Impact Analysis of Bumper through Computational Design and Analysis Method

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Abstract
Bumper is one of the main parts which are used as a protection for the driver and passengers from the accidental impact due to front and rear low-speed crashes. In response to safety point of view, a bumper becomes an important part in preventing the impact force from being transferred to the passengers. In this paper, a domestic Proton Wira car bumper is being studied. The computer simulation method is used to study the impact analysis of front bumper. A modelling of front bumper is carried out by using CATIA. The bumper with the specific load and boundary conditions are analyzed using dynamic explicit analysis ABAQUS v6.6. A few parameters including material, design, and impact conditions are studied in a low velocity impact to analysis of front bumper by using a rigid block. The impact deformation, displacement and acceleration of the front bumper is being studied which can provide a reference for the next design and improvement.
Keywords: front bumper; impact analysis; acceleration

1.0 Introduction

Vehicle safety design is one of the major attributes in vehicle product development. The vehicle designed is to absorb enough impact energy through structural deformation and reduce the impact force in order to protect the occupants when impact occurs. The full frontal impact is commonly used to design and validate the vehicle front end structures while satisfying the safety regulations. Frontal impact is the most frequent type of road crashes that resulting in serious or fatal injuries of the occupants.

Bumper is the first component to take part in frontal crash or impact during accident hence it is important component to be designed and analyzed for the crashworthiness of the vehicle during frontal accident. Bumper is a structure integrated with front and rear ends of the motor vehicle. The main function is to absorb the impact in case of any minor collision, ideally protecting occupants and minimizing the repair costs.

The main parameters for the desired work are the type of material, and its impact specifications like the kinetic energy of the model during impact analysis gives the detailed explanation of the material selection for the bumper. The most important variables such as materials, structures, shapes and impact conditions are studied for analysis of the bumper beam in order to improve the crashworthiness during collision.

Many researchers have being studied several variables during crash simulation and analysis. The first variable is material. The effect of modulus of elasticity and yield strength on impact behaviour of frontal bumper was investigated. Shape of the bumper is the second variable that has been studied in order to relate between bumper and

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shape that can affect the impact of collision. The last variable is impact condition in order to measure how much the crash simulation test may affect the condition of bumper after collision.

1.1 Objectives

The objectives of this project are:

a) To analyse impact deformation, displacement and acceleration of the front bumper due to direct frontal impact.
b) To propose the materials for frontal bumper.
c) To compare the analysis result with a conventional and modification design of bumper.

2.0 Literature review

Marzbanrad J.M et.al (2009) discussed the most important parameters including material, thickness, shape and impact condition 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 is made of three materials: aluminium, glass mat thermoplastic (GMT) and high-strength sheet moulding compound (SMC) is studied by impact modelling to determine the deflection, impact force, stress distribution and energy-absorption behaviour. 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.

Hosseinzadeh R.M et.al (2005) says that bumper beams are one of the main structures of passenger cars that could protect them from front and rear collisions. In this paper, a commercial front bumper beam made of glass mat thermoplastic (GMT) is studied and characterized by impact modelling. Three main design factors for this structure such as shape, material and impact conditions are studied and the results are compared with conventional metals like steel and aluminium. Masoumi A et.al (2011) describes the design of a new frontal vehicle structure that directs the asymmetric crash load of an offset collision as an axial load to the second unloaded longitudinal member. Only by using both longitudinal members and through a progressive folding pattern, enough energy can be absorbed in the front structure to prevent a deformation of the passenger compartment. According to Tim Dun et al (2014) cast iron is an alloy or combination of materials. Gray cast iron is a cast iron that contains carbon in the form of graphite, plus silicon, manganese and phosphorus. It is brittle and can absorb shocks. It resists heat and corrosion, and can be cast into many different shapes. It is used for many components such as engine cylinder block and crankcase.

3.0 Methodology

Automotive bumper has consistently grown over the years. Although it is evolved ergonomically there is no systematic study which explains design and analysis of front bumpers in the presence of solid mechanics using advanced FEA tools. In this research, three cases are studied in order to analysis performance of the bumper structure. For the first case study, Gray Cast Iron is used as a baseline model. In the second case, Carbon Steel is used as a different material. While in the third case, modification has been done on the bumper structure and Gray Cast Iron is used as a material. Figure 1 show the process involved in this study.

