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Crash Analysis of Bumper Assembly with Solver to Improvise the Design for Impact Tests

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ABSTRACT - Car bumpers can deform to absorb impact energy. For static and modal analysis, a Benz vehicle bumper was used. These analyses used a variety of bumper materials, including glass-mat thermoplastic, aluminium alloy, and mild steel with chromium plating (GMT). The majority of modern cars have bumpers composed of PC/ABS, a material blend of polycarbonate (PC) and Acrylonitrile butadiene styrene (ABS). PETG, ABS, and TPU. The deformation and strains grow as the car's speed rises from 55 km/hr to 90 km/hr, according to the static study. At a car speed of 75 km/h, the deformation and stress in the automobile bumper were at their highest. It was found through the static analysis that the stress values for PP material were lower.

KEYWORDS - ABS, PETG, TPU, CATIA, Solid Works and stress analysis.

I. INTRODUCTION

The purpose of a bumper is to protect and support a vehicle. A bumper is formed of an extended guide that may be attached to the front and rear of the car body and spans the width of the car body, as well as a shock absorber that runs parallel to the support portion and becomes dramatically convex as it gets closer to the front and rear of the car body. The bumper also has an elastic outer shell that may be linked to the support component and forms a roughly U-shaped enclosure around the front and back of the vehicle. The support element's side that faces away from the side that deals with the front and back of the vehicle body is also covered by the exterior shell.

Bumper is split in sorts; they're the front bumper and rear bumper. Principal function for a bumpers to absorb impact electricity and decrease damage caused to the auto in addition to physical injury throughout an twist of fate. This research work is centered at the rear vehicle bumper gadget and it has 3 fundamental components.

A. Substances Used for Car Bumpers

Most recent bumpers were made of a polycarbonate (PC) and Acrylonitrile butadiene styrene (ABS) blend known as computer/ABS, polypropylene (PP), polyurethane (PUR), and polyvinyl chloride (PVC) percentage. Modern bumpers are created using a variety of various elements. The main component is an impact-absorbing spring system, usually in the form of gasoline-filled cartridges that mount the front bumper to the chassis.This enables the bumper device to absorb minor impacts without suffering any damage.

The lateral beam, a steel or aluminium support structure, is the next component. On top of that is a honeycomb-shaped or egg-crate-shaped HDPE plastic piece that defines the bumper's final exterior form and aids in the shape of the bumper cover. These might be fastened to the vehicle's other bodywork or parts at the back. This section of the bumper construction is typically the one that is broken but not visible in more serious accidents.

Subsequently, a urethane or different flexible polyethylene plastic bumper cowl is located on the outdoor to provide the car a completed look. These are both charcoal and flat black and they could paint to in shape the auto finish. They're designed to be impact resistant and may take a blow with little or no harm. Bumpers in cars are intended for absorbing shock or impact at low pace like injuries that occur when reversing the car. Bumper material is selected in this kind of way that it have to have the functionality to take in the effect (i.e.) either nullify the effect or lessen the impact of the impact. Metals are not considered as excellent cloth for bumpers since they switch the load applied at one quit to the alternative with negligible loss. Plastics and polymer substances can be applied as bumper considering the fact that they have the tendency to absorb the applied effect load and thereby reduce the impact of the impact.

II. LITERATURE REVIEW

Mr. Hosseinzadeh. [1] studied bumper beams inside the vehicles that cushion the devastating front and rear impacts for the occupants and the vehicle. Researchers looked at a front bumper beam made of glass mat thermoplastic (GMT), and their research was carried out using ANSYS LS-DYNA. A front bumper beam made of three unique materials—aluminum, GMT, and high-electricity SMC—was studied by Marzbanrad et al. [2]. In order to improve the crashworthiness design for low-speed impacts, the most important parameters, including material, thickness, form, and effect scenario, have been investigated for layout and evaluation of an automobile's front bumper beam. The analysis was completed using impact modelling to determine the deflection, impact pressure, pressure distribution, and energy-behavior absorption. The researchers compared the aforementioned characteristics to determine the best fabric, form, and thickness. The researchers determined that a changed SMC bumper beam can decrease the bumper beam deflection, impact force and stress distribution and maximize the elastic strain strength.

