Front Bumper Crashworthiness Optimization

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Abstract

During a vehicles frontal crash, passengers jeopardize high acceleration and energy opposite to the mass follow direction of their bodies. This fact causes high injury to the passengers' whole body; head, neck, chest, and legs. We started thinking of reducing this deceleration effect on passengers during the crash. This is because succeeding in reducing mass deceleration effect on the passengers' bodies will lead to save passengers form serious injuries. Increasing the length of the front bumper crash boxes was a method to improve the impact energy absorption. However, increasing the geometry (the length of the crash box) of the front bumper assembly will lead to an endless chain of structure subassembly changes.

Our methodology works on combing different types of materials and design optimization to control the crash deceleration while maintaining the geometry of the front bumper

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This methodology works on absorbing or discharging the energy of the impact before the energy being transmitted in full to the passenger. On other word, we protect the passengers from the excessive energy which is generated by the crash before it reaches them.

By having the control over these variables, our vehicles become safer to insure the safety for everyone.
This methodology has a high potential to be applied to improve the side impact crash worthiness as well.

Introduction

Car manufacturers are aiming to improve car crashworthiness. Computer simulation and FEA are used by all carmakers to achieve this objective. A lot of software is able to carryout crash simulation in a precise way. In addition, coarse mesh causes unstable behavior which develops hourglass energy. Ls-Dyna allows one to ignore or control the hourglass energy which might destruct the total output energy of the analysis that could be a result of non-perfect or coarse meshing for shell or/ and solid elements.
Total energy = Kinetic energy + Internal energy
The goal of this optimization is to improve and maximize the efficiency of the front bumper rail and crash boxes. Front bumper must allow absorbing the maximum possible energy and velocity, which are generated by the impact or the crash, in a very rapid and efficient way. This is because the more energy the bumper assembly absorbs, the less energy the passengers face. Not only maintaining the weight and the length of the bumper low, but decreasing both of these variables to improve the general characteristics of the vehicle is another goal of this technique.

Model Example

In order to start studying this technique, an experiment was carried out on an ideal front bumper model. Alfa Romeo 156 Front bumper assembly model (2000) was taken as an example for this experiment (see figure. 1).

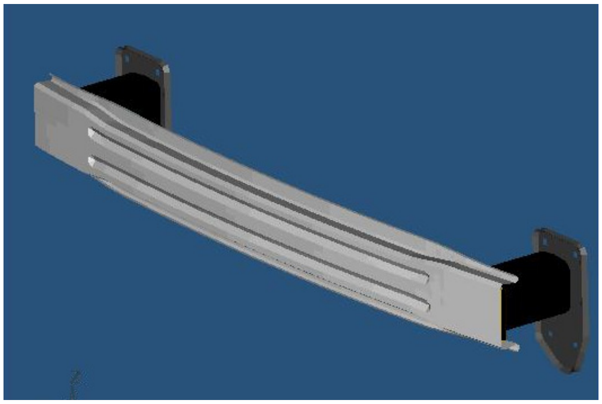

Figure 1. Alfa Romeo 156 front bumper

The bumper structure components:

Front rail	Front rail case	Two crash boxes	Two flanges	Spot welding

The test used to evaluate this optimization is the frontal curved hummer with 40% offset (i.e. 40% of the width of the widest part of the car, not including the side view mirrors), and initial impact velocity of 64kph.
This model was subjected to the new methodology. The result of this test pointed out to the possibility of decreasing the thickness of both the crash box and the front rail.

Geometry Modified Crash Box

Passing from the idea of decreasing the thickness of the crash box while maintaining the reaction of the bumper model to the impact, to decreasing both the length and the thickness of the crash box became the second goal to fulfill.
During running the simulations we first came across instable analysis behavior as a result of the hourglass energy. We had both shell and solid elements in the model.
We could come over the hourglass energy by using the following:

A- Tern off the hourglass energy for both shell and solid elements (HGEN: EQ1), (SHGE: EQ1)

B- Hourglass control for solid elements (EQ.6: QM=0.001-0.01) or (IBQ= EQ.1)

The results that came out from manipulating the different materials and elements of the bumper model are as follows:

- Improving the resultant kinetic energy of the bumper.
- Improving the resultant internal energy of the bumper. (See figure. 2).
- Rapid velocity absorption. (See fig. 3).
- Maintaining the folding behavior of the crash box to maximize the energy absorbance.
- Decreasing the length and thickness of the crash box.
- Decreasing the thickness of the front rail.
- Decreasing the overall mass of the bumper model.
- Reducing the cost of material