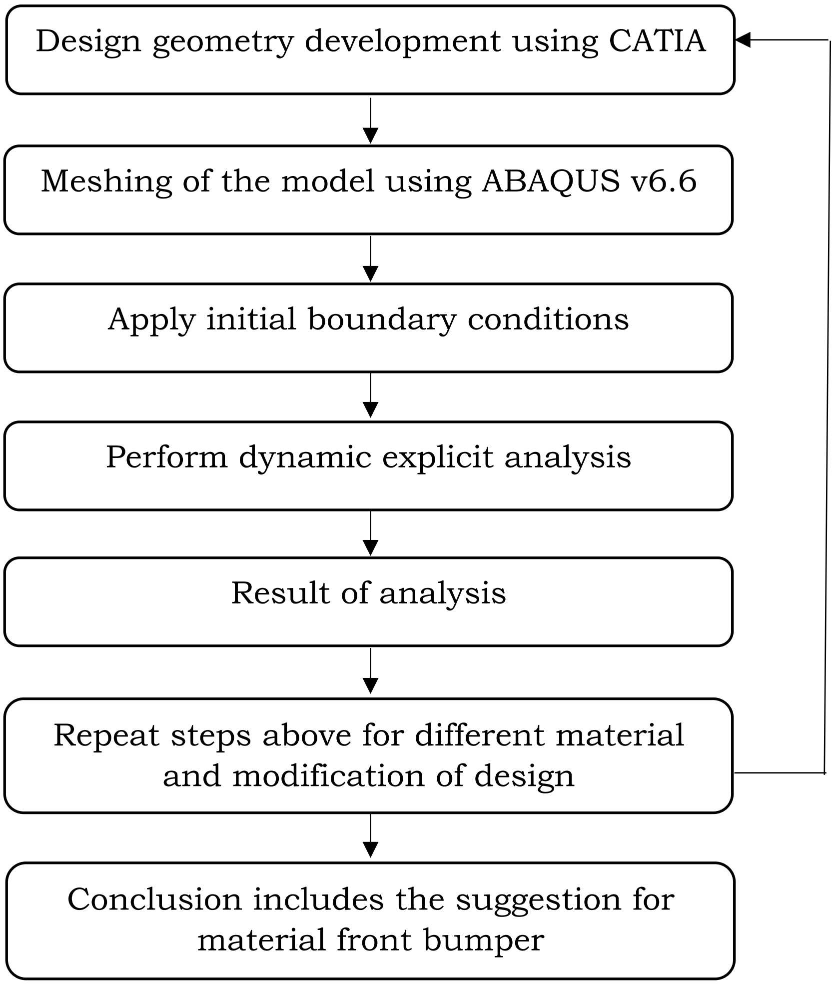

Figure 1: The process involved of this research

3.1 Modelling

Figure 2 and 3 shows the modelling and modification of the front bumper and its component are carried out by using CATIA software.

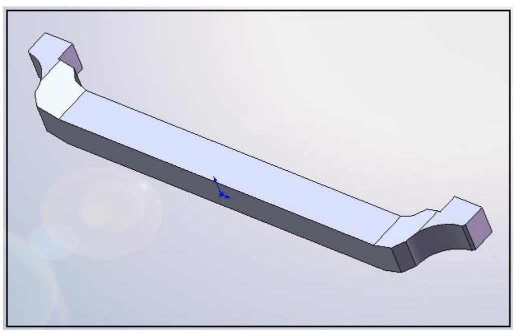

Figure 2: Proton Wira front bumper (left) and 3D model (right)

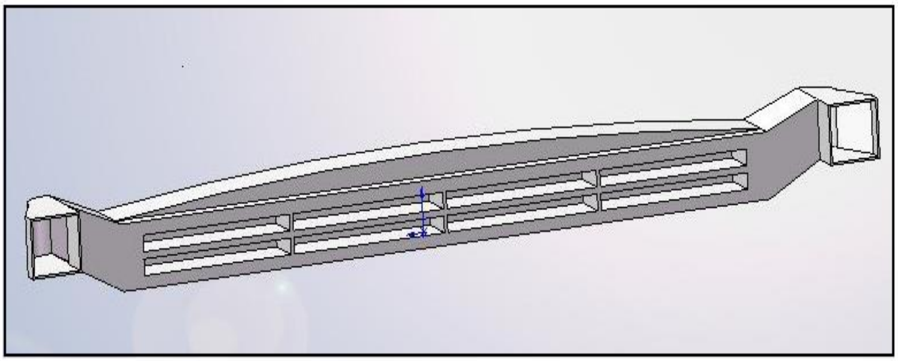

Figure 3: Modification on bumper

3.2 Boundary Conditions

A boundary condition holds a node and prevents it from translating or rotating. Its acts like a rigid support between the model and the ground. Meshed model (Figure 4) and boundary condition of the bumper in red marks for a rigid block as shown in Figure 5.

a) A rigid block and bumper model are set for displacement.
b) A rigid block will only have displacement in z-direction.
c) The velocity of rigid block in z-direction which is 7.2 km/h (2 m/s)
d) The distance of rigid block and bumper model is set at 10 cm.
e) Constrain is applied at mounting points of the bumper structure.
f) The frontal structure frame is 2mm in thickness.