According to Mohapatra [3], as a result of shorter automobile development cycles and increased market competition, it is crucial for OEMs and dealers to develop time-saving alternatives. The researchers also brought up the fact that some bumpers are created with foam padding while others are made with energy absorbers or brackets.

Andersson et al. [4] used intrinsic and simulative checks to examine the relative performance of three high power carbon steels and high strength chrome steel grades. The five sheets that were examined for formability and behaviour under load were used by the researchers to create the rear bumper for a Volvo car. The bumpers had been secured in a setup that enabled quasi-static impact evaluations. Through the use of the impact test, the bumper's capacity to absorb power was assessed.

According to Butler et al. [5], crash safety additives must transmit or absorb power, and a specific element's ability to do so depends on both its geometry and fabric housing. These requirements have led to a growing interest in the usage of excessively strong stainless steels. The chosen fabric should have excessive yield energy and moderately excessive elongation to fracture.

The goal of Carley et alstudy .'s [6] was to design effective epoxy structural foam reinforcements to increase the electrical absorption of the front and rear car bumper beams. They did this by analysing three bumper structural performance standards. Modern enhanced Polypropylene (EPP) foam technology and techniques were extensively studied by Evans and Morgan [7].

III. MODELING OF CAR BUMPER USING CATIA

Computer Aided Three-dimensional Interactive Application is known as CATIA. It is a top 3D modelling programme utilised by businesses across a variety of sectors, including consumer goods, transportation, and aerospace.

CATIA makes it possible to see designs in three dimensions. This idea was novel when it was first presented. Because Dassault Systemes lacked marketing experience, they partnered with IBM on a revenue-sharing basis, which was quite successful for both businesses in spreading the word about CATIA.

Figures 1 and 2 display the car bumper in both 3D and 2D formats. Using CATIA software, the bumper was modelled with the aid of features like a cushion and a pocket. The material was added using a pad, and it was removed using a pocket.

