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DESIGN AND ANALYSIS OF A COMPOSITE BEAM FOR SIDE IMPACT PROTECTION OF A CAR DOOR

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Abstract –

Side Impact crashes can be generally dangerous because there is no room for large deformation to protect an occupant from the crash forces. The side impact collision is the second largest cause of death. Day by day increase in the fuel cost and the emission of the smoke from the automobile industry are also the major concerns in the contemporary world, hence the safety, fuel efficiency and emission gas regulation of the passenger cars are important issues in contemporary world. The best way to increase the fuel efficiency without sacrificing the safety is to employ composite materials in the body of the cars because the composite materials have higher specific strength than those of steel. Increase in the usage of composite material directly influences the decrease in the total weight of car and gas emission. In this thesis, Carbon/Epoxy AS4/3051-6 is used as material for side impact beam which has adequate load carrying capacities and that it absorbs more strain energy than steel. The Finite Element models of a car door and the Moving solid block have been utilized for the analysis in this thesis. The current side impact beam is removed from the car and the new beam which is developed using CATIA is merged on to the driver side of the front door of the car model. The total energy absorption of the new beam with steel and composite material is compared with the current beam. The intrusion of the beam is evaluated by using FMVSS 214 side impact safety methods. Total energy absorption of the current beam, new beam with steel and composite material will be compared. Effectiveness of the above beams will be compared by testing the beams according the FMVSS 214 side impact protection test methods. By implementing the new side impact beam the effect of intrusion of the side door will be analyzed. There is considerable effect in the weight of the beam will be analyzed.

Key words: CATIA***, ANSYS, FEM, Ribs***

1. INTRODUCTION

Crashworthiness is the ability of the vehicle structure to sustain impact loading and to prevent the occupant injuries at the time of accidents. Side impact crash is generally dangerous, since there is no room for large deformation of the vehicle structures. The side impacts is the second most common type of vehicle impacts after frontal impact that results in injuries to occupants which account to 25 percent of fatalities due to impacts between passenger cars and light trucks and approximately 30 percent between passenger car crashes [1]. The fuel efficiency and gas emission regulation of the passenger are also very important in the contemporary world. Every day the price of the fuel and the requirement of the fuel is increasing randomly, eventually emission of chemicals from the vehicle exhaust pollute the environment and increase the global temperature. Therefore the safety and gas emission regulation of passenger car are very important issues in automotive industry. They directly impact the final vehicle design. The manufacturers meet the requirements of a particular crashworthiness standard and fuel efficiency by making the approximate design change in their vehicle structure and by introducing necessary structural components that satisfy the overall design objectives

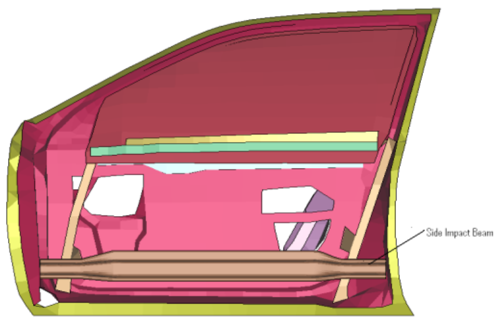


Figure1: Door with Side Impact Beam

The present vehicle standard requires each door to resist crash forces that are applied by loading solid block. The manufacturers are generally required to meet the requirement of the side door strength by reinforcing the doors with door beams (intrusion beam). The main function of the side-impact beam is to provide the occupant with a high level of safety.

1.1 Federal Motor Vehicle Safety Standard (FMVSS 214) 1

Side Impact Protection was amended in 1990 under the Federal Motor Vehicle Safety Standard (FMVSS) 214 to guarantee the occupant protection in a crash test that simulates a serious perpendicular collision. Since the Side Impact caused 33 percent of fatal injuries in 1993 to passenger car occupants, it was manifested to new passenger car models during the year 1994 to 1997. It is among the most critical and promising safety regulation circulated by the National Highway Traffic Safety Administration (NHTSA).

