SIDE IMPACT GLASS FIBER COMPOSITE BEAM AND ENHANCED PASSENGER CAR LATERAL IMPACT CRASHWORTHINESS

R.Rajasundaram[1], Dr.A.Dhanapal[2], M. Raja mohan[3], E. Manopriya[4]

[1]PG Scholar, [2]Principal, [3]Head of the Department, [4]Assistant Professor,
Department of Mechanical Engineering,
Sri Ramanujar Engineering College, Chennai, TN, India.

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Abstract - *Side impact crash is generally dangerous, since there is no room for large deformation of the vehicle structures. The fuel efficiency and gas emission regulation of the passenger are also very important in the contemporary world, as the emission of chemicals from the vehicle exhaust pollute the environment and increase the global temperature. Composite materials have been used in aircraft and space vehicles as they have high specific strength (Strength/Density), high specific stiffness (Stiffness/Density) and very good fatigue properties. Therefore increased usage of composite material in the automotive parts can directly influences the vehicle by weight reduction and gas emission. Glass filled composite parts can be manufactured with low cost compared to Carbon filled composites, hence efficiently designed glass filled composite side impact beams absorb very high impact load and deformation with great damping properties. The main objective of this research work is to replace the current side impact beam with the better design and using a glass filled composite material instead of traditional steel in order to reduce the total weight of the car without sacrificing the safety of the passenger and thereby improving the fuel efficiency. This study in accordance with the basic principles of crashworthiness which state that the intrusion of the striking vehicle should be minimal and the energy absorbing capability of the deforming structure should be high, the usage of the glass filled composite side impact beams on the car door has been proposed and its effectiveness in reducing intrusion has been evaluated*

*Key Words***:** Body in White (BIW), Side Impact, Cost, Safety Regulation, Performance, Door, Side Impact Test, FMVSS, Crashworthiness.

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. In United States 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.

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.

2. MODELING SIDE IMPACT BEAM

The Finite Element Method (FEM) is used for the computational analysis of the behavior of new side door impact beam under impact loading with the aim to compare the capability of the impact energy absorption in relation to a current steel impact beam. The different fiber orientation of the composite beam are analyzed in order to find the most suitable sequence in terms of strength, stiffness, absorbed energy and weight.

2.1 Design of the side door impact beam

The strength of the beam depends on the section modulus. Section modulus (Z) is defined by

$$Z = I/Y_{max}, \quad I = \text{Moment of Inertia}$$

$$Y_{max} = \text{distance from the Neutral axis}$$

The common sections used for side impact beam are circular tubes, C sections, and rectangular tubes. In all these sections resistance to the deformation is increased by increase in the thickness. 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.
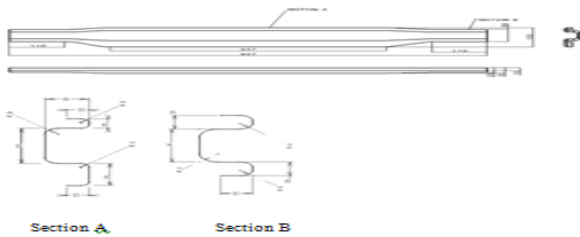

Fig -1: Dimensions of Side Impact Beam

2.2 Material Description

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. The mechanical properties of the carbon fiber composites can be changed according to the requirement by changing orientation of the fiber in the loading direction, layer stacking and by changing the volume fraction of the fiber and the matrix. Carbon fiber composite can sustain the same load as of steel even with the 40 percent of the steel weight.

Table -1: E-Glass/Epoxy and Laminate Properties

PROPERTIES	E-Glass / E-poxy	Carbon /Epoxy
Mass Density (tonnes/mm3)	2.82E-09	1.58E-09
Longitudinal Modulus E1**(Mpa)**	44800	140000
Transverse Modulus E2 **(Mpa)**	12400	10300
In-plane Shear Modulus G12 **(Mpa)**	5520	7200
Poisson's Ratio	0.28	0.27
Longitudinal Tensile Strength F1t **(Mpa)**	1035	1830
Transverse Tensile strength F2t **(Mpa)**	48.3	57
In-plane shear Strength F6 **(Mpa)**	68.9	71
Long. Compressive Strength F1c **(Mpa)**	620	1096
Trans**.** Compressive Strength F2c **(Mpa)**	137.9	228

Table -2: Material Properties for steel

Mass Density	7.85E-9
Young's	200000 Mpa
Poison's Ratio	0.3
Yield Stress	215 Mpa

2.2 Beam Modeling

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 ANSA. The beam is uniformly meshed with 10 mm element size. The beam is meshed with shell elements. The ends of the beam are constrained in all the directions both in translational and rotational. Composite S3RS/S4RS element formation is used, because it gives better results with bending stress.
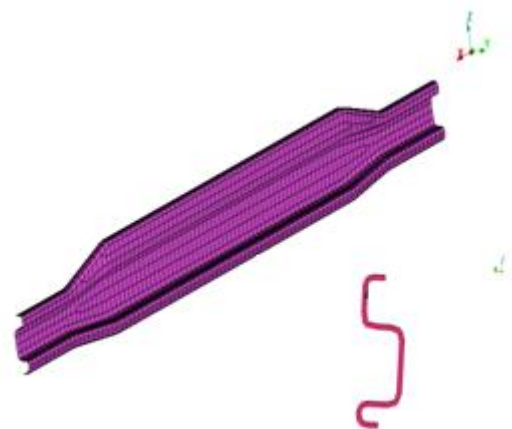

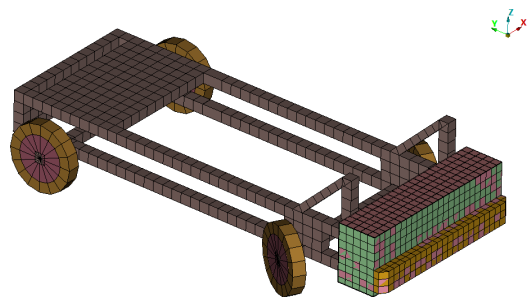**Fig -2**: Side Impact Beam mesh

Fig -3: Impactor Modeling

Mass and geometry of the MDB defined in FMVSS 214 (Side Impact) represents the general U.S vehicles. The impact angle represents the most common side impact. The relative speed and direction of the MDB and the target vehicle is considered the threshold for serious injury in actual crashes. The MDB face assembly includes a bumper constructed of honeycomb 1690+/-103 kPa sandwiched between 3.2 mm thick aluminum plates.