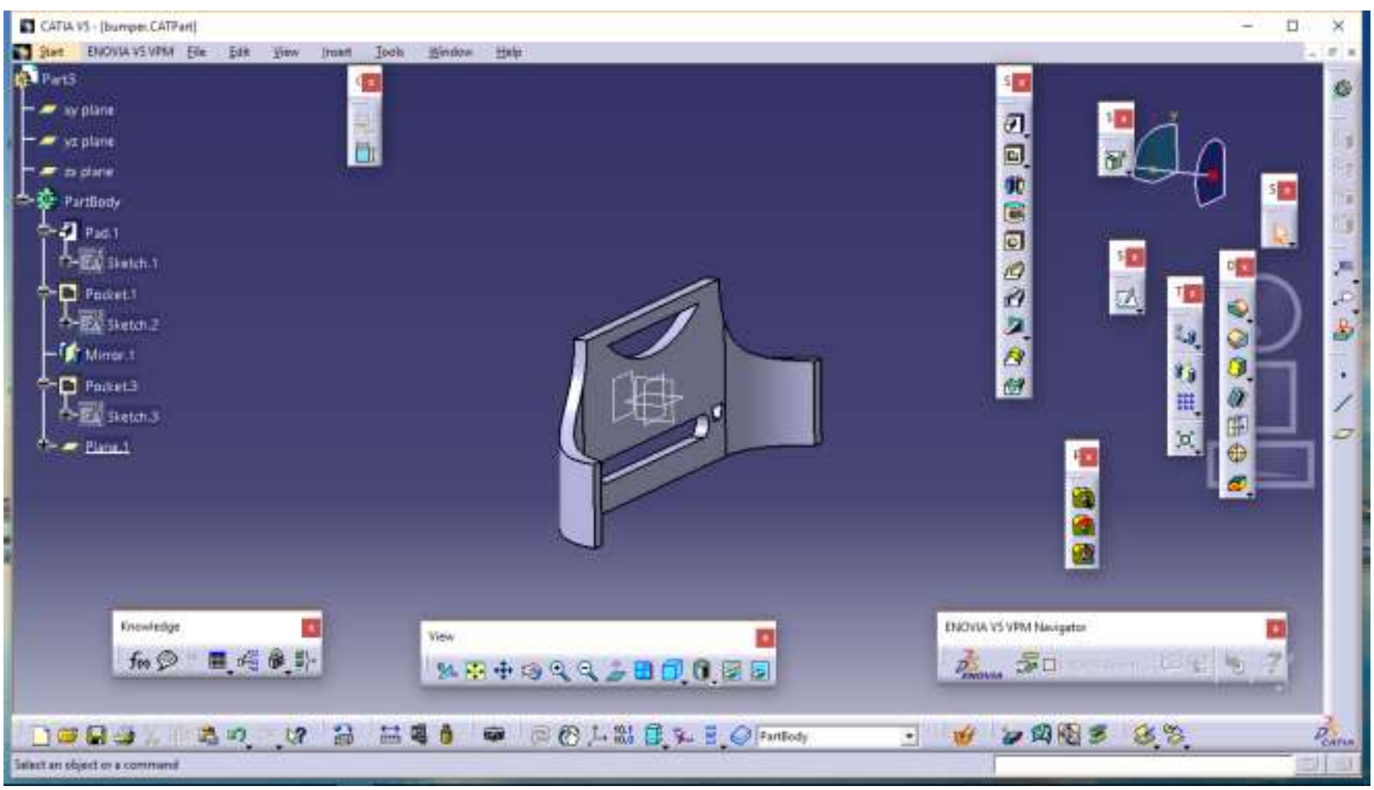

Figure 1: Car Bumper 3D Model

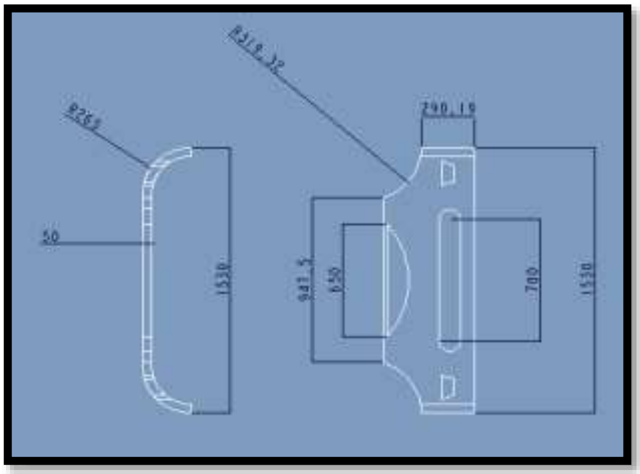

Figure 2: Car Bumper 2D Model

IV. RESULTS AND DISCUSSIONS

A. Analysis of Car Bumper Using Cosmos Works

For analysis, COSMOS Works software employs the Finite Element Method (FEM). A numerical method for assessing engineering designs is called FEM. Due of its generality and suitability for computer application, FEM is recognised as the industry standard for analysis techniques. A complex problem is effectively replaced by numerous simple problems that must be handled simultaneously by FEM, which breaks the model up into many little, simple-shaped components called elements. Each component's behaviour under every conceivable support and load scenario is fully understood. Elements with various shapes are used in the finite element approach. Interpolation is used to create the response at any location within an element from the response at the element nodes. A design analysis automation tool that is completely integrated with SOLIDWORKS is called COSMOS Works. This programme simulates the operating environment of your designs and forecasts their behavior using the Finite Element Method (FEM).

