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The Effect of Different Type of Material for Front Car Hood Panel Impact Simulation

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Abstract: In this research, an analysis was conducted on the topic of crash analysis. The objective is to analyze the total deformation and equivalent stress of the front car hood panel when collision happen at different velocity with different material. The analysis is done by doing a simulation using Ansys Workbench, SOLIDWORKS and Mechanical ADPL. Type of crash test for the crash analysis is frontal impact. The subject of analysis for the simulation are front car hood panel that being designed in SOLIDWORKS and for fixed support is a rigid wall. Three types of material will be subjected to the simulation model, which is structural steel, aluminium alloy and AL6061-T6. For the fixed support, which is the rigid wall, concrete will be used as the general material. Various incoming speeds were considered when the front car hood front model was simulated to crash into a wall. Five different velocities will be simulated in the simulation. The velocity are 20 km/h, 40 km/h, 60 km/h, 80 km/h and 100 km/h. Material that has the highest total deformation at velocity of 100 km/h is structural steel with the deformation of 0.20549 m followed by aluminium alloy with the deformation of 0.20185 m and then AL6061-T6 with deformation of 0.11139 m. Structural steel has the highest equivalent stress at velocity of 100 km/h with the reading of 1.6641e+009 Pa followed by Aluminium alloy with the reading of 5.8816e+008 Pa and lastly AL6061-T6 with the reading of 3.0382e+008 Pa. This simulation show that structural steel has the highest total deformation and equivalent stress than aluminium alloy and AL6061-T6. It can be concluded that structural steel is the most suitable material to use as the front car hood panel than aluminium alloy and AL6061-T6.

Keywords: Crash Analysis, Explicit Dynamic

1. Introduction

Car is the most popular vehicle for people to travel across Malaysia. There's sometime road crash can't be absolutely prevented. Some road accidents can lead to loss of life and property damage. This

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bad news is not something that only happened in Malaysia, even global people have suffered from this ever-increasing road accident phenomenon [1]. Data of the crash are needed to formulate counter measure from these tragedies. This data can be applied in creating a new design of a car model to lessen the fatalities from the crash.

One way to mimic a real-life accident is the crash simulation, and the data obtained by the test can be used to formulate the car's updated design and material properties. The effect of new design could reduce the risk of anyone dying if a car accident occurs. Around the world, there are many organizations that carry out crash testing. They are working to provide both modern and old model cars with comprehensive data regarding the protection of the customer. These organizations work to make sure that all cars sold are reliable when on the road and are likely to be safe.

Therefore, a crash test is an important phase in the validation of the development of a new vehicle. However, high costs in experimental testing cap the amount of crash tests, so adequate data could not be collected. In response, computer modelling, and simulation are widely used to analyze car crashes, in addition to experimental testing. In crash test simulations, the Finite Element Method (FEM) plays a key role as an important computational tool [2].

Crash simulations are used by manufacturers during the computer-aided engineering (CAE) analysis of crashworthiness in the computer-aided design (CAD) process of modelling new vehicles. During a crash simulation, the kinetic energy, or motion energy, that a vehicle has before the impact is transformed into deformation energy, often by plastic deformation (plasticity) at the end of the impact of the vehicle body material (Body in White). Data gathered from a crash simulation demonstrates that the car body or rail guard device is capable of shielding occupants of vehicles (and even pedestrians hit by a car) from injury [3].

Car always has been a preferable mode of transportation for most people for travelling but car accident are one of the most vehicles accident that occurred on the road. Usually it was a frontal collision that always have death involved. Car that don’t have a good crashworthiness for its panel will even increase the probability death. Types of material for the car panel are important to the car crashworthiness level. This death tolls can be reduced by having a car with a good crashworthiness. One of the panel that involved with the collision is the front hood of the car. With a not suitable material for the front car hood panel, the crashworthiness level of a car may drop and cause death and severe injury after the front collision of the accident.

