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Analysis of Typical Cross Sectional Bumper Beam

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ABSTRACT: *One of the major concerns while designing a new vehicle is safety. Crash is inevitable, but the damages caused by it can be reduced. The bumper system in the car absorbs the impact energy by deforming and guide the remaining energy to the body during crashes, the amount of energy is being absorbed is not only depends up on the material but also depends up on the cross section of the bumper beam that is used. In this paper a new cross section is tested and compared with two other cross sections. The experiment was conducted according to ENCAP frontal crash analysis procedure. The impact conditions are 40% offset barrier and the speed of 64 Km/Hr., this study is done using different cross sectional bumper beam modeled, the bumper beam and support is modeled fully, rest of the car is modeled as plate and mass of the car added to it. Simulation of crash is analyzed in Explicit Dynamics up to 0.01s. The result shows the energy absorbing capabilities of new cross section and other cross sections with help of kinetic energy drop till 0.01s. The new cross section C shows better performance than other cross sections B and A.*

Keywords: *Bumper Beam, Crash analysis, Frontal impact, kinetic energy, energy absorption, explicit dynamics.*

I. INTRODUCTION

Inevitable crash occurs every day. It is impossible to predict or to avoid certain crash, so the best way is to reduce the damage and the casualties. In an automobile industry, a new vehicle undergoes crash test to verify the crashworthiness of the vehicle. Especially in car manufacturing companies real prototype of the car is tested against the crash to ensure the safety of the passenger during crashes, safety can be increased by primary as well as secondary measure. Primary measures which are used to prevent collision and Secondary measures are to reduce damages, Secondary measures such as bumper system, airbags, seatbelts etc.., are used to reduce the fatalities of the car accidents. In cars both front and back ends are supported by Bumper systems, that used to reduce the damage occurs to the cooling system, fuel tank and pedestrian during low speed collision, and to prevent the occupant from the severe injury during high speed collision. The Bumper systems priorities vary with speed of the car within 15Km/Hr. speed the concern is about to reduce the repair cost, and between 15Km/Hr. to 40Km/Hr. is about to protect the pedestrians above 40Km/Hr. ensure the safety of occupant inside the car.

The bumper system consists of three major parts such as cover, mechanical energy absorber and the reinforcement. In bumper system longitudinal member called bumper beam, this bumper beam act as an energy absorber and guide the remaining energy to the body. Bumper beam and crash boxes sacrifice themselves and absorb the impact energy. The absorption of energy is not only depend on the material and also depend on the cross section of the bumper beam, the cross section of bumper beam play vital role in the bumper system. By changing the cross section of the beam can enhance the absorbing ability of the bumper system. The more it absorbs the impact energy the less, the occupant gets hurt. So many papers have been published with different solution for these problems.

Composite in bumper beam not only increases the absorption capabilities and also reduce the bumper weight, so they have optimized the bumper beam profile made up of E glass/epoxy pultruded, compared these capabilities with steel and E glass/epoxy fiber composite using numerical simulation [1-2]. Improved crashworthiness of the bumper beam assembly by using different material and measured energy absorption capabilities [3]. The parameters like deflection, stress, and impact force, energy absorption capabilities of aluminum alloy, carbon woven composite,(GMT)Glass Mat Thermoplastics, and (SMC) Sheet Molding Compound, through numerical analysis [4,7-9]. The energy absorbing capacity of bumper beam made of steel and composite in first phase and used honey comb structure and foam in front of bumper beam to absorb the energy efficiently [10]. Measured the impact energy for different cross sections in order to improve the crashworthiness of the bumper beam with aluminum alloy, the shape optimization bumper beam under low velocity is carried out on the basis of Euro NCAP crash test procedure [12]. Numerical and experimental analysis of laboratory based motor cycle crash test [13]. Crash worthiness of fully graded foam filled bumper beam is studied [14]. Presented thesis about the rib reinforced thin walled hollow tube like beam bending characteristics on impact conditions and optimized the shape design is used to improve the energy absorption and crashworthiness [15].In this presented work a new honey comb like cross section is modeled and the crash analysis held according to the procedure of Euro NCAP.