B. Static Analysis - Deformation, Stress and Strain in Car Bumper at various Speeds

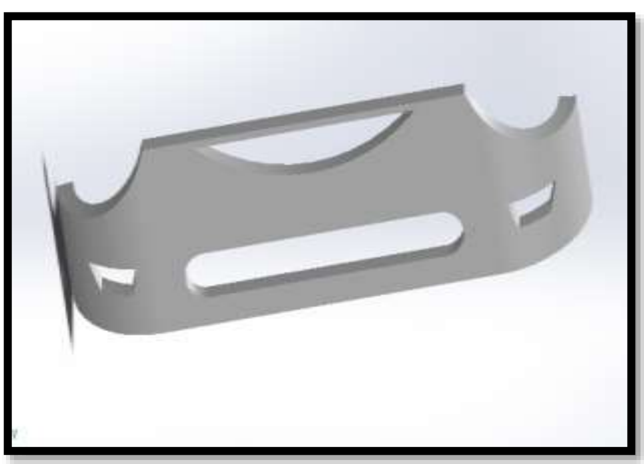

Figure 3: Imported model of bumper

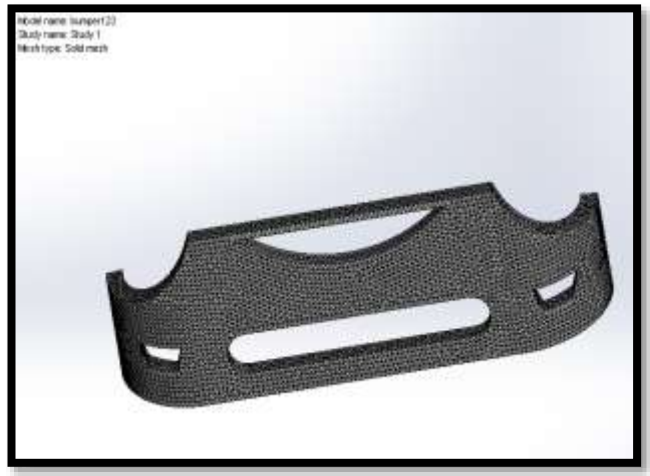

Figure 4: Meshed model for bumper

The car bumper underwent static analysis by using boundary conditions. Figure 5 depicts the entire deformation of an automobile bumper. From the above figures, it can be seen that the minimal distortion is shown in blue and the greatest deformation is shown in red. The fixed ends of the bumper experienced the least distortion, whereas the middle area of the bumper saw the most deformation.

As seen in Figure 6, locations with the highest and lowest levels of stress are denoted by red and blue colours, respectively. The boundary conditions were used, and the bumper's outside ends experienced the least stress while its middle half produced the most stress. According to Figure 7, the maximum strain zones are shown in red, while the least strain regions are shown in blue. Figure 7 shows that the most stress was created in the middle of the bumper while the least strain was found at the bumper's outer edges.

