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Structural Analysis of Bumper Beam with Different Alloys

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ABSTRACT:

Now a day's bumper beam plays a vital role for accidental prevention in low speed collisions. The main purpose of this paper is to increase the crashworthiness of the bumper, lessen the weight, and enhance the cost of the component. Designing a heavy vehicle bumper beam and sequential analysis on how it affects the parameters such as shape, thickness and materials will help in increase the beam strength and reduction in weight. This also provides a way of using materials that are recyclable and biodegradable which help in controlling environmental pollution. The bumper beam of a heavy vehicle is modelled and analyzed with the steel materials and then the design is modified and improvised by using a shape optimization tool in the Ansys. Based on the shape optimization results, the shape of the model, is modified and analyzed with aluminium and composites (composite material).

In this paper the main parameters that are considered in this analysis are material, thickness and the shape of the bumper beam are premeditated for the analysis on an automotive bumper beam to enhance the properties of the beam particularly to stand against the impact forces of crash, ranging from medium speed to high speed impact collisions. In this project work conventional materials like steel, magnesium and aluminium were studied and their impact behaviour is discussed. This study is cantered on the selection of Bumper beam under varying parameters such as shape and material to cater the needs of safety during the stage of product design specification (PDS). From this work, it is proposed that S2- glass epoxy and the New and modified bumper is performing very well were compared to the existing bumper beam.

The stress developed in the new bumper beam is reduced by32.86% and the deformation is reduced 17.75%.

Key words:

Bumper beam, vehicle, controlling, impact, Collisions, parameters.

1. INTRODUCTION:

In automobile world, bumper is a basically a bar or a beam which is mounted on the chassis through the connections such as fasteners or by shock absorbers or sometimes it may be welded directly to the chassis. The bumper beam is attached front and rare side of the automobile, which is designed to absorb the impact energy during the frontal or rare collisions [1]. Regulations for automobile bumper have been implemented to allow the automobile to withstand at low velocity impacts without damaging any of the vehicle systems. The main objective of the bumper is to guard the automobile body at low speeds, typically in reverse gear, parking etc. Accidents are happening every day, according to the statistics given by NHSTA, thousand dead and hundred of thousand to millions are wounded every year [2]. In the modern generation the beam is made up with conventional materials like steel, aluminium etc. and in few sports cars carbon fiber is also used. In most prerogatives, bumpers are legitimately compulsory on all vehicles. The safety regulations from E.C.E UNITED NATIONS AGREEMENT, REGULATION NO-42, 1994 placed few benchmark.

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According to this safety regulation, "when the bumper beam is collided with exact same object then beam should not show any deformation at the collation [3]. The placement and the height at which the bumper beam is also authorize specified as well, this is to safeguard that when automobiles of dissimilar heights are in an accident, the smaller vehicle will not slide under the larger automobile. Bumpers are not capable of reducing injury to vehicle occupants in high-speed impacts [4]. The bumper beam is s structural member which is incorporated in front and the rare portion of the automobile. The function of the bumper is to absorb the impact energy in the case of collusion [6].
Bumper beam absorbs the accidental kinetic energy by deflection in low-speed impact and by deformation in high-speed impact [7]. The main motive of this work is to increase the crashworthiness of the bumper, minimizing the weight, and reducing the cost of the component [8]. The new bumper beam should have enough strength to resist the collision and at the same time should flexible enough to desperate the impacted kinetic energy. There are many parameters that effects the bumper beam performance, among them few are listed below.1) Thickness, 2) Shape, 3) Material 4) Frontal Curvature, 5) Connections etc. [9]. The composite materials have the desirable properties such as low weight, high fatigue strength, easy forming and high strength, they are suitable for material replacing.

2. BUMPER BEAM:

Bumper is consists of cover, reinforced beam and connecters. Which is attached to the automobile skeleton. Bumper is a protection structure which is used to guard the car from low speed crashes by deflecting, and shielding the passengers under high speed impacts by deforming. The bumper system is design for the avoidance or plummeting the physical damage in the front and rear end collisions. Bumpers are designed to guard the hood, trunk, grille, fuel, exhaust and cooling system as well as safety related equipment such as parking lights, headlamps and taillights in low speed collisions.

3. MODELLING AND ANALYSIS:

The bumper beam is modelled and analyzed. The modelling is done in solid modelling software (Creo 2.0). It is analyzed in Ansys workbench 15.0. The parameters which effects the performance of the bumper is thickness, speed, materials and shape of the object. The thickness of the bumper is 2mm. The material used for designing this bumper is steel and its properties are mentioned in bellow table 1.

