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CRASH ANALYSIS OF RACING CAR NOSE CONE SUBJECTED TO FULL FRONTAL IMPACT

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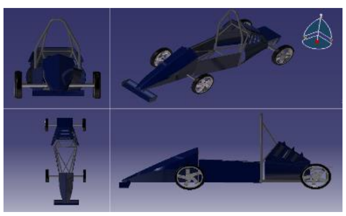
Graphical abstract



Abstract

Racing a car involves high-speed and having high possibility to crash either among the racer or hitting the bench. Concerning the driver safety, impact structures such as nose cone is designed to absorb the race car kinetic energy to limit the decelerations acting on the human body. In this study, analysis of different type of nose cone material were conducted. The objective is to find the highest specific energy absorption (SEA) based on three different materials which are mild steel, aluminium and composite material. The nose cone was modelled using CATIA V5R16 while the crash simulation was done using LS-DYNA and LS-Prepost software with an average velocity of 80km/hour according to United States New Car Assessment Program (US-NCAP) frontal impact velocity and based on European Enhanced Vehicle-safety Committee. The simulation results show that fiberglass E with thickness of 2.6 mm and lay-up configurations of [0°/30°/60°/90°/120°] give the highest internal energy and specific energy absorption of 41.28845 kJ and 6.9104 kJ/kg. This concludes that fiberglass E is a suitable material to build a lightweight structure compared to steel and aluminium.

Keywords: Crashworthiness, racing car, specific energy absorption, frontal impact

1.0 INTRODUCTION

Racing cars demonstrate maximum speeds which may lead to severe accidents with high amounts of energy involved. Special measures such as driver's protective equipment (like helmet, harness or head and neck support device) and the circuit's safety features (like run-off areas and barriers) are taken in order to ensure the driver's safety in case of high-speed crashes [1]. Besides that the race car itself is designed for crashworthiness and possesses special sacrificial impact structures that absorb the race car's kinetic energy and limit the decelerations acting on the human body [2]. The main scope of the strict crashworthiness regulations, imposed by race governing bodies, is to assure that the driver is enclosed within a strong survival cell, surrounded by energy absorbing structures in the front, back and sides. Besides static tests such as nose push-off tests, side tests etc., the vehicle structure has to withstand dynamic impact tests for example like frontal impact test, rear impact test, side impact test and steering column test. The front impact structure and bodywork is important part for a vehicle especially racing car to protect the driver and passenger in case of an accident or any moving impurity outside of the vehicle [3].

2.0 METHODOLOGY

2.1 Design Selection

The main purpose with the frontal impact structure is to protect the driver and components of the car. It is also used for aerodynamic and aesthetic reasons. Other important demands are high stiffness and low weight. These factors have a great influence on the choice of materials and designing method. Commonly, the rules of racing car frontal panel structure prescribe the following requirements: the vehicle must meet the rules relating with the bodywork, must be rigidly secured to the entirely sprung part of the car (rigidly secure means not having any degree of freedom) and must remain immobile in relation to the sprung part of the car. The dimensions of the bodywork must of course be compatible with the dimensional constraints set by the frame, suspension and other vehicle components.

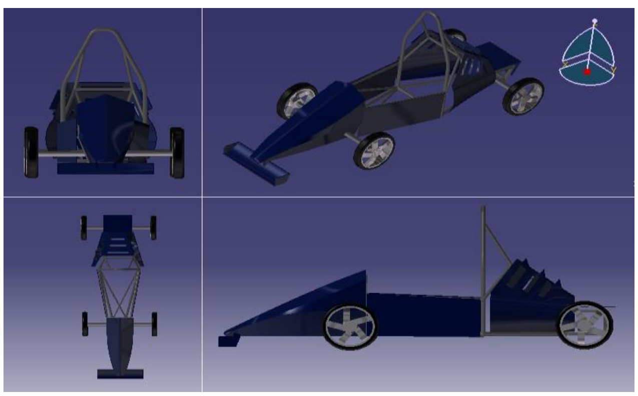


Figure 1 Multiple view of car body design

The design workflow process is started with product design specification (PDS) as mentioned by [4]. Followed by other stages such as conceptual design, solution generation, evaluation and selection of concept, weighting factor and finally the analysis of the selected design.

