Simulation of Structural Latches in an Automotive Seat System Using LS-DYNA

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ABSTRACT

Latches play an increasingly vital role in an automotive seat system due to the recent introduction of the mandatory 3-point restraint system for center occupants. Traditionally, latches were designed to carry the seat back load, the head restraint load, and the luggage intrusion load. For the new Seat Integrated Restraint (SIR) systems, latches have to meet a very high load requirement with a very low range of allowable displacement. Hence, a latch has to meet its basic function, which is to fold and tumble, and it has to pass this stringent non-linear loading condition.

Finite Element Analysis (FEA) has been widely used to simulate latches on a component level. With the introduction of the displacement requirement limitation for the SIR retractor, component level analysis is redundant. The paper discusses an efficient new method to simulate the seat system along with latches that yield meaningful results and a consistent level of correlation.

INTRODUCTION

The design of a structural latch for a seat system has become more and more complicated because of the various kinds of loading conditions that it has to pass. This is over and above the fact that a latch needs to fulfill the basic kinematics and still meet the strict packaging constraints for styling and comfort purposes. Latches are designed for rearward loading conditions such as the seat back strength test and head restraint test. The forward loads are generally the inertia load of the seat system during a dynamic test and the luggage retention load when the seat back is impacted by solid blocks. Also, depending on the height and the H-point of the seat system, latches are subjected to ISOFIX loading as per the new FMVSS 225 requirements.

The severest of all the loading conditions is the seat belt anchorage load due to the 3-point restraint system. For vehicles with more than two rows of seats such as Sport Utility Vehicles (SUVs) and minivans, the second row seat system can have various configurations. For a 2-occupant seat system, the retractor for the seat restraint, in most cases, is mounted on the seat pillar and the belts are buckled on to the seat mounting brackets. In case of a 3-occupant seat system, the two out-board occupants will have a similar arrangement. The center occupant generally has a lap-belt-only restraint system attached to the seat brackets that mount on the floor pan. For the 2002 models for European and the 2004 models for the North American markets, 3-point restraint system is a mandatory requirement for the forward facing center seats. In an SIR seat, the restraint for the shoulder belt is mounted on the top of the seat back. The latch, which holds the seat back in its upright position, has to be designed accordingly to hold this huge moment generated by the shoulder belt.

A seat latch generally consists of an arm that attaches to the seat back. This upper arm rotates about the seat system pivot point and folds the seat. The upper arm locks the seat back at the upright position (design position) and at the folded down position. Depending on the kinematics of the seat system, complicated inner mechanisms are used to achieve this. These mechanisms are supported by package plates that attach to the floor mounting brackets.

For the SIR seats, the seat belts are attached to the seat. Hence, it has to comply with the requirements under the FMVSS 207 as well as FMVSS 210[1] loading conditions. These standard apply to seats, their attachment assemblies, and seat belt assembly anchorages and are to ensure their proper location for effective occupant restraint and minimize the possibility of their failure by forces acting on them as a result of vehicle impact. United Nations regulation ECE14[2] restricts the forward displacement of retractors beyond the H-point of the seat system. This strict displacement requirement makes it impossible to design a latch by itself. Figure 1 shows a 2nd row seat system under the 207/210 loading condition.

Loading Conditions

The seat structure was mounted on to a rigid fixture with the seat back in the design position. A rigid load bar was attached to the seat back frame, at the CG of the seat system. A forward load, equivalent to 23 times the weight of the seat was applied linearly to the load bar in 30 seconds and was held for 11 seconds. Simultaneously, a forward load of 3450 lbf (15,346N) was applied to each of the shoulder and the lap blocks. This load is 15% above the FMVSS requirement of 3000 lbf (13,344 N).

