Efficiency Improvement of Seat Belt Pull CAE Analysis by Technology and Process Changes

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Abstract

*This work addresses the capabilities of LS-DYNA® and LS-PrePost® in reducing the run-time for quasi-static and dynamic analysis involving large models using the following commands, *DEFORMABLE_TO_RIGID_AUTOMATIC and *CONTROL_MPP _DECOMPOSITIO_TRANSFORMATION. CAE analysis of seat belt pull assessments for FMVSS regulations is often a time consuming task with each iteration running overnight. This paper describes a new methodology that significantly reduces the model run time to few hours (70-80% reduction). The new methodology allows the users to take advantage of some of the new features and control cards in LS-PrePost and LS-DYNA solver, respectively, with a negligible set-up time. These features are included in the input deck as an add-on, which will allow the user to go back to the "live-buck" (baseline deformable model) without any issues for a final verification. The new technology and process have shown dramatic improvements for most of the LS-DYNA related simulations in terms of time and cost. This methodology has been verified and found to be very effective for engineers working on quasi-static analysis involving seat belt anchorage pull analysis (FMVSS 207/ 210) using LS-DYNA.*

Introduction

Seat belt anchorage pull analysis is performed to verify whether the designs of body structure and seats meet the FMVSS207/ 210 and ECE14 load requirements [1]. This requires the model to be checked for plastic strains, seat and body deformations, spot weld failures etc. Due to these output requirements in conjunction with large model size , the run-times for this regulation is relatively high which leaves the engineers with fewer design iterations leading to less design solutions over a given period of time[2]. However, this particular task can be carried out in a much faster way by efficient model set up and efficient use of control cards from LS-DYNA [3]. This paper describes the methodology that will significantly reduce the running time to a few hours. The methodology includes creation of sled models (containing deformable to rigid parts in less deformation zones) in LS-PrePost and utilization of different decomposition methods that allows efficient allocation of CPUs [4]. The analysis is performed using LS-DYNA (explicit) for better predictability [5].

Test specification

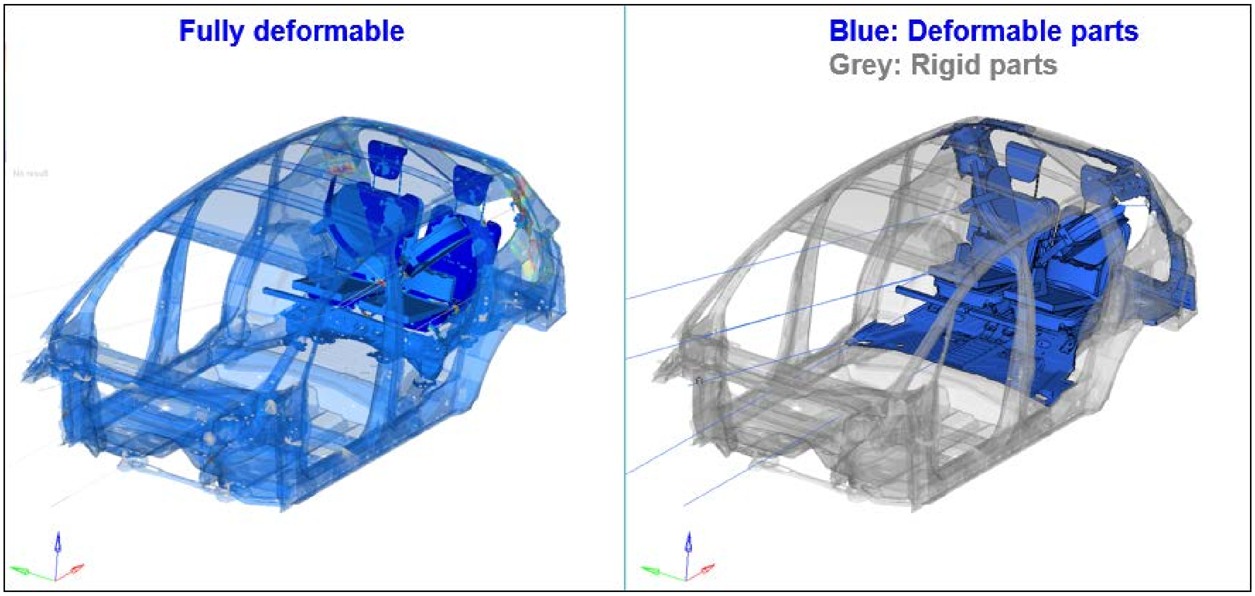
FMVSS207/210 and ECE 14 are tests to ensure the strength of the seats, seatbelt anchorage points and some body structural parts. Therefore, test loads are applied over loading devices such as shoulder block and lap block. There are two main differences between the ECE 14 and FMVSS 210 testing. ECE 14 classifies the vehicle based on the maximum allowed weights and requires them to sustain different loads depending on the weight. However, FMVSS 210 requires the same loads to be applied to all vehicles, regardless of their weight. The second difference is the velocity of load increase and the time the vehicle has to sustain the maximum load. ECE 14 requires the load to be increased as fast as possible for a time of at least 0.2 seconds. FMVSS 210 requires a long ramp not more than 30 seconds and the structure must sustain the loads for 10 seconds.