In general vehicles are judged from the point of view of active and passive safety . Biomechanical limits, which can be resisted without more or less serious damage, are defined for human body. From the point of view of biomechanics size of acceleration, which the body moves by, is one of the most significant parameters. Various criteria for estimating the effect of super-critical acceleration on human body damage were. determined by an analysis of car accidents and crash tests. Head injury is the most common and most dangerous consequence of human body damage. Head injuries occur in 70 % of car accidents. WSU (Wayne State University) concussion tolerance curve was determined for super - critical acceleration of head, which indicates straight delay of head dependent on effect time. 80 g during 3 ms is given as super - critical acceleration of head [4]. To test crashworthiness prospectively, multiple parameters are used, including the deformation patterns of the body panel of the vehicle. So analysing data such as total deformation and equivalent stress are needed to increases the crashworthiness of the front car hood panel.

1.2 Objective of Study

The objectives of this study are:

- To analyse the total deformation of the front car hood panel when collision happen at different velocity with different material.

- To analyse the equivalent stress on the front car hood panel after the collision happen at different velocity with different material.

1.3 Scope of Study

This study is conducted based on the identified scope as follow:

- The speed of the car front hood panel in the simulation is 20 km/h, 40 km/h, 60 km/h , 80 km/h and 100 km/h.
- This research data and result will be produced based on ANSYS Workbench software.
- This study are focusing on 3 material for the front car hood model which is structural steel, aluminium alloy and AL6061-T6.
- This study are specially created for frontal collision of the car hood.
- The thickness of the front car hood panel is 0.7 mm.
- The dimension for the car front hood panel is 1800 mm x 1200 mm x 73 mm.
- The dimension of the fixed support or the rigid wall is 20 mm x 2000 mm x 50 mm.
- The fixed support or barrier for the collision are assigned with concrete material.
- The end time for the simulation is 0.009 seconds.
- The distance between the front car hood model and the rigid wall model is 1 mm.

2. Materials and Methods

The beginning of this project is to get the literature review from another researcher's journal on how to start the project. Draw the front car hood panel and rigid wall in SOLIDWORKS and import the file in IGES format files into the Workbench. Edit the model and it will be imported into explicit dynamic analysis. Define the thickness for the surface of the model as 0.7 mm. Update the mesh for the solid body of the front car hood panel and the rigid wall. Setup the simulation. The simulation on the front car hood panel will be solve with three type of material that will be assigned to the model which is structural steel, AL6061-T6 and aluminium alloy. The velocity parameter for the frontal impact of the front car hood panel with the rigid wall is 20 km/h, 40 km/h, 60 km/h, 80 km/h and 100 km/h. The solution that will be insert to explicit dynamic analysis is total deformation and equivalent stress. Collect the data after the simulation had been solved. After the simulation data have been collected, the result from the simulation of the front car hood panel will be compared. The collected data then will be analyzed and discuss. The last step is to do the conclusion by writing the conclusion and recommendation based on the simulation that have been done.

2.1 Materials

Three materials are assigned to the front car hood panel model in Ansys Workbench which is structural steel, aluminium alloy and AL6061-T6. Structural steels are chosen because it already been use commercially as body panel in automotive industry. Aluminium alloy and AL6061-T6 has a lightweight property compared to the structural steel.

For the rigid wall model, the material assigned to it in Ansys Workbench is concrete. Structural steel material, concrete material and aluminium alloy material comes from general material data sources in Engineering Data in Ansys Workbench. While AL6061-T6 material comes from explicit material data sources in Engineering Data in Ansys Workbench [5]. Table 1 shows the properties of material selected for the simulation. Table 2 show the mass of the model after being assigned to structural steel, aluminium alloy and AL6061-T6 material and the mass can be obtained in the Mechanical ADPL software.

Table 1: Properties of material [5]

Property	Value		
	Structural Steel	Aluminium Alloy	AL6061-T6
Density	7850 kg/m³	2770 kg/m³	2703 kg/m³
Young's Modulus	2e+11 Pa	7.1e+10 Pa	6.89e+10
Tensile Ultimate Strength	4.6e+08 Pa	3.10e+08 Pa	2.90e+08 Pa
Compressive Yield Strength	2.5e+008 Pa	2.8e+008 Pa	6.8e+008 Pa

Table 2: Mass of front car hood panel model after being assigned a material

Material	Mass of Model (Kg)
Structural Steel	8.074
Aluminium Alloy	2.8491
AL6061-T6	2.7801

2.2 Computational Method

First procedure is designing the model of the front car hood panel from Peugeot Pars and rigid wall. This process is done by using SOLIWORKS software. The dimension is as stated in the subtopic 1.3. The file model then will be saved in IGES format. Figure 1 shows the model being design in SOLIDWORKS.