Table 1 Material Properties of steel

Material Name	Poisson's Ratio	Density kg/m3	Yield Strength
Structural Steel (SS)	0.3	7850	380 MPa

The heavy vehicle bumper beam is modelled and drawing specification of the eicher 15.0 bumper is shown in fig1.

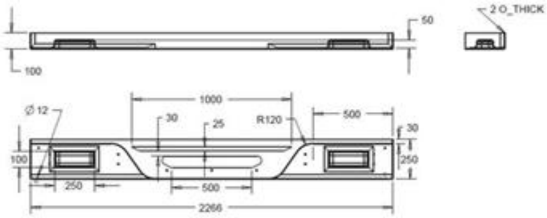

Fig.1 Specification s of Eicher 15.0 bumper

The isometric view of heavy vehicle bumper beam is shown in bellow fig 2. Bumper beam is analyzed in ANSYS 15.0 by importing the system in to the work bench. Analysis had been performed on the beam both in statics and in dynamics. In the case of the statics the impact problem has to convert to an equivalent structure of the bumper beam system. Defining the boundary conditions and loading conditions are the important parameters. First of all we have to define the material properties like mass density, young`s modules and Poisson's ratio. Into the engineering data. Then by importing the above models in to the workbench to analysis. The existing bumper beam was 2mm thick, and according to the Indian standards the bumper beam should not yield under the 2.5kmph collision.

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Input data:

Mass of the car with bumper =4255 kg
Speed of the car = 2.5kmph
Assume this car is hitting at another identical one and it will stop in 0.1 seconds.
Force acted during collision = m*a
Force acted during collision =4255*7 = 29785 N
m= mass of car in kg,
a = acceleration of car in m/s2
In ANSYS we can directly apply this load on the beam as a point load. We are applying the load as point because, when the bumper beam is impacted with impactor the area of concentration is very less. So the load is treated as point load. But for full impact we have to convert this load in to pressure. For the easiness of calculation this force is converted into a pressure which is acted on the front surface of the modelled bumper. By considering the total load is acting on the frontal area of the beam the boundary conditions will change.
Area of the front face of bumper = 431180 mm
Pressure acted on the bumper =F/A= 0.07 N/mm2
F= Force acted during collision in Newton's,
A = Area of the front face of bumper in mm2.

Table 2 Equivalent pressure to the corresponding Velocity

Equivalent pressure to the corresponding velocity	
Velocity (kmph)	Pressure (N/mm2)
2.5	0.07
5.0	0.137
8.0	0.2193

Geometric model:

The geometric model for the Steel bumper is as shown in the Fig 2.

Fig.2 Geometric Model of the Steel bumper

Meshed Model:

The meshed model for the Steel bumper is as shown in the Fig 3.

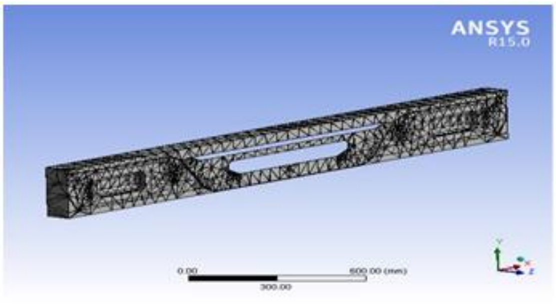

Fig.3 Meshed model of the bumper

Boundary Conditions:

The boundary conditions for the Steel bumper is shown in the Fig 4

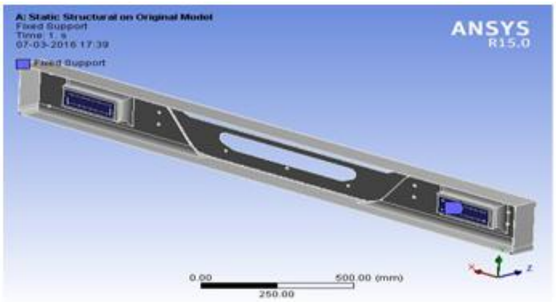

Fig.4 Boundary Conditions of the Steel bumper

The Flow Processes:

The bumper is fixed to the body by using the fasteners and fixers assembly which is theoretically treated as a fixed joint. This practical application is simplified by considering the beam only and the fastening area is reacted as the fixed supporting area. In Ansys that area is treated as the fixed supported area and it is shown below. Loading conditions for the steel bumper at an impact of 2.5kmph is shown in Fig 5.

