Aspects of Simulation of Automobile Seating Using LS-Dyna 3D

Peter Williamson

P+Z Engineering GmbH
TVS A2.112-122
Am Grauen Stein
51105 Köln

Summary:

The simulation of automotive seating continues to reduce prototype turnaround times and the cost involved with unnecessary prototype testing. With the increasing complexity of seat design, driven mainly by OEM requirements and consumer wishes, modeling techniques and methods are also being challenged to improve the ability to make quick and accurate judgements on the kinematic behavior and stability of the seat structure. Complex systems such as rails, latches, retractors, seat foam, removable-seats-systems or belt pretensioners rely on complex loading and unloading functions and or robust contact formulations to ensure stability during the simulation.

This paper will investigate a problem for which, during testing and simulation, notable interaction was seen between the seatbelt and the upper backrest of seat structure. In order to analyse this interaction a 2-D model of the shoulder belt complete with shell elements and a simple D-Ring model was constructed. This approach along with an alternative configuration will be touched upon.

This paper also aims to show some of the options LS-Dyna uses to keep the simulation of the seat structure, including loading devices, stable for which extreme loading and large deformation will be prevalent. The elements and models used i.e. dummy, seat and restraint system will be outlined. A short description of the pre- and post- processors used has been included. Methods used and developed by P+Z Engineering used in seat positioning will also be shown.

Keywords:

D-Ring, Dummy, Seat, Pre-stressed Foam.

1 Introduction

The behaviour of the seat structure in an automobile accident has a direct effect on the way luggage and occupants are restrained. The seat behaviour is affected by the size and weight of both occupants and luggage along with the external loading on the body of the vehicle itself. Brought about by the transferral of the occupant and luggage loads through the seat, the deformation, rotational and translational characteristics of the seat are, in turn, directly related to the way the floor of the BIW structure behaves. Both movement and structural deformation of the seat itself will have a direct effect on the way both occupants and luggage are restrained.

These facts present a system in which different modules, in this case seat, BIW structure and loading device, each play a significant role in the judgement of the way a modern automobile seat structure behaves under loading occurring during a vehicle crash. For this reason extensive knowledge is required in the specialisation of FE simulation, automobile seat structure analysis and the “ins and outs” of a powerful FE solver. LS-Dyna has proven itself as a solver capable of representing and in turn solving a realm of problems engineers are confronted with when analysing seat structures.

1.1 The Problem

Typically for an analysis in which a dummy is used as the loading device it is often preferred that the shoulder belt be modelled using 2-D elements. This method has the advantage of distributing the contact forces more evenly over the chest and avoiding problems which may occur as a result of extreme concentration of the contact forces over a small area. Seatbelt elements are then used at the ends of the ends to the 2-D sections in order to allow the use of the ***SEATBELT_SLIPRING** elements at the buckle and pillar attachment points, figure 1.0.

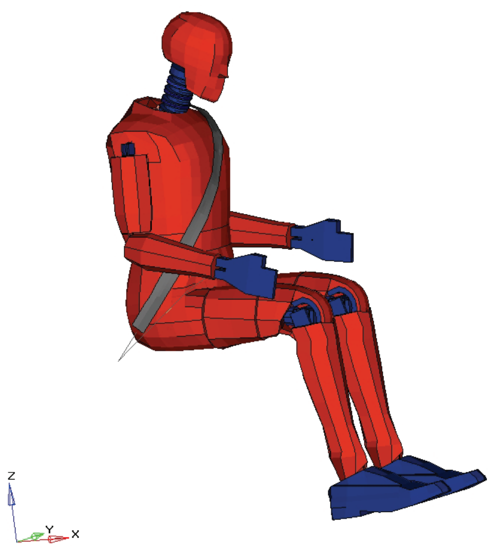

Figure 1.0: Hybrid III 95% Deformable Loading Device Dummy

As stated in the summary, the structure of the seat had taken a load such that the deformation of the vehicle BIW floor structure and the seat kinematics allowed the seat to move closer to the pillar connection point. This type of un-symmetric deformation of the structure was a result of the force transfer through the restraint anchorage point and the dummy interaction with the seat. One side was connected to the seat through the belt buckle and on the other directly connected to the body floor. It was clearly seen during testing that the belt exerted enough force through contact on the upper outside edge of the seat backrest structure. This interaction with the seat structure resulted in a differences between dummy behaviour during testing and simulation along with an inability to draw accurate results regarding the loading which the BIW floor structure had undergone.

