Design and Impact Analysis of Automobile Front Bumper Beam by Varying Materials

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Abstract

Front and rear collision is consistently taken over by a main part of an automobile vehicle which is called bumper beam. In this study, impact analysis on a typical automobile front bumper beam was carried out successfully by varying the materials. The ultimate objective of this analysis is to design an automobile front bumper beam and establish the different impact behaviour of the bumper beam by varying the material. In this analysis, bumper material was varied and the corresponding impact behaviors were studied on bumper beam with the aim of material optimization. The imitation and impact analysis of an automobile front bumper beam is distinguished by impact modeling using CREO modeling software and ANSYS 18.1 software to establish the results. Different impact analysis outputs were established and compared with each other for three bumper beam materials through ANSYS 18.1 software. Impact analysis results revealed that the superior impact behaviour was found in Carbon fiber F300 material which is higher than other two materials.

Keywords: Automobile front bumper beam, design, impact analysis, varying material.

1. Introduction

An automobile's bumper is the front-most or rear-most part, designed to allow the car to sustain an impact without damage to the vehicle's safety systems. In order to improve the crashworthiness during collision in a car bumper, different parameters such that the material, structures, shapes and impact conditions were studied [1]. Simulation and analysis of a Rear Under Run Protection (RUPD) system under crash scenario was focused. The choice of material and the structural design are the two major factors for impact energy absorption during a crash. It is important to know the material and mechanical properties and failure mechanism during the impact. Component functions, geometry, behavior of material and other parameters that influence the compatibility of the car bumper and rear under run protection device [2]. Improvement of GFRP car bumper’s impact strength by the introduction of non-isotropic laminate composite methodology is studied. Comparative analysis was also done between GFRP, Glass fiber with Aluminum lamina by Ansys Workbench 13.0 [3]. Impact behavior of a
composite car bumper made from new materials. The study is performed using CREO software for the design of the new car bumper made from new composite materials and the stress concentration distribution is evaluated by use of finite element analyze with Abacus software for the impact cases [4]. Design and analysis bumper beam subjected to offset impact loading with different materials using FE-code ANSYS-LS DYNA are analyzed and suggested the best material for the bumper. Attempt also been made with simulation of forming process for generating the FE-model of the bumper beam with required curvature [5]. A commercial front bumper beam made of glass mat thermoplastic) is studied and characterized by impact modeling using LS-DYNA ANSYS 5.7. Three main design factors for this structure: shape, material and impact conditions are studied and the results are compared with conventional metals like steel and aluminum. Finally the aforementioned factors are characterized by proposing a high strength SMC bumper instead of the current GMT [6]. Most important parameters including material, thickness, shape and impact condition are studied for design and analysis of an automotive front bumper beam to improve the crashworthiness design in low-velocity impact. In this research, a front bumper beam made of three materials: aluminum, glass mat thermoplastic and high-strength sheet molding compound is studied by impact modeling to determine the deflection, impact force, stress distribution and energy-absorption behavior. The mentioned characteristics are compared to each other to find best choice of material, shape and thickness .The results show that a modified SMC bumper beam can minimize the bumper beam deflection, impact force and stress distribution and also maximize the elastic strain energy. In addition, the effect of passengers in the impact behaviour is examined [7]. A bumper system including a bumper cover, an energy absorber formed of a synthetic resin material through a foam moulding process, an impact beam for supporting the energy absorber, the impact beam being formed of a glass mat thermoplastics and having a "C"-shaped section, and a stay for connecting the impact beam to a vehicle body. Tips are formed on front upper and lower portions of the impact beam, and a web portion is formed on the impact beam between the tips. Tip insertion grooves in which the tips are inserted are formed on an inner surface of the energy absorber, and a pressure receiving surface corresponding to the web portion is formed on the inner surface of the energy absorber [8]. In this current work, a typical bumper beam was designed and analyzed for three materials to establish the different impact outputs numerically.

2. Design and Analysis

Commercial modeling software is used to design the absolute three dimensional model of a bumper beam. Inputs for three dimensional modeling were obtained from the existing bumper beam design data base. Modeling inputs obtained from the data base were successfully executed in the modeling software package. An inclusive three dimensional model of a bumper beam which is obtained from modeling software with different orientations are shown in figure.1 (a), (b) and (c) respectively. The complete 3D model of the bumper beam is imported in ANSYS 18.1 version to establish the various impact outputs for the three different materials. Boundary conditions were applied to imported bumper beam model in ANSYS software to obtain the impact analysis outputs. The boundary conditions applied bumper beam models were illustrated in figure.2 (a) and (b). Meshing process in initiated to carve up the entire surfaces of the imported bumper beam model to get the accurate results for the desired inputs. Tetrahedral mesh elements were used to get the complete mesh model of the 3D bumper beam. A complete mesh model of the three dimensional bumper beam is shown in figure.2 (c). Properties for bumper beam material are given in material description domain in the ANSYS software. The following three
materials were chosen as the bumper beam material to investigate the effects of impact load on the bumper beam. Compute domain is initiated after the complete inputs feeding process into the ANSYS software. Desired different outputs were defined in the compute domain to get the complete impact behaviour of the bumper beam for three materials. The different color plots which are obtained from the ANSYS software where shown in results and discussions chapter.