II. IMPACT MECHANISM

When two body colloids with certain velocity the motion during the impact always satisfies the energy equation, Momentum equation, and Newton's third law of Motion [14].
These Impact occurs between two bodies can be categorized into two types.

I. Elastic Impact
II. Plastic Impact

In an elastic impact, when two bodies colloids there will be very less amount of energy loss between bodies. They rebound after the impact with very little change in their velocity. In a plastic impact, when two bodies colloids there will be significant amount of energy loss between bodies. So the velocity of the bodies gets reduced.

Two bodies having mass of m1 & m2 are going to colloid at velocity of v1 and v2 respectively, the change in kinetic energy and the change is velocities V1 & V2 as follow.

If the impact is perfectly elastic there is no energy loss, then the kinetic energy before impact is equal to kinetic energy after impact. This is given by the equation (1).

$$\frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 = \frac{1}{2}m_1V_1^2 + \frac{1}{2}m_2V_2^2 \quad (1)$$

If the impact is plastic, then the amount of energy dissipated during the impact is given by the equation (2).

$$\frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 + E_{Plastic} = \frac{1}{2}m_1V_1^2 + \frac{1}{2}m_2V_2^2 \quad (2)$$

If there is energy loss the relative velocity will not be equal, but the difference in velocities between bodies after the impact (V1 - V2) is less than the difference in velocities between bodies before the impact (v1 - v2), it is given by equation (3) & (4). Energy loss is determined by measuring the velocities of the body.

$$(V_1 - V_2) = -e\,(v_1 - v_2) \quad (3)$$

$$e = -\frac{(V_1-V_2)}{(v_1-v_2)} \quad (4)$$

The term e is coefficient of restitution, used to measure the energy loss during impact. When e = 1 the impact is elastic then there is no energy loss between bodies, when e = 0 the impact is plastic then the energy of the body is fully absorbed, the colliding bodies remain in contact after impact.

III. ANALYSIS SETUP

According to Euro New Car Assessment Program, a car should undergo the following crash analysis to make sure, that the car is safe enough for the occupant inside of the car and pedestrian.
Types of crash analysis:

1. Frontal impact
2. Rear impact
3. Side impact
4. Pole impact
5. Pedestrian impact

A car undergoes these analyses to make sure the safety. In this most often occurring accident in real time is offset frontal crash analysis. In this presented thesis offset frontal impact analysis was done based on the procedure of Euro NCAP. During impact the frontal barrier should be 40% offset on either side of the car, and the speed of the car should be 64 Km/Hr (17.778 m/s) as shown in fig 1. Here the barrier is kept as rigid and the bumper beam is made of aluminum alloy. The rest of the car mass is added to a plate. The crash analysis is carried out in explicit dynamics in Ansys 16.2 for few milliseconds, Explicit method is better than the implicit method in impact analysis.

Figure 1: Offset frontal impact [15]

3.1Geometry

The bumper beam system consists of bumper beam, rigid barrier, bumper beam support and a plate is modeled to add the rest of the car mass. Three different cross sectional bumper beams are modeled. The Bumper beams are modeled according to dimensions taken from [15] and as shown in fig 2. The bumper beams were model in Catia V5