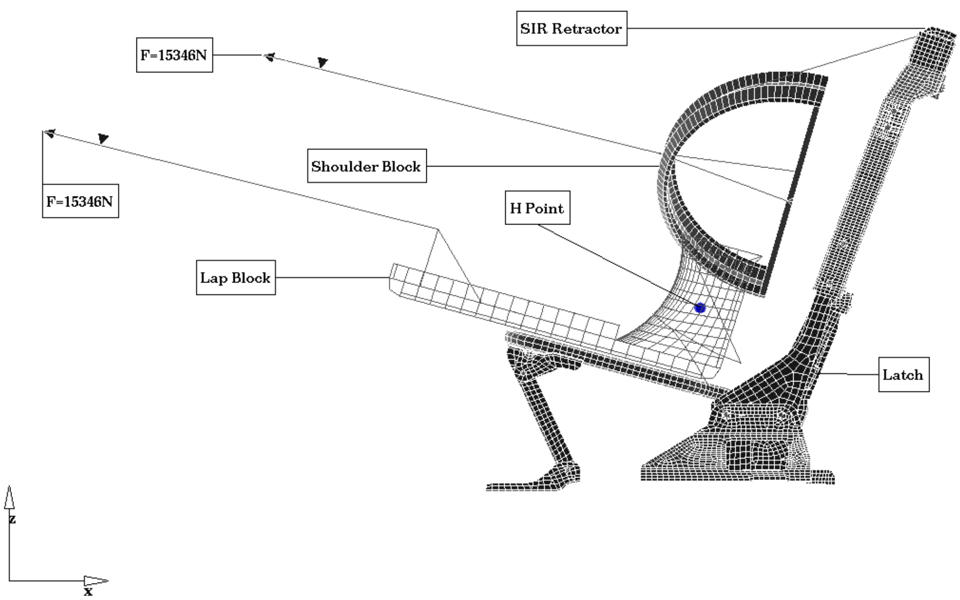

Figure 1. A 2nd row SIR seat subjected to 207/210 load.

APPROACH

In the automotive seating industry, FEA is performed as a part of the mainstream design process and it drives the structural design, especially for the purpose of designing for safety and NVH. Generally, different loading conditions on a structural latch were simulated on a component level. Development was done by the latch supplier. The latch assembly was meshed in detail using solid elements and was simulated for various load cases. Once, a reasonable level of confidence was gained, the design was approved to be packaged into the seat system. With the introduction of the stringent displacement requirements, the design and the verification process has changed. To design a robust structural latch, the whole seat system has to be analyzed in order to get meaningful results that comply with these new requirements.

FEA Setup

The static loading condition mentioned above was simulated using LS-DYNA by loading the seat quasi-statically. The applied load was attained in 60ms and was held for 10ms.

The majority of the seat structures are made up of metal stampings and tubes and were modeled using shell elements. Bolts and rivets that attach the different parts of the seat assembly together were modeled using beam elements. Pivoting action of the seat back and the internal components of the latch were modeled using pivot-beam elements which were regular beam elements with a very low value of polar moment of inertia (J). The rigid fixture was modeled using shell elements and was assigned rigid material property. The FE seat model was connected to the rigid fixture using a method developed at Lear Corporation [3]. *CONSTRAINED_SPOTWELD and *CONSTRAINED_NODAL_RIGID_BODY were used for connections. *CONTACT_AUTOMATIC_SINGLE_SURFACE[4] was used to define contact. The seating system discussed here is in the development phase. Hence, limited information will be revealed about the exact geometry and the material properties of different components.

Old Method

A detailed latch model, meshed with layered solid elements, as used during the component level analysis, can have elements in the range of 5000 or more. This combined with the seat model would make the analysis of a whole seat assembly inefficient. Hence, the seat model was assembled using a simplified latch assembly. Shell elements were used to represent the upper arm, the internal mechanisms, and the package plates. The components were assigned its respective thickness. All the internal mechanisms were connected with the assumption that the latch will remain locked at the seat design position. The upper arm and the package plates were made up of stamped, high strength steel. The thickness were in the range of 2.50 to 3.00 mm. Due to the huge amount of load that these latches need to carry, the internal mechanisms are powder metallurgy parts made up of high strength steel. The thickness were in the range of 6.00 to 8.00 mm.