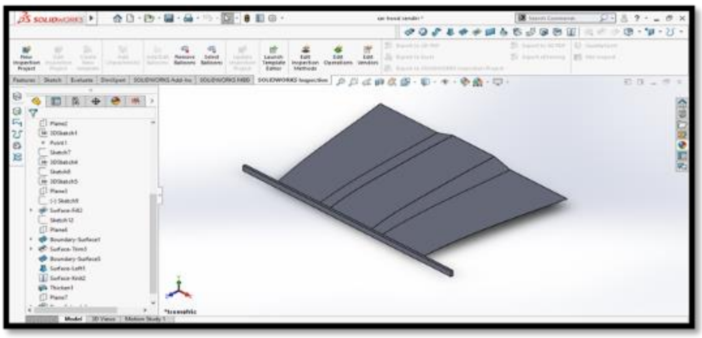

Figure 1: Model for the simulation being design in SOLIDWORKS

Launch ANSYS workbench and choose Explicit Dynamic as the analysis type. Insert material in engineering data. The material chosen are structural steel, aluminium alloy and AL6061-T6. Import geometry into ANSYS Workbench. Then launch Mechanical ADPL. Edit geometry to assigning type of material to the front car hood panel and rigid wall. Generate meshing to the model. The model being mesh is shown in Figure 2. By applying meshing process, we can determine the efficiency and effectiveness of any analysis. The number of nodes for the meshing is 5396 and the number of element is 15040. The number of nodes are low because of the simple model geometry and the meshing are coarse.

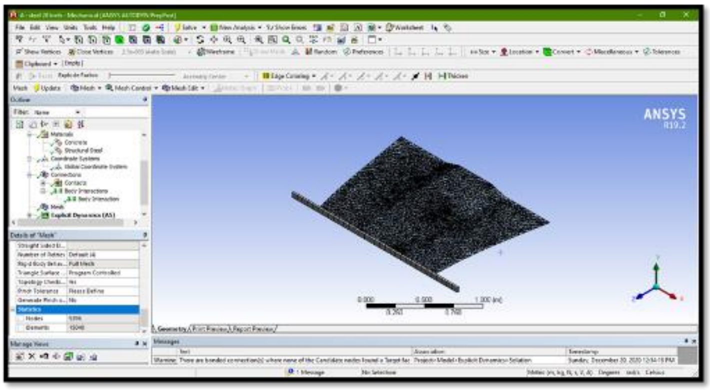

Figure 2: Model being mesh in Mechanical ADPL

In explicit dynamic setting, velocity is inserted. The velocity is defined by component. The component of velocity is Z-axis. The velocity is applied to the front car hood panel model. The velocity for the first simulation is 20 km/h. Fixed support is applied to the concrete wall, so that the wall is constrained in all degrees of freedom, and it would withstand different types of loads. Figure 3 show the model being assigned to velocity and fixed support.