Conventional Approach

As part of product development, CAE Engineers conduct several iterations in order to meet or exceed all necessary requirements while optimizing the design and making geometry changes accordingly. This process is carried out on all rows of seats at numerous program milestones.
Conventionally, this process is conducted using a full BIW model with seats, belted body blocks and loading cables. In the case of a truck or a large vehicle model, the number of elements in the model are increased significantly. The model is set up to calculate deformations, plastic strain, failures, belt and bolt forces.

Process improvements

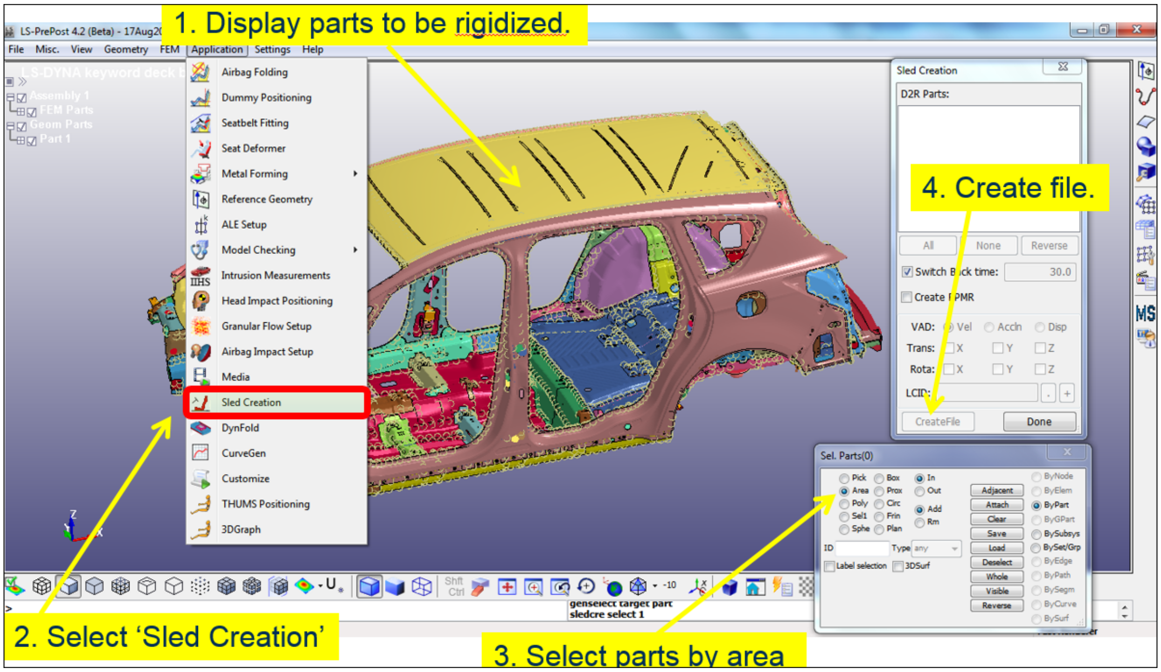
Sled model creation (Deformable to Rigid parts): An option in LS-PrePost allows the users to transform components from deformable to rigid parts by selection of a box. Once the parts that need to be rigid are selected, LS-PrePost automatically creates a new file with the part ID's having rigid properties. The setup for this method requires minimal time.
The plastic strain contour in Figure 1(a) shows the major deformation area. Based on the contours, Deformable-to-Rigid card has been set up shown in Figure 1(b).



