Kaunas University of Technology
Faculty of Mechanical Engineering and Design

Analysis of Side Impact Beams in Car Side Door

Master's Final Degree Project

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Kaunas, 2018

Kaunas University of Technology
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Vehicle Engineering (621E20001)

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Kaunas, 2018

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Analysis of Side Impact Beams in Car Side Door

Declaration of Academic Integrity

I confirm that the final project of mine, Shanmugapriyan Ponnadai, on the topic „Analysis of Side Impact Beams in Car Side Door“ is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarised from any printed, Internet-based or otherwise recorded sources. All direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by law) have been paid to anyone for any contribution to this project.

I fully and completely understand that any discovery of any manifestations/case/facts of dishonesty inevitably results in me incurring a penalty according to the procedure(s) effective at Kaunas University of Technology.

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KAUNAS UNIVERSITY OF TECHNOLOGY
FACULTY OF MECHANICAL ENGINEERING AND DESIGN

Study programme VEHICLE ENGINEERING (621E20001)

TASK ASSIGNMENT FOR FINAL DEGREE PROJECT OF MASTER STUDIES

Given to the student: Shanmugapriyan Ponnadai

1. Title of the Project

Analysis of Side Impact Beams in Car Side Door

Automobilio Durų Šoninių Apsauginių Sijų Analizė

2. Aim and Tasks of the Project

To analysis the 10 cross section side impact beams with different materials in the static and explicit analysis of ANSYS Workbench and LS DYNA PREPOST to find the force reaction and energy absorption of the beam to prevent the occupant from the side collision.

Tasks:

- Design the 10 different cross section beams with materials of Aluminium alloy, cast alloy steel, Steel AISI 1060.
- Analysis the 10 different cross section beams in the static and explicit analysis of ANSYS Workbench to find the displacement, force reaction and energy absorption.
- Analysis the circular cross section beam fitted in car side door of explicit analysis in LS DYNA PREPOST to find the reaction force and energy absorption.
- Comparison the displacement, force reaction, energy absorption of 10 cross section beams result values are plotted in graph and data table.

3. Initial Data:

- Dimensions of 10 cross section beams – (length - 1000mm, thickness - 2mm, width - 100mm).
- Material properties – Aluminium alloy, cast alloy steel, steel AISI 1060.

4. Main Requirements and Conditions

- CAD software – SOLIDWORKS.
- CAE software - Static and Explicit dynamic analysis in ANSYS Workbench.

- CAE software - Explicit dynamic analysis in LS DYNA PREPOST.

5. Structure of the Text Part

- Identified the problem of side impact crashes in the car with the help of literature review by previous authors researched.
- Designed the 10 cross section side impact beam models using CAD software.
- Tested the side impact beams in Three point bending test using CAE software's.
- Analysed the Side impact beams in the static and explicit analysis using CAE software's.
- Discussed the results of displacement, reaction force, energy absorption of the side impact beams.

6. Structure of the Graphical Part

- Force reaction Vs Displacement graph of the static implicit analysis in ANSYS workbench is analysed which beam has high force reaction and energy absorption.
- Energy absorption Vs Displacement graph of the explicit dynamic analysis in ANSYS workbench is analysed which beam has low displacement and high energy absorption.
- Reaction force, Energy absorption graph of the side impact beams are analysed in LSDYNA PREPOST.

7. Consultants of the Project

Student: ....

(Name, Surname, Signature, data)

Supervisor..

(Name, Surname, Signature, data)

Programme Director of the Study field *Janina Jablonskytė*

(Name, Surname, Signature, data)

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Shanmugapriyan Ponnadai. Analysis of Side Impact Beams in Car Side Door. Master's Final Degree Project / supervisor Assoc. Prof. Dr. Lukosevicius Vaidas; Faculty of Mechanical Engineering and Design, Kaunas University of Technology.

Study field and area (study field group): Transport Engineering (E12), Engineering Science.

Keywords: Side impact beams, collision, occupant, Solidworks, ANSYS, LS DYNA PREPOST.

Kaunas, 2018. 73 pages.

