Middle-East Journal of Scientific Research 24 (S1): 415-418, 2016
ISSN 1990-9233
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DOI: 10.5829/idosi.mejsr.2016.24.S1.1

Design and Analysis of Automotive Bumper Beam Using Polymer Matrix Composite

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Abstract: An automotive bumper beam is a structural component with intended function to absorb kinetic energy during dynamic loading condition. Generally, most of the researches focus on the substitution of new material such as polymeric based composite to achieve higher energy absorption capacity. This project is aimed to investigate the most suitable geometry of bumper beam at conceptual design stage. The various geometry of automotive bumper such as Square, Channel, T and I- sections were analyzed. The suitable shape of bumper beam was selected due to its high stiffness, low weight and high load sustainability. Also, compare the analysis results for epoxy polymer/ glass fiber material with steel, aluminum and copper materials.

Key words: Bumper beam · Conceptual design · Composite

INTRODUCTION

Automobile bumper is a structural component of an automotive vehicle, which contributes to vehicle crashworthiness or occupant protection during front or rear collisions[1]. The bumper systems also protect the hood, trunk, fuel, exhaust and cooling system as well as safety related equipments. A bumper is a shield normally made of aluminum, steel rubber, composite or plastic that is mounted on the front and rear of an automobile vehicle[2]. When a low speed collision takes place, the bumper system absorbs the shock and energy to prevent or reduce damage to the vehicle. In some bumpers energy absorbers or brackets are used and others are made with foam cushioning material.

Objectives: The main objectives of this project are to investigate the effective cross section of bumper beam, to provide a bumper beam that is compact and light [3] weight, to provide the bumper beam an effectively absorb energy, to propose the material for the bumper beam system, also to compare the analysis results with the conventional materials like steel, aluminum and copper.

Steps to Be Followed: The following steps were carried-out in this project, viz.

- Construct 3D- modeling of four different cross sectional shape or profile of beam
- Perform finite element analysis to 3D modeling to determine the maximum deflection of beam
- To decide the best profile of bumper beam based on their total deformation
- Identify the polymeric based composite material for the bumper beam system
- Comparing the analysis results for polymeric based composite material with conventional material

The following solid modeling views are obtained from Pro-E 2.0 for bumper beam analysis shown in Fig. 1.

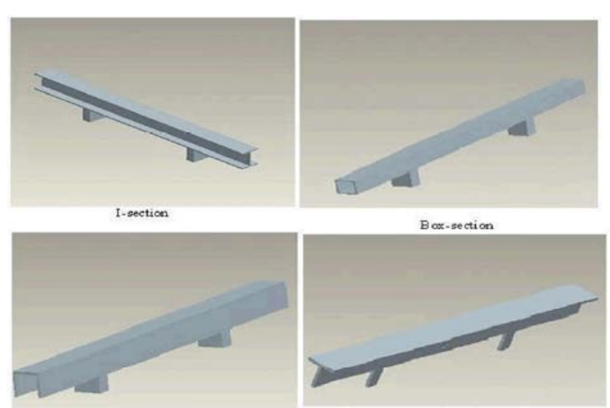

Fig. 1: Modeling of various bumper beam profile

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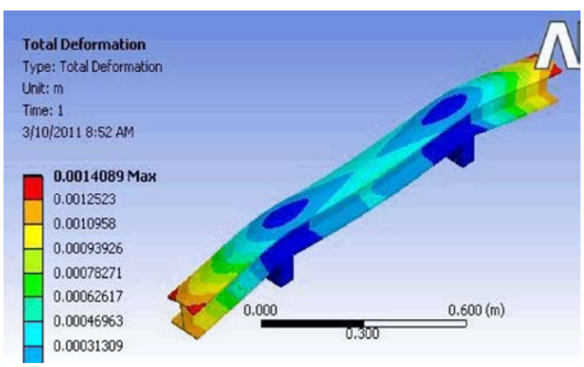
Material Properties: The various materials were chosen to investigate this bumper beam analysis. Viz., Table 1:

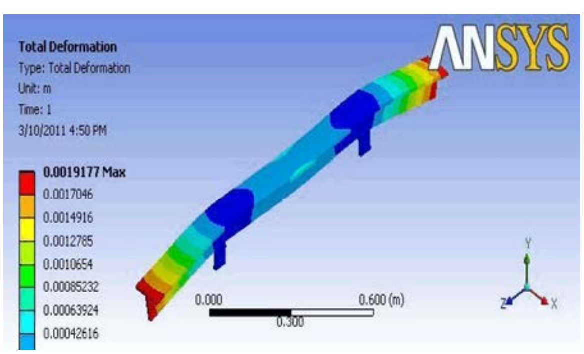
Table 1: Material Properties

Si. No	Property	Structural steel	Al - alloys	Cu - alloys	Epoxy fiber/glass
1	Density	7850 kg/m^3	2770 kg/m^3	8300 kg/m^3	1850 kg/m^3
2	Tensile Strength (Ultimate)	460MPa	310 MPa	430 MPa	965 Mpa
3	Young's Modulus	200GPa	71 GPa	110 GPa	39.3 Gpa
4	Poisson's Ratio	0.3	0.33	0.34	0.32
5	Co-efficient of Thermal expansion	1.2e-5 1/°C	2.3e-5 1/°C	1.8e-5 1/°C	8.7e-6 1/°C

