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Evaluation of the Robustness of Intrusion Beam and Biw Structure of Passenger Car through Side Impact Collision

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Abstract - *The traffic accidents are one of the leading causes of mortality in modern society. Notably, side-impact collisions are the second leading cause of death and injury. Side-door beams were developed to reduce the velocity and depth of door intrusion into the passenger compartment in side impact crashes. Side-door beams is significant for reducing occupant fatalities and serious injuries. The capability of impact energy absorption of side-door beams is discussed herein. The main objective of this project is to protect the occupant and reduce the damage in side impact collision in pole and mobile barrier impact collision. This can be achieved by introducing or replacing the circular intrusion beam to "S" shape intrusion beam as well as replacing the conventional material to "Docol" for BIW Structure.*

Key Words: **DOCOL, Intrusion Beam**

1. INTRODUCTION

The traffic accidents are one of the leading causes of mortality in modern society. Car safety became the important issue. Notably, side-impact collisions are the second leading cause of death and injury in the traffic accidents after frontal crashes. Side impacts are the most common and regularly result in extremely dangerous crashes and these are classified as

- Vehicle to vehicle (Mobile Barrier Impact)
- Vehicle to narrow object impact. (Pole Impact)

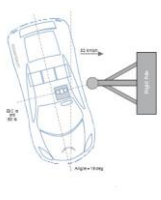


Fig. 1 Pole impact

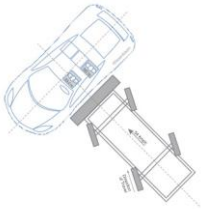


Fig. 2 Barrier Impact

1.1 Objective of the Project

The main objective of this project is to protect the occupant and reduce the damage in side impact collision in pole and mobile barrier impact collision. This can be achieved by introducing or replacing the circular intrusion beam to "S" shape intrusion beam as well as replacing the conventional material to "Docol" for BIW Structure. And also overcome challenging environments in the automotive industries they are as follows.

- Light weight vehicle.
- To increase fuel efficiency.
- To decrease the overall cost of the vehicle.

2. Geometric Modelling

Yaris is a car manufactured by the Toyota Motor Corporation it is a four door sedan. Yaris is powered by 4 cylinders 1.5 liter petrol engine coupled with 4 speed automatic transmission. It is a front wheel drive car. The exterior dimensions are as follows length 4300, width 1690mm, height 1460mm wheelbase 2550.

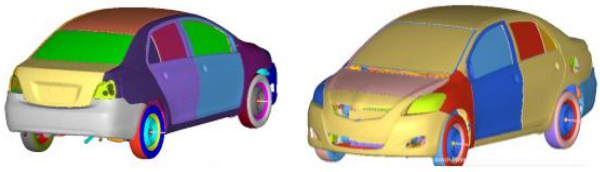


Fig. 3 Toyota Yaris

2.1 Circular Intrusion Beam:

An Intrusion beam is a safety device, installed in the car doors of vehicle, The role of an intrusion beam is to absorb the kinetic energy of the colliding vehicles The Yaris has a circular intrusion beam of length 928mm, outer diameter of 34.746 and inner diameter of 30.546 i.e. thickness 2.1mm.

Fig. 4 Circular Intrusion Beam

2.2 "S" Shaped Intrusion Beam:

Length of beam is 1000 mm the strengthening region, It is 55 mm wide in narrowest section and 105 mm wide in widest

section. The thickness of the three dimensional is 3.2 mm is constant throughout the whole structure.

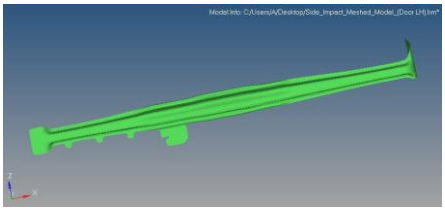


Fig. 5 'S' Shape Intrusion Beam

2.3 Impactor

There are two types of Impactor we are going to use in this project

- Pole Impactor
- Mobile Barrier Impactor

2.3.1 Pole Impactor

Pole Impactor consists of a cylindrical rigid pole of diameter 254 mm ± 3 mm (10 inch). The pole is aimed at the head of the front seat occupant.

