International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 01 | Jan 2021 www.irjet.net p-ISSN: 2395-0072

DESIGN AND CRASH TEST ANALYSIS OF SIDE DOOR INTRUSION BEAM

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Abstract - *Road accidents have become a threat to the entire world, due to lack of safety measures prescribed in an automobile leads to the death of person. About 8000 – 10000 peoples every year die due to Side impacted Accidents i.e., the vehicle1 hits the other vehicle 2 at an angle of 90^0 or some other angle, the passenger, or the occupant of vehicle 2 undergo the severe injury or death to lack of safety precautions taken in vehicle 2. So, in order to avoid the cause of accident, the Side Door Intrusion Beam, a beam implemented inside a car door to resist the impact force of the vehicle 1. Here the Beam is designed in such a way that it overcomes the drawback of Structural steel which is commonly used in present Automobile Industries because of its Physical and Mechanical properties and even the design like Hollow square, Hollow circular and M shaped beam are replaced with the new designs called "Hollow square beam with 5 plates and 2C Hollow square beam with 5 Plates". The Intrusion Beam which is designed are affordable to the customers who are buying the car at an affordable price and the materials used for the plates are of having very good and better Physical and mechanical properties than Structural steel.*

***Key Words*: Side Door Intrusion Beam, Catia Designs, Ansys Simulation, Structural Materials, Car door etc.**

1. INTRODUCTION

Road accidents are one of the major causes of death in India. In today's automobile development sector, car safety is the major issue. Accidents which are causing Injuries that can be controlled significantly if sufficient attention is given to accident and injury avoidance strategies. Unlike a front collision, side-impact collisions are mostly dangerous; that is, the space between an occupant and the side of the vehicle is negligible. There is engine, bumpers and so on to help to absorb the energy of the impact in a front impact. Hence, Passenger has very little safety when a vehicle is hit on its side. To develop a safe and effective passive safety device is necessary for reducing occupant injuries in a side on crash [1].

Crashworthiness is the most important safety feature which must be fulfilled by every vehicle. Vehicle crashworthiness, defined as the degree of occupant safety, when vehicle is involved in the collisions. Passenger Safety is paramount importance in modern vehicle design. Investigators in their works analyze side impacts of three types: Static door strength, car to car, and car to pole. In the first static door strength is tested to avoid the intrusion in the cabin. In the second case, impact of a vehicle moving straight or at some angles are tested with stationary vehicle are analyzed. In the third case the tested vehicle side impact against stationary fixed pole, imitating tree, lighting pole or another obstacle is analyzed [3].

Though recently in the world there are about ten independent organizations analyzing and evaluating vehicles' safety according to their own rules and standards, no united testing methods exist. Existing standards and regulations substantially differ in strictness of evaluation of tests results.[4]

Federal motor vehicle safety standards (FMVSS) require that side intrusion beams meet certain load or energy absorbing criteria for a specified lateral displacement of the door in response to a vehicle being subjected to a side impact. Reducing the cost of implementing the federal safety standards is an ever-present goal of automotive vehicle manufacturers [5].

2. STRUCTURAL REQUIREMENTS

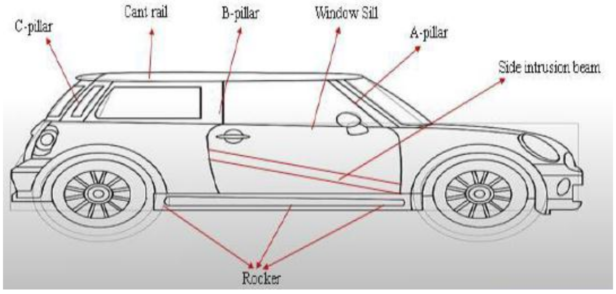


Figure-2: Side Door Intrusion Beam with Force absorbing parts

1. The transfer of energy and force depends upon the weight of the vehicle and the speed of the vehicle.
2. In side impact the upper limb injury chances are more as compared to frontal impact. Therefore, the door beam should be stiff enough to take up the load.

3. In case of side pole impact test, the vehicle car door is subjected to a concentrated load of speed 32 km/hr.
4. As per the regulation (FMVSS 214) the vehicle hits the pole at velocity of 32kmph and the door encounters the pole. In Europe and India for pole impact load case the recommended speed of the vehicle is 29kmph.
5. In case of side barrier impact the B- pillar also takes up the

load. The cant rail, rocker, seat cross member regions are also affected by the impact. Some load goes to Roof Bow on the top of the vehicle. Some load distributed to rear door beam and near C-pillar region in case of side barrier impact. For front occupant the major load comes on the intrusion beam, Cant - rail.

2.1 Components of Side Door of a Car

Car door itself includes many parts embedded inside the panel where it includes the safety units and also the technologies which would help in easy functions like Car frame, Window, Windowsill, Beam, Clamp (Brackets), Front end wall, Flange, Rear end wall, Door hardware (Speakers, Scissor linkage, Window guide rail, Window motor, Wiring).

The component needs to be ductile to avoid crack and failure that may injured the occupants although the break of the beam will reduce the velocity of impact load on the occupants.