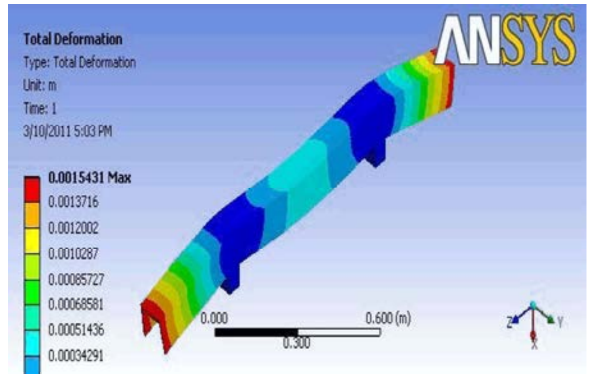
Analysis Results: For [4]our design considerations the following factors are included: uniform cross-sections, material properties of each bar are same and load applied remains same (SSB with UDL). Fig.2. Then the following results were obtained while analyzing with the aid of an sys work bench 11.0 mode for the different materials. Viz



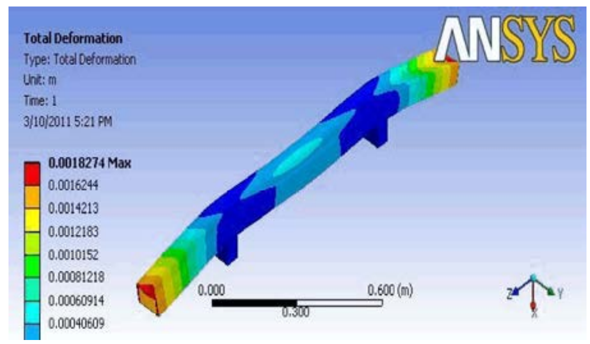
I-section



T-section



C-section



Box-section

Fig. 2: Total deformation of Bumper beam for the Epoxy – Glass fiber material

Tabulated Results: The following data are obtained from ansys11.0 while analyzing the above profiles for various materials. Table 2.

Table 2: Data for various material and cross section from Ansys 11.0

1.Structural steel				
Parameter/Section	I	T	C	Box
Deformation	2.7672 e-004 m	3.7727 e-004 m	3.0288 e-004 m	3.5878 e-004 m
Von-misses stress	1.1226 e+008 Pa	2.2855 e+008 Pa	1.7327 e+008 Pa	1.0271 e+008 Pa
Shear stress	2.2721 e+007 Pa	3.4305 e+007 Pa	1.5796 e+007 Pa	1.5976 e+007 Pa
Normal stress	3.9976 e+007 Pa	2.1594 e+007 Pa	2.5631 e+007 Pa	1.2736 e+007 Pa

Table 2: Continued

Parameter/Section	I	T	C	Box
2.Aluminum alloys				
Deformation	7.7997 e-004 m	1.0608 e-003 m	8.5458 e-004 m	1.0119 e-003 m
Von-misses stress	1.0978 e+008 Pa	2.242 e+008 Pa	1.7636 e+008 Pa	1.0062 e+008 Pa
Shear stress	2.2459 e+007 Pa	3.7612 e+007 Pa	1.5758 e+007 Pa	1.5784 e+007 Pa
Normal stress	4.0051 e+007 Pa	2.4279 e+007 Pa	2.8707 e+007 Pa	1.263 e+007 Pa
3.Copper alloys				
Parameter/Section	I	T	C	Box
Deformation	5.0349 e-004 m	6.843 e-004 m	5.5188 e-004 m	3.5878 e-004 m
Von-misses stress	1.0897 e+008 Pa	2.2266 e+008 Pa	1.7749 e+008 Pa	1.0271 e+008 Pa
Shear stress	2.2369 e+007 Pa	3.8694 e+007 Pa	1.5744 e+007 Pa	1.5976 e+007 Pa
Normal stress	4.0076 e+007 Pa	2.5209 e+007 Pa	2.9816 e+007 Pa	1.2736 e+007 Pa
4.Epoxy/glass fiber				
Parameter/Section	I	T	C	Box
Deformation	1.4089 e-003 m	1.9177 e-003 m	1.5431 e-003 m	1.8274 e-003 m
Von-misses stress	1.106 e+008 Pa	2.257 e+008 Pa	1.7528 e+008 Pa	1.0134 e+008 Pa
Shear stress	2.2547 e+007 Pa	3.6519 e+007 Pa	1.5771 e+007 Pa	1.5844 e+007 Pa
Normal stress	4.0025 e+007 Pa	2.3368 e+007 Pa	2.7641 e+007 Pa	1.2665 e+007 Pa

Comparisson: The comparison of stiffness for various cross sections of bumper beam must be formatted to find the effective cross sections among these. (Epoxy polymer glass fiber) Table 3.

