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Parametric Design and Analysis of Four Wheeled Car Bumper Using Catia & Ansys

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Abstract: Bumpers play a vital function in preventing the effect strength from being transferred to the car and passengers. Saving the effect energy in the bumper to be launched within the surroundings and reduces the damage of the car and the passengers. In this analysis, a bumper used for low passenger vehicle is used, this bumper absorbs the impact energy with its deformation or transfers it perpendicular to the effect route at distinct speeds (40, 60, 90&100 km/hr). The substances used for these analyses are Aluminum B390 alloy, Chromium coated mild steel and Glass Mat Thermoplastic (GMT) substances. Static & impact evaluation is to decide the deformation, stress of the car bumper, modal evaluation is to decide the frequency and deformation for mode shapes. 3-D modeled by means of the usage of the software program CATIA.

Keywords: Car bumper, Impact energy, Energy absorbers, 3D modelling, CATIA, Ansys

1. Introduction

In automobiles, a bumper is the front-most or rear-most part, ostensibly designed to allow the car to sustain an impact without damage to the vehicle's safety systems. They are not capable of reducing injury to vehicle occupants in high-speed impacts, but are increasingly being designed to mitigate injury to pedestrians struck by cars. Recent trends in automotive design worldwide have seen more emphasize towards addressing sustainability issue a part from meeting operational requirements of the component design especially in the early product development stage. A good design of car bumper must provide safety for passengers and should have low weight. Different countries have different performance standards for bumpers.

Bumpers play an important role in preventing the impact energy from being transferred to the automobile and passengers. Saving the impact energy in the bumper to be released in the environment reduces the damages of the automobile and passengers. The goal of this paper is to design a bumper with minimum weight by employing the Glass Material Thermoplastic (GMT) materials. This bumper either absorbs the impact energy with its deformation or transfers it perpendicular to the impact direction. To reach this aim, a mechanism is designed to convert about 80% of the kinetic impact energy to the spring potential energy and Release it to the environment in the low impact velocity according to American standard1. In addition, since the residual kinetic energy will be damped with the infinitesimal elastic deformation of the Bumper elements, modeling, solving and result's analysis are done in CATIA, LS-DYNA and ANSYS V8.0 software respectively [1].

Automotive bumper system is one of the key systems in passenger cars which help to protect the vehicle during impacts. The following paper deals with the design improvements in the front bumper of passenger cars in India, using impact analysis. The modification will be made considering size, shape and material. The study will focus on existing design performance, advantage and limitations. Based on observations design improvements will be made in terms of shape, size and or material based on design modification objectives. Modified front bumper design will be tested using FEM software for impact loads as per international standards [2].

The current pedestrian safety assessment procedure consists of several different tests that represent the impact of the leg, upper leg and head. The leg form impact test typically involves the front bumper, radiator grill, hood and headlights. In addition, some vehicle styles incorporate lower fascia structures that can have a significant effect on lower leg impact [3]. Mohapatra S[4] discusses that automotive development cycles are getting shorter by the day. With increasing competition in the marketplace, the OEM's and suppliers main challenge is to come up with time-efficient design solutions. Researchers are trying to improve many of existing designs using novel approaches. Many times there is conflicting performance and cost requirements, this puts additional challenge with R&D units to come up with a number of alternative design solutions in less time and cost compared to existing designs. These best solutions are best achieved in a CAE environment using some of the modern CAD and FEM tools. Such tools are capable of effecting quick changes in the design within virtual environment.

It is significant in the study of influences to distinguish between the two altered types of effects that occur, elastic & plastic impacts. In a elastic effect an immaterial amount of energy is lost among the two affecting bodies, for instance, the impact of two billiard balls. A plastic effect includes a lot of energy disseminated in the collision. An effect between two vehicles/between one vehicle & an rigid body, where the vehicles fold on affect, is a case of an elastoplastic effect. The impacting wonder between an impactor & the front guard in a low-speed full crash could be extremely confused, since transient and nonlinear examinations are included [5]. Be that as it may, in outlining the front guard, car producers demand that the guard framework ought not to have any material crash or disappointment. Along these lines, up to that point, the total energy is moderated all through the effect span.

