

Improvement Design of Vehicle's Front Rails for Dynamic Impact

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ABSTRACT

Frontal collision tests indicate that the energy absorbing components playing the main role of providing protection for the occupants during the crashing processing. The frontal rails are the main components to absorb energy during collision. The position of the spot welding, beads, the cross section and thickness of the frontal rails are significantly facts that affect the energy absorption during impact.

This paper is concentrated on improving the energy absorbing efficiency of the vehicle's front rails during impact and giving better existing space of the passenger compartment after collision by using LS-DYNA. Utilize the improved model to enhance the exiting vehicles and compare the results to the frontal impact test.

INTRODUCTON

Because of the frequently happening of the vehicles frontal collision, reducing the injuries of occupants during frontal impact is a major topic for vehicle safety. The impact energy is absorbed mostly by the components of the crash zone. For most of the sedans and plat-head minibus, the frontal rails are the main components to absorb energy when the frontal collision happened. To provide more protection for the occupants, there are two particulars need to be examined, one is the passenger compartment collapses; the other is the energy absorption during collision.

SCOPE OF IMPROVEMENT

To increase the energy absorbing ability and adjust deformation behavior to reserve a better passenger compartment are the targets of improving the front rails. It is often to consider the following methods to reaching the targets,

1. The cross-section of the frontal rails and the welding position.
2. The location of the beads.
3. The thickness of the rails.
4. Place the reinforced member.

Because of the limitations of manufacturing such as timing and costing, the thickness and the cross section of the frontal rails will not be changed in this research. The commercial finite element analysis package LS-DYNA will be employed.

In this study, the velocity of the target vehicle is set to be 50 km/hr, therefore the total energy during frontal collision will be 100kJ. The objective percentage of energy absorption by the frontal rails will be 70%. Therefore, each rail should have capacity to absorb 35 kJ of energy and still keep the passenger compartment. The design processing in this paper is shown as the Figure 1.

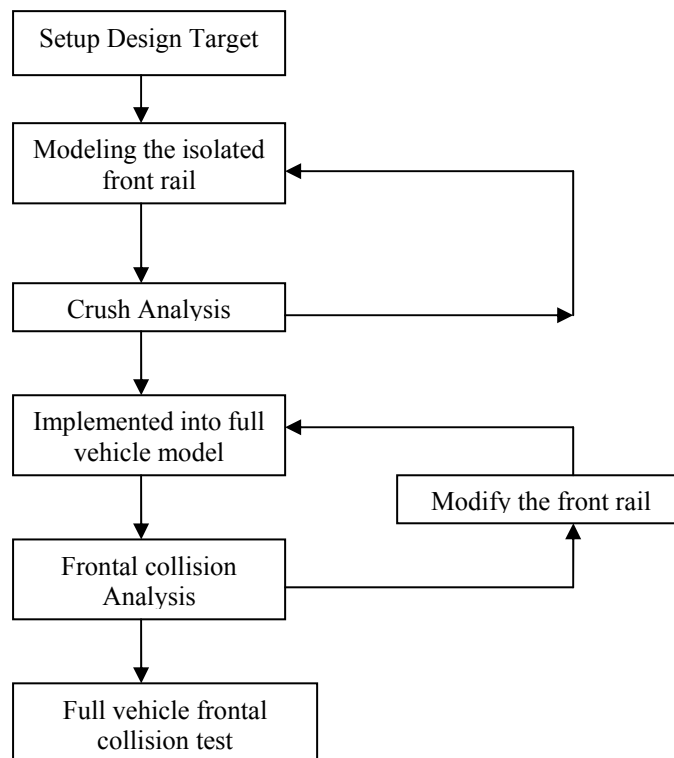


Figure 1: The processing of improving frontal rails

Because of the difficulties of changing the cross-section and the position of welding shown in Figure 2, adding the extra rail in front of cross member is a convenient way to improve the passenger compartment which shown in Figure 3.

