# Simulation of proposed FMVSS 202 using LS-DYNA Implicit

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## Abstract

Federal Motor Vehicle Safety Standard 202 applies to automotive seat head restraints, and their attachment assemblies. The regulation is aimed at reducing the frequency and severity of neck injuries due to huge forces resulting from vehicle crashes.

The main objective of this paper is to discuss the LS-DYNA IMPLICIT code vis-à-vis the simulation of the proposed FMVSS 202 regulation. The proposed changes to the FMVSS 202 standard incorporates a permanent set requirement for the head restraints. Since a quasi-static FE simulation cannot do permanent set calculations, LS-DYNA IMPLICIT code was used for this purpose. The paper explains in detail about the setting up of a seat model for the test, the various modeling techniques used and the correlation of results for the seat model.

## Introduction

The emphasis on occupant safety is at an all time high, thanks to the effective enforcement of the FMVSS regulations by NHTSA. The FMVSS regulations have been the backbone of vehicle design in recent years and continue to be. Increased passenger comfort and occupant safety have prompted NHTSA to continuously improve existing regulations. An integral part of that effort is the proposed FMVSS 202 regulation, which has been modified to include some new requirements.

The FMVSS 202 is a safety standard that specifies requirements for the head restraints on the seat system. It is aimed at reducing the severity of whiplash (neck) injuries during rear-end and other collisions. In the proposed version of the regulation, a requirement for the permanent set of the head restraints is introduced. Also, the back form load, which would be released prior to headrest loading in the actual regulation, now has to be maintained through the entire loading sequence.

The conventional FE methods used to simulate FMVSS 202 have to be revised in order to accommodate these changes. As permanent set calculations cannot be performed by an explicit code, the implicit LS-DYNA version was tried out. This paper discusses the effectiveness of the LS-DYNA implicit code in simulating the proposed regulation. A concerted effort has been made to explain the test set up, FEA modeling of the test set-up, comparison of test and FEA results, and the relevant commands used to set up the LS-DYNA implicit model from the existing FEA model.

# Approach

## Physical Test Setup

The actual test setup is as shown in Figure1. The backform and headform represent the torso and head of the occupant respectively. Both the backform and headform are mounted on the same fixture. The fixture is driven by cylinder [A], which applies the backform load, and the headform load is applied through cylinder [B].

## Physical Test Loading Sequence

The seat is preloaded using the backform to 37 Nm, and then loaded to 373 Nm, generated around the H- point. At this load, cylinder [A] is locked so that the backform maintains its current position till the end of the test. Now the headrest is preloaded using the headform, and at this stage the zero reading is set. The headrest is further loaded to 373Nm, generated around the H-point, and the displacement of the headrest is measured at this point. The headrest is then completely unloaded and the displacement of the headrest is measured again. The difference between the two displacement values gives the permanent set. The headrest is then loaded to 890 N to test the structural integrity. The whole loading sequence is shown in tabular format in Table 1.