3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1 FMVSS 214 Test Configuration

The test Vehicle is stationary. The line of action of the Moving Deformable Barrier makes an angle of 63 degrees with the test vehicles centerline. The longitudinal centerline of the moving deformable barrier is perpendicular to the longitudinal centerline of the test vehicle when the barrier strikes the test vehicle. In a test in which the test vehicle is to be struck on its left side: All wheels of the moving deformable barrier are positioned angle of 27 degrees to right of the centerline of the moving deformable barrier.
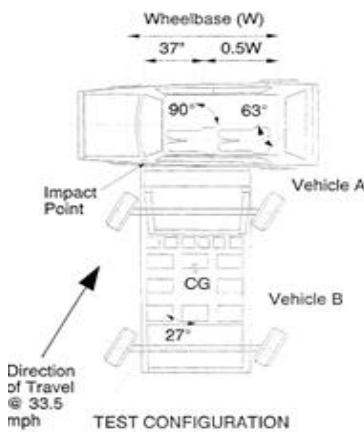

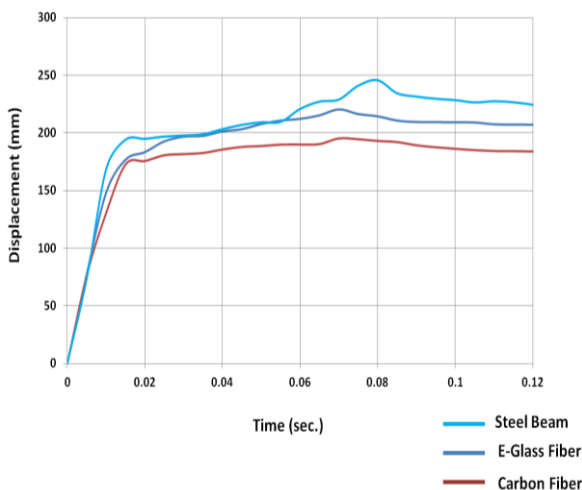**Fig -4**: FMVSS 214 Test Configuration

Fig -5: Intrusion of Beam in FMVSS214 Test

3.2 Insurance Institute for Highway Safety (IIHS) Side Impact Test Configuration

The test vehicle aligned with the Moving Deformable Barrier (MDB) is shown in the Figure 33.In IIHS test procedure the Moving Deformable Barrier strikes the stationary Ford Taurus car with a velocity of 31 mph (51 kmph). In case of IIHS the wheels of the Moving Deformable Barrier (MDB) are aligned with the longitudinal axis of the barrier to allow for 90 degree impact.
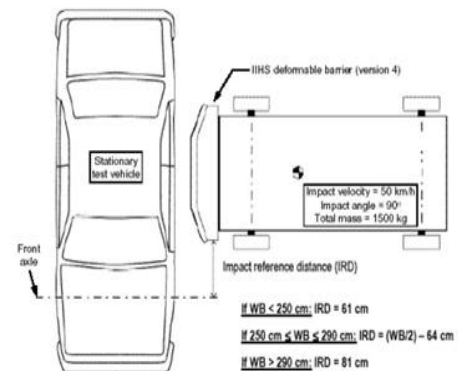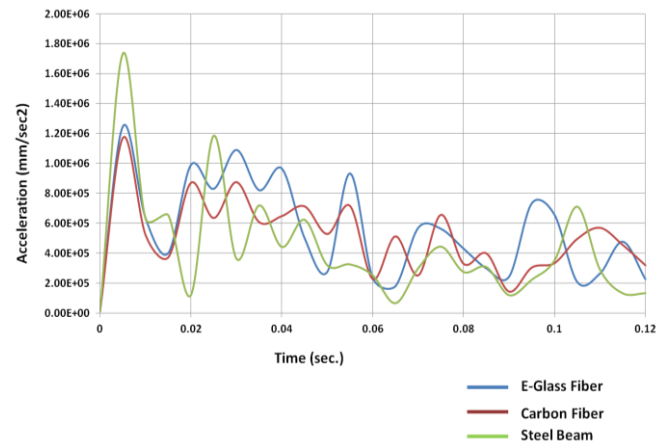

Fig -6: Test setup – IIHS side impact

Fig -7: Intrusion of Beam in IIHS Test

The intrusion in the steel beam is more when compared to the carbon and E-glass fiber composite beam. From the figure we can see that the intrusion shows clearly composite materials displacement is less as compared to steel material during the crash duration. Initially displacement will increase gradually with time then it will be constant for instance then it will reduces

Gradually because of its spring back effect due to the application of load.

4. CONCLUSIONS

By implementing the new side impact beam the intrusion of the side door can be reduced, eventually reducing the occupant injuries. The computational results of steel beam and composite beams has concluded that there is considerable reduction in the weight of the beam and absorb more deformational energy. On cost point of view glass filed composites are less expensive than carbon reinforced composites.

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