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DESIGN AND ANALYSIS OF AN AUTOMOBILE BUMPER BEAM

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ABSTRACT

Bumpers are structural components installed to reduce physical damage to the front and rear ends of a light/heavy motor vehicle from low-speed collisions. Damage and protection assessments are the commonly used design criteria in bumper design. For damage assessment, the relative displacements representing stiffness performance are examined and crash test will be done. In this study, impacts and collisions involving a car bumper beam model are simulated and analyzed using LS-Dyna software. The bumper should support the mechanical components and the body. It must also withstand static and dynamic loads without undue deflection or distortion. The given model is tested under frontal collision conditions at speed of 68 kmph and the resultant deformation and von-Misses stresses are determined. The five different materials including composites are used for the bumper beam analysis. The crash analysis simulation and results can be used to assess both the crashworthiness of current bumper and to investigate ways to improve the design. Five different materials used to determine the performance of the bumper beam in crash test. The comparison of baseline material with composite material is presented in the study. This type of study methods are an integral part of the design cycle and can reduce the need for costly destructive testing program.

Keywords— Bumper, CATIA, Hypermesh, Impact test, LS-dyna

I. INTRODUCTION

In recent days, in development of technology especially in engineering field make among the engineers more creative and competitive in designing or creating new product. They must be precise and showing careful attentions on what they produce. Here, we concentrate on automotive industry. The greatest demand facing the automotive industry has been to provide safer vehicles with high fuel efficiency at minimum cost. Current automotive vehicle structures have one fundamental handicap, a short crumple zone for crash energy absorption one of the options to reduce energy consumption is weight reduction. Substitution of polymeric based composite material in car components was successfully implemented in the quest for fuel and weight reduction. Among the components in the automotive industry substituted by polymeric based composite materials are the bumper beam, bumper fascia, spoiler, connecting rod, pedal box system, and door inner panel.

II. LITERATURE REVIEW.

Lingam Ramyasree, D.Venkataramaniah and G.Naveen Kumar[5] This study focuses on comparison with conventional (steel, aluminium) and composite materials such as natural long fibres. The pendulum hits the bumper with 48km/h velocity and 64km/h. The deflection is an important parameter to check the crashworthiness of the bumper beam material from a comparison of the graphs; it becomes clear that the KLFRT shows an increase in deflection. The deflection is directly proportional to material stiffness and yield strength. So the KLFRT can replace the conventional bumper materials.

AyyappaSwamy GV etc.[09] Present used material for car bumper is steel. By using steel the weight of the car bumper is more but by using composites the weight of the bumper is reduced since densities are very less compared with steel. By using S2 Glass/Epoxy, the weight is almost reduced by 4Kgs and by using carbon FiberReinforced PEI it is almost reduced by 5Kgs.By observing the analysis results for both the designs, the analyzed stress and displacement values are more for the actual model than the modified model

. S. Jeyanthi and J. Janci Rani [12] This study concentrates on the mechanical, thermal and recycling properties of a kenaf long fiber reinforced composites for consumption in automotive components. A twisted kenaf hybrid material HYBRID PP, which is fabricated by hot impregnation method, presents a superior mechanical and thermal property associated to the commercial LFRT material. This implies that a natural kenaf long fiber reinforced composites could be utilized in automotive structural components such as bumper beams, front end modules and also in interiors of automobiles. More over recycling properties of KLFRT is immense compared to its mechanical and thermal properties. It is clear that the natural kenaf fiber composites can undeniably replace the commercial LFRT for automotive components.

III.PROBLEM STATEMENT AND OBJECTIVES

Incorrect analysis & lower strength of bumper beam of a car may rise to damages in bumpers due to moderate impacts while driving. To strengthen the bumpers some study & correct analysis is needed in this field.

The objective of this work is to study front bumper of one of the existing passenger car in Indian market (TATA INDICA CAR BUMPER SYSTEM) and suggest design Improvement in front bumper of a passenger car using Impact Analysis such that the following objective will be served.

