DEBRE BERHAN UNIVERSITY

Design and analysis of air bag based front bumper system

A Thesis Submitted to Collage of Engineering in Partial Fulfilment of the Requirements for the Degree of Masters of Science in Mechanical Engineering (Motor Vehicle)

By: Abebaw Fentie Zewdu

Thesis Advisor: Dr. B Dayal

Debre Berhan, Ethiopia

October, 2021

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DECLARATION

I hereby, declare that this Master Thesis entitled " Design and analysis of air bag based front bumper system " is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been properly referred and acknowledged through citation.

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Name of the student Signature Date

APPROVAL SHEET

DEBREBRHAN UNIVERSITY

The undersigned thesis committee approves the thesis titled by

Design and analysis of airbag based front bumper system

By:- Abebaw Fentie Zewdu

Approved by Board of Examiner

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Abstract

It is known that safe transportation is one of the biggest concerns of vehicle manufacturers; Automobile accidents threaten human lives and have become a socio-economic problem ,and occupant safety in vehicle accidents is a great challenge. The severity of the crash reflects the energy absorption of the car's structure during the accident and also has a close relationship with the amount of energy absorbed by the restraint system. Among the components involved in the restraint system, the front vehicle bumper is the most common one. In the past, important variables like material, structures, shapes and impact conditions were studied for analysis of the bumper in order to improve its crashworthiness during a collision; but this alternative solution did not face the harmful consiquences of the accident . This study is focused on the design and analysis of an air-bag based bumper system. The Air-bag based bumper system is a new feature in which the front bumper with air-bag is designed and analysed with ANSYS. The outside air-bag system, which is fitted in front car bumper, is designed to improve. In this study mainly, impact analysis performed at moderate speed of 40km/hr, 50km/hr and 60km/hr dynamic explicitly ANSYS package software and comparative study of bumper with air bag system and bumper without air bag system ,energy absorption of the system measured after collision are performed and the energy absorption of the airbag 193KJ, 240KJ and 256KJ at vehicle speed of 40Km/hr,50Km/hr and 60Km/hr with pressure of 2.731 MPa, 3.416MPa and 4.1MPa respectively, but the conventional one absorbed 1.68KJ,2.4KJ and 3.71KJ with external pressure of 2.731MPa, 3.416MPa and 4.1 MPa. Therfore, it conclude that the new airbag based bumper is better energy absorber than the conventional one. The significant of the study is it can reduce loss of human lives, chassis damage of the vehicle due to low transmission of energy to the vehicle body

Keywords: Bumper, bumper with air bag, impact analysis, ANSYS package, Dynamic explicitly

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List of Abbreviations

AIS	Abbreviated Injury Scale
CATIA	Computer Aided Three-Dimensional interactive application
DOE	Design of experiment
E.C.E	Educational Credential Evaluator
FCI	Functional Capacity Index
FEA	Finite element analysis
FMVSS	Federal motor vehicle safety standard
GMT	Glass Mat Thermoplastic
IP	Instrument panel
IPM	Ideal point method
LS-DYNA ANSYS	Live more dynamic explicitly analysis software
SMC	Sheet molding compound

Chapter - 1

1. Introduction

Automobile accidents threaten human lives and have become a socio-economic problem. Accordingly; vehicle safety systems have gained increased attention and have become a prominent area of research and development [1]. An automotive vehicle, which contributes to vehicle crashworthiness or occupant protection during front or rear collisions. It has been known that a front crash in passenger cars is the most fatal accident among traffic mishaps. The bumper systems also protect the hood, trunk, fuel, exhaust and cooling system as well as safety related equipments [2].

A bumper is a car shield made of steel, aluminum, rubber, or plastic that is mounted on the front and rear of a passenger car. When a low speed collision occurs, the bumper system absorbs the shock to prevent or reduce damage to the car. An automotive bumper is the rear most or front most part of the vehicle which is used to protect the passengers inside from the impact during a collision [3].The prime aim of the bumper is to provide the safety and security to the passengers by absorbing the impact energy when low speed collision occurs in the car.

The automobile bumper was originally designed in the early 1900's to protect the front and rear of the vehicle in low-speed accidents. Bumpers were generally unsophisticated but effective a beam held by spring-like supports [4]. These bumper systems did not absorb energy (unless parts were permanently bent or broken under collision forces); rather, they stored energy for release in a rebound motion when struck [4].The first bumper standard issued under the 1966 act was FMVSS 215 exterior protection, which called for passenger cars, beginning with model year 1973, to withstand 5 mph front and 2 1/2 mph rear impacts against a barrier without damage to certain safety related components [5].

The frontal bumper system consists of the following parts: the cover, the mechanical and deformation energy absorber, the bumper reinforcement [5].

Airbags are a type of car safety device that expand when an automobile experiences a collision, offering a cushion of air that prevents an individual from bashing their face on the steering wheel or dashboard. Airbags are commonly fitted in the front seats. One of the primary patents for automobile airbags was awarded to Industrial Engineer, John Hetrick on August 18, 1953. After an accident in 1952, Hetrick planned an airbag, which involves a tank of compressed air beneath the hood and inflatable bags on the steering wheel, in the center of the dashboard and in the glove compartment to guard front-seat occupants and on the back of the front seat to guard rear-seat passengers [6].

Since in the 1960s, airbag-equipped cars in controlled tests and daily use have confirmed effectiveness and reliability. The study has been found by using data from 1985 to 1991 and concluded that driver fatalities in frontal collisions were decreased by 32% in automobiles outfitted with airbags [6].It consists of a flexible fabric bag, also known as air cushion. Designed to protect occupants in frontal crashes, airbags inflates in milliseconds after a crash is detected cushion that protects the body from the hard interior structures of a vehicle as it decelerates.

This study will focuses on automobile front bumper with air bag concept to improve the energy absorption capacity of the bumper at moderate speed impact. In this work both design and impact analysis are carried out and energy absorption measured but the new feature in the air bag comes it to the front bumper to improve the energy absorption by using appropriate material selection of the airbag.

1.1. Statement of Problem

Nowadays, car accidents are the main concern, Passengers are dead and the engine, radiator are also fully damaged due to the lower energy absorption capability of an impacting bumper system this leads to socio-economic crises. The customer also blamed the manufacturer regarding the bumper easily damaged although the collision was slow. The main significance of bumper system is to mainly protect the fender, radiator, engine hood, and lamps when a low-speed impact happens between the automobile and another automobile, but the impact energy is transfered to other components of the automobile when moderate speed or high-speed impact occurs.

1.2. Objective of the study

1.2.1. General objective

Design and analysis of air bag based front bumper system.

1.2.2. Specific objectives

- Design of the airbag based front bumper system.
- 3 –D modeling of air bag based automobile front bumper as well as the conventional bumper
- Energy absorption analysis of the bumper with an air bag and without an air bag using i.e ANSYS.

1.3. Significances of the study

This study will provide a lot of advantages to the researchers, the designers and also the automobile manufacturers. From many, the following are:

- It will help to the improve safety of passengers and the vehicle body during a front crash at moderate speed range.
- It will contribute to automobile technology with new features on the front bumper.
- It will contribute to reducing the maintenance cost of vehicle structure.
- It will help to motivate researchers to conduct addation research on high speed impact and energy absorption capacity.

1.4. Scope of the study

The study will focus on the design of an air bag based front bumper system in which the designed air bag and its inflation are based on the pressure which is obtained from the numerical analysis of the airbag. In this work, a comparative study has been performed for air bag based automobile bumpers and those without airbags. An impact analysis using the dynamic explicitly ANSYS package has been performed for the energy absorption analysis.

The scope of the present study has been delineated as follows;

- The study will focus only on the front bumper with an airbag.
- The study does not cover the side collision as well as the rear collision .
- The scope of this study does not include experimental validation or physical prototype.

1.5. Organization of the thesis

This study is organized in six chapters.

Chapter one: it outlines the introduction , the general idea of the researches and statement of the problems, the scopes of the study, the objectives of the study as well the significant of the study.

Chapter two: deal with literature review from previous studies for both bumper and airbag system.

Chapter three: deal with about material and methodology of the studyin addition to that load diturmination the airbag model are discussed.

Chapter four: Finite element impact simulation , mesh , boundary condtion and procedure using ansys software was briefly discussed and presented.

Chapter five: Results obtiand from the impact analysis using ansys software 2020R_2 are presented and discussed briefly.

Chapter six: Finally the conclusion , recommendations and future work are presented.

Chapter - 2

2. Literature Review

Hosseinzadeh RM *et.al* studied that bumper beams are one of the main structures of passenger cars that protect them from front and rear collisions. In this paper, a commercial front bumper beam made of glass mat thermoplastic (GMT) is studied and characterized by impact modeling using LS-DYNA ANSYS 5.7 according to the E.C.E. UNITED NATIONS AGREEMENT Uniform Provisions concerning the Approval of Vehicles with regards to their Front and Rear Protective Devices (Bumpers, etc.), E.C.E., 1994]. The researcher mainly focus three main design factors for this structure: shape, material and impact conditions are studied and the results are compared with conventional metals like steel and aluminum. Finally conclude that factors are characterized by proposing a high strength SMC bumper instead of the current GMT [7].

Marzbanrad JM *et.al* discussed the most important parameters including material, thickness, shape and impact condition are studied for design and analysis of an automotive front bumper beam to improve the crashworthiness design in low-velocity impact. The simulation of original bumper under condition impact is according to the low speed standard of automotives stated in E.C.E. United Nations Agreement Regulationno.42, 1994. In this study the bumper beam analysis is accomplished for composite and aluminum material to compare the weight and ,a front bumper beam made of three materials: aluminum, glass mat thermoplastic (GMT) and high-strength sheet molding compound(SMC)is studied by impact modeling to determine the deflection, impact force, stress distribution and energy-absorption behavior. The mentioned characteristics are compared to each other to find best choice of material, shape and thickness .The results show that a modified SMC bumper beam can minimize the bumper beam deflection, impact force and stress distribution and also maximize the elastic strain energy [8].

Butler M *et.al* did that to increase crash performance in automotive vehicles it is necessary to use new techniques and materials. Components linked to crash safety should transmit or absorb energy. In this study energy absorbing capability of a specific component with combination of geometry and material properties were studied. For these components the chosen material should have high yield strength and relatively high elongation to fracture. This property increase interest in the use of high strength stainless steels [9].

O. G. Lademo *et.al* discussed about a rib-reinforced thin-walled hollow tube-like beam (named as rib-reinforced beam) is presented for potential application in vehicle bumper. Through numerical simulation of the bending behavior under impact loads, the rib-reinforced beam is compared with thin-walled hollow tube-like beams filled with and without foam materials (empty beam and foam- filled beam) in crashworthiness. The effects of the shape of the reinforced rib are investigated and the shape optimization design is performed for increasing energy absorption and reducing the initial peak force. A multi-objective crashworthiness optimization formulation including maximum energy absorption, maximum specific energy absorption and minimum initial peak force is constructed based on the ideal point method (IPM). The optimum configuration of the reinforced rib is given with a normalized cubic spline function. Numerical example results show that, compared with the empty and foam-filled beams with same weights, the optimized rib-reinforced beam has higher energy absorption performance and lower initial crash force. It is found that for the rib- reinforced beam little rumple is formed around the compressed indention, which helps to retard the collapse of the side wall and means more energy absorption [10].

Ramazan Karakuz *et.al* has conducted the research on the damage prediction in glass/epoxy laminates subjected to low velocity impact loading using both numerical simulation and experimental laboratory analysis. The experimental laboratory test was done by using Fractures plus impact testing machine using 20 J of impact energy. In their paper the impact behavior of unidirectional laminated glass/epoxy composite plates with [0/±θ/90]s fiber orientation is investigated numerically equal energy of 40J, equal velocity 2m/s and equal imp actor mass 5kg. In order to examine the stacking effect, they chose five different ± θ fiber directions (15°, 30°, 45 °, 60° and 75°).Three different plate thicknesses at 2.9 mm, 5.8 mm, and 8.7 mm are also selected to survey the thickness effect on impact behavior of glass/epoxy composite plates. A transient finite element code 3D impact is used for numerical analysis in order to calculate the stress and contact forces according to composite plate during impact events. It can also be used for predicting the threshold of impact damage and initiation using choi and change failure/damage criteria. In this code an eight- point brick element and the direct gauss quadrature integration scheme are used by authors through the element thickness to account for the change in material properties from layer to layer. The Newmark scheme is also adopted to perform time integration step by step. In addition a contact law incorporated with the Newton raphson method is applied to calculate the contact forces during impact. Finally the researchers are compared the numerical results with the experimental study and it conclude that they are in good agreement with the experimental results [11].

Manideep Kumar *et al* studied about Design Optimization of Passenger Car Front Bumper .Now a day Increasing demand to the comfortable cars in low cost make the car makers try to reduce cost for potential components in a car. The dynamic crash sequence of vehicle is progressive in nature. The initial contactor (Bumper or Side Beam) deforms first, then the next structural component and the following component until the energy is absorbed. The initial contactors must be designed to withstand the anticipated crush loads for the various defined impact speeds from defined impact directions. The Insurance companies will evaluate the vehicle performance on frontal crash into a full width fixed barrier as most of the accidents occur due to frontal crash. The main aim of bumper is to absorb energy in case of a collision. Different materials have been used to develop these shock-absorbing capabilities, such as steel, aluminum, glass mat thermoplastics and sheet molding compound. The purpose of this study was to design a bumper which is to improve crashworthiness of the bumper beam. Crashworthiness is the ability of the bumper beam to prevent occupant injuries in the event of an accident and this is achieved by minimizing the impact force during the collision. This study was investigated the difference of producing bumper beam using roll forming method compare to stamping method. Based on observations design improvements will be made in terms of shape, size and or material based on design modification objectives. The study was focused on existing design performance, advantage and limitations. Modified front bumper design will be tested using FEM software for impact loads as per international standards[12].

Habtamu Molla studied on Automobile Bumper Beam Analysis to Improve Energy Absorption. The main purpose of this paper is to design a bumper beam which is to improve crashworthiness of the bumper and analyzes the impact behavior of a composite car bumper beam made from s-glass fiber reinforced epoxy composite materials with a volume fraction 60% fiber and 40% matrix. The vehicle model used was lifan 520 model bumper beam is replaced with composite bumper. The internal energy which is absorbed by steel material is 1200.9 J where the composite material is 1960 J which is 38.7 % higher than that of steel which is done by ANSYS. It concluded that s glass fiber reinforced epoxy composite has better energy absorption capacity than steel material and fiber reinforced plastic material is a suitable material for manufacturing the bumper [13].

Motgi *et.al* studied about Design Improvement in front Bumper of a Passenger Car using Impact Analysis. The objective is the design improvements in the front bumper of passenger cars in India, using impact analysis. The analysis made for finding the effects of size, shape, and materials on automobile bumper and the parameters such as deflection and stress. As per International Standard, speed is considered and it depends on the FEA results. Using CATIA the design of car bumper is modeled and using Optistruct solver the analysis has been carried out. It concluded that the automobile bumper of second design with 4mm thickness shows the best result compare with first design under the impact analysis [14].

Srikantha *et.al* studied about Impact analysis of toyota land cruiser Car Bumper using ANSYS AUTODYN 3D. Customer safety is the first priorit and occupant safety is prime most fidelity of the automotive industries. Bumper is the first component to take part in frontal crash or impact during accident hence its important component to be designed and analyzed for the crashworthiness of the vehicle during frontal accident. the researcher worked on three cases. Case-1 Explicit dynamic Analysis of bumper with steel material and which shows safety of passengers and engine components and observed maximum deformation for initial velocity 33 m/s. Deformation at this speed is sustainable 10.6 mm. But speed increases 40m/s, 48m/s and observed deformation is 15.13mm and 19.76mm, the respective von mises stresses is increases. Hence stress is very high which will surely fails the material but energy absorbed before it fails. From Case-2 Explicit dynamic Analysis of bumper with PEI composite material and this shows bumper really fails at lower speed of frontal impact than the required speed so PEI found to be less sustainable to the high speeds. The initial speed is 33m/s and respective deformation is 10.74mm. The speed is increases to 40m/s and 48 m/s, their respective deformation is 12.13mm and 15.13mm, the respective von mises stresses of 2777Mpa and 3842Mpa respectively. Stress induced is very low compare to steel material. From Case-3 Explicit dynamic Analysis of bumper with S2Glass epoxy composite material and gives the deformation of 11.95mm for the initial speed of 33m/s with von mises stress 1127 Mpa. The speed increases to 40m/s and 48m/s, their respective deformation is 15.96 and 19.97mm, the respective von mises stresses of 31781Mpa and 52302 Mpa. Stress induced is high compare to steel. The above three cases are analyzed for various speeds staring from 33m/s,40m/s and 48m/s based on the standards as the highest speed of the vehicle is 172Km/hr [15].

