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Design and Crash Analysis of Passenger Car Frontal Bumper Beam Using Hypermesh and Radioss

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Abstract—

Bumper is one of the main parts which are used as protection for passengers from front and rear collision. The aim of this study was to analyze and study the structure and material employed for car bumper in one of the car manufacturer. In this study, the most important variables like material, structures, shapes and impact conditions are included for analysis of the bumper beam in order to improve the crashworthiness during collision. The simulation of a bumper beam is characterized by impact modeling using a dedicated 3D modeling software CATIA V5 R20, meshing is done using HYPERMESH R13, impact analysis is performed by using ALTAIR RADIOSS software. As per regulations of Federal Motor Vehicle Safety Standards, FMVSS 208 the speed is 13.3 m/sec (48 kmph) is used to analyze the results. Occupant Crash Protection whereby the purpose and scope of this standard specifies requirements to afford impact protection for passengers is essential. In this research, work the analysis is carried for speed according to regulations and also by changing the speeds. Simulation using Finite Element Analysis software such as radios was used. Automotive bumper system plays a very important role not only in absorbing impact energy, which is the original purpose of safety, but also in a styling stand point. This project is for the design of bumper system summarized as a degree of absorption of impact energy in a limited clearance between back face of bumper and body parts of vehicle. This project attempts to show a method using computer simulation which has been broadly adapted in the various design stages of vehicle development. The analysis based on the international safety standards is done using a rigid wall impact with multiple materials. The finite element code is used for this study are Hypermesh, Radioss, Hyper View, ST Inspire and Hyper Graph.

Keywords— Bumper beam, Stiffners, Occupant crash, Radiosis, Hyper graph, Vehicle development

I. INTRODUCTION

In 1994, the National Safety Council estimated that 20 million vehicle crashes occurred on roads in the United States, resulting in 43,000 fatalities and 2.1 million injuries requiring hospitalization. From a public health perspective, motor vehicle crashes are the fourth leading cause of death after heart disease, cancer and stroke. Today, transportation safety efforts focus on crashworthiness, crash avoidance, driver performance, and highway construction. Over the past decade automakers have added many features to help the driver avoid a crash, such as anti-lock braking systems, traction control devices and daytime running lamps. Vehicles also include many crashworthiness features such as rigid steel occupant-cells surrounded by strategically placed, energy absorbing components. In addition, vehicles are equipped with an impressive array of restraint systems such as energy-absorbing steering columns, three-point belts, front and side air bags and head restraints to reduce the risk of injury. The contents of this treatise deal only with structural crashworthiness and related injury biomechanics issues. Before introducing crashworthiness, it seems appropriate to briefly discuss the evolution of the vehicle structure and the materials used in its fabrication.

II. PROBLEM DEFINITION

This analysis will be done by improving the existing bumper design, thus reducing the injuries sustained by the occupants and to reduce the damage of automotive body .This is done in accordance with crash worthiness standards, which require both mathematical and simulation models by using finite element methods. There are several areas of crash-impact space dynamics that need to be considered, in order to improve the crashworthy design of the front bumper .So far there have been many contributions towards understanding and analyzing the energy absorption characteristics of metals and composites. In this study FEM is used in studying the energy absorption of a front bumper .In addition the behavior of bumper under crash simulation is observed and improvisation is done in design of bumper. As a first approach to the problem it is decided to focus on the Front Bumper of a Car. The work in this project is performed to gain knowledge in FE-modeling of frontal bumper beam of car. The project will focus on consideration, material testing, component testing, FE-guidelines for the bumper.

SCOPE: Automotive bumper system plays a very important role not only in absorbing impact energy, which is the original purpose of safety, but also in a styling stand point. A great deal of attention within the automotive industry has been focused upon light weight and sufficient safety in recent years. Therefore, the bumper system equipped with thermoplastic and energy absorbing element is a new world trend in the market. This project is for the design of bumper system summarized as a degree of absorption of impact energy in a limited clearance between back face of bumper and body parts of vehicle. While experimental test is rather costly and time consuming, finite element analysis helps engineers to study design concept at an early design stage when prototypes are not available. This project attempts to show a method using computer simulation which has been broadly adapted in the various design stages of vehicle development. The analysis based on the international safety standards is done using a rigid wall impact with multiple materials. The finite element code is used for this study are Hypermesh, Radioss, Hyper View, ST Inspire and Hyper Graph.

