Design and Impact Analysis on front Bumper beam Crash box for a sedan car using glass fiber reinforced polymer

Pooja Sreerama¹*, K.V.N.V.N.Rao ²

Abstract
In this paper, the crash analysis was performed of Bumper beam crash box sub frame for automotive vehicle. The vehicle’s front platform assembly behaviour when subjected to a frontal crash is described in this work. The frontal crash of the integrated car system is successfully simulated and analysed in ansys software. According to the basic principle of the static non-linear finite element method, in this study were involved with different materials like Glass fibre epoxy composite laminate and conventional materials. An initial model, the initial specimen, was selected as a reference to compare with the optimum designs which would be obtained. And also some preliminary test was out with this specimen. The specimen is prepared by the hand layup method and the material used is Glass fiber reinforced polimer. And the prepared sample specimen is divided into various dimensions for the testing purpose. To find the young’s modulus of the material, the specimen is involved testing methods of tensile, compression and impact test. Bumper beam crash box is drawn through the Catia and analysis in made by applying the boundary conditions and the results are compared with the experimental results. The GFRP has more stress and strain characteristics compared to Structural steel. The structural analysis will performed and the results will compared. The laminate prepared by glass epoxy composite materials and then this will undergo for testing with data acquisition system.

Keywords
Bumper beam, Glass fiber, GFRP, Functionally Graded Foam

1 Introduction
The purpose of the front is to absorb energy at the start of a crash and to guide the remaining crash forces into the rest of the body structure. At low and medium speed: to minimize the damage of the vehicle in order to reduce insurance cost. At higher speed: to guide the crash forces into the body structure in such a way that the probability for a disintegration of the body structure is low and the survival of the occupants is ensured. The car bumper is designed to prevent or reduce physical damage to the front and rear ends of passenger motor vehicles in low-speed collisions. Automobile bumpers are not typically designed to be structural components that would significantly contribute to vehicle crashworthiness or occupant protection during front or rear collisions. It is not a safety feature intended to prevent or mitigate injury severity to occupants in the passenger cars. Bumpers are designed to protect the hood, trunk, grille, fuel, exhaust and cooling system as well as safety related equipment such as parking lights, headlamps and taillights in low speed collisions. The purpose of the integration of deformation elements into the crash management system is to control the level of force at the interfaces between the bumper system and the car body. They must prevent damage to the bumper system itself (low speed) and reduce damage to the rest of the vehicle structure (medium speed). Two types of energy absorbers are used:
• Regenerative energy absorbers which can be used several times (e.g. dampers filled with viscous material or compressible materials (for example expanded polypropylene (EPP))
• Non-regenerative energy absorbers which can be used

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only once (e.g. folding crash boxes, shear crash boxes, tube in tube systems, metallic foams, etc.). The variety of requirements on the bumper system will generally lead to the selection of different design solutions when the technically feasible alternatives are evaluated under the overall condition of cost effectiveness.

2. LITERATURE SURVEY

In this study, the hybrid glass/carbon composite bumper beam was designed and manufactured 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. Based on the final design, the real bumper beam was manufactured and its impact performances were measured. It was found that the optimally designed GCMT bumper beam had 33 less weight compared to the conventional GMT bumper beam while having the improved impact performances. Energy absorption performance is one of the most important indexes in the vehicle safety during impact. Research on the car frontal structure energy performance and structure optimization was conducted in this paper. Whole vehicle model was established by HyperMesh and simulated in LS-DYNA. Simulation results indicated that modification was need for the original structure to meet requirement. Based on simplified whole vehicle model, orthogonal design optimization was implemented, including bumper cross beam material (A), bumper cross beam thickness (B), energy absorber groove distance (C), and front longitudinal beam groove number (D), with 3 levels for each factor. The best option was B3D1A3C3 was gained by using range analysis and integrated balance method. Simulation results showed that both front and total energy absorption were improved. The optimized structure increased front energy absorption to 51.1, which can meet the industry requirement. Crashworthiness characteristics and axial collapse with damage propagation behavior of an aluminum/CFRP hybrid square hollow section beam were investigated under dynamic axial crushing load for crash box application. The low speed impact test referred to the RCAR regulations was performed with five different lay-up sequences and two different laminate thicknesses. Both tip ends of hybrid specimen were clamped by a specially designed jig to assign a similar boundary condition with an auto body crash test model. Each different direction of carbon fibers offers respective crashworthiness characteristics, and the characteristics from each direction were mixed when stacked together. The specific energy absorbed and crush force efficiency were improved simultaneously up to 38 and 30, respectively in the Al/CFRP hybrid SHS beam with a [0/90]2n lay-up sequence, and they were slightly improved by increasing the thickness of the CFRP laminates.