1.2 Possible Solutions

Initially a 2-D belt structure combined with a finely meshed D-Ring assembly was to be modelled in order to accurately build up the contact forces exerted between the seat's upper backrest and the belt itself. Although such modelling and analysis, as seen in [2], would have most likely been possible, it was chosen due to timing considerations, to exploit the **LTIME** "slip ring locking time" option of the ***ELEMENT_SEATBELT_SLIPRING**. When the LTIME is reached no more seat belt elements are allowed to travel through the seat belt element. Using this option required placing the exact length of 1-D seatbelt elements between the end of the 2-D portion of the upper shoulder belt and the slip ring element to achieve the correct tension in the shoulder belt without running out of 1-D seatbelt elements during tightening. An initial run was conducted to establish the required locking time for the slip ring. The locking time was applied and as expected the portion of the upper shoulder belt was locked just before its end. It should be noted that using this configuration the belt force limiter was omitted.

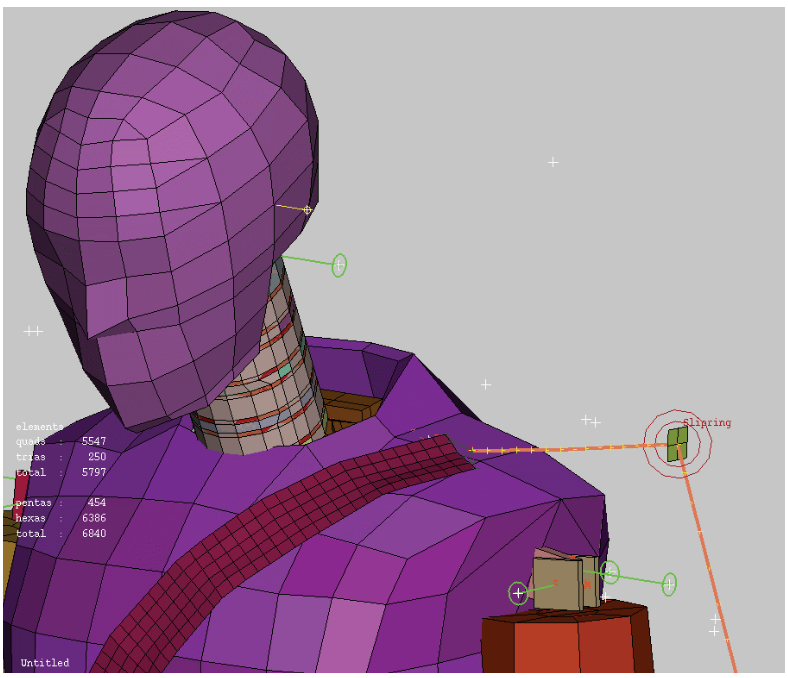

Figure 1.1 – Attachment of the restraint system to the B-Pillar

2 Behaviour of the Dummy Loading Device

Dummy behaviour is primarily affected by the way the belt and the seat interact with the dummy combined with the external boundary conditions. To ensure correct interaction between the loading dummy and the seat structure the dummy must be positioned and fastened correctly so that the dummy reaches the H-Point. To achieve this position the belt should not have too much slack nor should the dummy be sitting to far from the desired position.