III. LITERATURE REVIEW

Ramin Hosseinzadeh et al [1] in their work presented the parametric study of automotive composite bumper beams subjected to low-velocity impacts and stated that fuel efficiency and emission gas regulations are the main causes for reducing the weight of passenger cars by using composite structures. The year 1986 is a landmark in the history of the nonlinear FE method and marks a breakthrough in crash simulations [2]. Accidents occur in a random manner. An automobile can be impacted from any direction at different speeds. It can also include an automobile impacting another automobile, which in turn can be the same or different from the first automobile. This shows how automobiles affect and being affected by each other in crash situations [3]. An automobile can also impact a rigid barrier, a tree, a light post .etc, which may lead to severe deceleration and high loads, as a rigid body cannot deform to absorb part of the impact energy. A significant number of automobile collisions involved bumper-to-bumper contact at speeds which produce little or no permanent vehicle damage. Crashworthiness is an engineering term used to define the ability of vehicle structure to protect its occupants during an impact [4]. Crashworthiness is not limited to automobiles only, it is also applied to other transportation vehicles, such as ships, planes, and trains. In fact, the first systematic and scientific investigation of the subject was applied to railway axles between 1879 to 1890 by Thomas Andrews [5]. In other words, crashworthiness is the process of improving the crash performance of a structure by sacrificing it under impact for the purpose of protecting occupants from injuries [6]. To improve the structure design for crashworthiness, it is required to understand the different factors affecting the crash process. In the following, different fundamental aspects of design for crashworthiness have been described and pertinent works have been reviewed. An automobile can also impact a pedestrian which leads to the importance of design for pedestrian safety as well, and finally an automobile can go into rollover accidents. According to Galganski [7], crashworthiness problems can be characterized by displacement and energy of frontal structure. Crash pulse is the deceleration induced by impact on the human body. Head injury criterion (HIC) is used to measure the damage from crash pulse on the brain, and it should be less than a certain limit by regulations [8]. To provide the minimum level of safety, automobile manufacturers are obliged by law to ensure that their designs comply with governmental regulations. Automobile manufacturers must demonstrate that their vehicles are in compliance with safety standards before they are sold. For frontal collisions, vehicle designs are regulated by FMVSS 208 in the U.S., by CMVSS 208 in Canada, and by ECE R-12 in Europe [9-13]. This type of accidents can be prevented by controlling vehicle dynamic responses during driving and braking performance, as reported by El-Gindy et al. [14, 15]. The stiffeners used in SIFs and composite materials developed for the buckling phenomenon are studied in detail[16-18].

IV. MODELING OF BUMPER BEAM

The dimensions of bumper beam model is shown in Fig.1, from this using Catia V5 R19 a 3D model is developed which is shown in Fig.2a and FE model using Hypermesh is shown in Fig2b.

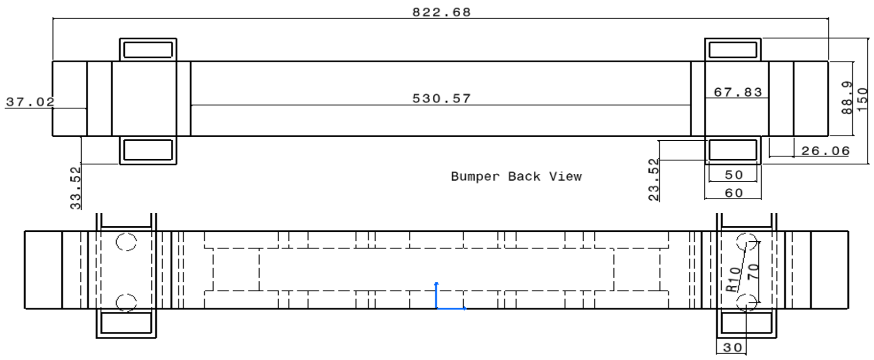
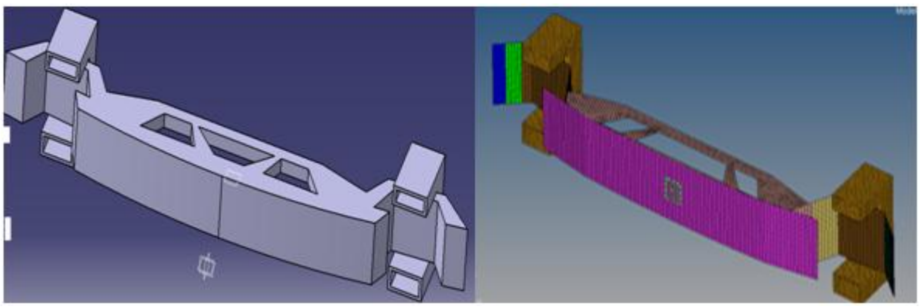


Fig:1. Drawing of bumper beam model



a. Geometric model created in Catia b. FE model created in Hypermesh
Fig: 2 3D geometric and FE model of a bumper beam

V. RESULTS AND DISCUSSIONS

The analysis is performed in the bumper beam model with different designs and materials. The materials used for crash test, for bumper is Aluminium 6063-t6, E-Glass Epoxy and Carbon Fiber Composite is used for the analysis. Steel material is used for the beam of bumper. The properties are given table1.