Fig. 6 Pole impactor

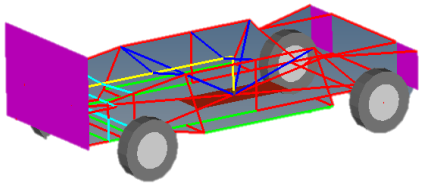


Fig. 7 Barrier Impactor

2.3.2 Mobile Barrier Impactor

Side impact mobile barrier Impactor mainly consist honeycomb structure covered by aluminum sheet. The total weight of the barrier Impactor trolley is around 1368kg and dimensions are 1500*500mm as shown in the figure.

3. Finite element modeling

Sheet metal parts are meshed using shell element quad4 with an average element size of 8mm. Triangular elements tria3 are also allowed in the finite element mesh in order to allow good mesh quality. Casting parts are meshed using solid element hex8 element. Engine block and battery are meshed with average element size of 25mm and other parts are meshed with average element size of 10 mm.

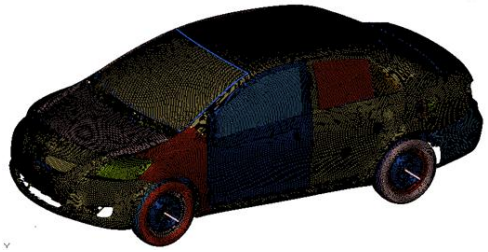


Fig. 8 Meshed Model

4. Martial

Parts	Material	Young's Modulus (E) (Mpa)	Yield Strength (S) (Mpa)	Poisson's Ratio	Density Ton/mm^3
BIW, Door Panels, Other Sheet Metal Parts	Low Carbon Steel	200000	271	0.3	7.890e-9
Intrusion Beam	Low Carbon Steel	200000	800	0.3	7.89e-9
	Docol 1000 Dp	200000	1100	0.3	7.89e-9
Engine Parts and Other Casting Parts	Cast Iron	200000	240	0.3	7.89e-9
Seats	Flexible Polymer Foam (LD)	3	0.3	.25	6.11e-11
Dash Board and Other Plastic Parts	Acrylonitrile Butadiene Styrene	1000	20	0.3	4.0e-10

Table -1 Materials

5. Simulation

In this project we conducted four simulations

- Pole impact with circular intrusion beam(Low carbon steel)
- Pole impact with 'S' shape intrusion beam(Low carbon steel)
- Mobile barrier impact 'S' shape intrusion beam (Low carbon steel)
- Mobile barrier impact 'S' shape intrusion beam (Docol)

5.1 Pole Impact with Circular Intrusion Beam (Low Carbon Steel)

Model setup for Pole Impact with Circular Intrusion Beam (Low Carbon Steel) is as shown in the figure .which consists of two part pole and car. Car wheels are constrained in all degree of freedom and 450mm displacement is applied to the pole in global X axis. In this setup circular intrusion beam is used to carry out the simulation.

5.2 Pole Impact with 'S' shape Intrusion Beam (Low Carbon Steel)

Model setup for Pole Impact with 'S' shape Intrusion Beam (Low carbon steel) is as shown in the figure which consists of two part pole and car. Car wheels are constrained in all degree of freedom and 450 mm displacement is applied to the pole in global X axis. in this setup 'S' shape intrusion beam is used to carry out the simulation.

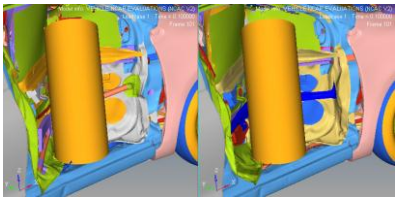
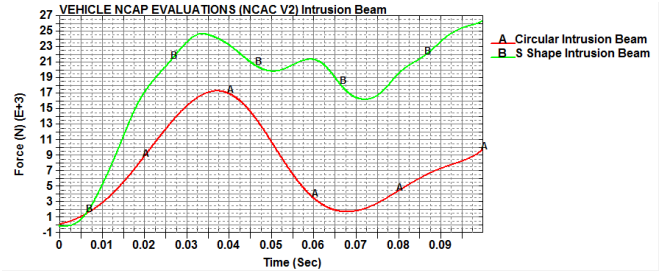