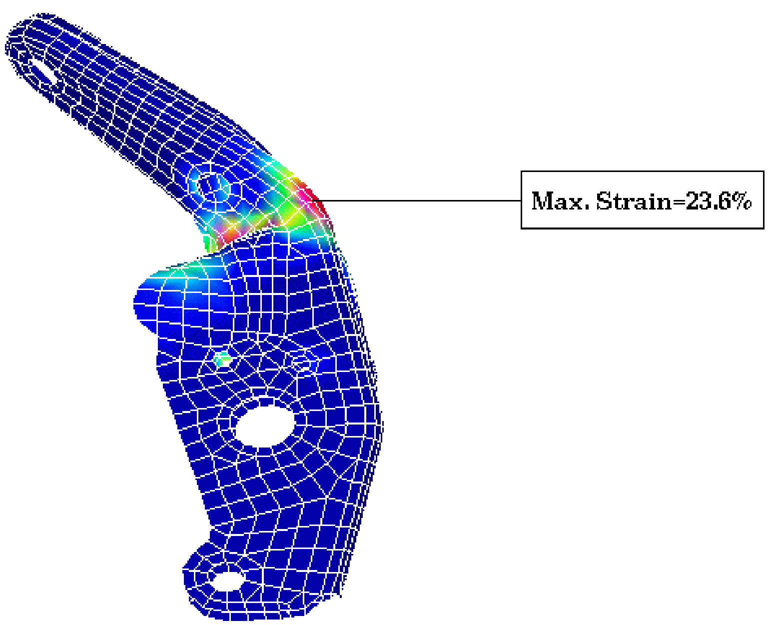

Figure 2. Deformed upper arm using the old method.

The seat system was loaded as per the conditions described earlier. Reasonable mass scaling was done following the basic guidelines for quasi-static analysis[5]. The only failure mode was found in the upper arm with a maximum plastic strain of 23.6%. The deformed strain plot of the side view of the upper arm is shown in Figure 2. Excessive deformation of the upper arm displaced the SIR retractor beyond the H-point. The simulation showed the maximum plastic strain values of the internal components, well within the permissible limits of the material used. This method predicted failure of the seat system.

The physical test performed on this seat system showed a different kind of failure mode. One of the internal mechanisms failed whereas the upper arm deformed much less than what was predicted by the analysis. Hence, the seat back could not hold the load and the retractor moved past the H-point.

New Method

It was obvious from the previous method that the internal mechanisms were not modeled properly to represent the physical test. The kinematics was simulated well and the seat back did not unlatch. But, the load transfer did not correlate with the physical test and resulted in a different failure mode. To overcome this problem and to achieve a better correlation, a new method was developed.

Component level analysis using solid elements had been successfully used to simulate different loads on a latch assembly. Since the internal mechanisms were the area of concern, they were modeled using fully integrated solid elements. Figure 3 illustrates a package plate meshed using shell elements and the internal mechanisms, modeled with solids. Table 1 shows the comparison of the FE entities used.

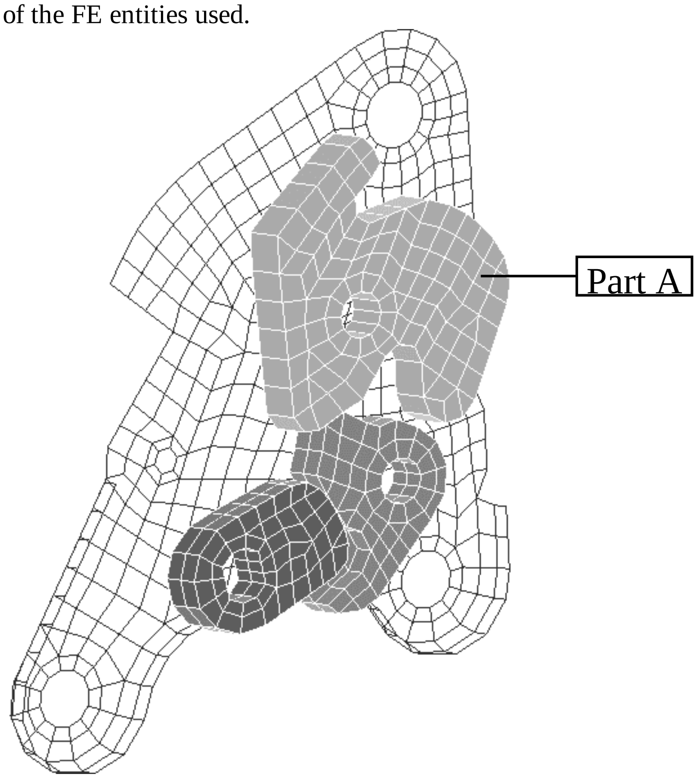

Figure 3. Combination of shell and solid elements to represent a latch assembly.