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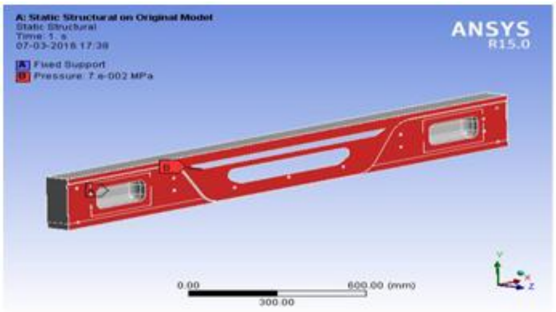

Fig.5 Boundary Conditions of the Steel bumper

When the bumper beam system is collided with an impact will generates an impact force which is the cause to deform the bumper beam. In static analysis the impact force which is generated in the collision is directly applied on the frontal area of the bumper. The impact load is converted to pressure and applied on the bumper which is shown in the fig 6.

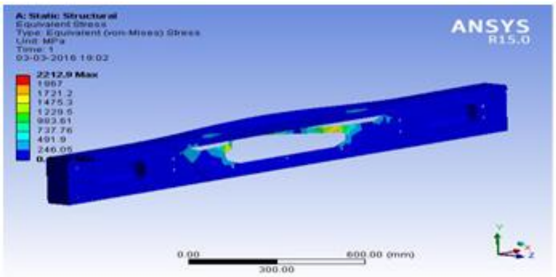

Fig.6 Stress Distribution of the bumper beam in Statics

The total deformation in Statics of the Steel bumper with 2 mm thickness at the impact of 2.5kmph is as shown in the Fig 7.

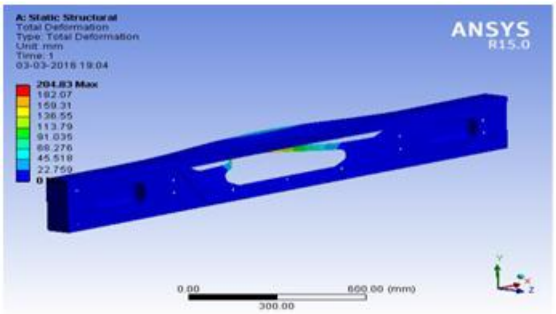

Fig.7 Deformation of the bumper beam in Statics

From this analysis, it is clear that the stress are generated at the middle section of the bumper, it is because there is an opening, and by the results of deformation the strip in the middle portion is deformed. By closing the middle portion with some additional material the stress will decreases, at the same time the weight of the bumper increases. The main objective of this work is to reduce the weight and increase the strength, to attain that a shape optimization is applied. The basic model of the foundation which has been modelled and analysed above is carried to do shape optimization in ANSYS workbench.

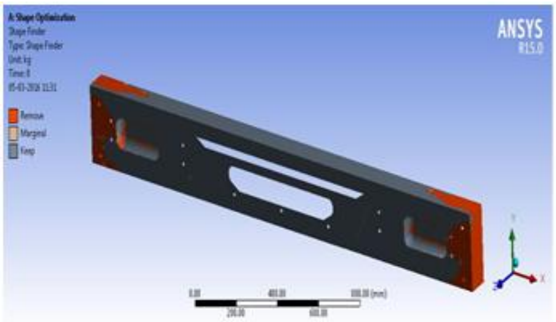

Fig.8 Material removals from foundation

The red colour indicates the amount of material that can be removed, by maintaining all the limitations. The mass of the basic foundation model is 22.4 kg and after shape optimization the mass of the foundation is 19.8 kg which shows the reduction in mass of foundation by 2.6kg. From this results a new and modified model is modelled in Creo parametric, the geometry of the bumper beam is shown in below fig 9.

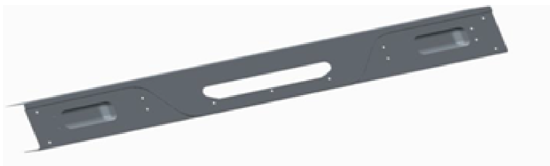

Fig.9 New and improvised bumper beam

Now to understand how this bumper is going to perform in the impact condition it is tested under the same impact conditions. And the obtained results.