TABLE 1 PROPERTIES OF MATERIALS USED FOR BUMPER BEAM

Properties	Bumper material			Beam material
	AL-6063T6	E-Glass/Epoxy	Carbon Fiber Composite	Steel (AISI 304)
Young's modulus, MPa	68900	78000	70000	210000
Density, Kg/m^3	2700	1900	1760	7800
Passions ratio	0.33	0.27	0.1	0.3
Yield stress, MPa	200	425	570	215

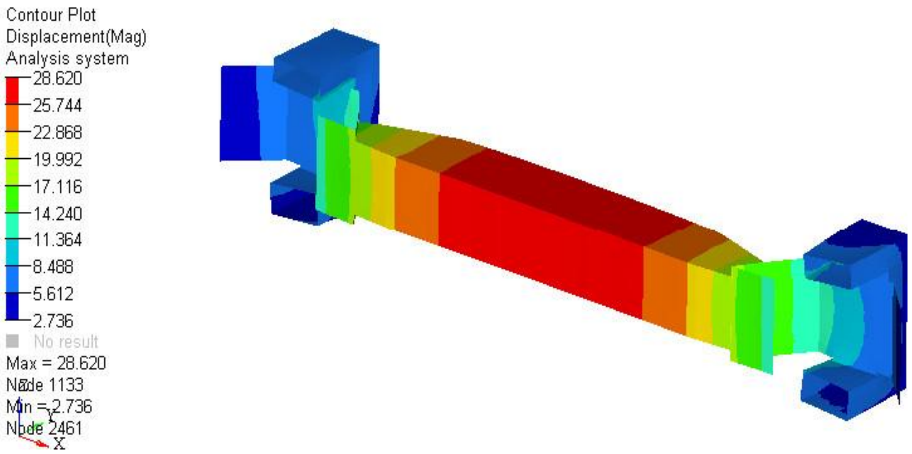


Fig 3a. The displacement induced in the bumper at 20Kmph

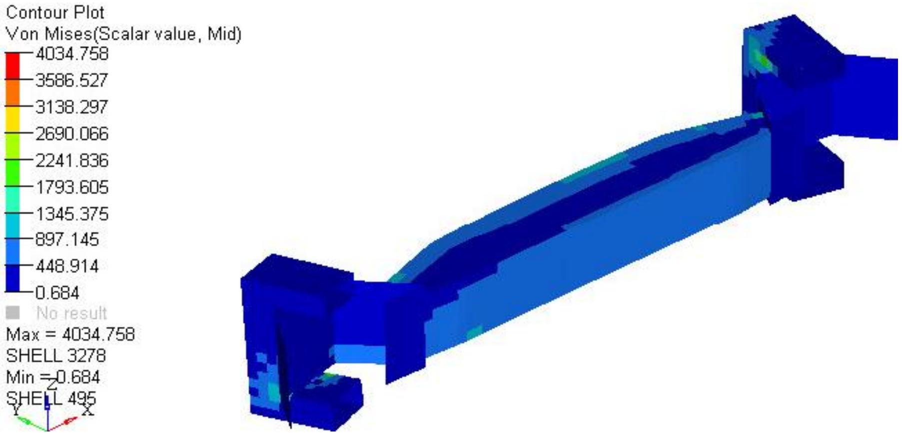


Fig 3b. The displacement and stresses induced in the bumper at 20Kmph

Fig.4 shows the detailed comparison of displacement of three different bumper beam designs with three different bumper materials at an impact speed of 48Kmph. From the figure it is observed that first and second design for all the materials used are relatively less displacement and aluminium bumper is the lowest in all the designs.

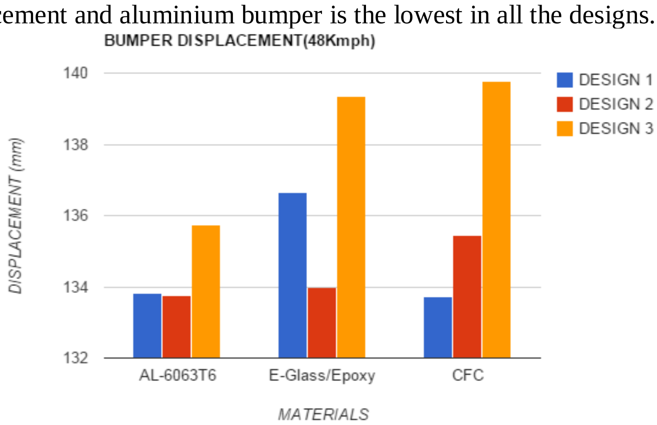


Fig.4. Bumper beam displacement at 48Kmph impact speed

Fig.5 and 6 shows the detailed comparison of stresses induced in bumper beam of three different bumper designs with three different bumper materials at an impact speed of 20Kmph and 48 Kmph. Fig.6 shows the detailed comparison of stresses induced in bumper beam of three different bumper designs with three different bumper materials at an impact speed of 48Kmph. It is observed that design 1 and design2 are having less stresses induced in all materials used as compared to design2. The bumper made of composite materials is showing least stresses.