Energy absorbers are designed to absorb a portion of the kinetic energy from a vehicle collision. Energy absorbers are very effective in a low speed impact, where the bumper springs back to its original position. Energy absorber types include foam, honeycomb and mechanical devices. All foam and honeycomb absorbers are made from one of three materials: polypropylene, polyurethane or low-density polyethylene. Mechanical absorbers are metallic and resemble shock absorbers. However, mechanical absorbers have several times the weight of foam or honeycomb absorber and receive very limited usage. In some bumper systems, the reinforcing beam itself is designed to absorb energy and separate energy absorbers are not required. The materials used for these analysis are Aluminium B390 alloy, Chromium coated mild steel and carbon composite. During the impact analysis, the composite shows the highest stress value, lowest deformation and the lowest strain value on compared with above materials. The analysis under the dynamic loading shows this carbon composite has the maximum stress value and it having the highest strength to weight ratio and producing low deformation [6].

2. 3D Modelling

CATIA is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program that runs on Microsoft Windows. Building a model in CATIA usually starts with a 2D sketch (although 3D sketches are available for power users). The sketch consists of geometry such as points, lines, arcs, conics (except the hyperbola), and splines. Dimensions are added to the sketch to define the size and location of the geometry. Relations are used to define attributes such as tangency, parallelism, perpendicularity, and concentricity. The parametric nature of CATIA means that the dimensions and relations drive the geometry, not the other way around. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside of the sketch.

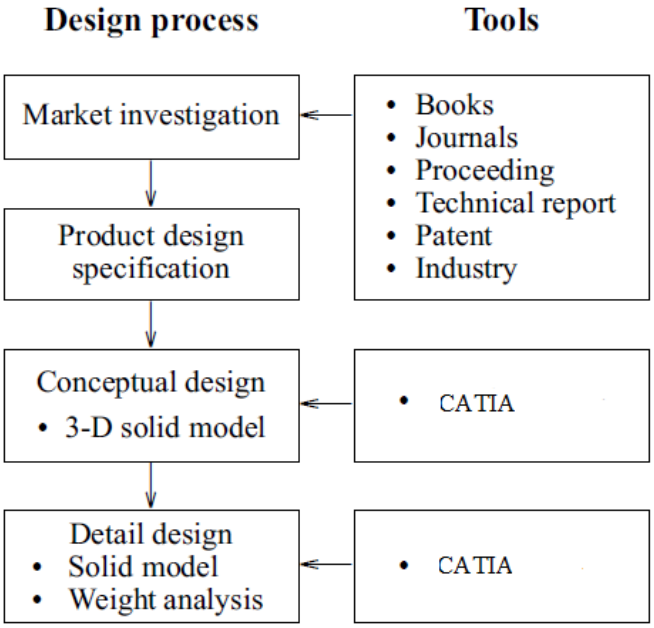

Fig.1 The architecture of the research

The bumper beam dimension is measured from local passenger car. From the measured dimension generate the 3D Bumper beam is generated in CATIA workbench. The analysis is nonlinear explicit type. Bumper beam generated is surface model. The Barrier is made as per the ECE R42 standards [7] this barrier acts

as rigid component. The bumper beam is attached to two semi-cubic plastic polypropylene (PEP) holders as shown in Fig.2. In this study to reduce the simulation time bumper beam is replaced with spring having stiffness equal to the stiffness of the crash can. These springs are attached to end plate, and the complete assembly is attached to car body. In this model half of car weight (with passenger) is applied to each end plate as point mass. Weight of the barrier is also equal to weight of car (with passenger).All the degree of freedom are restricted for end plates and barrier, except the degree of freedom in the direction perpendicular to barrier Bumper beam is meshed by shell element whereas barrier and end plate is meshed with rigid solid element. Material used for bumper beam is martensitic steel and for the barrier and end plate it is structural steel. Barrier was modeled according to dimensional drawings from E.C.E. standard. Fig.2 shows the model of bumper beam and barrier. As shown in the figure barrier impacts on bumper beam in straight and perpendicular direction. Frictionless contact was assumed between barrier and bumper beam surface and the car was taken to be lying on a flat and frictionless surface. Barrier velocity was 4kmph for straight impact as stated in E.C.E standard.