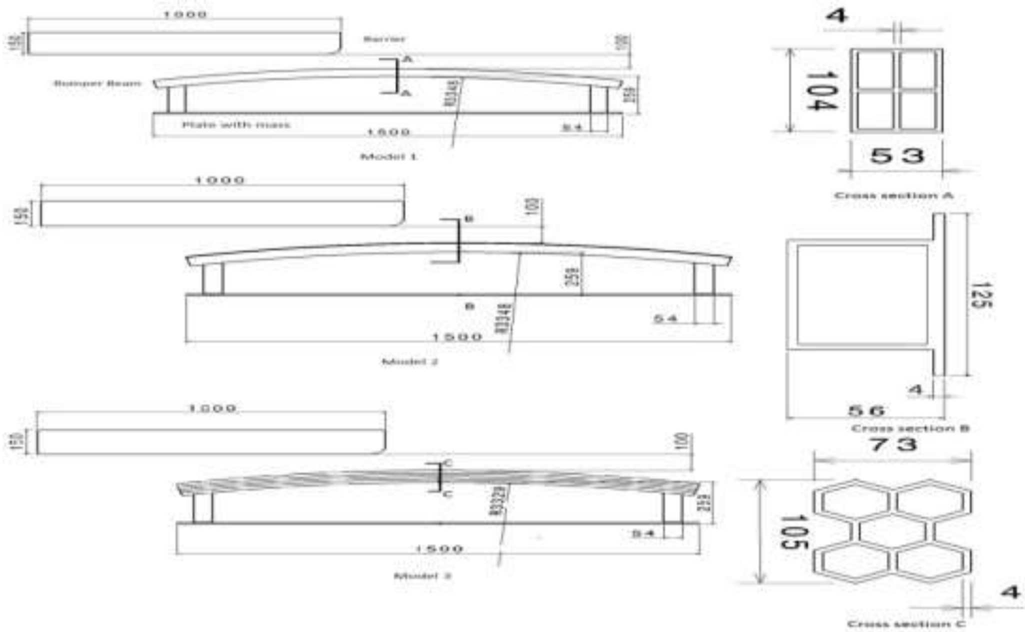

Figure 2: Geometry of the bumper system.

3.2Bumper Beam Material

In order to find the energy absorbing capacity of the bumper beam, these bumper beams should be made of same material. The material used in this study is Aluminum alloy Al 6061 T6 and the properties of the material is given in table1.

Table 1 **:** Material properties of the model

E (pa)	ρ (Kg/m^3)	ν	G (pa)	B	N	Y(pa)	C (J/Kg/k)
70E9	2700	0.33	2.76E10	125	0.1	2.9E8	885

3.3Boundary condition

The boundary condition of the analysis should be as same as the real time impact condition, by doing so only the behavior of the bumper beam can be predicted properly. In this analysis setup the impact conditions are the car is travelling at the speed of 64 Km/Hr. (17.778 m/s) hits a rigid barrier. So the initial Velocity of the car is 17.778 m/s is given to the bumper beam, bumper beam support and the plate having mass of 1500 kg. The rigid barrier is fixed therefore the velocity of the barrier is zero throughout the simulation. The velocity of the car is 17.778 m/s and the distance between the bumper beam and the barrier is 100 mm. The bumper hits barrier within 0.0056s, so the analysis time set as 0.01s.

IV. RESULT

Figure3. Shows the deformation behavior of three different cross sectional bumper beams, this result show how the bumper beam undergoes plastic deformation and absorbs the impact energy and guide the remaining to the body. The bumper beam cross section changes drastically when it hits the barrier and deform plastically, this plastic deformation shows the changes in impact energy.

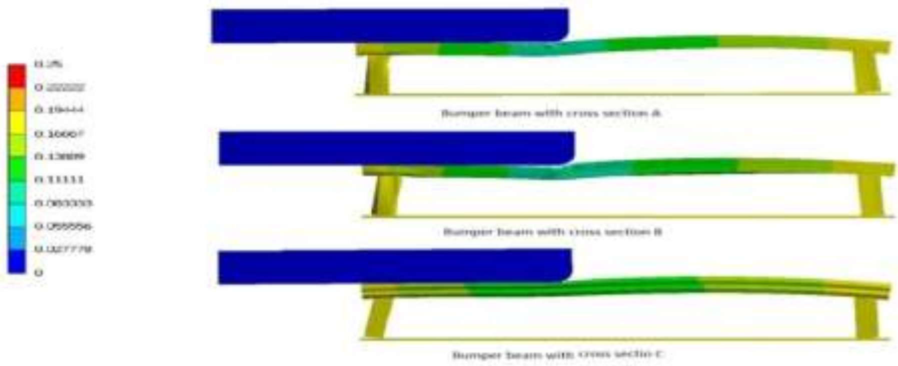

Figure 3: Deformation contour (in m) of bumper beam at 0.01s.