Fig. 9 Intrusion beam Impact

5.3 Results and Discussion

5.3.1 Forces induced in Intrusion beam

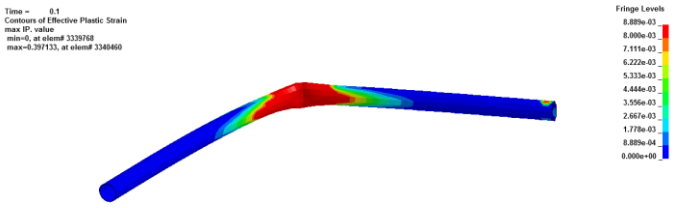
The below graph shows the forces induced in the during pole impact .The force 18 KN is induced in the circular type of intrusion beam whereas the force 26KN is induced in the 'S' shape intrusion beam. This proves there is an increase of 30.7% force observation in 'S' shape intrusion beam. This proves that the 'S' shape intrusion beam is best suitable for to implement in barrier impact.



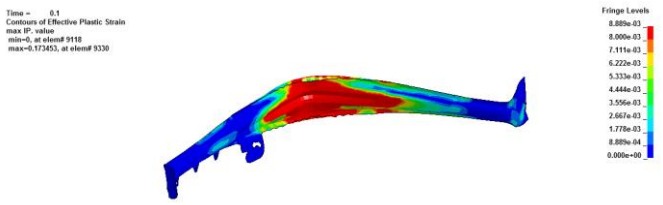
Plot 1 Forces in Intrusion Beam

5.3.2Strain plots of Intrusion beam

Effective strain induced in the circular intrusion beam is 39.75% where 17.3% of strain is observed by 'S' shape intrusion beam.



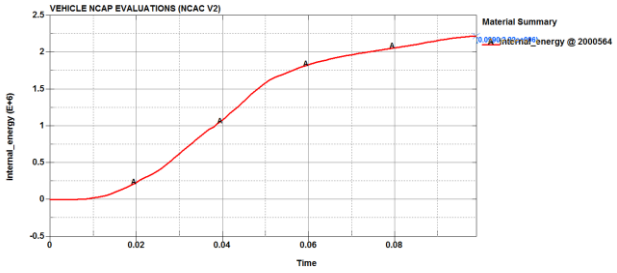
Plot 2 Strain in circuler beam



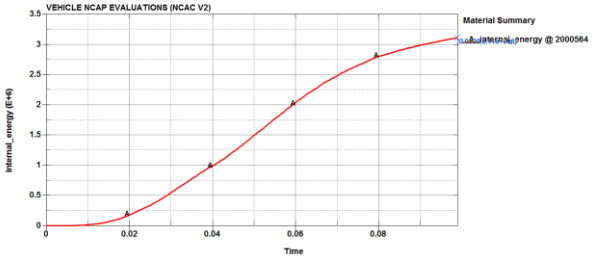
Plot 3 Strain in 'S' Shape beam

5.3.3Internal energy plot of intrusion beam

The energy absorbed by circular intrusion beam in pile impact is 22KJ whereas the energy absorbed by 'S' intrusion beam is 33KJ. 33.33% more internal energy is absorbed by 'S' shape intrusion beam. This proves the implementation of 'S' shape intrusion beam for barrier impact.



Plot 4 Internal Energy in Circular beam



Plot 5 Internal Energy in 'S' Shape beam

5.4 Mobile barrier impact 'S' shape intrusion beam (Low carbon steel)

Model setup for Mobile barrier Impact with 'S' shape Intrusion Beam (Low Carbon Steel) is as shown in the figure which consists of two part Barrier and car. Car wheels are constrained in y direction and displacement is applied to the Barrier in global X axis.

5.5 Mobile barrier impact 'S' shape intrusion beam (Docol)

Model setup for Mobile barrier Impact with 'S' shape Intrusion Beam (Docol) is as shown in the figure which consists of two parts, Barrier and car. Car wheels are constrained in Y direction and displacement is applied to the Barrier in global X axis.

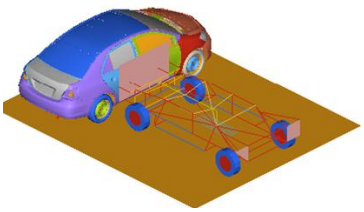


Fig 10 Barrier Impact

5.6 Results and Discussion

5.6.1 Weight reduction

It explains the weight of the car due to change of material of Biw from low carbon steel to Docol. The percentage of reduction in Docol Biw car is 20% compare to low carbon steel.

