

CRASH ANALYSIS OF STRUCTURAL BEAM MADE OF COMPOSITE MATERIALS

Submitted in partial fulfillment of the requirements for the award of

**Bachelor of Engineering degree in
Automobile Engineering**

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of NARAYANA ADITYA (37860019) and ROHIT VADAPALLI (37860026) who carried out the project entitled **"CRASH ANALYSIS OF STRUCTURAL BEAM MADE OF COMPOSITE MATERIALS"** under my supervision from NOVEMBER 2020 to APRIL 2021.

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I, ROHIT VADAPALLI (37860026), and NARAYANA ADITYA (37860019) hereby declare that the Project Report entitled “**CRASH ANALYSIS OF STRUCTURAL BEAM MADE OF COMPOSITE MATERIALS**” done by us under the guidance of Mrs. P.SIVASHANKARI, M.E., (Ph.D). at Sathyabhama Institute of Science and Technology is submitted in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Automobile Engineering.

DATE:

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I am pleased to acknowledge my sincere thanks to Board of Management of **SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

I convey my sincere thanks to **Dr. S. Prakash, M.E., Ph.D.**, Dean, School of Mechanical Engineering and **Dr. V.K. BUPESH RAJA, M.E., Ph.D.**, Head of the Department, Dept. of Automobile Engineering for providing me necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my Project Guide Mrs.P.SIVASHANKARI, M.E., (Ph.D)., for her valuable guidance, suggestions and constant encouragement paved way for the successful completion of my project work.

ABSTRACT

Polymers reinforced with fibers and Nano fillers are widely used in many industries like automotive, marine, and aerospace because of their high tensile and compressive strength, low coefficient of thermal expansion, good fatigue resistance and suitability for the production of complex shape materials.

While designing and fabricating a structural beam of an automobile it is important to consider the impact caused on the bumper of the vehicle. The first part to get involved in a collision is usually bumper in most of the cases. The design of the bumper should in such a way that it should absorb high amount kinetic energy to reduce the impact on the car and the passengers.

The material selection will play an important role in the physical properties of the bumper. So, it is important to choose the correct material for the fabrication of the bumper. Another important aspect of the bumper to lookout for is its weight percentage to the total weight of the vehicle. Selection of the correct composite material can help in decrease of the total weight of the car and increase the performance of the car in a collision as compared to existing materials such as Aluminum Alloy and other metal bumper. Nano composites are made by dispersing nano fillers (e.g., MMT, CNTs etc.) into a matrix (e.g., polymers, metals etc.)

Polymer based composite materials are part of the industry for over a decade but due to some technical barriers their usage has been constrained. Because of their excellent properties (e.g., high tensile and compressive strength, low coefficient of thermal expansion, production of complex shapes.), reinforced composites are very widely used.

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LIST OF ABBREVIATIONS

MMT	Montmorillonite
AFRP	Aramid Fiber Reinforced Polyester
ABS	Acrylonitrile Butadiene Styrene

CHAPTER 1

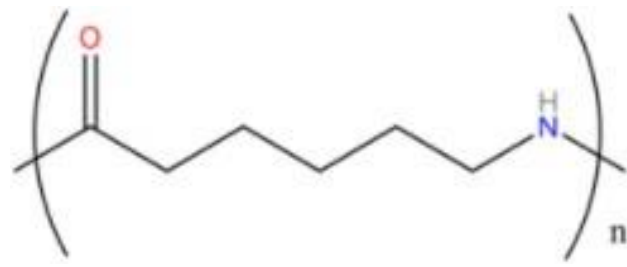
INTRODUCTION

In automobile structural beam the front and rear sections are more involved in a collision. So, it has to sustain and absorb as much as energy it can in case of collision. The bumpers are not capable of reducing the effect of impact at high speeds instead they are focused on mitigate injury to pedestrians struck by cars. Steel and Aluminum Alloys are used for preparation of bumpers mostly. But recent trends are disrupting the conventional materials.

In a way the front bumpers are more appealing than the rear bumpers. The composite materials have better machinability property than other metals that are used at present in the industry hence, they can be moulded or casted in any shape they want. The composite materials are also light in weight which makes it a desirable material for the bumper of a vehicle. There are two main factors to that has to be considered while the selection of bumper materials,

- It should be better performing than the previous material,
- There should be increase in strength at the cost of reduction of weight.

The weight of the bumper can be reduced by the use of composite and high- strength metallic sheet of thin material. Thus, composite materials can used to increase emphasis towards reduction of weight. Composite materials have a bulk phase called the matrix and non- continuous phase called the reinforcement. Fibers are the principle load carrying members, while the surrounding matrix keeps them in desired shape and location and acts as load transfer medium. And it also protects them from external damages such as temperature and humidity. The processing of polymer matrix will not involve high temperate and pressure so the equipment that are required for production are simple and easily available.



NYLON 6 with MMT



Fig 1.1: Bumper

ANSYS SOFTWARE

Ansys is used for developing and targets engineering simulation software for testing, product design and operating and provides services to worldwide customers. It is an American built company in Pennsylvania. John Swanson was the founder of this software in 1970. Venture capitalists bought John Swanson's interest in the company in 1993. In 1996 on NASDAQ Ansys went public. In 2019, on December Ansys became a component of NASDAQ-100. To produce or simulate computer mode structures, machine components, or electronics Ansys has finite element analysis software. Ansys is used to show the specifications. when John Swanson was working at Westinghouse Astronuclear Laboratory in the 1960s, he developed the idea of Ansys. FEA (finite element analysis) was performed by hand, by the engineers during that period of time. To develop the software on his own Swanson left the company in 1969 because his idea was disallowed by Westinghouse to program FEA by emerging general purpose engineering software. Ansys was formed under the name Swanson Analysis Systems Incorporation. Using a mainframe computer, that was rented by the hour and punch cards Swanson built the first Ansys software. Westinghouse employed Swanson as a consultant, under the circumstance that any code he established for the company can also be involved in the Ansys product line. Westinghouse was also the first user of Ansys.

Using the Ansys Workbench system many Ansys simulations are executed, which is one of the leading products for the company. Stereotypically Ansys users break bigger structures into minor components that are each exhibited and tested separately. A user starts by describing the dimensions of an object, and then tallying weight, pressure, temperature and other physical properties. In conclusion, the Ansys software act out and analyzes movement, fatigue, fractures, fluid flow, and other effects.

Data management, academic research and teaching are also developed by Ansys. Ansys software is sold on a twelve-monthly subscription basis.

Using Mechanical finite element analysis software in Ansys is used to develop computer models of structures, electronics fluid flow, and other characteristics. Ansys is used to show that product will function with different specifications, without constructing test products or showing crash tests. Ansys

software may show how a bridge will hold up after years of traffic, how to best method for salmon in a cannery to lessen waste, or how to create a slide that uses fewer materials without losing safety.

The first version of Ansys software was released in 1971 branded version 2.0. At the time, the software was built up of cases of punch cards, and the program was normally run immediate to get results the following morning. The software was completely used on supercomputers, up until version 3.0 which is the second release of Ansys was introduced in 1979 for the Vaxstation. A command line interface was built in version 3.0 similar to DOS.

Apple II was launched in 1980, permitting Ansys to change a graphical user interface in version 4.0 far ahead that year. Ansys released their 4th version software which was easy to use and additional features to act out electromagnetism. Ansys initiated to work with Compuflo in 1989; Compuflo's Flotran fluid dynamics software was included in Ansys in their version 5 or he 5th version which released in 1993. Performance was improved in version 5.1wich included shortening processing time 2 to 4-fold, and was tailed by a sequence of performance developments to keep pace with improvements in computing. ^lAnsys also began assimilating its software with CAD software, known as Autodesk.

CHAPTER 2

LITERATURE SURVEY

Alen John and Sanu Alex, studied about usage of composite materials in passenger vehicles. In which the properties of plastic based composite materials are studied.

Sarawut Rimdusitl, Parkpoom Lorjial, Kuljira Sujirote and Sunan Tiptipakorn studied that PC/ABS composites, Kevlar reinforced fibers which are generally termed as Aramide fiber reinforced polyesters (AFRP) has similar impact properties as the current material being used in automotive front bumpers in physical and mechanical characteristics of Kevlar fiber reinforced.

Lou JJ and Daniel IM wrote a publication on Characterization and modeling of mechanical properties and behavior of polymer and Nano composites in 2003. In which they studied about the mechanical behavior of the polymer/ nano composites.

V. Selvakumar, K. Palanikumar and K. Palanivelu (2010) studied about mechanical characterization of Polypropylene/Na⁺ - MMT Nano composites in which they concluded the mechanical properties of strength and modulus of the nan composites increases with addition of 5wt% of nano clay and impact strength and hardness of the Nano composites increases with addition of 3wt%.

Vishwanatha R H, Ajith A, Anand N, and Vasantha kumar concluded that composite materials can be used in bumper in their Design and Strength Validation of Front Car bumper Using Composite Material.

CHAPTER 3

AIM and SCOPE

3.1 AIM

The project aim is to do research for different materials and analyse those material which can replace the materials that are at present in usage in industry for bumpers at the same time being cost effective and have better properties than predecessors. Another silent feature of this project is to make the bumper lighter as it will require less engine power and in turn can help in reduction of usage of fuels and production of pollution.

3.2 SCOPE

- To find a material with good mechanical properties, low coefficient of thermal expansion that can be used in bumpers of a passenger cars.
- To find a Structural beam with good toughness and being cost effective.
- To make a bumper that can replace the present ones that are in use currently.
- To model a bumper lighter in weight so that the vehicle requires less fuel and reduce the number of pollutants produced by the vehicle.

CHAPTER 4

DESIGN, MATERIALS & ANALYSIS

4.1 DESIGN

The modelling of the bumper is done using CATIA 2019 edition. A solid model gives more information about a component. The geometric information of any part in this model can be changed if necessary. Complex shapes can be shown easily in a software such as this. Below are some pictures of the 3D model we made in several views.

Here are some pictures of the 3D model we have made in CATIA software. The below pictures are front bumper of a vehicle:

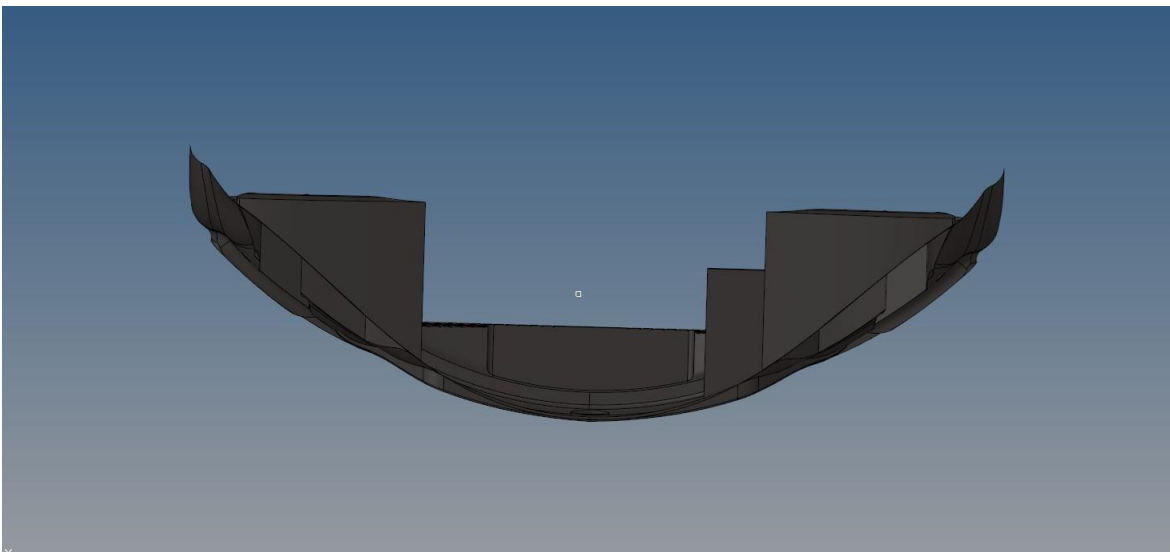


Fig 4.1: Top view of the front bumper.

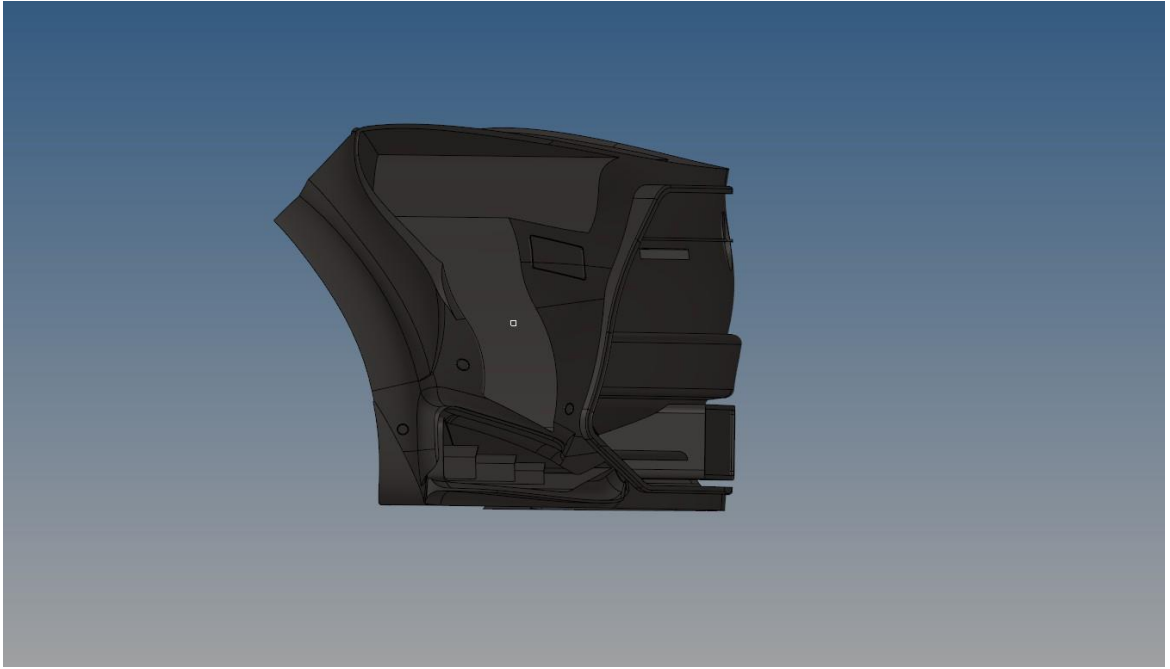


Fig 4.2: Side view of the front bumper.

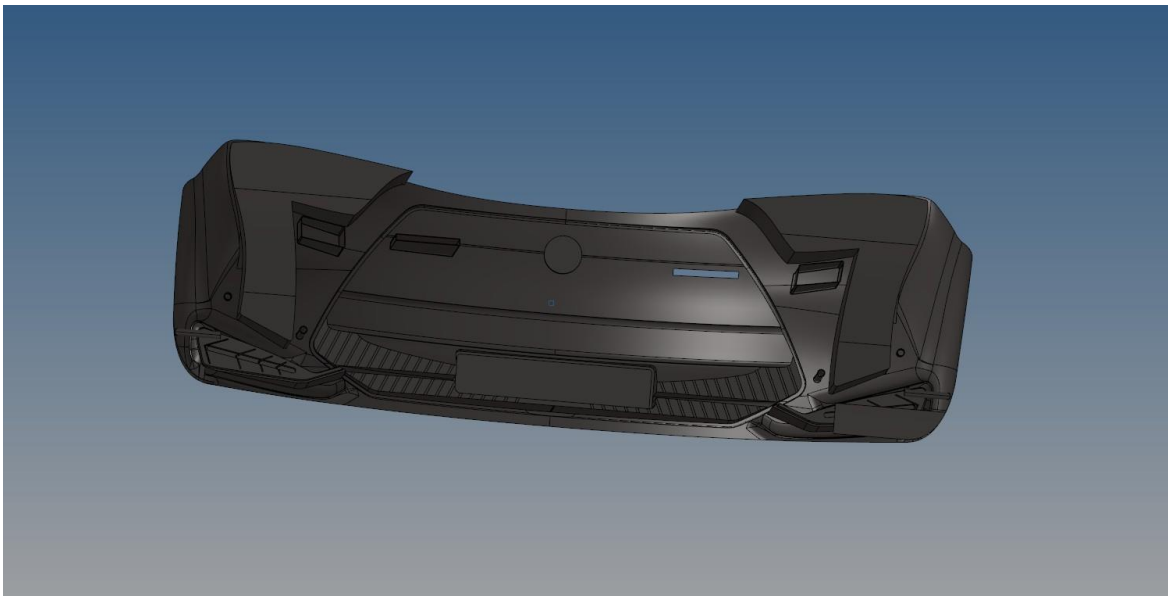


Fig4.3: Rear view of the front bumper.

The below figure describes the sketch of the front bumper of the vehicle we made in CATIA software.

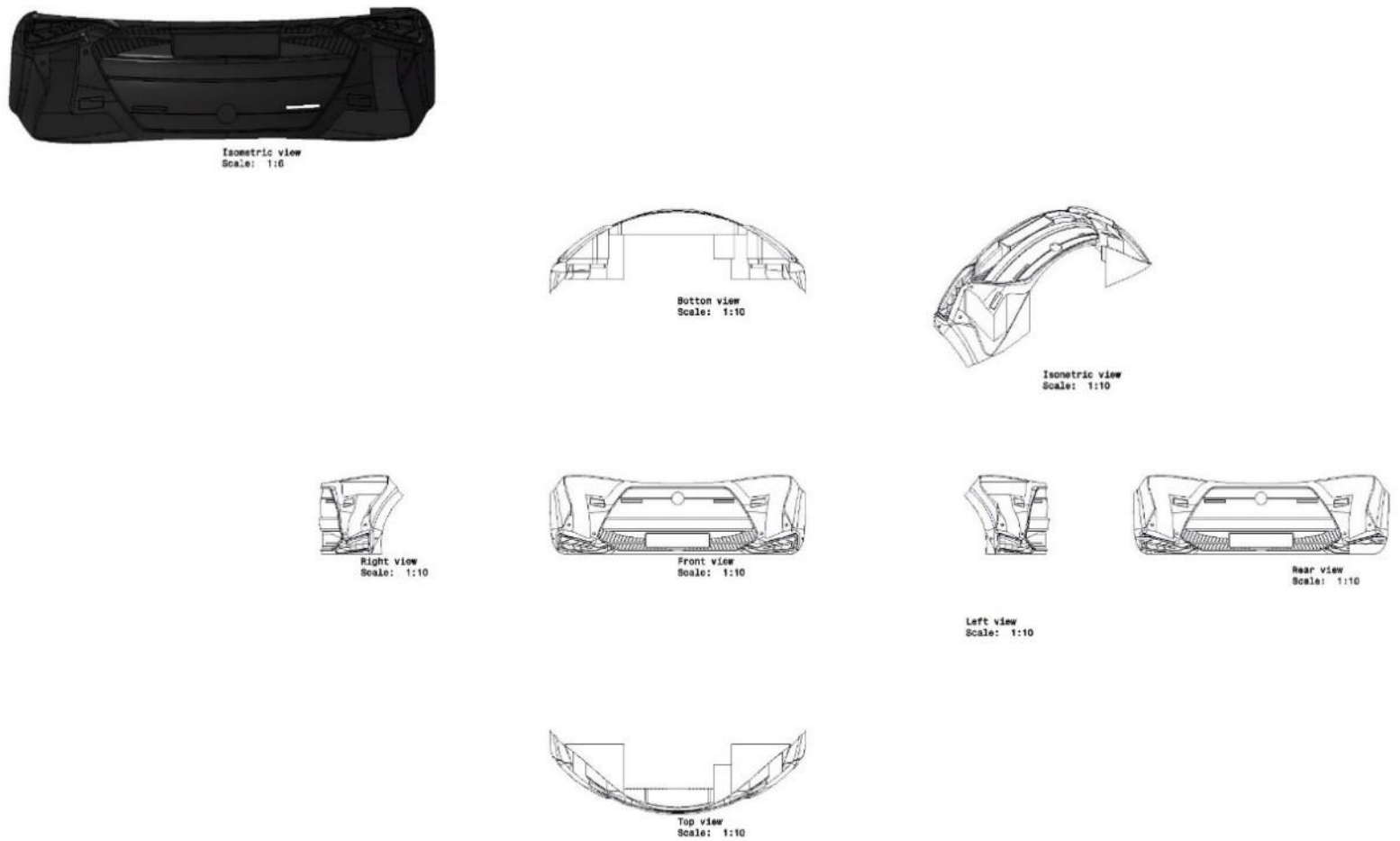


Fig4.4: Sketch of the front bumper

The below figures are the pictures of 3D model we made for this project:

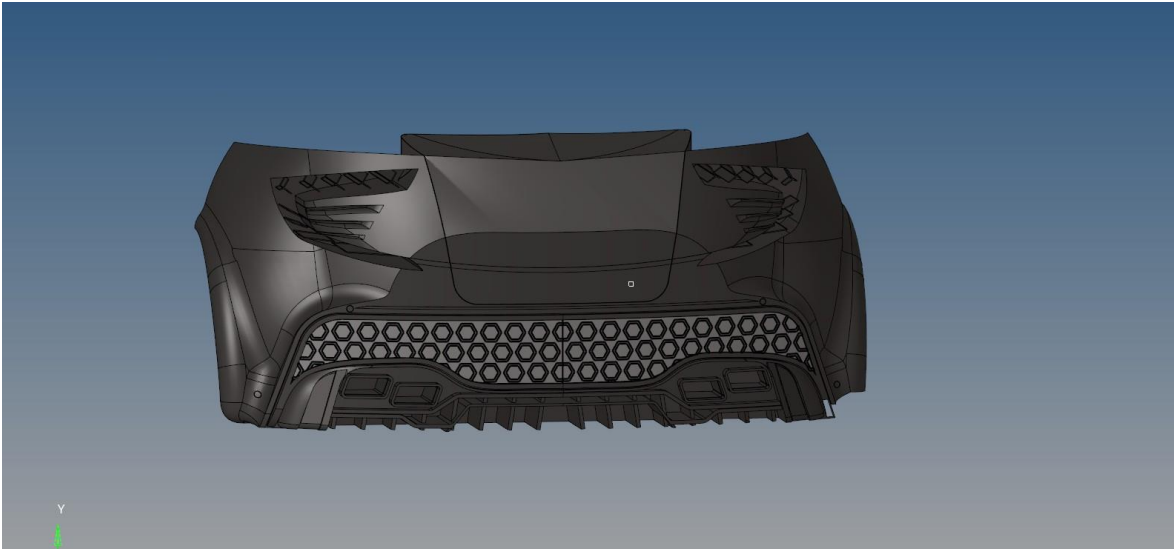


Fig 4.5: Front view of the rear bumper

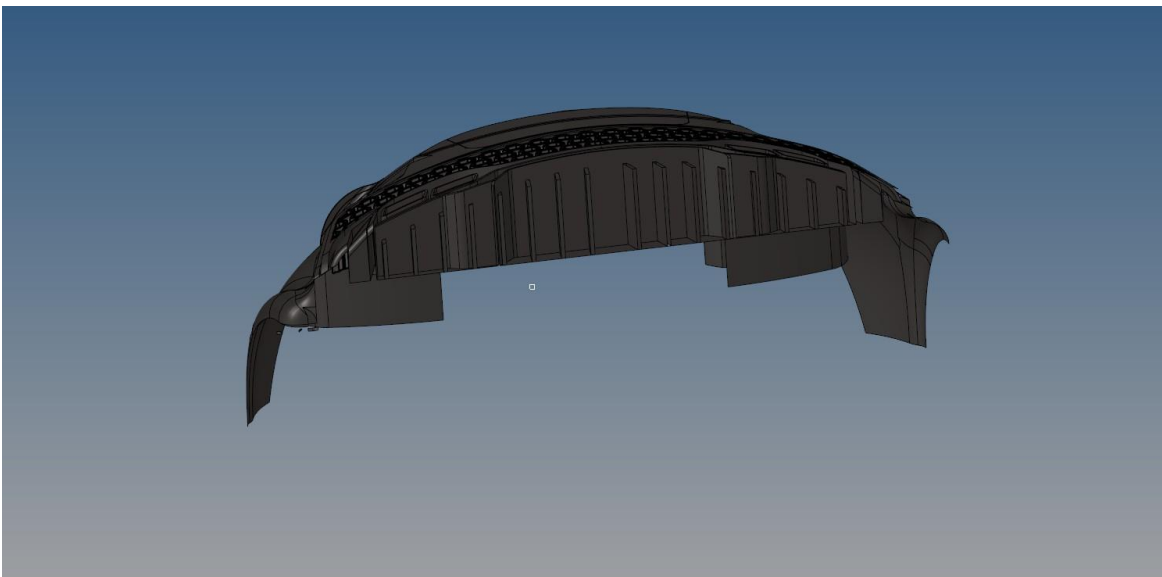


Fig 4.6: Bottom view of the rear bumper

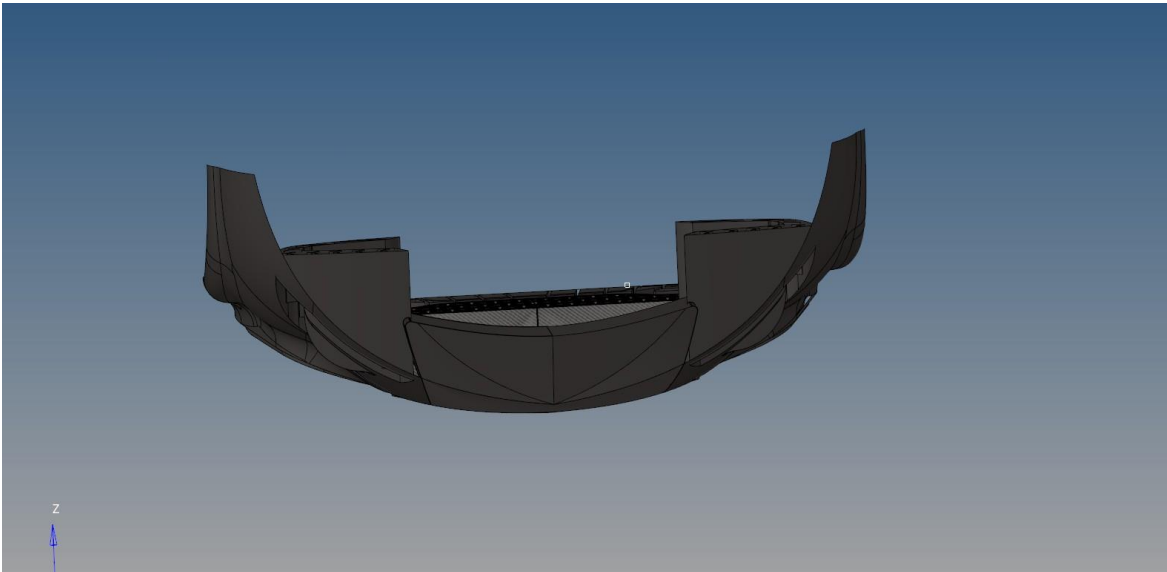


Fig 4.7: Top view of the rear bumper

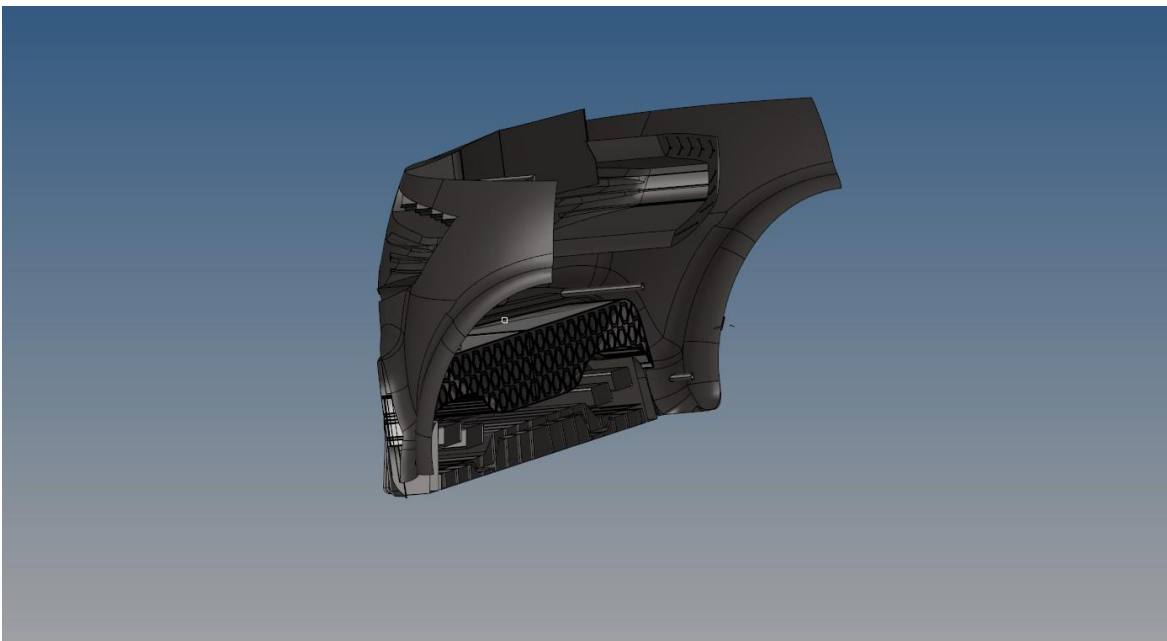


Fig 4.8: Isometric view of the rear bumper

The below figure shows the sketch of the rear bumper of the vehicle:

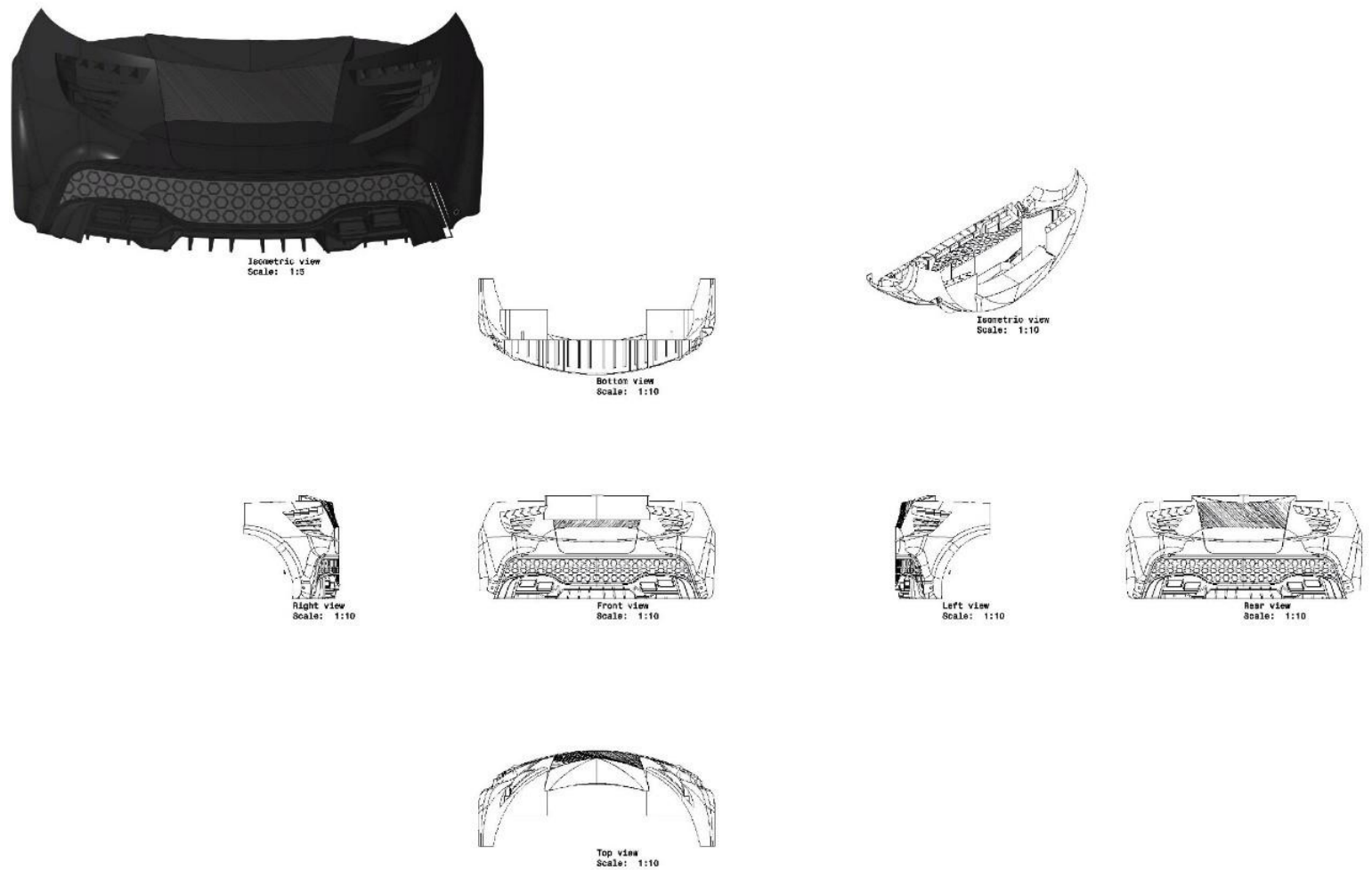


Fig 4.9: Sketch of rear bumper of the car

4.2 IMPACT ANALYSIS OF THE BUMPER

4.2.1 ANSYS SOFTWARE

ANSYS stands for analysis system. It is a software used to simulate computer models of structures, electronics, toughness, temperature distribution, electromagnetism and other attributes. It uses computer-based numerical techniques to solve physics problems. FEA stands for Finite Element Analysis.

After the 3D models were made model was meshed in ANSYS. All the models have same design but materials are different while analysis was being done.

4.2.2 Performing ANSYS Analysis

The ANSYS software has many capabilities in finite element analysis (FEA) ranging from linear, static to complex non-linear dynamic model. In this analysis we used explicit dynamic analysis of the front bumper. For this project we made bumpers in CATIA software.

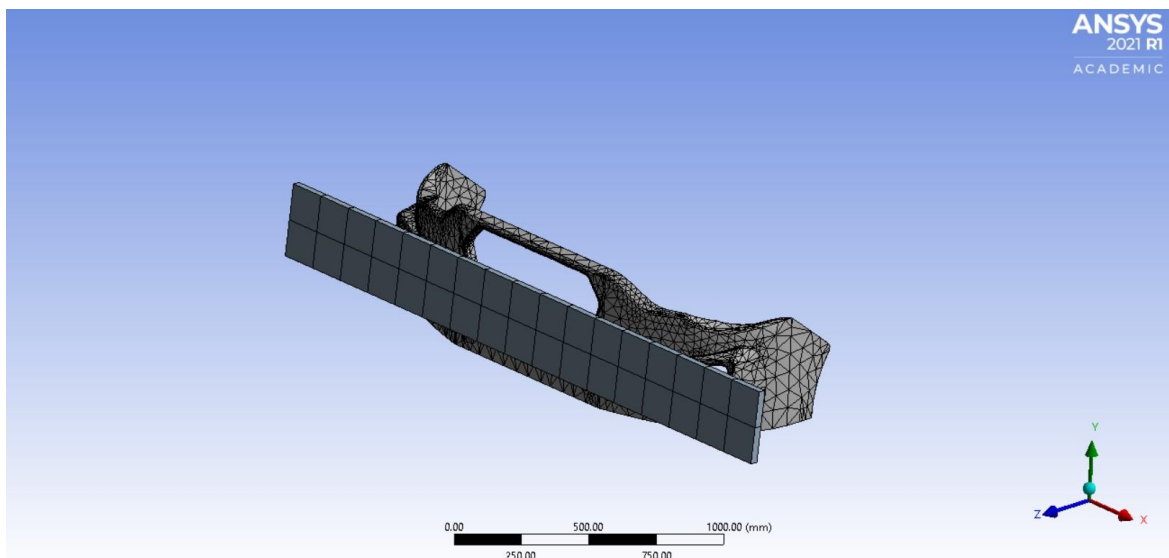


Fig 4.10: Meshing of the components in ANSYS WORKBENCH

Here the bumper moving with a velocity of 25000mm/s (90 km/hr) is used for impact analysis. It is made impacted against a wall made of structural steel which is fixed. It is shown in the below figure.

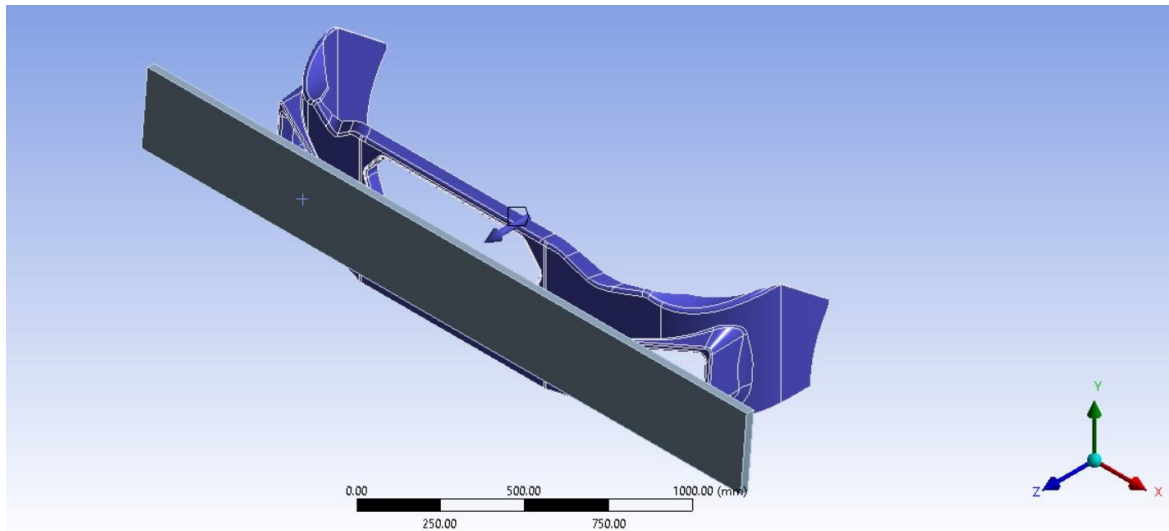


Fig 4.11: Simulation of the Impact phenomena in ANSYS.

The analysis consists of following steps and they can be classified into 3 types as shown below:

PREPROCESSOR	SOLUTION PROCESSOR	POST PROCESSOR
Assigning element type	Analysis definition	Read results
Geometry definition	Constant definition	Plot results on graph
Material definition	Load definition (Velocity)	View animated results
Mesh generation		
Model display		

Table 4.1: steps for analysis

4.3 MATERIALS

4.3.1 NYLON 6 with MMT reinforcements

Nano clays are nanoparticles of layered mineral silicates consisting of 2-dimensional, 1 nm thick layer with exceptional mechanical qualities. These fibers are tough and also have high tensile strength. Nylon 6 fiber has no or zero wrinkles and is also resistant to wear and tear to alkalis and acids and other chemicals as well. These fibers can absorb water up-to 2.4%, which lowers tensile strength. Nylon 6 is not a condensation polymer like the other nylon fibers.

These nylon 6 fibers have ring- opening polymerization which makes it easy while comparing it between condensation and addition polymers. General formula of nano-clay MMT is $M_x (Al_{4-x}Mg_x) Si_8O_{20}(OH)_4$. Nylon 6 has high tensile strength and compressive strength and is well known for its low coefficient of friction.

Montmorillonite also known as MMT is a mineral which belongs to the group of phyllosilicate. These are formed from the precipitation of water solution into micro crystals called clay. MMT which belongs to smectite group has two tetrahedral silica sheets filing between a sheet of alumina which is octahedral, hence it is known as 2:1 clay. MMT particles are shaped like a plate and have a diameter of 1micrometer and 0.96nm of thickness. To view each particle of MMT an electron microscope is required with magnification of around 25,000 times.

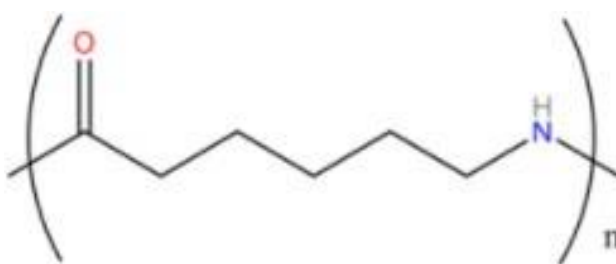


Fig 4.12: Structure of Nylon 6



Fig 4.13: Picture of Montmorillonite under a microscope.