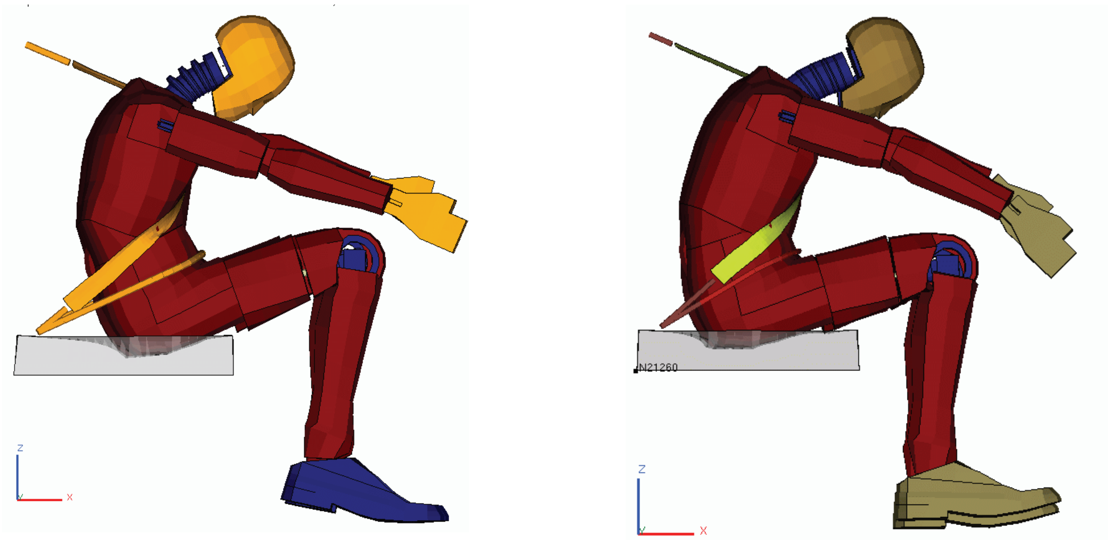

Figure 1.2: Comparison between dummy loading device behaviour with and without pre-positioning.

As seen in figure 1.2 the maximum forward displacement is reduced. The dummy shown on the right hand side, is being restrained on the H-Point using a tighter belt. On the left hand side it can be seen that the pelvis rotation and forward displacement has increased. An increase in the maximum belt force can also be seen due the delayed sudden take up of the belt slack.

3 Summary of LS-Dyna Features Utilised

3.1 Pre-Compressed Foam

Using foam in the cushion of the seat model provides a much more realistic stress distribution over the seat structure during loading using a dummy device. A better representation of the forces applied to the seat through the belt and the impact of the dummy on the seat itself is achieved using this approach.

Compressing the seat foam is a necessity if the dummy is to be positioned correctly. If a pre-compressed foam is used, the chance of encountering negative volumes with the seat cushion is increased. For this reason stress initialisation is required in the cushion at the start of the analysis.

LS–Dyna provides option with which the stresses can be initialised for the foam in it's compressed state using the material model ***MAT_LOW_DENSITY_FOAM**. Instead of having to include the free fall until the dummy loading device has reached correct position within the seat foam, a predefined pre-stressed foam structure can be, with relative ease, included into the model. The dummy is then able to be placed over the required H-Point of the seat.

A smaller model, due to it's size is used for purposes of presentation see figure 3.0. If the cushion's elements, property and material IDs were held within a predefined range and the foam included as a separate include file, a subsequent saving in time can be achieved.