3. MATERIALS USED IN BUMPER

At one time, most car bumpers were made of steel. Then, most were made of chrome or a chrome-plated material. Today, car bumpers can be made from anything from chrome-plated material to a variety of different rubber materials or plastics. This makes detailing car bumpers somewhat more complicated, as bumpers made from different materials require very different detailing treat-
Table 1. ASTM standard for mechanical testing

<table>
<thead>
<tr>
<th>Test</th>
<th>ASTM Standard</th>
<th>Specimen Size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tensile test</td>
<td>D635</td>
</tr>
<tr>
<td>2</td>
<td>Flexural test</td>
<td>D790</td>
</tr>
<tr>
<td>3</td>
<td>Impact test</td>
<td>D256</td>
</tr>
</tbody>
</table>

Table 2. Tensile test results

<table>
<thead>
<tr>
<th>Test parameter</th>
<th>Sample 1 (mm)</th>
<th>Sample 2 (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gauge Thickness</td>
<td>3.85</td>
<td>4.07</td>
</tr>
<tr>
<td>Gauge Width</td>
<td>24.77</td>
<td>24.87</td>
</tr>
<tr>
<td>Original Cross Sectional Area</td>
<td>101.82</td>
<td>101.82</td>
</tr>
<tr>
<td>Ultimate Tensile Load (KN)</td>
<td>49.95</td>
<td>49.41</td>
</tr>
<tr>
<td>Ultimate Tensile Strength (MPa)</td>
<td>381</td>
<td>388</td>
</tr>
</tbody>
</table>

Figure 4. Tensile test Specimen

Figure 5. Stress Strain Curve For Tensile Test

Figure 6. Load-Displacement Curve For Tensile Test

4. MODELLING, ANALYSIS AND EXPERIMENTAL RESULTS

The weight of the Gfrp reduced of about 36 percentage while compared to structural steel. The stress and strain values for the Gfrp vary by 6 and 11 percentage when compared to structural steel. And it is found the total deformation of the Gfrp increases by 14 percentage when compared to structural steel. As the deformation increases...
Table 3. Results compared between structural steel and GFRP

<table>
<thead>
<tr>
<th>SL NO</th>
<th>Property</th>
<th>Structural Steel</th>
<th>GFRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Weight (l)</td>
<td>344.7</td>
<td>124.52</td>
</tr>
<tr>
<td></td>
<td>Reduction in Weight</td>
<td>220.18</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Maximum Engaged stress</td>
<td>119.57</td>
<td>121.1</td>
</tr>
<tr>
<td></td>
<td>(at maximum)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Max Deformation (mm)</td>
<td>1.789</td>
<td>12.209</td>
</tr>
<tr>
<td>4</td>
<td>Maximum Strain (mm)</td>
<td>0.001599</td>
<td>0.013361</td>
</tr>
</tbody>
</table>

Figure 7. Compression test Specimen
Figure 8. Stress Strain Curve For Compression Test
Figure 9. Load-Displacement Curve For Compression Test
Figure 10. Catia model of bumper beam with crash box
Figure 11. 3D representation of bumper beam with crash box
Figure 12. Applying the boundary conditions
Figure 13. Meshing
the energy absorption also increases gradually.

5. CONCLUSION

The experiment is done to improve the crashworthiness of a traditional energy absorption device in order to increase the fuel efficiency and occupant safety. For this the bumper beam crash box of GFRP is performed.

An initial model, the initial specimen, was selected as a reference to compare with the optimum designs which would be obtained. And also some preliminary test where out with this specimen. The specimen is prepared by the hand layup method and the material used is Glass fiber reinforced polymer. And the prepared sample specimen is divided into various dimensions for the testing purpose. To find the young’s modulus of the material, the specimen is involved testing methods of tensile, compression and impact test. Bumper beam crash box is drawn through the Catia and analysis in made by applying the boundary conditions and the results are compared with the experimental results. The GFRP has more stress and strain characteristics compared to Structural steel. • The weight reduces 36 from the structural steel • The stress values increases by 6 for GFRP when compared to structural steel. • The strain values increases by 11 for GFRP when compared to structural steel. • The deformation for the GFRP increases by 14 while compared to structural steel.

FUTURE SCOPE AND WORK

The results can be further improved by optimizing the design of the bumper beam crash box and by adding good energy absorption materials along with the crash box. The experiments can be conducted to coat the inner surface of on the crash box with good resonating material which can help in increasing the impact energy at the time of accidents. The get the optimised result of the crash box by experimental method, crash box should be fabricated and should be involved through the crash analysis and by results can be compared with LS DYNA.

References


