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FEA analysis of Carbon Fiber, Polyethylene and Silicon Rubber for Automotive Car Door Protector

Eliza Shamsudin, Razis Othman and Ahmad Khairudin Anuar

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Eliza Binti Shamsudin[1] & Razis Bin Othman[1] Ahmad Khairudin Bin Anuar[1]

[1] Department of Mechanical Engineering, Politeknik Sultan Azlan Shah, Behrang, Perak

ABSTRACT
Quality car manufactured is important to certify the customer's satisfaction. Scratch and dent, as one of the critical issues lately and the problems frequently happen in the automotive industry, especially in the assembly-line process. The potential of the car could be scratch, and dent is high especially on car surface at door area, when a team member assembles the material. The objective of the research is to choose the best material for car door protector from three types of material with different mechanical properties, to analyze the Von misses stress and deformation of the materials and to compare the suitable material properties and apply as material protector to reduce to number of scratch and dent. The result of the comparison will be collected and presented on a table to compare the Von Misses Stress and deformation which can create the scratch and dent on the surface. The low value of data will present the good material of the protector.

Keywords: Von Misses Stress, deformation, dent, scratch

1. INTRODUCTION

1.1 Introduction
ABC Company Sdn Bhd is an automotive company that manufactures SUV in Malaysia. The SUV is a large car with an engine that supplies power to all four wheels and normally use as a passenger vehicle. There are many automobile industries nowadays which are different brand and models, by the time new cars roll off production lines they will have undergone a series of strict quality-control tests to ensure they hit the dealerships in immaculate condition. In the assembly line, the car has exposed the potential of scratch while assembling part of the car is done, the potential includes human mistake, machinery use, jig used, and tool that is involved in that process. The SUV car door will be exposed to scratch and dent while a team member does an assemble process of door accessories such as door handle, door strip, and door glass. A door cover should be created by a method of analysis and testing, then the problem of scratch and dent will be overcome.

In the context of product design, the main goal of material selection is to minimize cost while meeting product performance goals. Materials selection plays an essential role in the product design process (Faris M. AL-Oqla, 2017). Product materials determine the range of function, durability, certain costs, user feedback, and user experience. When users interact with products, their senses are in contact with the materials of those products. Users see the colors of materials, feel the texture and weight, and hear the sounds that the materials make when the object is moved. These sensory perceptions contribute to product usability and user experiences Product designers use materials to create these sensory (Faris M. AL-Oqla, 2017).

Material analysis is required to make sure the objective is achieved, materials selection for the cover is an aspect that should be lookout. Material selection is done by material analysis by using ANSYS Software to compare certain materials choose and this a step in the process of

designing any physical object. For this study, the material that was decided for analysis is Carbon Fiber, Polyethylene, and Silicon Rubber.

1.2 Project Background

The Assembly Department is assembling process of parts (usually interchangeable parts) are added as the semi-finished assembly moves from the workstation to another workstation where the parts are added in sequence until the finished car. This department consists of a few sections such as trim, chassis, and final which use to complete car produces, this study focuses on a process that deals with doors, those are in the trim and final section. In the trim section, the process is called door off and at this final area, it gives the potential of scratch and dent occur.

1.3 Problem Statement

The quality of the SUV cars that have been manufactured is very important for customer satisfaction and the future of a company in high demand. Lately, the quality of cars manufactured is commonly dealing with scratch and dent issues, especially door surface area, where that is a favorite area exposed to physical harm. The rejection area of the surface car door is very sensitive when touching which hard/sharp object during the assembly process. Hence, to overcome the issue a materials analysis of door protector material was developed to solve this problem and to compare the best and economical materials that should be used.

1.4 Objective

The objective of the research is to design choose the best material for Automotive Car Door Protector with three different mechanical properties which is from group of plastic, carbon fiber and rubber. To study the strength and toughness of material and analyse the Von Misses Stress and deformation.