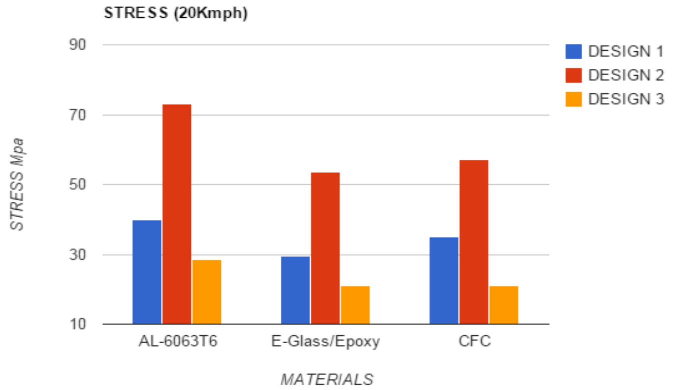


Fig.5: Stresses induced in the bumper at a impact speed of 20 Kmph

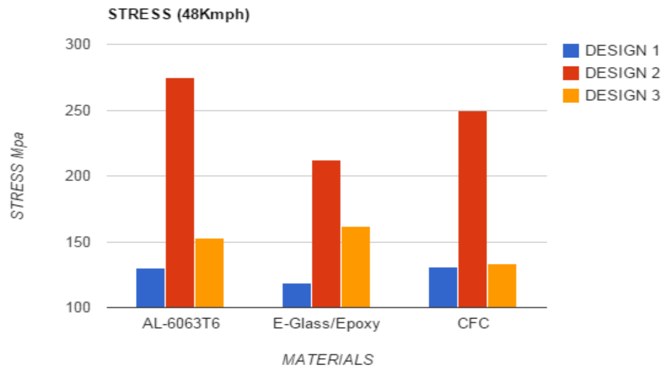


Fig.6: Stresses induced in the bumper at a impact speed of 48Kmph

Fig.7 shows the comparison of bumper beam weights of three different bumper beam designs with three different bumper materials.the weight of composite materials are least and the deign 2 is relatively low weight.

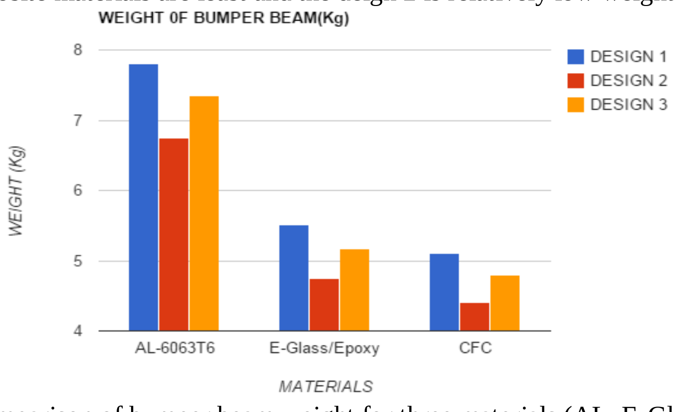


Fig.7: Comparison of bumper beam weight for three materials (AL, E-Glass, CFC)

VI. CONCLUSION

In the design of the automobile bumper, two constraint conditions are considered. First, the deflection of the bumper is taken in this study. Second, any plastic deformation should not be noticed in order to protect the assembly of the vehicle such as engine, fuel units, cooling units, ant, etc., from damage. Aluminium 6063-T6 as the original material of the bumper was studied in three stages which is for three materials like Al 6063-T6, E glass epoxy and Carbon Fiber Composite at two different speeds 20Km/Hr and 48Km/Hr. Firstly, bumper with the basic design has been studied, such as strengthening the bumper with adding the stiffeners and variable thickness of bumper. Bumper beams in passenger cars as a key structure for absorbing impact forces during collisions, were characterized by FEM modeling in accordance to low-velocity impact standards and high velocity impact standards. From the results there is an increase in the displacements from first base design to the improved third design and it is a maximum of 5mm increase in displacement for a decrease of 1Kg weight of bumper beam. Carbon Fiber Composite material found best bumper beam material as it is resisting the impact load as equivalent to AL 6063-T6 and comparatively very less in weight. Hence carbon fiber composite material is best suited as bumper beam material.

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