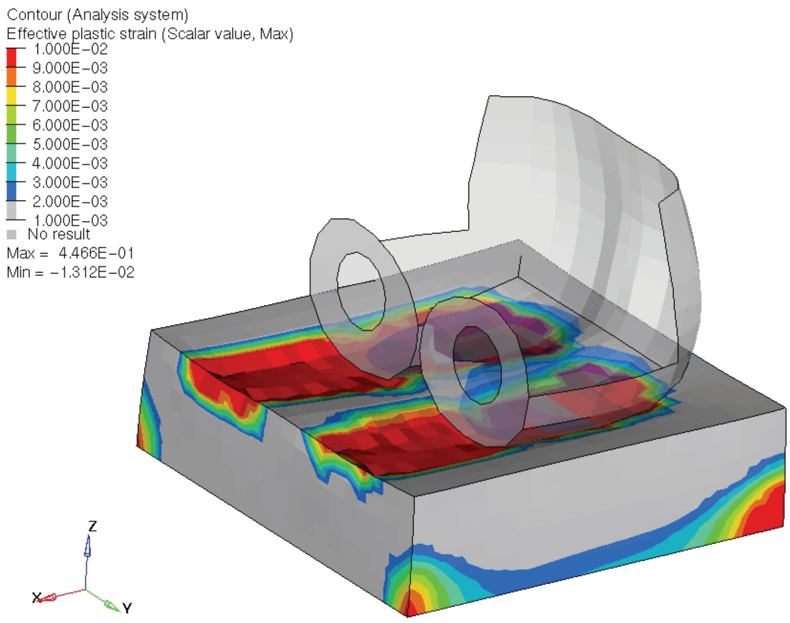

Figure 3.0: Stress initialisation in the seat cushion using LS-Dyna.

Using this option the correct centre of gravity of the dummy loading device is found thus enabling a more realistic contact force distribution to the seat structure through the correct kinematic behaviour of the dummy.

3.2 Contact Definitions

LS-Dyna has several features to ensure clean and stable behaviour of the contact definitions during high loading between contact surfaces. Both dissimilar mesh discretisation and differences in material stiffness of orders of magnitude between master and slave can be accounted for. As has already been seen seat models consist not only of steel components but several other materials such as rubber, foam or other synthetic materials for use within the dummy loading devices, seat cushion and belt. These contact options should be exploited for the analysis to ensure stability and restraint of the dummy loading device.

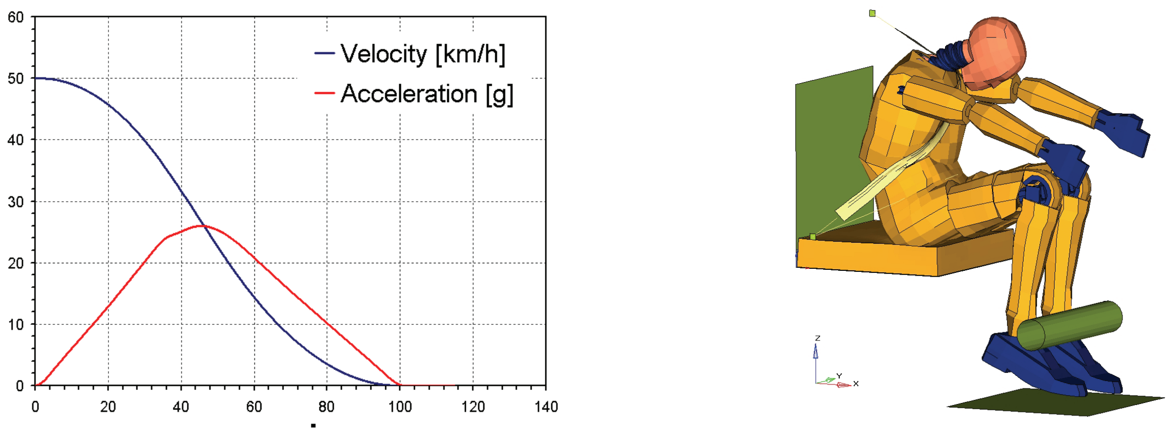

Figure 3.1: HyGee 25g Forward Impact Pulse

3.3 Belt Material

An accurate and validated belt material is of great importance to ensure the correct strain is achieved during loading. Forward movement of the dummy is greatly effected by this component of the model. With the use of the material ***MAT_FABRIC** (*MAT_34) the transverse shear deformation can be defined. This material model also utilises a flag with which the possibility of compressive stress are eliminated if need be.

3.4 Availability of Hybrid III Loading Device Models

Most likely due to the history, capabilities and popularity of LS-Dyna free dummies are obtainable through distributors. These dummies are delivered usually with the **.tree** hierarchical information required for correct positioning. All parts of the body arms, legs, hands feet etc. can be positioned using one of several modern pre-processors.

3.4.1 Dummy Positioning

Most modern pre processors have now included modules to facilitate positioning of most frequently used dummies. As long as enough information is supplied so that the pre-processor understands the hierarchy the dummies can be pre-positioned with great ease.