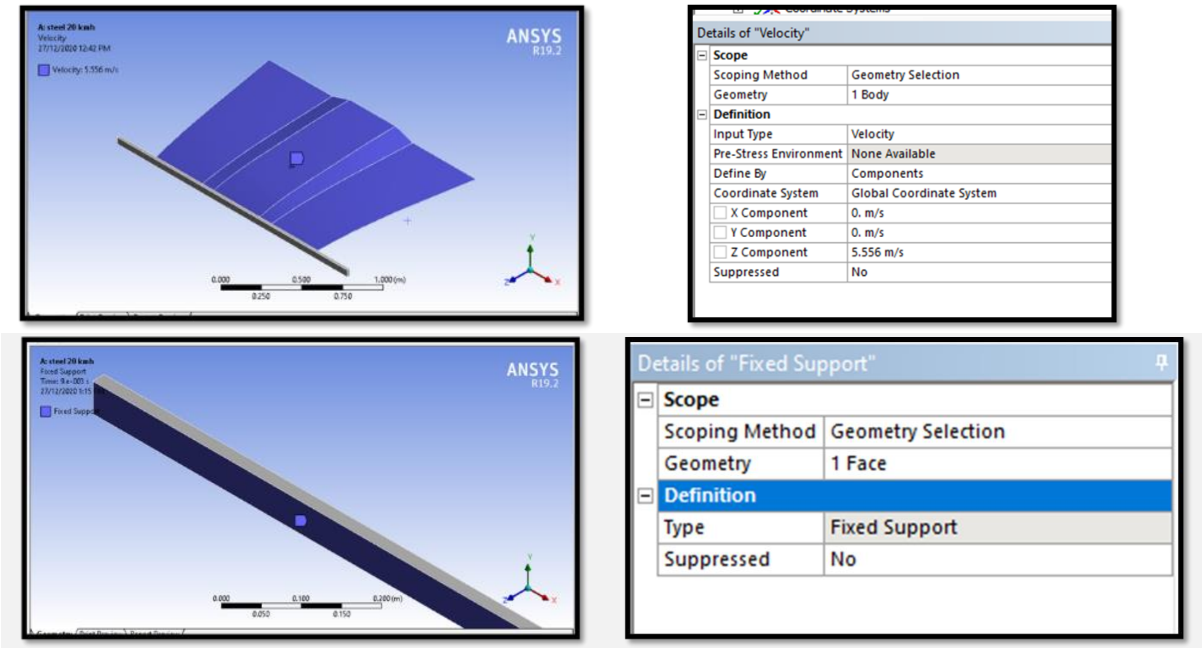

Figure 3: Model being assigned for velocity and fixed support in analysis setting

At solution, insert analysis for total deformation and equivalent stress. Option for inserting the solution for the analysis can be seen in Figure 4. Then solve the simulation and wait for the solution. Repeat procedure with front hood velocity of 40 km/h, 60 km/h, 80 km/h and 100 km/h also with other front material which is aluminium alloy and AL6061-T6.

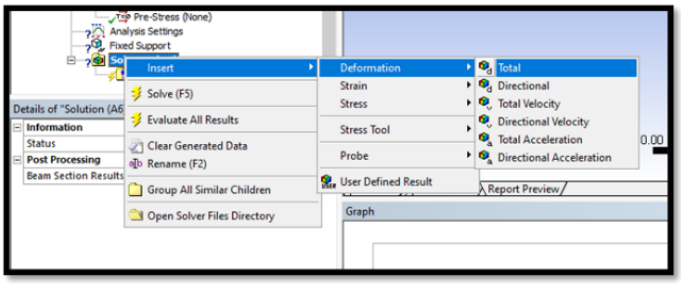

Figure 4: Inserting solution to be solve

2.3 Equation

To find force during the impact, two set of equation are used. Eq. 1 are to find work and Eq. 2 is to find the kinetic energy. From Eq. 1 we can derived it to find force. The work during the impact can be calculated using Eq 1 below:

$$W = F\ x\ D \quad Eq. 1$$

where W is kinetic energy or work in unit of Joules, F is force and D is distance. . Kinetic energy or work can be found in Eq. 2 below:

$$KE = \frac{1}{2}mv^2 \quad Eq. 2$$

where m is mass and v is velocity. The equation for Equivalent (von Misses) Stress are stated below:

$$\sigma_v = \sqrt{\frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}{2}} \quad Eq. 3$$

The axial, radial and tangential stresses are 1, 2, and 3. If the von Mises stress received from the expression above is equal to or greater than the material's basic tension yield stress, then it is expected that yielding should occur.

3. Results and Discussion

In this chapter, the data gathered will be discussed based on the simulation. This study focuses on the data obtained during the simulation using the ANSYS Workbench (Explicit Dynamic). In order to produce graphs, the data transferred to Microsoft Excel to compares the total deformation and equivalent stress of the front car hood panel against time. Structural steel, aluminium alloy and AL6061-T6 are the materials that will be compared in this table. Five different velocities are subjected to the front car hood panel which is 20 km/h, 40 km/h, 60 km/h, 80 km/h and 100 km/h when the frontal impact against the rigid wall happened.

Table 3 and Figure 5 shows the impact force for front car hood panel model when colliding with the rigid wall. There's different of force for each material and velocity.