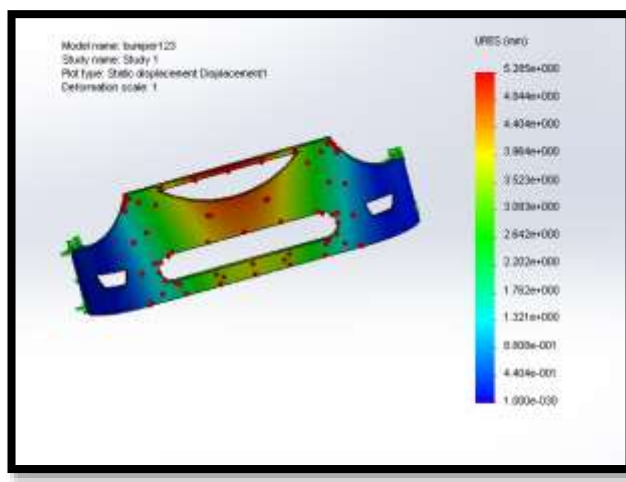

Figure 5: Total deformation of bumper

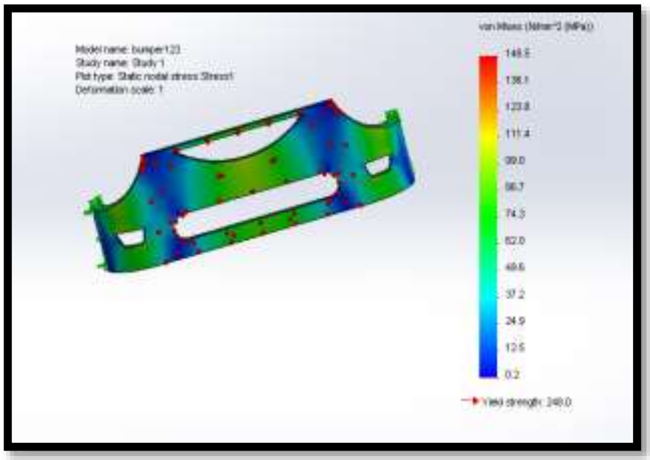

Figure 6: Stress distribution in bumper

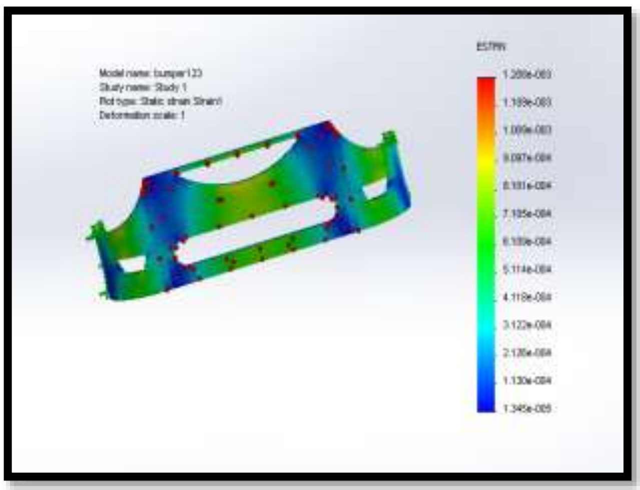

Figure 7: Strain distribution in bumper

The findings of the static analysis of the car bumper at various speeds for various materials are displayed in Table 1 below. From the results, it can be seen that Polyurethane (PUR) exhibits low deformation and strain values at 45 km/hr compared to Polypropylene (PP) and Polyvinyl chloride, the other two materials (PVC). When compared to other materials, Poly-Vinyl-Chloride (PVC) has a low stress value.

Table 1: Static Analysis Result

Material	Car speed(km/hr)	Deformation(mm)	Stress (MPa)	Strain
ABS	55	$5.685e^{+000}$	148.5	$1.208e^{-003}$
	70	$8.368e^{+000}$	224.4	$1.31e^{-003}$
	90	$1.421e^{+001}$	282.5	$2.304e^{-003}$
PETG	55	$2.012e^{+000}$	150.3	$4.551e^{-004}$
	70	$3.042e^{+000}$	224.7	$6.851e^{-004}$
	90	$3.820e^{+000}$	279.4	$8.615e^{-004}$
TPU	55	$3.44e^{+001}$	141.9	$8.368e^{-003}$
	70	$8.203e^{+001}$	276.1	$1.638e^{-002}$
	90	$1.282e^{+002}$	393.5	$2.450e^{-002}$

The results of the static study of the bumper at various speeds are displayed in table 1 above. In comparison to ABS and PETG, polyurethane (PUR) exhibits lower levels of deformation and strain when travelling at 55 km/h. TPU has a low stress value compared to other materials.

C. Modal Analysis of the Car Bumper

The study of dynamic systems in the frequency domain is known as modal analysis. Modal analysis is the process of identifying a system's natural frequencies, damping factors, and mode shapes in order to use them to create a mathematical model of the system's dynamic behaviour. Using COSMOS Works software, a modal study of an automobile bumper was carried out using the proper meshing and boundary conditions.

