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Design and Analysis of Local Passenger Vehicles Front Bumper Beam for Low Speed Impact

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ABSTRACT

The bumper beam is most important part for absorbing impact during front collision of vehicles. Which protect the vehicles parts such as engine, radiator, and other important parts during impact condition. In this paper, to improve the crashworthiness of vehicles, the most important parameters such as material and shape are studied. The paper presents a dynamic analysis of passenger vehicles front bumper beam. The displacement is studied for finding the best replacement for HS steel material. The analysis is done using different materials such as H S steel, aluminium are conventional materials, GMT, LFRT AND KLFRT as composite materials and bumper beam with adding vertical stiffeners to improve its stiffness. The low-velocity simulation of bumper beam was done as per the standards of automotive stated in E.C.E. United Nations Agreement, Regulation no. 42, 1994. ARAI India accepted this regulation, so it is used for study. Frist the steel is use as the base material and other materials compared with steel. From these comparison found that GMT is the best replacement for steel. A 3D model of the bumper beam is made using Solidworks modelling software. Then meshing is done in HYPERMESH. And analysis is done in Ls-Dyna.

Keywords – Bumper beam, Impact, low velocity, LS-Dyna, Solidworks.

1. INTRODUCTION

Bumper beam is the most important component in any vehicle. Which absorb the crash impact during collision, and protect the vehicle to reduce damage during collision. In the bumper beam system, long member is called main impact absorbing beam, after that boxes behind main beam are called crash box, crash box attached to the connecting plate which are bolted to the main frame.

The automobile bumper weight can be reduced by the use of composite and high- strength metallic sheet of a thinner thickness material [1].

At speeds up to 15 km/h, the main goal is to minimize repair costs, at speeds between 15 and 40 km/h, the first aim is to protect pedestrians and at speeds over 40 km/h, the most important concern is to guarantee occupant protection [9].

Kusekar and Chunge [1] studied the most important parameters including material, thickness, and shape and impact condition for design and analysis of an automotive front bumper beam to improve the crashworthiness design in low-velocity impact. The bumper beam analysis is accomplished for composite and aluminum material to compare the weight and impact behavior. Do-hyoung kim, Hyun-Gyung Kim et al. [2] designed and manufactured the hybrid glass/carbon composite bumper beam via the design optimization process combined with the impact analysis. The glass/carbon mat thermoplastic (GCMT) composite was devised to substitute for the conventional glass mat thermoplastic (GMT) for reducing the weight of bumper beam. For the design optimization, the mechanical properties of GCMT were predicted and the optimal design of bumper beam was performed with the impact simulation. Khedkar, Sonawane and Kumar [3] discussed experimental and numerical investigations for three different bumper beams having different geometries, to be proposed for Indian passenger cars. The strength of these bumper beams in elastic (static) mode is investigated with energy absorption capacity.

2. PROBLEM DEFINITION AND OBJECTIVES

The problem to be dealt with for this dissertation work is to Design, Optimization and Analyze using suitable CAE software for Bumper Beam. In present the local passenger vehicle bumper beam is made of Steel. By analyzing the literatures mention above we came to that by using existing material there is a scope in incrementing strength with updating existing geometry, and weight reduction by changing the material. The problem gaps are divided into three parts:

1. Related to modelling and design it was found that there is a scope of modelling improvement by adding stiffeners in existing geometry to improve strength of bumper beam.

2. Related to finite element analysis it was found that there is a scope in improvement of bumper beam strength by using different material rather existing.

3. Related to optimization it was found that there is a huge scope in optimization of bumper beam in weight, stress and deformation factors.

3. FINITE ELEMENT METHOD

For solving problems of engineering and mathematical physics, the finite element method (FEM) is (numerical method) used. For design a bumper beam, From local passenger car the bumper beam dimension are measured. From this measured dimension the 3D Bumper beam is generated in Solidwork software. The Barrier is made as per the RCAR standards this barrier acts as rigid component. After that fine meshing is done in altair hyperworks, for better meshing and reduce the solving time the surface mesh done on components. Here dynamic analysis has been performed which comes into the picture when impact or crash test come into mind. For dynamic analysis most suitable software Ls-Dyna is used. Different materials are used for analysis. HSS is used as base material and other material compared with it. Their mechanical properties are shown in Table 1

Table 1: Properties Of Different Materials

Sr. No.	Material	Density (kg/m^3)	Youngs Modulus (Gpa)	Poisson ratio	Yield Strength (Gpa)
1	Steel	7850	210	0.3	700
2	Aluminium	2710	70	0.33	480
3	GMT	1280	12	0.41	230
4	LFRT	1200	9	0.45	190
5	KLFRT	1240	8.5	0.42	220

3.1 Modelling of bumper beam

For bumper beam modelling SolidWorks software is used. Modelling of original and modified bumper beams are shown in Fig. 1 and Fig. 2 respectively. For modification vertical stiffeners add in original bumper beam. The length of bumper beam is 1020mm and width is 220mm. and the thickness is 2mm.