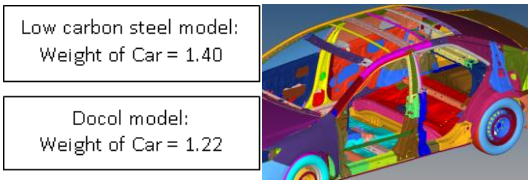
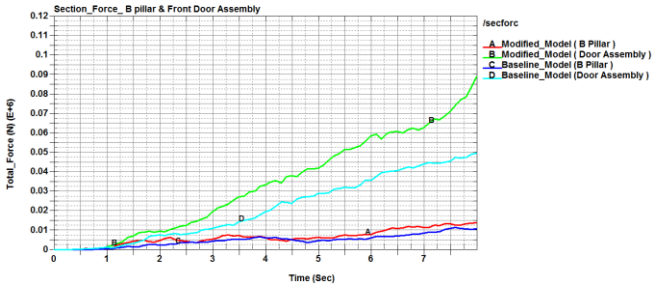


Fig 11 BIW Weight Reduction

5.6.2 Section force plot of B pillar and Door assembly

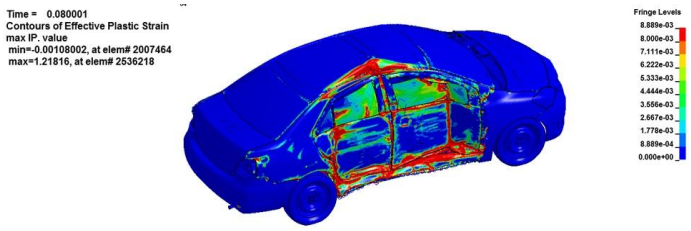
It explains the section forces induced in B pillar and Door assembly. The forces induced in low carbon steel B pillar are 8 KN whereas the forces induced in Docol B pillar is 10 KN. The percentage of increase in absorption criteria of B pillar is 12.5%.Where in Door assembly the force induced in low carbon steel is 50 KN and the force induced in Docol door assembly is 90 KN. The percentage of Increase in complete door assembly is 44.4%. This proves that changing the material from steel to Docol has increased the energy absorption criteria in barrier impact.



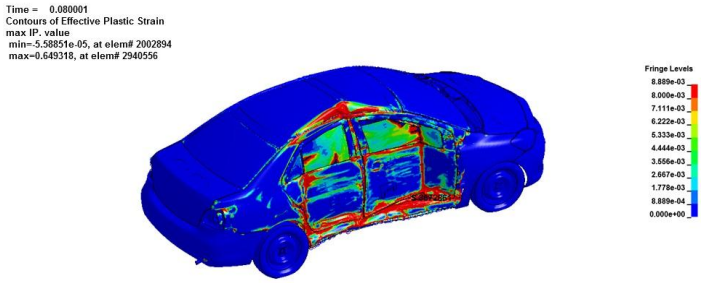
Plot 6 Section Force in B Pillar

5.6.3 Effective plastic strain plots

The below figure explains the effective strain plots in car models. The low carbon steel car shows 121.8% of plastic strain where the Docol car model shows the plastic stain of 64.9%. This explains the strain energy plot for the low carbon steel and Docol material from the figure the absorption of internal energy higher but percentage of permanent deformation is lower in Docol material.