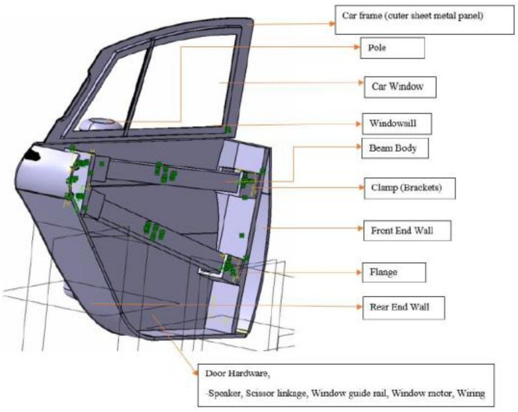


Figure-3: CATIA design and Nomenclature of Car door

3. STRUCTURAL MATERIAL

- **Structural Steel**
- **High Strength Low Alloy Steel**
- **Aluminium Alloy**
- **Sintered Silicon Carbide**

Structural Steel (SS): Is a category of steel used for making construction elements and is a cheapest metal. Higher the Tensile strength, stiffness and strength to weight ratio and is flexible enough to mold into wide variety of shapes. Light weight material and reliable to external forces.

High Strength Low Alloy Steel (HSLAS): High strength low alloy steel (HSLA steel) is an alloy that provides improved mechanical properties and greater atmospheric corrosion resistance than traditional carbon steel. These types of steels differ from 'normal' alloy steels as they are not designed to meet a specific chemical composition but to meet specific mechanical properties. To retain formability and weldability the carbon content is increase by 0.05-0.25%. Niobium can increase the strength and toughness of the material by grain refining. By addition of Vanadium transition temperature by precipitate strengthening and HSLAS have higher the Strength to weight ratio. Is 30-40% less ductile compared to Structural steel.

Aluminum Alloy 7075 T-6 (AA): 7075 Aluminium Alloy (AA7075) is an aluminium alloy, with zinc as the primary alloying element. It has excellent mechanical properties, and exhibits good ductility, high strength, toughness and good resistance to fatigue. It is more susceptible to embrittlement than many other aluminium alloys because of micro-segregation but has significantly better corrosion resistance than the 2000 alloys.

Is suited for applications that require High stress to strain ratio, Zinc as its primary alloying element, it is exceptionally strong and is super hard material. Light weight material and stronger than any other soft steel, Plasma electrolytic oxidation increases the wear resistance.

Sintered Silicon Carbide (SSC): Sintered alpha silicon carbide (SiC) is manufactured by mixing fine and pure silicon carbide powder with non-oxide sintering aids. The powdered material is compacted by using most of the conventional ceramic forming processes such as die pressing, isostatic pressing and injection molding. Following the forming stage, the material is sintered in an inert atmosphere at temperatures above 2000°C.

Density is about 40% less than Steel, low porosity, less thermal expansion, good wear and corrosion resistance.

4. METHODOLOGY:

4.1 CATIA Designs:

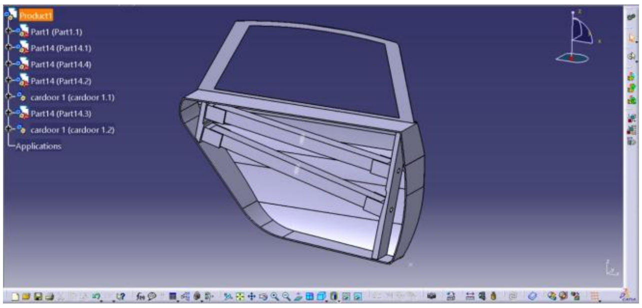


Figure-4: Isometric View of Car Door

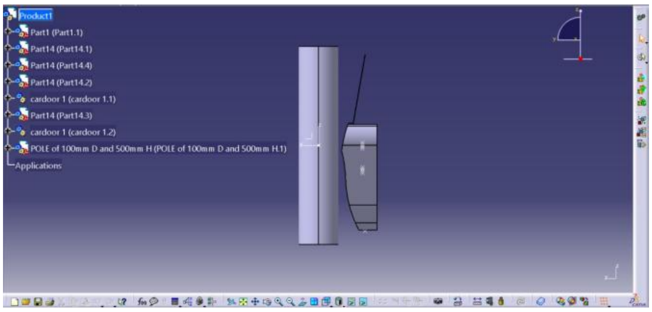


Figure-5: Side View of Car Door with Pole

The overlook of Catia Car door design consisting of Car frame, Clamps, Support, Beam and a Pole placed at few meters away from the car door. Here in this paper, we just concentrate on Beam designs (Geometry), the change in mechanical behavior of beam when the arrangement of plates of different material inside a Hollow beam is arranged based upon the requirements to achieve the best result as compared to the structural steel in terms of Physical, mechanical properties as well as the weight of the beam.