Fig. 1 CAD model of original bumper beam

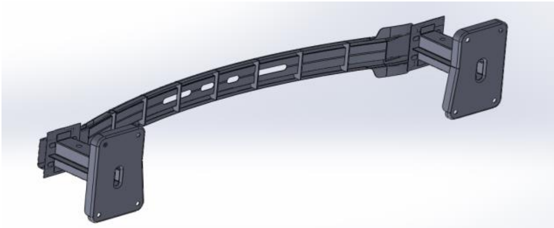

Fig. 2 CAD model of modified bumper beam

3.2 Meshing

Fig. 3 shows the mesh model of the original bumper beam and barrier. And Fig. 4 shows mesh model of modified bumper beam and barrier. The mesh size for the both bumper beams is 10mm. mid-surface meshing is done. Quadrilateral elements are preferred mostly, but due to corner and non- parallel edges, triangle elements are included. For reduced TRIA elements geometry used as a simple geometry. The total number of nodes are 14546 and 14832, and total number of elements are 14167 and 14514 respectively for original and modified bumper beam and barrier.

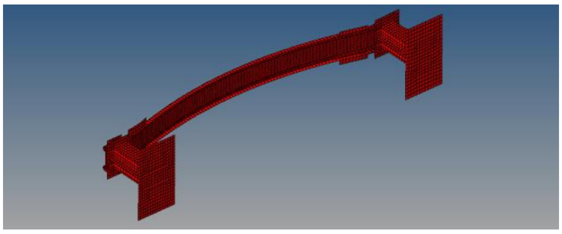

Fig.3 Meshing of original bumper beam

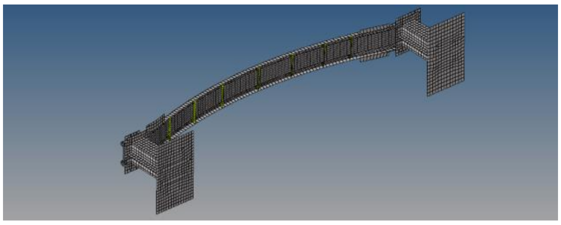

Fig. 4 Meshing of modified bumper beam

3.3 Displacement of original and composite bumper beam

This section shows the displacement of five different material with original and modified bumper beam of local passenger vehicle. And compared these displacement with each other for finding best optimization.

3.3.1 High Strength Steel: Fig. 5 shows the displacement of original bumper beam by using HSS material, in which total displacement is 22.39mm. And Fig. 6 shows the displacement of modified bumper beam with HSS material. The total displacement of modified bumper beam is 19.42mm.

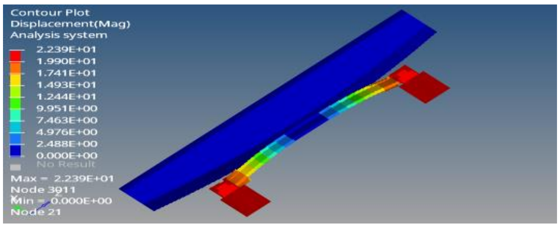

Fig. 5 Displacement of original bumper beam with HSS

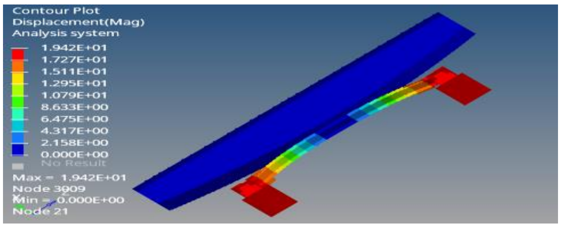

Fig. 6 Displacement of modified bumper beam with HSS

3.3.2 Aluminium alloy: Displacement of original bumper beam by using Aluminium alloy is shown in Fig. 7, the total displacement of original bumper beam with aluminium alloy is 23.73mm. Fig. 8 shows displacement of modified bumper beam with aluminium alloy material, and total displacement is 23.21mm.