Model and Simulate Car bumper beam for the 68 kmph impact at the centre of the beam. Use different materials in simulation to generate design parameters for better impact attenuation bumpers. Model and simulate impact phenomenon for composite materials in order to study crash dynamics. Compare the results of the conventional materials and composite materials for the crashworthiness. Compare Experimental & FEA results

IV. METHODOLOGY FLOWCHART

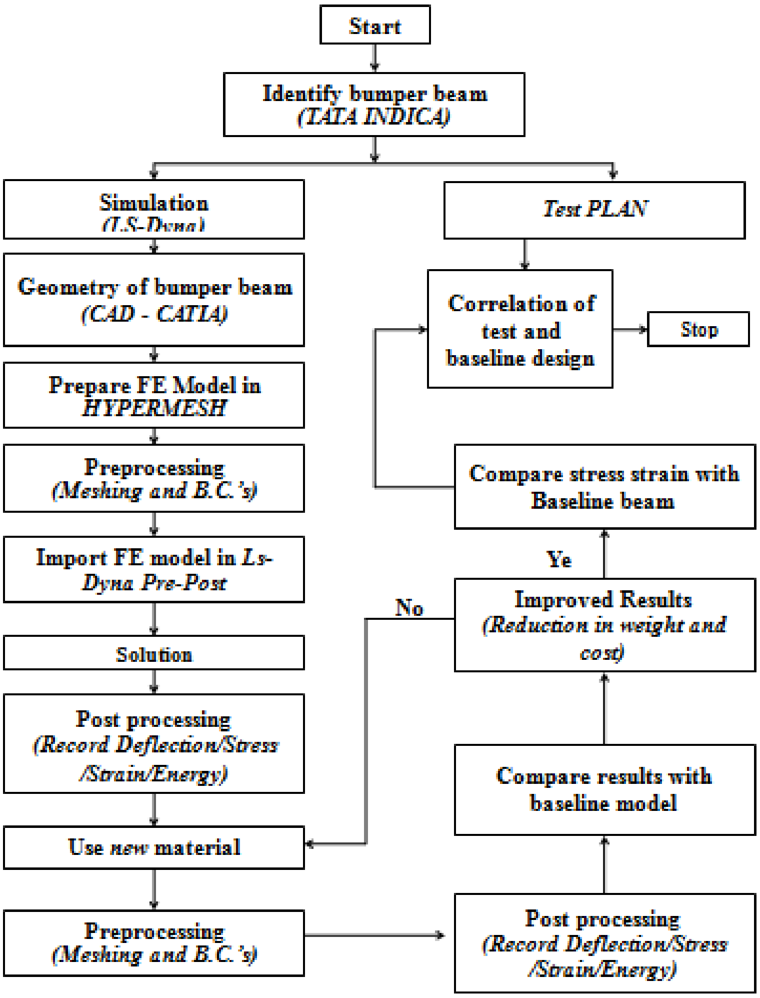


Fig.1 Flowchart

V.MECHANICAL PROPERTIES OF MATERIALS

Mechanical properties for the bumper materials are given below in Table..
Nomenclature: Long-fiber-reinforced thermoplastic (LFRTs). Glass-mat thermoplastic (GMT)
Kenaf natural fiber-reinforced thermoplastic (KLFRTs)

Table 1: Mechanical properties of the bumper materials

Sr. No.	Material	Young's Modulus (GPa)	Poisson's ratio	Yield Strength (MPa)	Density (Kg/m3)
1	Steel	210	0.3	700	7850
2	Aluminium	70	0.33	480	2710
3	LFRT	9	0.45	190	1200
4	GMT	12	0.41	230	1280
5	KLFRT	8.5	0.42	220	1240

VI. CAD Model

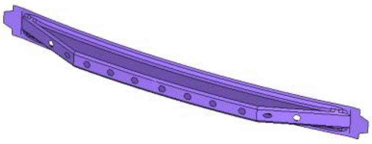


Figure2. CAD model – Bumper beam system

The above Figure shows the CATIA model of the bumper beam.

VII. BOUNDARY CONDITIONS

The below figure shows the boundary conditions of the bumper beam in Hypermesh software. The outer nodes of bumper shown in the picture are constraint in y and z direction while free in x-direction. The pink colour element nodes of the rigid wall are constraint in all directions as shown in the picture below.

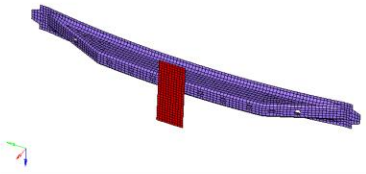


Figure3. Meshed model of bumper and rigid wall

The meshed model is imported to LS DYNA software for crash analysis. The Velocity is applied to whole of the bumper system is 68 kmph as per FMVS standard. The acceleration due to gravity is applied in the –z direction as shown in the picture.