(a) All parts as deformable (b) Grey parts are Rigid

Figure 1. Deformable vs. Rigid parts

The Deformable-to-Rigid file is used as an include file, which gives users the flexibility of going back to a fully deformable model at any time. Shown in Figure 2(a) are the steps for converting components from deformable to rigid with negligible set-up time:



1. Display parts to be rigidized.

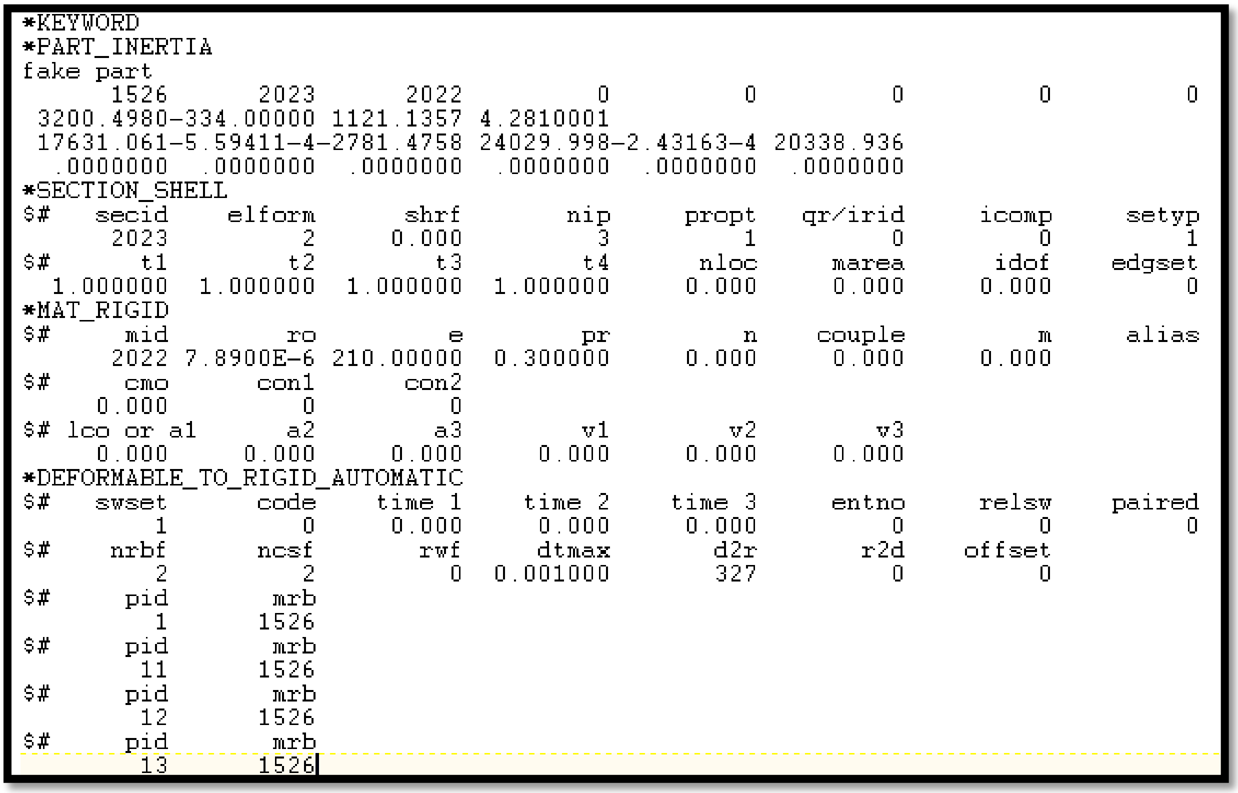
2. Select 'Sled Creation'

