Design and Analysis of Four Wheeler Car Bumper

K. Kiran m1, B. Anjaneulu2, K. Kiran Kumar Rao3, G.Nagamalleswara Rao4
M.Tech GATES Engineering College, GOOTY1
M.Tech-Coordinator, GUIDE, Assistant Professor, GATES Engineering College, GOOTY2
M.Tech, HOD of MECHANICAL Department, GATES Engineering College, GOOTY3
M.Tech, Ph.D, PRINCIPAL, GATES Engineering College, GOOTY4

Abstract:
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 standard. In addition, since the residual kinetic energy will be damped with the infinitesimal elastic deformation of the bumper elements, the passengers will not sense any impact. It should be noted that in this paper, modeling, and result’s analysis are done in Pro-E and ANSYS software respectively.

I. INTRODUCTION

Nowadays, 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. The bumper system consists of three main components, namely bumper beam, fascia and energy absorber. One of the options to reduce energy consumption is weight reduction. However, the designer should be aware that in order to reduce the weight, the safety of the car passenger must not be sacrificed. A new invention in technology material was introduced with polymeric based composite materials, which offer high specific stiffness, low weight, corrosion free, and ability to produce complex shapes, high specific strength, and high impact energy absorption. The automotive body is one of the critical subsystems of an automobile, and it carries out multiple functions. It should hold the parts of the vehicle together and serve to filter noise and vibration. Additionally, it should be able to protect its occupants when accidents happen. To do this, the automotive body designer should create a structure with significant levels of strength, stiffness, and energy absorption.

BUMPER DESIGN FOR VEHICLE SAFETY

Because of these limitations, the fatality rate increases dramatically in high speed impacts. In order to design a successful lightweight vehicle and significantly improve the crash performance of current cars, technological development is still needed. If the automotive body could extend its front end during or right before a crash, the mechanism of absorbing the crash energy would be totally different from that of the passive structure. During a frontal crash, the front side member is expected to fold progressively, so as to absorb more energy and to ensure enough passenger space. To do so, various cross sections and shapes have been investigated for the front rail of the automotive body to maximize crashworthiness and weight efficiency; their design included reinforcing the cross-section.

Figure 1. Automotive bumper system component

Today, what is interesting related of this research is now an innovative inflatable bumper concept, called the “I-bumper,” is developed in this research for improved crashworthiness and safety of military and commercial vehicles. The developed I-bumper has several active structural components, including a morphing mechanism, a movable bumper, two explosive airbags, and a morphing lattice structure with a locking mechanism that provides desired rigidity and energy absorption capability during a collision. Another additional innovative means for improving crashworthiness is the use of tubes filled with a granular material to absorb energy during the process of a crash.

1.3 MATERIAL PROPERTIES

The common use of the term stress analysis includes any kind of structural analysis. In the field of thermoplastics design, there is a growing awareness of the importance of stress analysis. In many years, plastics have been used for applications in load-bearing structural components in the automotive, aerospace, sporting, and construction industries. Hence, design engineers are increasingly concerned about...
stress-related problems, typically with the strength, stiffness and life expectancy of their products. About many years ago, these problems were primarily associated with the metallic components. Stress analysis has always been interdisciplinary, because an effective analysis needs to bring together a thorough knowledge of the operating characteristic of the product, material behavior, structural behavior and solid mechanics. Structural plastics design is a field that is evolving in the same manner as did the aero-space and nuclear power industries. That is, a sequence of products innovations, and better methods of design and analysis continuously reinforce each other and lead to the optimum design of the product. Stress analysis is a vital activity in this process. From the point of view of stress analysis, are the thermoplastics very different from metals? The answer is yes and no. Yes, because a few types of behaviors of thermoplastic materials call for advanced techniques of analysis, because such behaviors are encountered only in special applications of metals. No, because several calculations and test procedures for characterizing the mechanical properties of thermoplastics are very similar to those of metals. Thus such stress analysis is also similar. Material properties of plastics such as elastic modulus, yield point, tensile strength and fracture toughness are understood, measured and used in a manner similar to those for metals. Many structural plastics design may be performed using the familiar strength of material approach. Likewise detailed stress analyses of plastic components are performed assuming linear elastic behavior.