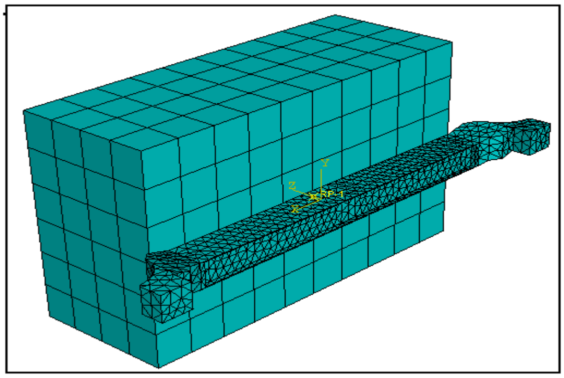

Figure 4: Meshed model

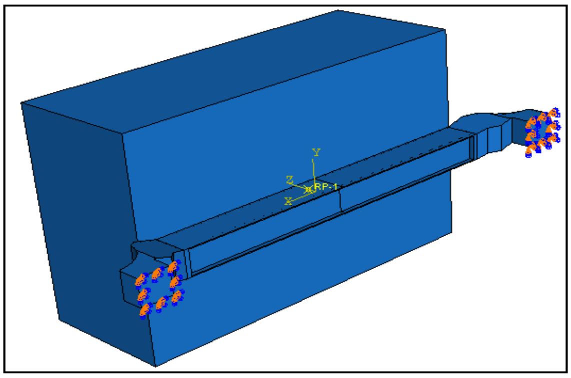

Figure 5: Boundary conditions of bumper in red marks for a rigid block

3.3 Material Properties

The materials chosen for the bumper are Gray Cast Iron and Carbon Steel. For the rigid block, Steel ASTM A-36 is used as a material. The material properties are summarized below in Table 1.

Table 1: Material properties for bumper and rigid block

Parts	Material	Modulus Young, E (GPa)	Material Density, ρ (kg/m3)	Poisson's Ratio, υ
Bumper	Gray Cast Iron	69	7200	0.23
Bumper	Carbon Steel	200	7872	0.29
Rigid block	Steel (ASTM A-36)	200	7860	0.30

4.0 Result and discussion

The results obtained will be discussed in this chapter. The results are shown in Figure 6 and 7 plotted graphs and contours. The results data was picked from the same node (node 41) at the bumper to compare the output data values. Then, the contour shows the deformed shape caused by the impact.

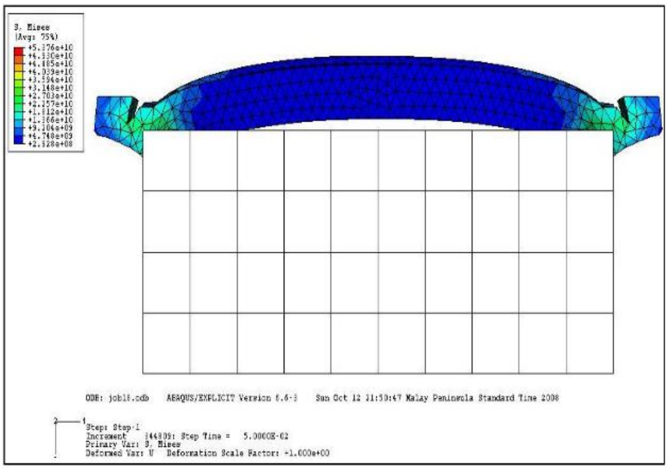

Figure 6: The deformed shape caused by impact a rigid block

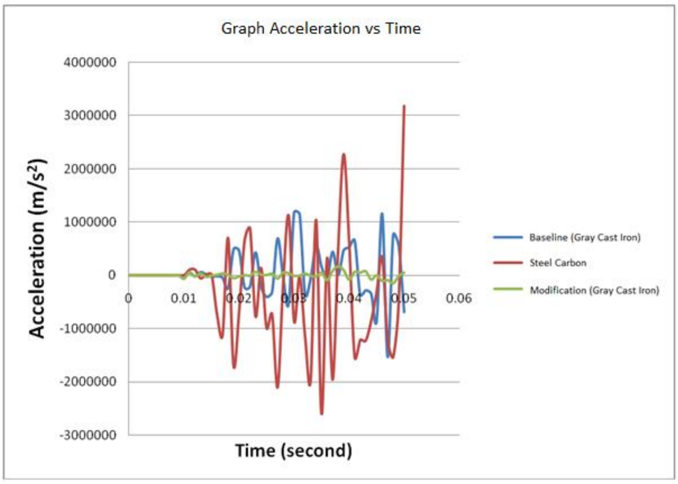

Figure 7: Graph acceleration versus time for front bumper impact analysis.

