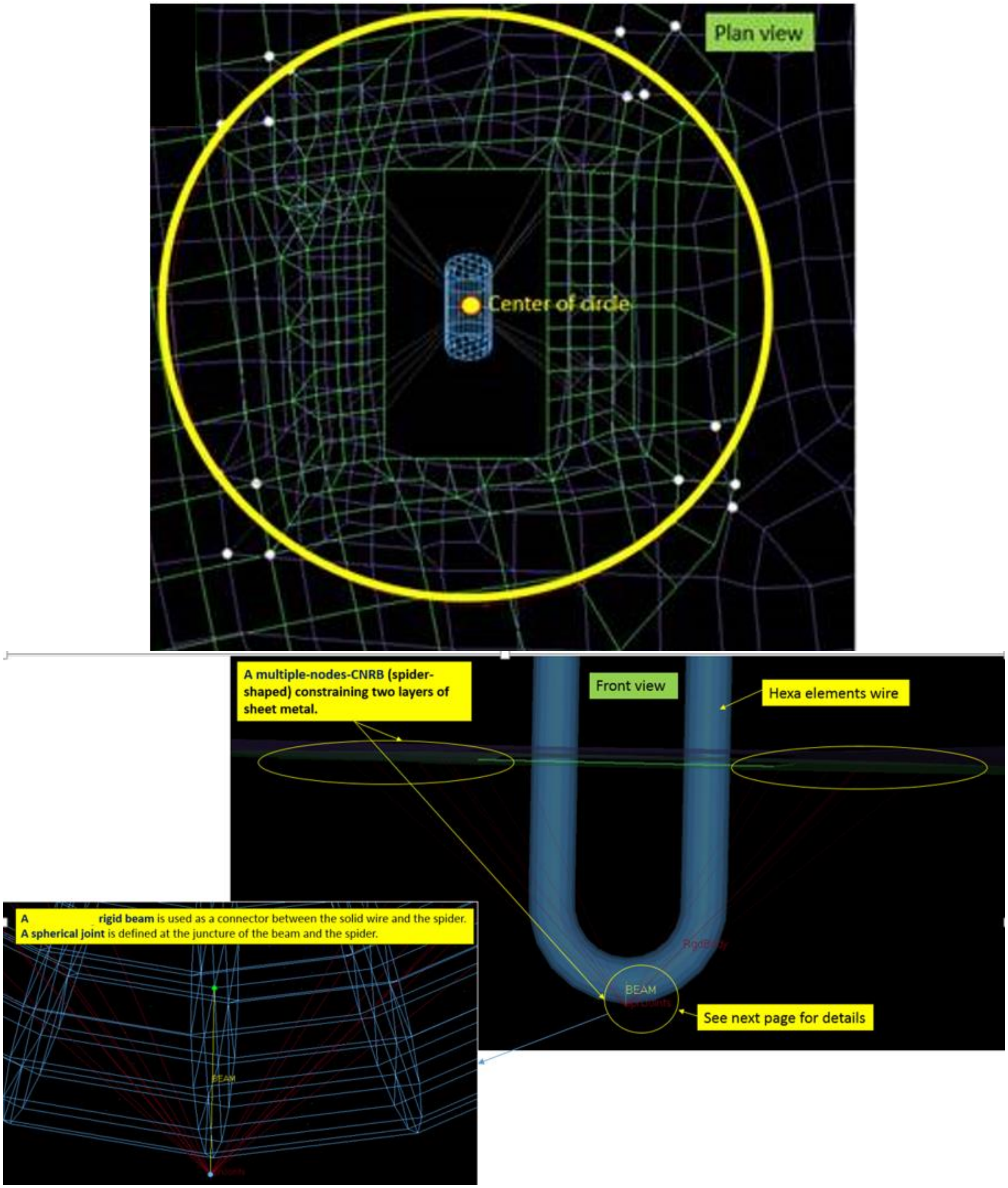

Figure 6

Source of Clip Retention Force Determination

Clip removal forces were measured from a supplier's lab test and the data was populated in the table shown in Figure 7. The data for Sample #1 (low retention clip) and GM design database were utilized to determine the removal force targets of Sample #1 and Sample #2. In an attempt to quantify the reasonable target values, each of 3rd pull data from a total of 5 testing clips was selected and averaged to yield a reasonable target. A force of 450 N for Sample #1 and a force of 550 N (test average: 551.6 N) for Sample #2 were used in the vehicle level CAE models to simulate the respective tests. This component level test was used to measure pull-out forces in multiple sets for repetitive push-in and pull-out cycles using the same part for each test.