P durga *et.al* in their study researcher worked on Impact analysis and material optimization of a front bumper in a heavy vehicle automobiles, a bumper is usually a metal bar or beam, attached the vehicle's front-most and rear-most ends, designed to absorb impact in a collision. The fuel efficiency and emission gas regulation of passenger cars are two important issues currently. The best way to increase the fuel efficiency without sacrificing safety is to employ fiber reinforced composite materials in the cars. Bumper is the one of the part having more weight. Fuel efficiency is the biggest design parameter of all heavy transport vehicles.The material used in their study Steel, composite and Honey Comb. The maximum deformation of the bumper when the material steel was 29.752 mm and the deformation when the material honey comb was 22.158mm,therefore honey comb material better regarding to deformation [16].

Mangesh P *et.al* studied about vibration and impact analysis of optimized automotive front bumper .mainly safety is the major concern in automotive engineering due to the case of rate of accident increasing worldwide. Mostily, in most of the accident during front collision bumper hits the other vehicle. The main function of front bumper is to absorb the possible crash energy during collision and should have low weight apart from the safety. In automobile industries importance also given to fuel efficiency and emission gas regulation, that gives advantage to manufacturer in weight reduction of automotive. The main factor affecting bumper like shape optimization, impact condition & vibration are studied for design and analysis of front bumper to improve cross worthiness. In this study shape geometry was studied to design the optimized structure of bumper and impact behaviour analysis is carried on it to find out energy absorption capacity also easiness of manufacturing studied parallelly. In this research, impact dynamic behaviour analysis of optimized front bumper without stiffener and with stiffener are carried out and compare their result against stress distribution, energy absorption, deformation and found that bumper with stiffener have more energy absorption capacity. Experimentally validate the natural frequencies obtained from FFT analyzer with Modal analysis using FEA software and those are closely matched. While building the prototype, found that designed bumper structure is easy to manufacture too [17].

Research gap in previous investigation on bumper

Many researchers' worked on material optimization, design modification regarding to the low speed collision which is done by pendulum test. There is a lack of researches on the moderate and high speed impact analysis. On the whole, after evaluating all the concerned research work, a conclusion can be made that the safety of the passenger needs to be increased.

Dr. Maria Segui-Gomez conducted a study entitled "Driver Air Bag Effectiveness by Severity of the Crash". "The goal of this analysis is to provide net effectiveness estimates of the driver-side air bag in preventing fatal and nonfatal injuries in frontal and near frontal crashes by severity of the crash, while controlling for characteristics known to influence the frequency and severity of injuries, such as age and sex of the driver, vehicle size and mass, and safety belt use". For this analysis, the data used was from the CDS years 1993-1996. Injuries/fatalities were measured using the Abbreviated Injury Scale (AIS), the Injury Severity Score (ISS), and the Functional Capacity Index (FCI). A multivariate logistic regression was conducted. Analysis originally pertained to airbag deployment, but was also run with regard to airbag presence and in both cases results were the same [18].

Amir Nazari and Behrouz Nourozi studied on Behavioral Analysis of Volvo Cars Instrument Panel during Airbag Deployment. Various component tests are to be performed in the sled environment, as opposed to a real vehicle, to save costs. Various modules are added to the sled once their behavior is verified by testing and in simulations. LS-DYNA is used for explicit finite element simulations of the instrument panel (IP) in question with different airbag models. Verification has been achieved by design of experiment (DOE); with tests conducted to capture both the movements of the airbag housing and IP movements in response. These movements are broken down in various phases, facilitating implementation in the sled environment [19].

Saeed barbat *et.al* performed the study on Bumper and Grille Airbags Concept for Enhanced Vehicle Compatibility in Side Impact. Analytical and numerical methods and hardware testing were used to help develop the deployable external airbags concept. Various Finite Element (FE) models at different stages were developed and an extensive number of iterations were conducted to help optimize airbag and inflator parameters to achieve desired targets. The concept development was executed and validated in two phases. This paper covers Phase II ONLY, which includes: (1) Re-design of the airbag geometry, pressure, and deployment strategies; (2) Further validation using a Via sled test of a 48 kph perpendicular side impact of an SUV-type impactor against a stationary car with US-SID-H3 crash dummy in the struck side; (3) Design of the reaction surface necessary for the bumper airbag functionality. This concept focused on feasible such as packaging of the airbags, inflators, and reaction surface. Most importantly, airbags deployment is irreversible and requires very reliable and robust pre-crash sensors in all weather conditions and day or night. Currently, these types of pre-crash sensing systems are not available for the automotive environment [20].

Research gap in previous investigation on air bag

From the above paper, it has been observed that most of the researcher focused only on test and effective implementation of the existing air bag system but very less has focused on the control mechanism. Therefore, this study will make an attempt some of the gaps, which has not been addressed through a control mechanism of external air bag system to the front bumper. The airbag system has been designed integrating with the front bumper to increase the energy absorption capacity at moderated speed impact.

Chapter - 3

3. Research Methodology

The methodology, which follow to achieve the objective of this study are:

- A relevant data analysis through literature review.
- Perform numerical calculation and design of the airbag geometry, pressure, and deployment strategy for airbags based on the automobile front bumper.
- 3-D modeling of an air bag based front bumper beam and a bumper beam without airbag using Catia V5 modeling software.
- Impact analysis of the front bumper with and without airbag was carried out at vehicle speeds of 40km/hr, 50km/hr and 60km/hr.
- Result and discussion.
- Finally, the conclusion and recommendations.

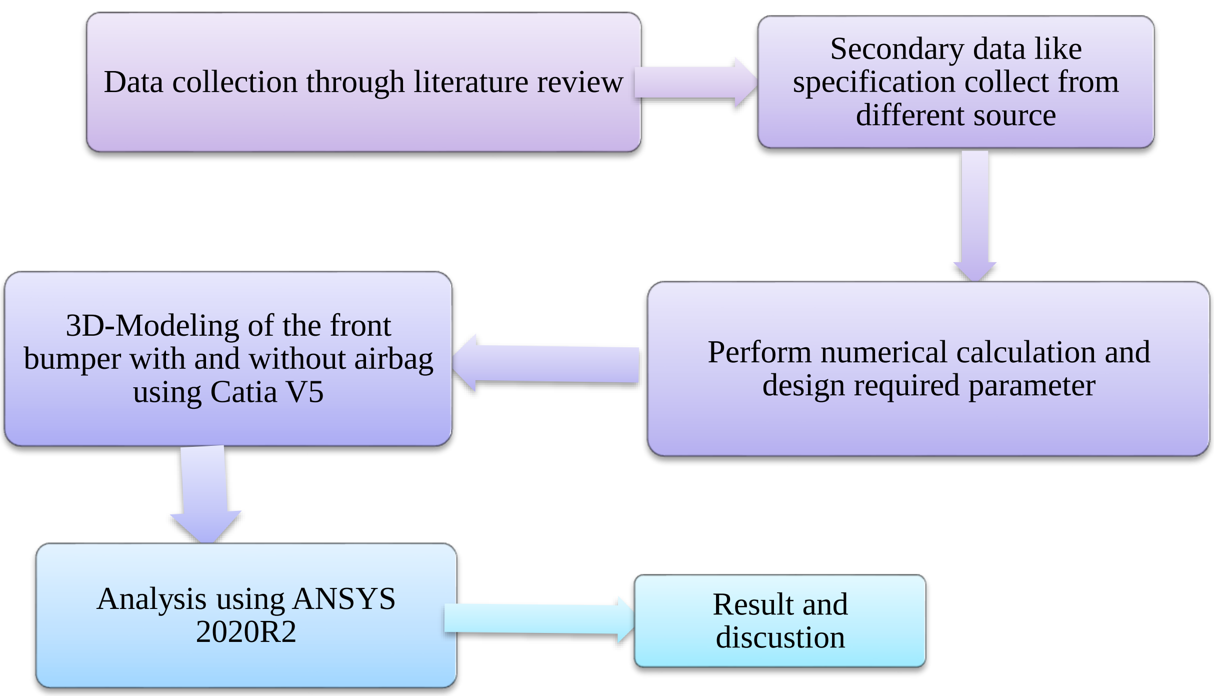


Figure 3.1 Methdology of the study

3.1. Concepts of the study

The concept of the system in the airbag based bumper system according to this study, the system has three units; the control unit, the inflator and pre-crash sensor. Hence, the first component of the airbag system is pre-crash sensor that can detect the speed of the front vehicle and also calculate the distance between the impactor and the impacting vehicle, and send the message to the control unit to deploy the airbag with nitrogen gas before crash happened. But in this study it covers the energy absorption capacity and deformation as airbag design in deployed position with internal pressure.

3.2. Material and method

Determining of the right material during the selection process is very important in automobile components. Selection of a suitable material in bumper beam development is crucial, bad selection may cause poor performance, and it leads to frequent maintenance or failure. Proper material selection for bumper beam requires information about type of loading (axial, bending, torsion or their combination), mode of loading (static, dynamic, fatigue, impact), operating environment [21]. Basically there are two approaches for material selection of the bumper beam. Due to the cost of manufacturing of the bumper beam, the designers usually attempt to find the most consistent material for the available process that offers the desired properties. Otherwise, the material selected initially and the optimized favorable manufacturing process developed to achieve the desired performance. Inappropriate material selection and manufacturing method may lead to product failure, performance reduction, and cost increment [22].

Basically in this study comparative study method used in which the existing material commercial steel used for the front bumper and appropriate material selected which used for used for the new feature airbag based bumper system. The selection of material for the automotive front bumper depends on the following common factors. Some of them are:

- Able to absorb more energy while in collision
- Easy for large-scale manufacturing
- High resistance to corrosion
- Availability of material
- Light in weight
- Low cost
- High performance

3.2.1. Energy absorption

In general, energy cannot be created or destroyed, but it can be changed from one form of energy to another form. During an impact or crash, energy absorption occurs, which the impact converts into the internal potential energy of a system. Theoretical calculation of energy absorption can be calculated using impact theory [23].

The main factor in the selection of the material for the front bumper is the ability of the material to absorb the kinetic energy of a collision. The capability of the material to absorb energy during a collision is called impact strength. Impact strength is defined as the mechanical measure of the material to absorb energy during impact.

3.2.2. Performance

Performance is defined as the ability of the material to stay rigid during an impact. The two common factors that determine the performance of the material are the flexural strength and flexural modulus. Flexural strength is defined as the ability of a material to withstand failure during bending. Flexural modulus is defined as the capability of the material to resist bending or deflection. Flexural strength is also commonly known as the stiffness of the material [24].

3.2.3. Service conditions

As the bumper is exposed to different kinds of weather conditions, the engineers must make sure that the bumper material should be resistant to different kind of weather conditions. The two basic material properties that must be considered for the bumper material are resistant to corrosion and water absorption capacity. As the name suggests, resistant to corrosion is the ability of the material to resist corrosion. Water absorption is defined as the amount of water absorbed by a material.

3.2.4. Availability of the material

The availability of the material can be described into two ways; namely the availability of the raw materials and the basic information about the raw materials. The information regarding the materials is very essential for the designer during the design process.

3.3. Existing automobile front bumper

The automobile selected for this study purpose was lifan 520 model released in 2011. The bumper of the existing model had steel bumper.

3.3.1. AISI 1006 steel steels

The material used in the existing automobile bumper is AISI 1006 Steel containing mainly carbon as the alloying element are called carbon steels. They contain about 0.4% silicon and 1.2%

manganese. Chromium, nickel, aluminum, copper and molybdenum are also present in small quantities in the carbon steels. The features of AISI 1006 carbon steel are mainly softness and ductility. The following datasheet will provide more details about AISI 1006 carbon steel [26].

Table 3.1.Properties of Steel 1006 [26]

Property	Value
Density	7896 Kg/m^3
Yield Strength	350 *MPa*
Hardening Constant	275 *MPa*
Hardening Exponent	0.36
Strain rate constant	0.022
Melting Temperature	1538 *0C*
Shear Modulus	81.8 *GPa*
Specific Heat	452 *J/Kg*

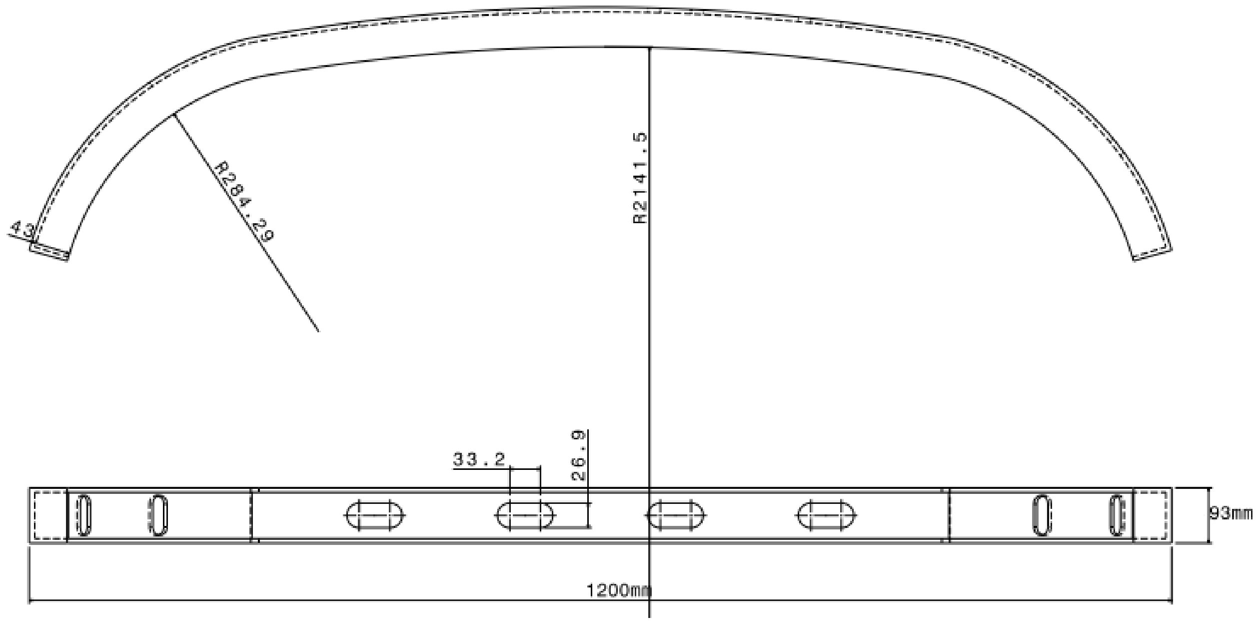
3.3.2. Dimension and 3D modeling of the conventional front bumper beam

This section presents the geometrical development of the front bumper of **LIFAN 520** model released 2011 vehicle system with steel made bumper. Here the conventional front bumper model has been referred from the **LIFAN 520** model released in 2011 vehicle and actual dimensions are measured and compared with the literature before proceeding to the geometrical development in the design modeler of ANSYS Work bench. Within the standard dimension of the **LIFAN 520** model released 2011 depicted in the figure below and these values are utilized to perform the 3D model on Catia V5 R19.

The geometrical dimensions of the Conventional front bumper model obtained from the literature

- Length of the bumper =1200 mm
- Width of the bumper = 93mm
- Thickness of the conventional steel bumper beam=5mm

From the dimensional value of the 3D modeling and geometrical configuration presented in the figure below.