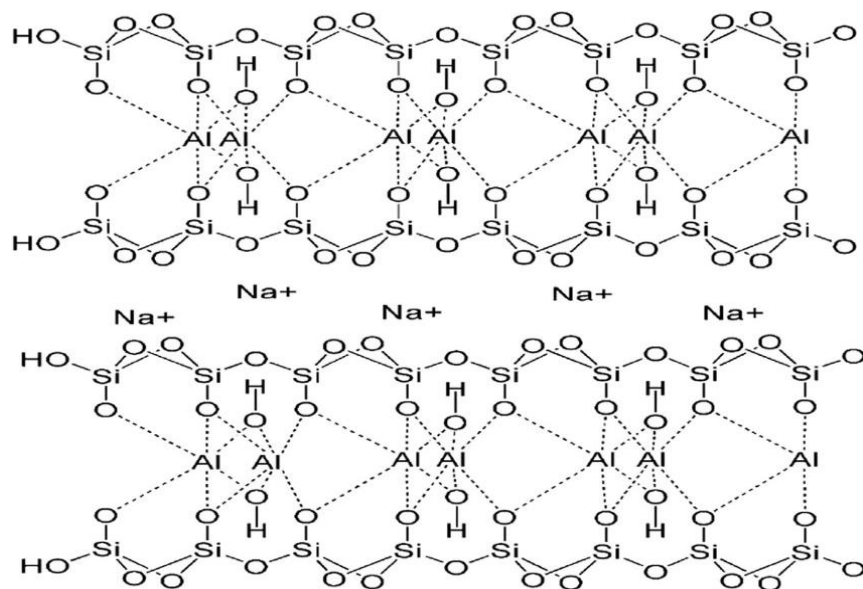


Fig 4.14: Structure of Montmorillonite

Nylon 6/clay Nano composites are made up of **nylon 6** matrix filled with Nano-sized montmorillonite platelets (**MMT**). The modulus is doubled, the strength increased by more than 50%, and the heat distortion temperature enhanced by 80 °C compared to neat **nylon 6**. Advanced properties such as thermal stability, dielectric properties, barrier properties and mechanical properties are seen in clay-based nano composites. The improved mechanical properties have attracted attention among all the other properties due to the incorporation of clay polymer into the polymer matrix.

Young's Modulus MPa	Density Kg/m³	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
5000	1130	0.39	7575.8	1798.6

Table 4.2: Properties of Nylon 6 with MMT

Length X	2518.6 mm
Length Y	540.75 mm
Length Z	704.32 mm
Properties	
Volume	3.1218e+007 mm ³
Mass	179.37 kg

Table 4.3: Dimensions and properties of bumper made of nylon6 with MMT

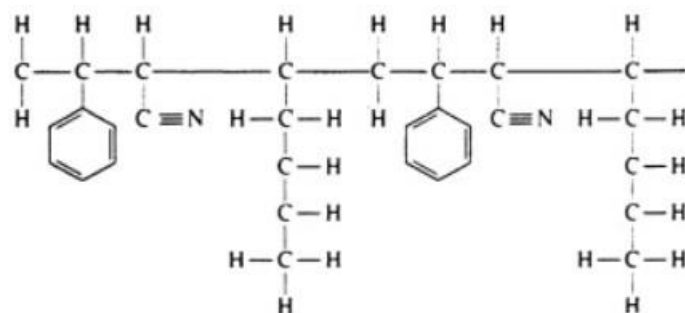
4.3.2 ACRYLONITRILE BUTADIENE STYRENE (ABS):

Acrylonitrile is an artificial monomer made out of propylene and ammonia; butadiene is a petroleum hydrocarbon acquired from the C4 fraction of steam cracking; styrene monomer is made by dehydrogenation of ethyl benzene — a hydrocarbon acquired in the response of ethylene and benzene. This ABS is currently new trend in the automotive industry. It is reinforced with steel. Acrylonitrile butadiene styrene is a not unusual thermoplastic polymer. 105 °C is the transition temperature for glass. ABS is amorphous and consequently has no authentic melting point. ABS is a terpolymer made through polymerizing styrene and acrylonitrile with-inside the presence of polybutadiene. The proportions can range from 15% to 35 acrylonitrile, 5% to 30% butadiene and 40% to 60% styrene. The end result is an extended chain of polybutadiene crisscrossed with shorter chains of poly(styrene-co-acrylonitrile).

The acrylonitrile additionally contributes chemical resistance, fatigue resistance, hardness, and rigidity, even as growing the warmth deflection

temperature. The styrene offers the plastic a shiny, impervious surface, in addition to hardness, rigidity, and advanced processing ease. The polybutadiene, a rubbery substance, provides toughness and ductility at low temperatures, on the value of warmth resistance and rigidity. For the bulk of applications, ABS may be used between -20 and $80\text{ }^{\circ}\text{C}$ (-4 and $176\text{ }^{\circ}\text{F}$), as its mechanical residences range with temperature. The residences are created through rubber toughening, wherein first-rate debris of elastomer are disbursed at some point of the inflexible matrix. Chemical formula of ABS is $(\text{C}_8\text{H}_8)_x \cdot (\text{C}_4\text{H}_6)_y \cdot (\text{C}_3\text{H}_3\text{N})_z$.

ABS offers favorable mechanical properties inclusive of impact resistance, toughness, and strain whilst compared with different common polymers. A shape of modifications can be made to enhance impact resistance, toughness, and heat resistance. The impact resistance can be amplified via developing the proportions of polybutadiene as regards to styrene and moreover acrylonitrile, despite the fact that this reasons adjustments in distinct properties. Impact resistance does now not fall off abruptly at lower temperatures. Stability beneath the load is remarkable with restricted loads. Thus, via changing the proportions of its components, ABS can be prepared in unique grades.



**Fig 4.15: Chemical structure of ACRYLONITRILE
BUTADIENE STYRENE**

Young's Modulus MPa	Density Kg/m ³	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
2300	1140	0.33	2254.9	864.66

Table 4. 4: Properties of ABS

Length X	2518.6 mm
Length Y	540.75 mm
Length Z	704.32 mm
Properties	
Volume	3.1218e+007 mm ³
Mass	179.47 kg

Table 4.5: Dimensions and properties of bumper made of ABS

4.3.3 ARAMIDE FIBRE REINFORCED POLYESTER COMPOSITE

Aramid fibers are high synthetic fibers with good heat resistance. For producing ballistic body armour fabric these fibers are used for military operations and for aerospace as well. They are also used for marine cordage and marine hull reinforcement as a substitute for asbestos. These fibers have highly oriented chain molecules along their axis due to which the chemical bond contributes the higher proportion to the strength of the fibers than any other synthetic fibers. These fibers have a high melting point of > 500°C. Aramid is also known as Kevlar, Nomex and Twaron. The chemical shape of the chain

molecules is such that the bonds are aligned (for the maximum part) alongside the fiber axis, giving them top notch strength, flexibility and abrasion tolerance. With top notch resistance to warmth and flammability, they may be uncommon in that they do not now no longer melt – they simply begin to degrade (at approximately 500 degrees Centigrade).

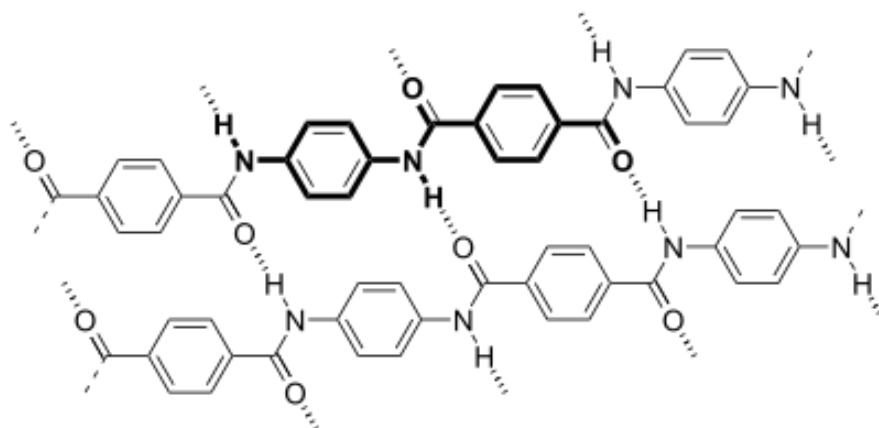


Fig 4.16: Molecular structure of Aramide Fibre

They additionally have very low electric conductivity making them perfect electric insulators. With excessive resistance to natural solvents, the all-around ‘inert’ elements of those substances provide excellent versatility for a big variety of applications. The best blot on their horizons is that they may be sensitive to UV, acids, and salts. They construct static strength too until they may be specifically treated The exceptional properties which those fibers experience offer benefits which lead them to best for an extensive variety of applications. However, with any composite material, it's miles critical to take care in coping with and processing. Using gloves, masks, etc. is advisable. Chemical formula of Armide is $-(NH-Ar-CO)_n-$ + n HCl

Young's Modulus MPa	Density Kg/m ³	Poisson's Ratio	Bulk Modulus Mpa	Shear Modulus Mpa
4500	1450	0.31	3947.4	1717.6

Table 4.6: Properties of AFRP

Length X	2518.6 mm
Length Y	540.75 mm
Length Z	704.32 mm
Properties	
Volume	3.1218e+007 mm ³
Mass	182.5 kg

Table 4.7: Dimensions and properties of bumper made of AFRP

4.3.4 ALUMINIUM ALLOY

The aluminum alloy used for preparation of bumpers in passenger cars is Al 6061. Its composition is Magnesium – 0.8% to 1.2% by weight, Chromium – 0.04% to 0.35% max., Copper – 0.15% to 0.4% max., Iron – 0% to 0.7% max., Manganese – 0.15% max., Silicon – 0.4% to 0.8% max., Zinc – 0.25% max., Titanium – 0.25% max. and remaining weight% is Aluminium.

AL 6061 is a precipitated hardened aluminum. It contains Mg and Si as major alloying elements. It has good mechanical properties. It has good welding properties and can easily be extruded. It is one of the most commonly used alloys.

Fig 4.17: Aluminum Alloy Bumper



Length X	2518.6 mm
Length Y	540.75 mm
Length Z	704.32 mm
Properties	
Volume	3.1218e+007 mm ³
Mass	195.4 kg

Table 4. 8: Dimensions and properties of bumper made of Aluminum alloy

Young's Modulus MPa	Density Kg/m ³	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
71000	2700	0.33	69608	26692

Table 4.9: Properties of Aluminum alloy

CHAPTER 5

RESULT AND DISCUSSIONS

ANSYS RESULTS

The initial conditions for all the Impact analyses taken are given in the below table:

Table 5.1: initial conditions

Model (C4) > Explicit Dynamics (C5) > Initial Conditions > Initial Condition

Object Name	Pre-Stress (None)	Velocity
State	Fully Defined	
Definition		
Pre-Stress Environment	None Available	
Pressure Initialization	From Deformed State	
Input Type		Velocity
Define By		Components
Coordinate System		Global Coordinate System
X Component		0. mm/s
Y Component		0. mm/s
Z Component		25000 mm/s
Suppressed		No
Scope		
Scoping Method		Geometry Selection
Geometry		1 Body

5.1.1 ANSYS results for nylon 6 with nano reinforcements

Assuming that the bumper is made of Nylon 6 with MMT and made impact against a wall of structural steel the following results are produced.

5.1.1.1 Total deformation in Nylon 6 with MMT

Max deformation = 1.8588 mm

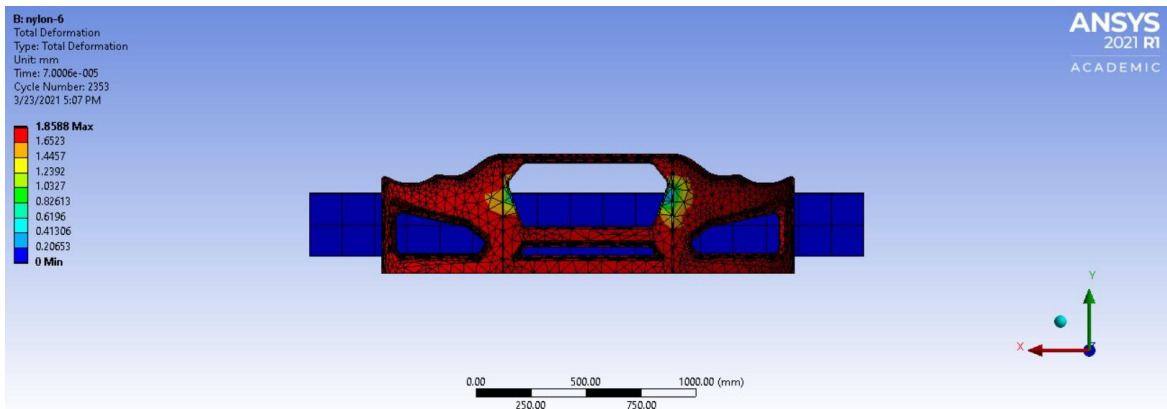


Fig 5.1: Total deformation in nylon 6 with MMT

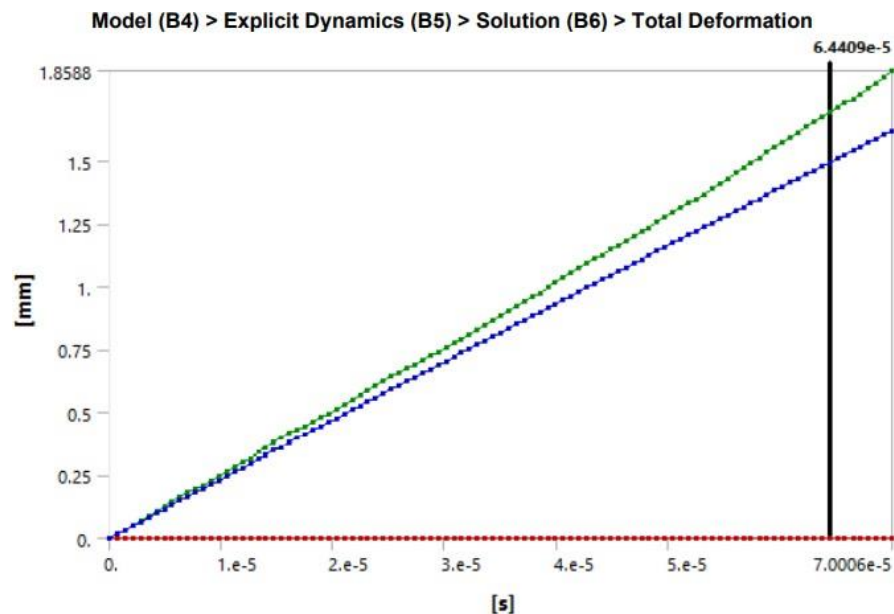


Fig 5.2: graph for total deformation in nylon 6 with MMT

Below table is a step-by-step value of total deformation of bumper made of nylon 6 with MMT:

Time [s]	Minimum [mm]	Maximum [mm]	Average [mm]
1.1755e-038	0.	0.	0.
7.2108e-007		1.7329e-002	1.6971e-002
1.4059e-006		3.4117e-002	3.3087e-002
2.1205e-006		5.2237e-002	4.9902e-002
2.8053e-006		7.0194e-002	6.6014e-002
3.5199e-006		8.9352e-002	8.2826e-002
4.2047e-006		0.10786	9.8935e-002
4.9193e-006		0.1271	0.11574
5.6041e-006		0.14532	0.13185
6.3187e-006		0.16381	0.14866
7.0035e-006		0.18062	0.16476
7.7181e-006		0.19681	0.18156
8.4029e-006		0.21101	0.19766
9.1175e-006		0.22794	0.21445
9.8023e-006		0.24679	0.23054
1.0517e-005		0.26625	0.24733
1.1202e-005		0.28381	0.26341
1.1916e-005		0.30104	0.28019
1.2601e-005		0.31681	0.29626
1.3316e-005		0.33833	0.31303
1.4001e-005		0.36093	0.32909
1.4715e-005		0.38236	0.34584
1.543e-005		0.40102	0.36258
1.6114e-005		0.41598	0.37862
1.6829e-005		0.42878	0.39534
1.7514e-005		0.44098	0.41136
1.8228e-005		0.45978	0.42807
1.8913e-005		0.47755	0.44408
1.9628e-005		0.49562	0.46078
2.0313e-005		0.51235	0.47677
2.1027e-005		0.53187	0.49345
2.1712e-005		0.55093	0.50942
2.2427e-005		0.57065	0.52608
2.3112e-005		0.58924	0.54204
2.3826e-005		0.60818	0.55869
2.4511e-005		0.62573	0.57464
2.5226e-005		0.64327	0.59128

2.591e-005	0.65925	0.60722
2.6625e-005	0.67496	0.62384
2.731e-005	0.68905	0.63977
2.8024e-005	0.7064	0.65637
2.8709e-005	0.72402	0.67228
2.9424e-005	0.742	0.68888
3.0109e-005	0.75881	0.70477
3.0823e-005	0.77584	0.72135
3.1508e-005	0.79291	0.73723
3.2223e-005	0.81056	0.7538
3.2907e-005	0.82859	0.76967
3.3622e-005	0.84757	0.78623
3.4307e-005	0.86571	0.80209
3.5021e-005	0.88458	0.81864
3.5706e-005	0.90262	0.83449
3.6421e-005	0.9214	0.85104
3.7106e-005	0.93936	0.86688
3.782e-005	0.95804	0.88342
3.8505e-005	0.97589	0.89926
3.922e-005	0.99605	0.91578
3.9904e-005	1.0159	0.93161
4.0619e-005	1.036	0.94813
4.1304e-005	1.0548	0.96395
4.2018e-005	1.074	0.98045
4.2703e-005	1.092	0.99625
4.3418e-005	1.1105	1.0127
4.4103e-005	1.1283	1.0285
4.4817e-005	1.1478	1.045
4.5502e-005	1.1663	1.0607
4.6217e-005	1.1851	1.0772
4.6901e-005	1.2024	1.0929
4.7616e-005	1.2195	1.1094
4.8301e-005	1.2352	1.1251
4.9015e-005	1.255	1.1415
4.97e-005	1.2746	1.1572
5.0415e-005	1.2944	1.1736
5.1129e-005	1.3136	1.1899
5.1814e-005	1.3315	1.2056
5.2529e-005	1.3498	1.222
5.3214e-005	1.3682	1.2376
5.3928e-005	1.3896	1.254
5.4613e-005	1.41	1.2696
5.5328e-005	1.4313	1.2859

5.6012e-005	1.4517	1.3015
5.6727e-005	1.4729	1.3178
5.7412e-005	1.4931	1.3334
5.8126e-005	1.5141	1.3497
5.8811e-005	1.5342	1.3653
5.9526e-005	1.5551	1.3816
6.0211e-005	1.5749	1.3971
6.0925e-005	1.5955	1.4134
6.161e-005	1.615	1.4289
6.2325e-005	1.6352	1.4451
6.3009e-005	1.6543	1.4607
6.3724e-005	1.6739	1.4769
6.4409e-005	1.6925	1.4924
6.5123e-005	1.7116	1.5086
6.5808e-005	1.7295	1.5241
6.6523e-005	1.748	1.5402
6.7208e-005	1.7654	1.5557
6.7922e-005	1.7879	1.5718
6.8607e-005	1.8112	1.5873
6.9322e-005	1.8355	1.6034
7.0006e-005	1.8588	1.6189

Table 5.2: step value of total deformation of bumper made of nylon 6 with MMT

5.1.1.2 Equivalent stress in nylon 6 with MMT Maximum

equivalent stress = 57.558

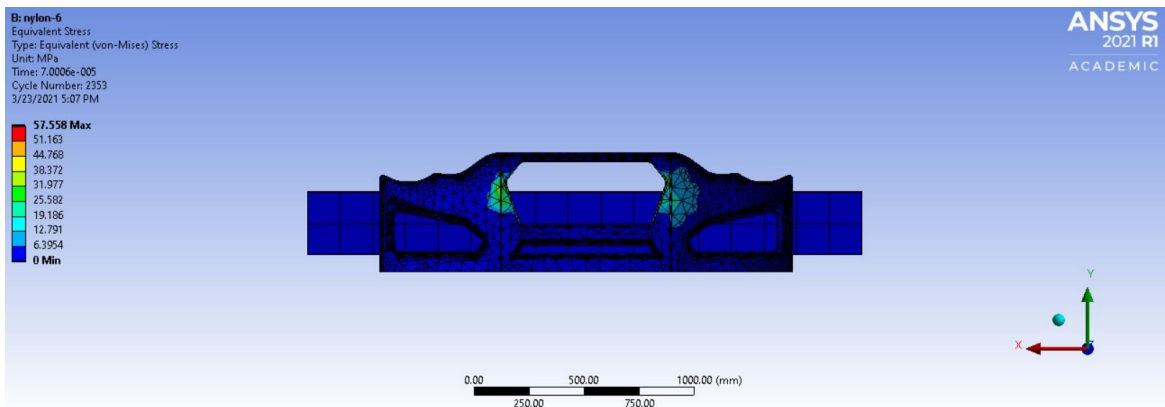
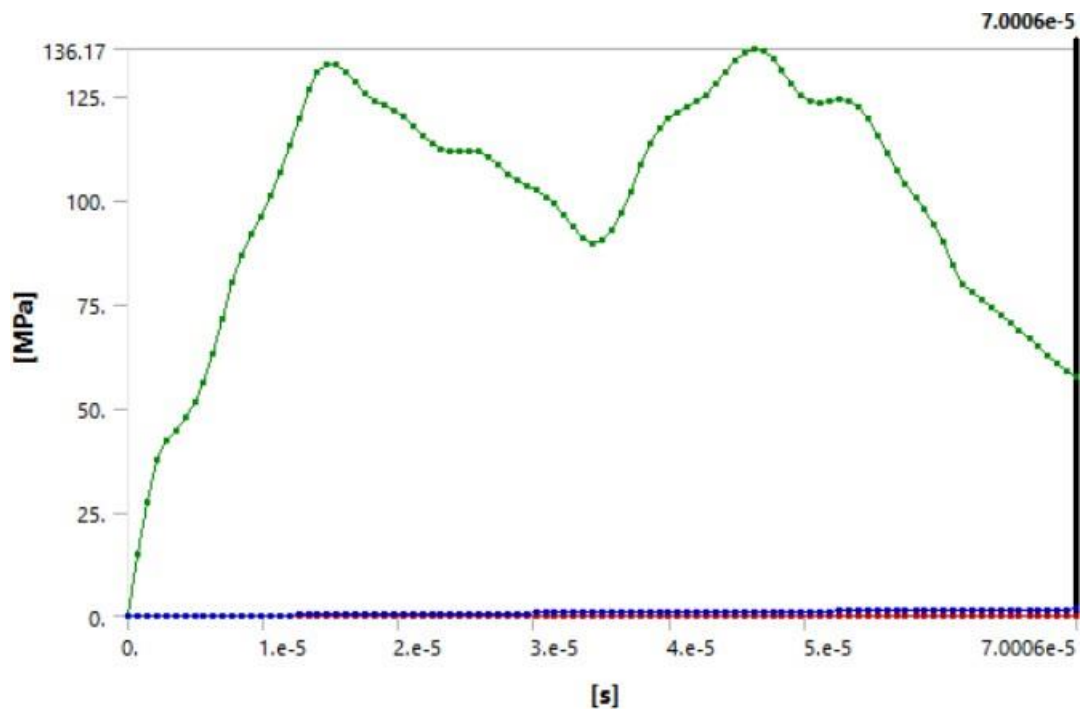


Fig 5.3: Equivalent stress in nylon 6 with MMT



Model (B4) > Explicit Dynamics (B5) > Solution (B6) > Equivalent Stress

Fig 5.4: graph for equivalent stress in nylon 6 with MMT

The below table shows step wise values of equivalent stress in bumper made of Nylon 6 with MMT.