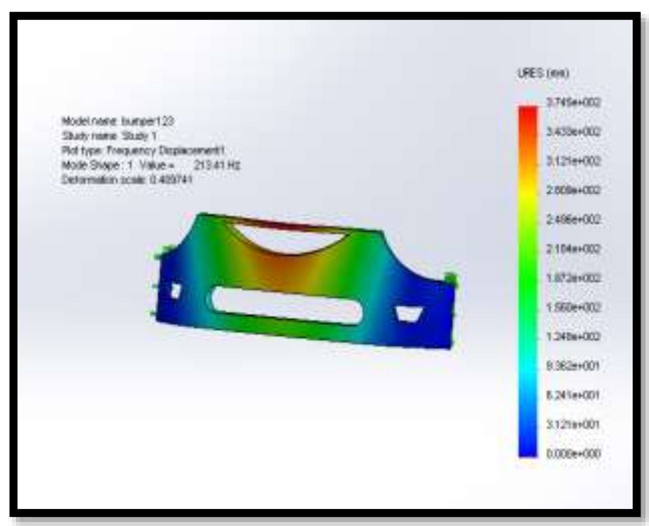

Figure 8: Frequency displacement plot 1 for bumper

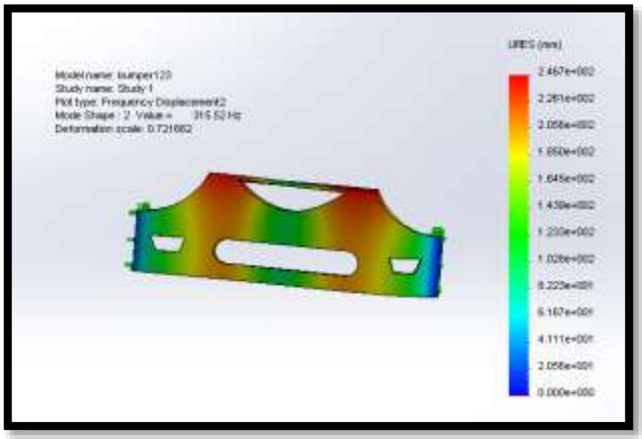

Figure 9: Frequency displacement plot 2 for bumper

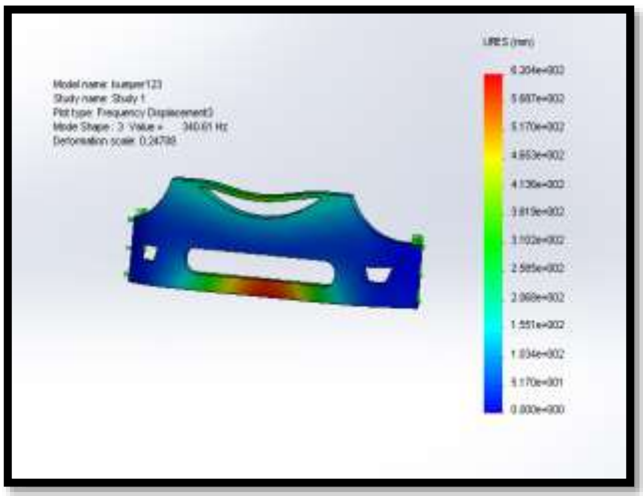

Figure 10: Frequency displacement plot 3 for bumper

Table 2: Modal Analysis Result

Material	Mode shapes	Deformation (mm)	Frequency (Hz)
ABS	Mode1	3.745e^{+002}	231.41
	Mode2	2.467e^{+003}	315.52
	Mode3	6.204e^{+003}	340.611
	Mode4	1.703e^{+002}	366.37
	Mode5	4.252e^{+003}	572.43
PETG	Mode1	3.73e^{+002}	342.44
	Mode2	2.441e^{+002}	505.59
	Mode3	6.198e^{+002}	549.53
	Mode4	1.701e^{+003}	588.09
	Mode5	4.153e^{+002}	922.91
TPU	Mode1	3.770e^{+002}	82.449
	Mode2	2.543e^{+002}	122.58
	Mode3	6.219e^{+002}	129.66
	Mode4	1.708e^{+003}	141.47
	Mode5	4.520e^{+002}	218.28

The frequency values for various modes and bumper materials are shown in the above table 2. The frequency values for the TPU material at five modes are higher than those for the other materials, as can be seen in the above table 2.

D. Impact Analysis of Car Bumper at Different Speeds

At several speeds, including 45 km/h, 60 km/h, and 75 km/h, the impact analysis of a car bumper was conducted. Figures 11, 12, and 13 show the deformation plot, stress plot, and strain plot produced from the impact analysis and impact analysis result is showing in table 3.