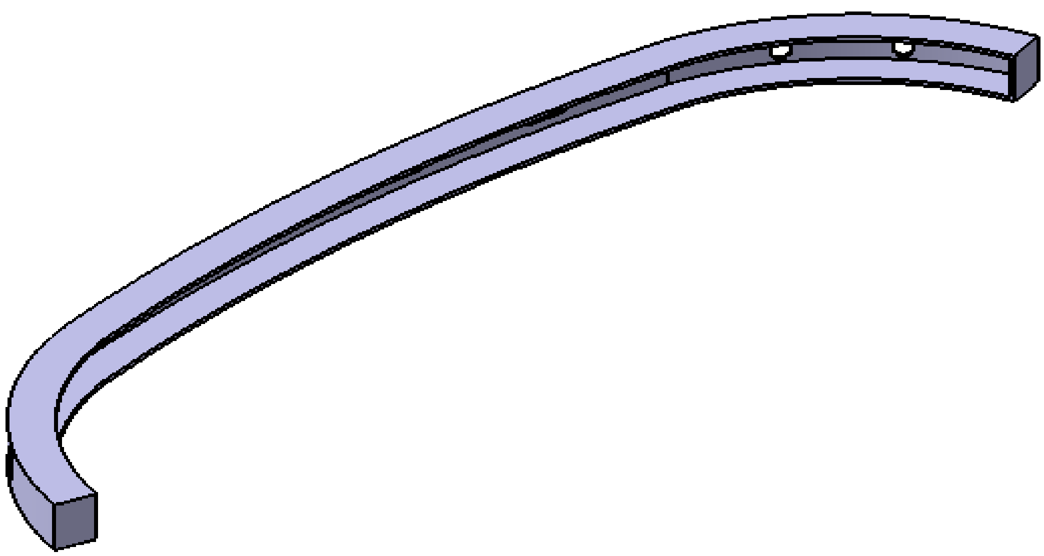


Figure 3.2 3D model of the front bumper beam

3.4. Impact theory

There are two types of impacts, elastic impact and plastic impact. Total energy is conserved throughout the impact process. Momentum before impact and after impact is equal. energy and momentum conservation equations can be expressed as follows.

$$\frac{1}{2}m_{A2}v_{A2}^2 + \frac{1}{2}m_{B1}v_{B1}^2 = \frac{1}{2}m_{A1}v_{A1}^2 + \frac{1}{2}m_{B2}v_{B2}^2 \quad (3.1)$$

$$m_A v_{A1} + m_B v_{B1} = m_A v_{A2} + m_B v_{B2} \tag{3.2}$$

m_A is the mass of the vehicle A where as, m_B is the mass of vehicle B. v_{A1} , v_{A2} and v_{B1} , v_{B2} are speed of vehicle A and B respectively.

3.4.1. Vehicle-to-vehicle frontal collisions (Types of impact modes)

Vehicle-to-vehicle collisions include many types of impact modes. In this research, only frontal collision is considered. In fact, in most crashes between two vehicles, it is generally the lighter vehicle that is damaged more extensively and whose occupants are subjected to higher loads [27].

a) Full overlap collision b) glance –off collision c) Offset collision at 30 degree

Figure 3.3 Types of impact modes [27]

The simplest model is to deal with the collision as an impulsive phenomena. Assuming that time during which the vehicles remain in contact is extremely short. (typically of the order of 0.1 sec). The forces the vehicles exchange are infinitely large. The model is based on the momentum theorem, which states that the variation of the momentum of the vehicles is equal to the impulse of the forces they exchange. The model looks into how the motion changes between the instant t_1 which precedes the collision and the instant .

3.5. Load determination

When two vehicles collides which masses m_1 and m_2, the two collides vehicles with velocities $V_A$and $V_B$respectively. Since both m_1 and $m_2$are two vehicles with similar masses .

Basic assumption to determine the force during collision are:

- Momentum is conserved in which, it explain in the above equation .
- Assumed as perfect elastic collision
- Consider as elastic collision, from energy coccept to determine the force during collision**;**

$$\int F d_t = \int_{v1}^{v2} (mdv) \tag{3.3}$$

$$F.t = m_A V_{A2} - m_A V_{A1} = m_B V_{B2} - m_B V_{B1} \tag{3.4}$$

$$F = \frac{m_A V_{A2} - m_A V_{A1}}{t} \quad (3.5)$$

Case 1) when two vehicle moving with the same speed of 40 $\frac{km}{hr}$ = 11.111 $\frac{m}{s}$ in opposite direction.

m_A=m_B, Mass of the vehicle = 1250 kg (from lifan motors company manual)

In the above equation , F = $\frac{m_{AV_2} - m_{AV_1}}{t}$ since V_1= 11.111 $\frac{m}{s}$, and then the seed of the vehicle after collision .

V_2 = V_1 + $m_B V_{R1}$ (1 + e)/(m_A +m_B)

V_2 = 33.3333$\frac{m}{s}$, In most crash time t is of the order of 0.1s.

F = $\frac{1250 \times 33.333 - 1250 \times 11.111}{0.1}$= 277.78 KN

The Design Factor of Safety, FSd was taken as 1.1. This relatively high value is taken to account for the uncertainty in the nature of forces.

F = 1.1 ×277.777 KN = 305.547 KN

Hence for design purposes force is taken to be 305.547 KN

This force is not appoint load so it converted into a pressure which is acted on the front surface of the modelled bumper.

Area of the front face of bumper beam = l*b = 0.11184 m^2

l= length of front face in mm, b = breadth of front face in *mm*.

Pressure acted on the bumper = F/A = $\frac{305.547 \text{ KN}}{0.11184\ m^2}$ = 2.732 MPa.

Case 2) when two vehicle moving with the same speed of 50 $\frac{Km}{hr}$ = 13.8888$\frac{\text{m}}{\text{s}}$ in opposite direction.

m_A=m_B, Mass of the vehicle = 1250 kg (from lifan motors company manual)

In the above equation , F = $\frac{m_{AV_2} - m_{BV_1}}{t}$ since V_1= 13.8888$\frac{m}{s}$, and then the speed of the vehicle after collision V_{A2} ,

$$V_{A2} = V_{A1} + m_B V_{R1} (1 + e)/(m_A + m_B) \quad (3.6)$$

V_{A2} = 41.65777 $\frac{m}{s}$, In most crash time t is of the order of 0.1s.

F = $\frac{1250 \times 41.65777 - 1250 \times 13.8888}{0.1}$= 347.2225 KN

The Design Factor of Safety, FSd was taken as 1.1. This relatively high value is taken to account for the uncertainty in the nature of forces.

F = 1.1 ×347.2225 KN = 381.9 KN

Hence for design purposes force is taken to be 381.9 KN

This force is not appoint load so converted into a pressure which is acted on the front surface of the modelled bumper.

Area of the front face of bumper beam = l*b = 0.11184 m^2

l= length of front face in mm, b = breadth of front face in mm.

Pressure acted on the bumper = F/A = $\frac{381.9 \text{ KN}}{0.11184 \, m^2}$ = 3.416 MPa

Case 3) when two vehicle moving with the same speed of 60 $\frac{Km}{hr}$ = 16.67 $\frac{m}{s}$ in opposite direction.

m_A=m_B, Mass of the vehicle = 1250 kg (from lifan motors company manual)

In the above equation , F = $\frac{m_{AV_2} - m_{BV_1}}{t}$ since V_1= 16.67 $\frac{m}{s}$, and then the speed of the vehicle after collision V_2,

V_2 = V_1 + $m_B V_{R1}$ (1 + e)/(m_A +m_B)

V_2 = 49.99 $\frac{m}{s}$, In most crash time t is of the order of 0.1s.

F = $\frac{1250 \times 49.99 - 1250 \times 16.666}{0.1}$= 416.625 KN

The Design Factor of Safety, FSd was taken as 1.1. This relatively high value is taken to account for the uncertainty in the nature of forces.

F = 1.1 ×416.625 KN = 458.287 KN

Hence for design purposes force is taken to be 458.287 *KN*

This force is not a point load therefore it converted into a pressure which is acted on the front surface of the modelled bumper.

Area of the front face of bumper beam =l*b =0.11184 m^2

l= length of front face in mm, b = breadth of front face in mm.

Pressure acted on the bumper = F/A = $\frac{458.287 \text{ KN}}{0.11184\ m^2}$ = 4.1 *MPa*

Table 3.2. Numerical result of the analytic

Speed in *Km/hr*	Force in *KN*	Area in m^2	Pressure in *MPa*
40	305.54	0.11184	2.732
50	381.9	0.11184	3.416
60	458.287	0.11184	4.1

The above numerical value which described in the table shows that the the calculated applied pressure at front bumper area with different vehicle speed . According to the numerical value as vehicle speed increase the applied pressure also increase.

3.6. Airbag based front bumper system

The frontal impact air bags are designed to absorb the vehicle occupant's kinetic energy during a crash so that the occupant comes to rest without sustaining injury. Energy absorption occurs when the occupant contacts and compresses the air bag, forcing gas to escape the bag [28] . However, in this study, the concept of an airbag system was used as an external air bag system on the front bumper beam to increase the energy absorption capacity of the bumper. Because of front bumper limitations, the fatality rate increases dramatically in moderate and high speed impacts. In order to design a successful automobile front bumper and significantly improve the crash performance of current cars, if the automotive body could extend its front end during or right before a crash, the mechanism of absorbing the crash energy would be very different from that of the passive structure. A modern frontal airbag system consists of an electronic control unit (ECU) and one or several airbag modules, if the vehicle has a passenger bag, side-impact bag, etc. The electronic control unit is usually installed in the middle of the car or on the steering wheel. The sensor continuously monitors the acceleration and deceleration of the vehicle and sends this information to a microprocessor where the crash algorithm of a vehicle is stored. The algorithm, which is specific for each car model, was determined by crash tests. When the microprocessor "recognizes" the crash pulse from the sensor, an electrical current is sent to the initiator (or squib) in the micro gas generators of the seat belt pretensions and/or to the inflator of the airbag that should be deployed. Capacitors in a ECU are used as back-up energy, in case the main battery of the vehicle is disconnected during the crash. An electro mechanical safing sensor prevents cellular telephones and other electromagnetic interference from setting off the airbags inadvertently.

3.6.1.Types of air bags

Mainly , there are three types of air bags that are used in commercially available vehicles .The driver side airbag, the passenger side air bags and the side impact air bags . The driver side airbag and the passenger side air bags for frontal crashes and the side impact air bags for side crashes [29]. The different types of air bags are shown in the figure 3.4.

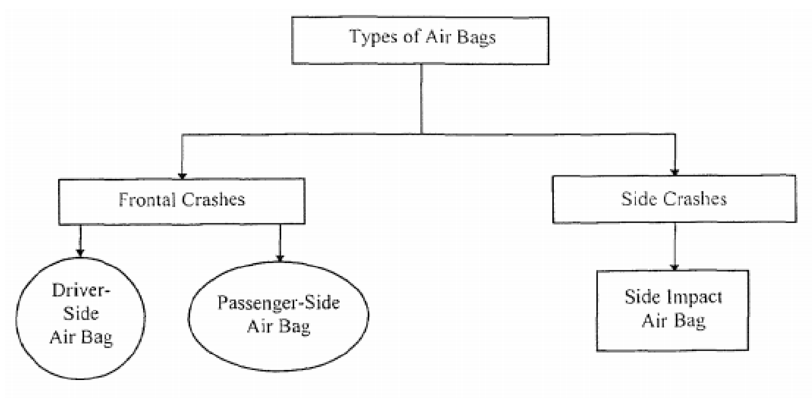


Figure 3. 4 Types of air bags [29].

The frontal air bags are designed to absorb the vehicle occupant's kinetic energy during a crash . Therfore, the occupant comes to rest without sustaining any injury. Energy absorption occurs during the occupant contacts and it compresses the air bag, forcing gas to escape the bag. The side impact air bags system , on the other side, is not able to absorb energy but to exert force and move the occupant away from the actual crash area . Side impact air bags are designed to protect occupants' chests, and they are likely to provide some head protection during side collision [29].

3.6.2. Material for air bag construction

Preferably airbag fabrics are sufficiently flexible to be able to be folded into relatively small volumes, but also sufficiently strong to withstand the deployment at high speed, e.g. under the influence of an explosive charge, and the impact of passengers or other influences when inflated and withstand impact [30] . According to this study, the airbag was subjected to an impact load during a front collision . The proposed material properties may help the material engineers to perform the right material selection during the selection stage. Today, the latest research on potential airbag materials including polyester fiber continues to point the industry towards nylon 66. Nylon is the material of choice for airbags because Nylon offers various advantages in airbag application compared to other fibres. In general, the Nylon fiber exhibits high specific strength, abrasion resistance, and toughness or energy-absorption properties. The aging characteristics of Nylon are also very good.

Table 3.3. Properties of nylon 66 and polyester [30].

Parameters	Nylon 66	Polyester
Density (Kg/m3)	1140	1390
Specific heat capacity (kJ/kg/K)	1.67	1.3
Melting point (○ C)	260	258
Softening point (○ C)	220	220
Young's modulus(MPa)	1850	920
Tensile strength (MPa)	38.6 - 93.1	27
Energy to melt (kJ/kg)	589	427

From the table above, nylon 66 and polyester have similar property like melting points, the large difference in specific heat capacity causes the amount of energy required to melt polyester to be about 30% less than that required to melt nylon 66 and nylon is low densitythan ploester ,therefore nylon 66 selected for the study.

3.6.3. Components of airbag

An automobile air bag system consists of three main elements or subsystems: the crash sensing equipment, the inflator and the inflatable bag [31].

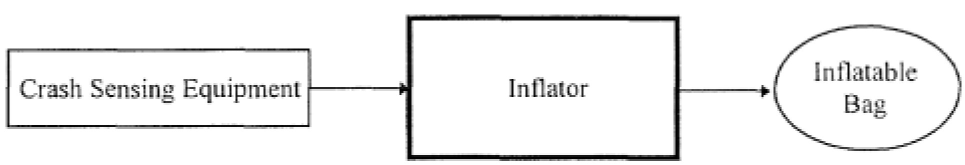


Figure 3.5 Components of air bag [31].

Airbag Control unit

The control unit is the heart of the air bag system and is installed centrally in the Vehicle. It can generally be found in the dashboard area, in the central tunnel . It can generally be found in the dashboard area, on the central tunnel. The unit is responsible for the following points, which is mentioned below.

- Detecting accidents
- Dynamic detection of the signals sent by the sensors timely.
- Activating the air bag indicator lump if the system fails.

Providing the power supply to the firing circuits

3.7. Design of airbag based front bumper system

3.7.1. Design consideration

The basic design consideration of the airbag based front bumper system are;

- Assumed the front face of the conventional steel bumper as a rigid plate**.**
- The maximum pressure inside the airbag always less than the yield strength of the material which is used in the airbag construction.
- The airbag plated on the rigid steel bumper beam , and the shape of the airbag is rectangular with a fillet on both side of the geometry.
- For design simplicity, the model of the airbag is draw as the airbag in the deployed position.

The Concept of the airbag based front bumper system is shown in the figure 3.6.

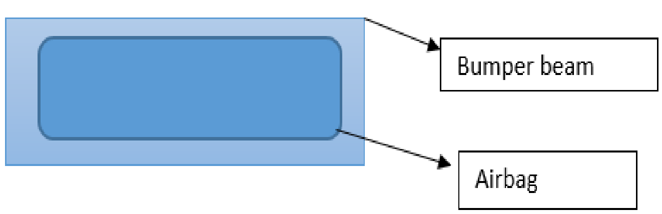


Figure 3.6 Concepts of airbag based front bumper system

3.7.2. Dimension of the airbag

This is a new feature air bag based front bumper system**,** the geometrical dimensions of the airbag .

- Length airbag based front bumper =1200 mm.
- Height of the airbag = 400 mm.
- width of the air bag when it inflated =200mm.

From the dimensional value the 3D modeling and geometrical configuration of the airbag the airbag is shown in the figure 3.7.

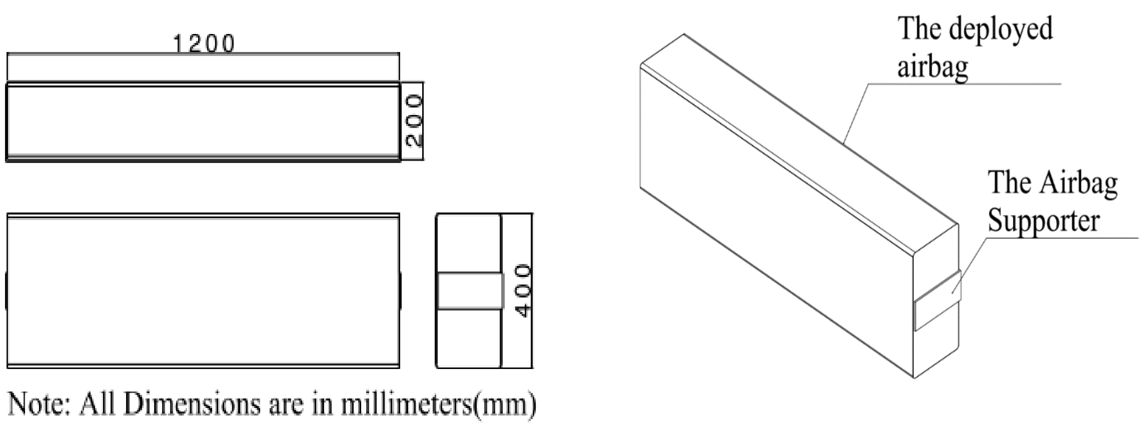


Figure 3.7 Geometry of the airbag

3.7.3 . Airbag deployment

For modeling simplicity and uniform distribution of gas flow in airbag in this study uniform pressure approach model was used. Basic assumptions of the model:

- The gas used to inflate the airbag is Nitrogen.
- Uniform pressure distribution is assumed.
- Application of force is perpendicular to the defined airbag surface.
- Pressure is applied normal to the air bag fabric.
- There is no discretization of the fluid flow.

