Structural Topology Optimization of Car Body Using ATOM

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Abstract: *The weight reduction of components and systems is of utmost importance in the automotive industry. Reducing weight translates into higher performance and lower fuel consumption.*

In this paper, we suggest an optimization process for linear and nonlinear load cases of car body. In order to achieve this goal without sacrificing the current performance of selected model, we use Abaqus Topology Optimization Module (ATOM).

Current geometry models are simulated with the specified load cases to establish a baseline performance in terms of stiffness and reaction force. We then generate design envelopes representing the available space for topology optimization and the same load cases are applied to the optimization models with the volume as upper limit constraints, the reaction force as lower limit constraints and minimum strain energy as objective functions.

Optimization results suggest new conceptual sections for important components and new positions of structural adhesives compared to the current model with significant increase in stiffness and reaction force.

Keywords: Nonlinear Analysis, Strength Optimization, Abaqus Topology Optimization Module, ATOM

1. Introduction

The strength of the roof of a vehicle is the main factor to protect its passengers from rollover events. Although the repetition rate of such events is very low, the associated death rate is too high and mainly caused by neck injuries. Figure 1. shows a vehicle after a rollover accident, and how the roof intruded into the passenger's space. Therefore, the analysis of the roof strength performance is one of the most important parameter of the body structure design.

Figure 1. The car deformation status for rollover accident

Figure 2. shows the Finite Element (FE) model and final deformation. Some important parts have deformed and buckled. Because of large deformation, geometry and material nonlinearity have to be considered in this analysis.

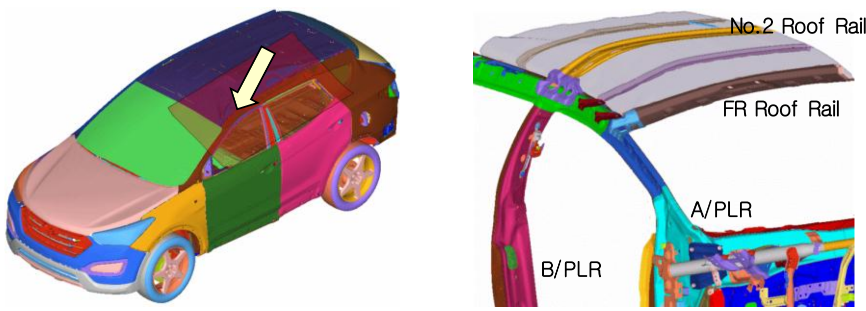

Figure 2. FE model and deformation result

Abaqus Topology Optimization Module (ATOM) was used in order to optimize the roof strength performance while taking into account these severe nonlinearity effects, .

2. Finite Element Model

The output monitored for a roof strength analysis is the reaction force on the rigid ram used to compress the roof (as shown by the red surface pointed by the arrow on Figure 2.). Figure 3. shows section reaction forces for some important components, the B-Pillar of the vehicle (B/PLR) being the most important of them from a reaction force perspective.

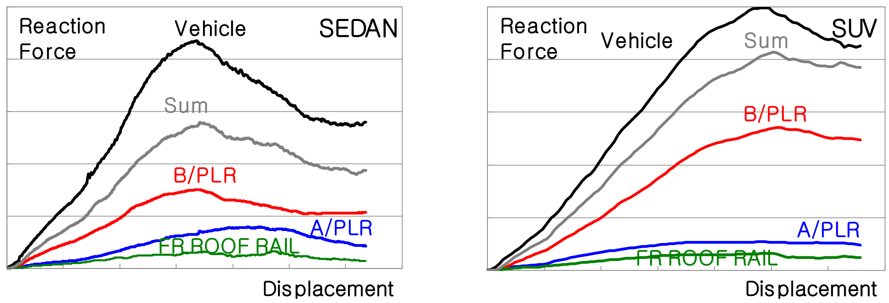

Figure 3. Reaction force rate for important component

The B/PLR unit was selected for this study mainly for calculation efficiency reasons. Figure 4. shows the simplified FE model for B/PLR and Figure 5. shows the displacement and rotation of a full car for the upper surface.

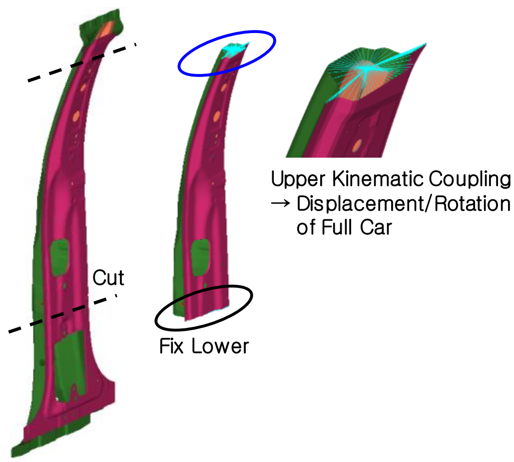

Figure 4. Simplified B/PLR FE model

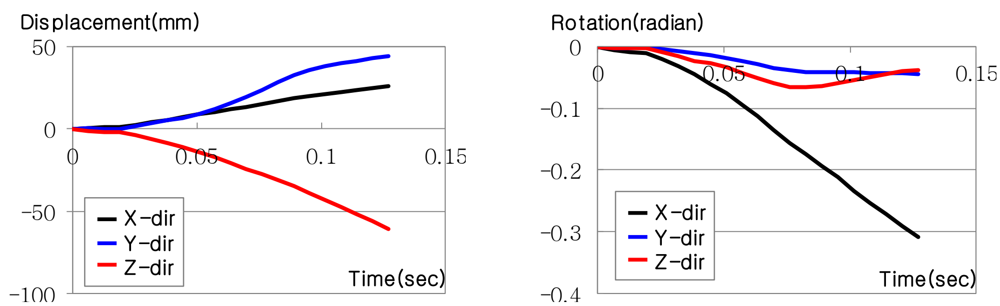

Figure 5. Displacement and rotation history of full car for upper surface

ATOM is using Abaqus/Standard, so some convergence problems have to be solved for a large nonlinear problem.