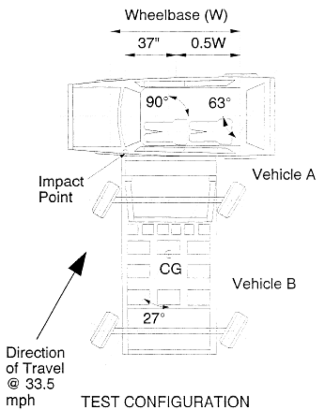


Figure 2 : FMVSS 214 Test Configuration

The present FMVSS 214 is the outcome of many years of research to manufacture the passenger vehicle less susceptible to Side Impacts, and mainly to reduce casualty to the nearside occupant during the vehicle struck by another vehicle near door area, which is primary responsible for the majority of side-impact casualties.In this test procedure the crash is similar to the one used in Federal Motor Vehicle Safety Standard (FMVSS 214) but the wheels on the moving deformable barrier(MDB) are aligned with the longitudinal axis of the cart(zero degrees) to allow for 90 degree impact with velocity of 50 Kmph (31 mph) [3].

1.2 Objective 2

The main object of this research work is to replace the current side impact beam with the better design and using a composite material instead of steel in order to reduce the total weight of the car without sacrificing the safety of the passenger. Therefore in this study in accordance with the basic principles of crashworthiness which state that the intrusion of the striking vehicle should be minimum and the energy absorbing capability of the deforming structure should be high, the usage of the composite side impact beams on the car door has been proposed and its effectiveness in reducing intrusion has been evaluated.

1.3 Methodology 3

This project begins with the development of the better designed side impact beam, then comparing the new steel beam with a current steel beam for total energy absorption. The material property of the new beam is changed from steel to carbon fiber composite. The material orientation and thickness of the composite beam is found out by finding the total energy absorption and peak load. Effectiveness of the current steel beam, new steel beam and new beam with composite material is found out by finding the intrusion and acceleration at the center of the beam by implementing them into the finite element model of Ford Taurus car and tested according to the FMVSS 214 and IIHS.

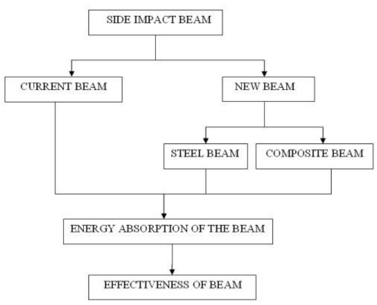


Figure 3 : Methodology

2 LITERATURE REVIEWS 2

2.1 Requirements of Side Impact Beam 1

Federal Motor Vehicle Safety Standards (FMVSS) No. 214 establishes the minimum strength required for side doors of passenger cars. The side doors must be able to withstand 0an initial crush resistance of at least 2,250 pounds after 6 inches of deformation, and intermediate crush resistance of at least 3,500 pounds(without seats installed) or 4,375 pounds(with seats installed)after 12 inches of deformation and a peak crush resistance of two times the weight of the vehicle or 7,000 pounds whichever is less(without seat installed) or 3-1/2 times the weight of the vehicle or 12,000 ponds whichever is less(with seats installed) after 18 inches of deformation [1].The major factors in considering the materials for the side door are load path and maximum resisting load of the door.

2.2 Side Impact Protection 2

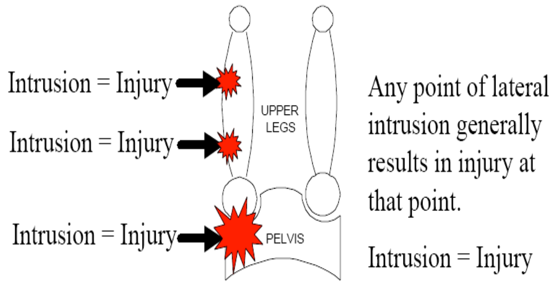


Figure 4 : Injury Pattern in Side Impact

2.3 Energy Absorbed Per Unit Mass. 3

The energy absorbed per unit mass, or specific energy absorption, E, is defined as he energy absorbed by crushing E, per unit mass of deformed structure. Using the notation of Fig,

$$E_S = \frac{E}{\rho \delta A_{mat}} = \frac{\int_0^{\delta} F dx}{\rho \delta A_{mat}}$$

For the ease of analysis, Eq.1 is often estimated using an average collapse load, $\bar{F}$ or n average collapse stress $\bar{\sigma}$. This approximate E_S, given in Eq 2 is sometimes known as specific sustained crushing stress [8].

$$E_S \approx \frac{\bar{F}}{\rho A_{mat}} = \frac{\bar{\sigma}}{\rho}$$

Specific energy absorption is an especially useful measure for comparing the energy absorption capabilities of different materials for structures in which weight is an important consideration.

2.4 Energy Absorbed Per Unit Volume.4

The energy absorbed per unit volume will be of interest in situations in which the space available for energy absorption deformation zone or device is in some way restricted. It may also be appropriate when mechanisms other than deformation of the parent material contribute significantly to a structure's overall energy absorption capability.