Table 3: Force during impact with the rigid wall

Velocity [km/h]	Force (kN)		
	Structural Steel	Aluminium Alloy	AL6061-T6
20	124.62	43.97	42.91
40	498.39	175.87	171.61
60	1121.43	395.72	386.14
80	1993.54	703.47	686.43
100	3115.47	1099.37	1072.74

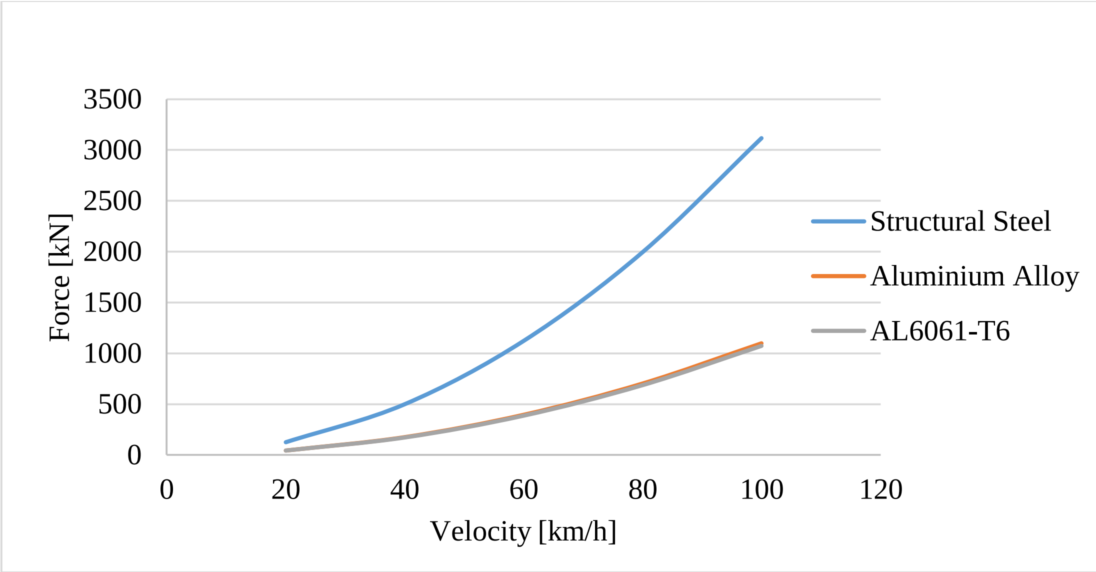

Figure 5: Comparison of force during impact for car front car hood panel with each material with different velocity

As the mass of the structural steel is highest among the other two materials, so it has the highest force for each one of the velocity. Mass of the front car hood panel for each material can be found in Table 2. It follows by the second highest mass which is aluminium alloy and followed by AL6061-T6 material. The differences between aluminium alloy and AL6061-T6 are just a slight because of little difference of density between the two materials. The forces also increasing linearly with velocity. The force during impact at velocity of 20 km/h are the lowest and the forces at 100 km/h are the highest. This happens for all of the material and the differences of force between material only happen because of difference in density and mass for each material.

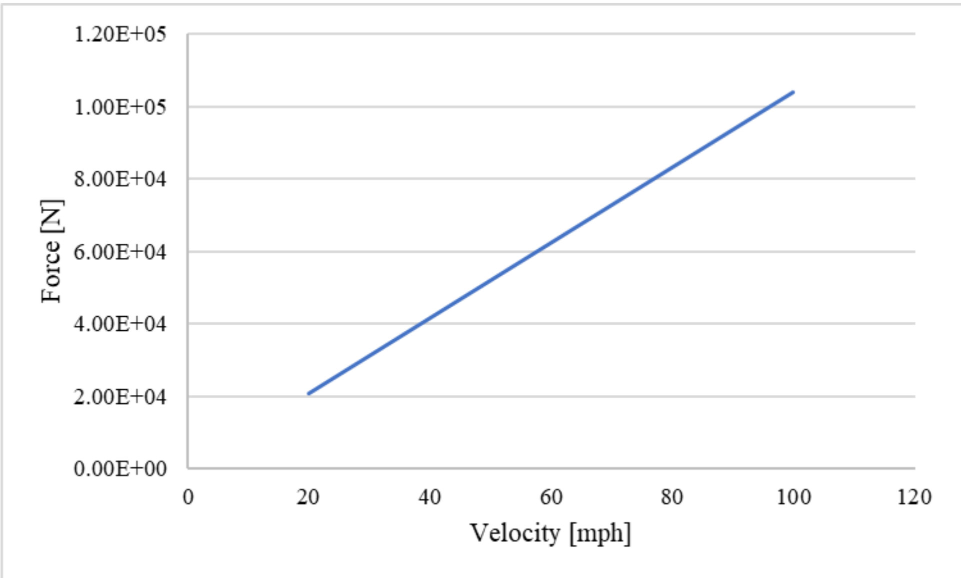

Figure 6: Force during impact of Ford Explorer at different velocity [6]