Summary

In the case of side impact in contrast to frontal one, there are no distinguished deformation zones. Nevertheless, vehicle safety is characterized by various tests and regulations, but none of them defines strength characteristics of side doors anti-intrusion beams. After experimental testing of side doors anti-intrusion beams produced by different manufacturers it was stated, that the beams support very different bending loadings, what allows to do an assumption, that a beam being mounted not always fulfils its function or mechanical features are chosen unreasonably. Computational models of side doors anti-intrusion beams, allowing preliminarily evaluation of structure stiffness during vehicle impact against side obstacle, were developed.

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Shanmugapriyan Ponnadai. Automobilio Durų Šoninių Apsauginių Sijų Analizė. Magistro baigiamasis projektas / vadovas Assoc. Prof. Dr. Lukosevicius Vaidas; Kauno technologijos universitetas, Mechanikos inžinerijos ir dizaino fakultetas.
Studijų kryptis ir sritis (studijų krypčių grupė): Transporto inžinerija (E12), Inžinerijos mokslai.
Reikšminiai žodžiai: Šoninio smūgio sijos, susidūrimas, keleivis, SolidWorks, ansys, LS Dyna Prepost.

Kaunas, 2018. 73. p.

Santrauka

Įvykus šoniniam susidūrimui, priešingai nei priekiniam, nebūna išskirtinių deformacinių zonų. Nors transporto priemonių saugumą apibūdina įvairūs testai, tačiau nė viename iš jų nėra nustatytos šoninų durelių apsauginių sijų stiprumo charakteristikos. Atlikus skaitinius eksperimentinius skirtingų gamintojų šoninių durelių apsauginių sijų bandymus pastebėta, jog sijų atlaikomos lenkimo apkrovos labai skiriasi, kas leidžia daryti prielaidą, kad montuojama sija ne visuomet atlieka savo funkciją arba mechaninės charakteristikos parenkamos neracionaliai. Sukurti šoninių durelių apsauginių sijų skaitiniai modeliai, leidžiantys preliminariai vertinti konstrukcijos standumą transporto priemonei susiduriant su šonine kliūtimi.

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Chapter-1

Introduction

Side impact collision accidents happen every day in various countries are mostly dangerous stage condition leads to death. Moreover, the space required of the side impact is less than the frontal impact. Side impact collision is directly impacted by the structure of a vehicle which affects the occupant. The vehicle structure which absorbs the impact energy from the side impact which passes the limited injuries to the occupant from the accident and side impact beam should resist from the crash impact forces, absorb the energy which minimizes the impact to the passenger compartment [1].

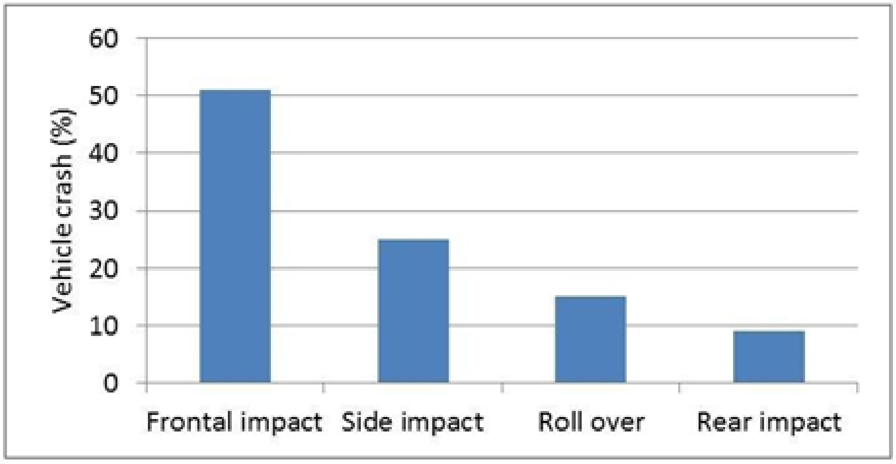

Figure 1.1 Percentage of the crash in different impacts [1]

The impact beam is attached on the door panel of the vehicle which has strengthened the car door for safety and side impact beam should be a high static strength, stiffness is a most important factor for the collision impact. Many car companies, manufacturing the vehicle structure of the door with standard regulation which concerns the weight reduction, high stiffness, high toughness and absorbs the deformation energy. They are two techniques to reduce the mass of the side impact beam, the first technique is to redesign cross-section of the beam and second technique is to change the materials of the beam like aluminum alloy, mild steel, and composite material. This method is generally very useful to the lightweight automobile impact beams and body structures of the vehicle [2].