Time [s]	Minimum [MPa]	Maximum [MPa]	Average [MPa]
1.1755e-038	0.	0.	0.
7.2108e-007		14.617	7.8472e-003
1.4059e-006		27.133	1.5815e-002
2.1205e-006		37.678	2.5326e-002
2.8053e-006		42.14	3.4138e-002
3.5199e-006		44.561	4.4124e-002
4.2047e-006		47.737	5.4902e-002
4.9193e-006		51.606	6.642e-002
5.6041e-006		56.052	7.6795e-002
6.3187e-006		62.926	8.6731e-002
7.0035e-006		71.392	0.1069
7.7181e-006		80.034	0.12198
8.4029e-006		86.59	0.13317
9.1175e-006		91.639	0.14726
9.8023e-006		95.94	0.16158
1.0517e-005		100.92	0.17819
1.1202e-005		106.35	0.20007
1.1916e-005		112.85	0.22686
1.2601e-005		119.71	0.25095
1.3316e-005		126.24	0.27282
1.4001e-005		130.48	0.29053
1.4715e-005		132.39	0.31079
1.543e-005		132.27	0.32613
1.6114e-005		130.74	0.33932
1.6829e-005		128.21	0.35392
1.7514e-005		125.66	0.36789
1.8228e-005		123.67	0.38318
1.8913e-005		122.57	0.3994
1.9628e-005		121.55	0.41746
2.0313e-005		119.89	0.43477
2.1027e-005		117.55	0.45282
2.1712e-005		115.36	0.46992
2.2427e-005		113.53	0.48775
2.3112e-005		112.28	0.50471
2.3826e-005		111.64	0.52223
2.4511e-005		111.65	0.53935
2.5226e-005		111.83	0.55835
2.591e-005		111.45	0.57794
2.6625e-005		110.07	0.59929

2.731e-005	108.15	0.61983
2.8024e-005	106.25	0.64076
2.8709e-005	104.82	0.65974
2.9424e-005	103.5	0.67854
3.0109e-005	102.19	0.69653
3.0823e-005	100.71	0.71544
3.1508e-005	98.96	0.73304
3.2223e-005	96.473	0.75097
3.2907e-005	93.535	0.76817
3.3622e-005	90.734	0.78659
3.4307e-005	89.423	0.8046
3.5021e-005	90.13	0.82338
3.5706e-005	92.63	0.84148
3.6421e-005	96.807	0.86094
3.7106e-005	102.08	0.87984
3.782e-005	108.16	0.89955
3.8505e-005	113.39	0.9181
3.922e-005	117.29	0.93657
3.9904e-005	119.56	0.95275
4.0619e-005	121.02	0.96769
4.1304e-005	122.18	0.98012
4.2018e-005	123.52	0.99144
4.2703e-005	125.2	1.0012
4.3418e-005	127.66	1.0107
4.4103e-005	130.56	1.0197
4.4817e-005	133.49	1.0293
4.5502e-005	135.44	1.0386
4.6217e-005	136.17	1.0483
4.6901e-005	135.54	1.0581
4.7616e-005	133.65	1.0692
4.8301e-005	130.93	1.0809
4.9015e-005	127.74	1.0941
4.97e-005	125.15	1.1071
5.0415e-005	123.61	1.1209
5.1129e-005	123.29	1.1345
5.1814e-005	123.66	1.1472
5.2529e-005	124.06	1.16
5.3214e-005	123.83	1.1723
5.3928e-005	122.38	1.1855
5.4613e-005	119.59	1.1986
5.5328e-005	115.46	1.2128
5.6012e-005	111.12	1.2274
5.6727e-005	107.01	1.2435

5.7412e-005	103.72	1.2595
5.8126e-005	100.67	1.2766
5.8811e-005	97.693	1.2937
5.9526e-005	94.152	1.3122
6.0211e-005	89.898	1.3305
6.0925e-005	84.246	1.3503
6.161e-005	79.716	1.3701
6.2325e-005	77.72	1.3917
6.3009e-005	75.908	1.4135
6.3724e-005	74.11	1.4367
6.4409e-005	72.418	1.4587
6.5123e-005	70.603	1.481
6.5808e-005	68.761	1.5019
6.6523e-005	66.718	1.5238
6.7208e-005	64.687	1.5451
6.7922e-005	62.584	1.5681
6.8607e-005	60.692	1.5913
6.9322e-005	58.949	1.6173
7.0006e-005	57.558	1.6438

Table 5.3: step wise values of equivalent stress in bumper made of Nylon 6 with MMT

5.1.1.3 Equivalent elastic strain in nylon 6 with MMT Maximum

equivalent stress = 4.773×10^{-2}

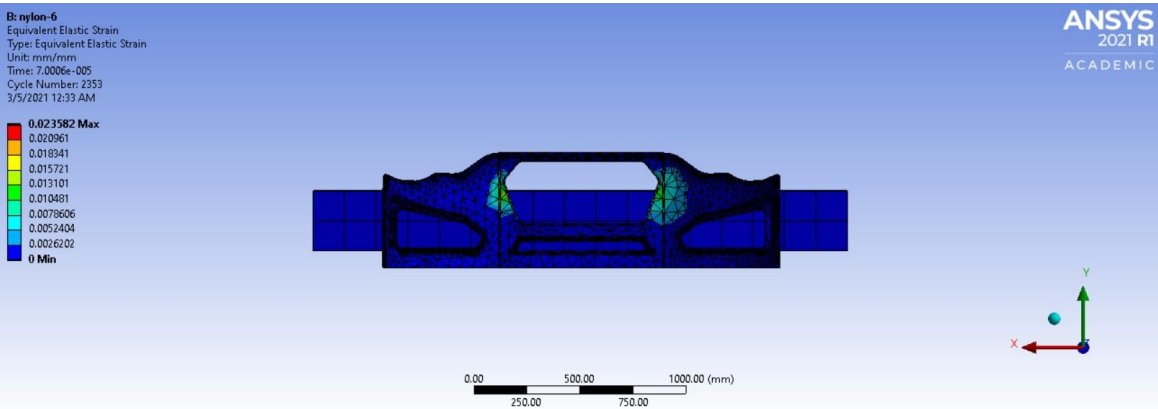


Fig 5.5: Equivalent elastic strain in nylon 6 with MMT

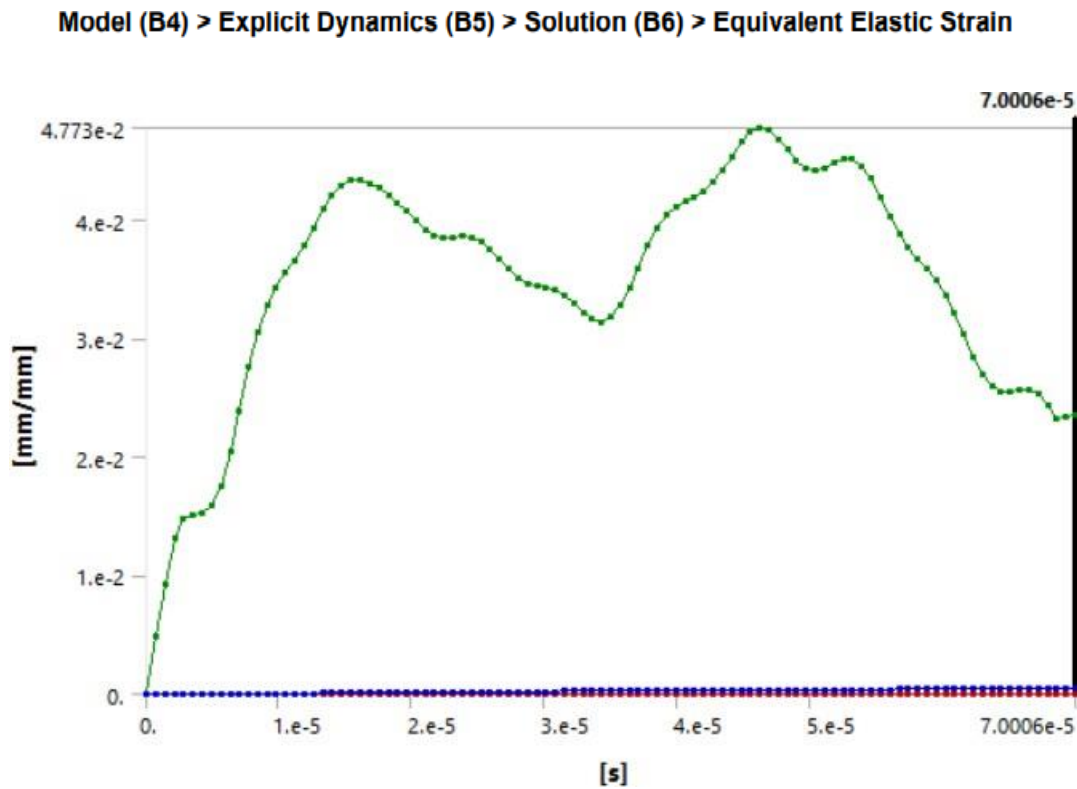


Fig 5.6: graph for equivalent elastic strain in nylon 6 with MMT

The below table gives step wise details of Equivalent elastic strain in bumper made of nylon 6 with MMT.

Time [s]	Minimum [mm/mm]	Maximum [mm/mm]	Average [mm/mm]
1.1755e-038	0.	0.	0.
7.2108e-007		4.9495e-003	2.4347e-006
1.4059e-006		9.3063e-003	5.0582e-006
2.1205e-006		1.3176e-002	8.3456e-006
2.8053e-006		1.4832e-002	1.1335e-005
3.5199e-006		1.5135e-002	1.4363e-005
4.2047e-006		1.5248e-002	1.7454e-005
4.9193e-006		1.5928e-002	2.0981e-005
5.6041e-006		1.7531e-002	2.4497e-005
6.3187e-006		2.0389e-002	2.8244e-005
7.0035e-006		2.388e-002	3.4432e-005
7.7181e-006		2.7551e-002	3.9867e-005
8.4029e-006		3.0514e-002	4.4511e-005
9.1175e-006		3.2788e-002	4.9713e-005
9.8023e-006		3.4299e-002	5.4658e-005
1.0517e-005		3.5479e-002	5.9964e-005
1.1202e-005		3.6516e-002	6.5464e-005
1.1916e-005		3.78e-002	7.2406e-005
1.2601e-005		3.9288e-002	7.9199e-005
1.3316e-005		4.0864e-002	8.5868e-005
1.4001e-005		4.2085e-002	9.1842e-005
1.4715e-005		4.2896e-002	9.8273e-005
1.543e-005		4.328e-002	1.0384e-004
1.6114e-005		4.3313e-002	1.088e-004
1.6829e-005		4.3057e-002	1.1383e-004
1.7514e-005		4.2619e-002	1.185e-004
1.8228e-005		4.2063e-002	1.2369e-004
1.8913e-005		4.1467e-002	1.295e-004
1.9628e-005		4.0737e-002	1.362e-004
2.0313e-005		3.9937e-002	1.4274e-004
2.1027e-005		3.916e-002	1.4945e-004
2.1712e-005		3.867e-002	1.5577e-004
2.2427e-005		3.8488e-002	1.624e-004
2.3112e-005		3.8519e-002	1.6905e-004
2.3826e-005		3.8589e-002	1.7627e-004
2.4511e-005		3.8529e-002	1.8317e-004
2.5226e-005		3.8199e-002	1.9039e-004

2.591e-005	3.758e-002	1.9739e-004
2.6625e-005	3.6691e-002	2.0472e-004
2.731e-005	3.5804e-002	2.1158e-004
2.8024e-005	3.5075e-002	2.1835e-004
2.8709e-005	3.4656e-002	2.2442e-004
2.9424e-005	3.4435e-002	2.3061e-004
3.0109e-005	3.4287e-002	2.3668e-004
3.0823e-005	3.405e-002	2.4305e-004
3.1508e-005	3.363e-002	2.4895e-004
3.2223e-005	3.2964e-002	2.5488e-004
3.2907e-005	3.2212e-002	2.604e-004
3.3622e-005	3.158e-002	2.6603e-004
3.4307e-005	3.1406e-002	2.712e-004
3.5021e-005	3.1835e-002	2.7631e-004
3.5706e-005	3.28e-002	2.8114e-004
3.6421e-005	3.4259e-002	2.8632e-004
3.7106e-005	3.5945e-002	2.9141e-004
3.782e-005	3.7762e-002	2.9681e-004
3.8505e-005	3.9287e-002	3.0205e-004
3.922e-005	4.0451e-002	3.0747e-004
3.9904e-005	4.1149e-002	3.1236e-004
4.0619e-005	4.1601e-002	3.1701e-004
4.1304e-005	4.1962e-002	3.2108e-004
4.2018e-005	4.2442e-002	3.2499e-004
4.2703e-005	4.3131e-002	3.2848e-004
4.3418e-005	4.4155e-002	3.3196e-004
4.4103e-005	4.5344e-002	3.3537e-004
4.4817e-005	4.6547e-002	3.3927e-004
4.5502e-005	4.7385e-002	3.433e-004
4.6217e-005	4.773e-002	3.4757e-004
4.6901e-005	4.7509e-002	3.5152e-004
4.7616e-005	4.6809e-002	3.5543e-004
4.8301e-005	4.5891e-002	3.5895e-004
4.9015e-005	4.4954e-002	3.6243e-004
4.97e-005	4.4332e-002	3.6564e-004
5.0415e-005	4.4128e-002	3.6899e-004
5.1129e-005	4.4348e-002	3.7256e-004
5.1814e-005	4.4759e-002	3.7634e-004
5.2529e-005	4.5104e-002	3.8065e-004
5.3214e-005	4.5087e-002	3.8504e-004
5.3928e-005	4.4522e-002	3.8985e-004
5.4613e-005	4.3439e-002	3.9464e-004
5.5328e-005	4.1907e-002	3.9976e-004

5.6012e-005	4.0329e-002	4.0481e-004
5.6727e-005	3.8841e-002	4.1025e-004
5.7412e-005	3.7682e-002	4.1563e-004
5.8126e-005	3.6703e-002	4.2142e-004
5.8811e-005	3.5849e-002	4.2713e-004
5.9526e-005	3.4867e-002	4.3324e-004
6.0211e-005	3.3676e-002	4.3918e-004
6.0925e-005	3.209e-002	4.4542e-004
6.161e-005	3.0319e-002	4.5145e-004
6.2325e-005	2.8458e-002	4.5792e-004
6.3009e-005	2.6965e-002	4.6437e-004
6.3724e-005	2.5937e-002	4.7134e-004
6.4409e-005	2.5499e-002	4.7814e-004
6.5123e-005	2.5486e-002	4.8521e-004
6.5808e-005	2.5657e-002	4.9176e-004
6.6523e-005	2.5684e-002	4.9828e-004
6.7208e-005	2.5278e-002	5.0426e-004
6.7922e-005	2.4301e-002	5.104e-004
6.8607e-005	2.3286e-002	5.1646e-004
6.9322e-005	2.3448e-002	5.233e-004
7.0006e-005	2.3582e-002	5.3046e-004

Table 5.4: step wise details of Equivalent elastic strain in bumper made of nylon 6 with MMT

5.1.2 ACRYLONITRILE BUTADIENE STYRENE (ABS)

Assuming that the bumper is made of Acrylonitrile Butadiene styrene the bumper and is made impact with fixed wall made of structural steel the following results are produced.

5.1.2.1 Total Deformation in bumper made of ABS

Maximum deformation = 1.9648 mm

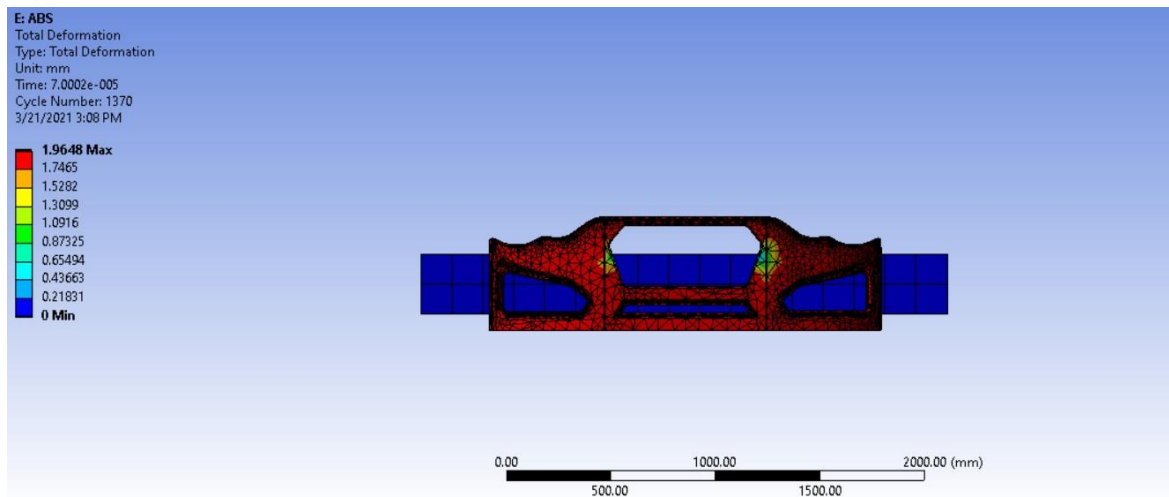


Fig 5.7: total deformation in bumper made of Acrylonitrile Butadiene Styrene

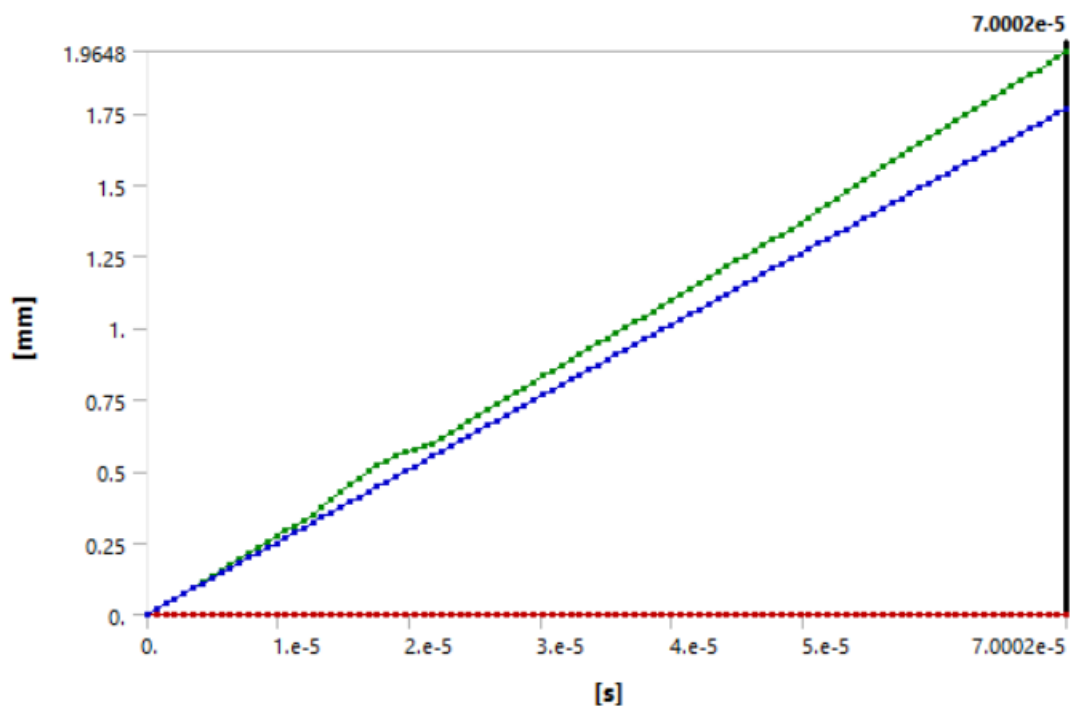


Fig 5.8: Graph of total deformation in Bumper made of ABS

Below table is step by step values of total deformation of bumper made of ABS:

Time [s]	Minimum [mm]	Maximum [mm]	Average [mm]
1.1755e-038	0	0.	0.
7.2743e-007		1.8922e-002	1.8547e-002
1.4437e-006		3.7732e-002	3.6808e-002
2.1088e-006		5.5535e-002	5.3765e-002
2.8251e-006		7.5125e-002	7.2024e-002
3.5414e-006		9.5157e-002	9.0281e-002
4.2065e-006		0.11409	0.10723
4.9228e-006		0.1347	0.12549
5.639e-006		0.15542	0.14374
6.3042e-006		0.17465	0.16069
7.0204e-006		0.1953	0.17893
7.7367e-006		0.21579	0.19717
8.4018e-006		0.23459	0.21412
9.1181e-006		0.25439	0.23236
9.8344e-006		0.27348	0.2506
1.0551e-005		0.2916	0.26884
1.1216e-005		0.30741	0.28576
1.1932e-005		0.32692	0.30399
1.2648e-005		0.34932	0.32222
1.3313e-005		0.37378	0.33914
1.403e-005		0.40088	0.35737
1.4746e-005		0.42786	0.37559
1.5411e-005		0.45193	0.3925
1.6127e-005		0.47637	0.4107
1.6844e-005		0.49894	0.4289
1.7509e-005		0.51796	0.4458
1.8225e-005		0.53612	0.46399
1.8941e-005		0.55206	0.48218
1.9606e-005		0.56502	0.49906
2.0323e-005		0.57725	0.51724
2.1039e-005		0.58801	0.5354
2.1704e-005		0.59701	0.55227
2.242e-005		0.61453	0.57043
2.3137e-005		0.63565	0.58858

2.3802e-005		0.65462	0.60544
2.4518e-005		0.67392	0.62358
2.5234e-005		0.69405	0.64172
2.5951e-005		0.71486	0.65985
2.6616e-005		0.73385	0.67669
2.7332e-005		0.75385	0.69481
2.8048e-005		0.77328	0.71292
2.8713e-005		0.79076	0.72974
2.943e-005		0.81156	0.74784
3.0146e-005		0.83222	0.76594
3.0811e-005		0.85121	0.78273
3.1527e-005		0.87137	0.80081
3.2244e-005		0.89112	0.81889
3.2909e-005		0.90901	0.83567
3.3625e-005		0.9277	0.85374
3.4341e-005		0.94571	0.8718
3.5006e-005		0.96467	0.88857
3.5723e-005		0.9849	0.90662
3.6439e-005		1.0041	0.92467
3.7104e-005		1.0209	0.94143
3.782e-005		1.0379	0.95946
3.8537e-005		1.0556	0.9775
3.9202e-005		1.0732	0.99424
3.9918e-005		1.0932	1.0123
4.0634e-005		1.1147	1.0303
4.1351e-005		1.1359	1.0483
4.2016e-005		1.1553	1.065
4.2732e-005		1.1759	1.083
4.3448e-005		1.196	1.101
4.4113e-005		1.2144	1.1177
4.483e-005		1.2336	1.1357
4.5546e-005		1.2524	1.1537
4.6211e-005		1.2693	1.1704
4.6927e-005		1.2887	1.1884
4.7644e-005		1.3083	1.2063
4.8309e-005		1.326	1.223
4.9025e-005		1.3445	1.241
4.9741e-005		1.364	1.259

5.0406e-005		1.3831	1.2756
5.1123e-005		1.4069	1.2936
5.1839e-005		1.4304	1.3116
5.2504e-005		1.4519	1.3282
5.322e-005		1.4747	1.3462
5.3937e-005		1.497	1.3641
5.4602e-005		1.5175	1.3808
5.5318e-005		1.54	1.3987
5.6034e-005		1.5622	1.4167
5.6751e-005		1.584	1.4346
5.7416e-005		1.6039	1.4512
5.8132e-005		1.625	1.4692
5.8848e-005		1.6459	1.4871
5.9513e-005		1.665	1.5037
6.023e-005		1.6853	1.5216
6.0946e-005		1.7053	1.5395
6.1611e-005		1.7238	1.5561
6.2327e-005		1.7435	1.574
6.3044e-005		1.7636	1.5918
6.3709e-005		1.7829	1.6084
6.4425e-005		1.8034	1.6263
6.5141e-005		1.8238	1.6441
6.5806e-005		1.8424	1.6607
6.6523e-005		1.8621	1.6785
6.7239e-005		1.8814	1.6964
6.7904e-005		1.901	1.7129
6.862e-005		1.923	1.7307
6.9337e-005		1.9448	1.7485
7.0002e-005		1.9648	1.765

Table 5.5: step by step values of total deformation of bumper made of ABS

5.1.2.2 Equivalent elastic strain in bumper made of ABS

Maximum equivalent elastic strain = 7.1824×10^{-2}

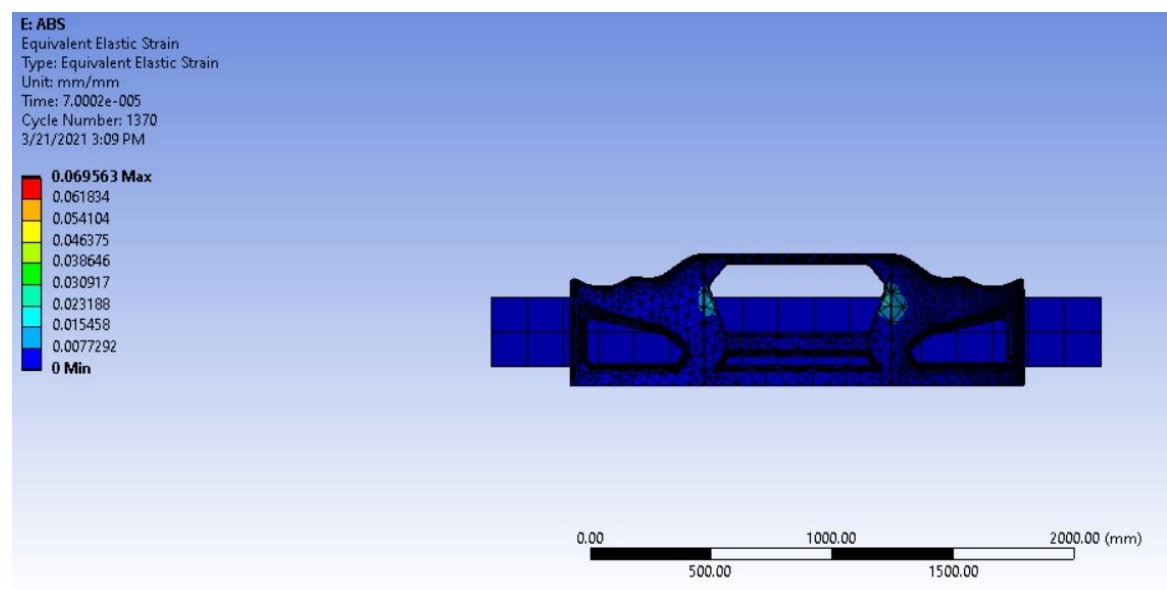


Fig 5.9: equivalent elastic strain in bumper made of ABS

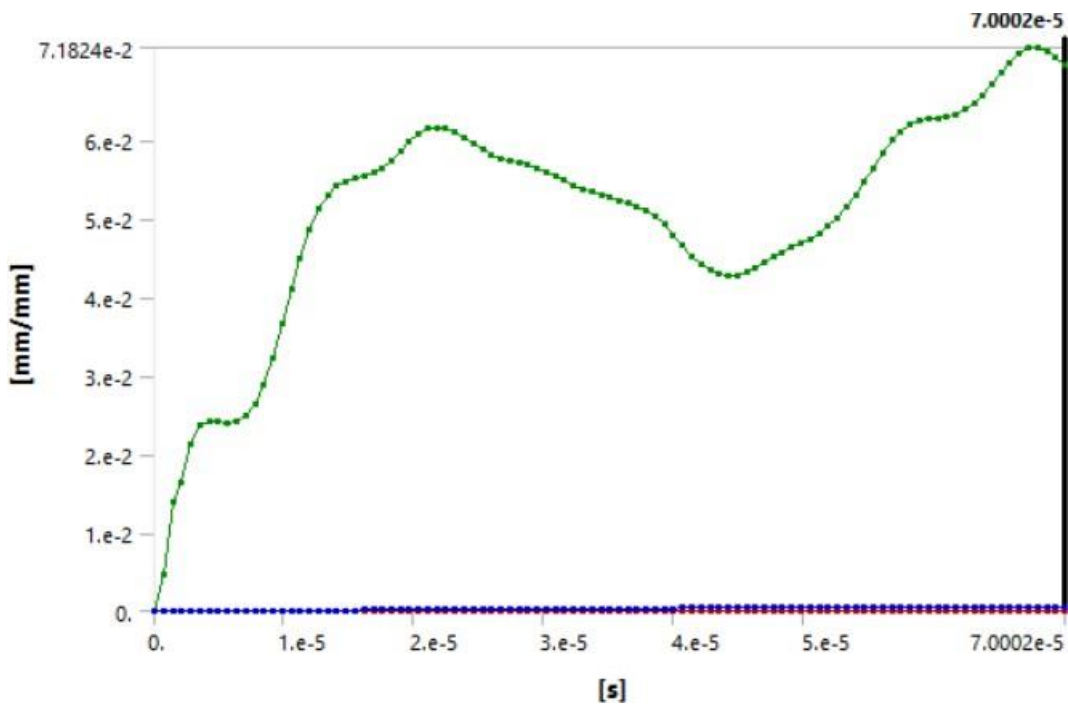


Fig 5.10: graph for equivalent elastic strain in bumper made of ABS

The below table gives step wise details of Equivalent elastic strain in bumper made of ABS.

Time [s]	Minimum [mm]	Maximum [mm]	Average [mm]
1.1755e-038	0	0.	0.
7.2743e-007		1.8922e-002	1.8547e-002
1.4437e-006		3.7732e-002	3.6808e-002
2.1088e-006		5.5535e-002	5.3765e-002
2.8251e-006		7.5125e-002	7.2024e-002
3.5414e-006		9.5157e-002	9.0281e-002
4.2065e-006		0.11409	0.10723
4.9228e-006		0.1347	0.12549
5.639e-006		0.15542	0.14374
6.3042e-006		0.17465	0.16069
7.0204e-006		0.1953	0.17893
7.7367e-006		0.21579	0.19717
8.4018e-006		0.23459	0.21412
9.1181e-006		0.25439	0.23236
9.8344e-006		0.27348	0.2506
1.0551e-005		0.2916	0.26884
1.1216e-005		0.30741	0.28576
1.1932e-005		0.32692	0.30399
1.2648e-005		0.34932	0.32222
1.3313e-005		0.37378	0.33914
1.403e-005		0.40088	0.35737
1.4746e-005		0.42786	0.37559
1.5411e-005		0.45193	0.3925
1.6127e-005		0.47637	0.4107
1.6844e-005		0.49894	0.4289
1.7509e-005		0.51796	0.4458
1.8225e-005		0.53612	0.46399
1.8941e-005		0.55206	0.48218
1.9606e-005		0.56502	0.49906
2.0323e-005		0.57725	0.51724
2.1039e-005		0.58801	0.5354
2.1704e-005		0.59701	0.55227
2.242e-005		0.61453	0.57043

2.3137e-005
2.3802e-005
2.4518e-005
2.5234e-005
2.5951e-005
2.6616e-005
2.7332e-005
2.8048e-005
2.8713e-005
2.943e-005
3.0146e-005
3.0811e-005
3.1527e-005
3.2244e-005
3.2909e-005
3.3625e-005
3.4341e-005
3.5006e-005
3.5723e-005
3.6439e-005
3.7104e-005
3.782e-005
3.8537e-005
3.9202e-005
3.9918e-005
4.0634e-005
4.1351e-005
4.2016e-005
4.2732e-005
4.3448e-005
4.4113e-005
4.483e-005
4.5546e-005
4.6211e-005
4.6927e-005
4.7644e-005
4.8309e-005
4.9025e-005

0.63565	0.58858
0.65462	0.60544
0.67392	0.62358
0.69405	0.64172
0.71486	0.65985
0.73385	0.67669
0.75385	0.69481
0.77328	0.71292
0.79076	0.72974
0.81156	0.74784
0.83222	0.76594
0.85121	0.78273
0.87137	0.80081
0.89112	0.81889
0.90901	0.83567
0.9277	0.85374
0.94571	0.8718
0.96467	0.88857
0.9849	0.90662
1.0041	0.92467
1.0209	0.94143
1.0379	0.95946
1.0556	0.9775
1.0732	0.99424
1.0932	1.0123
1.1147	1.0303
1.1359	1.0483
1.1553	1.065
1.1759	1.083
1.196	1.101
1.2144	1.1177
1.2336	1.1357
1.2524	1.1537
1.2693	1.1704
1.2887	1.1884
1.3083	1.2063
1.326	1.223
1.3445	1.241

4.9741e-005	1.364	1.259
5.0406e-005	1.3831	1.2756
5.1123e-005	1.4069	1.2936
5.1839e-005	1.4304	1.3116
5.2504e-005	1.4519	1.3282
5.322e-005	1.4747	1.3462
5.3937e-005	1.497	1.3641
5.4602e-005	1.5175	1.3808
5.5318e-005	1.54	1.3987
5.6034e-005	1.5622	1.4167
5.6751e-005	1.584	1.4346
5.7416e-005	1.6039	1.4512
5.8132e-005	1.625	1.4692
5.8848e-005	1.6459	1.4871
5.9513e-005	1.665	1.5037
6.023e-005	1.6853	1.5216
6.0946e-005	1.7053	1.5395
6.1611e-005	1.7238	1.5561
6.2327e-005	1.7435	1.574
6.3044e-005	1.7636	1.5918
6.3709e-005	1.7829	1.6084
6.4425e-005	1.8034	1.6263
6.5141e-005	1.8238	1.6441
6.5806e-005	1.8424	1.6607
6.6523e-005	1.8621	1.6785
6.7239e-005	1.8814	1.6964
6.7904e-005	1.901	1.7129
6.862e-005	1.923	1.7307
6.9337e-005	1.9448	1.7485
7.0002e-005	1.9648	1.765

Table 5.6: Step wise values of equivalent elastic strain in bumper made of ABS

5.1.2.3 Equivalent stress in bumper made of ABS

Maximum Equivalent stress = 91.269 MPa

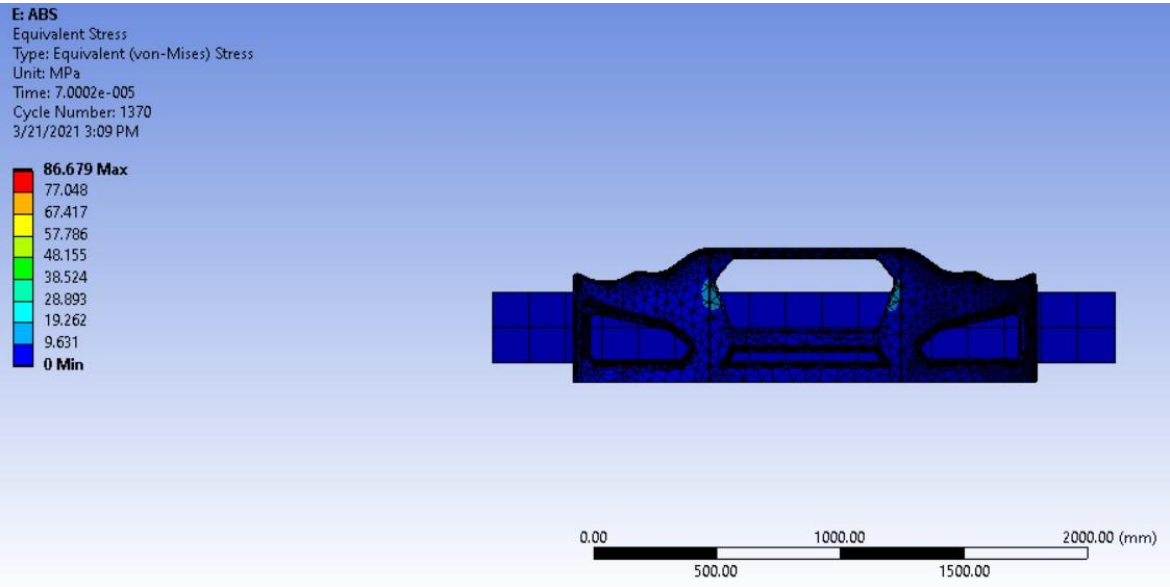


Fig 5.10: equivalent stress in bumpers of Acrylonitrile Butadiene Styrene

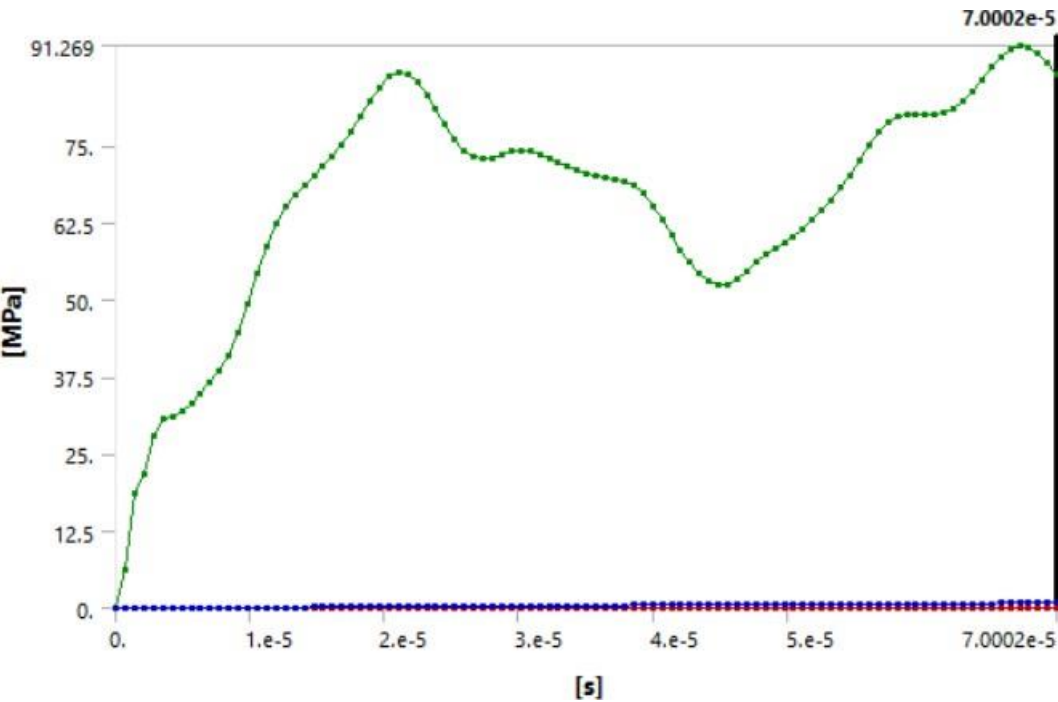


Fig 5.11: graph for equivalent stress in bumpers of Acrylonitrile Butadiene Styrene

The below table shows step wise values of equivalent stress in bumper made of ABS.