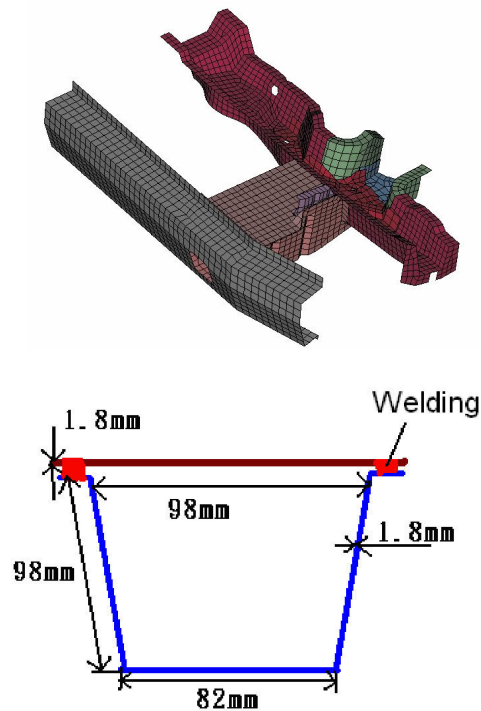


Figure 2: Schematic of the original model and cross-section of frontal rail

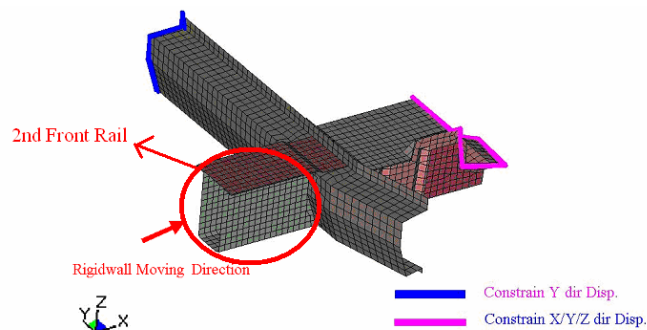


Figure 3: Schematic of the model of frontal rail with adding rail

THE INDIVIDUAL RAIL MODEL

In order to verify the energy absorbing behavior of the frontal rail efficiently, the static analysis will be done first. The original rail model was built isolated and was set to crush into a rigid wall as the outcome shown in Figure 4. The results show that the amount of energy absorbed by a rail is 15 kJ which is far away from the target. For improving, the extra rail with 150mm length will be added to the original model also with one bead added for first comparison. The second improving model will be added an extra rail with 220mm length and two beads to the original model. Figure 5 and Figure 6 show the first and second improving models and their outcomes respectively.

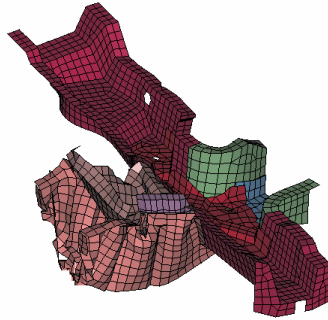


Figure 4: Schematic of the deformation of the original design

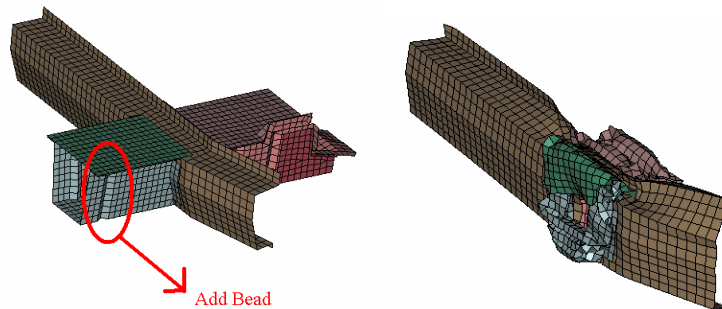


Figure 5: Schematic of the 150mm addition frontal rail with one bead

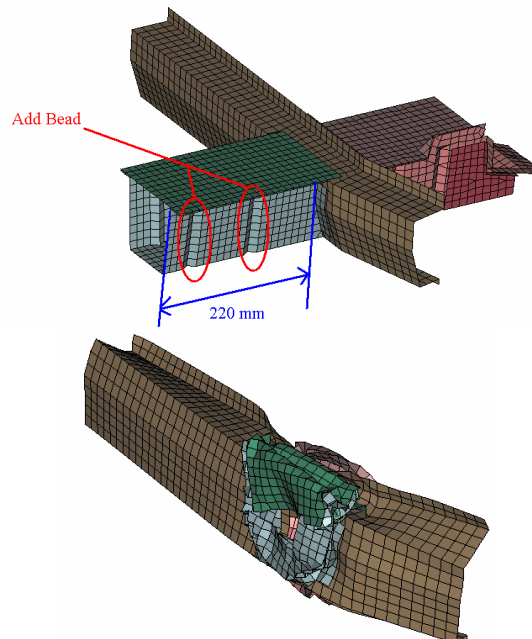


Figure 6: Schematic of the 220mm addition frontal rail with two beads

From the results of the two improving models, the first model which has 150mm extra rail and one bead added will absorb 28 kJ of energy. The second model with 220mm extra rail and two beads added will absorb 35.3 kJ of energy. It is clear that the model with 220mm additional front rail and two beads will be closer to the target value of 35kJ.