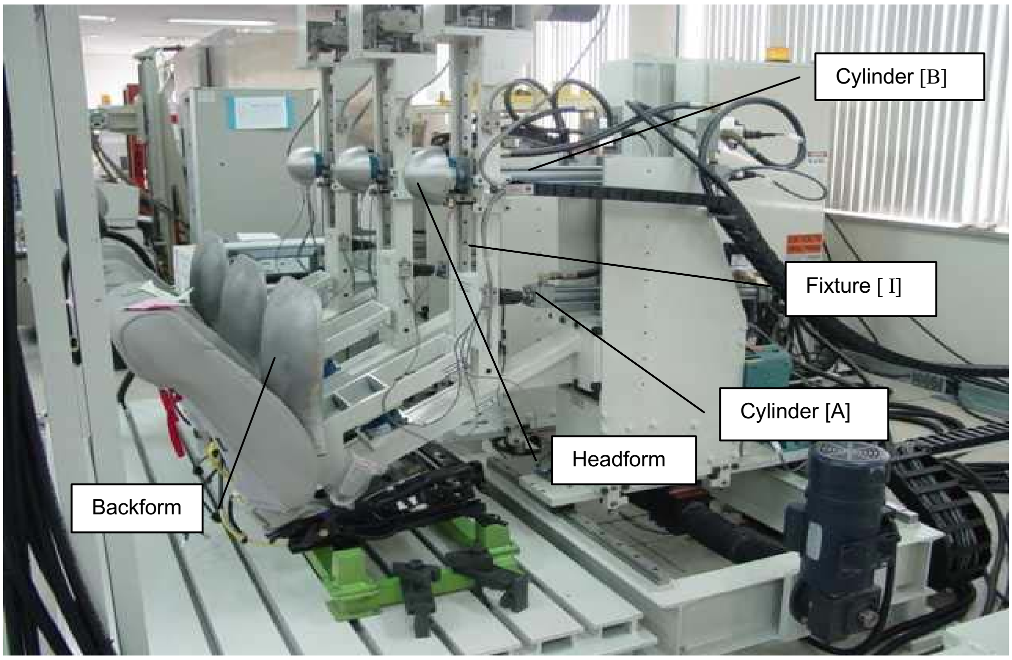



**Figure 1 : Test Setup**

### Loading Sequence for the Proposed FMVSS202

| Load Description | Load | | | Requirements |
|---|---|---|---|---|
| | | Time (sec.) | Load (N-m) | |
| Seat Back Load | Start | 0 | 37.3 | Pre-Load |
| | Intermediate | 120 | 373 | Backform Load |
| | Hold | 360 | 0 | Maintain Fixture Location for the remainder of the test |
| Headrest Load | Start | 0 | 37.3 | Pre-Load |
| | Intermediate | 120 | 373 | Headrest load $\Delta X < 102$ mm at load application point |
| | Hold | 5 | 373 | Hold |
| | Unload | 120 | 0 | Headrest Unload Calculate Set $\leq 10$ mm |
| | Ultimate | 120 | 890 N | Structural Integrity |

**Table 1**

## Finite Element Model Setup

The FE model setup is as shown in Figure 2. It consists of the seat structure and two back forms. The backform is attached with a nonlinear spring, to a small mass. The mass is constrained in all degrees of freedom. Most of the seat structure is made up of metal stampings and tubes, and is modeled using shell elements. Critical latches and strikers are modeled as solid elements[2]. Bolts and rivets that attach the different parts of the seat assembly were modeled using beam elements. Washers at the bolt attachment locations were modeled for accurate stress and strain levels[3].

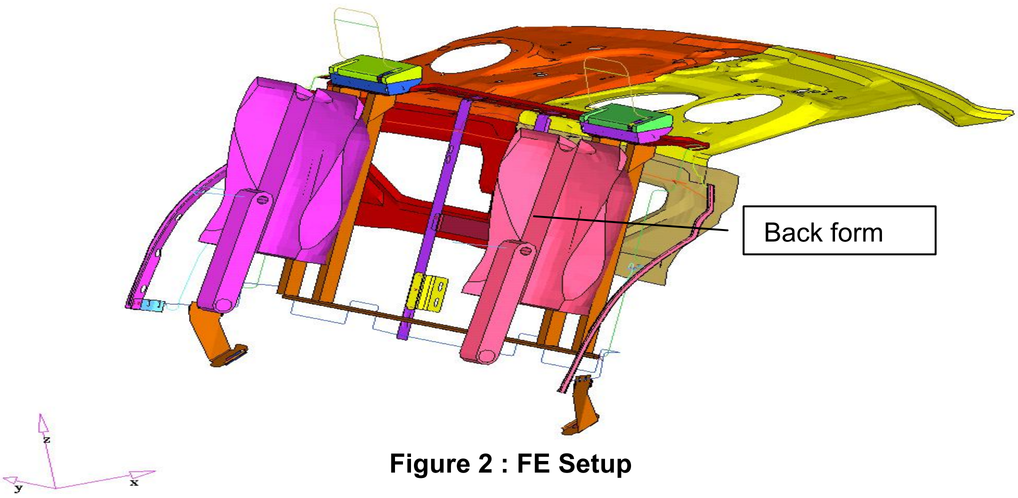



**Figure 2 : FE Setup**

Pivoting action of a bolt or joint was simulated by a regular beam element with a very low value of torsional rigidity. The back forms were modeled using shell elements and rigid material property was assigned to them. The spring attached to the backform is modeled using a nonlinear spring element in LS-DYNA. The properties of the nonlinear spring were modified such that the spring does not compress while it can still handle tensile loads.

The back form is placed parallel to the seatback and then moved very close to the seatback. Basic Surface to Surface or Nodes to Surface contact can be defined between the backform and the structure depending on the geometry of the contacting entities. The headform load is simulated using a point load applied on a rigid , which is connected across the headrest at 65 mm from the top of the headrest, the headrest adjusted at the full up position. The point load was forced to be perpendicular to a plane parallel to the backform.

## FE Loading

The forces on the seatback and the headrest are calculated based on the moment generated about the H-point location.

**a.** The force on the seatback should be applied normal to the seatback, and generate a moment of **373 N-m** about the H-point; the distance of the moment arm is calculated along the **plane of the seatback.**

b. The change in the seatback angle at the end of seatback loading establishes the new reference line **(R)**.

c. The force on the headrest should be calculated the same way as for the seatback. The difference is that the force is now applied normal to the new reference line **(R)**.

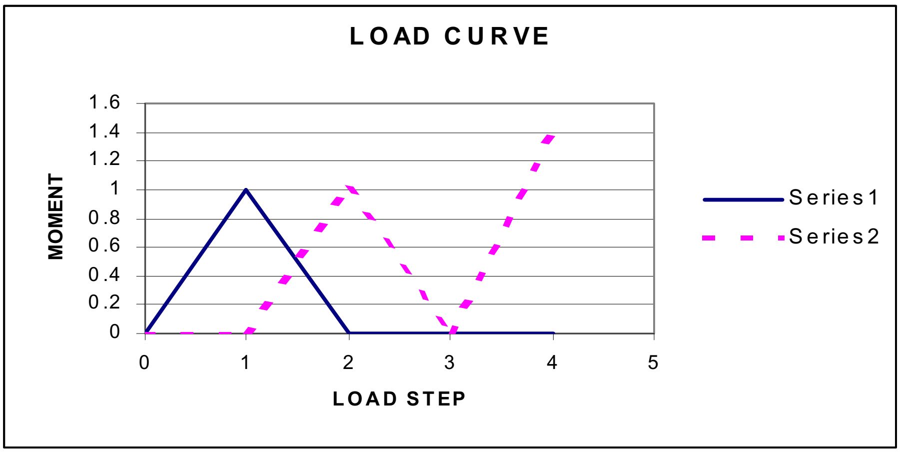
1. Load curve for applying seatback load (Figure 3):