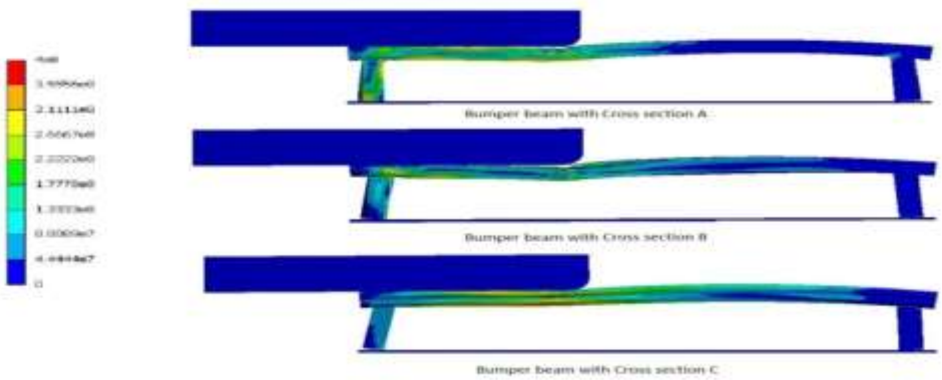

Figure 4 : Von misses Stress Contour (in pa) of bumper beam at 0.01s

Figure4. Shows the Von misses stress distribution of three different cross sectional bumper beams. Von misses stress is the yield criteria for ductile metal, it shows where the yielding occurs, from material properties the yield stress is 2.9e8 pa, where ever the stress exceed this limit yielding occurs and plastic deformation take place.

Kinetic energy dissipates during the impact as shown in figure5. From equation no. 4 energy drop during impact is difference between the kinetic energy before the impact to the kinetic energy after the impact. During impact the kinetic energy of the bumper system is monitored till 0.01s and the data is generated as chart.

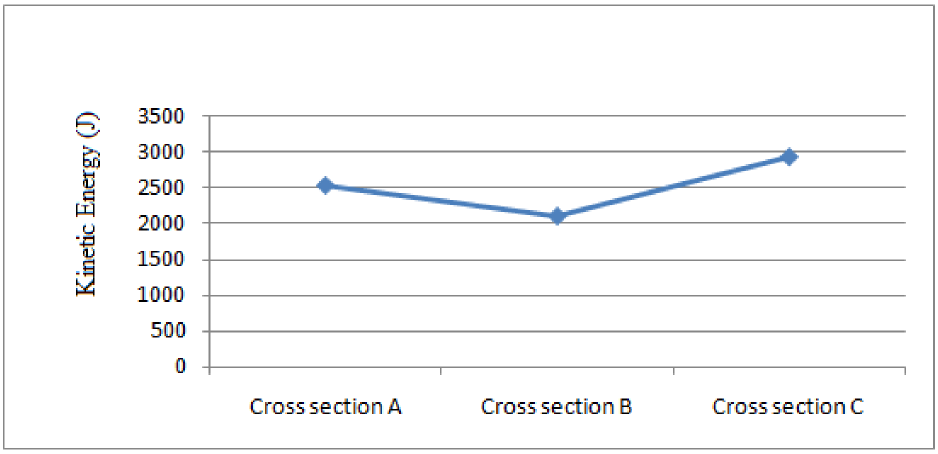

Figure 5 Kinetic energy drop chart till 0.01s

V. CONCLUSION

Energy absorption is a primary concern while selecting bumper system along with the ability to manufacture and price of it. The energy absorbing capacity is depend on various factors such as material, cross section of bumper beam, energy absorber such as honey comb structure or foam etc.., Higher the absorbing capacity lowers the fatalities at high speed crash. The analysis result up to 0.01s shows the kinetic energy drop of the bumper beam made of same material, same boundary condition with different cross sections A, B & C.

The kinetic energy drop of cross section c is higher than other two cross sections. Which means the energy absorbing capacity of the cross section is greater than other cross section. This show cross section C can effectively reduce the casualties during crash.

The analysis was done up to 0.01s, with enough facilities it can be studied fully and the energy absorbing capacity of profile C cross sectional bumper beam can be enhance even more with help of light weight composite and energy absorbers.

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