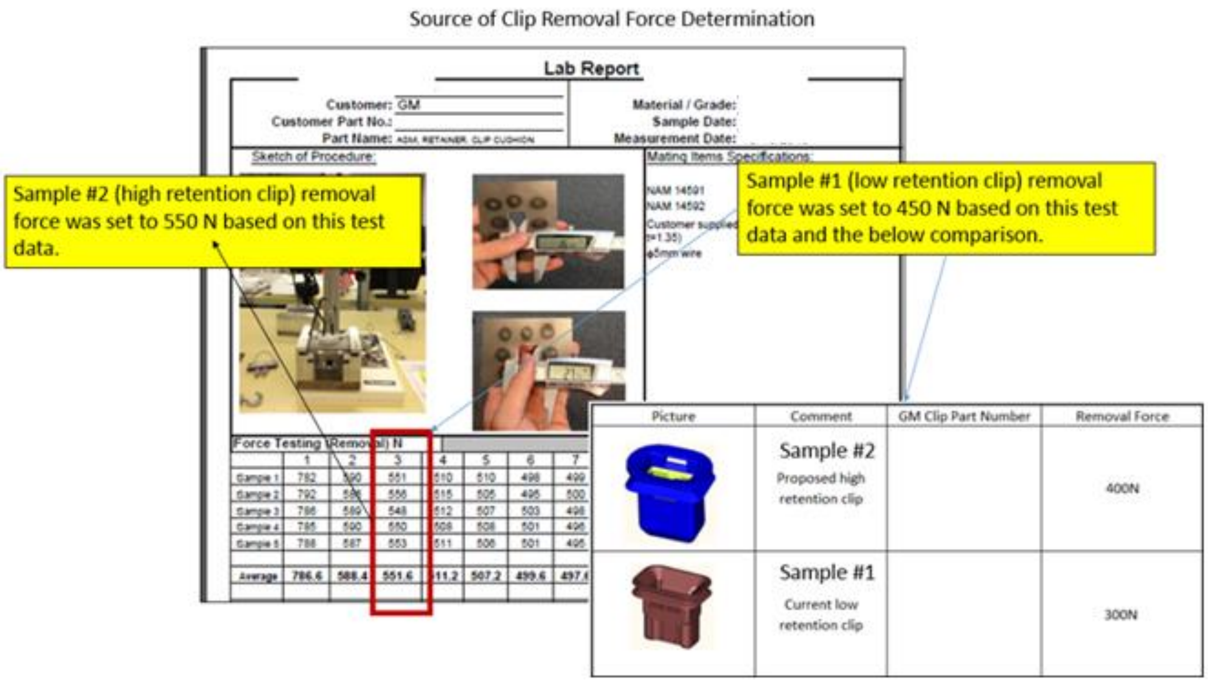

Figure 7

A model technique introduced in Figures 5 and 6 include a rigid beam element associated with a spherical joint feature. This particular feature addition was critical to properly represent the design for an accurate simulation of the load transfer starting from the FMVSS 207 pull cable to the seat cushion foam and, finally, to the vehicle body floor. The correlation facts as shown in Figure 8 confirm the accuracy of the CAE method introduced in this paper.

A local contact *CONTACT_AUTOMATIC_GENERAL was used to define to the parts in the neighborhood of the Clip.

Correlation Facts

As shown in Figure 8, in the first vehicle level test with Sample #1, the clip released the wire at a pull load of 1.22 kN. A removal force of 450 N (for Sample #1) which was derived from the Sample #2 component test, then, was used as a removal force criterion for the vehicle level test with the same Sample #1 Clip. A vehicle level Sample #1 CAE model was set up based upon the results collected from the above described test and run to observe a separation at the load of 1.21 kN (the test vs. its simulation discrepancy rate is less than 1%).