The graph from Figure 6 is force produced during impact of Ford Explorer at different velocity. This result is from previous researcher Andrew Hickey and Shaoping Xiao [6]. The material for the Ford Explorer body panel is Aluminium Alloy. For comparison we can see the force are increasing linearly with the velocity. This graph pattern also can be seen in Figure 5, and this justifies that force are increasing linearly with velocity.

Table 4 and Figure 7 show the maximum total deformation for front car hood panel with different material at different velocity.

Table 4: Maximum total deformation for front car hood panel with different material at different velocity

Velocity [km/h]	Maximum Total Deformations [m]		
	Structural Steel	Aluminium Alloy	AL6061-T6
20	3.8876e-002	3.8213e-002	3.8042e-002
40	7.9645e-002	7.8055e-002	7.8272e-002
60	0.12107	0.1187	0.1081
80	0.16301	0.15999	0.1138
100	0.20549	0.20185	0.11139

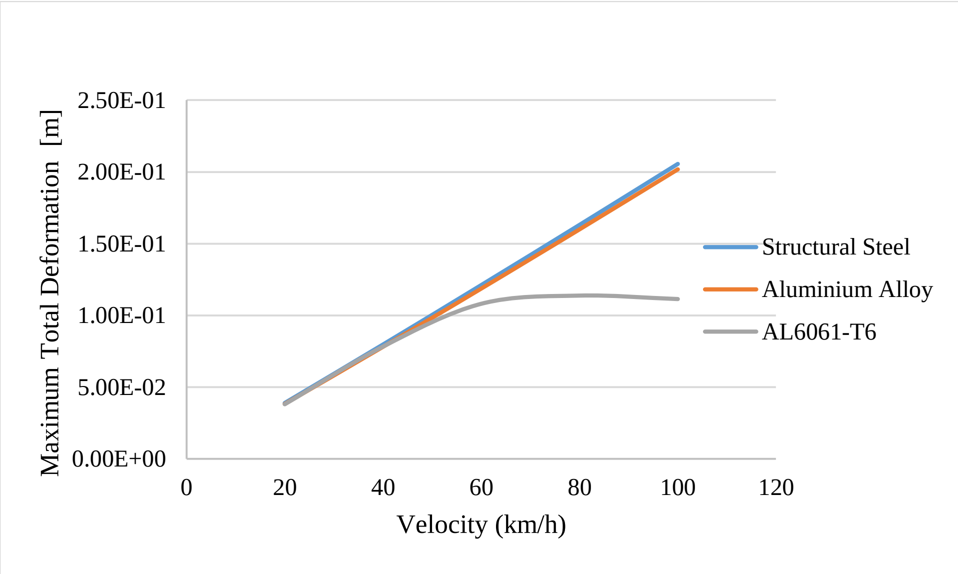

Figure 7: Maximum total deformation of the front car hood panel for different material at different velocity

From the table we can see that maximum total deformation happen at 100 km/h velocity. This is because deformation happen over time. The total deformation at 20 km/h are the lowest among other total deformation at different velocity. This is because of the kinetic energy for the front car hood panel for 20 km/h velocity are lower from the other velocity that studied in this research. The formula for kinetic energy is KE=1/2 mv^2, which m is mass and v is velocity. This show that mass has linear relationship with kinetic energy of the front car hood panel when it’s moving with certain velocity. Kinetic energy which has linear relationship with force play a big role with the total deformation of the front car hood.

Front car hood panel with structural steel material has the highest total deformation from aluminium alloy and AL6061-T6. The difference of total deformation between structural steel and aluminium alloy are small compared to the total deformation between structural steel and AL6061-T6. This may relate to the compressive yield strength of the material. The compressive yield strength of structural steel is 2.5e+008 Pa while for aluminium alloy is 2.8e+008 Pa and this may cause the difference of total deformation between these two materials to be small. While compressive yield strength of AL6061-T6 is 6.8e+008 Pa and the big difference of this properties with structural makes AL6061-T6 has much lowered of total deformation. From this result it shows that aluminium alloy has good crashworthiness while being lightweight than structural steel.