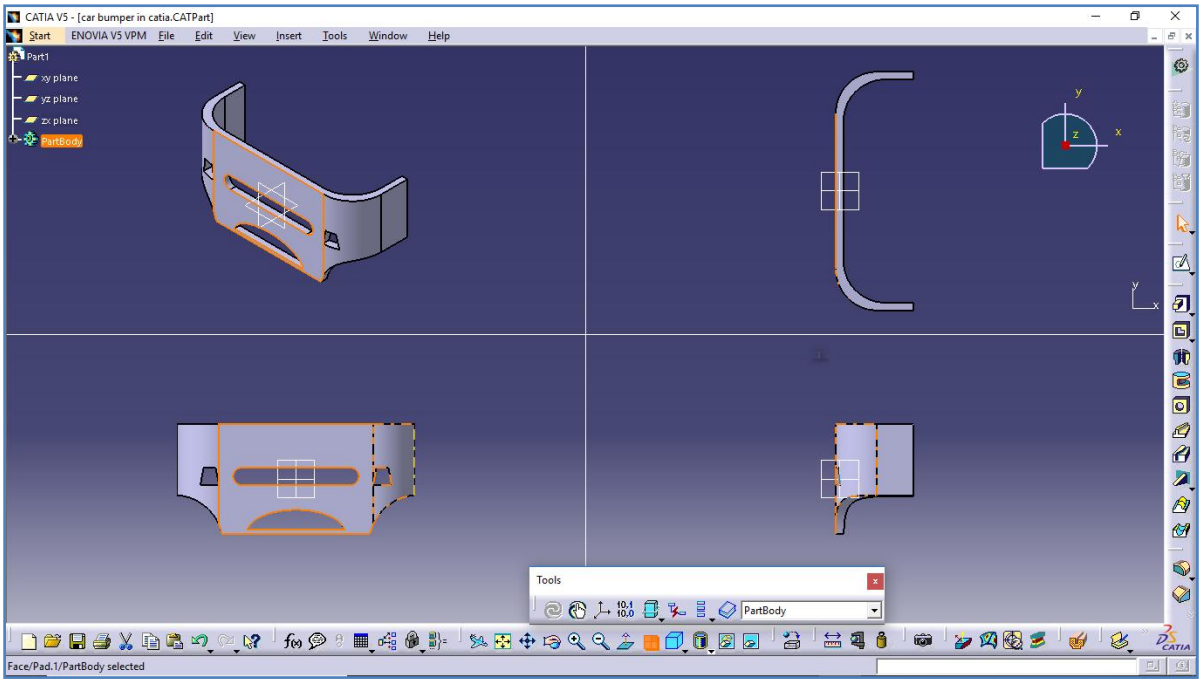

Fig.2 3D model views of front bumper in CATIA 3D software

From the above study it is clear that if the bumper beam is tested considering effect of mass, it is critical case nearer to actual case. If this is safe then it is definitely safe for the case without passenger. In the second place, any plastic deformation of the bumper beam should be avoided as much as possible in low-speed mode. Maximum deformation of bumper beam should be within the acceptable limit which in this study is 40mm limit is considered. The maximum stress of the bumper must be below the yield stress. From the material study it is conclude that bumper beam material must have high yield strength and high modulus of elasticity. Fig. 3 shows the Von-Mises stress distribution in bumper beam. Maximum stress is induced at the middle portion of the bumper beam as it is less than the yield stress of material so the bumper beam is safe (only a sample model figure obtained from ANSYS is provided but analysis not included in the present paper).