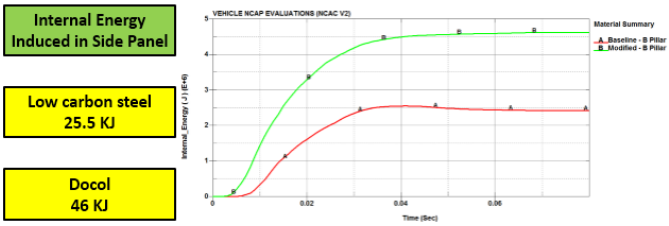
Plot 7 Strain plot low carbon steel



Plot 8 Strain plot Docol

5.6.4 Internal energy in side panel

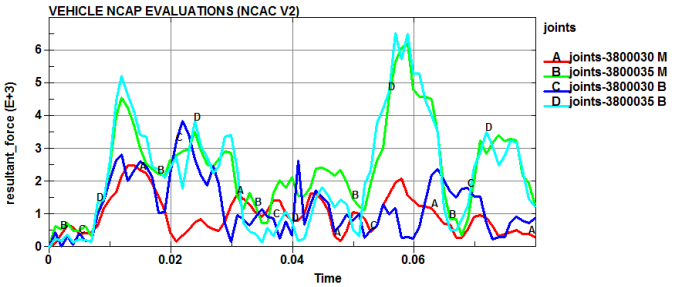
The internal energy absorbed by low carbon steel side panel is 25 KJ whereas the the internal energy absorbed by Docol side panel is about 46 KJ. The percentage of increase is 45.56% is seen in the Docol side panel



Plot 9 Internal Energy in Side Pannel

5.6.5 Spot weld forces

It explians the forces induced in spot weld connection of Door assembly. The docol material spot weld force is 6 KN whereas low carbon steel matreial is 6.5 KN. 7.6% lesser forces are trasmitted to spot welds which proves the docol is better than the low carbon steel and helps in inprove failure crteitria of spot weld.



Plot 10 Spot Weld

6. Summary of results

A. Pole Impact

Parameter	Low carbon steel circular intrusion beam	Low carbon steel 'S' shape intrusion beam	Increase/Decrease in percentage
Stress induced in intrusion beam	18 KN	26 KN	30.7% (increase)
Effective strain	39.7%	17.3%	22.4% (Decrease)
Internal energy	22 KJ	33 KJ	33.33% (Increase)

Table -2 Pole impact Summary

B. Barrier Impact

Parameter	Low carbon steel 'S' shape intrusion beam	Docol 'S' shape intrusion beam	Increase/Decrease in percentage
Weight	1.4 Ton	1.22 Ton	20% (Decrease)
Section force in B pillar	8 KN	10 KN	12.5% (Increase)
Section force in door assembly	50 KN	90 KN	44.4% (Increase)
Strain plots	121.8%	64.9%	56% (Increase)

Table -3 Barrier Impact Summary

7. CONCLUSION

By introducing the Docol material in the BIW structure of the vehicle body we can see many changes in the behavior. The changes are as follows:

1. The intrusion beam play measure role in force absorption. The force 18 KN is induced in the circular type of intrusion beam whereas the force 26KN is induced in the 'S' shape intrusion beam. This proves there is an increase of 30.7% force observation in 'S' shape intrusion beam.This proves that the 'S' shape intrusion beam is best suitable for to implement in barrier impact.
2. The effective strain induced in the circular intrusion beam is 39.75% of strain where 17.3% of strain is observed by 'S' shape intrusion beam during pole impact.
3. The energy absorbed by circular intrusion beam is 22KJ whereas the energy absorbed by 'S' intrusion beam is 33KJ. 33.33% more internal energy is absorbed by 'S' shape intrusion beam during pole impact. This proves the implementation of 'S' shape intrusion beam for barrier impact.
4. There is 20 % of weight reduction due to change in Biw material from low carbon steel to Docol.
5. The forces induced in low carbon steel B pillar is 8 KN whereas the forces induced in Docol B pillar is 10 KN. The percentage of increase in absorption criteria of B pillar is 12.5% during barrier impact.
6. Door assembly the force induced in low carbon steel is 50 KN and the force induced in Docol door assembly is 90 KN. The percentage of Increase in complete door assembly is 44.4% during barrier impact.
7. The low carbon steel car shows 121.8% of plastic strain where the Docol car model shows the plastic stain of 64.9%. This explains the strain energy plot for the low carbon steel and Docol material.
8. The internal energy absorbed by low carbon steel side panel is 25 KJ whereas the internal energy absorbed by Docol side panel is about 46 KJ. The percentage of increase is 45.56% is seen in the Docol side panel during barrier impact.
9. The docol material spot weld force is 6 KN whereas low carbon steel matreial is 6.5 KN. 7.6% lesser forces are trasmitted to spot welds which proves the docol is better than the low carbon steel.

By these conclusions we can say that the modified Model with Docol 'S' shape intrusion beam is safe and improves the Crashworthiness of the vehicle.

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