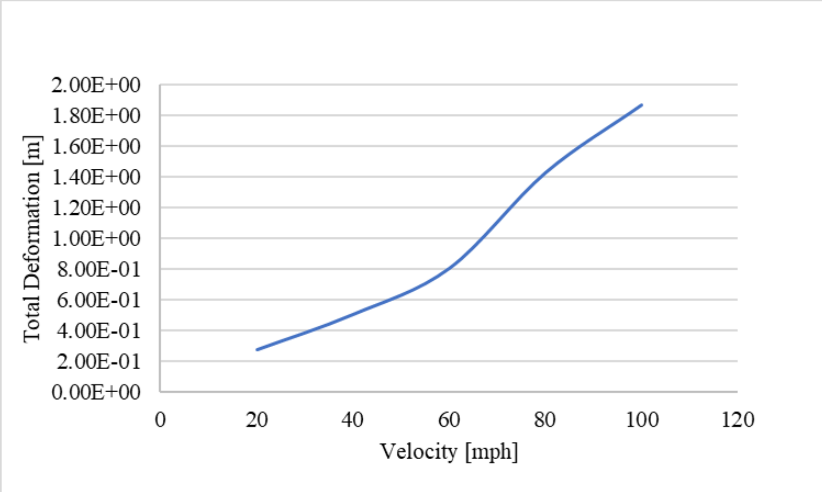

Figure 8: Total deformation of Ford Explorer for different velocity [6]

Figure 8 show the total deformation of the Ford Explorer in research done by Andrew Hickey and Shaoping Xiao [6]. The material for the Ford Explorer body panel is Aluminium Alloy. From the figure it shows that the highest deformation happens at 100 mph and the lowest deformation happen at 20 mph. The pattern of the graph in Figure 8 is increasing linearly for both force and velocity and it was the same as the pattern of the graph in Figure 7. This justify that deformation are increasing linearly with the velocity of the front car hood panel.

Table 5 and Figure 9 show maximum equivalent stress of the front car hood panel with different material at different velocity.

Table 5: Maximum equivalent stress for front car hood panel with different material at different velocity

Velocity [km/h]	Maximum Equivalent Stress [Pa]		
	Structural Steel	Aluminium Alloy	AL6061-T6
20	4.9017e+008	1.4826e+008	1.2542e+008
40	1.0321e+009	3.9766e+008	2.7019e+008
60	1.28e+009	4.3719e+008	2.8743e+008
80	1.3535e+009	4.9627e+008	3.0053e+008
100	1.6641e+009	5.8816e+008	3.0382e+008

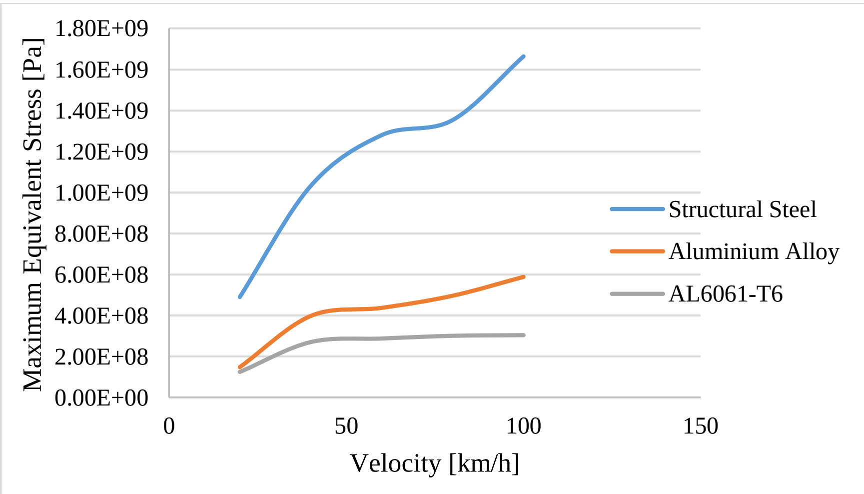

Figure 9: Maximum equivalent stress of the front car hood panel for different material at different velocity

From the table and figure, we can see that equivalent stress at velocity of 100 km/h has the highest value. This are cause by the force of the front car hood panel when it is colliding with the rigid wall. From the data from Table 3, it shows that the higher the velocity the higher the force of the front car hood. Stress is increasing as the force increase. This can be show in the Eq. 4:

$$\sigma = \frac{F}{A} \quad Eq. 4$$

The lowest value for the equivalent stress is at 20 km/h, as the force for all three materials are the lowest at this velocity.