2. LITERATURE REVIEW

Carbon fiber is currently being used in engineering design and analysis, from car manufacturing to aerospace, machinery manufacturing, and processing almost all areas are inseparable from finite element technology (Wu, 2016). The existing carbon fiber material is an advanced composite material with high strength, anisotropy, and poor thermal conductivity. Mingyang etc developed a simulation of FEA for drilling a carbon fiber material since it has strength and durability. The selection of carbon fiber material as one of the material protectors can be recommended since the performance of material properties itself to reduce scratch and dent during the process.

High-Density Polyethylene (HDPE) has many advantages, it uses for non-safety-related applications in nuclear power plants. Since the mechanical properties of HDPE able to be facing extra loadings such as gravity, temperature, and earthquake (Shi, 2021). Jiangfeng Shi etc study the HDPE for pipe in nuclear power plants and simulate in FEA. It shows the stress concentrations were found on the surface of the elbow pipe. It convinces the performance of HDPE can be considered for this study. The vibration and some impact while assembling the tool can cause a scratch and dent on the surface.

Silicon rubber can be the function as an absorber to absorb the impact of tools. the rubber has important application in the high-speed machine. Some research mentions a silicon rubber has a good deformation condition while facing an impact to force. According to the result for

silicon rubber, even speed of machine tools is high, is no obvious impact on the deformation degree (CHAI, 2016)

3. METHODOLOGY

There are several phases need to be accomplished to complete the analysis of three different material for automotive/SUV car door protector. The proposed material selection is based on Figure 1- strength and toughness materials chart, as well supported from journal review. Group classes of material are from material elastomers, thermoplastics polymers, and fibers. Properties of material for three different classes will analyze according to their material class which is plastic, natural rubber, and nylon. Selected materials come from the same categories, but they have different mechanical properties. The mechanical properties for three materials are used to setting in ANSYS software to simulate the situation almost the same with a real situation. Later the author will compare the simulation result will a real situation condition.

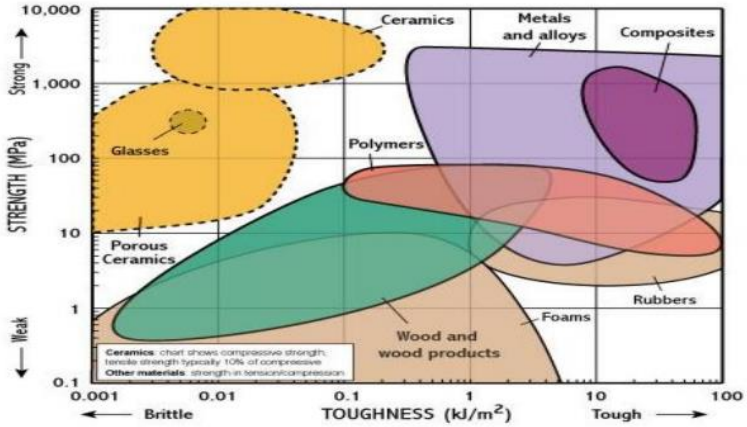


Figure 1: Strength- Toughness materials selection charts (Material Engineering, 2021)

3.1 ANSYS Software Simulation

This analysis uses computer software or simulation to simulate to force impact on the protector. information about their material properties is gathered, since ANSYS does not specify the unit to be used in the system, unit systems can be used arbitrarily, but they must be consistent in the problem. In this analysis, considering newton (N) for the load and millimeters (mm) as the unit for displacement. The value is set for high-density polyethylene, E=1.4 GPa, σY=32 MPa. In ANSYS, for high-density polyethylene value of Young's modulus input as E=1400 MN/m^2 and σy=32 MN/m^2 and silicon rubber the respective values are E=5 MN/m^2 and σy=8 MN/m^2 then for carbon fiber the respective values are E=265000 MN/m^2 and σy=4930 MN/m^2

After setting up the material, a structural analysis will continue for the next phase. The structural analysis function is to find the deformation and stress associated with the protector surface by considering the pressure load and surface area. The deformation result will illustrate on deformation force in-unit meter (m), while for stress the result illustrates in Pascal (Pa) Von Misses Stress. A deformation and stress values are pre-calculated and applied as real forces on the actual model that is developed in ANSYS. The force that will be applied in this analysis is the force use almost similar during the assembly process of the car door. The force example such as bolt or nut drop and touch to the door surface.