In the deployment of the airbag, an inflator supplies high velocity gas into an airbag causing it to expand rapidly. The gas inside the airbag assumed to be ideal, to be of constant entropy, and to satisfy the equation of state. [32]. In this study the analysis carried out at moderate speed of 40 km/hr, 50 km/hr and 60 km/hr and also the deployment system was taken as applying internal pressure to the ANSYS and measuring the analysis.

Determination of the air bag pressure

The pressure used in the airbag is the absolute pressure . Therfore ,the absolute pressure is the summation of guage pressure and atmospheric pressure.The gas used to fill the airbsg was nitrogen gas. Nitrogen is an inert gas whose behavior can be approximated as an ideal gas at the temperature and pressure of the inflating airbag. Thus, the ideal-gas law, PV = nRT, provides a good approximation of the relationship between the pressure (P) and volume of the airbag (V).[32]. During the inflation, the pressure which is used to inflate the airbag is the sum of the pressure which is obtained from the design (the gauge pressure) plus the atmospheric pressure.

Absolute pressure = Gauge pressure +Atmospheric pressure = 4.1MPa + 0.101MPa =4.2MPa, From this pressue it can easily find the mass of the nitrogen of the airbag from the equation of the ideal gas law. The volume of the airbag from the above dimensioof the geometry.

V = L$\times W \times h$ = 200$mm\times$ 200$mm \times$ 400mm = 1.2 $m\times$ 0.2$m \times$ 0.4m= 0.096m^3, the after the mass of the nitrogen gas used within this volume can be calculated from the ideal gas equation.

$$PV = MRT \tag{3.7}$$

$$P = \frac{MRT}{V}, \text{ since } \frac{M}{V} = \rho$$

$$P = \rho RT \tag{3.8}$$

$$M = \frac{PV}{RT}$$

Since P is the absolute pressure, v is the volume of the airbag , R is the ideal gas constant of nitrogen, and T is the operating temperature of the nitrogen gas. The absolute pressure which is calculated in in the above is the maximum pressure which obtained at a speed of 60km/hr and the atmospheric pressure . The pressure is used as internal pressure inside the airbag for deployment purposes. This calculated maximum pressure placed inside the airbag statically applied in ANSYS.

Chapter - 4

4. Finite Element Analysis using ANSYS 2020R2 softweare

Basically, the finite element method comprises of three major phases:

- Pre-processing, in which the analyst develops a finite element mesh to divide the subject geometry into small for mathematical analysis, and applies material properties and boundary conditions.
- Solution, during which the program derives the governing matrix equations from the model and solves for the primary quantities.
- Post-processing, in which the analyst checks the validity of the solution, examines the values of primary quantities (such as displacements and stresses), and derives and examines additional quantities (such as specialized stresses and error indicators).

4.1. Finite element analysis of the conventional steel bumper

4.1.1. Meshing

The geometrical model developed previously was imported to the ANSYS explicit dynamics tool. The first case of analysis has started with a traditional steel made bumper as per the model developed in the Catia -V5 and the meshing is done using tetrahedron elements with fine mesh and the quality check has been done to see the mesh quality. To understand the properties of stress, strain , etc.

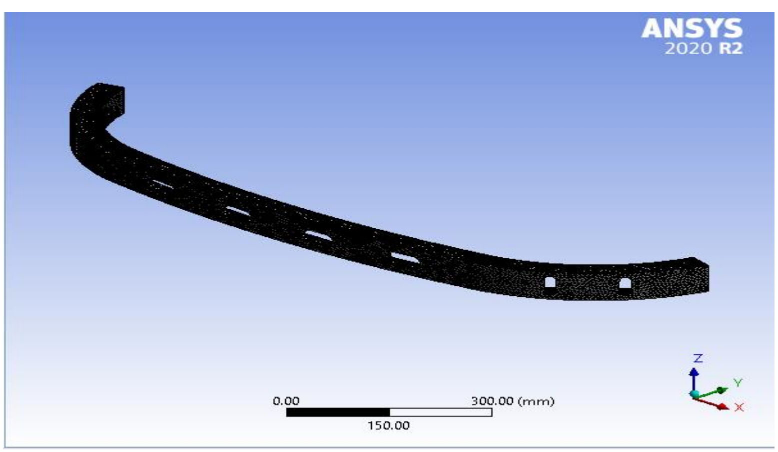


Figure 4.1 Meshing of the steel bumper

Table 4.1 Mesh Detail of front bumper .

Mesh details of front bumper	
Element Size	5 *mm*
Initial Size seed	Active Assembly
Smoothing	High
Transition	Fast
Element type	Tetrahedron
Minimum edge length	4.3433e-003 *m*
Material	Steel 1006
INFLATION	
Transition Ratio	0.272
Maximum layers	5
Growth Rate	1.2
STATISTICS	
Nodes	15836
Elements	46514

4.1. 2. Fixed support

A fixed support which is from the boundary condition in which it placed where a car bumper beam is mounted on a vehicle body position.

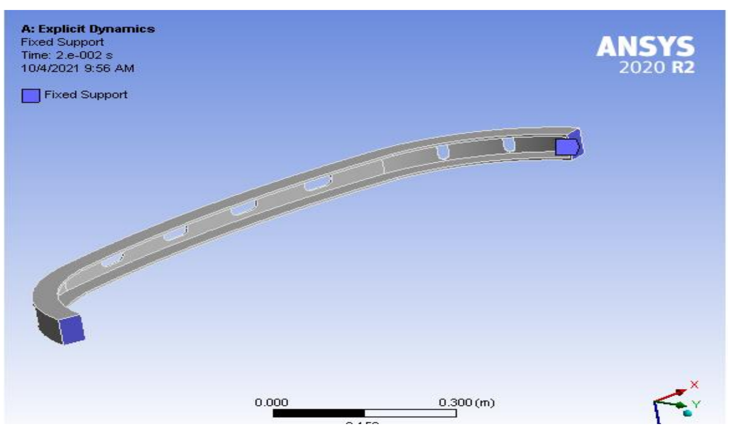
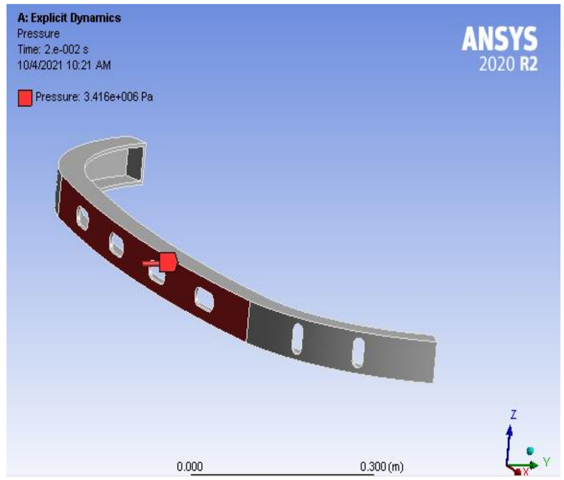


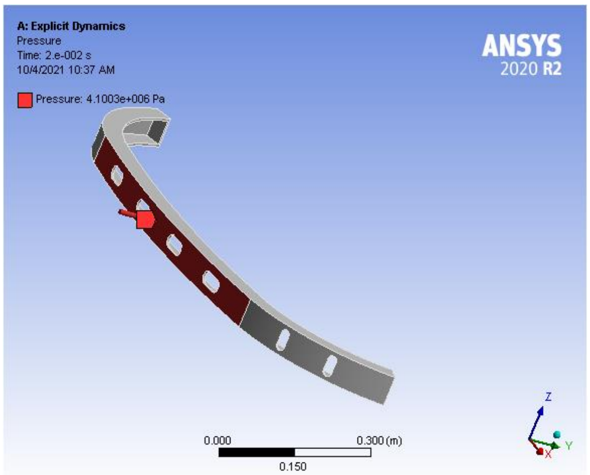
Figure 4.2 Fixed support of the bumper

4.1.3. Impact load

Here in this study, the impact force applied by the moving car is not a point load, so it should converted to a pressure load on the frontal surface of the bumper . Since the input of the static structural is also the input of the explicit dynamics the impact load is applied on the static structural and it is also dragged to the explicit dynamics.



(a) (b)



(c)

Figure 4.3 Impact load at speed of (a) 40km/hr, (b) 50km/hr and (c) 60km/hr

4.2. Finite element analysis of the airbag based bumper system

4.2.1. Meshing

The geometrical model developed in previously was imported to the ANSYS explicit dynamics tool. The first case of analysisnstarted with a traditional steel made bumper as per the model developed in the Catia -V5 and the airbag based front bumper meshing is done using tetrahedron elements with fine mesh and the quality check has been done to see the mesh quality. To understand the properties like stress, strain etc.

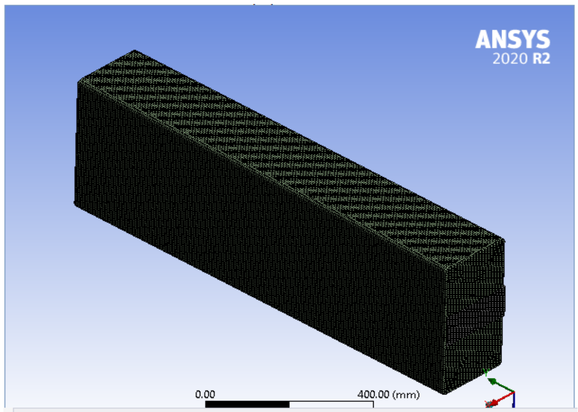


Figure 4.4 Meshing of airbag based bumper system

Table 4.2 Mesh detail of airbag based front bumper

Mesh detail of airbag based bumper system	
Element Size	5mm (0.005m)
Initial Size seed	Active Assembly
Smoothing	High
Transition	Fast
Element type	Tetrahedron
Minimum edge length	4.3433e-003 m
Material	Nylon 6,6
Inflation	
Transition Ratio	0.272
Maximum layers	5
Growth Rate	1.2
STATISTICS	
Nodes	113058
Elements	87426

4.2.2. Fixed support

A fixed support which is from the boundary condition in which it placed where a car bumper beam is mounted on a vehicle body position.

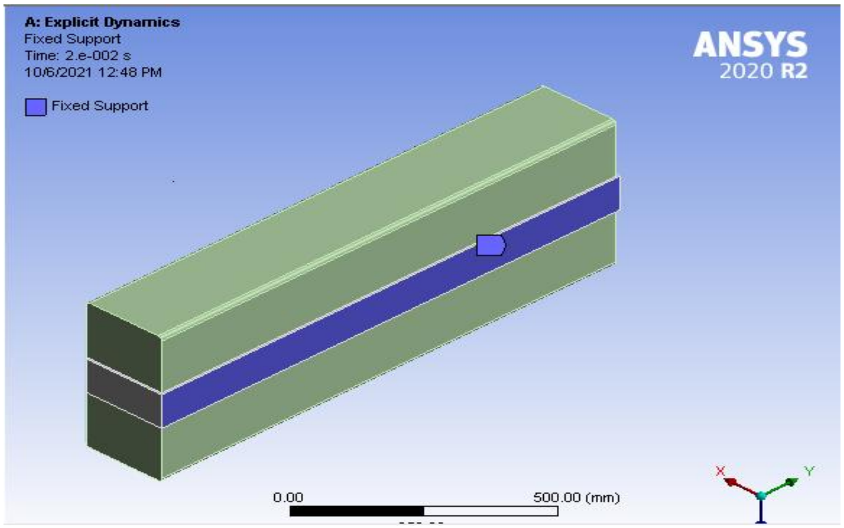


Figure 4.5 Fixed support of the bumper

4.2.3. Applying internal pressure

Applying of internal pressure to inflate the airbag

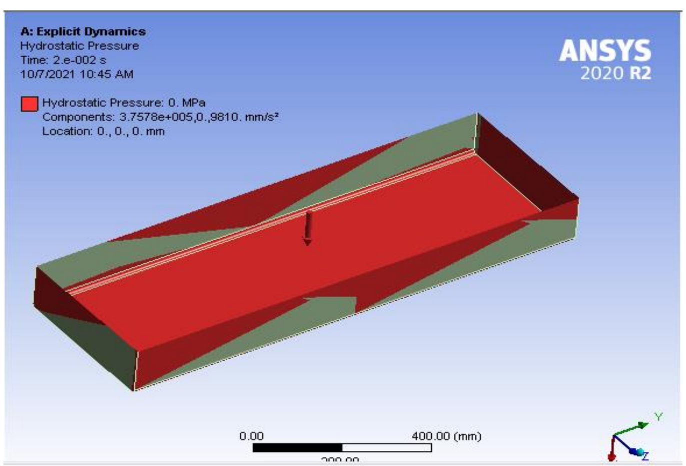
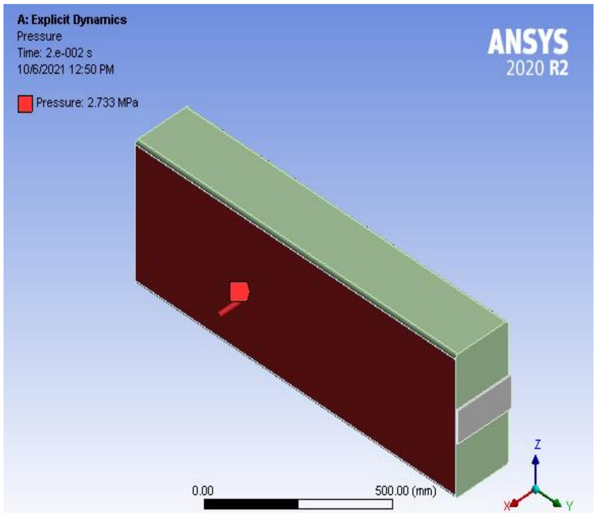


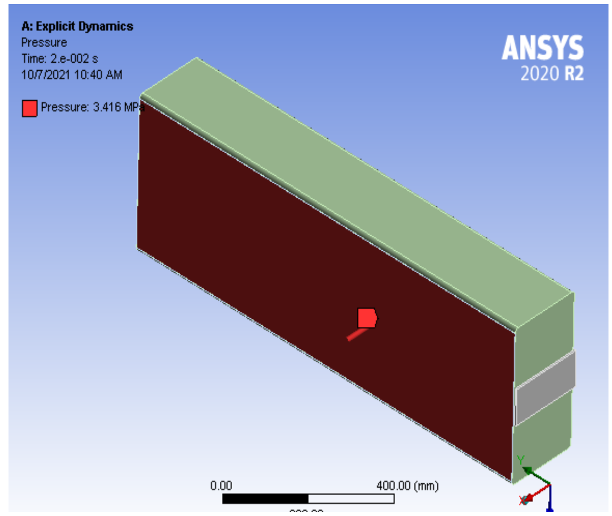
Figure 4.6 Internal pressure of the airbag.

4.2.4. Impact load

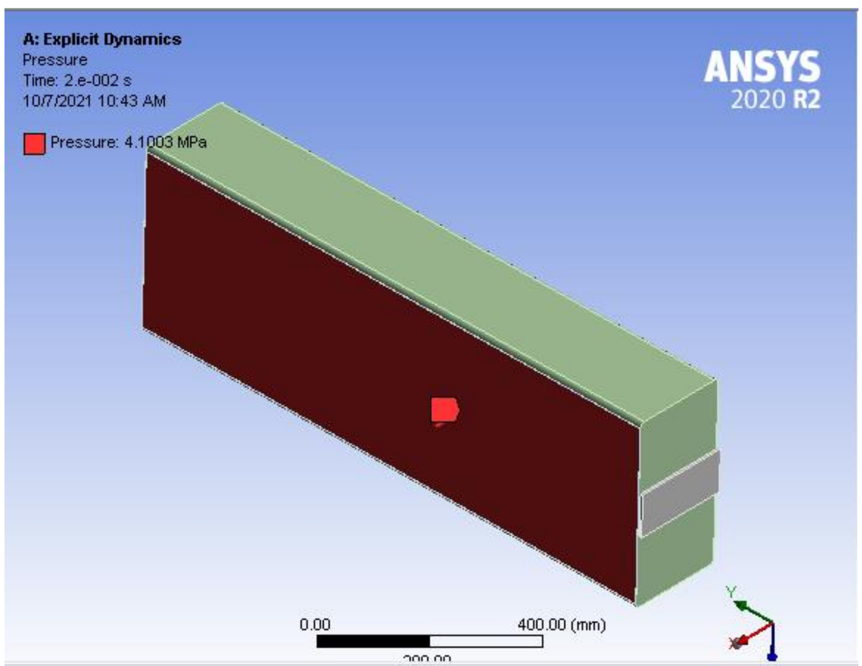
Here in this study, the impact force applied by the moving car is not a point load, so it should convert to a pressure load on the frontal surface of the airbag bumper . Since the input of the static structural is also the input of the explicit dynamics, the impact load is applied to the static structural and it is also dragged in the explicit dynamics.