II. OBJECTIVES AND SCOPE

a) To analyze the mechanical properties on front part (fascia) of car bumper:

i. To analyze on mechanical properties focus on stress analysis
ii. To modeling the actual dimension of the car bumper into the UG software and analyze by using FE software (Analysis).
iii. To investigate polymer composite material bumper (Proton Pesona) based on their geometry and other parameters that influence the compatibility of car bumper.

b) To evaluate failure mechanism of the car bumper:

i. To study the load distribution on the bumper either it is uniformly distributes to all the part during the analysis.

ii. To predict the critical point.

II. MODELING

III. STRUCTURAL ANALYSIS

1. Importing the Model

In this step the PRO/E model is imported into ANSYS workbench as follows:

In utility menu file option and select import external geometry and open file and click on generate. To enter into simulation module click on project tab and click on new simulation.
Defining Material Properties

To define material properties for the analysis, following steps are used:

1. Choose the main menu, select the model and create new material enter the properties again select simulation tab and select material.

Defining Element Type

To define type of element for the analysis, these steps are to be followed:

1. Choose the main menu, select type of contacts and then click on mesh-right click-insert method

Method - Tetrahedrons
Algorithm - Patch Conforming
Element Midside Nodes – Kept

Meshing the model

To perform the meshing of the model these steps are to be followed:

Chose the main menu click on mesh-right click-insert sizing and then select geometry enter element size and then click on generate mesh.

Applying Boundary conditions and Loads

To apply the boundary conditions on the model these steps are to be followed:

Chose the main menu, click on new analysis tab select static structural click on face and then select face of the geometry-right click-insert-fixed support. Choose the main menu, select face and click on face of geometry-right click – insert – force
Aluminum B390 alloy Properties

Table 1. Static Structural Analysis

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young’s Modulus</td>
<td>71000 MPa</td>
</tr>
<tr>
<td>Poisson’s Ratio</td>
<td>0.33</td>
</tr>
<tr>
<td>Density</td>
<td>2.77e-006 kg</td>
</tr>
<tr>
<td>Thermal Expansion</td>
<td>2.3e-005 1/°C</td>
</tr>
<tr>
<td>Alternating Stress</td>
<td></td>
</tr>
<tr>
<td>Tensile Yield Strength</td>
<td>280. MPa</td>
</tr>
<tr>
<td>Compressive Yield Strength</td>
<td>280. MPa</td>
</tr>
<tr>
<td>Tensile Ultimate Strength</td>
<td>310. MPa</td>
</tr>
<tr>
<td>Compressive Ultimate Strength</td>
<td>0. MPa</td>
</tr>
</tbody>
</table>

Figure 9. Equivalent stress

Figure 10. Total Deformation

Model Analysis

Figure 11. Mode 1

Figure 12. Mode 2

Figure 13. Mode 3

Figure 14. Mode 4

Figure 15. Mode 5
IV. CARBON FIBER PROPERTIES

Table 2. Static structural analysis

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young’s Modulus</td>
<td>3.88e+005 Mpa</td>
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<tr>
<td>Poisson’s Ratio</td>
<td>0.358</td>
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<tr>
<td>Density</td>
<td>1.6e-006 kg/m³</td>
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<td>Thermal Expansion</td>
<td>0.1 1/°C</td>
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</table>

Figure 16. Mode 6

Figure 17. Equivalent stress

Figure 18. Total Deformation

Figure 19. Mode 1

Figure 20. Mode 2

Figure 21. Mode 3

Figure 22. Mode 4
Table 3. Chromium coated mild steel properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young's Modulus</td>
<td>2.1e-005 MP</td>
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<tr>
<td>Poisson's Ratio</td>
<td>0.303</td>
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<tr>
<td>Density</td>
<td>7.85e+006 kg</td>
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<tr>
<td>Thermal Expansion</td>
<td>2.3e-005 1/°C</td>
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<tr>
<td>Alternating Stress</td>
<td></td>
</tr>
</tbody>
</table>