The differences of equivalent stress between the three materials also can relate to the force when the frontal impact happen. The different density of the material will affect the mass of the front car hood panel. This data of density and mass can be seen in the Table 1. Because of higher mass, the force also increases which will also increases stress. This is shown in Table 2 as structural steel with higher mass and forces has higher equivalent stress for every velocity. This result pattern is followed by aluminium alloy which has the second highest mass and then followed by structural steel.

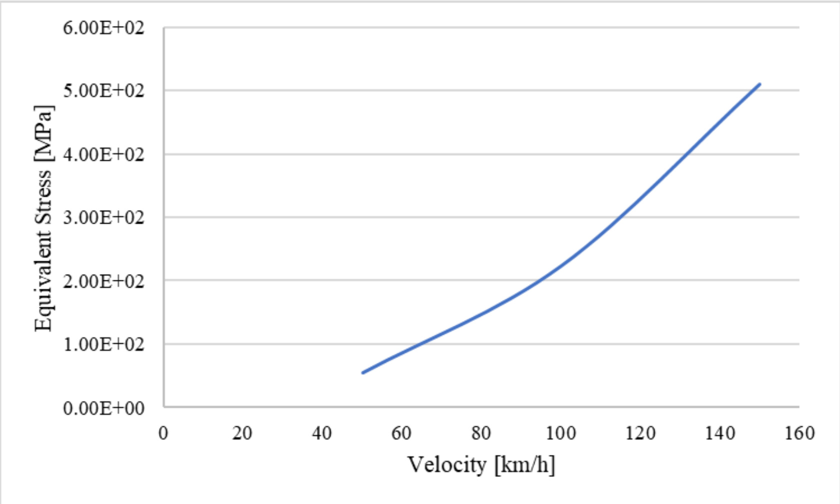

Figure 10: Equivalent stress of car body after crash impact against rigid wall [7]

Graph of Figure 10 are from previous researcher that do a study on crash analysis of composite car body. The material of the car body is Kevlar-49. From Figure 10 we can see that equivalent stress increases linearly with velocity. The lowest of equivalent stress is at velocity of 50 km/h with the reading of 55.22 MPa and the highest is at 150 km/h with the reading of 510.26 MPa [7]. The pattern of the graph in Figure 10 are almost identical with the graph in Figure 9 and this justify that equivalent stress increase linearly with velocity.

4. Conclusion

As for the conclusion, the objective of this simulation is to study the effect of different type of material for front car hood panel when subjected to frontal impact against rigid wall is considered successful. The simulation was conducted to analyze the total deformation of and the equivalent stress of the front car hood panel when it's being assigned to three different materials. The simulation was conducted on different velocity which is 20 km/h, 40 km/h, 60 km/h, 80 km/h and 100 km/h. The material that been assigned to the model of the front car hood panel is structural steel, aluminium alloy and AL6061-T6. The model is designed SOLIDWORKS software. The simulation is run in ANSYS Workbench. Analysis type for this simulation is Explicit Dynamic. Material that has the highest total deformation at velocity of 100 km/h is structural steel with the deformation of 0.20549 m followed by aluminium alloy with the deformation of 0.20185 m and then AL6061-T6 with deformation of 0.11139

m. Structural steel has the highest equivalent stress with reading of 1.6641e+009 Pa. Aluminium alloy has the second highest equivalent stress with the reading of 5.8816e+008 Pa followed by AL6061-T6 with the reading of 3.0382e+008 Pa. This simulation show that structural steel has the highest total deformation and equivalent stress than aluminium alloy and AL6061-T6. Material with higher total deformation and equivalent stress are good and suitable to be use as body panel as it increases the collision time. Lengthening the time is usually a goal in mitigating the effect of collisions. So, it can be concluded that structural steel are the most suitable material to use as the front car hood panel than aluminium alloy and AL6061-T6.

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