**Table 1 Properties of proposed bumper beam material**

<table>
<thead>
<tr>
<th>Material</th>
<th>Young’s modulus E (GPa)</th>
<th>Yield strength YS (MPa)</th>
<th>Poisson ratio v</th>
<th>Density ρ (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum alloy 6060-T5</td>
<td>69.5</td>
<td>243</td>
<td>0.33</td>
<td>7850</td>
</tr>
<tr>
<td>Carbon fiber T300</td>
<td>233</td>
<td>13.9</td>
<td>0.22</td>
<td>1760</td>
</tr>
<tr>
<td>M220</td>
<td>200</td>
<td>1350</td>
<td>0.3</td>
<td>7890</td>
</tr>
</tbody>
</table>

Figure 1(a), (b) and (c) Inclusive three dimensional model of a bumper beam
Figure 2 (a) & (b) Applied boundary conditions on bumper beam (c) complete mesh model of bumper beam
3. Results and Discussions

Impact analyses in an automobile front bumper beam with three different materials were successfully analyzed with the help of ANSYS 18.1 software successfully and the following results were obtained for all materials. Total deformation accomplished by the front bumper beam of a typical automobile vehicle for M220, Aluminium alloy 6060-T5 and Carbon fiber - F300 is demonstrated in figure.3 (a), (b) and (c) correspondingly. From these color plots, it was found that the automobile front bumper beam analyzed with M220 material reach the minimum total deformation of 0.0093976 mm and also the maximum total deformation of 0.084578 mm is attained by the same material. Total deformation attained by an automobile front bumper beam analyzed with aluminum alloy 6060-T5 is shown in figure.3 (b). It was noted that the minimum and maximum total deformation of 0.012023 mm and 0.10821 mm were attained by the aluminum alloy 6060-T5 material bumper beam respectively. Analyzed results on total deformation for Carbon fiber F300 bumper beam material were illustrated in figure.3 (c). It was observed that the automobile bumper beam analyzed with Carbon fiber F300 exhibits the minimum total deformation of 0.0062805 mm and 0.056525 mm respectively. Equivalent elastic strain revealed by the automobile front bumper beam under the three materials change during the impact analysis in ANSYS software is demonstrated in figure.4 (a), (b) and (c) correspondingly. Analyzed output results on equivalent elastic strain for M220 material automobile bumper beam were shown in figure.4 (a). Bumper beam analyzed with M220 material is exhibits the minimum equivalent elastic strain of 0.000011311 and maximum equivalent elastic strain of 0.00081446 respectively. Equivalent elastic strain established by the automobile front bumper beam which is analyzed with aluminium alloy 6060-T5 is shown in figure.4 (b). ANSYS results revealed that the front bumper beam analyzed with aluminium alloy 6060-T5 exhibits the minimum equivalent elastic strain of 0.000090496 and minimum equivalent elastic strain of 0.00081446 respectively. Bumper beam analyzed with carbon fiber F300 for equivalent elastic strain was illustrated in figure.4 (c). Minimum and maximum equivalent elastic strain of 0.0000098417 and 0.000085336 were obtained through the ANSYS results for the bumper beam, which is analyzed with Carbon fiber F300 accordingly. Equivalent elastic stress leaves go off by an automobile bumper beam under an impact load for three different materials (M220, Aluminium alloy 6060-T5 and Carbon fiber - F300) were represented in figure.5 (a), (b) and (c) correspondingly. Bumper beam analyzed in ANSYS, M220 as a bumper beam material under impact analysis for the equivalent elastic stress is shown in figure.5 (a). It was noted that the minimum equivalent elastic stress of 1.5645 MPa and 14.081 MPa is exhibited by the M220 bumper beam material during the impact analysis. Bumper beam analyzed with aluminum alloy 6060-T5 for equivalent elastic stress is shown in figure.5 (b). The color plots shows that the bumper beam which is analyzed in ANSYS with aluminum alloy 6060-T5 as bumper beam material exhibits the maximum and minimum equivalent elastic stress of 127.77 MPa and 14.196 MPa respectively. Equivalent elastic stress established by the bumper beam which is analyzed with Carbon fiber F300 is depicted in figure.5 (c). Bumper beam analyzed with Carbon fiber F300 as bumper beam material delivered the maximum and minimum equivalent elastic stress of 0.9191 MPa and 8.2719 MPa respectively. Comparative graphical representation of total deformation, equivalent elastic strain and equivalent stress exhibited by the M220 material, Aluminium alloy 6060 – T5 material and Carbon fiber – F300 material during the impact analysis through ANSYS 18.1 software is shown in figure.6 respectively.
Figure 3 Total deformation in bumper beam for (a) M220 material (b) Aluminium alloy 6060 – T5 material (C) Carbon fiber – F300 material
Figure 4 Equivalent elastic strain in bumper beam for (a) M220 material (b) Aluminium alloy 6060 – T5 material (C) Carbon fiber – F300 material
Figure 5 Equivalent stress in bumper beam for (a) M220 material (b) Aluminium alloy 6060 – T5 material (C) Carbon fiber – F300 material
Conclusion

Impact analysis on a typical automobile front bumper beam was carried out using ANSYS software by varying the materials such as M220, Aluminium alloy 6060-T5 and Carbon fiber F300 respectively. Different impact behaviors like, total deformation, equivalent elastic strain and equivalent elastic stresses of an automobile front bumper beam under the sudden impact load were established for three materials all the way through the ANSYS software. Established results of impact behaviour in a bumper beam under three materials were compared with each other and the following conclusions were made. Total deformation and equivalent elastic strain in bumper beam was found very low in Carbon fiber F300 material. In contrast, equivalent elastic stress exposed by the bumper beam was observed very high in Aluminium alloy 6060-T5. It was concluded that the Carbon fiber F300 material shall be used as a bumper material than the existing material and it can exhibits the superior impact behaviour during the vehicle crash.
References