The study of force will calculate by using a falling parameter, Figure 2, while by placing the value of height object drop and the mass of bolt or nut and another involved object. The result will appear in velocity; therefore the force formula will be used to find out the force value, Force, F = mass, m x acceleration, a. From the falling parameter calculator, the value of force will be used to set in as the input force for static impact.

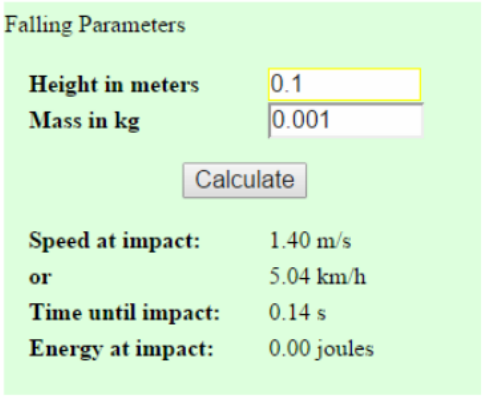


Figure 2: Falling parameter calculator.

3.2 Data Collection

This study continues by the observation of a team member do an assemble the part using a tool in a production line. The reason observation was done is to get the data on how the real process has happened. In other words, the simulation analysis can be set up as a natural setting. Therefore, the result will come out will almost be like the real situation. The presence of the research may lead to problems with validity and a technique for verifying or nullifying information provided in face-to-face encounters.

The observation shows the scratch pattern that happened at the door surface area after exiting from the assembly line. The observation continues at production line 2 (L2) which to identify the possible process that deals with the door surface and give potential a door gets scratch or dent. A check sheet techniques method was proposed for collecting data through observation while in assembly process at L2 was running. This observation only marks which process that involve in a car door, a summary of observation found there are five processes in the trim section and there are five processes in the final section.

3.3 Descriptions

Collection data summary is presented in Table 1. The description of data presented in categories of people and situation/environment. The check sheet developed to categories the most potential of scratch and dent in the process that happened, process versus the potential of scratch and dent. The observation starts from marking the grade of potential (level of the treat), remark the potential such as tool, human mistake, jigs or machine to find out which of the process could contribute toward these problems.

Table 1: Marking check sheet.

			Potential of scratch and dent				
No	Process	Section	1	2	3	4	5
1	body loading	Trim					
2	wire door	Trim					
3	wire floor	Trim					
4	door off	Trim					
5	door on	Trim					
6	underpit	Final					
7	fluid filling	Final					
8	quality gate	Final					

Remark	
1	no potential
2	small potential
3	medium potential
4	high potential but can avoid
5	high potential but can not avoid

The observation remains by monitoring the certain process and all observations are remark on the check sheet, the mark is important to classify which processes are highest and lowest potential. Based on the observation, it can see no level five marking, it can be concluded that all potential can be controlled. The process that has the highest mark (four) is the process that deals with a jig (door manipulator), which the insertion of the jig to the door is remark as high potential because it touches with the door surface.

Furthermore, the process indicates as level three shows the process of assembling the door accessory such as door handle which cause the potential when the door handle is a slip from the slotted and it will touch the door surface. In addition, for the process that marking at level two, it seems not too serious and small potential to occur and will occur because of human error, like picking the bolt and nut but the bolt slip from hand and drop to the door surface and in handling tool in the process.

4. RESULTS AND DISCUSSION

Explicit dynamic analysis was used to analyze the three different types of material to know the material strength by using their specific mechanical properties. Material properties of carbon fiber, silicon rubber, and high-density polyethylene were key-in into material-specific data in ANSYS software. All materials that want to measure design as small bar were contacted to two pairs of half-sphere block as fix support then were applied displacement -0.00006 m along the Y axis to the presser object with mass 0.25 kg toward the materials. Overview of the simulation as shown in Figure 3.