Table 3: Evaluation of bumper beam

Cross- Section	Stiffness, MN/m
I	42.59
C	38.88
T	31.29
Box	32.83

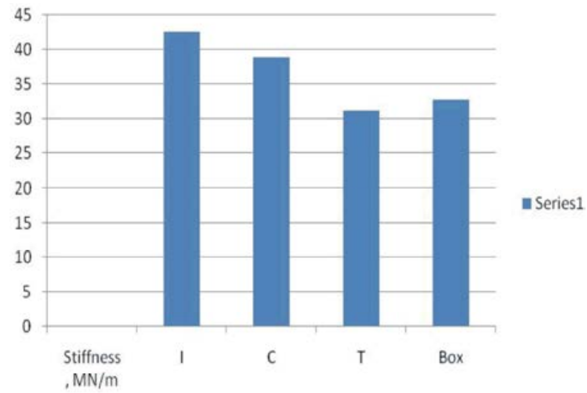
From this table, we can identify I-section as best profile for bumper beam. Also, here the analysis results for various materials are compared below in Table.4. For selecting suitable material for the bumper design

Table 4: Material selection

I) Specific modulus	
Material	Specific modulus (E/ñ), MJ/kg
Structural steel	25.48
Aluminum alloys	25.63
Copper alloys	13.25
Epoxy /Glass fiber	21.24
ii) Specific strength	
Material	Specific strength $(\sigma_{ult}/ñ)$, kJ/kg
Structural steel	58.6
Aluminum alloys	129.96
Copper alloys	51.8
Epoxy /Glass fiber	521.6
iii) Mass of the beam	
Material	Mass, kg
Structural steel	28.26
Aluminum alloys	9.98
Copper alloys	29.88
Epoxy /Glass fiber	6.66
iv) Stiffness of the beam (I-beam)	
Material	Stiffness, MN/m
Structural steel	216.83
Aluminum alloys	76.93
Copper alloys	119.17
Epoxy /Glass fiber	42.59

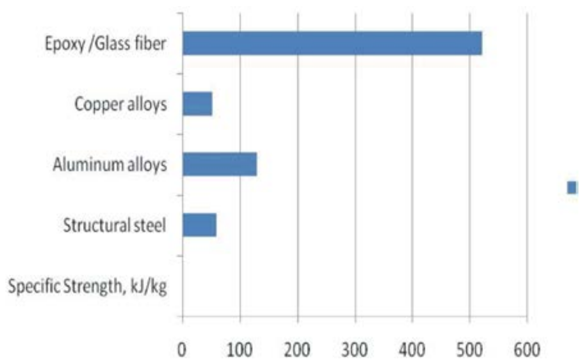
Charts:

i)Cross section-investigation

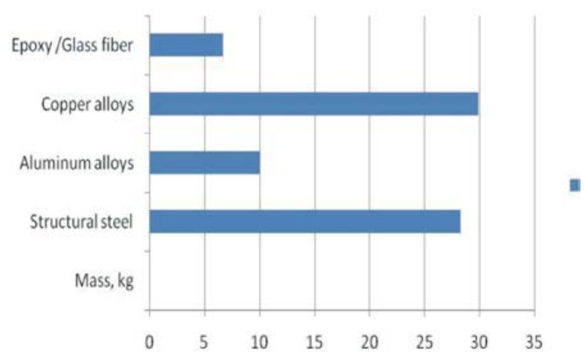


Cross section v /s Stiffness

ii)Material investigation



1. Specific strength



2.Mass of the beam

Summary: This paper shows that the design and analysis of automotive bumper beam is a new system that has been developed to select the most suitable materials [5]. It enables to produce a high quality design in the final design stage. 3-D solid modeling software such as Pro/Engineer has been used extensively in bumper beam to investigate the most suitable geometry of bumper beam design. The tool used for analysis is ANSYS WORKBENCH 11.0

CONCLUSION

Thus, the automotive bumper beam was successfully analyzed using FEA- software. Finally, I-shape bumper beam is propose to concept deign. From the analyzed results it is being concluded that the epoxy polymer/ Glass fiber can be chosen as a suitable material for making automotive bumper beam. Moreover the epoxy polymer/ Glass fiber has a great strength, good fatigue resistance, less weight and easy to manufacture. Also, the results for polymeric based composite were compared with conventional material.

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