One of the internal mechanisms, labeled as part A, failed during the test. All the connections were same as the previous method. Contact was defined to transfer the load between the internal mechanisms. Previously, when the shell elements were used, internal mechanisms were welded at the areas of contact.

Table1. Summary of the FE entities.

Entity	Old method	New method
Nodes	16750	19961
Shell Elements	17573	17719
Solid Elements	0	292
Beam Elements	86	86
Welds and NRBs	92	98

The behavior of the seat system using the new method was exactly like the physical test. Figure 4a shows the plastic strain plot of part A. The maximum strain measured was 11.6%, around the pivot hole area. Part A cracked at the same area during the physical test correlating the load path. The deformation mode of the upper arm correlated as well.

Further iterations were performed using this correlated model. By making some minor design changes in the latch assembly, the seat system was able to hold the load. Figure 4b shows the strain plot of the modified part A, with the maximum plastic strain of 1.26%. The location of the maximum strain was also at a non-critical area. Figure 5 shows the deformed strain plot of the side view of the upper arm. The maximum plastic strain measured was 8.2%, well below the permissible limits of the material used.

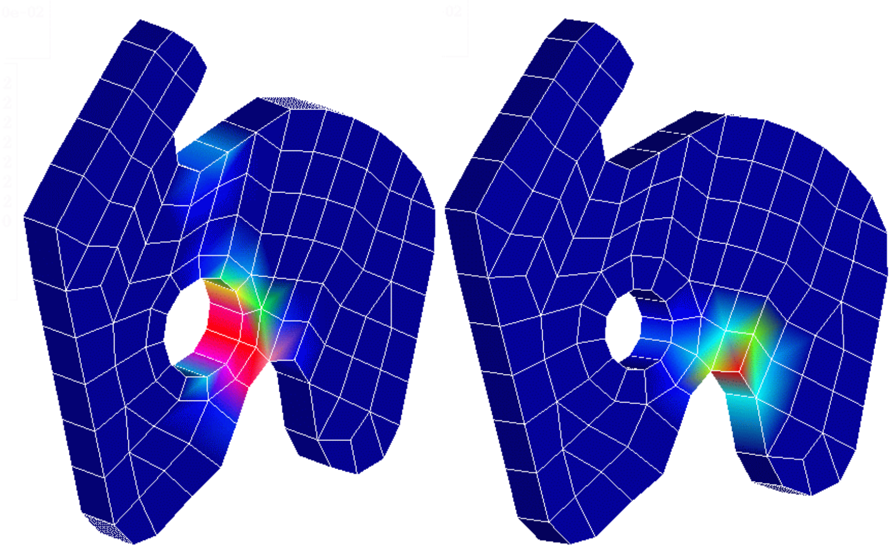

Figure 4a. Strain plot of part A using the new method.
Figure 4b. Lower strain at a non-critical area after the design changes.

SUMMARY

A very quick and a simple change in defining the critical load carrying components yielded an excellent correlation. Occupant safety regulations are becoming more and more stringent.

Component level analysis will phase out and suppliers of different components will have to work together for better system level simulations. Instead of validating individual components and assemblies, efficient energy management as a system can only lead to a viable design. Number of elements used in the above analysis were around 18,000. Total elements will easily exceed 100,000 when this model will be assembled on the body-in-white of a vehicle. In order to get meaningful results from these huge system level models, the method discussed above can be very efficient and cost effective. For complicated systems that need to withstand huge load, this method can successfully correlate a physical test with an LS-DYNA simulation.

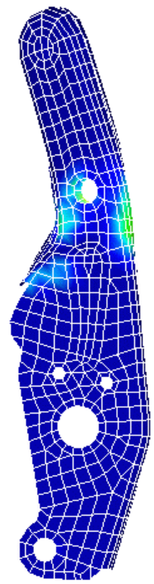

Figure 5. Strain plot of the deformed upper arm after the design changes.

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