THE FULL VEHICLE MODEL

In the full vehicle model, there are two subjects will be considered. The first one is the capability of energy absorption of the frontal rail. The second one is the deformation of the A/B pillars.

Based on the previous static study, the frontal rail with additional 220mm extra rail and two beads will be implemented into the full vehicle model which has initial velocity of 50kg/hr for collision simulation. The results show that the amount of energy absorbing by the frontal rail is 34kJ, also during the 80ms of the impact time, the maximum distance between A/B pillars reaching 160 mm. It reveals that this model does not meet the requirement of energy absorption and the passenger compartment need to be improved.

For improving, the simulation results show that the rail bent up under the front floor during the frontal collision analysis, it could be adding the reinforce plates on the top and bottom sides of these weak points to increase the deformation in longitudinal direction. Figure 7 shows a schematic of the locations of the reinforce plates.

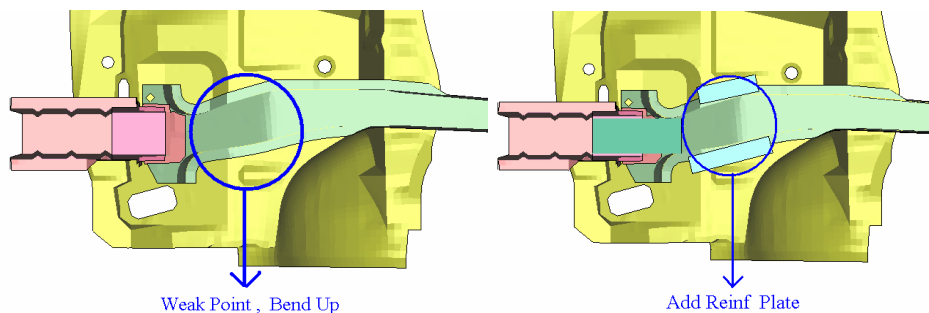


Figure 7: Schematic of the location of the additional reinforce plates

The effect of the reinforce plate and improvement of the passenger compartment are shown in Figure 8.

Also the analysis shows this model can only absorb 49% of impact energy, this is because most of energy bends the frontal rail during the 80 ms of the impact time and the part of the rail which is not bended does not functional absorb the energy as shown in Figure 9.

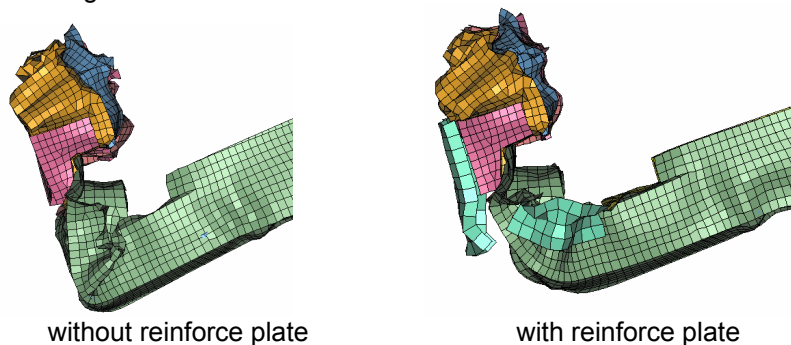


Figure 8: Deformation comparison plot of the rails with and without reinforce plates