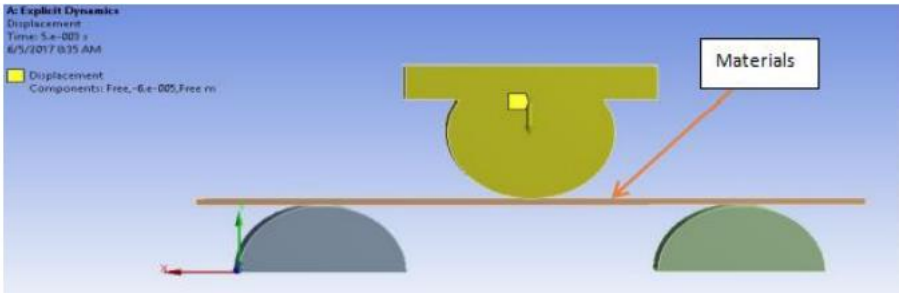


Figure 3: Downward displacement applied toward material.

4.1 Material Analysis Result

4.1.1 Carbon fiber analysis

Carbon fiber properties were measured by Von Misses equivalent stress and deformation. After, the presser presses the object with 0.25 kg mass is applied, -0.00006 m displacement toward the carbon fiber bar and resulted maximum stress occur appeared as a red contour at the red circle as mentioned in Figure 4 above side. Corresponding with their properties the maximum stress occurs on the left side center about 324.46 Pa and there occur maximum deformation behind the maximum stress about 0.000060004 m. The maximum deformation is a little more with displacement applied, this means only 0.0000000004 m deformation occur toward this material.