4.2 Designs of Side Door Intrusion Beam:

- **Hollow Square Beam:**

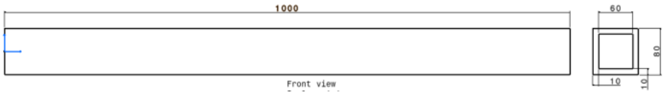


Figure-5: Hollow Square Beam

- **Circular Hollow Beam:**

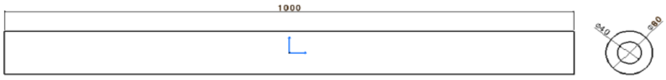


Figure-6: Hollow Circular Beam

- **I Beam:**

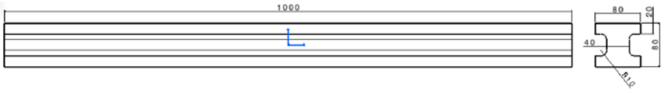


Figure-7: Taper Flange Beam

- **Solid Square Beam:**

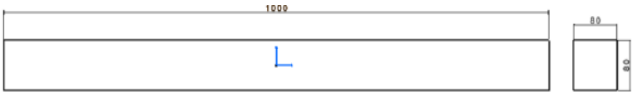


Figure-8: Solid Square Beam

- **Solid Circular Beam:**

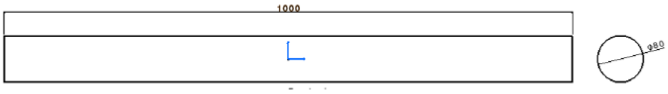


Figure-9: Solid Circular Beam

- **Hollow Square Beam with 5 Plates:**

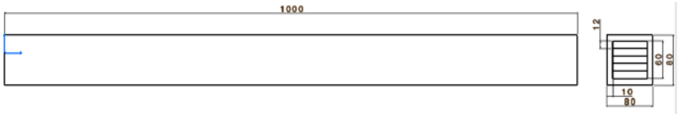


Figure-10: Hollow Square Beam with 5 Plates

- **2C Square Beam with 5 Plates**

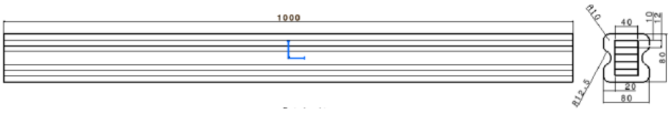


Figure-11: 2C Square beam with 5 Plates

- **Flat Plate:**

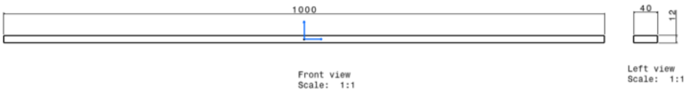


Figure-12: Flat Plate

- **Pole:**

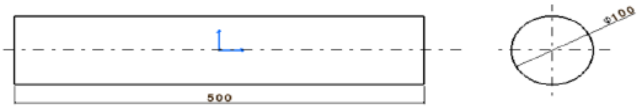


Figure-13: Pole

4.3 Construction:

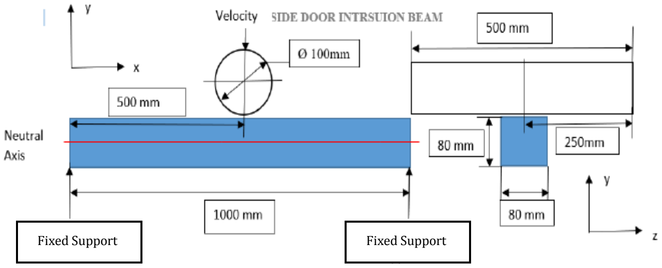


Figure-14: Fixed-Fixed, Center Load Beam Construction

Here is the placement of the Beam on the two dead corners which are the supporting unit of the beam placed at 1000mm distance apart and the Pole of 100mm in diameter is placed as shown in Figure 14, which is placed a few meters distance apart from the Beam. In short, Fixed-Fixed, center load Beam with Pole as a loading unit, which would act a axial force in the negative y-direction.

4.4 Ansys Simulation:

The initial conditions are implemented on the beam by selecting the end faces with all degrees of freedom as zero to define the beam is Fixed-Fixed Beam and as well as the Pole is given a velocity in negative z – direction as shown in figure 15. The Beam is making a deflection in the negative z – direction due to application of the unidirectional force by the

Pole at the center of the beam. The stresses in the beam is shown in different colors starting with minimum as Blue and Maximum as Red as shown in figure 16.

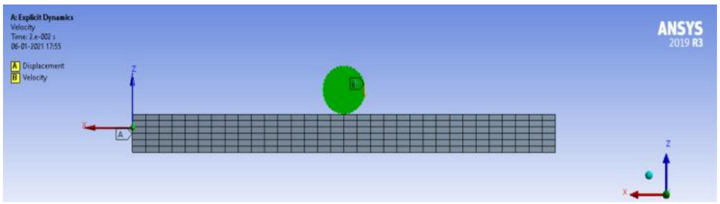


Figure-15: External Properties

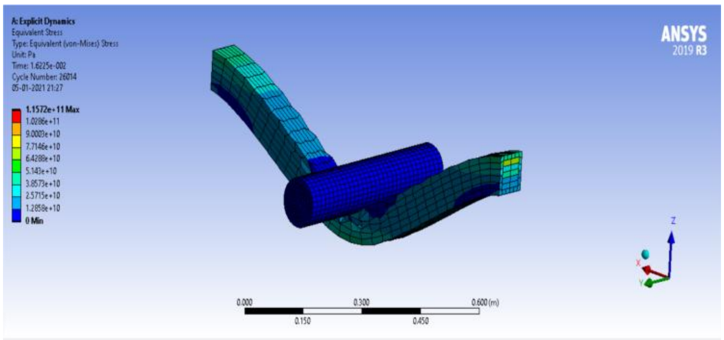


Figure-16: Maximum Stress

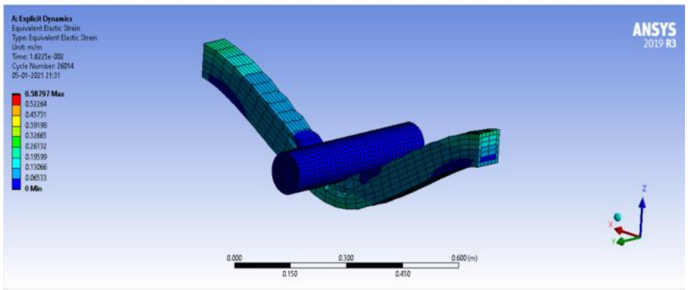


Figure-17: Maximum Strain

Similarly, the strain behavior is as shown in figure 17.

5. RESULTS AND CALCULATIONS:

In this paper, the Side door intrusion (SDI) beams which are designed in 7 different shapes using 4 different materials and 8 different arrangements of plates, among them the best beams are selected based upon the following Considerations,

1. The SDI beam should resist the externally applied force by the pole i.e, the beam should not break even after causing a unidirectional deformation of 154mm to beam.