Static structural analysis

Figure 23. Mode 5

Figure 24. Mode 6

Modal Analysis

Figure 25. Equivalent stress

Figure 26. Total Deformation

Figure 27. Mode 1

Figure 28. Mode 2

Figure 29. Mode 3
V. DYNAMIC ANALYSIS RESULTS

Material: Carbon Fiber

Figure 30. Mode 4

Figure 31. Mode 5

Figure 32. Mode 6

Figure 33. Geometry

Figure 34. Messing part

Figure 35. Directional Deformation-z Hitting Wall With 60 Km/Hr

Figure 36. Directional Deformation-Z Hitting Wall With 60 Km/Hr

Figure 37. Total Deformation
Figure 38. Equivalent stress

Figure 39. Directional Deformation-z Hitting Wall With 80 Km/Hr

Figure 42. Directional Deformation-z Hitting Wall with 60 Km/Hr

Figure 43. Directional Deformation-Z Hitting Wall with 60 Km/Hr

Figure 40. Total Deformation

Figure 41. Equivalent stress

Chromium coated mild steel

Figure 44. Total Deformation

<table>
<thead>
<tr>
<th>Materials</th>
<th>Equivalent stress (Mpa)</th>
<th>Total Deformation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum B390 alloy</td>
<td>51.719</td>
<td>1.2881</td>
</tr>
<tr>
<td>Carbon Fiber</td>
<td>51.566</td>
<td>0.23427</td>
</tr>
<tr>
<td>Chromium coated mild steel</td>
<td>51.82</td>
<td>0.43751</td>
</tr>
</tbody>
</table>
Figure 45. Equivalent stress

Figure 46. Directional Deformation - Hitting Wall With 80 Km/Hr

Figure 47. Total Deformation

Figure 48. Equivalent stress

Figure 49. Directional Deformation - Hitting Wall With 60 Km/Hr

Figure 50. Directional Deformation - Z Hitting Wall With 60 Km/Hr

Figure 51. Total Deformation

Aluminum B390 alloy
VI. RESULTS

<table>
<thead>
<tr>
<th>Mode</th>
<th>Aluminum B390 alloy</th>
<th>Carbon Fiber</th>
<th>Chromium coated mild steel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Total deformation</td>
<td>Frequency</td>
</tr>
<tr>
<td>Mode 1</td>
<td>75.837</td>
<td>30.615</td>
<td>234.07</td>
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<tr>
<td>Mode 2</td>
<td>91.862</td>
<td>42.472</td>
<td>282.89</td>
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<tr>
<td>Mode 3</td>
<td>108.98</td>
<td>38.605</td>
<td>336.24</td>
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<td>Mode 4</td>
<td>137.4</td>
<td>56.419</td>
<td>423.4</td>
</tr>
<tr>
<td>Mode 5</td>
<td>151.48</td>
<td>41.4</td>
<td>467.54</td>
</tr>
<tr>
<td>Mode 6</td>
<td>164.8</td>
<td>62.671</td>
<td>509.35</td>
</tr>
</tbody>
</table>
VII. DYNAMIC ANALYSIS RESULTS:

<table>
<thead>
<tr>
<th>Material</th>
<th>Directional deformation - Z(mm)</th>
<th>Total deformation(mm)</th>
<th>Equivalent stress(Mpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60kmph</td>
<td>80kmph</td>
<td>60kmph</td>
</tr>
<tr>
<td>Aluminum B390 alloy</td>
<td>52.853</td>
<td>70.256</td>
<td>55.236</td>
</tr>
<tr>
<td>Carbon Fiber</td>
<td>47.832</td>
<td>61.11</td>
<td>49.087</td>
</tr>
<tr>
<td>Chromium coated mild steel</td>
<td>53.004</td>
<td>74.186</td>
<td>55.452</td>
</tr>
</tbody>
</table>

VIII. REFERENCES