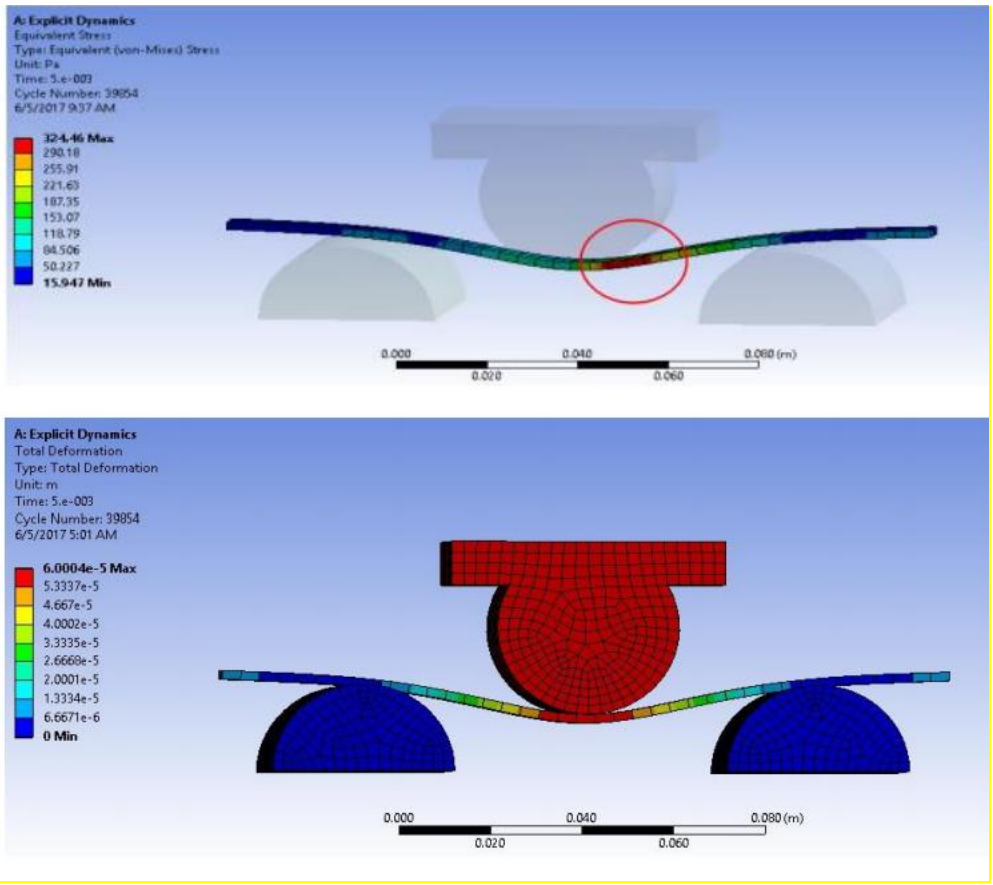


Figure 4: Carbon fiber equivalent stress and deformation result

4.1.2 Polyethylene Analysis

Analysis continues by carried out to evaluate polyethylene by using their properties and measured by equivalent stress and deformation. After the presser press, the object with 0.25 kg mass is applied -0.00006 m displacement toward the polyethylene bar and resulted maximum stress occurs appeared as a red contour at the red circle as mentioned in Figure 5. Corresponding with their properties the maximum stress occurs on the same center about 58.496 Pa and there occur maximum deformation behind the maximum stress of about 0.000000013 m. The maximum deformation is a little more with displacement applied but more than carbon fiber, this means only 0.0000000013 m deformation occur from its original shape toward this material.