Time [s]	Minimum [MPa]	Maximum [MPa]	Average [MPa]
1.1755e-038	0.	0.	0.
7.2743e-007		6.1456	3.2814e-003
1.4437e-006		18.711	1.0289e-002
2.1088e-006		21.83	1.2948e-002
2.8251e-006		27.902	1.8179e-002
3.5414e-006		30.597	2.2667e-002
4.2065e-006		31.177	2.6622e-002
4.9228e-006		31.9	3.1487e-002
5.639e-006		33.191	3.6918e-002
6.3042e-006		34.78	4.6287e-002
7.0204e-006		36.627	5.9205e-002
7.7367e-006		38.642	7.0006e-002
8.4018e-006		41.075	7.7538e-002
9.1181e-006		44.731	8.5574e-002
9.8344e-006		49.383	9.4719e-002
1.0551e-005		54.391	0.10575
1.1216e-005		58.72	0.11766
1.1932e-005		62.529	0.12904
1.2648e-005		65.287	0.13873
1.3313e-005		67.071	0.14648
1.403e-005		68.571	0.15393
1.4746e-005		70.057	0.1608
1.5411e-005		71.56	0.17011
1.6127e-005		73.305	0.18045
1.6844e-005		75.188	0.19023
1.7509e-005		77.176	0.19894
1.8225e-005		79.64	0.20943
1.8941e-005		82.268	0.22029
1.9606e-005		84.498	0.22956
2.0323e-005		86.211	0.23958
2.1039e-005		86.918	0.24858
2.1704e-005		86.609	0.25629
2.242e-005		85.33	0.26403
2.3137e-005		83.282	0.27132
2.3802e-005		80.977	0.27795
2.4518e-005		78.421	0.28515
2.5234e-005		76.115	0.29239

2.5951e-005	74.32	0.29979
2.6616e-005	73.272	0.30697
2.7332e-005	72.869	0.31517
2.8048e-005	73.107	0.32391
2.8713e-005	73.633	0.33245
2.943e-005	74.147	0.3419
3.0146e-005	74.31	0.35142
3.0811e-005	74.089	0.36028
3.1527e-005	73.57	0.36993
3.2244e-005	72.912	0.37986
3.2909e-005	72.27	0.38946
3.3625e-005	71.588	0.40024
3.4341e-005	70.943	0.41135
3.5006e-005	70.427	0.42178
3.5723e-005	70.024	0.433
3.6439e-005	69.776	0.44405
3.7104e-005	69.596	0.45405
3.782e-005	69.26	0.46439
3.8537e-005	68.51	0.47417
3.9202e-005	67.25	0.48268
3.9918e-005	65.278	0.49132
4.0634e-005	62.883	0.49966
4.1351e-005	60.383	0.50798
4.2016e-005	58.196	0.51578
4.2732e-005	56.11	0.52436
4.3448e-005	54.361	0.53321
4.4113e-005	53.145	0.54172
4.483e-005	52.472	0.55123
4.5546e-005	52.585	0.56106
4.6211e-005	53.33	0.57045
4.6927e-005	54.596	0.58081
4.7644e-005	56.041	0.59139
4.8309e-005	57.295	0.60134
4.9025e-005	58.416	0.6121
4.9741e-005	59.359	0.62289
5.0406e-005	60.249	0.63287
5.1123e-005	61.413	0.64348
5.1839e-005	62.871	0.65374
5.2504e-005	64.436	0.66284
5.322e-005	66.26	0.6721
5.3937e-005	68.243	0.68087
5.4602e-005	70.298	0.68866
5.5318e-005	72.726	0.69669

5.6034e-005	75.184	0.70425
5.6751e-005	77.361	0.7112
5.7416e-005	78.878	0.71703
5.8132e-005	79.84	0.72264
5.8848e-005	80.172	0.72773
5.9513e-005	80.12	0.7322
6.023e-005	79.969	0.73693
6.0946e-005	80.003	0.74177
6.1611e-005	80.365	0.74646
6.2327e-005	81.17	0.75176
6.3044e-005	82.39	0.75726
6.3709e-005	83.862	0.76278
6.4425e-005	85.731	0.76917
6.5141e-005	87.71	0.77547
6.5806e-005	89.388	0.78167
6.6523e-005	90.708	0.78867
6.7239e-005	91.269	0.7958
6.7904e-005	91.024	0.80255
6.862e-005	90.015	0.80988
6.9337e-005	88.433	0.81716
7.0002e-005	86.679	0.82384

Table 5.7: step wise values of equivalent stress in bumper made of ABS.

5.1.3 ARAMIDE FIBRE REINFORCED POLYESTER COMPOSITE (AFRP)

Assuming that the bumper is made of Aramide Fiber Reinforced Polyester composite and made impact against a fixed structural steel wall the following results are produced.

5.1.3.1 Total Deformation in bumper made of AFRP

Total deformation = 1.9915 mm

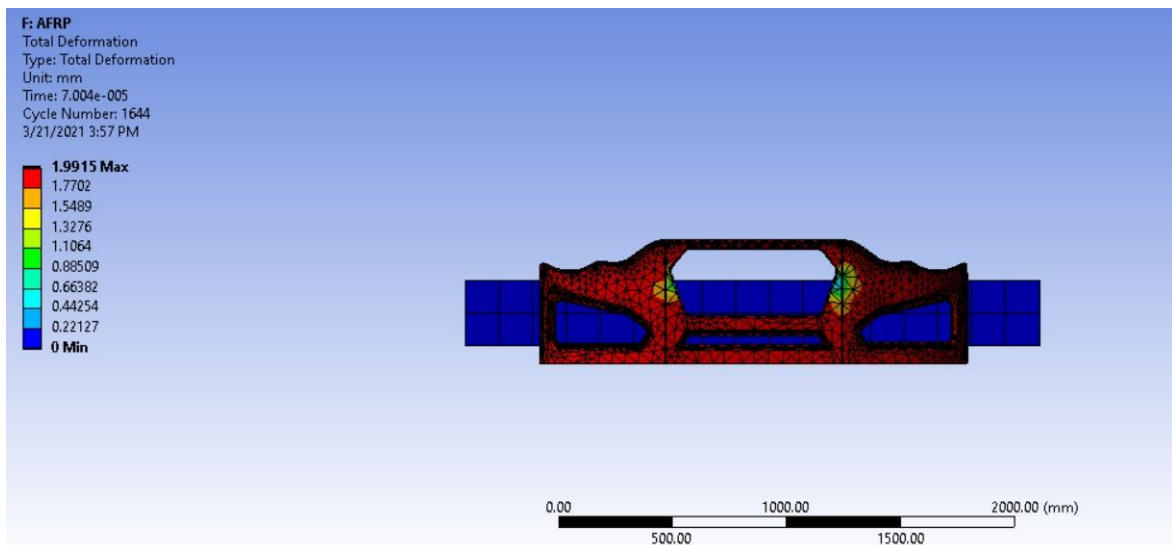


Fig 5.12: deformation in bumper made of AFRP

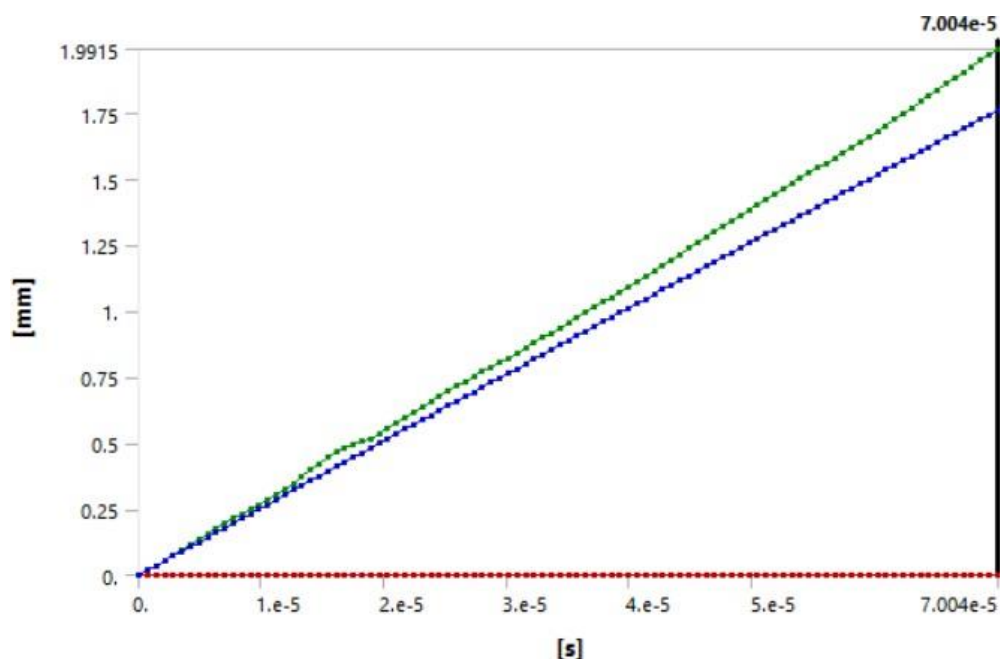


Fig 5.13: graph of deformation in bumper made of AFRP

Below table is a step by step value of total deformation of bumper made of AFRP:

Time [s]	Minimum [mm]	Maximum [mm]	Average [mm]
1.1755e-038	0.	0.	0.
7.3434e-007		1.9109e-002	1.8723e-002
1.4167e-006		3.7114e-002	3.6121e-002
2.1418e-006		5.6733e-002	5.4604e-002
2.8242e-006		7.5706e-002	7.1998e-002
3.5066e-006		9.5083e-002	8.9391e-002
4.2316e-006		0.11592	0.10787
4.914e-006		0.13571	0.12526
5.6391e-006		0.15673	0.14373
6.3215e-006		0.17609	0.16112
7.0039e-006		0.19501	0.1785
7.7289e-006		0.21465	0.19697
8.4113e-006		0.23211	0.21435
9.1364e-006		0.24929	0.23281
9.8188e-006		0.26648	0.25018
1.0501e-005		0.28518	0.26755
1.1226e-005		0.30536	0.286
1.1909e-005		0.32393	0.30336
1.2634e-005		0.34854	0.3218
1.3316e-005		0.37355	0.33915
1.4041e-005		0.3999	0.35759
1.4723e-005		0.42323	0.37493
1.5406e-005		0.44461	0.39227
1.6131e-005		0.46478	0.41068
1.6813e-005		0.48104	0.428
1.7538e-005		0.49564	0.4464
1.8221e-005		0.50717	0.46371
1.8903e-005		0.51701	0.48101
1.9628e-005		0.53604	0.49939
2.0311e-005		0.55565	0.51668
2.1036e-005		0.57625	0.53504
2.1718e-005		0.59532	0.55232
2.24e-005		0.614	0.56959
2.3125e-005		0.63439	0.58793
2.3808e-005		0.65415	0.60519
2.4533e-005		0.67503	0.62351
2.5215e-005		0.69451	0.64076
2.594e-005		0.71496	0.65907

2.6623e-005	0.73388	0.67629
2.7305e-005	0.75239	0.69352
2.803e-005	0.77149	0.71181
2.8713e-005	0.78884	0.72902
2.9438e-005	0.80648	0.7473
3.012e-005	0.82225	0.7645
3.0802e-005	0.83925	0.7817
3.1528e-005	0.8591	0.79996
3.221e-005	0.87809	0.81714
3.2935e-005	0.89793	0.83539
3.3617e-005	0.91702	0.85256
3.4342e-005	0.938	0.87079
3.5025e-005	0.95745	0.88795
3.5707e-005	0.97655	0.9051
3.6432e-005	0.99638	0.92331
3.7115e-005	1.0145	0.94045
3.784e-005	1.0332	0.95866
3.8522e-005	1.0512	0.97579
3.9204e-005	1.0707	0.99291
3.993e-005	1.0913	1.0111
4.0612e-005	1.1107	1.0282
4.1337e-005	1.1313	1.0464
4.2019e-005	1.1505	1.0635
4.2702e-005	1.1698	1.0806
4.3427e-005	1.1929	1.0988
4.4109e-005	1.2147	1.1159
4.4834e-005	1.238	1.1341
4.5517e-005	1.2595	1.1512
4.6242e-005	1.2818	1.1693
4.6924e-005	1.3024	1.1864
4.7606e-005	1.3226	1.2035
4.8332e-005	1.3437	1.2216
4.9014e-005	1.3632	1.2387
4.9739e-005	1.3837	1.2568
5.0421e-005	1.4028	1.2738
5.1104e-005	1.4218	1.2909
5.1829e-005	1.4427	1.309
5.2511e-005	1.4627	1.326
5.3236e-005	1.4838	1.3441
5.3919e-005	1.5033	1.3611
5.4601e-005	1.5221	1.3781
5.5326e-005	1.5414	1.3961
5.6009e-005	1.5589	1.4131

5.6734e-005	1.5796	1.4311
5.7416e-005	1.6002	1.4481
5.8141e-005	1.6219	1.4661
5.8823e-005	1.6422	1.483
5.9506e-005	1.6621	1.5
6.0231e-005	1.6829	1.518
6.0913e-005	1.7031	1.5349
6.1638e-005	1.7265	1.5529
6.2321e-005	1.7485	1.5698
6.3003e-005	1.7705	1.5867
6.3728e-005	1.7937	1.6047
6.4411e-005	1.8155	1.6216
6.5136e-005	1.8385	1.6395
6.5818e-005	1.8601	1.6564
6.65e-005	1.8817	1.6732
6.7225e-005	1.9044	1.6911
6.7908e-005	1.9257	1.708
6.8633e-005	1.9482	1.7259
6.9315e-005	1.9692	1.7427
7.004e-005	1.9915	1.7606

Table 5.8: step by step value of total deformation of bumper made of AFRP:

5.1.3.2 Equivalent Stress in bumper made of AFRP

Maximum equivalent stress = 120.27 MPa

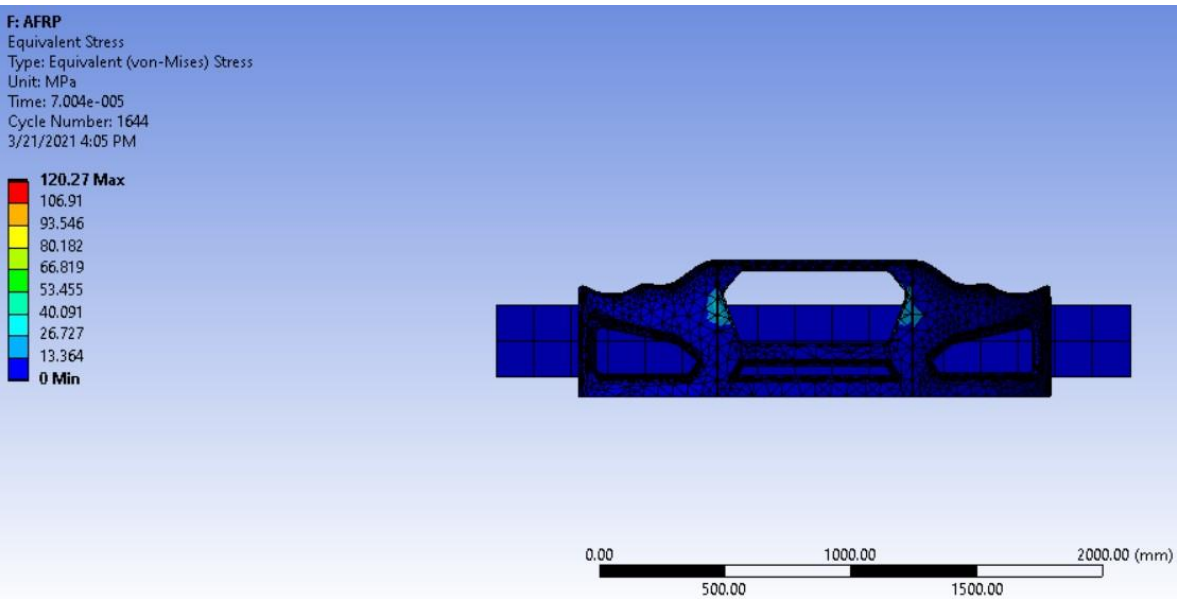


Fig 5.14: equivalent stress in bumper made of AFRP

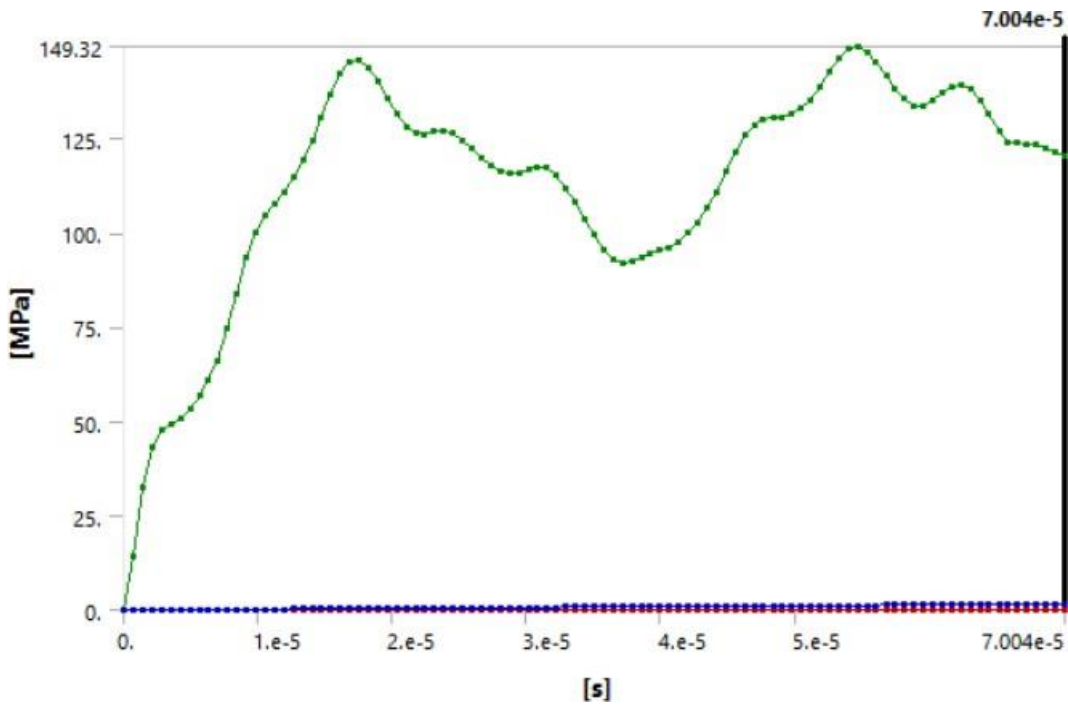


Fig 5.15: graph for equivalent stress in bumper made of AFRP

The below table shows step wise values of equivalent stress in bumper made of AFRP.

Time [s]	Minimum [MPa]	Maximum [MPa]	Average [MPa]
1.1755e-038	0.	0.	0.
7.3434e-007		14.182	7.5898e-003
1.4167e-006		32.396	1.8236e-002
2.1418e-006		43.401	2.7234e-002
2.8242e-006		47.885	3.4983e-002
3.5066e-006		49.178	4.3081e-002
4.2316e-006		50.611	5.2966e-002
4.914e-006		53.454	6.3467e-002
5.6391e-006		57.112	7.5059e-002
6.3215e-006		60.858	9.4609e-002
7.0039e-006		66.171	0.11694
7.7289e-006		74.547	0.13449
8.4113e-006		83.981	0.14712
9.1364e-006		93.352	0.16341
9.8188e-006		100.04	0.17567
1.0501e-005		104.38	0.19538
1.1226e-005		107.63	0.21976
1.1909e-005		110.8	0.24061
1.2634e-005		114.91	0.26038
1.3316e-005		119.3	0.27738
1.4041e-005		124.61	0.29424
1.4723e-005		130.4	0.31607
1.5406e-005		136.57	0.33645
1.6131e-005		142.18	0.35493
1.6813e-005		145.28	0.37096
1.7538e-005		145.75	0.38779
1.8221e-005		143.8	0.40122
1.8903e-005		140.17	0.41422
1.9628e-005		135.52	0.42771
2.0311e-005		131.36	0.44111
2.1036e-005		127.98	0.45672
2.1718e-005		126.3	0.47259
2.24e-005		126.08	0.48905
2.3125e-005		126.73	0.50686
2.3808e-005		127.07	0.52369
2.4533e-005		126.3	0.5414
2.5215e-005		124.56	0.55796

2.594e-005	122.21	0.57559
2.6623e-005	119.98	0.59231
2.7305e-005	118.02	0.60934
2.803e-005	116.46	0.62806
2.8713e-005	115.79	0.64664
2.9438e-005	116.03	0.6676
3.012e-005	116.87	0.68819
3.0802e-005	117.56	0.70901
3.1528e-005	117.14	0.73047
3.221e-005	115.21	0.74943
3.2935e-005	111.83	0.76813
3.3617e-005	107.98	0.7846
3.4342e-005	103.61	0.80132
3.5025e-005	99.454	0.81686
3.5707e-005	95.664	0.83284
3.6432e-005	92.846	0.85074
3.7115e-005	91.816	0.86867
3.784e-005	92.257	0.88882
3.8522e-005	93.421	0.90842
3.9204e-005	94.555	0.92818
3.993e-005	95.407	0.94901
4.0612e-005	96.213	0.9684
4.1337e-005	97.693	0.98872
4.2019e-005	99.924	1.0074
4.2702e-005	102.78	1.0255
4.3427e-005	106.45	1.0441
4.4109e-005	110.75	1.0612
4.4834e-005	116.17	1.0789
4.5517e-005	121.34	1.0948
4.6242e-005	125.86	1.1103
4.6924e-005	128.58	1.1234
4.7606e-005	129.9	1.1351
4.8332e-005	130.4	1.1462
4.9014e-005	130.74	1.1557
4.9739e-005	131.53	1.1654
5.0421e-005	132.96	1.1745
5.1104e-005	135.24	1.1838
5.1829e-005	138.65	1.194
5.2511e-005	142.47	1.204
5.3236e-005	146.3	1.2151
5.3919e-005	148.7	1.2261
5.4601e-005	149.32	1.2378
5.5326e-005	147.98	1.2511

5.6009e-005	145.3	1.2644
5.6734e-005	141.7	1.2789
5.7416e-005	138.33	1.2921
5.8141e-005	135.39	1.3053
5.8823e-005	133.78	1.3172
5.9506e-005	133.66	1.3287
6.0231e-005	135.04	1.3412
6.0913e-005	137.04	1.3533
6.1638e-005	138.8	1.3666
6.2321e-005	139.23	1.3796
6.3003e-005	138.08	1.393
6.3728e-005	135.23	1.4078
6.4411e-005	131.43	1.4221
6.5136e-005	126.72	1.4375
6.5818e-005	123.84	1.4522
6.65e-005	123.73	1.4672
6.7225e-005	123.54	1.4835
6.7908e-005	123.19	1.4995
6.8633e-005	122.54	1.5171
6.9315e-005	121.62	1.5342
7.004e-005	120.27	1.5528

Table 5.9: step wise values of equivalent stress in bumper made of AFRP.