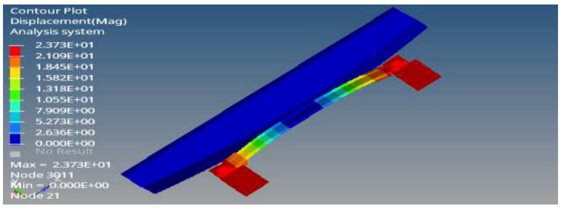

Fig. 7 Displacement of modified bumper beam with Aluminium alloy

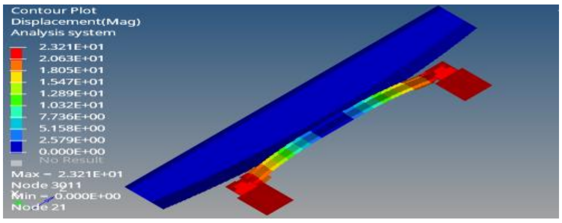

Fig. 8 Displacement of modified bumper beam with Aluminium alloy

3.3.3 GMT: Fig. 9 shows the displacement of original bumper beam by using GMT material, in which total displacement is 22.85mm. And Fig. 10 shows the displacement of modified bumper beam with GMT material. The total displacement of modified bumper beam is 22.58mm.

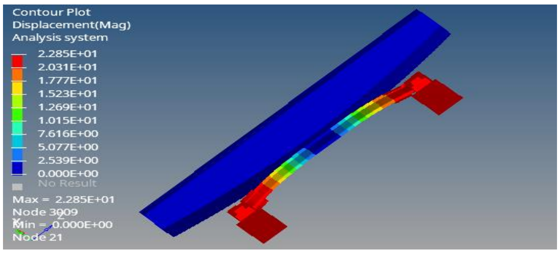

Fig. 9 Displacement of modified bumper beam with GMT

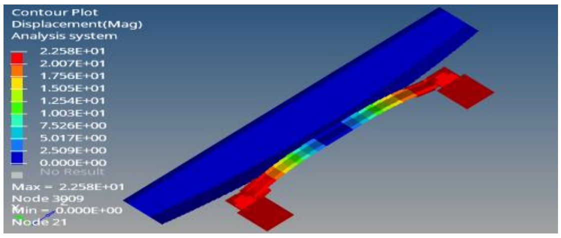

Fig. 10 Displacement of modified bumper beam with GMT

3.3.4 LFRT: Displacement of original bumper beam by using LFRT is shown in Fig. 11, the total displacement of original bumper beam with LFRT is 23.52mm. Fig. 12 shows displacement of modified bumper beam with LFRT material, and total displacement is 23.45mm.

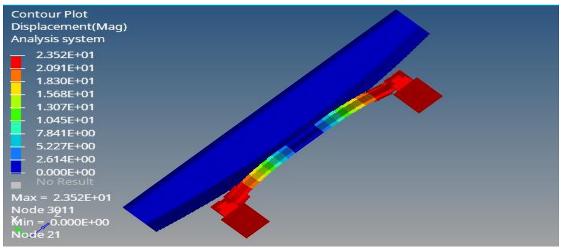

Fig. 11 Displacement of modified bumper beam with LFRT

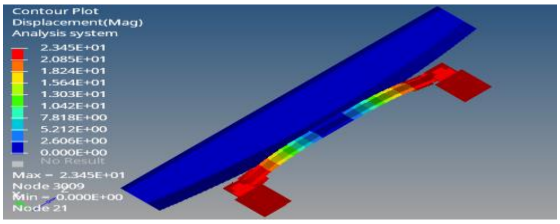

Fig. 12 Displacement of modified bumper beam with LFRT

3.3.5 KLFRT: Fig. 13 shows the displacement of original bumper beam by using KLFRT material, in which total displacement is 23.71 And Fig. 14 shows the displacement of modified bumper beam with KLFRT material. The total displacement of modified bumper beam is 23.62mm.