2.2 Analysis of the Design.

Although the FIA-Formula One's regulating body uses physical tests to determine the crash worthiness of a Formula One race car, finite element analysis (FEA) is a popular method to gain a greater understanding of a race car's structural integrity [2]. The analysis begin with the modelling of the selected design using CATIA software as shown in Fig. 1. With the help of clear visualize of car model, the analysis can be carried out in better way which is the shape of the nose cone itself that is more aerodynamics compared to others. Nose cone is functioning as the frontal energy absorbing structure which is able to absorb energy in the case of a head-on collision. It is one of the reasons for choosing E-glass/epoxy composite material to construct the car body by comparing with steel and aluminium. Different thickness of nose cone will be analyze ranging from 1.2 – 2.6 mm.

After selecting the materials and its properties data as an input for the finite element (FE) model of the nose cone. Other input needed before starting the simulation analysis is to setup the boundary conditions of the FE model. The boundary conditions of the simulation are the velocity average speed of 80km/hour according to United States New Car Assessment Program (US-NCAP) [5] frontal impact velocity and based on European Enhanced Vehicle-safety Committee which moving at the direction of x-axis and crashed to rigid wall where the average weight of the race car 300kg as in Fig. 2. The crash simulation analysis was conducted using LS-DYNA software.

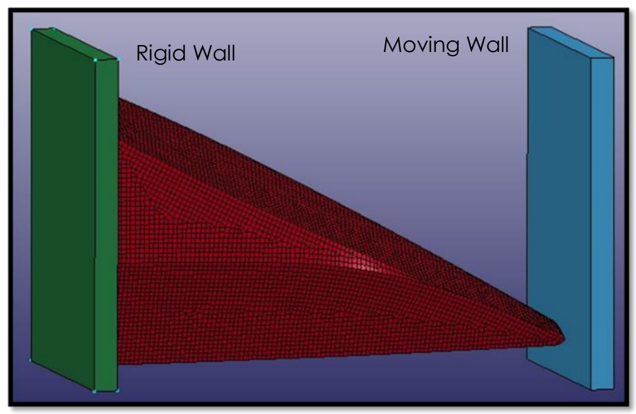


Figure 2 Boundary conditions for simulation

After the simulation process finished, the results that needed for this project can be obtained such as the simulation condition and internal energy. The value of Specific Energy Absorption (SEA) can be obtained from the value of Internal Energy and mass which is calculated using Eq. 1:

$$\text{SEA} = \text{Internal Energy (kJ) / Mass (kg)} \qquad (1)$$

where the final SEA units will be in kJ/kg.

3.0 RESULTS AND DISCUSSION

The results obtained for the crash analysis of the front impact structure from the simulation using finite element software, LS-DYNA and presented in the form of figures and graphs. The condition of the nose cone structure impacting the rigid wall is shown in Fig. 3 at time from 0.002 to 0.02s in order to see the distance that can secure the safety of the driver. This impacting process were same for every FE model of different materials and thickness in order to obtain results of kinetic energy and internal energy and calculate the value of SEA. While Fig. 4 shows graph of internal energy produced by the nose cone structure after the impacting event. All materials of the nose cone showing a positive linear relationship between thickness and internal energy value. The thickest structure will gave highest internal energy value. From the graph the highest internal energy

All data such as the materials, material configuration, thickness, Internal Energy, Specific Energy Absorption, and mass were tabulated in Table 1. From the results shown in Table1, it shows that the linear positive relation between thickness and mass of the nose cone structure. The thickest structure will gave the highest mass in each materials. But among the materials at thickness 2.0mm, fiberglass has the highest SEA value compare to aluminium and steel. This shows that the capability of fiberglass to absorb the impact force during the crash event. Apart from that, other advantage of fiberglass it has the smallest mass compared to other materials at 2.0 mm. This condition will help the designer to build a lightweight structure of racing car.