2.5 Energy Absorbed Per Unit Length.5

The energy absorbed per unit length, E_L is defined as the energy absorbed per unit of deformation distance. This can be expressed as;

$$E_L = \frac{E}{\delta}$$

2.6 Energy Absorption Capability of Composites 6

The energy absorption capability [8], [9], [10] of the composite structure mainly depends on the Fiber Material –The brittle nature of the fiber results in more energy absorption rather than the ductile nature of the fiber, which fails by progressive folding.

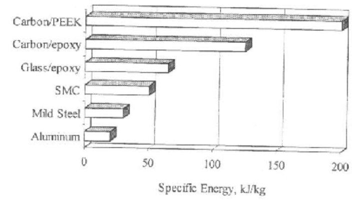


Figure 5: Specific Energy of Different Materials [11]

The composite materials have high specific energy absorption when compared to steel.

3.1 Design considerations of the Side Door Impact Beam 1

The strength of the beam depends on the section modulus. Section modulus (Z) is defined by
Z = I/Ymax
I=Moment of Inertia
Ymax=distance from the Neutral axis
The new beam is designed in accordance to fit the existing door. The new beam contains the double S curved side wings which offer additional strengthening, which cause the deflection to decrease. Some part of the beam is under tension and some part of the beam under compression, so the spring back effect is more in such a type of cross sections. The largest proportion of the absorbed energy, taken upon by side wings is in plastic region of the material deformation. It is expected that the side wings will curve inward under the applied load. Smooth passage from one cross section to the other ensures that high stress concentration is avoided [2].

3.2 MODELING OF SIDE IMPACT BEAM AND DOOR USING CATIA 2

Modeling of Impact Beam is done by "Manufacturing Methodology" which is called as "Party Body" method. This method is used by various automotive companies like "Hyundai", "Tata Motors", etc.This process uses "Boolean Operation" of CATIA, which includes the process like add, subtracts, assemble and remove.

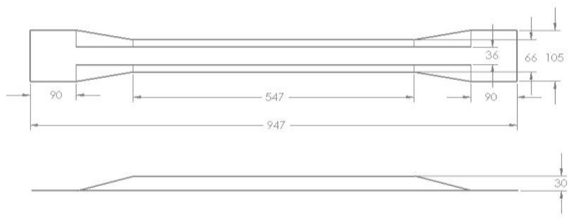


Figure 6: Dimensions of Current Side Impact Beam

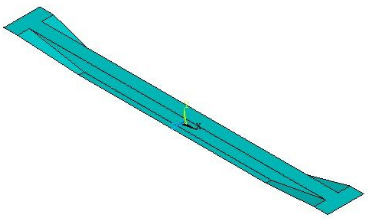


Figure 7: Current Side Impact Beam

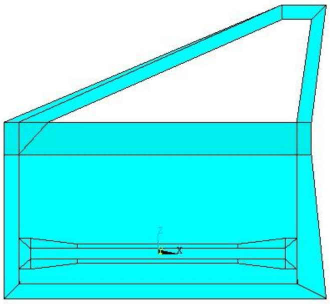


Figure 8: Current Side Impact Beam with Door

3.3 Comparison of Current Beam with New Beam 3

Current beam has C cross section and the new beam has double S cross section. Current beam has uniform width throughout but the new beam has more strengthening in the middle.

4.1 ELEMENT TYPE 4

SHELL163 is a 4-node element with both bending and membrane capabilities. Both in-plane and normal loads are permitted. The element has 12 degrees of freedom at each node: translations, accelerations, and velocities in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes. This element is used in explicit dynamic analyses only which is called as *LS-DYNA*.

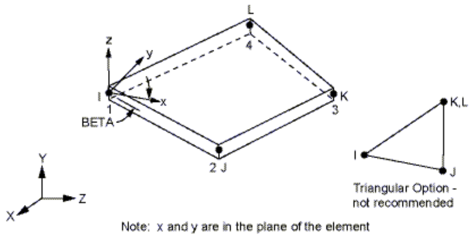


Figure 9: SHELL 163 Geometry

4.2 Material Description 2

The carbon fiber composites are light weight material because of its low density. The mechanical properties of the carbon fiber are very much suitable as they have high impact energy absorption before fail and also they have high strength requirements.