3. Optimization

Figure 6. shows optimization model and base model. All parts are made of steel and have the same density. The volume of the base reinforcement model is 3.6% of that of the solid part used as a starting point of the optimization model.

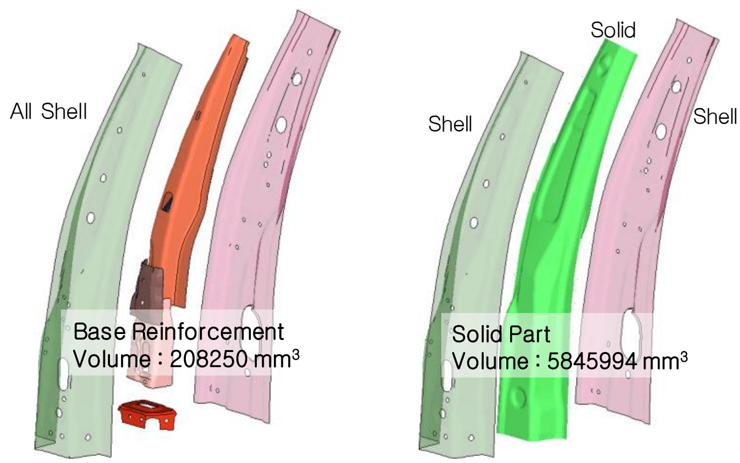

Figure 6. Base reinforcement model and optimization solid model

3.1 Optimization Problem Definition

▣ Problem definition: topology optimization using ATOM

▣ Object function: minimize strain energy → Derive optimized shape for maximum stiffness

▣ Boundary conditions:

- Volume: below base reinforcement structure volume
- Reaction force: above base reinforcement structure reaction force

3.2 Optimized Results

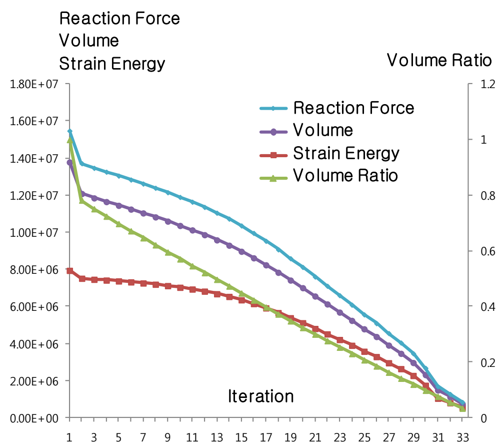

Figure 7. History of important variables during optimization process

Figure 7. shows the history of important variables during the optimization process. The total iteration number is 33 and the calculation time was 5.5 hours using 12 cores.

The final optimized structure is shown in Figure 8. and Figure 9. shows the reaction curves for the base and optimized structures.

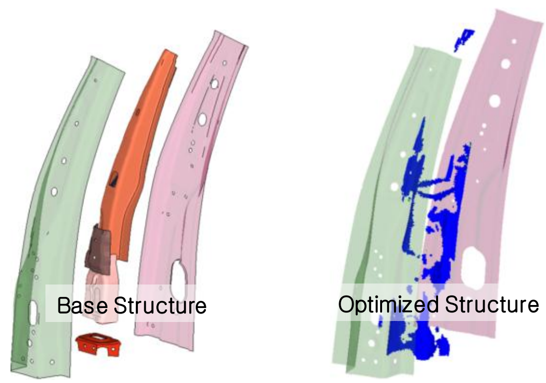

Figure 8. Comparison of base and optimized structure

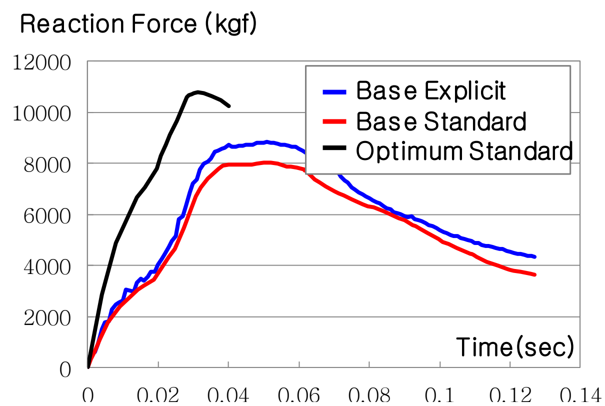

Figure 9. Reaction force curves for base and optimized structure

The volume of optimized structure was reduced by 5.8% and the reaction force was increased by 29% compared to the base structure.

4. Conclusion

Nonlinear optimization of a B-Pillar structure was considered using ATOM.

1) Nonlinear topology optimization analysis was conducted for nonlinear strength problem with large deformation
2) Analytical convergence problem have to be solved in advance of the optimization because ATOM can only uses Abaqus/Standard.

5. References

1. Abaqus Users Manual, Version 6.11, Dassault Systèmes Simulia Corp., Providence, RI.