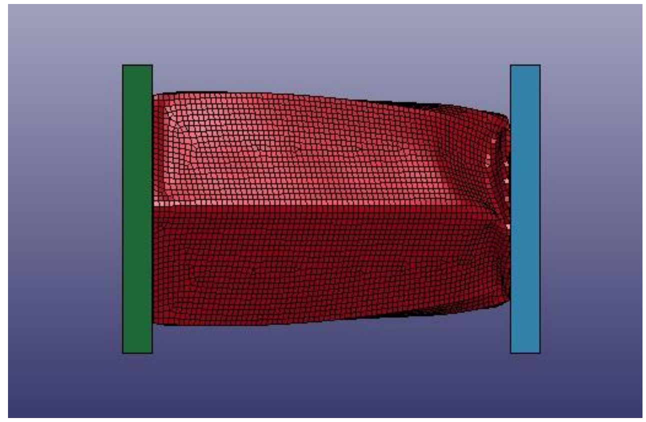
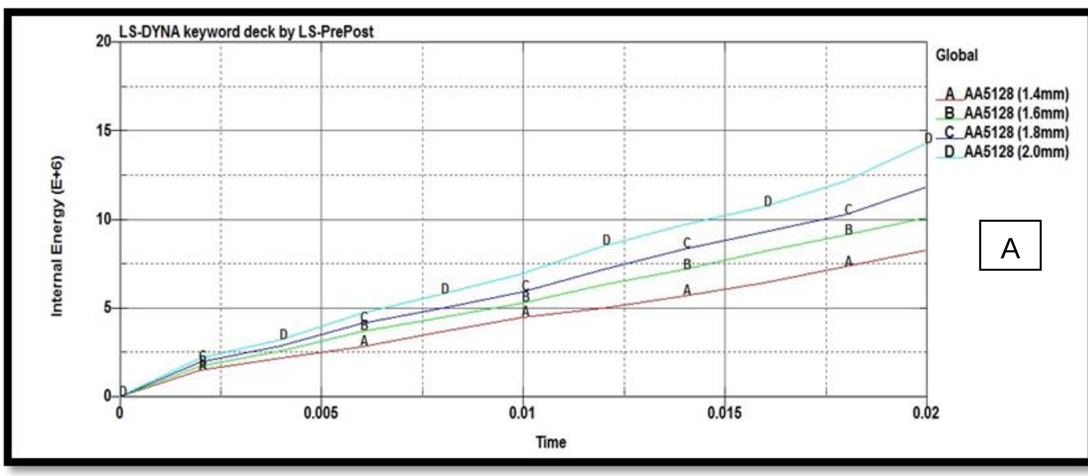
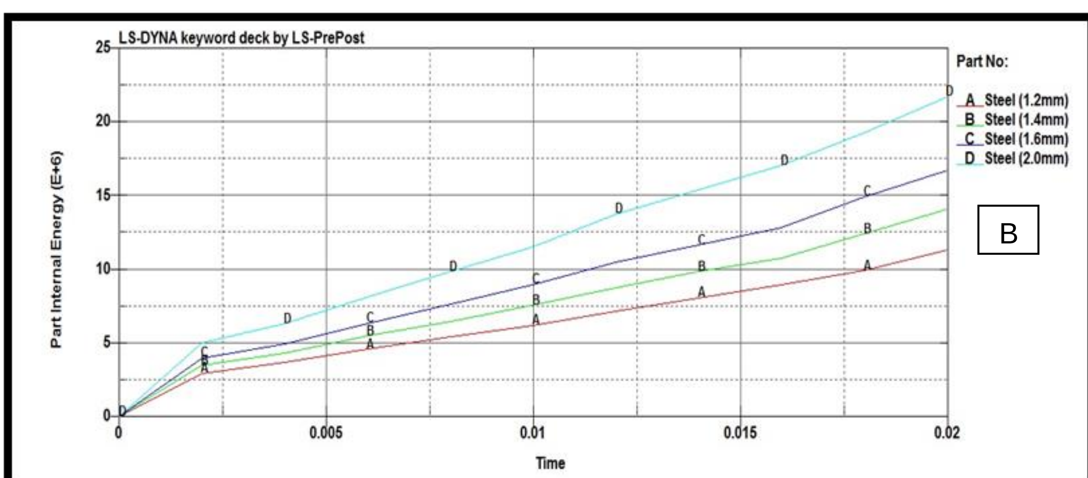