(a)



(b)



(c)

Figure 4.7 Impact load at speed of (a) 40km/hr, (b) 50km/hr and (c) 60km/hr

Chapter - 5

5. Result and Discussion

5.1. Existing AISI 1006 steel Bumper Beam Results

5.1.1. Total Deformation at 40km/hr

At a given pressure of 2.733 *MPa* pressure applied due to vehicle speed of 40 *km/hr*, the deformation length is 9.0778 *mm*, as shown in the figure 5.1.

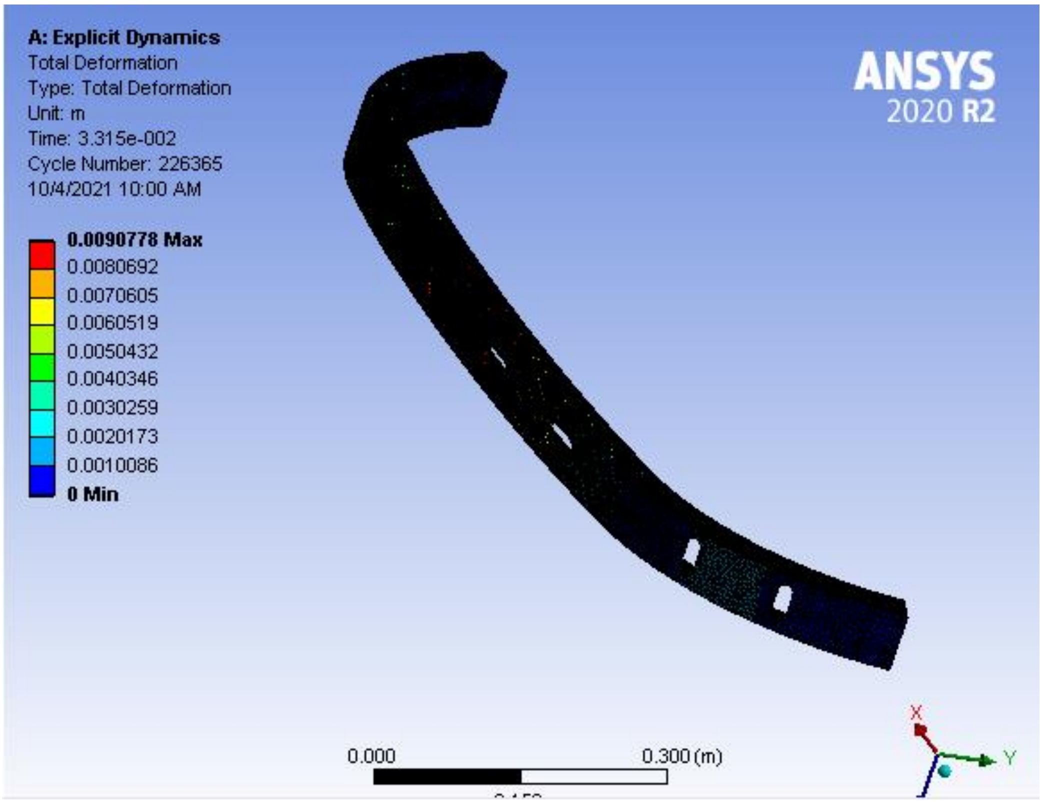


Figure 5.1 Total deformation at 40Km/hr

5.1.2. Equivalent elastic strain at 40km/hr

The maximum equivalent strain in the analysis with gives pressure of 2.713MPa at a vehicle speed of 40 km/hr is 0.005364 as show in the figure 5.2.

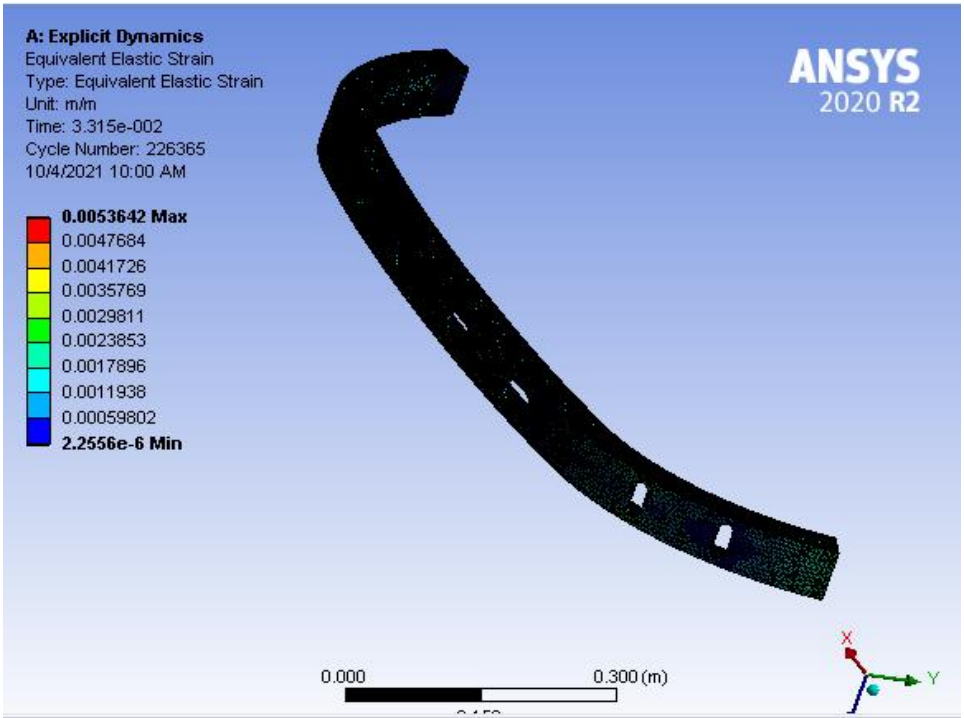


Figure 5.2 Equivalent elastic strain at 40km/hr

5.1.3. Equivalent (Von –Mises) stress at 40 km/hr

The equivalent (Von-Mises) at agiven pressure of 2.713 Mpa applied within vehicle speed of 40 km/hr is 1.109×10^{9}Pa as shown in the figure 5.3.

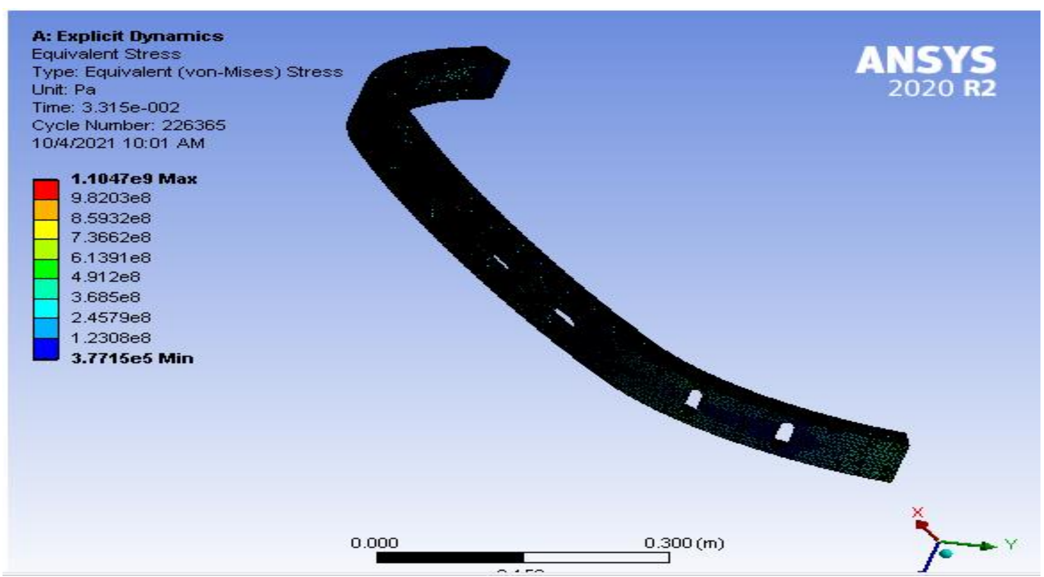
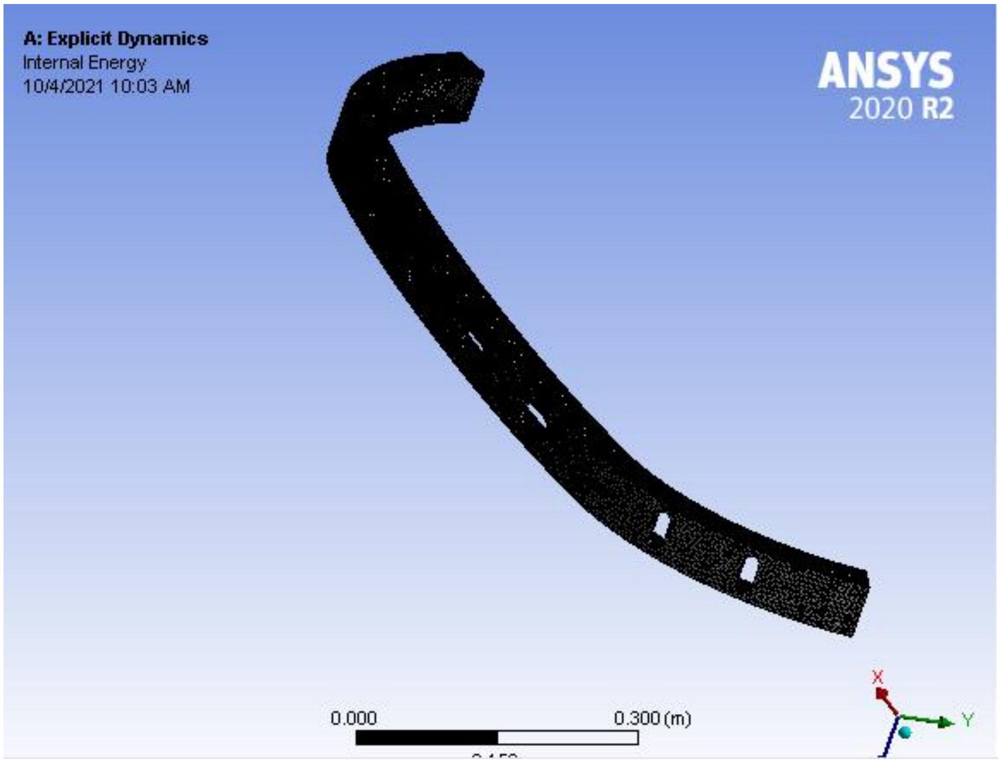


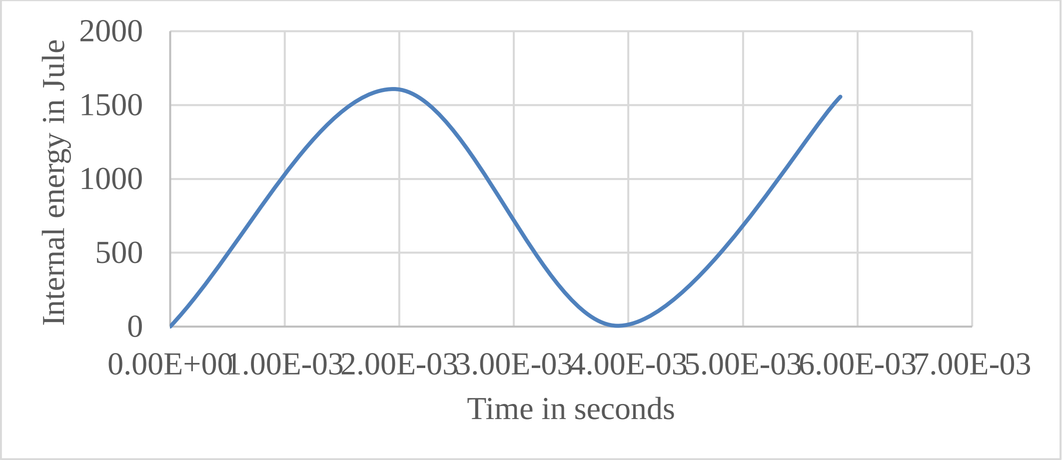
Figure 5.3 Equivalent (Von-Mises) stress at 40 km/hr

5.1.4. Internal energy at 40km/hr

The energy in which absorbed by the 1006 steel bumper beam material at a pressure of 2.733 MPa of within a given vehicle speed of 40km/hr is 1608.3J.



(a)



(b)

Figure 5.4 Internal energy at 40 km/hr

5.1.5. Total deformation at 50km/hr

At a given pressure of 3.416 MPa Pressure applied due to vehicle speed of 50 km/hr, the total deformation length is 17.627 mm , as shown in the figure 5.5. As it shows when the vehicle speed as well the pressure applied increase the deformation of the material increase.

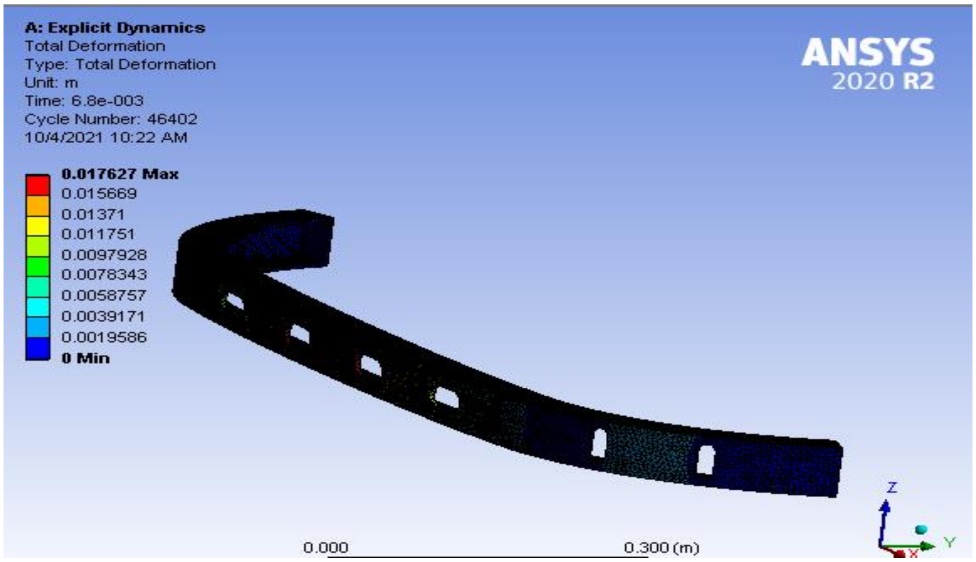


Figure 5. 5 Deformation at 50km/hr

5.1.6. Equivalent elastic strain at 50km/hr

The maximum equivalent strain in the analysis with a given pressure of 3.416 MPa at avehicle speed of 50 Km/hr is 0.011213 as show in the figure 5.6. From the analysis, it shows as when the vehicle speed increase , aswell as the pressure which impact the vehicle; the equivalent strain also increase.