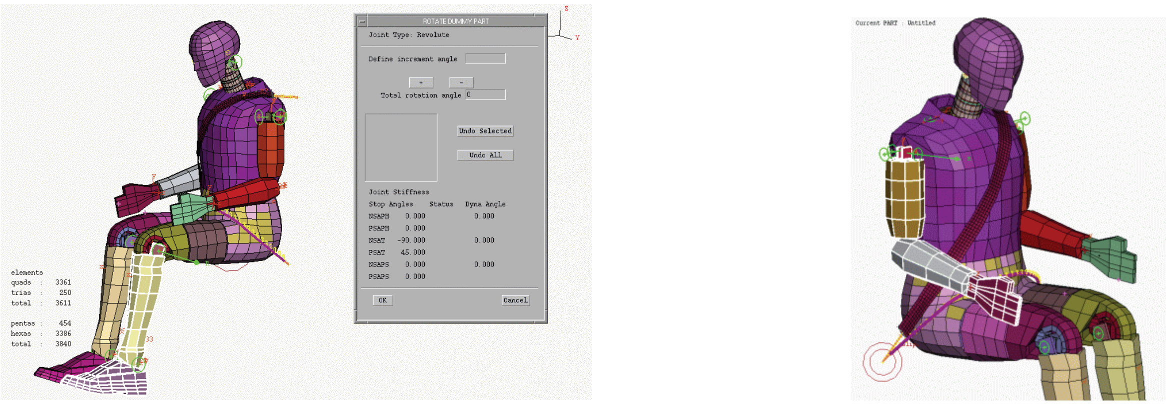

Figure 3.2: Positioning the dummy using ANSA 12.01

3.5 *ELEMENT_SEATBELT_RETRACTOR

A simple retractor configuration can be used to facilitate tightening of the belt during both positioning of the dummy and, when combined with the pretensioner element, initial stages of a vehicle crash. Using the type the correct pretensioner configuration with the retractor element an additional belt force limiter may also be included to reduce the loading on the dummy and provide more realistic behaviour between dummy and seat. These configurations require corresponding loading and unloading curves for correct treatment of the seat belt elements and the application of belt forces.

3.6 New Additions to LS-Dyna 970 Useful for Seat Simulation

Some of the new features released in LS-Dyna are listed below:

Penetration warnings for the contact option, for the option, ignore initial penetration are added as an option. Previously no penetration warnings were written when this contact option was activated. This can be very helpful during the initial stages of modelling.

For the arbitrary spot weld option, the spot welded nodes and their segments are optionaly written to the d3hsp file. See *CONTROL_CONTACT.

For the arbitrary spot weld option, if a spot weld cannot be found for the spot welded node, an option now exists to terminate with error. This is an important check as to assess whether the spot weld have been defined correctly.

4 Using Include Functionality for Model Manipulation

To improve passenger comfort and safety or provide extra space for carriage of equipment automotive seating must be functional in its design to facilitate adjustment when required. Depending on the load case, type of analysis, or passenger size, the seat structure must be tested in pre-specified positions. With some good planning and the correct software complicated pre-processor repositioning is not required.

Using the include method the transform option in LS-Dyna provides a quick and flexible way to read independent files containing model data. The kinematics of the model is modelled exactly so that the complete mechanical behaviour can be exploited. This provides realistic representation of the structural behaviour and easier adjustment of the seat model. Combining the include option with a defined transformation option, modules can be included and repositioned as required without having to read the model into a pre-processor and repositioning the nodes. Transformation sets must therefore be defined and included correctly. A procedure using this approach has been in place at P+Z Engineering for some time now.

5 Pre and Post Software used

5.1 HyperWorks

The HyperWorks (figure 5.0) Suite from Altair Engineering is well equipped to handle finite element models created for LS-Dyna. From complete model generation to post-processing this powerful suite provides the modules and resources required for the analysis of crash and durability of automotive seating.