3. Select parts by area

4. Create file.

Figure 2(a). Steps for converting deformable parts to rigid in LS-PrePost

The input deck with deformable to rigid card is shown in Figure 2(b) as an example. By adding this card, the deformable part defined in the model will be converted to rigid during the calculation.



```
*KEYWORD
*PART_INERTIA
fake part
      1526      2023      2022         0         0         0         0         0
 3200.4980-334.00000 1121.1357 4.2810001
 17631.061-5.59411-4-2781.4758 24029.998-2.43163-4 20338.936
  .0000000  .0000000  .0000000  .0000000  .0000000  .0000000
*SECTION_SHELL
$#   secid    elform      shrf       nip     propt   qr/irid     icomp     setyp
      2023         2     0.000         3         1         0         0         1
$#      t1        t2        t3        t4      nloc     marea      idof    edgset
  1.000000  1.000000  1.000000  1.000000     0.000     0.000     0.000         0
*MAT_RIGID
$#     mid        ro         e        pr         n    couple         m     alias
      2022 7.8900E-6 210.00000  0.300000     0.000     0.000     0.000
$#     cmo      con1      con2
     0.000         0         0
$# lco or a1        a2        a3        v1        v2        v3
     0.000     0.000     0.000     0.000     0.000     0.000
*DEFORMABLE_TO_RIGID_AUTOMATIC
$#   swset      code    time 1    time 2    time 3     entno     relsw    paired
         1         0     0.000     0.000     0.000         0         0         0
$#    nrbf      ncsf       rwf     dtmax       d2r       r2d    offset
         2         2         0  0.001000       327         0         0
$#     pid       mrb
         1      1526
$#     pid       mrb
        11      1526
$#     pid       mrb
        12      1526
$#     pid       mrb
        13      1526
```

Figure 2(b): Snapshot of Input deck for deformable to rigid parts

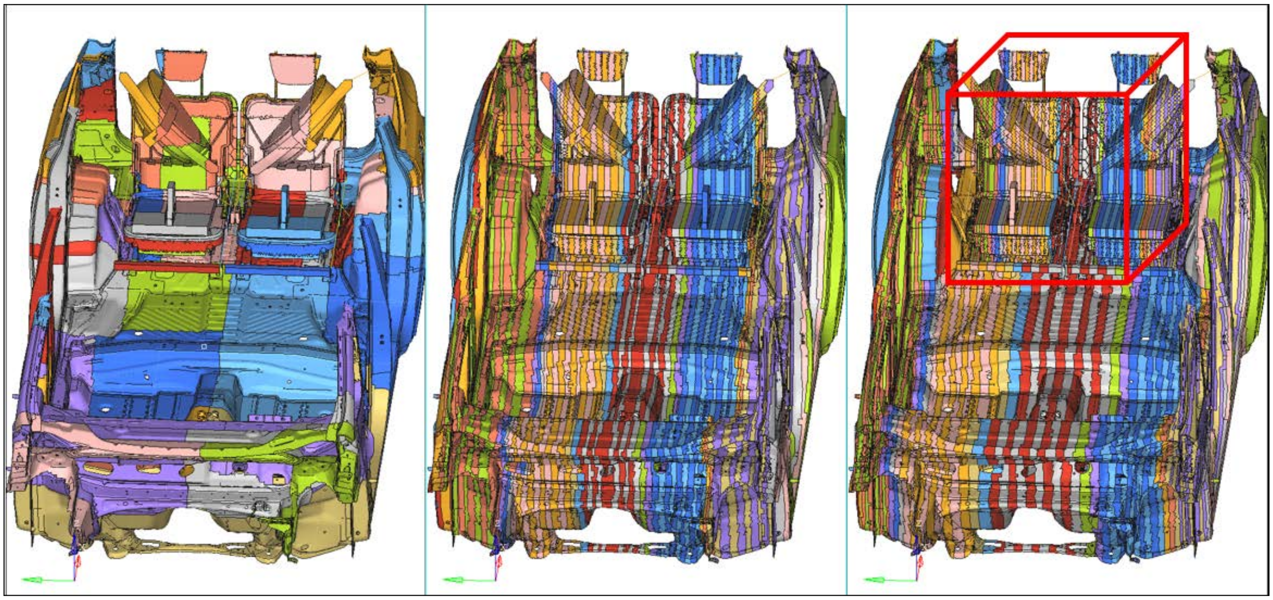
Decomposition methods: For seat belt pull analysis, large models with fine meshes are generally used. The increase of computational time by the large models has been improved by domain decomposition in LS-DYNA. In domain decomposition, the model is divided into several domains, and each domain is assigned to each core in the CPU. Based on the impact area, the model can be divided along with a specific axis. In this paper, we use a SUV model for seat belt pull analysis run up to 180 milliseconds. Three types of decompositions as shown in Figure 3 are tested.