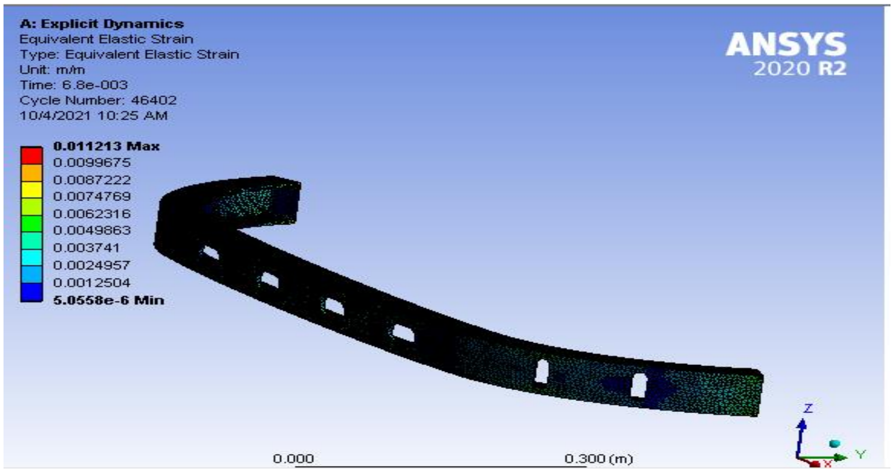


Figure 5.6 Equivalent elastic strain at 50km/hr

5.1.7. Equivalent (Von –Mises) stress at 50km/hr

The equivalent (Von-Mises) stress at agiven pressure 3.416 MPa applied within vehicle speed of 50 km/hr is 2.3×10^{9}Pa as shown in the figure 5.7. It express, in the analysis equivalent stress increses regarding to the vehicle speed as well as the pressure value.

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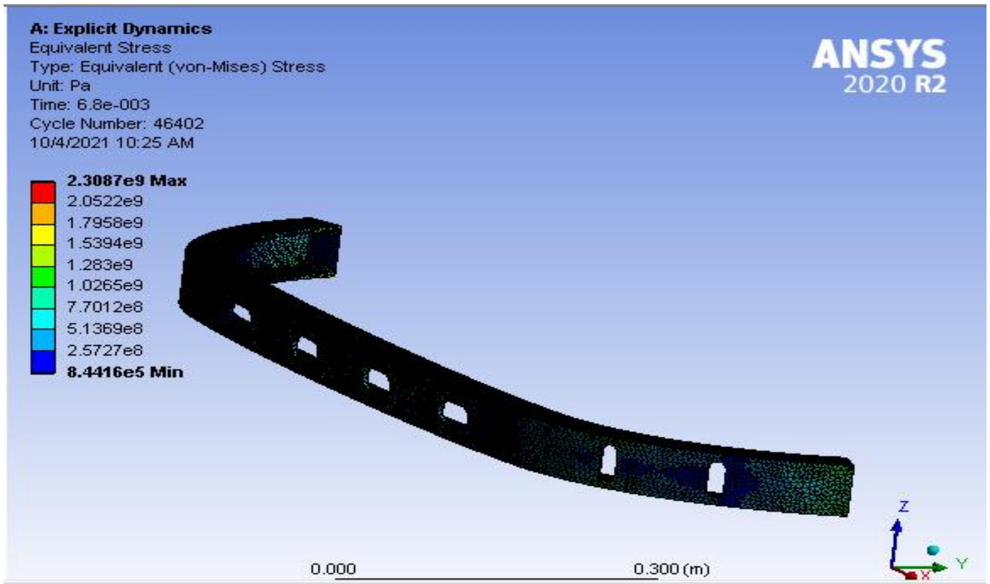
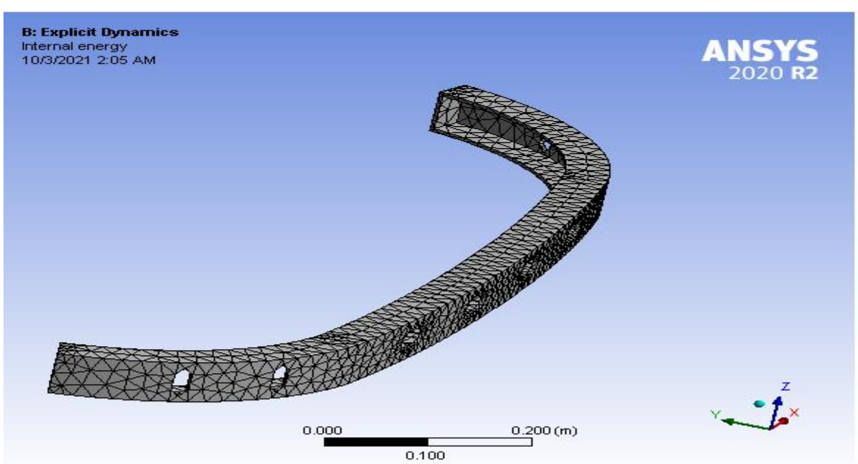


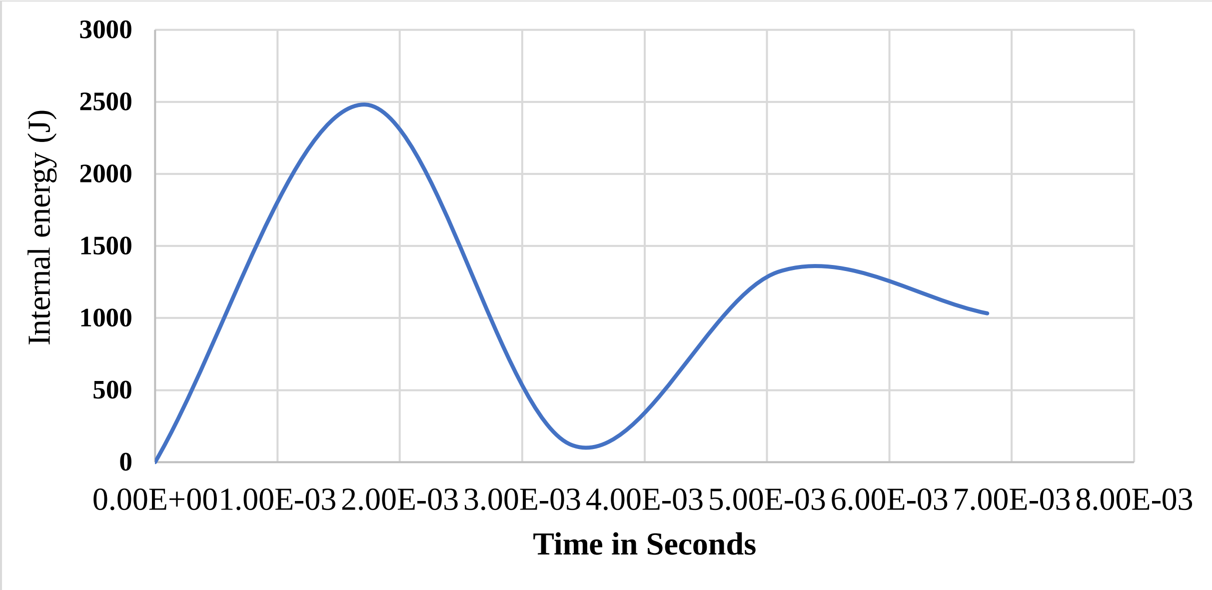
Figure 5.7 Equivalent(Von-mises stress) at 50 km/hr

5.1.8. Internal energy at 50km/hr

The maximum energy in which absorbed by the 1006 steel bumper beam material at a pressure of 3.416 MPa of within a given vehicle speed of 50km/hr is 2481J as the analysis shown as in figure 5.8.



(a)



(b)

Figure 5.8 Internal energy at 50km/hr

5.1.9. Deformation at 60 km/hr

At a given pressure of 4.1 MPa pressure applied due to vehicle speed of 60Km/hr ,the total deformation length is 22.218 mm as shown in the figure 5.9. As it shows when the vehicle speed aswell the pressure applied increase the deformation of the material increase.

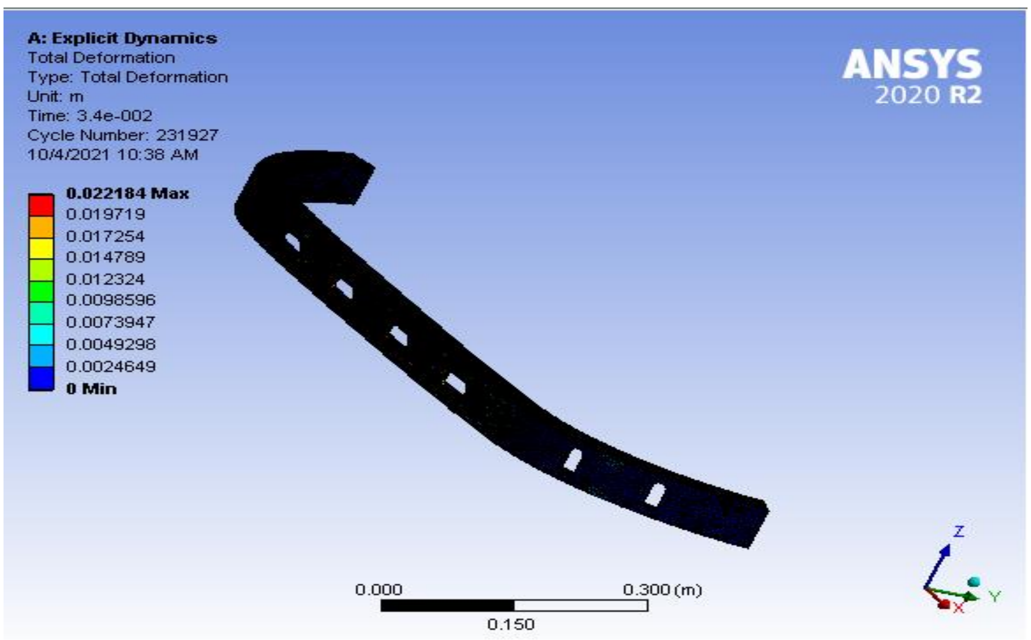


Figure 5.9 Maximum deformation at 50km/hr

5.1.10. Equivalent elastic strain at 60km/hr

The maximum equivalent strain in the analysis with a given pressure of 3.416 MPa at avehicle speed of 60 km/hr is 0.012542 as show in the figure 5.10.

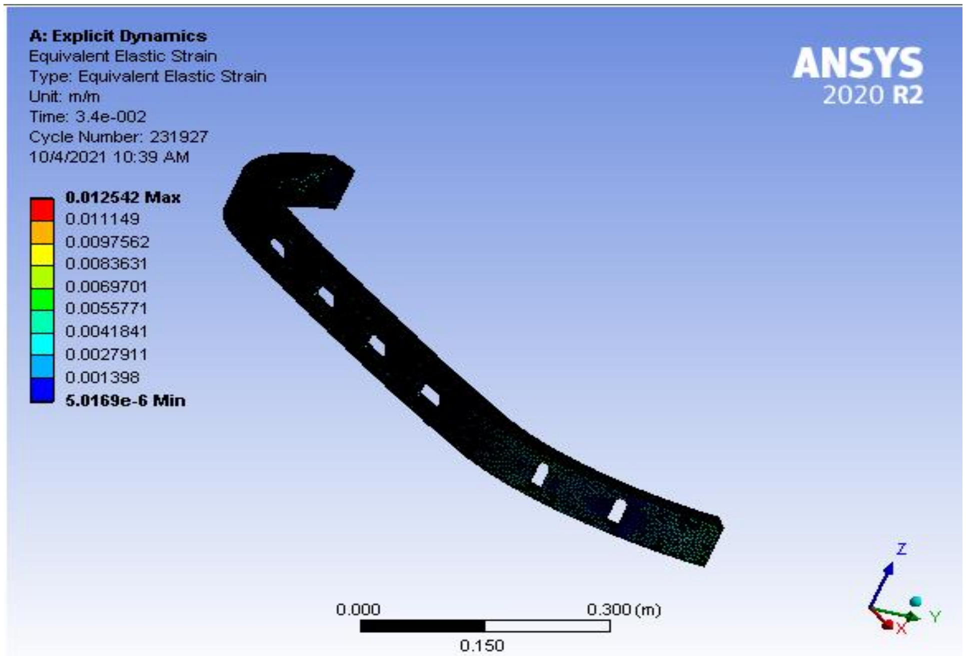


Figure 5.10 Equivalent elastic strain at 60 km/hr

5.1.11. Equivalent (von –mises) stress at 60km/hr

The equivalent (von-mises) stress at agiven pressure 4.1 MPa applied within vehicle speed of 60 km/hr is 2.58×10^9Pa as shown in the figure 5.11. It shows that in the analysis equivalent stress increases regarding to the vehicle speed as well as the pressure value.

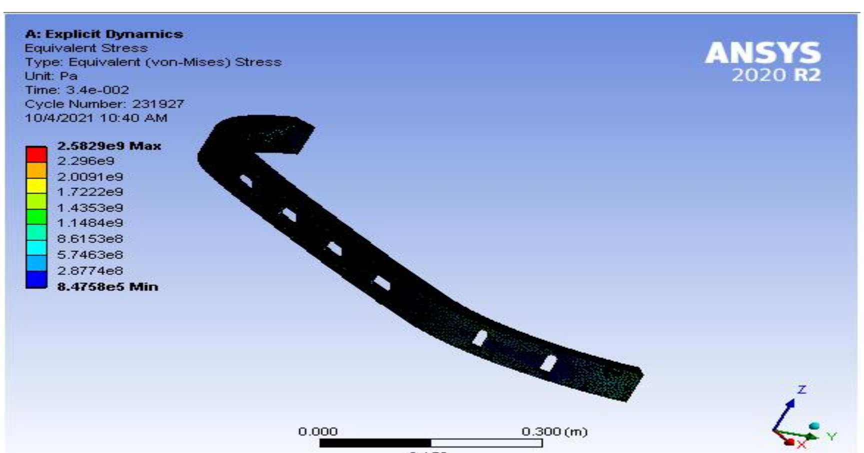
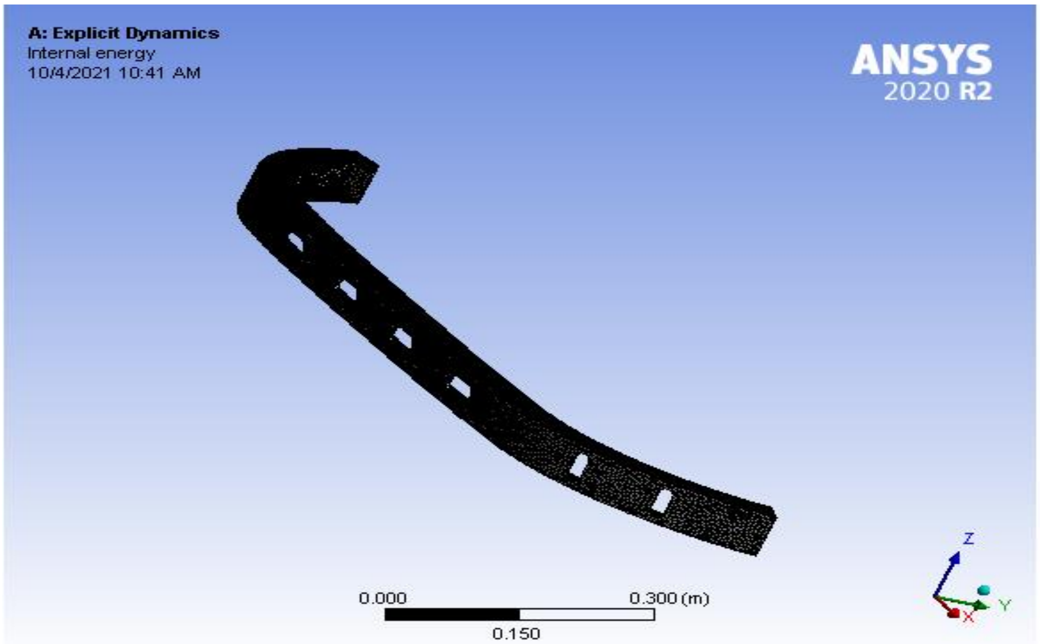


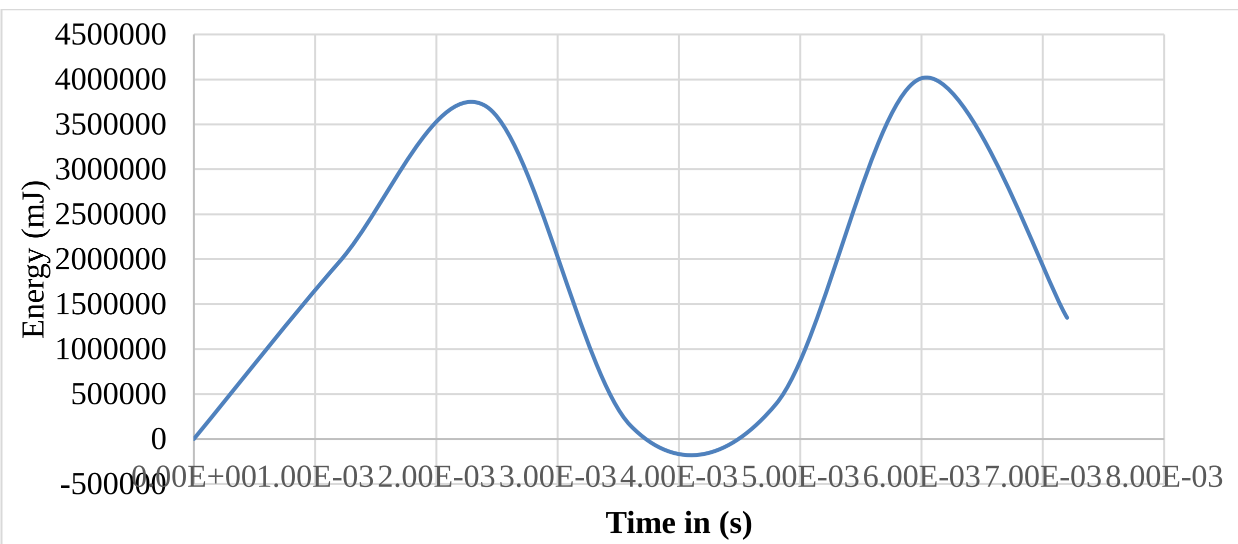
Figure 5.11 Equivalent(Von-Mises) Stress at 60 km/hr

5.1.12. Internal energy at 60 km/hr

The maximum energy in which absorbed by the 1006 steel bumper beam material at a pressure of 4.1 MPa of within a given vehicle speed of 60km/hr is 4010J as the analysis shown in figure 5.12.