VIII. RESULT AND DISCUSSIONS

The effect of impact loading on bumper beam system is investigated by comparing the displacement between five different materials within model. The deflection contour plots are shown in the following pictures.

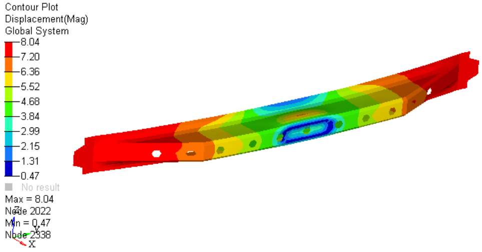


Fig.4 Displacement contour plot: Steel Bumper System

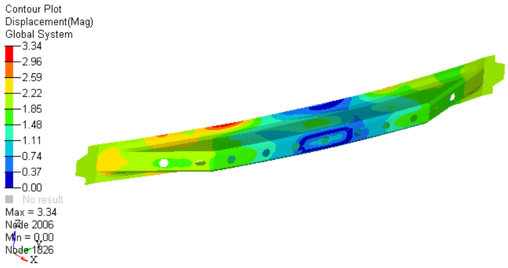


Fig. 5 Displacement contour plot: Aluminium Bumper System

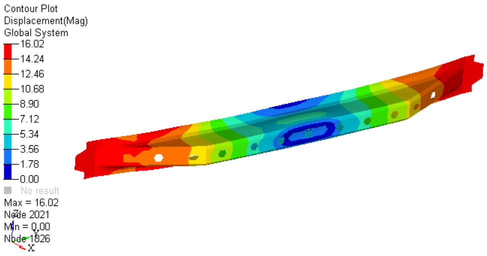


Fig.6 Displacement contour plot: LFRT Bumper System

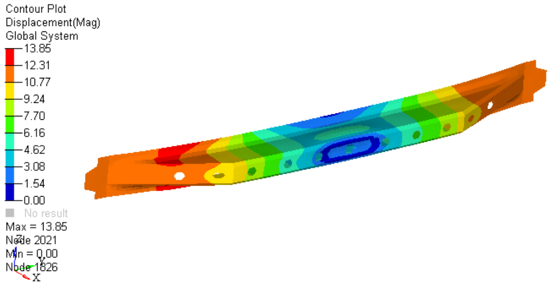


Fig.7 Displacement contour plot: GMT Bumper System

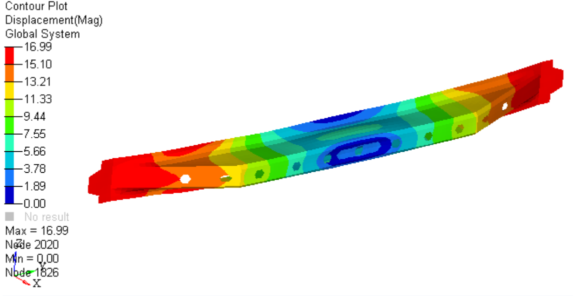


Fig.8 Displacement contour plot: KLFRT Bumper System

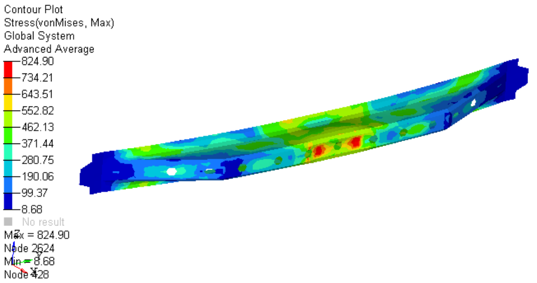
Following Table shows the Displacement of different bumper beam during the frontal collision. KLFRT material bumper beam shows more displacement compared to other material bumper beams during the collision.

Table2: Displacement Results of the bumper materials

Sr. No.	**Material Name**	**Displacement, mm**
1	Steel	8.04
2	Aluminium	3.34
3	LFRT	16.02
4	GMT	13.85
5	KLFRT	16.99

IX. VON-MISES STRESS RESULTS

Following contour plots shows the von-Mises stress for the bumper beam system for the velocity of 68 kmph when it gets crash with the rigid wall at the centre.