(a) Default: Figure 3(a) shows the seat belt pull model with default CPU allocation. This type of CPU allocation is generally acceptable. However, for some of the loading and deformation conditions, it does not always allocate CPUs efficiently for calculation.

(b) Global decomposition (x, y, z): Figure 3(b) shows the allocation of CPUs with respect to domain decomposition using multi-parallel processors. Since the impact zone for this analysis is in the 3rd row seat area, each subdomain is allocated to one processor along longitudinal direction of vehicle in the domain decomposition (specifically, here, sy=10000). Based on the impact zones, the domain decomposition can be changed accordingly by a specific axis.

(c) Decomposition by region: Based on Global decomposition, Figure 3(c) shows the further allocation of more CPUs with respect to decomposition by region, in a “box” by using multi-processors. All the CPUs are allocated to the highly deformed zone, which leads to better job turnaround for the problems with large local deformations.

These enhanced decomposition methods provide a critical step to distribute equal amount of calculation to all computing processors.
The three types of domain decompositions are shown in Figure 3(a), 3(b), and 3(c) below:



(a) Default (b) Global decomposition (c) Decomposition by region

Figure 3. CPU allocation comparison of three type of decomposition technologies

Runtime comparison: In Figure 4, we will see the effect of deformable to rigid parts and domain decompositions on the overall runtime for seat belt pull analysis.