It is observed that the stress are reduced to 727.15 N/mm2 and the total deformation is reduced to 33.25 mm. The over percentage of stress that reduced in the new model is 67.14% and the overall percentage dropped in the total deformation is 84.25%. To study the effect of parameters like thickness, speed and material, a set of thickness and materials are considered to study. Thickness is started varies from 2mm to 7mm, and where coming to the material two conventional materials where taken in to consideration, one is steel and another one is aluminium. These materials were selected based on their usage in automobile industry. And there were two other materials, one is carbon fiber and another one is the S2 glass epoxy. Material properties are shown in below table.

Table 3 Different materials with their properties

Type of Material	Young's Modulus (GPa)	Poisons Ratio (μ)	Density (ρ Kg/m3)
Steel	210	0.3	7860
Aluminium	68.9	0.33	2720
Carbon Fibre Epoxy	85	0.15	1600
S2 Glass Epoxy	86.9	0.23	2460

4. RESULTS AND DISCUSSIONS

In this study all four materials are analyzed at different speeds with different thickness, in this process of analysis we can understand how thickness and material is going to effect the performance of the bumper beam.

Table 4 result of steeel bumper of 2mm to 7mm at 2.5kmph

S.No	Thickness (mm)	Stress (N/mm^2)	Deflection (mm)	Weight (kg)
1	2	727.15	33.25	21.8
2	3	554.23	16.5	29.8
3	4	323.3	9.08	37.8
4	5	240.23	5.712	45.8
5	6	177.42	3.79	53.8
6	7	141.25	2.652	61.8

From the results the deformation and the stresses are reduced. According to the European standards, the bumper beam should not show any yielding when it is impacted at the speed of 8kmph. To study that we changed the speed from 2.5kmph to 5kmph and it is finally tested at a speed of 8kmph.From the results bumper beam of 7mm thickness having a stress of 142.25N/mm2 at the impact of 2.5kmph collision, according to the European standards, stresses developed in the bumper should always less than the yielding stress of the material. Here the material used is steel. The yield stress of the SS-Steel A1011 of Grad 55 is 380 N/mm2. But the beam of 7mm thickness is came close but unable to withstand the impact. The ultimate strength of this steel is 480N/mm2, it will is within the stress region but there will be some permanent deformation will observed in bumper beam. The weight of the 7mm thickness steel bumper beam is 61.8 Kg`s, in automotive industry the weight minimization is main criteria, so we need the beam to be strong enough to withstand the crash at same time the weight also should be less. This kind of requirement will be obtain with alloying the material or composites. In this study four materials where considered based on their properties, they are steel, aluminium, carbon fibre epoxy, S2 glass epoxy. Analysis of Bumper beam with Different materials and thickness under impact load of 2.5kmph, 5kmph, and 8kmph was done. In this project work steel, aluminium, carbon fibre and S2 glass fibre epoxy were taken in to study. Steel is the material which is used in making of existing bumper.

Table 5 Stress and Displacement of varies Thickness Bumper with steel material at 8kmph

Steel			
Thickness (mm)	Stress (N/mm^2)	Deflection (mm)	Weight (kg)
2	2278	104.17	21.8
3	1736.3	51.664	29.8
4	1012	28.466	37.8
5	752.62	17.895	45.8
6	555.83	11.893	53.8
7	442.51	8.3082	61.8

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Table 6 Stress and Displacement of varies Thickness Bumper with S2 Glass Fiber Epoxy material at 8kmph

S2 Glass Fiber Epoxy			
Thickness (mm)	Stress (N/mm^2)	Deflection (mm)	Weight (kg)
2	2532.4	251.1	6.8
3	1764.4	119.17	9.4
4	995.2	64.889	12
5	737.13	40.503	14.6
6	549.55	26.864	17.2
7	439.29	18.774	19.8

From the results the stress developed in this bumper is 439.29 N/mm2 and the total deformation is 18.774mm, the yield strength of S2 Glass fibre epoxy is 480 N/mm2. It is clear that the bumper beam is withstanding to 8kmph impact and the deformation is also within the region.

5. CONCLUSION:

In the design of the automotive bumper beam, the deflection of the bumper beam should be below the critical value; 20mm is considered in this study. The S2 Glass epoxy material with 7 mm thickness have shown better stress and deflection results incorporative to steel.In order to achieve higher stability, cost effective and manufacturability of the product, the S2 glass epoxy is proposed that could replace the steel, based on strength and weight criteria.

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