Fi.9 Von-Mises stress : Steel Bumper System

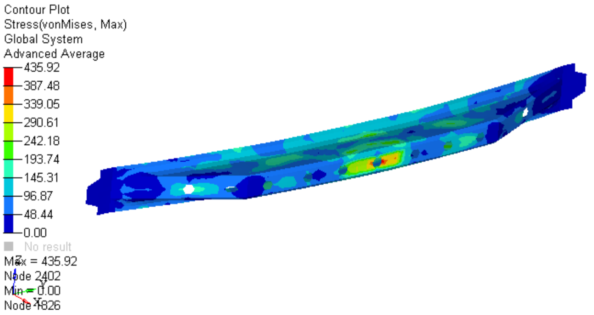


Fig.10 Von-Mises stress :Aluminum Bumper System

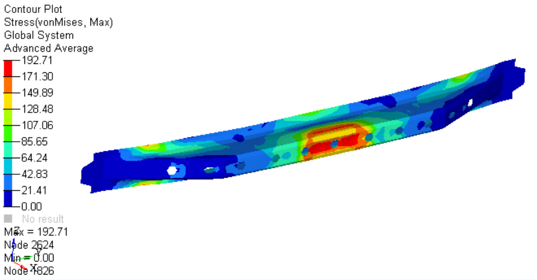


Fig.11 Von-Mises stress : LFRT Bumper System

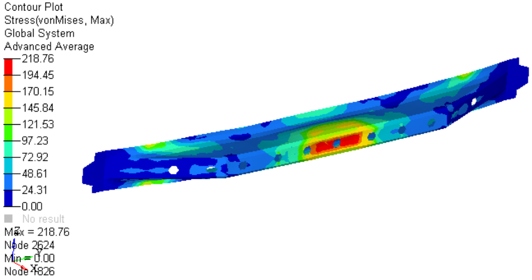


Fig12 Von-Mises stress : GMT Bumper System

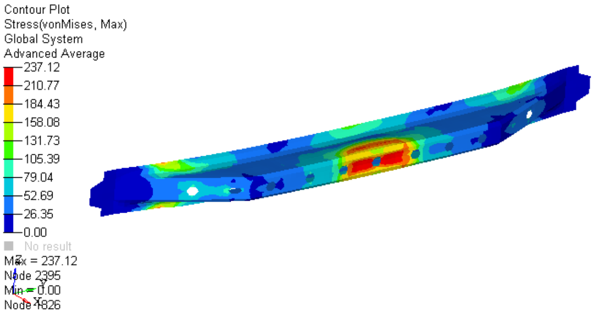


Fig.13 Von-Mises stress: KLFRT Bumper System

Table3: von-Mises stress results of the bumper materials

Sr. No.	Material Name	von-Mises stress, MPa	Yield Strength MPa	Factor of Safety
1	**Steel**	**824**	**700**	**0.88**
2	**Aluminium**	**435**	**480**	**1.12**
3	**LFRT**	**192**	**190**	**1.88**
4	**GMT**	**218**	**230**	**1.78**
5	**KLFRT**	**237**	**220**	**2.15**

X. ENERGY DISTRIBUTIONS

Steel Bumper

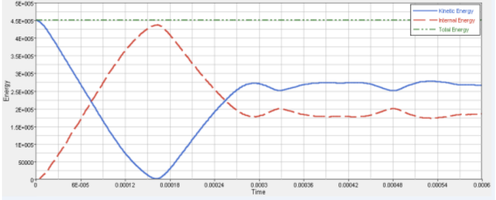


Fig.14 Energy Curves: Steel material

From the above Figure the energy distribution of the steel bumper was analysed and conventional steel material showed good energy absorption during collisions.

Aluminium Bumper

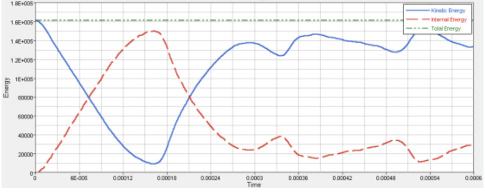


Fig.15 Energy Curves: Aluminium material

Similarly from the Figure the energy distribution of the aluminium was plotted. Even the light weighted aluminium bumper system stores more energy.

LFRT and GMT Bumper

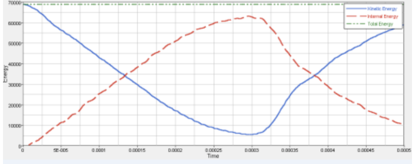


Fig.16 Energy Curves: LFRT material

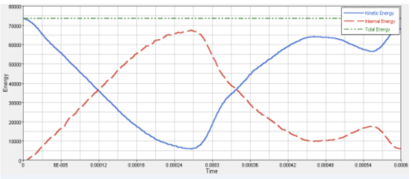


Fig.17 Energy Curves: GMT material

The energy absorption of the thermoplastic bumper beams were studied and it has challenging energy absorbing capacity equal to the conventional materials and having advantage of the light weight compared to steel and aluminium

KLFRT Bumper

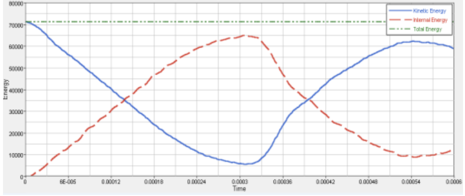


Fig.18 Energy Curves: KLFRT material.