Mass Density	**1.58 g/cc**
Longitudinal Modulus E1	**142GPa**
Transverse Modulus E2	**10.3GPa**
Inplane Shear Modulus G12	**7.2GPa**
Poisson's Ratio	**0.27**
Longitudinal Tensile Strength F1t	**1830Mpa**
Transverse Tensile strength F2t	**57MPa**
Inplane shear Strength F6	**71MPa**
Longitudinal Compressive Strength F1c	**1096MPa**
Transverse Compressive Strength F2c	**228Mpa**

Table 1: Material Properties for Carbon Fiber Laminate

Mass Density	**7.8 g/cc**
Young's Modulus	**200 GPa**
Poison's Ratio	**0.3**
Yield Stress	**0.215 GPa**

Table 2: Material Property for Steel

4.3 Beam Modeling 3

The geometric modeling of the side impact beam is done by using CATIA V5 and mesh, boundary conditions, material properties and section properties are defined using Ansys LS-DYNA. The beam is uniformly meshed with 10 mm element size..

Element Length	10mm
Number of Nodes	3062
Number of Elements	1684

Table 3: Beam Model Summery

4.4 Modeling of Impact Body 4

The solid block is considered as impact body. The impact body is considered an analytically rigid body with mechanical properties of the steel. The length and breadth of the impact body are 150mm & 100mm and the height is of 100 mm. The impact body is coarse meshed with the element size of 20mm, since the number of elements does not influence the solution. Weight of the impactor is 20 kg.

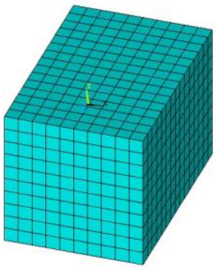


Figure 10 : Impactor

Element Size	20mm
Number of Nodes	1449
Number of elements	1280

Table 4: Impactor Model Summary

4.5 Current Impact Beam 5

The current Impact beam is C section with the length 947 mm long and 105 mm wide with a uniform thickness of 2.3 mm. The weight of the beam is 2.44 Kg. Steel is the material used.

4.7 Comparative Analysis of Impact Beam 7

The comparative analysis of the Impact beam is carried out by finding the total energy absorption of the beam under impact loading. The Beam is fully constrained at the ends. The impactor is considered as a rigid body with mass 20 kg and diameter of 200 mm cylinder. The initial height of the impactor is 20 mm from the beam. The initial velocity of 70 kmph is given to the impacter and hit the beam at the center.

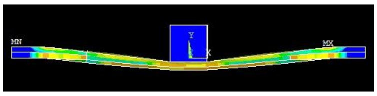


Figure 11 : New Side Impact Beam after Impact

5.1 SIMULATION RESULTS WITH SIDE IMPACT BEAM 1

Car with current impact beam is impacted by the Moving solid block according to the FMVSS 214. Figure 22 shows the finite element model of the side impact after crash. The moving solid block hits the driver side of the stationary car at an angle of 90 degrees with the longitudinal axis of the barrier at a speed of 70 kmph.

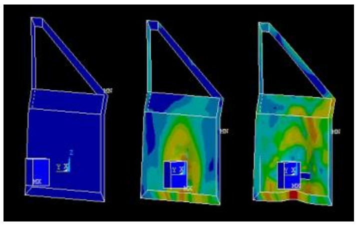
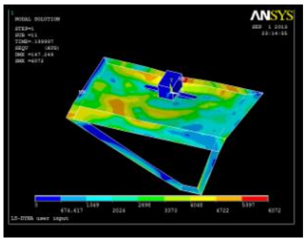


Figure12: Side Impact Model of car front door

5.2 Simulation results with current side impact beam 2



5.3Comparison of current steel beam with new steel beam 3

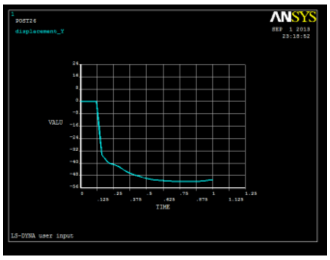


Figure 13: Displacement comparison between current

CONCLUSIONS

Total energy absorption of the current beam, new beam with steel and composite material is compared. Effectiveness of the above beams is compared by testing the beams according the FMVSS 214 side impact protection test methods. By implementing the new side impact beam the intrusion of the side door can be reduced, eventually reducing the occupant injuries. By comparing the computational results of steel beam with the composite beam it can be concluded that There is considerable reduction in the weight of the beam. Composite beam can absorb more deformational energy than steel and more effective. The reduction in weight is 65%.Composite beam is more effective for FMVSS 214 side impact protection standards. Although the composite beams fail by buckling during impact loading, by proper design, fiber orientation and fiber matrix combination buckling failure can be reduced.

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