| | | | |
|---|---|---|---|
| **Time (ms)** | **0** | **1** | **2** |
| **Load (Scale Factor)** | **0** | **1** | **0** |

b) Load curve for applying headrest load (Figure 3):

| | | | | | |
|---|---|---|---|---|---|
| **Time (ms)** | **0** | **1** | **2** | **3** | **4** |
| **Load (Scale Factor)** | **0** | **0** | **1** | **0** | **1.4** |

**Figure 3**



2. The **final Headrest displacement (D)** is calculated by measuring displacement at end of step2. This value has to be less than 102mm.

3. The permanent **set** is calculated by taking the difference between the Headrest displacement at the end of step2 and end of step3. This value should be less than 10mm.

## Results Discussion

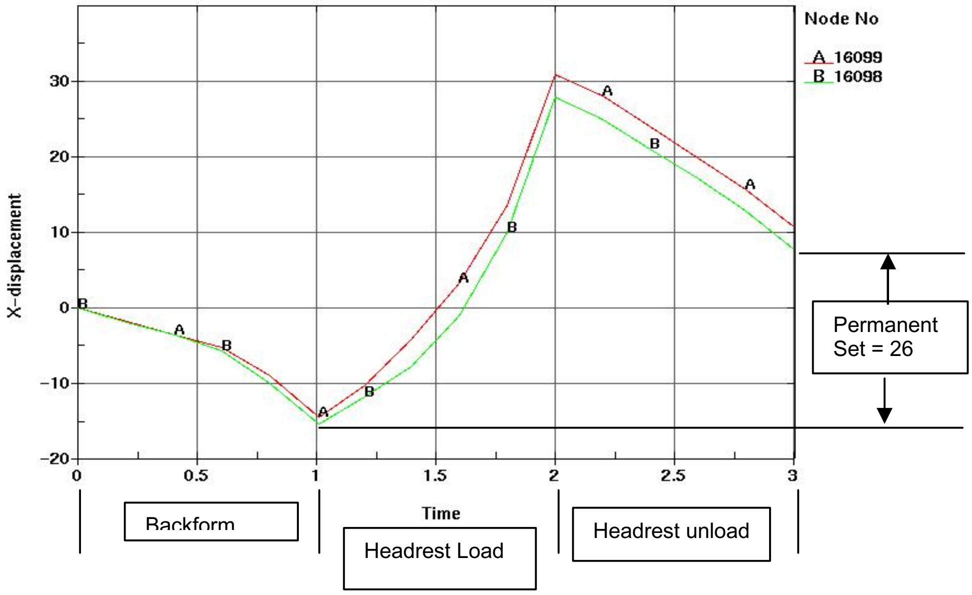



Figure 4: Displacement Plot for Headrest

## Results Matrix

| | Explicit method | Implicit method | Physical Test |
|---|---|---|---|
| Headrest Displacement at 100% load | 55mm | 47mm | 37mm |
| Permanent set | N/A | 26mm | 24mm |

## Conclusions

- The LS-DYNA implicit method can be effectively used to predict the permanent set of seat systems under proposed FMVSS 202 loads.
- The implicit model is easier to set up once you have an existing LS-DYNA model.
- The correlation between the FEA and test displacement values encourages the use of LS-DYNA Implicit code to simulate other static tests like seat back Torsional Rigidity etc. where permanent set is measured.

## Appendix I

**SAMPLE LS-DYNA INPUT CONTROL CARDS**

```
*KEYWORD
*CONTROL_IMPLICIT_AUTO
       1         0         0    0.005      -2002
*CONTROL_IMPLICIT_DYNAMICS
       1       0.6      0.38
*CONTROL_IMPLICIT_GENERAL
       1     0.005         0         0         0         0         0
*CONTROL_IMPLICIT_SOLUTION
       0       100         0       0.0       0.0                 0.0
       0         0         0         1
       0         0       0.0         0         0
```

```
*DEFINE_CURVE
2002,
0,0.1
1,0.1
2,0.1
3,0.1
```

*NOTE

Perform a quick EIGEN value analysis by using the following implicit card.

*CONTROL_IMPLICIT_EIGEN

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The authors would like to thank Lear Corporation for encouraging the use of FEA as a part of the design and development process and allowing the group to experiment with new techniques. This work would have been incomplete without the input and suggestions from the LEAR Test lab and BRAD MAKER, SURI BALA, and JOHN HALLQUIST of LSTC.

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