5.1.3.3 Equivalent elastic strain in bumper made of AFRP

Maximum equivalent elastic strain = 6.0339×10^{-2}

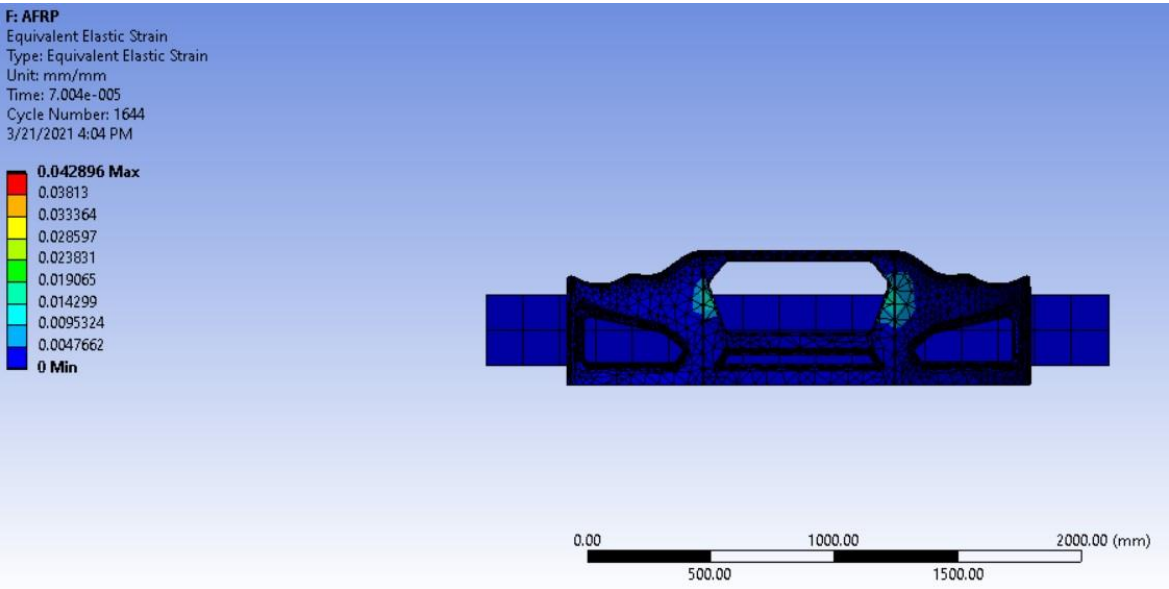


Fig 5.16: Equivalent elastic strain in bumper made of AFRP

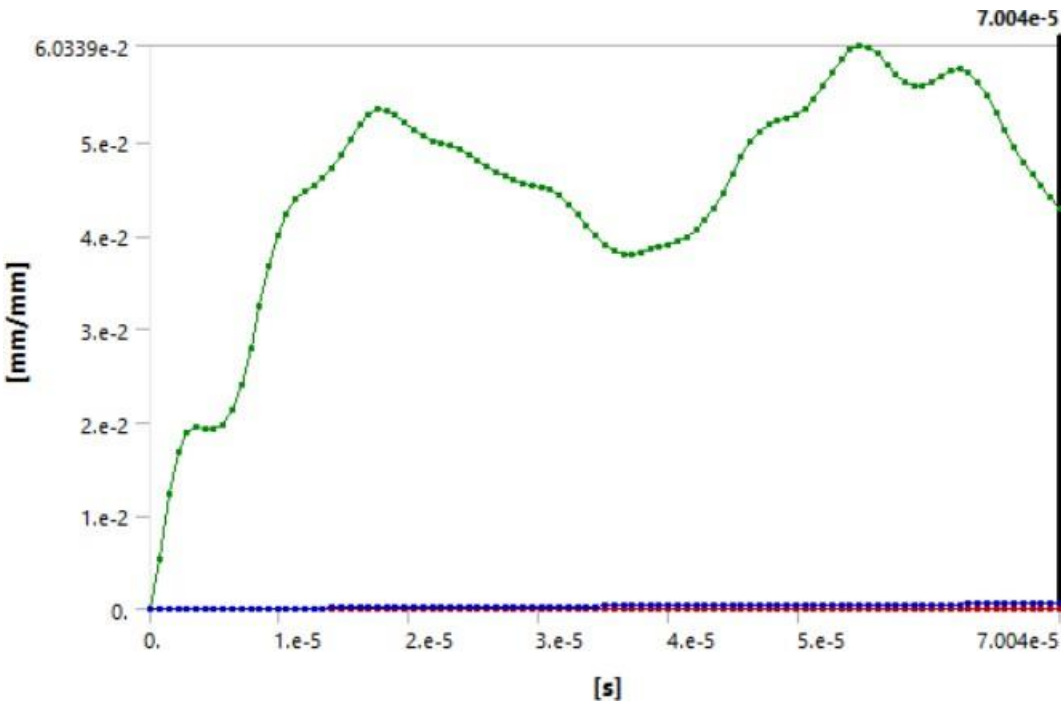


Fig 5.17: graph for Equivalent elastic strain in bumper made of AFRP

The below table gives step wise details of Equivalent elastic strain in bumper made of AFRP

Time [s]	Minimum [mm/mm]	Maximum [mm/mm]	Average [mm/mm]
1.1755e-038	0.	0.	0.
7.3434e-007		5.3353e-003	2.6132e-006
1.4167e-006		1.23e-002	6.4109e-006
2.1418e-006		1.6821e-002	9.8972e-006
2.8242e-006		1.8963e-002	1.3005e-005
3.5066e-006		1.9547e-002	1.6037e-005
4.2316e-006		1.9334e-002	1.9292e-005
4.914e-006		1.9212e-002	2.2625e-005
5.6391e-006		1.9767e-002	2.6542e-005
6.3215e-006		2.1261e-002	3.267e-005
7.0039e-006		2.395e-002	3.9883e-005
7.7289e-006		2.7993e-002	4.6634e-005
8.4113e-006		3.2327e-002	5.231e-005
9.1364e-006		3.6699e-002	5.9006e-005
9.8188e-006		4.0042e-002	6.4466e-005
1.0501e-005		4.2369e-002	7.0415e-005
1.1226e-005		4.3859e-002	7.7927e-005
1.1909e-005		4.468e-002	8.475e-005
1.2634e-005		4.5344e-002	9.1702e-005
1.3316e-005		4.6077e-002	9.8107e-005
1.4041e-005		4.7219e-002	1.0505e-004
1.4723e-005		4.8673e-002	1.1273e-004
1.5406e-005		5.034e-002	1.2004e-004
1.6131e-005		5.1973e-002	1.2696e-004
1.6813e-005		5.305e-002	1.3282e-004
1.7538e-005		5.354e-002	1.385e-004
1.8221e-005		5.3429e-002	1.4305e-004
1.8903e-005		5.2899e-002	1.474e-004
1.9628e-005		5.2103e-002	1.5243e-004
2.0311e-005		5.1321e-002	1.5799e-004
2.1036e-005		5.0607e-002	1.6478e-004
2.1718e-005		5.0132e-002	1.7178e-004
2.24e-005		4.9835e-002	1.7911e-004
2.3125e-005		4.9589e-002	1.8695e-004
2.3808e-005		4.9264e-002	1.9423e-004
2.4533e-005		4.8719e-002	2.0177e-004
2.5215e-005		4.8067e-002	2.0873e-004
2.594e-005		4.7351e-002	2.1611e-004

2.6623e-005	4.6759e-002	2.231e-004
2.7305e-005	4.6285e-002	2.3011e-004
2.803e-005	4.5897e-002	2.376e-004
2.8713e-005	4.5631e-002	2.4481e-004
2.9438e-005	4.5428e-002	2.5267e-004
3.012e-005	4.5236e-002	2.6028e-004
3.0802e-005	4.4918e-002	2.6797e-004
3.1528e-005	4.4293e-002	2.76e-004
3.221e-005	4.3397e-002	2.8327e-004
3.2935e-005	4.2225e-002	2.906e-004
3.3617e-005	4.1067e-002	2.9718e-004
3.4342e-005	3.9932e-002	3.0391e-004
3.5025e-005	3.9039e-002	3.1013e-004
3.5707e-005	3.8375e-002	3.163e-004
3.6432e-005	3.7995e-002	3.2291e-004
3.7115e-005	3.7954e-002	3.2923e-004
3.784e-005	3.8168e-002	3.3606e-004
3.8522e-005	3.8482e-002	3.4258e-004
3.9204e-005	3.8784e-002	3.4908e-004
3.993e-005	3.907e-002	3.5578e-004
4.0612e-005	3.9385e-002	3.6179e-004
4.1337e-005	3.989e-002	3.6792e-004
4.2019e-005	4.0611e-002	3.7358e-004
4.2702e-005	4.1596e-002	3.7926e-004
4.3427e-005	4.296e-002	3.854e-004
4.4109e-005	4.4569e-002	3.9126e-004
4.4834e-005	4.6524e-002	3.9746e-004
4.5517e-005	4.8363e-002	4.0306e-004
4.6242e-005	5.0029e-002	4.0863e-004
4.6924e-005	5.1157e-002	4.1345e-004
4.7606e-005	5.186e-002	4.1789e-004
4.8332e-005	5.2285e-002	4.2225e-004
4.9014e-005	5.2578e-002	4.2617e-004
4.9739e-005	5.2986e-002	4.3029e-004
5.0421e-005	5.3613e-002	4.3427e-004
5.1104e-005	5.4572e-002	4.3841e-004
5.1829e-005	5.5948e-002	4.4303e-004
5.2511e-005	5.743e-002	4.4756e-004
5.3236e-005	5.8908e-002	4.5247e-004
5.3919e-005	5.991e-002	4.5706e-004
5.4601e-005	6.0339e-002	4.6155e-004
5.5326e-005	6.013e-002	4.6616e-004
5.6009e-005	5.9425e-002	4.7034e-004

5.6734e-005	5.8373e-002	4.7457e-004
5.7416e-005	5.735e-002	4.7839e-004
5.8141e-005	5.6471e-002	4.823e-004
5.8823e-005	5.6017e-002	4.8599e-004
5.9506e-005	5.6023e-002	4.8985e-004
6.0231e-005	5.6477e-002	4.943e-004
6.0913e-005	5.7111e-002	4.988e-004
6.1638e-005	5.7671e-002	5.0386e-004
6.2321e-005	5.7808e-002	5.0879e-004
6.3003e-005	5.7408e-002	5.139e-004
6.3728e-005	5.6373e-002	5.1955e-004
6.4411e-005	5.4932e-002	5.251e-004
6.5136e-005	5.3096e-002	5.3112e-004
6.5818e-005	5.1269e-002	5.368e-004
6.65e-005	4.9514e-002	5.4245e-004
6.7225e-005	4.7856e-002	5.4849e-004
6.7908e-005	4.6523e-002	5.543e-004
6.8633e-005	4.528e-002	5.6069e-004
6.9315e-005	4.4153e-002	5.669e-004
7.004e-005	4.2896e-002	5.7363e-004

Table 5.10: step wise details of Equivalent elastic strain in bumper made of AFRP

5.1.4 ALUMINIUM ALLOY

Assuming that the bumper is made of Aluminum alloy the bumper is made impact with fixed wall made of structural steel and the following results are produced.

5.1.4.1 Total Deformation in bumper made of Al alloy

Maximum Deformation = 2.0681 mm

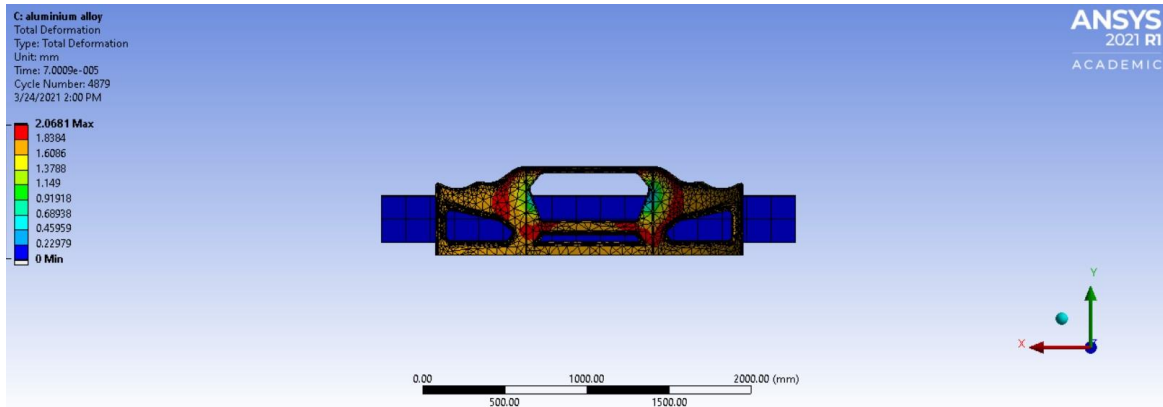


Fig 5.18: Total deformation in Al Alloy

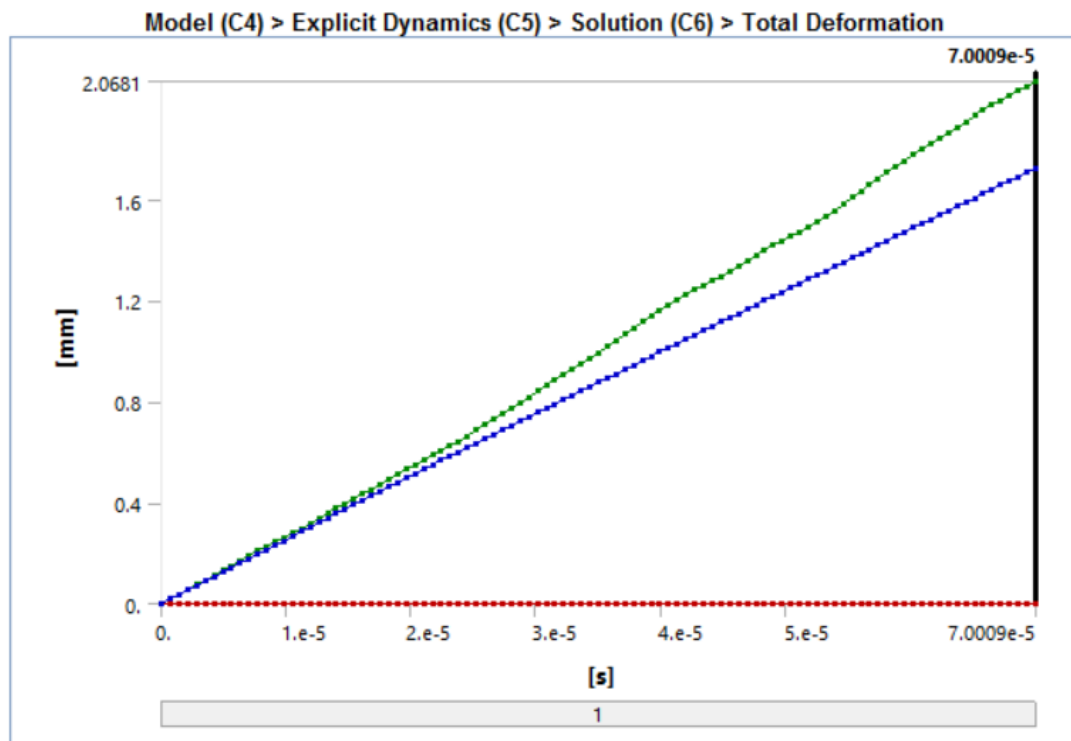


Fig 5.19: Total deformation graph of bumper made of Aluminum alloy

Below table is a step-by-step value of total deformation of bumper made of Aluminium alloy:

Time [s]	Minimum [mm]	Maximum [mm]	Average [mm]
1.1755e-038	0.	0.	0.
7.0648e-007		1.7799e-002	1.732e-002
1.4098e-006		3.6656e-002	3.4558e-002
2.1132e-006		5.6215e-002	5.1793e-002
2.8022e-006		7.4771e-002	6.8675e-002
3.5055e-006		9.1182e-002	8.5907e-002
4.2089e-006		0.10933	0.10313
4.9122e-006		0.1274	0.12036
5.6012e-006		0.14523	0.13723
6.3046e-006		0.16408	0.15444
7.0079e-006		0.18306	0.17165
7.7113e-006		0.20123	0.18885
8.4003e-006		0.2183	0.20569
9.1036e-006		0.23484	0.22287
9.807e-006		0.25162	0.24004
1.051e-005		0.26875	0.2572
1.1214e-005		0.28644	0.27434
1.1903e-005		0.30521	0.29111
1.2606e-005		0.32429	0.3082
1.3309e-005		0.34344	0.32528
1.4013e-005		0.36191	0.34233
1.4702e-005		0.38038	0.35901
1.5405e-005		0.39917	0.37603
1.6108e-005		0.41698	0.39304
1.6812e-005		0.43545	0.41003
1.7501e-005		0.45444	0.42667
1.8204e-005		0.47366	0.44364
1.8907e-005		0.49275	0.46058
1.9611e-005		0.5117	0.47752
2.0314e-005		0.53044	0.49444
2.1003e-005		0.54849	0.511
2.1706e-005		0.56656	0.52789
2.241e-005		0.58427	0.54477
2.3113e-005		0.60169	0.56163
2.3802e-005		0.61848	0.57813
2.4506e-005		0.63694	0.59496
2.5209e-005		0.65797	0.61175

2.5912e-005	0.67877	0.62852
2.6601e-005	0.69908	0.64491
2.7305e-005	0.72011	0.66163
2.8008e-005	0.7401	0.67831
2.8711e-005	0.76234	0.69498
2.94e-005	0.78424	0.71128
3.0104e-005	0.80634	0.7279
3.0807e-005	0.8281	0.7445
3.151e-005	0.84944	0.76108
3.2214e-005	0.87028	0.77764
3.2903e-005	0.8901	0.79386
3.3606e-005	0.90962	0.81039
3.4309e-005	0.92833	0.82691
3.5013e-005	0.9513	0.84342
3.5702e-005	0.97585	0.85958
3.6405e-005	1.0006	0.87607
3.7108e-005	1.0249	0.89256
3.7812e-005	1.0487	0.90905
3.8501e-005	1.0714	0.92521
3.9204e-005	1.0939	0.9417
3.9907e-005	1.1157	0.95819
4.0611e-005	1.1366	0.97466
4.1314e-005	1.1568	0.99113
4.2003e-005	1.1757	1.0072
4.2706e-005	1.1942	1.0237
4.341e-005	1.2122	1.0401
4.4113e-005	1.2298	1.0565
4.4802e-005	1.2468	1.0726
4.5506e-005	1.2639	1.089
4.6209e-005	1.281	1.1054
4.6912e-005	1.3027	1.1218
4.7601e-005	1.3233	1.1378
4.8305e-005	1.3434	1.1541
4.9008e-005	1.3628	1.1705
4.9711e-005	1.3815	1.1868
5.04e-005	1.3991	1.2028
5.1104e-005	1.4166	1.2192
5.1807e-005	1.4336	1.2355
5.251e-005	1.4533	1.2519
5.3214e-005	1.4748	1.2682
5.3903e-005	1.4959	1.2842
5.4606e-005	1.5188	1.3006
5.5309e-005	1.543	1.317