Figure 3 Nose cone impacting the rigid wall (top view)



(a)



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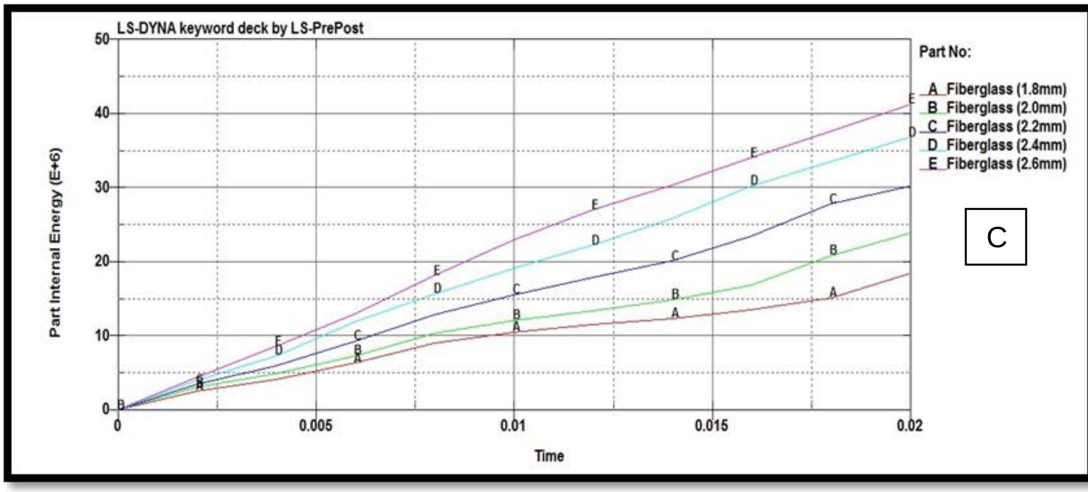

(c)

Figure 4 Internal energy graph for (a) Aluminium (b) Steel and (c) Epoxy-Fiberglass

Table 1 Crash analysis results of nose cone

No.	Front Impact Structure Material	Material Configurations	Total thickness (mm)	Mass (kg)	Internal Energy (kJ)	Specific Energy Absorption (kJ/kg)
1	Steel A	Isotropic	1.2	10.6114	11.29740	1.0646
2	Steel B	Isotropic	1.4	12.3799	14.08499	1.1377
3	Steel C	Isotropic	1.6	14.1485	16.71837	1.1816
4	Steel D	Isotropic	2.0	16.1345	20.74424	1.2857
5	AA 5182a	Isotropic	1.4	4.1792	8.293921	1.9846
6	AA 5182b	Isotropic	1.6	4.77614	10.11332	2.1175
7	AA 5182c	Isotropic	1.8	5.37317	11.84156	2.2038
8	AA 5182d	Isotropic	2.0	5.97019	14.30132	2.3955
9	Fiberglass A	[0°]s	1.8	4.13693	18.39027	4.445
10	Fiberglass B	[0°/60°]s	2.0	4.59599	23.93593	5.2080
11	Fiberglass C	[0°/30°/60°]s	2.2	5.05561	30.28152	5.9897
12	Fiberglass D	[0°/30°/60°/90°]s	2.4	5.5152	36.85472	6.6824
13	Fiberglass E	[0°/30/60°/90°/120°]s	2.6	5.9748	41.28845	6.9104

4.0 CONCLUSION

In conclusion, among the materials, fiberglass has the lowest mass value compared to others. This contribute to lighter weight of racing car body structure. It also gives the highest internal energy and specific energy absorption of 41.28845 kJ and 6.9104 kJ/kg. This means that fiberglass can absorb more impact energy during crash event. This make fiberglass material as a suitable candidate for body structure of a racing car which required a lightweight structure in order to accelerate in the racing competition.

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