2. Maximum Equivalent von – mises stress should be more i.e, the internal resisting force offered by the beam to the applied external force per unit area of cross section should be more. If beam breaks before 154mm of deflection the stress of beam with highest directional deformation is chosen.

3. Maximum Equivalent von – mises strain should be less i.e, the change in length to the original length should be less. If beam breaks before 154mm of deflection the strain of beam with highest directional deformation is chosen.

4. Total energy absorbed due to application of load at breaking point.

5. Bending stress developed on the surface of the beam when it is simply supported to the applied load should be more and it should be more than SS.

6. Stiffness of beam should be more than SS.

7. Specific energy consumption (SEC) i.e, the energy absorbed per unit application of load in - order to resist the deformation should be more.

Solid Square Beam:

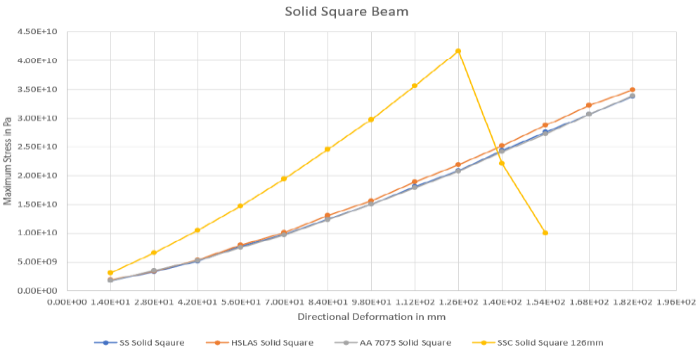


Figure – 18: Max. stress in Pa vs Direc. deformation in mm

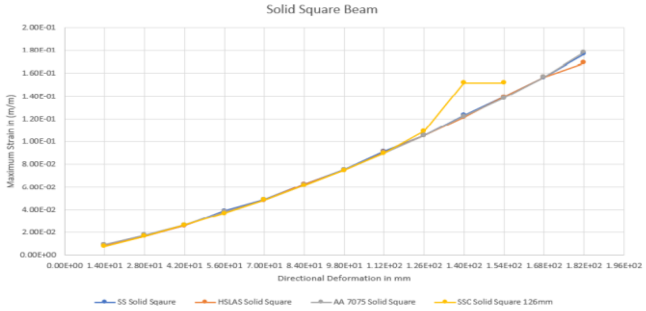


Figure – 19: Max. Strain vs Directional deformation in mm

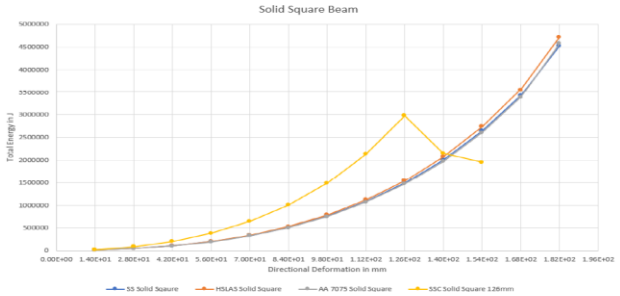


Figure – 19: Total Energy in J vs Direc. Deformation in mm

Solid Circular Beam:

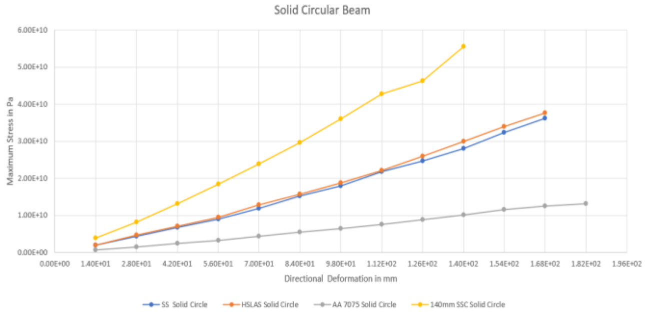


Figure – 20: Max. Stress in Pa vs Direc. Deformation in mm

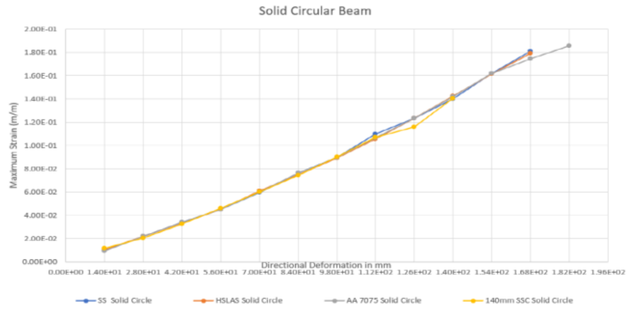


Figure – 21: Max. Strain vs Directional deformation in mm

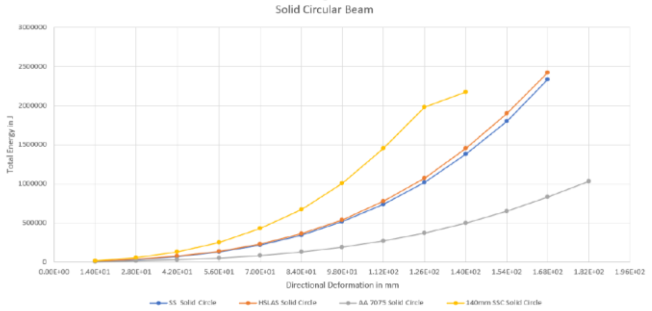


Figure – 22: Total Energy in J vs Direc. Deformation in mm

Hollow Square Beam:

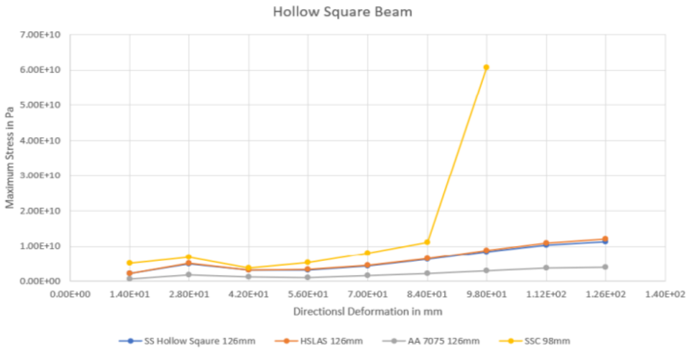


Figure – 23: Max. Stress in Pa vs Direc. Deformation in mm

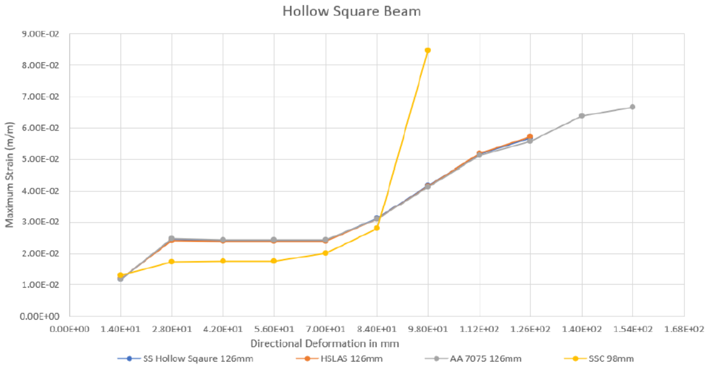


Figure – 24: Max. Strain vs Directional deformation in mm

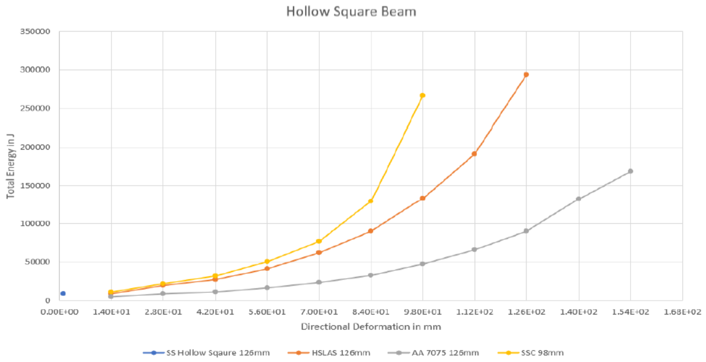


Figure – 25: Total Energy in J vs Direc. Deformation in mm

Hollow Circular Beam:

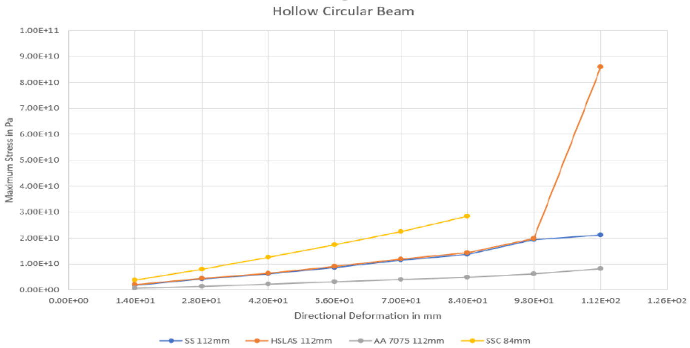


Figure – 26: Max. Stress in Pa vs Direc. Deformation in mm

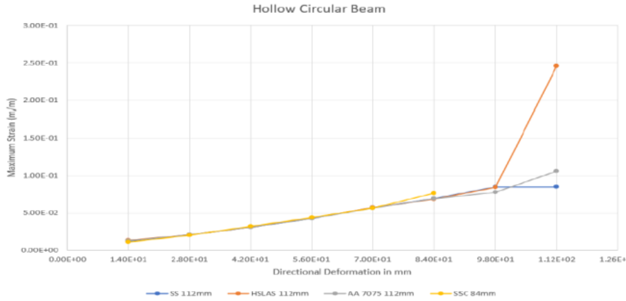


Figure – 27: Max. Strain vs Directional deformation in mm

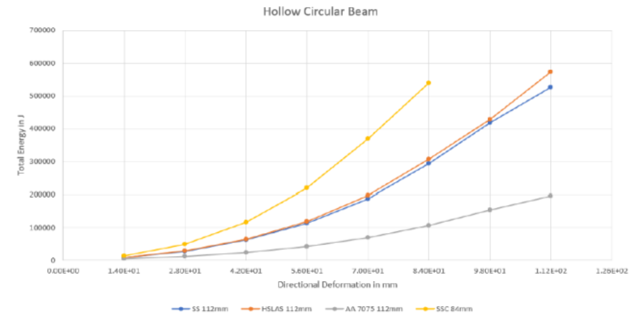


Figure – 28: Total Energy in J vs Direc. Deformation in mm

I Beam:

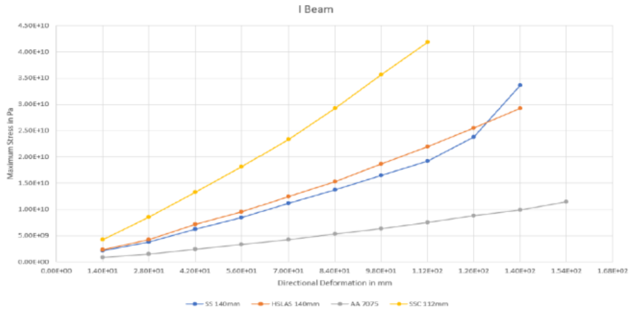


Figure – 29: Max. Stress in Pa vs Direc. Deformation in mm

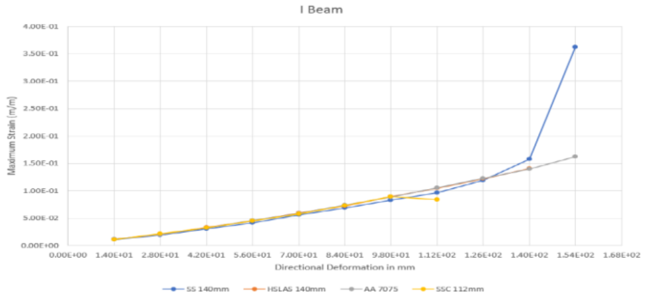


Figure – 30: Max. Strain vs Directional deformation in mm

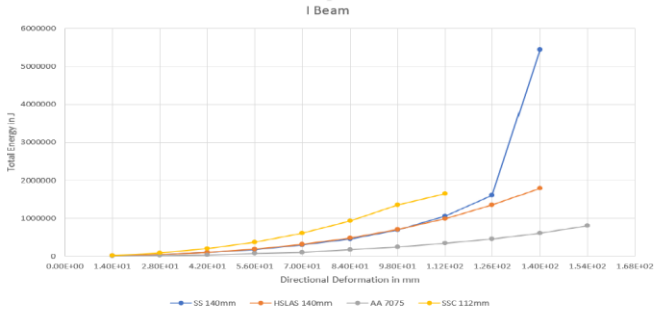


Figure – 31: Total Energy in J vs Direc. Deformation in mm

Hollow square beam with 5 plates:

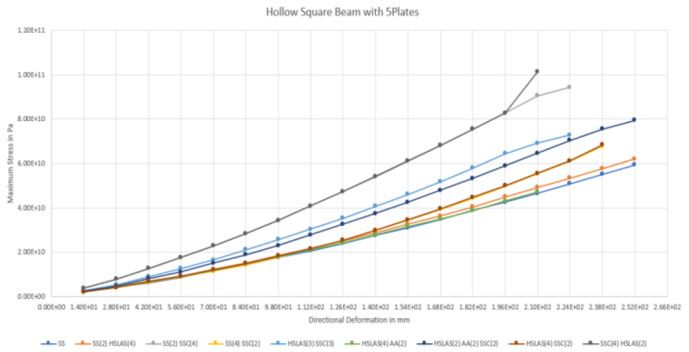


Figure – 32: Max. stress in Pa vs Direc. Deformation in mm

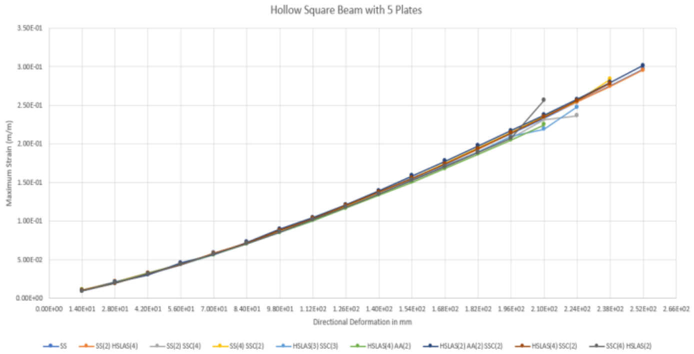


Figure – 33: Max. Strain vs Direc. Deformation in mm

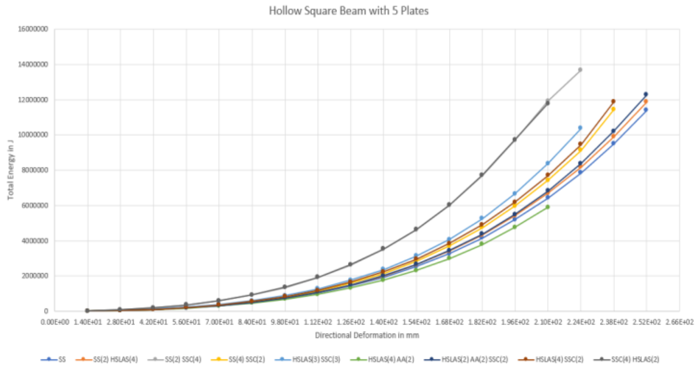


Figure – 34: Total Energy in J vs Direc. Deformation in mm

2C Square Beam with 5Plates:

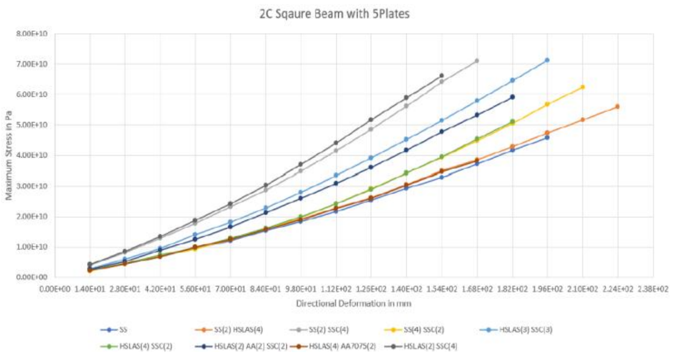


Figure – 35: Max. stress in Pa vs Direc. deformation in mm

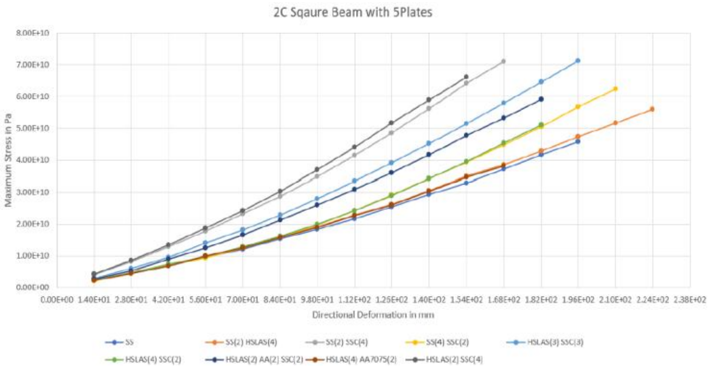


Figure – 36: Max. strain vs Direc. deformation in mm

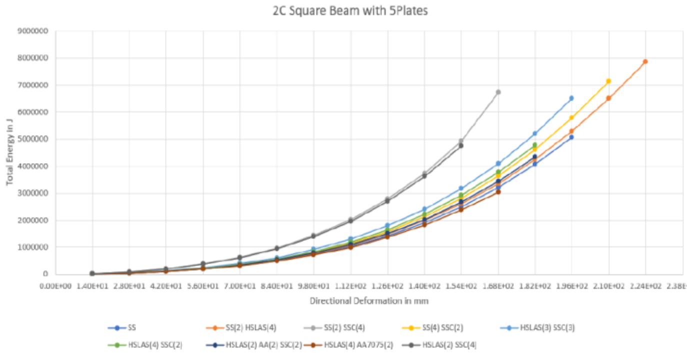


Figure – 37: Total Energy in J vs Direc. deformation in mm

Mechanical Properties:

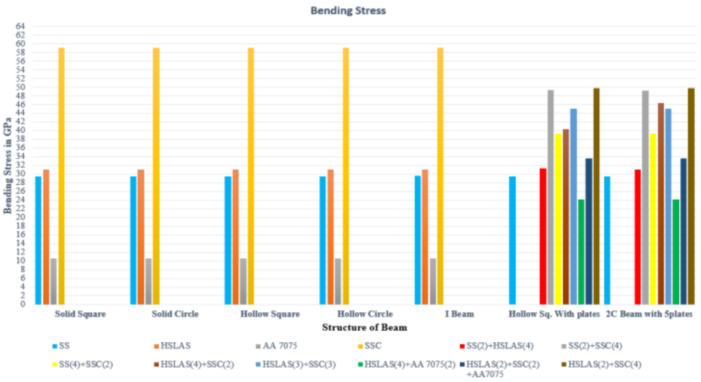


Figure – 38: Bending Stress in GPa vs Structure of Beam

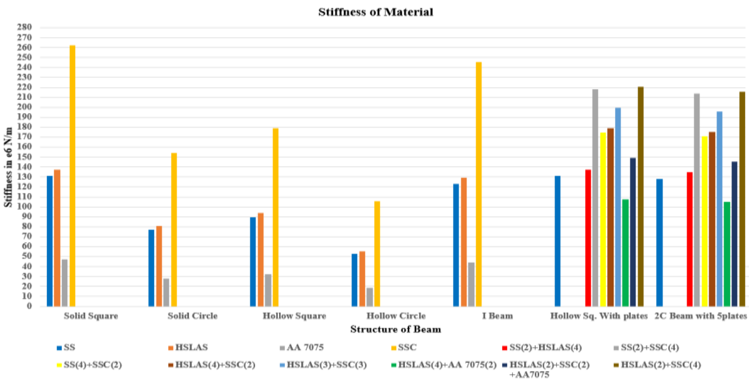


Figure – 39: Stiffness in N/m vs Structure of Beam

Specific Energy Consumption: Is expressed in terms of specific energy absorption (SEA), *Es* which is the ratio of energy absorbed to the unit mass of the material. Is defined as J/Kg.

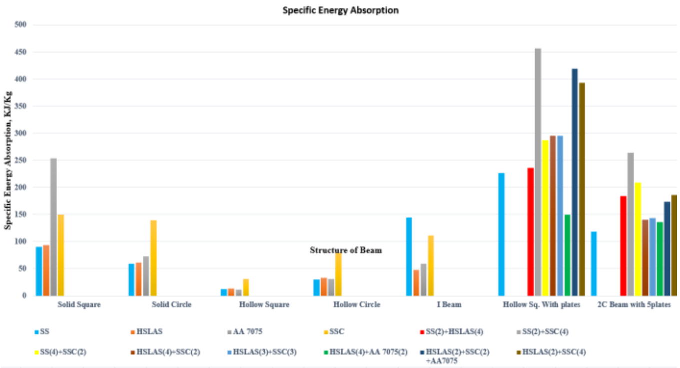


Figure – 39: Specific Energy Consumption in KJ/Kg vs Structure of Beam

Example: SS (2) SSC (4) means Hollow Plate-SSC, Plate1-SSC, Plate2-SS, Plate3-SSC, Plate4-SS, Plate5-SSC.