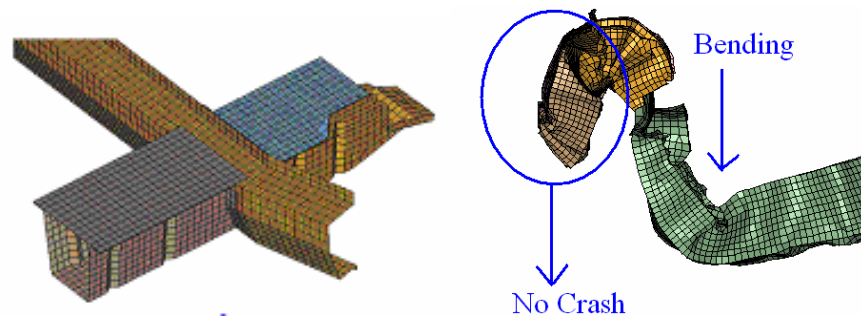


Figure 9: Schematic of the model with addition rail and deformation

In order to increase the value of energy absorption in the crash zone, it needs to make the structure of the unbended part of rail weaker. To add a couple of beads on the rail is employed. As the Figure 10 shows the unbended part of rail is successfully taking care some of the energy but the frontal rail is bending down which caused the maximum deformation between the A/B pillars became 140mm. From the schematic of the deformation shows that the second section of the frontal rail is not deforming much enough which means it need to be less stiff. To make this requirement, the holes will be placed on the second section of the rail which yields the results shown in Figure 11. The crash zone is increasing the ability of absorbing the energy and still keeping the larger passenger compartment comparing with the original design.

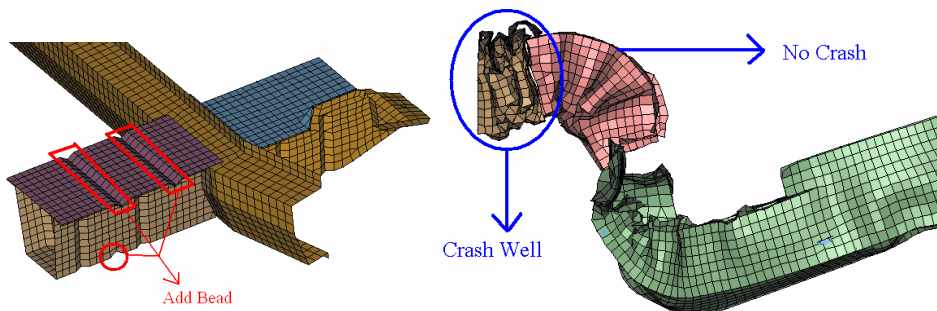


Figure 10: Schematic of the model with addition beads and the deformation

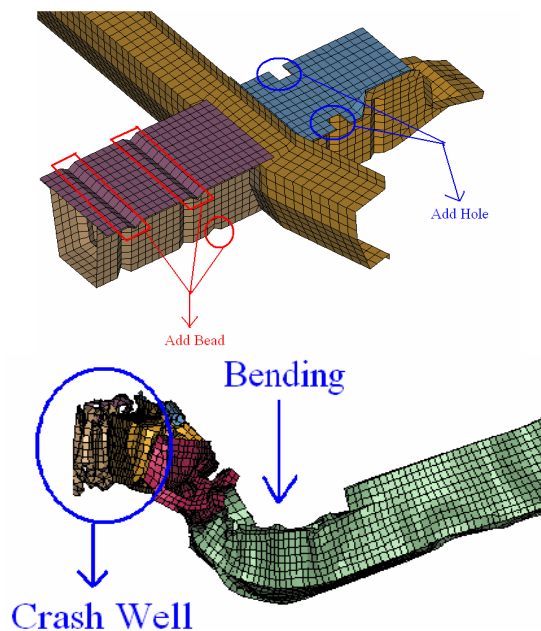


Figure 11: Schematic of the model with addition holes and the deformation

Table 1. shows the comparison of the capability of energy absorption and the maximum deformation between A/B pillars which means less maximum deformation will results better passenger compartment of all the models.

Full Vehicle Model	Original Design	Adding reinforce plates	Adding reinforce plates and beads	Adding reinforce plates, beads and holes
Absorbing Energy	34%	49%	53.2%	52.3%
The Max Deformation between A/B Pillars during 80 ms of impact time	160mm	143mm	140mm	88mm

Table 1: Comparison the absorbing energy rate and the max deformation between A/B pillars during the different designs

EXPERIMENTAL INVESTIGATIONS

After using LS-DYNA to improve the model of the frontal rail, the final design is implemented into the prototype of the vehicle shown in the Figure 12 and Figure 13. With the speed 50 km/hr frontal collision test, the deformation results shown as the Figure 14. The resultant deformations of the frontal rail from FEM analysis and the real vehicle test are real closed and the resultant passenger compartments from both studies are agreed too.