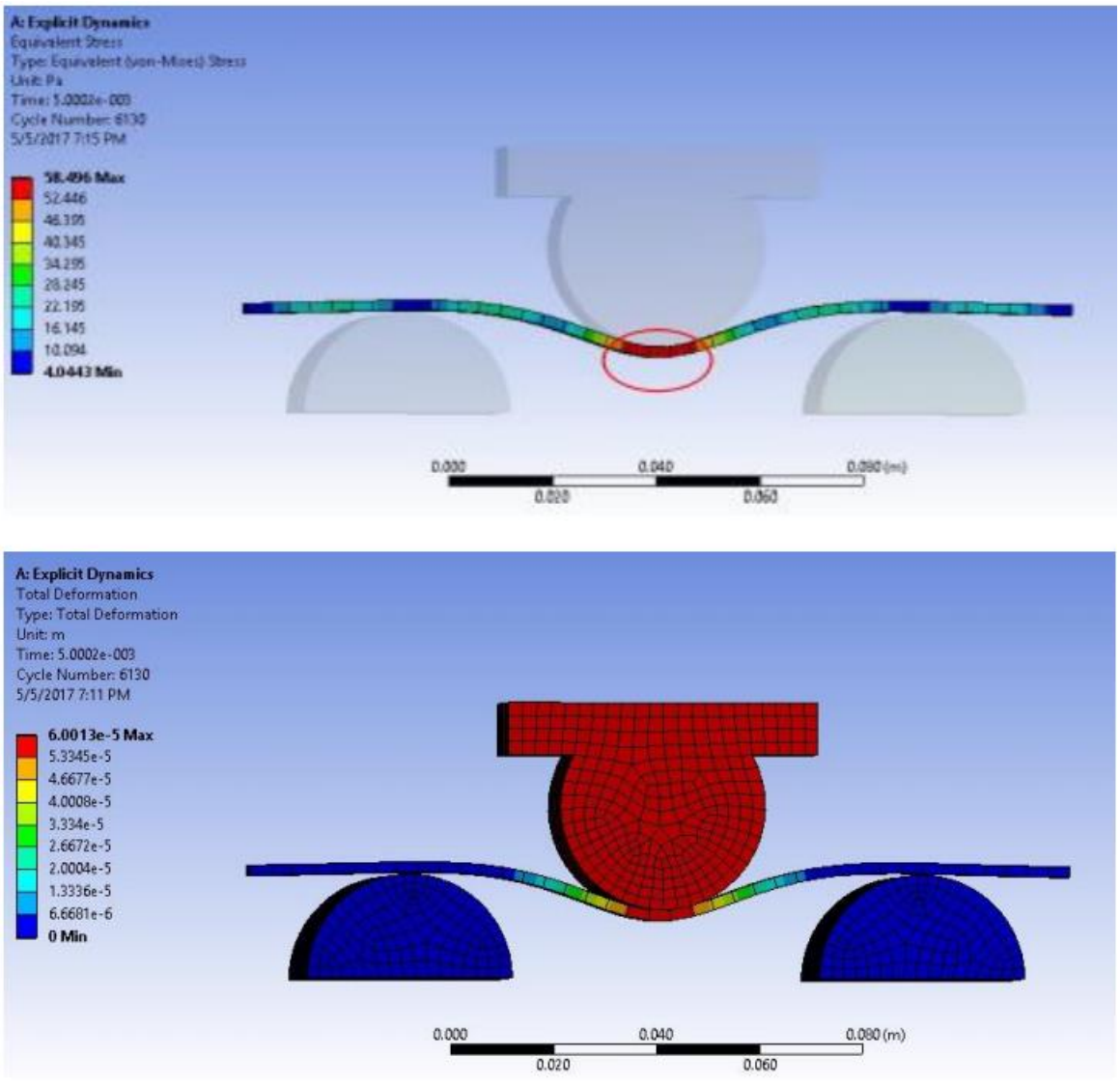


Figure 5: Polyethylene equivalent stress result

4.1.3 Silicon rubber Analysis

The last material analysis was continued by carried out analysis on silicon rubber by using their mechanical properties and measured by equivalent stress and deformation. After the presser object with 0.25 kg mass is applied -0.00006 m displacement toward the polyethylene bar and resulted maximum stress occurs appeared as a red contour at the red circle as mentioned in the figure. Corresponding with their properties the maximum stress occurs on the same center about 15.3999 Pa and there occur maximum deformation behind the maximum stress about 0.000060124 m. The maximum deformation is a little more with displacement applied but greater than carbon fiber and polyethylene, this means only 0.0000000124 m deformation occurs from its original shape toward this material.