6. Result:

		Condition							
Beam	**Shape**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total Conditions satisfied**
SS(2) SSC(4)	X Y	+ +	+ +	+ -	+ +	+ +	+ +	+ +	13
HSLAS(2) SSC(4)	X Y	+ +	+ -	- -	+ +	+ +	+ +	+ +	11
SS(4) SSC(2)	X Y	+ +	- -	- -	- +	+ +	+ +	+ +	11
HSLAS(4) SSC(2)	X Y	+ +	- -	- +	+ -	+ +	+ +	+ +	10
HSLAAS(2) AA(2) SSC(2)	X Y	+ +	+ -	- -	+ -	+ +	+ +	+ +	10
HSLAS(3) SSC(3)	X Y	+ +	- +	- -	- +	+ +	+ +	+ +	10
SS(2) HSLAS(4)	X Y	+ +	- -	+ +	- +	+ +	- +	+ +	10
HSLAS(4) AA(2)	X Y	+ +	- -	+ +	- -	- -	- +	- +	6
SS	X Y	+ +	- -	- -	- -	- -	- -	- -	2
SS	I	-	+	-	+	-	-	-	2
HSLAS	I	-	-	-	-	+	+	-	2
AA 7075 T6	I	+	-	+	-	-	-	-	2
SSC	I	-	-	-	-	+	+	-	2
SS	HC	-	-	+	+	-	-	-	2
HSLAS	HC	-	+	-	+	+	+	+	5
AA 7075 T6	HC	-	-	-	-	-	-	-	0
SSC	HC	-	-	-	-	+	+	+	3
SS	HS	-	-	-	-	-	-	-	0
HSLAS	HS	-	+	-	+	+	+	+	5
AA 7075 T6	HS	-	-	+	-	-	-	-	1
SSC	HS	-	-	-	+	+	+	+	4
SS	SC	+	-	+	-	-	-	-	2
HSLAS	SC	+	+	+	+	+	+	+	7
AA 7075 T6	SC	+	-	-	-	-	-	+	2
SSC	SC	-	-	-	-	+	+	+	3
SS	SSB	+	-	-	-	-	-	-	1
HSLAS	SSB	+	+	+	+	+	+	+	7
AA 7075 T6	SSB	+	-	-	-	-	-	+	2
SSC	SSB	-	-	-	-	+	+	+	3

Note: X = Hollow Square Beam with 5 Plates; Y = 2C Square Beam with 5 Plates; I = I Beam; HC = Hollow circular beam; HS = Hollow square beam; SC = Solid Circular beam; SSB = Solid square beam.

Formulas:

- **Bending Stress(σb):**

$\boxed{(\sigma_b) = My/I \text{ in GPa}}$ y=h/2, For rectangular or square Cross-section
y=d/2, For Circular cross-section

Where, M=FL/8 in case of Fixed-Fixed Beam

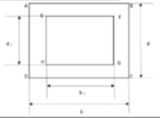
- **Deflection (⍰):** ⍰=$FL^3/192EI$

  ⍰=F/K, Where K=Stiffness of Beam, $K=192EI/L^3$ for Fixed-Fixed beam.

- Moment of Inertia (I):

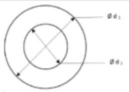
- Solid Circular Beam, $I=(\pi/64) \times d^4$
- Solid Rectangular Beam, $I= (b \times d^3)/12$ in m^4
- Solid Square Beam, where b=d $I=b^4/12$ in m^4
- **Hollow Square Beam,** $\boxed{\text{I=Moment of Inertia of ABCD – Moment of Inertia of EFGH}}$

$= (b \times d^3)/12 - (b_1 \times d_1^3)/12$ in m^4
$=(b^4)/12 - (b_1^4)/12$



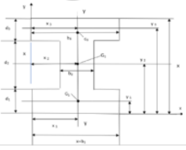
- **Hollow Circular Beam,** $\boxed{\text{I=Moment of Inertia of External body – Moment of inertia of internal Body}}$

$=((\pi/64) \times d_1^4) - ((\pi/64) \times d_2^4)$ in m^4



- **I section**

$X_c=(A_1x_1+A_2x_2+A_3x_3)/(A_1+A_2+A_3)$ in m
$Y_c=(A_1y_1+A_2y_2+A_3y_3)/(A_1+A_2+A_3)$ in m
$I_{xx}= I_{xx1}+ I_{xx2}+ I_{xx3}$
$I_{xx1}=I_{Gx1}+A_1(Y_c - y_1)^2$
$= ((b_1 \times d_1^3)/12) +A_1(Y_c - y_1)^2$ in m^4



7. Conclusion:

The Side Door Intrusion Beam is the beam which resists the impact force applied when the vehicle hits the car from the sideways at an average speed of 70 – 80Km/hr and it protects the Passenger or the driver from the cause of death. This paper concludes, the Beam is designed in such a way that it overcomes the drawback of Structural steel which is commonly used in present Automobile Industries because of its better Physical and Mechanical properties and even the design like Hollow square, Hollow circular and M shaped beam are replaced with the new designs called "Hollow square beam with 5 plates and 2C Hollow square beam with 5 Plates". The Intrusion Beam which is designed are affordable to the customers who are buying the car at an affordable price but the beams which are design are of 15 - 20% more weight than Structural steel beam alone. The weight of beam could be a drawback in case of resulting in decrease of mileage and even the fuel consumption is also more but for the 15% increase in weight of beam resulted in a Better Side intrusion beams. The Beams standing in the above table based upon the Conditions satisfied states that SS can be replaced by the above beams in all the ascpects.

References:

1. Raghvendra Krishana et.al, "Development and Analysis of side door intrusion beam of SUV".
2. Yogesh K. Nichit, "Development of Side Door Intrusion Beam of Passenger Car for Maximum Bending Load".
3. Girish M. Patil, Optimization of Side Door Intrusion Beam for Automotive Safety.
4. Dhaneesh K P et.al. 2016 "Study and advanced concept for side impact protection beams to reduce the injury of the occupant using CAE"
5. Teng, K. C. Chang, T. H. Nguyen, 2007 "Crashworthiness Evaluation of Side Door Beam of Vehicle".
6. "Crashworthiness design of vehicle side door beams under low-speed pole side impacts" Ali Ghadianlou N.