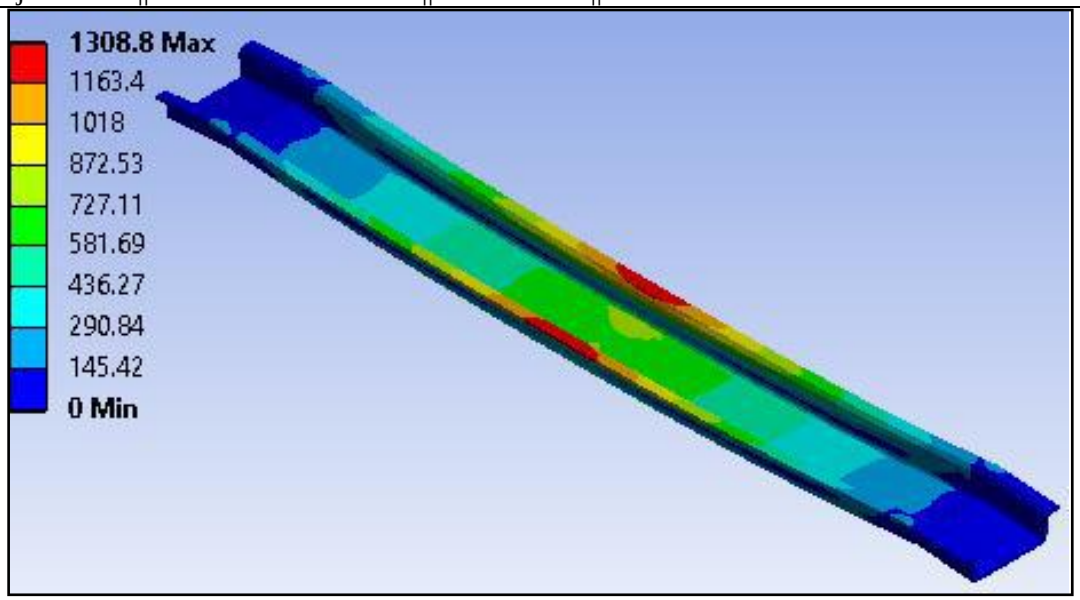

Fig. 3 Von Mises stress distribution in bumper beam (ANSYS sample figure)

3. Results and Discussions

3.1 Modal Analysis Results

The results obtained for the modal analysis of three different materials are discussed under this section. While doing the analysis, the natural frequencies are found out. Natural frequency is the frequency at which a system tends to oscillate in the absence of any driving or damping force. A free vibration of any elastic body is called natural vibration and happens at a frequency called natural frequency. Natural vibrations are different from forced vibrations which happen at frequency of applied force (forced frequency). If forced frequency is equal to the natural frequency, the amplitude of vibration increases manifold which is known as resonance. As we studied earlier, the value of natural frequency will depend on the stiffness and the mass of the material. Mass will varied for each material which is also depending upon the value of density. Like that the stiffness will depend on the force and the deflection of the geometry. Since all the geometries taken in these analyses are identical, the chances for the variation of the frequencies are only due to the change in the density of the materials.

3.2 Dynamic Analysis results in ANSYS

After completing this step the harmonic response analysis should be carried out to find out the total deformation, von mises stress and strain components at various frequencies. In this analysis all loads as well as the structure's response vary sinusoidally at the same frequency. A typical harmonic analysis will calculate the response of the structure to cyclic loads over a frequency range and obtain a graph of some response quantity (usually displacements) versus frequency. "Peak" responses are then identified from graphs of response vs. frequency and stresses are then reviewed at those peak frequencies. Separate meshing and material selections are not necessary, since this harmonic analysis is doing as a continuation of the modal analysis which is completed in ANSYS Workbench. In the analysis setting option of the software, we have to select the range minimum and maximum of frequency, mode frequency range, number of modes, mode range minimum and maximum, constant damping ratio. After completing the boundary condition and the load have to been applied in the respective area of the imported model. While calculating the pressure the self-weight of the each bumper are calculated. From that, the forces are calculated by multiplying it with the acceleration due to gravity. Since the assumption used here is that dynamic load acted is only due to self-weight of the bumper, it is acted at the inner surface of the bumper which is clearly identified from the fig 3. Force calculated is converted into pressure by adopting the value of surface area of the face where pressure is applied. The value of surface area is found by using CATIA software and the mass of the different bumpers by using ANSYS Workbench itself.

4. Conclusions

The systematic design approach is able to guide the designer to achieve the set goals. The conceptual design is very important in design activities because it forms the background work of the bumper design. The systematic conceptual design enables the designer to produce a high quality design in the final design stage. 3-D solid modelling software such as CATIA has been used extensively in conceptual design and the detail design stage [8,9]. The parametric software is the best because it can provide an opportunity for the designer to optimize the thickness of the bumper. The advantages of Aluminum B390 alloy, Chromium coated mild steel and Glass Mat Thermoplastic (GMT) such as low weight, corrosion free, easier to produce complex shapes, high specific strength, and high specific stiffness make it suitable material for the bumper.

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