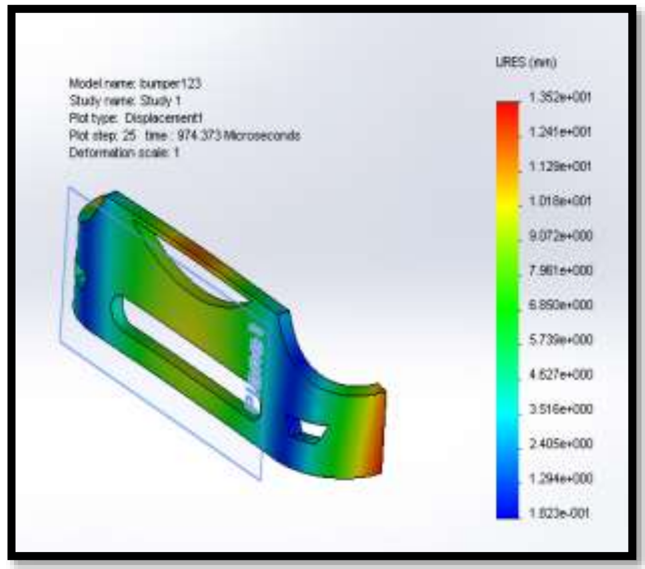

Figure 11: Total deformation in bumper

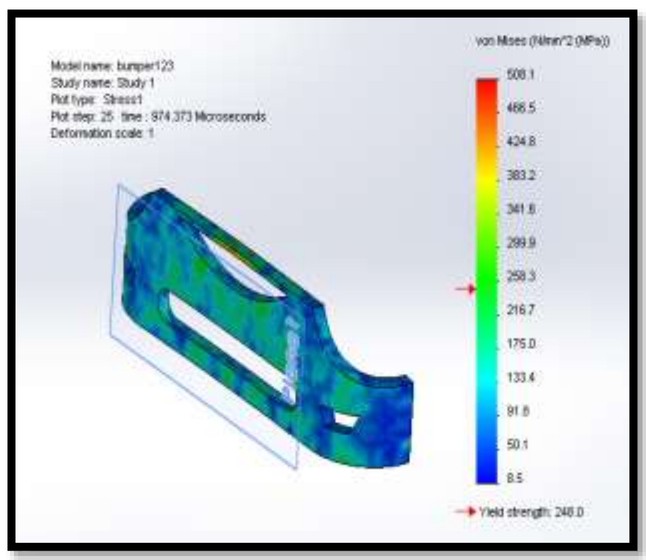

Figure 12: Stress distribution in bumper

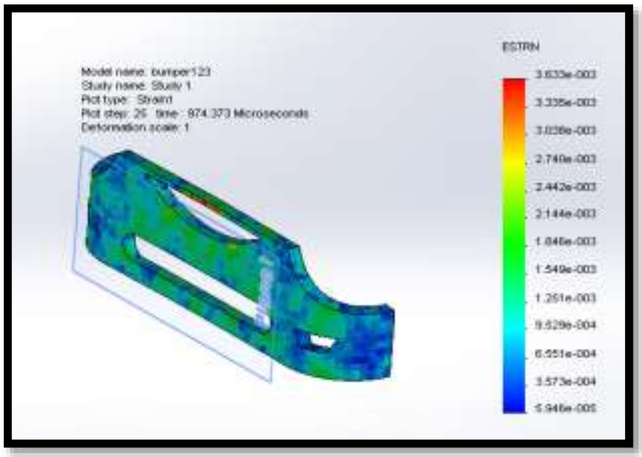

Figure 13: Strain distribution in bumper

Table 3: Impact Analysis Result

Material	Car speed(km/hr)	Deformation(mm)	Stress (MPa)	Strain
ABS	55	$1.385e^{-001}$	91.7	$5.075e^{-003}$
	70	$2.088e^{-001}$	133.3	$7.273e^{-003}$
	90	$2.617e^{-001}$	163.3	$9.352e^{-003}$
PETG	55	$1.040e^{-001}$	776.5	$2.528e^{-003}$
	70	$1.561e^{-001}$	1150.2	$3.743e^{-003}$
	90	$1.952e^{-001}$	1434.2	$4.662e^{-003}$
TPU	55	$1.352e^{-001}$	508.1	$3.633e^{-003}$
	70	$2.021e^{-001}$	753.9	$5.591e^{-003}$
	90	$2.521e^{-001}$	1022.9	$7.658e^{-003}$

V. CONCLUSION

A Benz vehicle guard was used for examination in this experiment. The effect energy is assimilated by this guard with deformity at different speeds (55, 70, and 90 km/hr). The materials ABS, PETG, and TPU were used for these experiments.

According to the static analysis, the deformation and strains rise as the vehicle speed increases from 55 km/hr to 90 km/hr. At a vehicle speed of 55 km/h, the deformation and stress in the vehicle guard were highest for each of the materials. The static investigation revealed that, at all vehicle speeds, TPU's pressure values were lower than those of PETG and ABS materials. From modular examination, the recurrence for PETG was the best when contrasted with TPU and ABS . From modular examination; it was likewise seen that the distortion for ABS material was the least when contrasted with both PETG and TPU.

From the effect examination, it tends to be seen that the deformity was expanded with an expansion in the vehicle speed for every one of the materials. The pressure for TPU was the least when contrasted with ABS and PETG.

Consequently, it was reasoned that the TPU is the ideal materials for vehicle guard in view of the static, effect and modular examination.

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