5.6013e-005	1.5673	1.3333
5.6702e-005	1.5912	1.3493
5.7405e-005	1.6155	1.3657
5.8108e-005	1.6394	1.3821
5.8812e-005	1.6629	1.3984
5.9501e-005	1.6853	1.4145
6.0204e-005	1.7075	1.4308
6.0907e-005	1.7289	1.4472
6.1611e-005	1.7493	1.4635
6.2314e-005	1.77	1.4799
6.3003e-005	1.7908	1.4959
6.3707e-005	1.8111	1.5123
6.441e-005	1.8334	1.5286
6.5113e-005	1.8552	1.545
6.5802e-005	1.8761	1.561
6.6506e-005	1.8967	1.5773
6.7209e-005	1.9167	1.5937
6.7913e-005	1.936	1.6101
6.8602e-005	1.9542	1.6261
6.9305e-005	1.9722	1.6425
7.0009e-005	1.9896	1.6589

Table 5.11: step-by-step value of total deformation of bumper made of Aluminium alloy

5.1.4.2 Equivalent stress in bumper made of Al Alloy

Maximum Equivalent stress = 1122.5 MPa

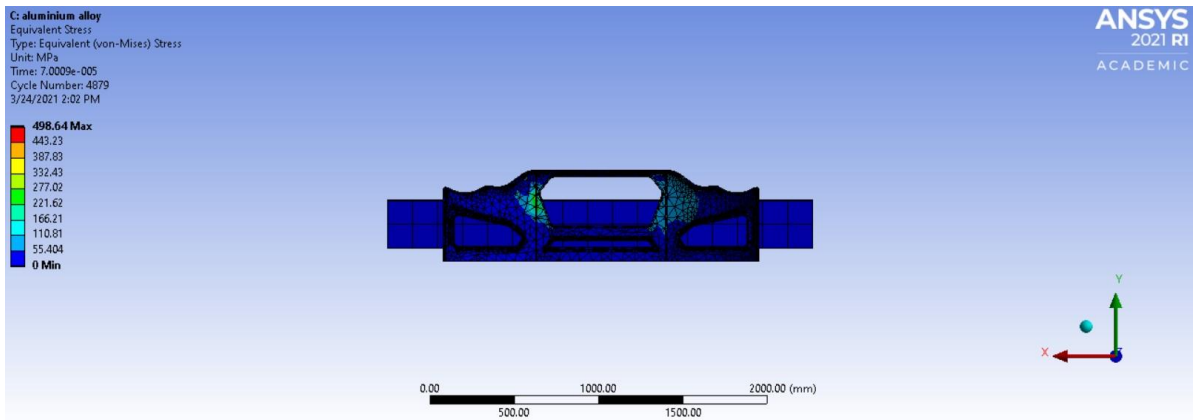


Fig 5.20: Equivalent Stress in Al Alloy

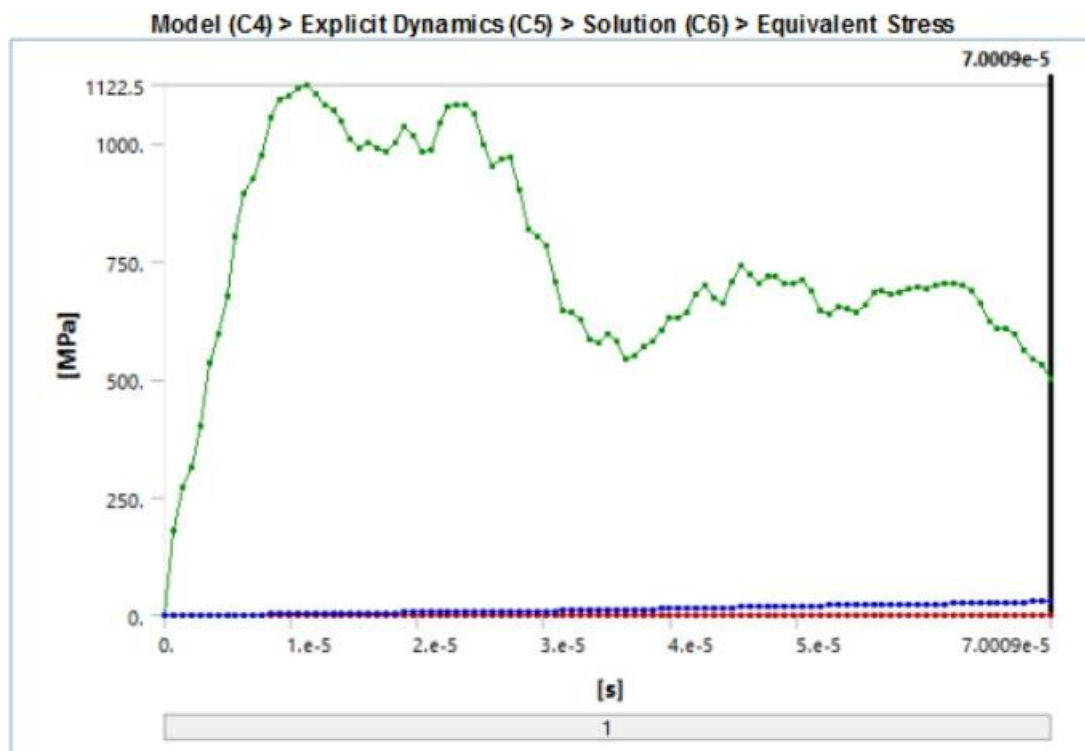


Fig 5.21: graph for equivalent Stress in Al Alloy

The below table shows step wise values of equivalent stress in bumper made of Aluminum alloy.

Time [s]	Minimum [MPa]	Maximum [MPa]	Average [MPa]
1.1755e-038	0.	0.	0.
7.0648e-007		169.88	9.8163e-002
1.4098e-006		259.74	0.23177
2.1132e-006		300.08	0.39137
2.8022e-006		382.79	0.54331
3.5055e-006		512.57	0.6569
4.2089e-006		571.53	0.76526
4.9122e-006		648.79	0.92325
5.6012e-006		768.7	1.1001
6.3046e-006		857.84	1.2671
7.0079e-006		888.49	1.4189
7.7113e-006		933.74	1.6324
8.4003e-006		1012.2	1.8788
9.1036e-006		1053.4	2.1208
9.807e-006		1068.4	2.3545
1.051e-005		1087.5	2.5752
1.1214e-005		1100.8	2.8465
1.1903e-005		1085.6	3.0522
1.2606e-005		1069.7	3.2467
1.3309e-005		1063.7	3.4561
1.4013e-005		1044.8	3.7161
1.4702e-005		1009.2	3.9973
1.5405e-005		990.63	4.2693
1.6108e-005		995.84	4.5227
1.6812e-005		979.11	4.7598
1.7501e-005		965.25	5.0015
1.8204e-005		985.98	5.2704
1.8907e-005		1022.7	5.5028
1.9611e-005		1007.8	5.6871
2.0314e-005		968.98	5.8416
2.1003e-005		962.17	5.9738
2.1706e-005		1001.6	6.127
2.241e-005		1030.	6.29
2.3113e-005		1044.	6.4711
2.3802e-005		1062.9	6.6495
2.4506e-005		1054.3	6.7975
2.5209e-005		988.81	6.9463
2.5912e-005		933.1	7.1546
2.6601e-005		947.12	7.4068

2.7305e-005	960.71	7.6622
2.8008e-005	905.37	7.9071
2.8711e-005	829.32	8.1665
2.94e-005	810.97	8.4636
3.0104e-005	790.81	8.7638
3.0807e-005	722.62	9.0413
3.151e-005	665.71	9.3245
3.2214e-005	659.43	9.6389
3.2903e-005	637.24	9.952
3.3606e-005	591.68	10.245
3.4309e-005	580.23	10.551
3.5013e-005	601.4	10.893
3.5702e-005	591.84	11.233
3.6405e-005	560.82	11.585
3.7108e-005	557.4	11.959
3.7812e-005	558.42	12.319
3.8501e-005	560.91	12.649
3.9204e-005	587.35	12.998
3.9907e-005	625.78	13.385
4.0611e-005	626.98	13.783
4.1314e-005	627.38	14.169
4.2003e-005	657.42	14.55
4.2706e-005	683.23	14.946
4.341e-005	661.1	15.319
4.4113e-005	650.47	15.7
4.4802e-005	690.55	16.105
4.5506e-005	728.93	16.522
4.6209e-005	718.26	16.925
4.6912e-005	703.06	17.32
4.7601e-005	715.41	17.714
4.8305e-005	714.56	18.116
4.9008e-005	698.89	18.503
4.9711e-005	702.74	18.863
5.04e-005	720.24	19.187
5.1104e-005	701.53	19.491
5.1807e-005	660.13	19.802
5.251e-005	642.19	20.139
5.3214e-005	649.9	20.465
5.3903e-005	644.56	20.758
5.4606e-005	634.88	21.049
5.5309e-005	648.25	21.332
5.6013e-005	668.38	21.603
5.6702e-005	670.66	21.849

5.7405e-005	665.36	22.078
5.8108e-005	671.23	22.308
5.8812e-005	677.33	22.543
5.9501e-005	674.39	22.785
6.0204e-005	672.36	23.032
6.0907e-005	683.81	23.272
6.1611e-005	691.22	23.539
6.2314e-005	690.67	23.858
6.3003e-005	691.93	24.196
6.3707e-005	690.47	24.541
6.441e-005	667.48	24.892
6.5113e-005	631.74	25.277
6.5802e-005	614.01	25.695
6.6506e-005	616.27	26.142
6.7209e-005	604.58	26.579
6.7913e-005	573.36	27.001
6.8602e-005	551.51	27.418
6.9305e-005	537.04	27.865
7.0009e-005	512.46	28.337

Table 5.12: step wise values of equivalent stress in bumper made of Aluminium alloy

5.1.4.3 Equivalent elastic strain in bumper made Al Alloy

Maximum Equivalent elastic strain = 2.726×10^{-2}

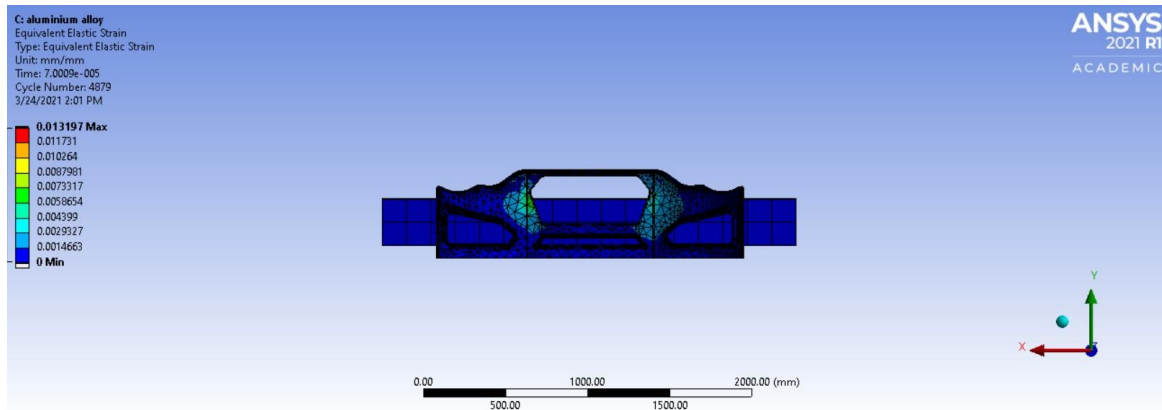


Fig 5.22: equivalent elastic strain in Al alloy

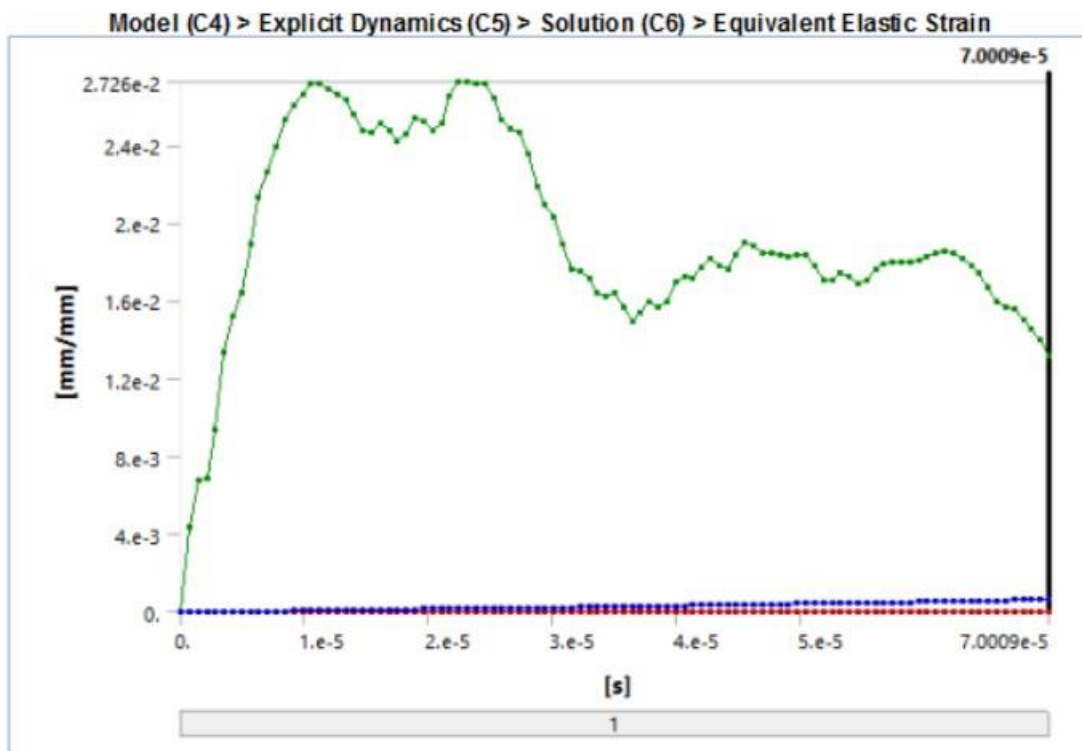


Fig 5.23: graph equivalent elastic strain in Al alloy

The below table gives step wise details of Equivalent elastic strain in bumper made of Aluminum alloy

Time [s]	Minimum [mm/mm]	Maximum [mm/mm]	Average [mm/mm]
1.1755e-038	0.	0.	0.
7.0648e-007		4.1117e-003	2.2104e-006
1.4098e-006		6.515e-003	5.4578e-006
2.1132e-006		6.569e-003	8.766e-006
2.8022e-006		8.9892e-003	1.2571e-005
3.5055e-006		1.2839e-002	1.5921e-005
4.2089e-006		1.4623e-002	1.8497e-005
4.9122e-006		1.5766e-002	2.1625e-005
5.6012e-006		1.8129e-002	2.504e-005
6.3046e-006		2.0438e-002	2.832e-005
7.0079e-006		2.1769e-002	3.2122e-005
7.7113e-006		2.3004e-002	3.7227e-005
8.4003e-006		2.4338e-002	4.2733e-005
9.1036e-006		2.5195e-002	4.7521e-005
9.807e-006		2.591e-002	5.2333e-005
1.051e-005		2.6487e-002	5.7561e-005
1.1214e-005		2.6589e-002	6.389e-005
1.1903e-005		2.6388e-002	6.9995e-005
1.2606e-005		2.6368e-002	7.6077e-005
1.3309e-005		2.619e-002	8.2314e-005
1.4013e-005		2.5484e-002	8.8716e-005
1.4702e-005		2.4696e-002	9.4892e-005
1.5405e-005		2.4543e-002	1.013e-004
1.6108e-005		2.4873e-002	1.0782e-004
1.6812e-005		2.4551e-002	1.1392e-004
1.7501e-005		2.3995e-002	1.1923e-004
1.8204e-005		2.4292e-002	1.2416e-004
1.8907e-005		2.5088e-002	1.2875e-004
1.9611e-005		2.4899e-002	1.3282e-004
2.0314e-005		2.4231e-002	1.3632e-004
2.1003e-005		2.4453e-002	1.3956e-004
2.1706e-005		2.5609e-002	1.431e-004
2.241e-005		2.6262e-002	1.469e-004
2.3113e-005		2.6322e-002	1.5136e-004
2.3802e-005		2.6573e-002	1.56e-004
2.4506e-005		2.6735e-002	1.6024e-004

2.5209e-005	2.6031e-002	1.642e-004
2.5912e-005	2.4859e-002	1.6894e-004
2.6601e-005	2.4404e-002	1.7448e-004
2.7305e-005	2.4397e-002	1.8014e-004
2.8008e-005	2.3588e-002	1.8518e-004
2.8711e-005	2.2062e-002	1.9032e-004
2.94e-005	2.1168e-002	1.9657e-004
3.0104e-005	2.0487e-002	2.0342e-004
3.0807e-005	1.9157e-002	2.0978e-004
3.151e-005	1.7966e-002	2.1601e-004
3.2214e-005	1.7713e-002	2.2253e-004
3.2903e-005	1.7273e-002	2.2922e-004
3.3606e-005	1.6409e-002	2.3594e-004
3.4309e-005	1.6355e-002	2.4307e-004
3.5013e-005	1.6655e-002	2.5039e-004
3.5702e-005	1.5989e-002	2.5687e-004
3.6405e-005	1.5166e-002	2.6346e-004
3.7108e-005	1.5396e-002	2.7086e-004
3.7812e-005	1.5595e-002	2.7794e-004
3.8501e-005	1.5276e-002	2.8396e-004
3.9204e-005	1.5647e-002	2.9045e-004
3.9907e-005	1.6686e-002	2.9758e-004
4.0611e-005	1.6892e-002	3.0457e-004
4.1314e-005	1.6768e-002	3.1127e-004
4.2003e-005	1.7335e-002	3.1831e-004
4.2706e-005	1.7924e-002	3.2599e-004
4.341e-005	1.7569e-002	3.3314e-004
4.4113e-005	1.7294e-002	3.4022e-004
4.4802e-005	1.7963e-002	3.4782e-004
4.5506e-005	1.8739e-002	3.5596e-004
4.6209e-005	1.8735e-002	3.6376e-004
4.6912e-005	1.842e-002	3.7134e-004
4.7601e-005	1.8355e-002	3.7877e-004
4.8305e-005	1.8282e-002	3.8642e-004
4.9008e-005	1.8155e-002	3.942e-004
4.9711e-005	1.8276e-002	4.0189e-004
5.04e-005	1.8492e-002	4.0909e-004
5.1104e-005	1.8062e-002	4.1584e-004
5.1807e-005	1.7284e-002	4.2234e-004
5.251e-005	1.7072e-002	4.2916e-004
5.3214e-005	1.7301e-002	4.3595e-004
5.3903e-005	1.7114e-002	4.4207e-004
5.4606e-005	1.6762e-002	4.4796e-004

5.5309e-005	1.6925e-002	4.538e-004
5.6013e-005	1.7247e-002	4.5982e-004
5.6702e-005	1.7349e-002	4.6581e-004
5.7405e-005	1.7459e-002	4.7205e-004
5.8108e-005	1.7684e-002	4.7839e-004
5.8812e-005	1.7682e-002	4.8433e-004
5.9501e-005	1.7542e-002	4.9009e-004
6.0204e-005	1.7651e-002	4.9637e-004
6.0907e-005	1.7975e-002	5.0278e-004
6.1611e-005	1.8166e-002	5.0956e-004
6.2314e-005	1.8144e-002	5.1695e-004
6.3003e-005	1.801e-002	5.2468e-004
6.3707e-005	1.785e-002	5.3284e-004
6.441e-005	1.7553e-002	5.4098e-004
6.5113e-005	1.6885e-002	5.4947e-004
6.5802e-005	1.6201e-002	5.5863e-004
6.6506e-005	1.5924e-002	5.6859e-004
6.7209e-005	1.5687e-002	5.7853e-004
6.7913e-005	1.5174e-002	5.8814e-004
6.8602e-005	1.4713e-002	5.9752e-004
6.9305e-005	1.4255e-002	6.075e-004
7.0009e-005	1.3502e-002	6.177e-004

Table 5.13: step wise details of Equivalent elastic strain in bumper made of Aluminum alloy

5.2 ASSUMPTIONS MADE

- The momentum is conserved assuming this collision is perfectly elastic.
- Friction between the wall and the bumper is nil.
- Assume that the wall does not bend after collision.
- The kinetic energy is completely converted into strain energy

CHAPTER 6

SUMMARY AND CONCLUSION

In this world of machines and ever-changing technologies we trust in software and computers analysis more than anything else. So, there is no reason to not trust in this report created by a software.

After having seen the results we can conclude that a computer model can be used to predict the impact analysis of a model. Depending on the type of material we give as input the outcome varies vastly. After having a discussion, we agreed that no one material is best in everything.

By looking at the impact analysis we can say that Nylon 6 with MMT is most suitable material for bumper in both terms of strength because it has least deformation of 1.8588mm compared to others, after having an impact.

If we look at Equivalent stress graphs ABS has the least Equivalent stress among others which is 91.269 MPa. So, it absorbs the most of the kinetic energy during collision. So, it is the best material from impact of view.

In terms of designing and molding the material with most machineability should be selected which is Nylon 6 with MMT so that numerous numbers of designs can be made. So, overall we conclude that Nylon 6 is a better alternative material that can be used for bumpers.

CHAPTER 7

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