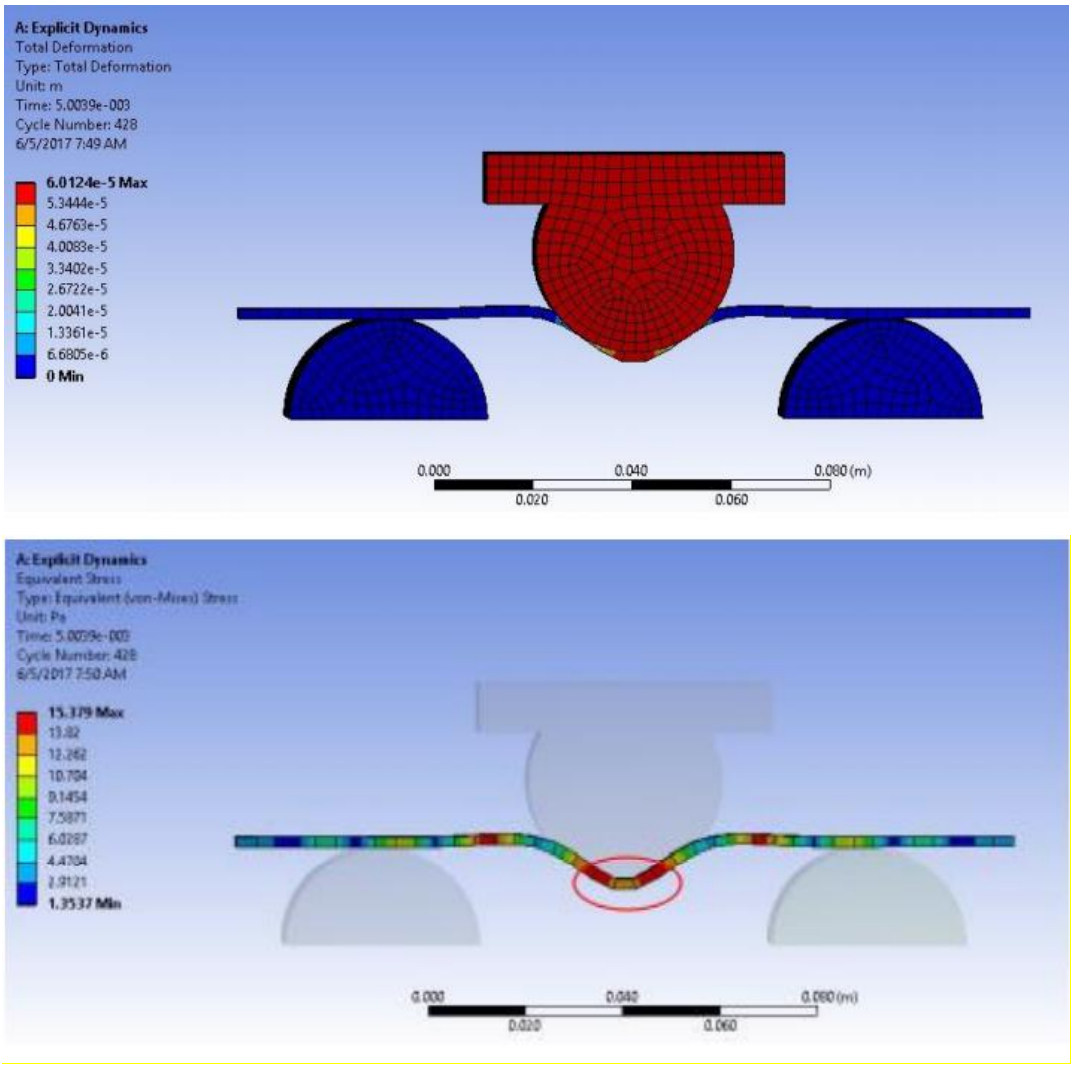


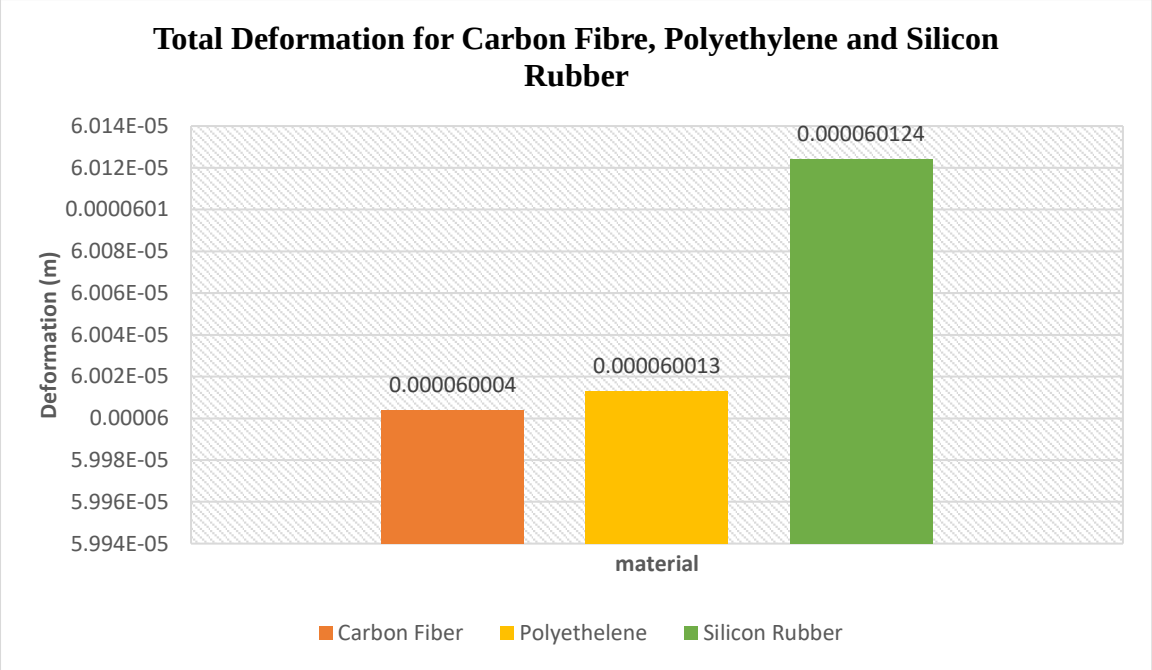
Figure 6: Silicon rubber equivalent stress result

4.2 Result Analysis

Figure 7 represent the summary of a result obtained from explicit dynamic analysis for three different materials, after displacement of 0.25 kg object force is applied and attach the fixed support the result the best material by stress and deformation reading is evaluate.