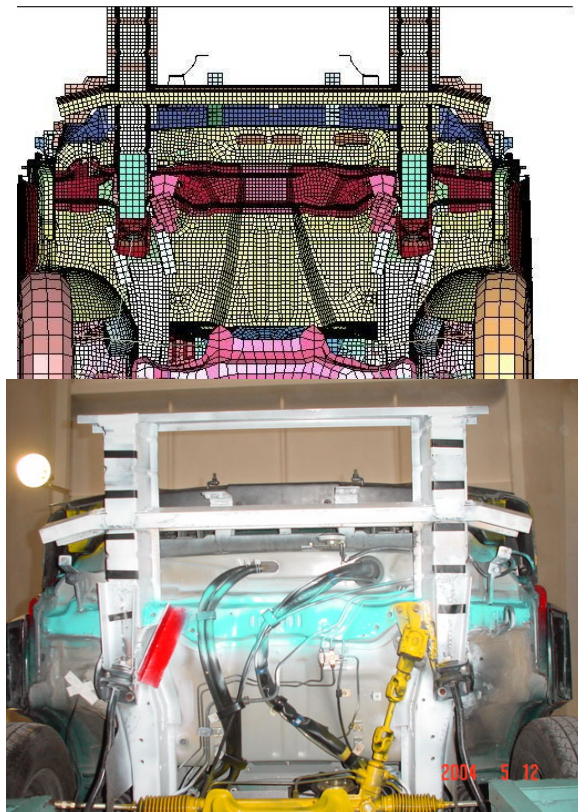


Figure 12: Bottom views of the full vehicle model and the test vehicle

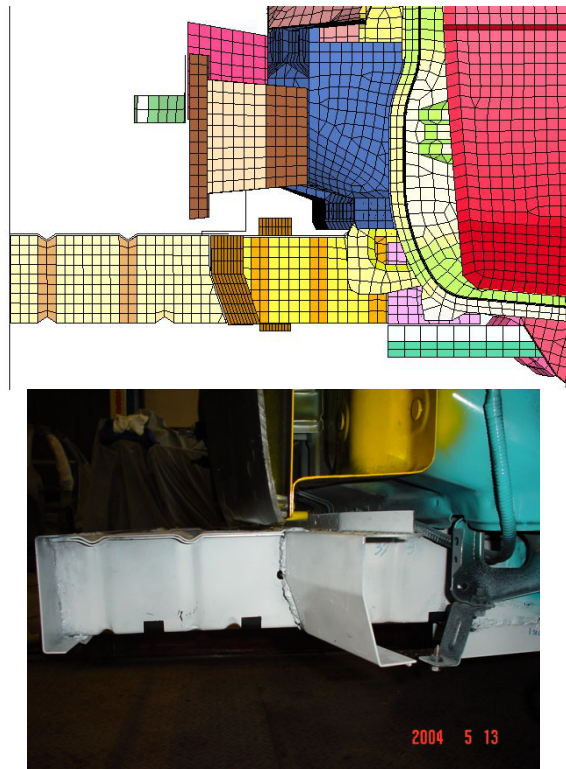


Figure 13: Side views of the full vehicle model and the test vehicle

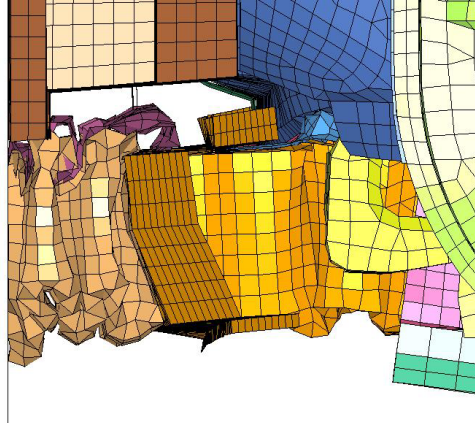


Figure 14: Side views of the full vehicle model and the test vehicle after the frontal collision

SUMMARY AND CONCLUSIONS

The approach by adding additional frontal rails, beads and holes to improve the energy absorbing rate of the frontal rails and decrease the deformation of the passenger compartments had been developed and the FEM simulation results had been compared with the real vehicle frontal collision test.

Due to the difficulties of redesigning the whole structure of the vehicles and the limitations from manufacturing such as the changing the thickness and the cross section of the rail and the welding positions, it is clear that the car manufacturer gain a great benefit on the cost and timing by utilizing the FEM package to modify the structure of the vehicle to improve the safety of this type of vehicle.

The future work will cooperate the manufacturing and focus on the effects of changing the cross section and the thickness of the frontal rails to find out the better trade off between safety and cost.