Based on graph acceleration versus time, the material steel carbon has maximum acceleration of 3.18×10^6 m/s^2. The modification structure shows the lowest value of acceleration which is 2.74×10^3 m/s^2. If the material shows the higher value of acceleration it means the material is not suitable for the passenger safety. It is because the material cannot absorb more energy during the impact. The node that has been chosen was moving too fast. In the other hand, if the material has lower value of acceleration, it means the material can absorb more energy during impact. The modification structure shows the good quality in term of acceleration and safety for the passengers. In views of the front bumper impact analysis, it is clearly stated that the displacement is proportional to the time as illustrated in Figure 8.

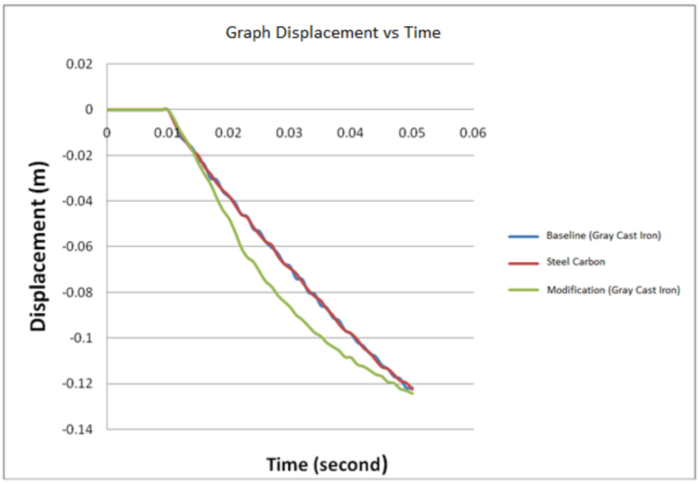

Figure 8: Graph displacement versus time for front bumper impact analysis.

When the time increasing, the deflection during impact also increasing. The rigid block was moving in opposite direction of the origin and the displacement of the model shows the negative values. For this analysis, the maximum deflection is -0.12437m. The modification structure shows the highest value of deflection. If the bumper easy to deflect with respect to the time during collision, it means it has the higher impulse force. When it happen, it is dangerous to the passengers because the bumper cannot absorb more energy during impact due to the higher impulse force. In term of displacement, baseline model shows the lowest value compare to the others. Gray cast iron shows more benefit in order to improve bumper based on this material selection. This is supported with findings from other studies that agreed Gray cast iron is suitable material for front bumper.

5.0 Conclusion

From the above discussion, it can be concluded that Gray cast iron is better than carbon steel for frontal bumper material. From the safety point of view, the bumper is an important parts of an automobile. The project data can be used for best bumper designs of modern vehicles from material point of view. The bumper must absorb more energy during impact to prevent the passenger from the injury. This paper will be helpful to have an optimum materials choice for frontal vehicle bumper design based on comparative results of the materials.

6.0 References

Alen J., & Nidhi M.B. (2014). Modelling and Analysis of an Automotive Bumper Used for a Low Passenger Vehicle. International Journal of Engineering Trends and Technology (IJETT), vol.15, no. 7, 2014

Azizul Azrin Ahmad (2008). Frontal Impact Simulation of a Passenger Car. *Thesis of Universiti Teknologi Malaysia.*

Ferdinand P. B., Russell J., John T. D. (2006), Mechanics of Materials Fourth Edition in SI Units. McGraw-Hill Hill Companies, Inc. Singapore

Hosseinzadeh R.M., Shokrieh M., & Lessard L.B. (2005). Parametric study of automotive composite bumper beams subjected to low-velocity impacts. Journal of Composite Structure, vol. 68, 419-427

Marzbanrad J.M., Alijanpour M., & Kiasat M.S. (2009). Design and analysis of automotive bumper beam in low speed frontal crashes. Thin Walled Struct, 47, 902-911

Masoumi A, Mohammad H.S., & Amir N. (2011). Comparison of steel, aluminum and composite bonnet in terms of pedestrian head impact. College of Engineering,University of Tehran, Iran, 1371–1380.

Rimy M.M. & Faieza A.A. (2010). Simulation of Car Bumper Material using Finite Element Analysis. Journal of Software Engineering, 4, 257-264

Srikantha K., Manjunatha B. & Mohan K. (2017). Impact analysis of Toyota Land Cruiser car bumper using ANSYS Autodyn 3D. Journal of Innovative Research in Advanced Engineering, Volume IV, 28-37

Tie W., & Yonggang L. (2015). Design and analysis of automotive composite bumper beam based on finite element analysis. Advances in Mechanical Engineering, 7, 1–12

Tim D., Kevin J. Brad K. & Robert M. (2014). Automotive Light Vehicle. Burlington MA Jones & Bartlett Learning.