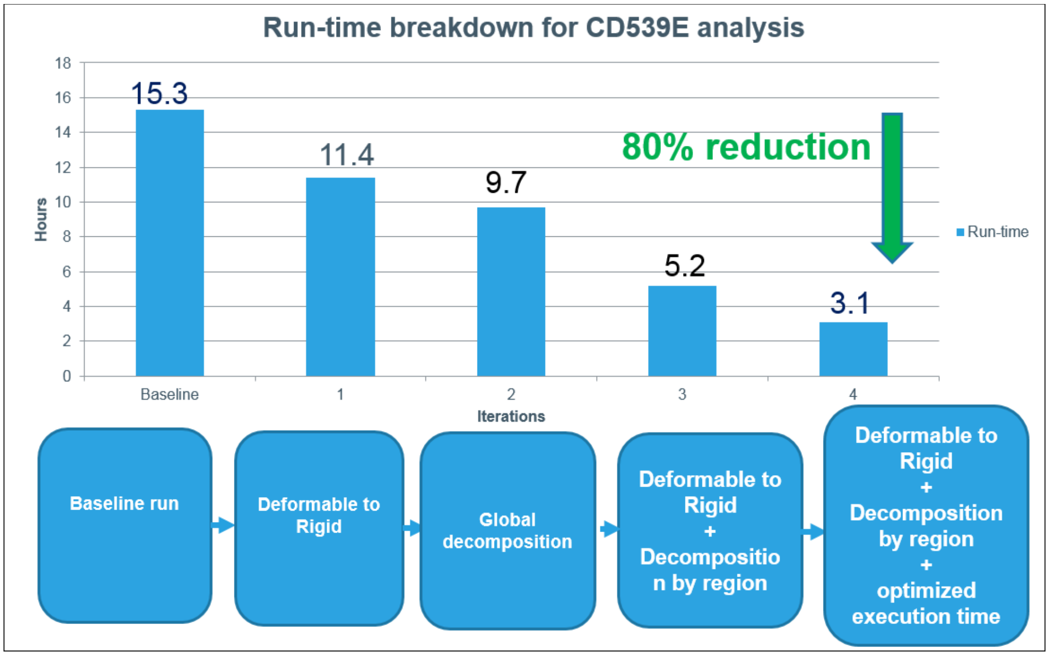


Figure 4. Comparison of runtime for various iterations

Analysis Results: Comparison of the methodology implementation on final results, such as plastic strain on floor and on seat, and seat belt forces are shown in Figure 5(a), 5(b) and 5(c).