(a)



(b)

Figure 5.12 Internal energy at 60 Km/hr

From the above graph the internal energy absorbed by the steel bumper at applied pressure of 2.713MPa, 3.417MPa and 4.1MPa is 1600J, 2500J and 3000J respectively. From the given result as it indicates as vehicle speed increase the energy absorption increase due to the reason why the kinetic energy converted to internal energy.

5.2. Airbag based bumper system results

5.2.1. Deformation at 40 km/hr

At a given pressure of 2.713MPa Pressure applied due to vehicle speed of 40Km/hr when the air bag inflated with 4.2 MPa it deforms 0.057mm as shown in the figure 5.13.

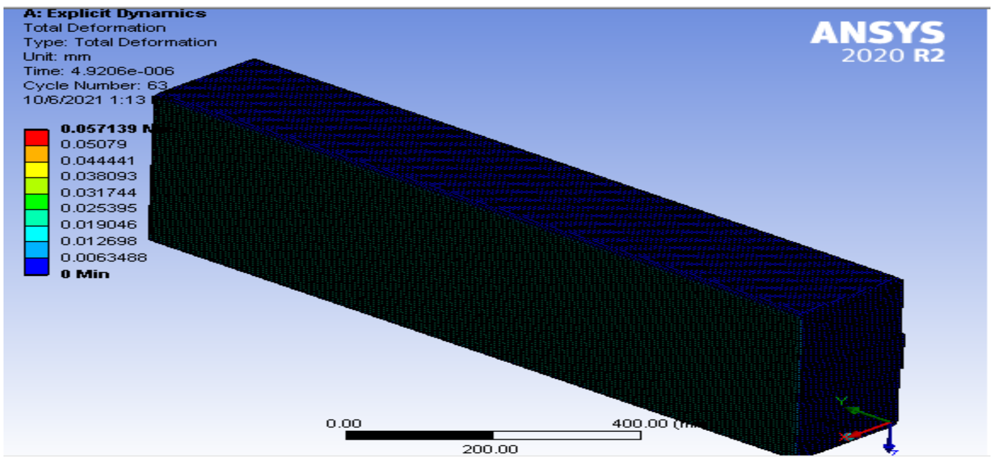


Figure 5.13 Deformation at 40km/hr

5.2.2. Equivalent elastic strain at 40 km/hr

The equivalent elastic strain in the analysis with a given pressure of 2.713 MPa at a vehicle speed of 40Km/hr when the airbag inflated with 4.2 MPa is 0.1159 as show in the figure 5.14.

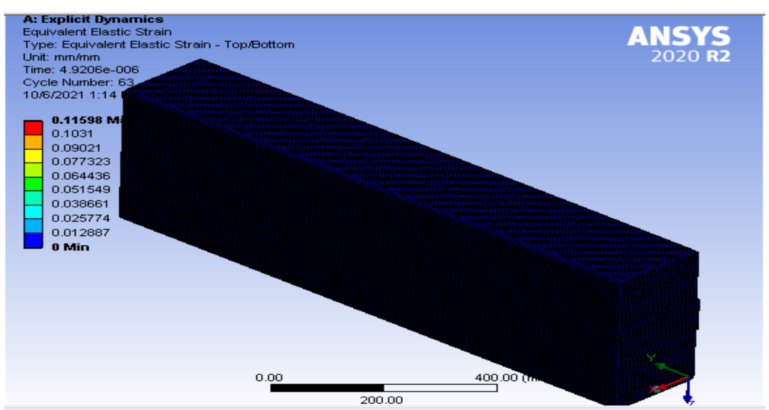


Figure 5.14 Equivalent elastic strain at 40Km/hr

5.2.3. Equivalent (Von –Mises) stress at 40km/hr

The equivalent (Von-Vises) stress at agiven pressure of 2.713 MPa applied within vehicle speed of 40 km/hr , when the airbag inflated with 4.2 MPa is 23.89×10^9Pa as shown in the figure 5.15.

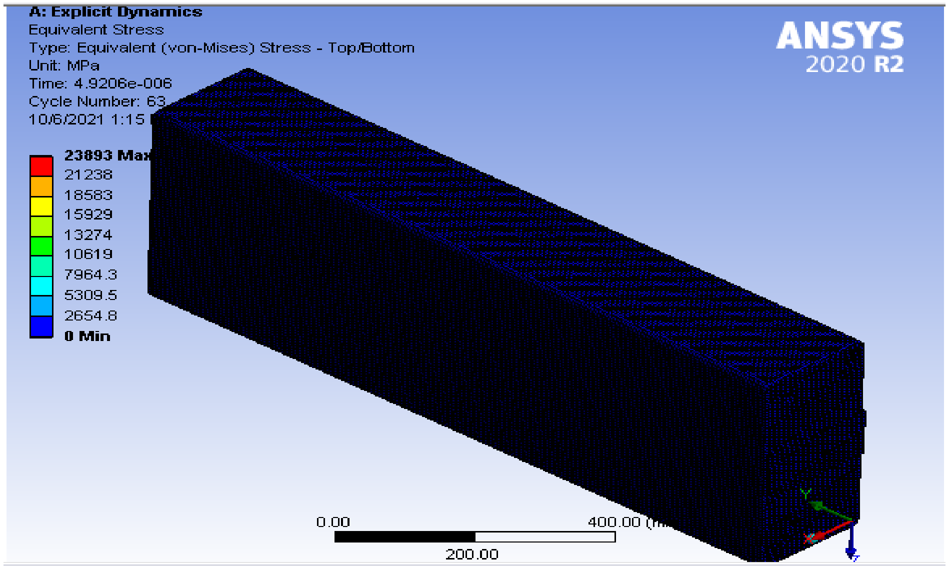


Figure 5.15 Equivalent (Von-mises) Stress at 40km/hr

5.2.4. Internal energy at 40Km/hr

The maximum internal energy absorbed by the airbag based bumper at the applied pressure of 2.713MPa, when the airbag inflated with 4.2 MPa is 193 KJ .

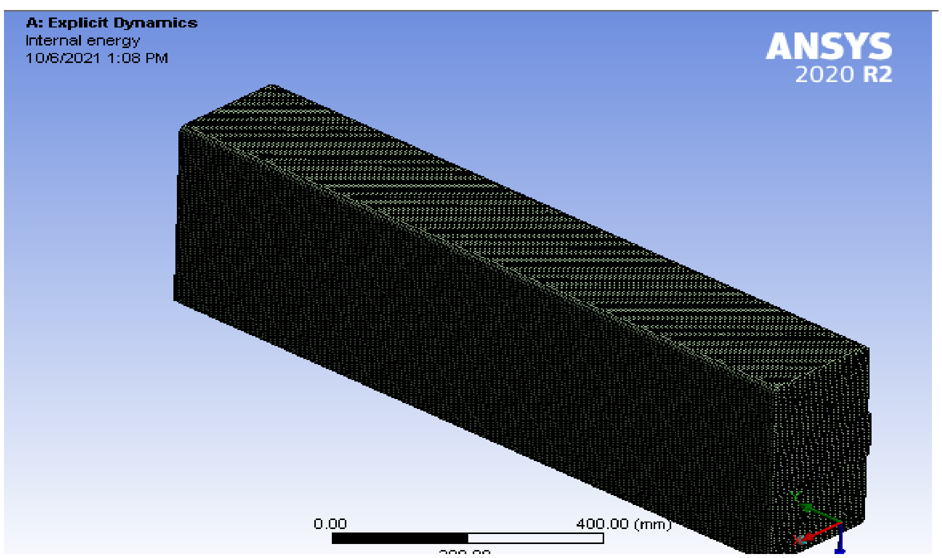


Figure 5.16 Internal energy at 40km/hr

5.2.5. Deformation at 50km/hr

With the given pressure of 3.416MPa Pressure applied due to vehicle speed of 50Km/hr when the airbag inflated with 4.2 MPa it deforms 0.063mm as shown in the figure 5.17.

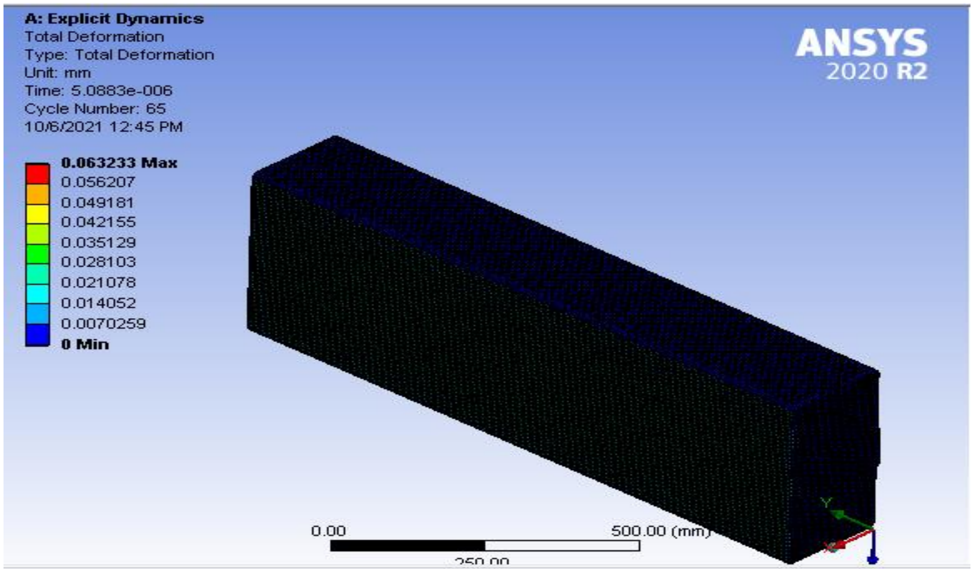


Figure 5.17 Deformation at 50Km/hr

5.2.6. Equivalent elastic strain at 50km/hr

The equivalent elastic strain in the analysis with agive pressure of 3.416MPa at a vehicle speed of 50Km/hr when the airbag inflated with 4.2 MPa is 0.1328 as show in the figure 5.18.

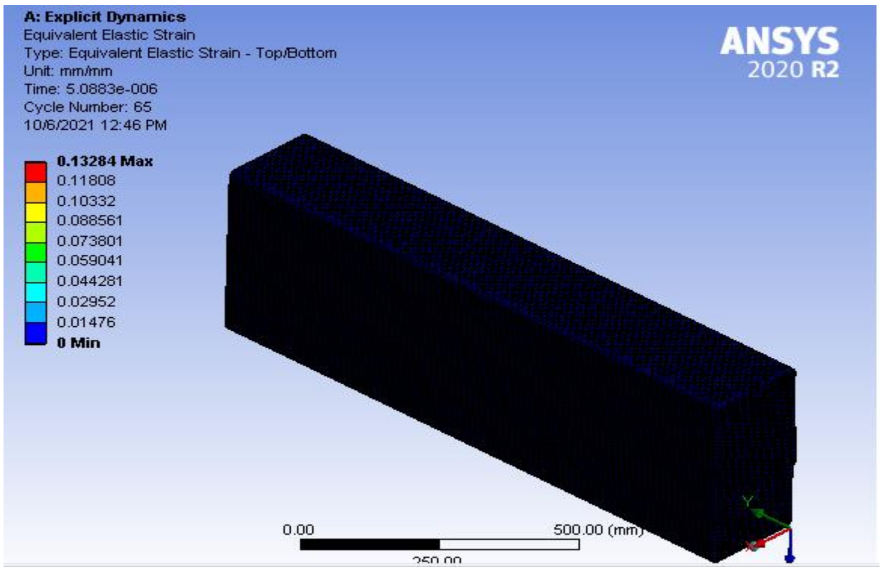


Figure 5.18 Equivalent elastic strain at 50 km/hr

5.2.7. Equivalent (Von –Mises) stress at 50km/hr

The equivalent (von-mises) stress at agiven pressure of 3.416 MPa applied within vehicle speed of 50 km/hr , when the airbag inflated with 4.2 MPa is 27.365 $\times$ $\mathbf{10^9}$Pa as shown in the figure 5.19.

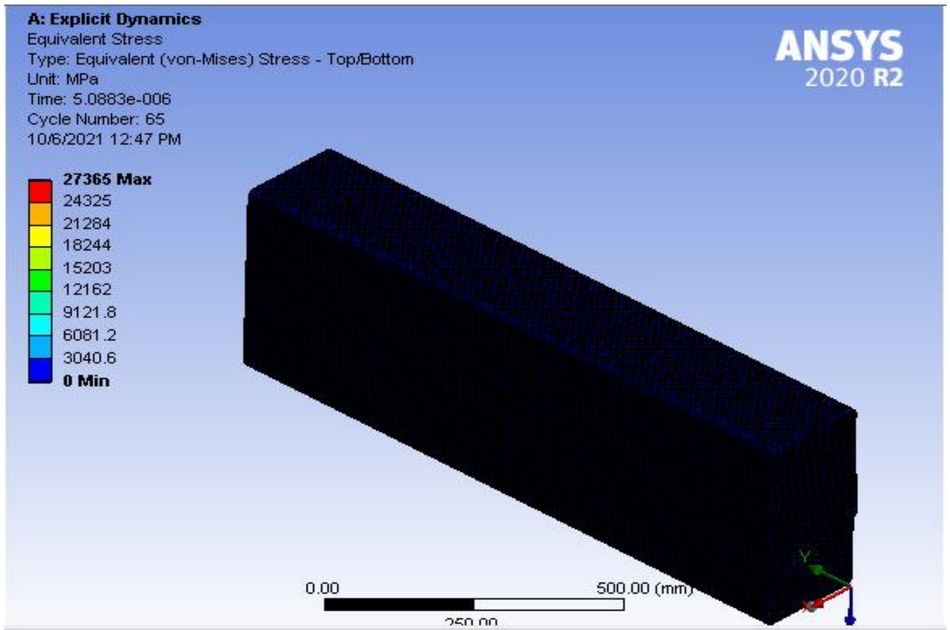


Figure 5.19 Equivalent (Von-mises) Stress at 50 km/hr

5.2.8. Internal energy at 50Km/hr

The maximum internal energy absorbed by the airbag based bumper at the applied pressure of 3.416MPa, when the airbag inflated with 4.2 MPa is 240 KJ.

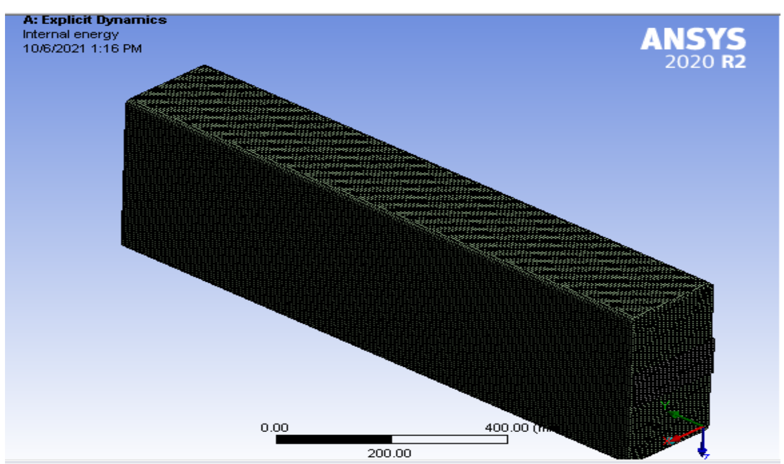


Figure 5.20 Internal energy at 50 km/hr

5.2.9. Deformation at 60km/hr

With the given pressure of 4.1 MPa Pressure applied due to vehicle speed of 50km/hr when the airbag inflated with 4.2 MPa it deforms 0.13 mm as shown in the figure 5.21.