The first material is carbon fiber, it is a hard material that has a high modulus it also pliable but has low elongation. It shows, the carbon fiber material has the highest equivalent stress occur when the presser was applied but have the lowest elongation compare other two material. The second material is from the polymer group is polyethylene is known as tough material which has a high modulus (steep-slope) and high elongation, above can see the result occur on this material, is medium stress and medium elongation Third material from the elastomer group that is silicon rubber it has soft tough properties which low modulus and have high elongation, in Figure 7 show the comparison of result for stress occur on this materials is lowest compared other two material because this material has a soft surface and was absorb the force received but has big elongation.

Based on the description, the best material selection was gone to the material that has low result in stress and elongation if the type of the materials were same, but for this case, the material was from other groups with have different stiffness, toughness, and elongation. In this study, silicon rubber was the best material than polyethylene and carbon fiber because based on the result it shows it had low stress and although the largest deformation occurs on this object, this is because that is their properties and its soft material with have high elongation but with low equivalent stress.



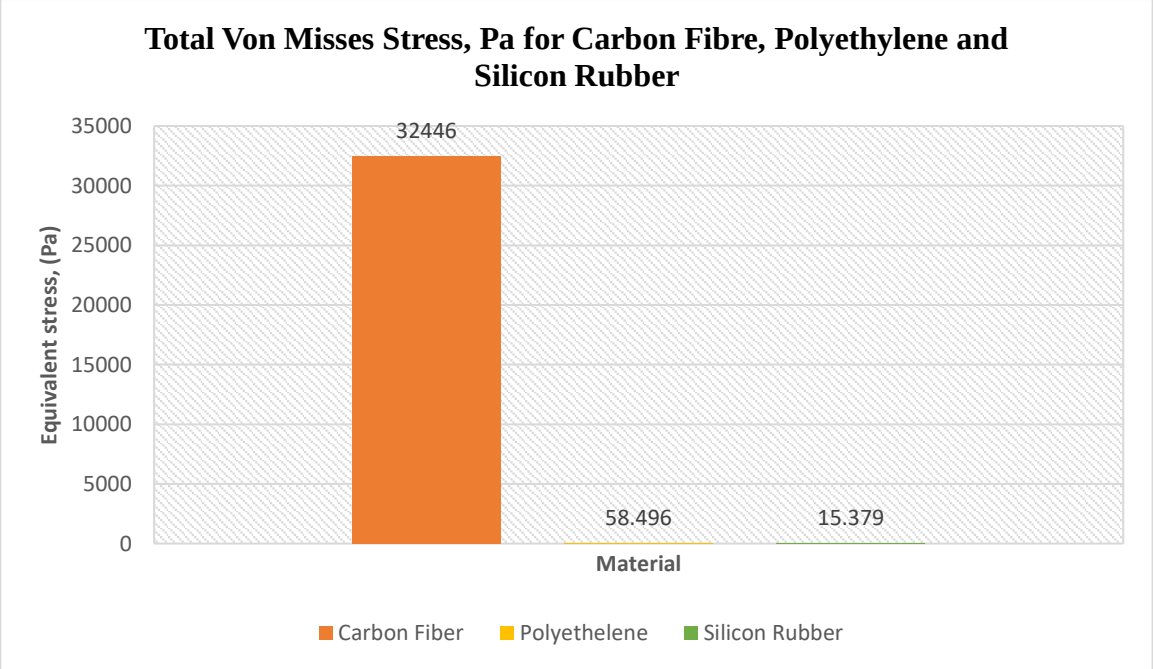


Figure 7: Material comparison selection

5. CONCLUSION

This study introduces a material selection for three different groups of material is used as an SUV door protector to analyze the impact force during assembly of a part at the production line. Its use to reduce a scratch and dent mark on the surface car door of SUV, by the method of analysis using structural and explicit dynamic analysis method as an instrument to measure the results in ANSYS software. The result was measured by deformation and stress occur in every material and force applied. The lowest deformation and stress appear in the design shows the strengths material. Based on the comparison of the result, materials that had less stress and ideal deformation were judge as to the best material and were used in the design each design that had been selected, from the result previous chapter by comparing that three types of material, the silicon rubber were chosen as the best material which has low stress and deformation occur will give stable and strong structure to resist with a force that is contact and this material choose to use in protector.

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