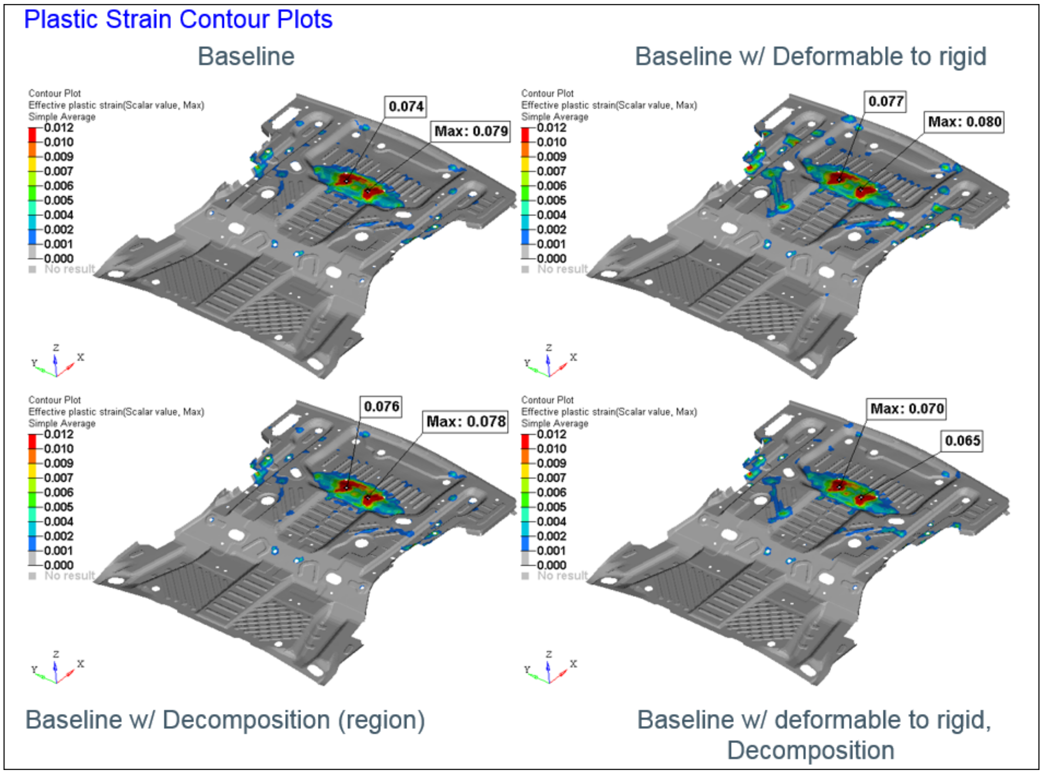


Figure 5(a). Floor plastic strain comparison

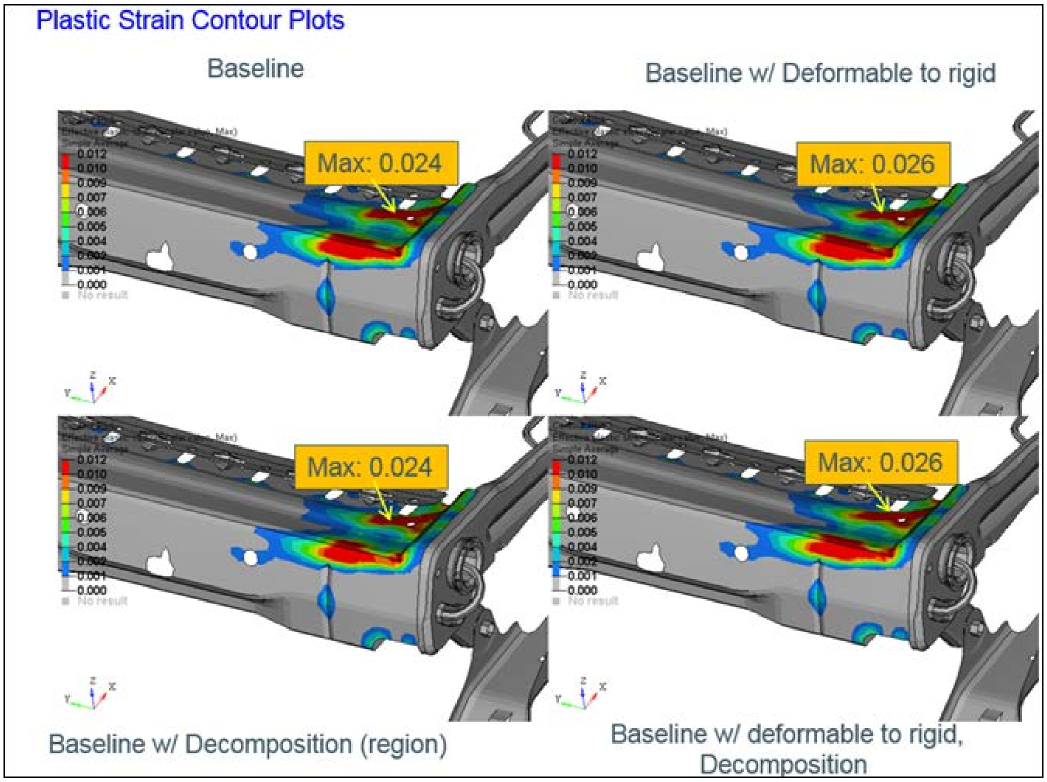


Figure 5(b): Seat plastic strain comparison

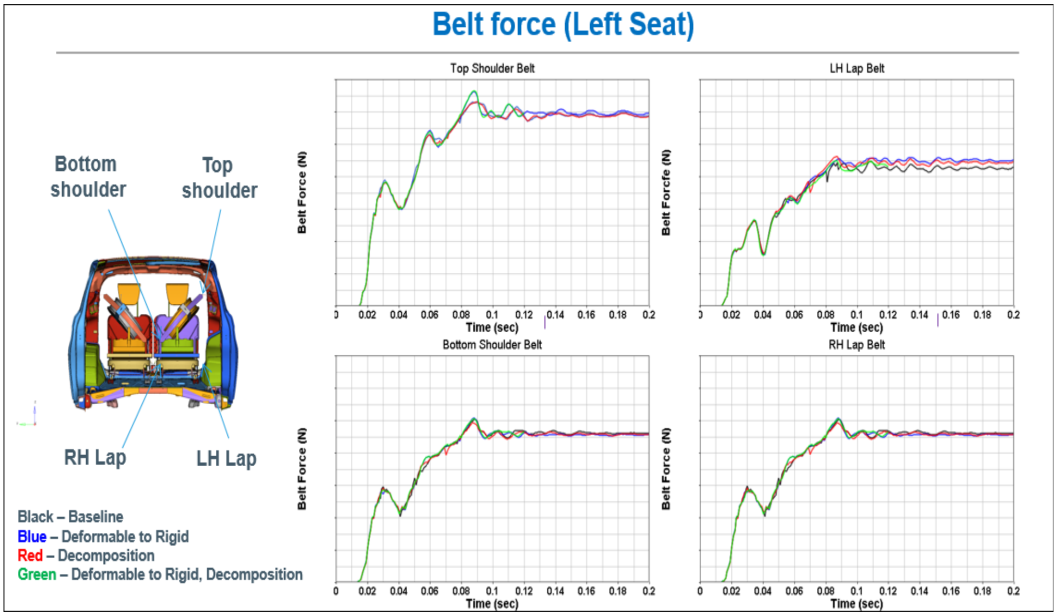
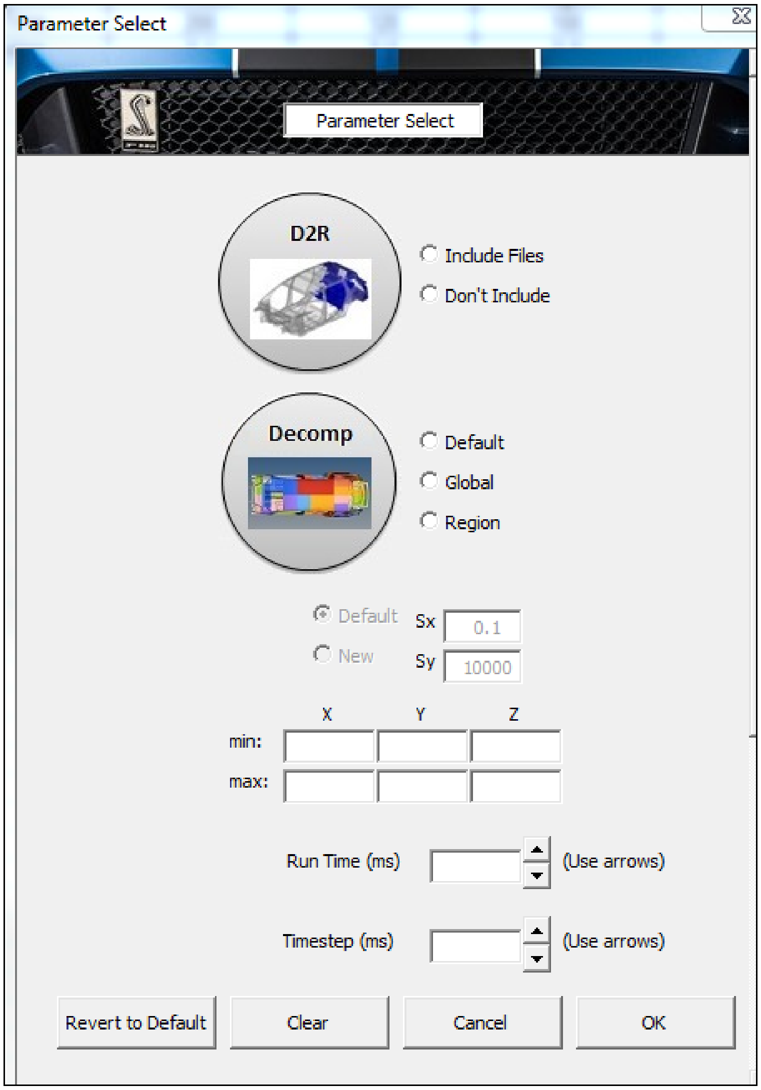


Figure 5(c): Belt attachment force comparison

The above plastic strain contours, force curves show that the implementation of technologies such as deformable to rigid and decomposition are very well correlated to the baseline model.

Automation: Automated scripts can easily execute the aforementioned technologies with negligible set up time. As shown in Figure 6, the automated card helps the user to select specific technologies based on the required iteration.



● Default

Sx 0.1

Sy 10000

Figure 6: Automation for easy job execution

Conclusion

This paper introduces technology for analyzing large numbers of elements by using deformable-to-rigid and domain decomposition methods. Process improvements using these options can reduce the run-time significantly. Such process improvements lead to better job turnaround time for problems with large local deformations. These methods enable the engineers executing a large number of iterations understand the effect of small changes to the model.

Therefore, this enhanced method would provide many advantages for all the design iterations during the product design cycle for FMVSS 207/ 210 and ECE14 regulations. In addition, this process can also be extended to different crash modes in safety analysis, especially in sled tests.

References

[1] Federal Motor Vehicle Safety Standard (49 CFRPART 571) FMVSS 207/210. Final amendment: FR Vol.63 #113, 12.06.1998

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