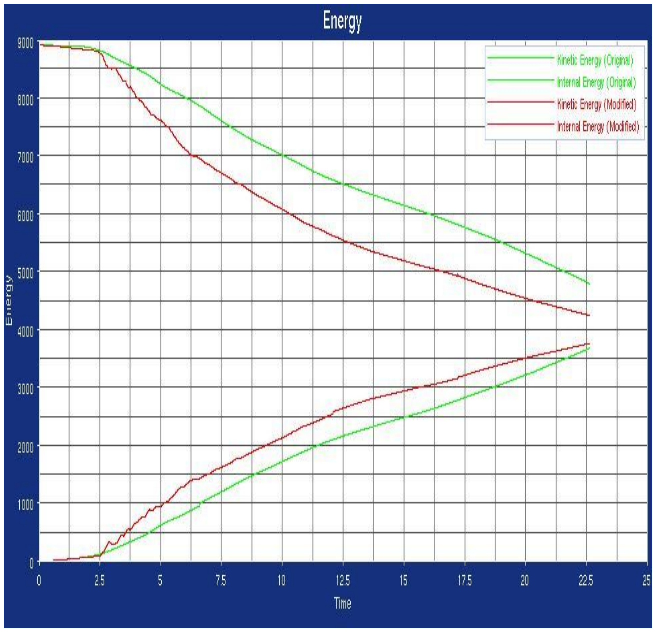

Figure 2. Internal and Kinetic Energies (Green – Original bumper, Red- Optimized bumper)

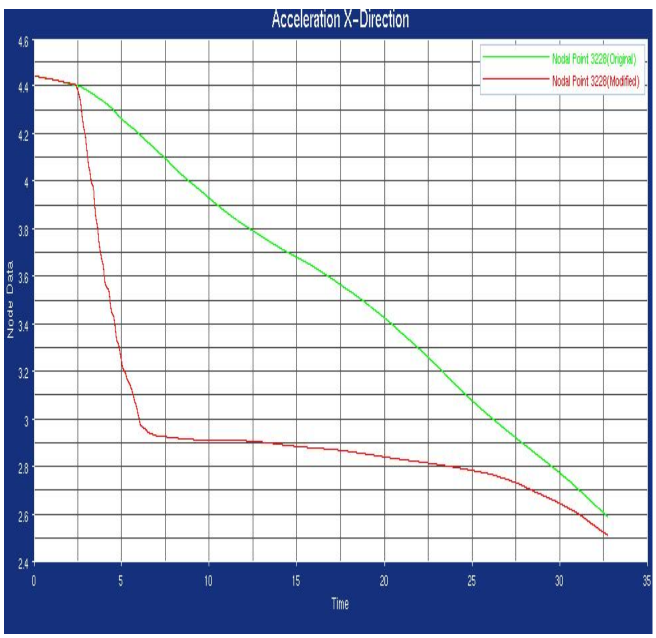

Figure.3 Acceleration comparison between the optimized and original models
(Green- Original model, Red- Modified model)

In addition, the use of this optimization leads to other important advantages:

- Structure stability.
- Improving the crash test evaluation.

Structure Stability

Having two sensors for stability at the end quarter of the crash box is the way that we used to measure the structure stability during the impact. The sensors started to read the reaction of the impact after 9.5 ms of the start time of the impact. In other words, the sensors started to register when the end part of the crash, where the sensors are situated, box starts to interact with the crash.

Crash Test Evaluation

The capacity of the modified bumper to absorb the impact energy has hugely improved. Figure 4 shows a comparison between modified and unmodified models after ≈30 ms of the impaction test. It is important to notice that the length and thickness of the crash box and the thickness of the front rail of the modified bumper are much less than the original one. However, the residual part of the crash box of the modified bumper is longer that the one of the unmodified one. Accordingly, the front rail deforms in a better shape than the one of the original bumper model, which allowed better energy absorption. (See Figure. 4). This fact gives advantage for the modified crash box to absorb more energy on the original model.
Since this technique allows for less structure deformation as a consequence of better energy absorption, crash test evaluation for the modified bumper as a result is improved.

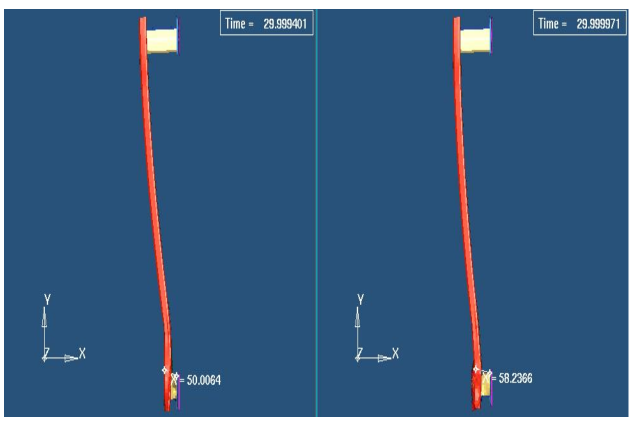

Figure.4 Impact comparison between optimized (right) and non-optimized (left) bumpers in 30ms

Conclusion

Optimizing the front bumper to absorb the most possible energy of the impact can carry the whole concept of car safety to different level.
In addition, this methodology can be applied to improve the car side impact. Farther studies in this filed are required to obtain the desired results.
Never the less, this optimization study opens the door for using different concepts and materials for absorbing impact energy.

References

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