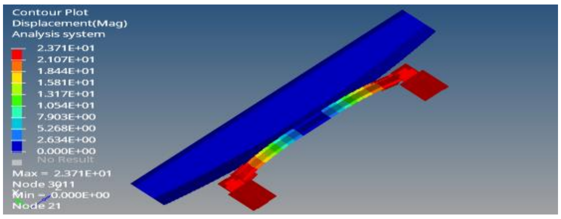

Fig. 13 Displacement of modified bumper beam with KLFRT

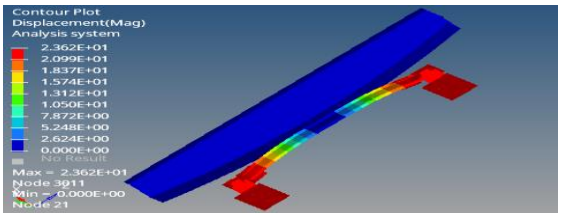

Fig. 14 Displacement of modified bumper beam with KLFRT

4. RESULT DISCUSSION

Table no 2 and Fig. 15 shows the displacement of all materials, and compare original component with modified component.

Table 2: Displacement of bumper beam

Sr. No.	Material	Displacement (Original bumper beam) mm	Displacement (Modified bumper beam) mm
1	HSS	22.39	19.42
2	Aluminium Alloy	23.73	23.21
3	GMT	22.85	22.58
4	LFRT	23.52	23.45
5	KLFRT	23.71	23.62

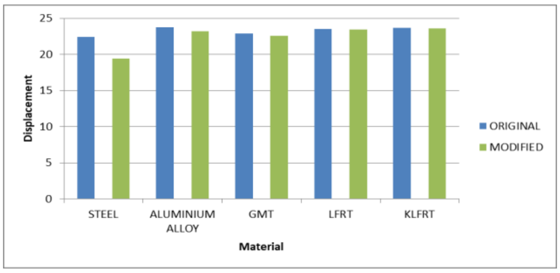

Fig. 15 Displacement v/s Material

From above table and diagrams it is seen that existing component with existing material has displacement of 22.39 mm. And comparing it with another four materials, it is seen that GMT is the best material for replacement of HSS material.

From modified bumper beam data it is fount that with using vertical stiffeners the stiffness of existing bumper beam will increase without changing the material. And in the composite material, by comparing original and modified component there is not any major change in stiffness. The displacement reman slightly equal. It is shown in Fig 15.

4.1 Optimization

In this section mass optimization is discussed. From Fig. 16 it is seen that HSS has more mass, 2.275 kg for original component and 2.3192 kg for modified component. There is slight increment in modified component as compare to original component.

Composite material shows very less mass as compare to existing material. Here GMT material shows same stiffness like HSS material but the weight is very less than HSS. Mass of GMT material is 1.1131Kg for original component and 1.1345Kg of modified component. Therefore GMT is the best material replacement for original HSS material, and it will definitely reduce the weight and manufacturing cost of the vehicle.

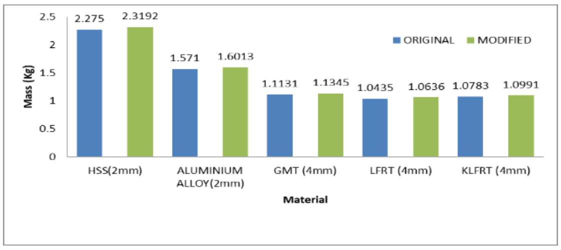

Fig. 16 Mass v/s Material

5. CONCLUSION

In this study, dynamic analysis (low-velocity impact test) of local passenger vehicles bumper beam was carried out. The analysis was done with original and modified bumper beam. Also analysis was done with different conventional and composite materials for both original and modified bumper beam. In this study for reduce the crash impact during front collision of vehicle, The displacement was studied with modification in original geometry and with using the different materials.

- From above study, seen that by adding vertical stiffeners in existing geometry the weight increment is very less. And in composite material the weight increment is very negligible.
- In conventional material like HSS and Aluminium Alloy the displacement of original and modified bumper beam is vary. But in composite material the displacement between original and modified bumper beam is same. There for there is no need of modification when using composite material.
- Displacement of HSS is 22.39 mm for original and 19.42mm for modified bumper beam. And displacement of GMT is 22.85 mm for original and 22.58 mm for modified bumper beam. Therefore GMT is the best replacement for original HSS material of vehicles bumper beam.
- In weight optimization, for same stiffness with different materials, the HSS has weight of 2.275 kg for 2mm thickness and GMT has weight of 1.1131 kg at 4mm thickness. So the GMT will reduce the total weight of vehicle, therefore GMT is best replacement for HSS. And cost of GMT is less as compare to HSS.

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