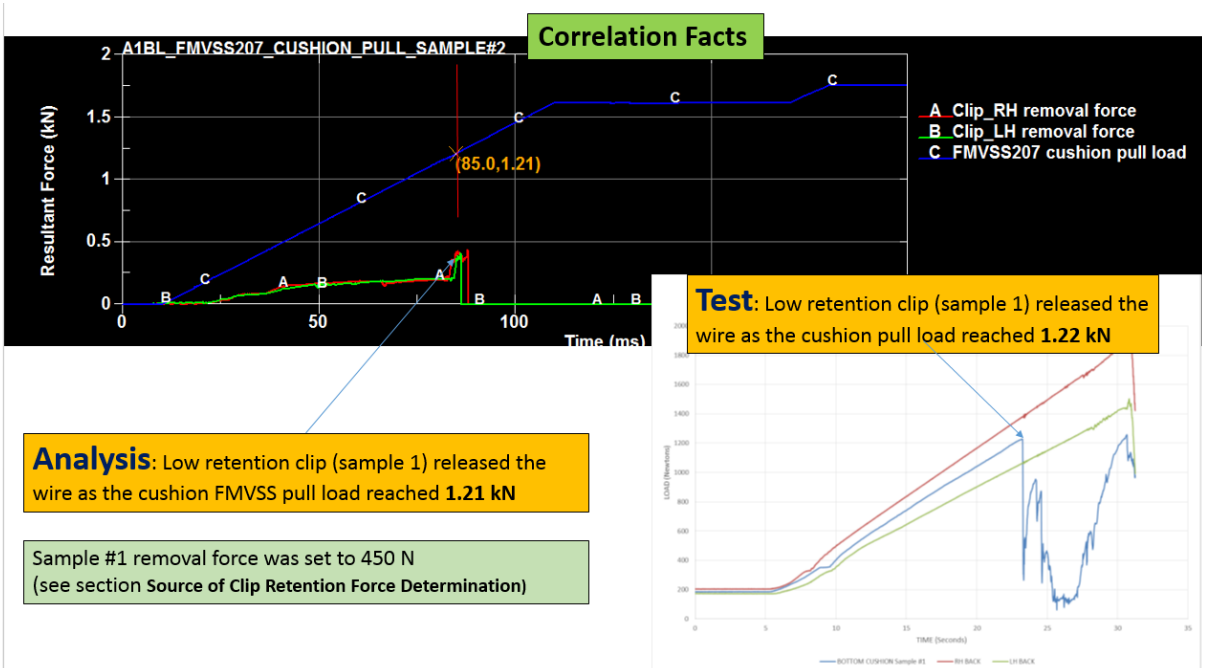

Figure 8

Proof Run

As the next step of the CAE approach, the second vehicle level test model with Sample #2 Clip was run and observed a successful hold for its entire loading, as was the case with its test. This positive CAE correlation to its test proves the method developed by data acquisition as described above is valid (Figures 3 and 8).

In this second vehicle level test, the removal force of the Sample #2 was set to 550 N based on the data available from the component level tests (Figure 7).

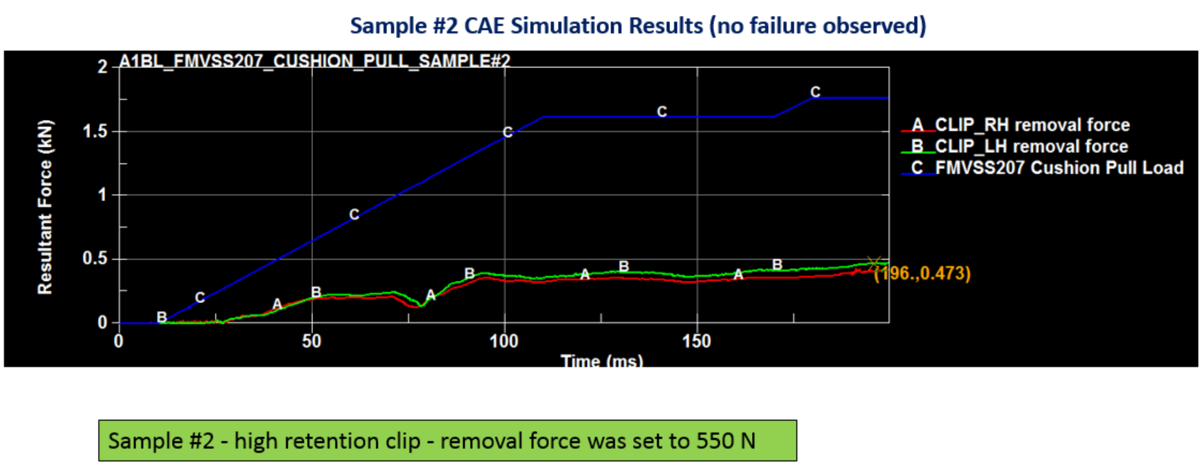

Figure 9

Conclusion/Discussion

A CAE method of the Seat Cushion Clip behavior simulation for the FMVSS 207 load was successfully developed by employing a modeling technique for Clip retention force prediction, including*DATABASE_JNTFORC request and an ALE/FSI option applied at the interface between the foam material and solid and beam parts embedded inside. Such a method discussed in this paper was shared globally inside GM with affected CAE areas and seat suppliers to establish a smooth and reliable CAE process between departments for an effective vehicle body and seat design development.

This method reinforced the ability for the CAE to lead the design by increasing the simulation capability to represent the link between the seat structure and body that is a continued challenge, especially with the amount of different bodies and seat structures used by all OEMs.

It is considered a CAE achievement to witness a 99% correlation between analysis and its empirical data.

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