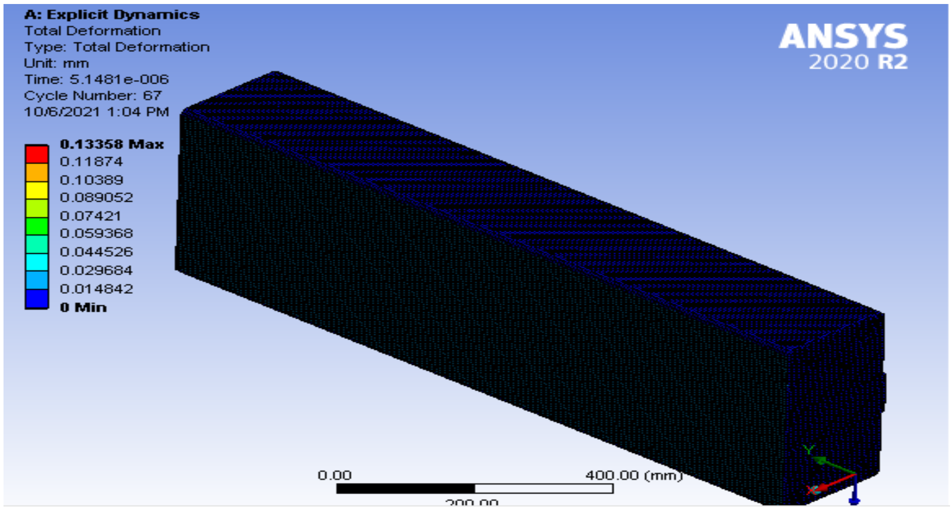


Figure 5.21 Deformation at 60km/hr

5.2.10. Equivalent elastic strain at 60km/hr

The equivalent elastic strain in the analysis with a given pressure of 4.1MPa at a vehicle speed of 60 km/hr when the airbag inflated with 4.2 MPa is 0.207 as show in the figure 5.22.

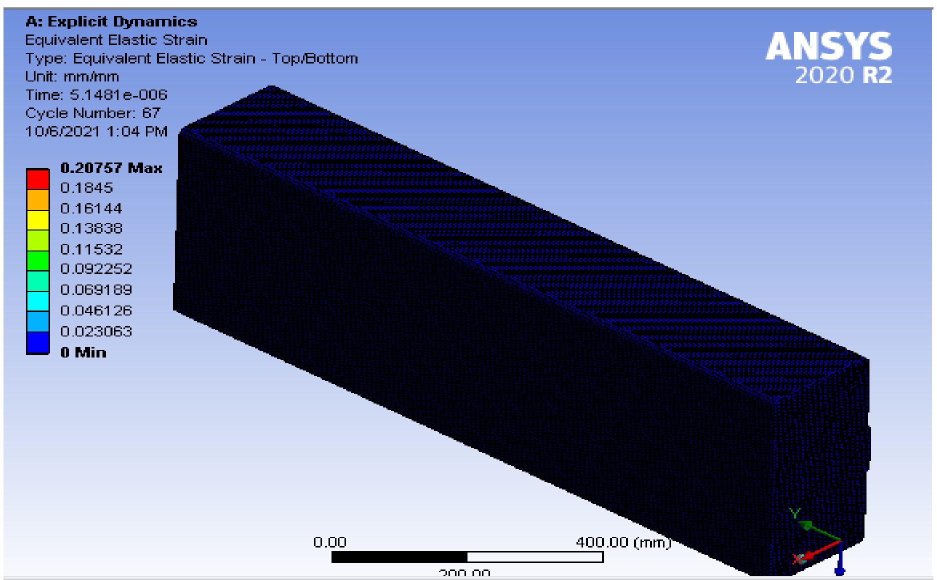


Figure 5.22 Equivalent elastic strain at 60 km/hr

5.2.11. Equivalent (Von –Mises) stress at 60km/hr

The equivalent (Von-Mises) stress at agiven pressure of 4.1 MPa applied within vehicle speed of 60 km/hr , when the airbag inflated with 4.2 MPa is 42.7 $\times$ $\mathbf{10^9}$Pa as shown in the figure 5.23.

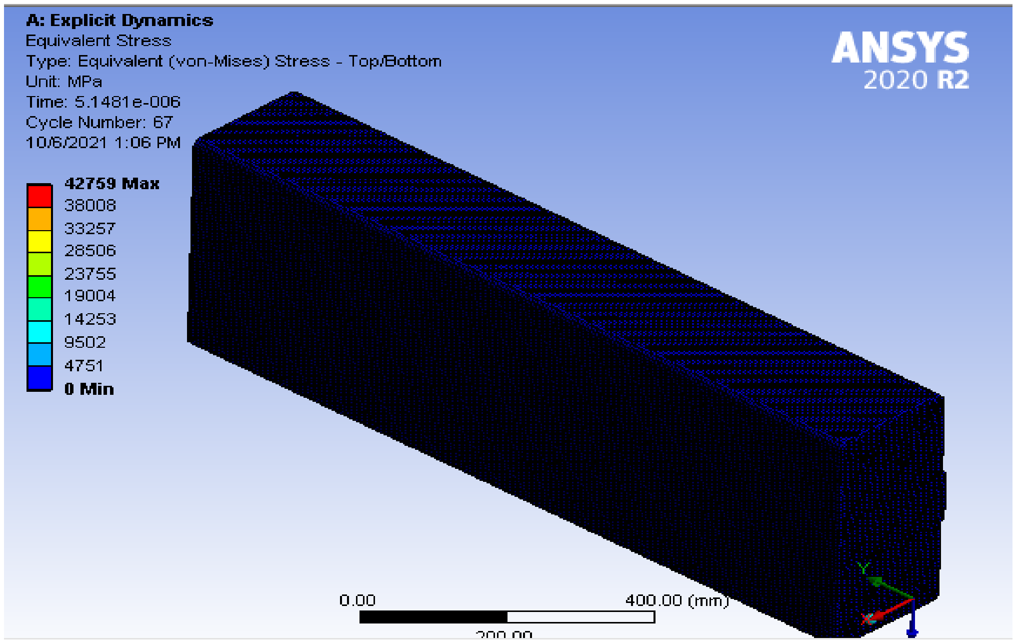


Figure. 5.23 Equivalent(Von-mises) Stress at 60 km/hr

5.2.12. Internal energy at 60km/hr

The maximum internal energy absorbed by the airbag based bumper at the applied pressure of 4.1 MPa, when the airbag inflated with 4.2 MPa is 256 KJ.

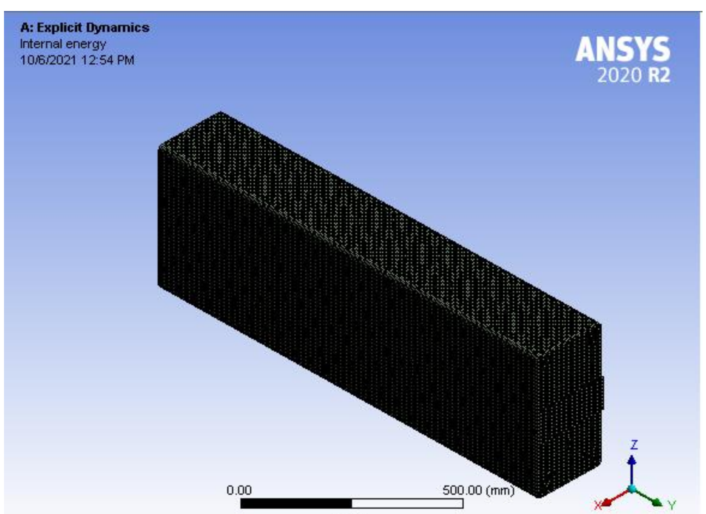


Figure 5.24. Internal energy at speed of 60km/hr.

Table 5.1 Over all result of deformation and internal energy

Vehicle speed	Conventional steel bumper		Airbag based bumper	
	Deformation(mm)	Internal energy(KJ)	Deformation(mm)	Internal Energy(KJ)
40 Km/hr	9.08	1.68	0.057	193
50Km/hr	17.65	2.4	0.06323	240
60Km/hr	22.18	4.01	0.13	256

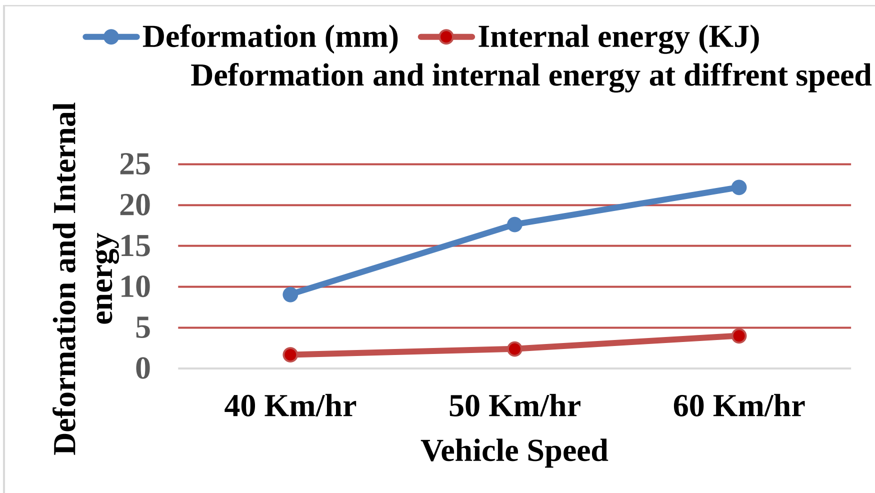


Figure 5.25 Deformation and Internal energy at different vehicle speed

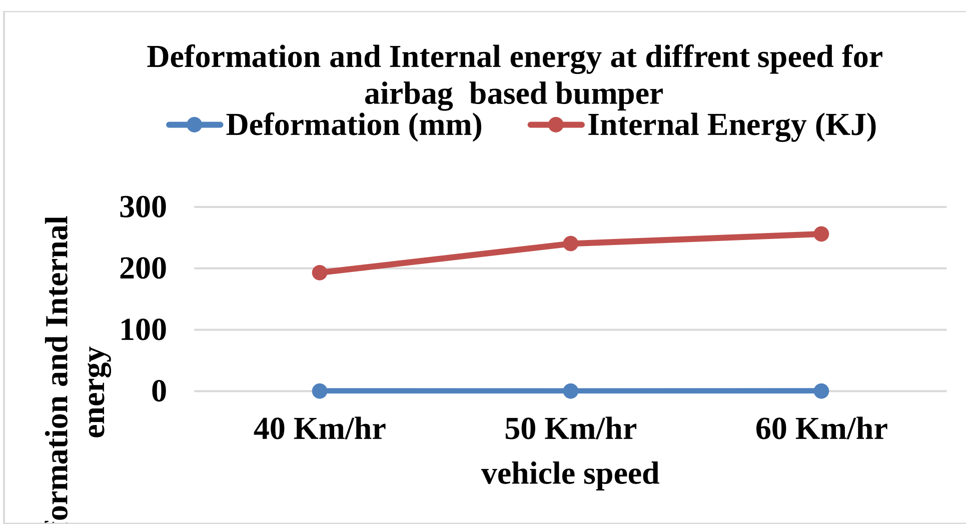


Figure 5.26 Deformation and internal energy at different speed for airbag based bumper system

The over all result of the comparative study of the conventional steel bumper and the airbag based bumper system described in the table above, as the result shows, as vehicle speed increase the deformation aswell as the internal energy also increase.In this analysis the comparative study done as airbag based bumper system in deployed postion with internal deployed pressure of 4.2MPa. In the analysis external pressure of 2.713 *MPa*, 3.416 *MPa* and 4.1 *MPa* applied in the conventional steel bumper as vehicle speed of 40 *Km/hr*, 50 *Km/hr* and 60 *Km/hr*, the deformation and the internal energy was 9.08 *mm*, 17.65 *mm*, 22.18 *mm* and 1.68 *KJ*, 2.4 *KJ*, and 4.01 *KJ* respectively . Where as , in the new airbag based bumper design the same external pressure applied with the same speed of vehicle like a conventional one, the deformation and the internal energy was 0.057 mm, 0.06323 mm, 0.13 mm and 193 *KJ*, 240 *KJ* and 256 *KJ* respectively**.**

Chapter - 6

6. Conclusion, Recommendation and Future work

6.1. Conclusion

- The steel bumper has a deformation of 9.08 mm ,17.625 mm and 22.18 mm at vehicle speed of 40 Km/hr,50Km/hr and 60Km/hr respectively, whereas the new airbag based front bumper same pressure. Therefore, the new airbag based bumper system has better than the conventional one.
- The internal energy which is absorbed by the conventional is 1.608.3 *KJ*, 2.4 *KJ* and 4.01 *KJ* at vehicle speed of 40Km/hr, 50Km/hr and 60Km/hr where the new airbag based bumper system has 193KJ,240KJ and 256KJ with the same speed as well as the same pressure . Therefore, the new airbag based bumper system has better than the conventional.
- The result of the airbag based bumper system shows how nuch energy absorbed before the airbag blow in.
- The existing and the new airbag based is analyzed in ANSYS 2020R2 and the Maximum stress induced in the conventional steel bumer is 1.1×10^9 *Pa*, 2.3×10^9 *Pa* and 2.58×10^9 *Pa* within agiven speed of 40 ,50 and 60 *Km/hr* at apressure of 2.7, 3.5and 4.01003 *MPa* where as 23.89×10^9 *Pa*, 27.36×10^9 *Pa* and 42.7×10^9 *Pa* the new airbag based bumper system with the same speed aswell as the same pressure .Therefore, the new airbag based front bumer system is better than the conventional one. From the study, it is concluded that airbag based front bumper system has better energy absorption and deformation than steel bumper beam material.Accordingly,the designed airbag based bumper system with internal pressure of 4.2 ,MPa can safely withstand the external pressure applied in the front face of the bumper at vehicle speed of 40 *Km/hr*, 50 *Km/hr* and 60 *Km/hr*.

6.2. Recommendation

- A precrash sensor can be very effective to determine the reliability of the airbag deployment.
- Based on the impact analysis the result show that maximum energy absorbation at 60 Km/hr before the airbag blow in.
- Generally it recommend to use the bumper with airbag ,because as it shows the analysis the conventional bumper has less energy absorbation than the airbag based bumper.

6.3. Future work

- Considering a full vehicle model impact test in the simulation analysis can have more realistic results.
- It is recommended to include side collision along with the frontal collision to have accurate results of the safety concerns .
- It better to design the researcher the control system and integrate with the bumper.

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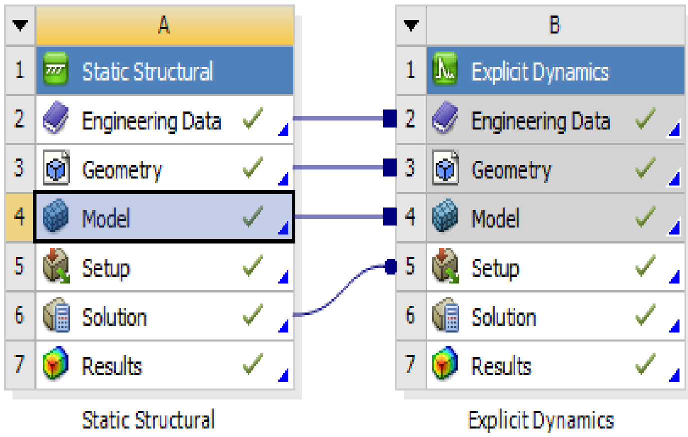
Appendix A: Finite element analysis of the study



- ❖ **Meshing** is the process of turning irregular shapes into more recognizable volumes called "elements." Before starting meshing, first upload a geometry or 3D model which modeld with $CATIAV_5$ into, ANSYS $2020R_2$ Mechanical to begin the simulation process and applies material properties and boundary conditions,

- ❖ **Applying internal pressure**: Applying internal pressure in the airbag in the form of density of nitrogen gas and the calculated pressure **.**

- ❖ **Applying external pressure**:After the analysis external pressure applied and measure the the deformation , the internal energy and other related parameter in the explicit dynamics.