Comparison of the displacement with respect to time was plotted for the various type of materials were plotted and the results were extracted from LSDYNA, according IIHS standard. The pendulum hits the bumper with 64km/h. The deflection is an important parameter to check the crashworthiness of the bumper beam material from a comparison of the graphs, it becomes clear that the KLFRT shows an increase in deflection. The deflection is inversely proportional to material stiffness. So the KLFRT is good alternative to replace the conventional bumper materials.

XI. VELOCITY OF BUMPER

The bumper beam impacts with the rigid wall with initial velocity of 68kmph. The following graph shows velocity of bumper beam for different materials. The result extracted at point of time where velocity becomes minimum as shown in the graph below.

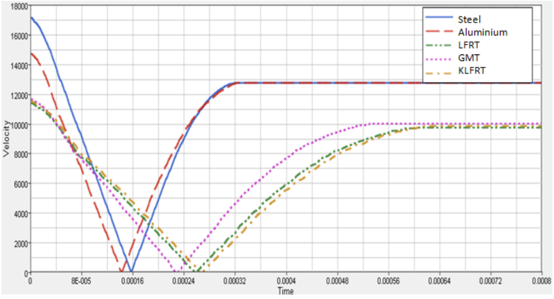


Fig.19 Velocity Vs time graph for all materials

XII. EXPERIMENTATION

Impact testing is used to determine material behaviour at higher deformation speeds. Classical pendulum impact testers determine the impact energy absorbed by a standardized specimen up to break. Test was carried out by means of two methods :

1) Used test specimen similar to bumper beam material (steel)
2) Used original bumper beam for impact

The specimen is fixed in the fixture as shown in the above pictures. The pendulum is released and impact energy is noted with the help of pointer and scale available in the impact machine. Test is carried out only for **steel material** to setup the correlation between the test and FEA. Once, we correlate the results between these two methods we can conclude that, the FEA setup is sufficient to predict the failure in other materials.

Fig20. Original Model of the INDICA Car Bumper Beam (Model – 2015)

Fig.21 Bumper Beam on Impact Tester

Following are the readings obtained from the test:

Sr. No.	Material Name	Test Results Displacement, mm
1	Steel-10x10 mm specimen	3.1
2	Actual bumper beam specimen-Steel	3.5

Energy absorbed during test impact in the steel material is listed below:

Sr. No.	**Material Name**	**Test Results Energy Absorbed, J**
1	Steel-10x10 mm specimen	410
2	Actual bumper beam specimen-Steel	430

COMPARISON OF RESULTS

Sr. No.	**For material Steel**	**Energy Absorbed, J**	**Displacement, mm**
1	FEA Results	450	2.94
2	Impact Test Results	430	3.5

XIII. CONCLUSION

Crash testing leads to improvement of the safety systems. These systems again have to be tested for their workability during a crash. Hence crash testing plays a vital role in continuous improvement of the safety systems. Design changes in vehicles and the location of engine block have been the results of evolution of crash testing.

During the FEA crash analysis test the maximum Von-Mises stress is observed up to 791 MPa in steel material for a speed collision with a velocity of 68 kmph. The aluminum material bumper shows von-Mises stress up to 427 MPa which occurs within the yield strength of the material. The LFRT, GMT and KLFRT show von Mises stress 101 MPa, 129 MPa and 102 MPa respectively. The stresses shown by the composite materials are below the respective values of yield strength of material.

From the crash test, it is concluded that, the LFRT is more suitable for the bumper beam system. KLFRT is also a good alternative since; LFRT has higher stiffness as compared to other materials.

Steel material adds additional weight to the bumper beam system. Aluminum lowers the weight of the system but, shows higher von-Mises stress as compared to other materials.

Therefore in future, further studiescould suggest many more design changes in shape or size in addition to material change, which could further minimize the probability of damage during a crash.

XIV. REFERENCES

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