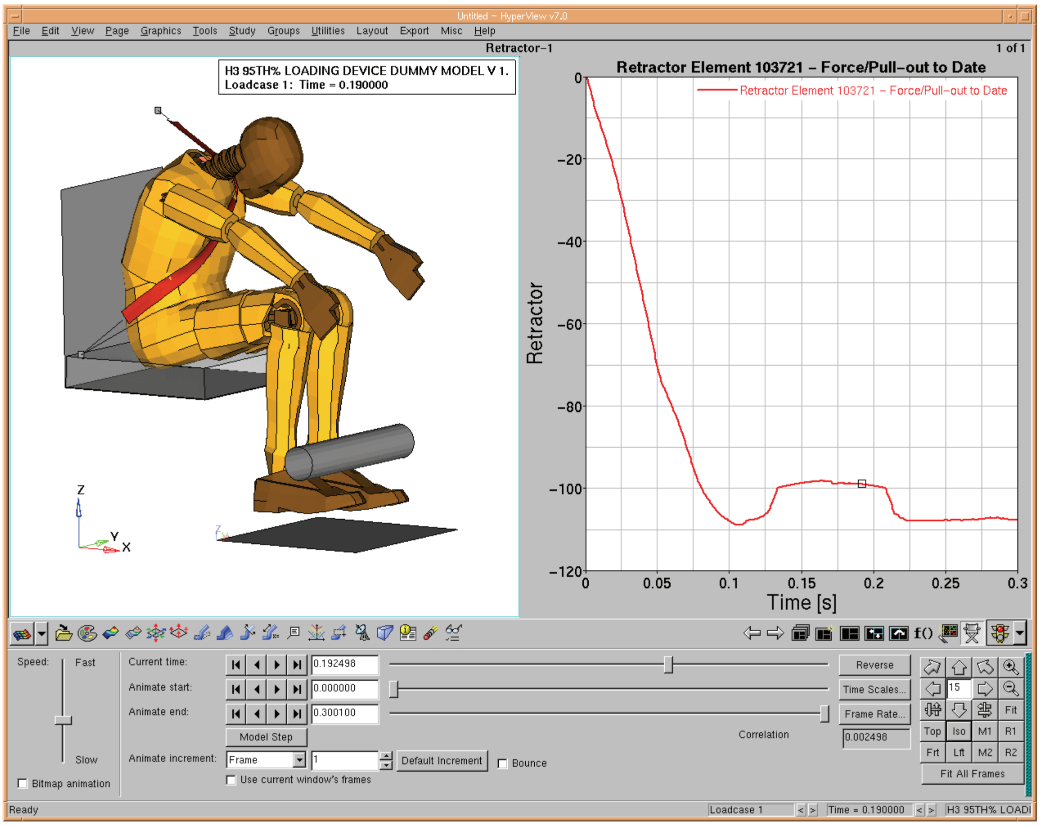

Figure 5.0: Post-Processing with HyperView v7.0

6 Conclusion

This paper shows just a few of the features which are commonly used when analysing automotive seat structures with LS-Dyna. As seen one of the most challenging aspects is ensuring that the dummy or loading device interacts with the seat structure correctly. Whether it be the interaction with the restraint system, the behaviour / properties of the restraint system, the modelling of the cushion or seat kinematics, each subsystem plays an important role in ensuring repeatability, stability and accuracy of the results obtained.

The increased complexity of modern automotive seat structures challenge the analyst to ensure all kinematics are correctly modelled and that seat can be repositioned as required so as ensure stability in all working positions. An extensive understanding of FE methods and techniques is a prerequisite in this field of expertise.

P+Z Engineering GmbH possesses many years of the experience coupled with the manpower and resources required for the crash analysis of automobile seating CAE crash analysis.

7 References

[1] LS-Dyna Keyword User's Manual – Nonlinear Dynamic Analysis of Structures – Version 970 – April 2003

[2] Pedrazzi, Elsäßer, Schaub, *Simulation of Belt Movement in a D-Ring During Crash* – 18. CAD-FEM User's Meeting – Internationale Technologietage – September 2000, Friedrichshafen

[3] John O. Hallquist, LS-Dyna, Theoretical Manuel, (Livermore Software Technology Corporation, Livermore, CA, 1998)