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1.1 Crashworthiness

Crashworthiness of the vehicle and passenger safety is the most important challenging design to the automobile industry. The vehicle safety is depending on crashworthiness and passive safety is to avoid the crash from the obstacle with different systems are ACC, ABS, AEBS (Auto emergency braking system), CMS (Collision mitigation braking system). In the automotive industry, measures the ability of the vehicle structure in crashworthiness which becomes plasticity deform and maintain the space to survive the crashes with deceleration load. Occupant restraint system which provides the safety protection to minimize the fatalities and injuries to the passenger. Evaluation of the Crashworthiness discovers the test and analytical methods. The design and suitable material for the vehicle structure crashworthiness which absorbs the energy of the collision structure are transform to internal work of the crushed structure. Crashed bodies are non-linear which obtained material failure, joints failure, unstable structure. When the collision takes place in the vehicle structure which collapsed in the deformation zone and forces will be gradually dangerous in acceleration. The load-deflection curve is under the area is equal to the amount of energy absorbed and addition designing of the vehicle structure can withstand the static load, fatigue load and design of the vehicle structure to be allowed maximum energy absorption while collision impact [3].

Crashworthiness of the vehicle and passenger safety is the most important challenging design to the automobile industry. The aim of the crashworthiness to avoid the deformation of the vehicle at possible ways.

1.2 Requirements of Crashworthiness

The stiffness of the structure of vehicle should withstand in bending and torsion load for the comfort handling condition. They should reduce the vibration for the handling which leads to harshness. The frontal structure has more space for the crumple zone which absorbs more kinetic energy for frontal collision in plastic deformation and gives safety to the occupant. If the vehicle is less frontal body structure the crashworthiness engineer has challenge task to reduce the impact of the collision [4].

- Side structure should be designed to withstand the collision and prevents the passenger from the crash impact.
- The frontal and rear structure should be designed accordingly with the proper material to protect the fuel tank and occupants from the collision impact.

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- The roof of the vehicle should be strong and stiffness with the proper material should withstand the rollover crashes and prevent the passenger from the crashes.
- Design the various type of chassis with spaces in the compartment and arrange the engine, transmission with the proper location which should not affect the occupants [4].

1.3 Safety Standards

1.3.1 National Highway Safety Administration (NHTSA)

The transportation of the US Department of National Highway Safety Administration (NHTSA) established the Highway Safety Act in 1970. NHTSA performs the safety program of National Traffic and Motor Vehicle Safety Act in 1966. The safety requirements of the Motor Vehicle to the manufactures and parts of vehicles. In 1972 the NHTSA performs the various programs of Motor Vehicle Information and Cost Savings Act are processed from the title of 49 outlines in Chapter 301 [3].

The safety standard goals of the NHTSA to prevent injuries from the impact and economic cost will be reduced from crashes of the vehicle. The safety standard sets the goals of achieving the acceptance and execute the standards for the automobile manufacturers and awareness program for the government safety standard. NHTSA safety standard continuously researching and investigating the new safety standards for the automobile which reduce the injuries from the collision. This safety standard helps the organization and government maintain to minimize the risk from the drunken drivers and set the standards for child safety seat and seat belts. Developing the safety standards of anti-theft automobiles and researches the driver's behavior and Road safety to innovate the safety standards to the automobile companies and passenger safety which helps to reduce the injury from the collision [3].

1.3.2 Federal Motor Vehicle Safety Standard (FMVSS 214)

Federal Motor Vehicle Safety Standard 214 is established in 1990 to protect the passenger in a dynamic test which simulates at an angle of crash impact. This standard is most important to the safety standards by means of National Highway Traffic Safety Administration (NHTSA).

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The fatalities of side impact have 33% for passenger car occupant so this safety standard used to decrease the injuries to the passenger if the car side door is struck with another car collision [5].

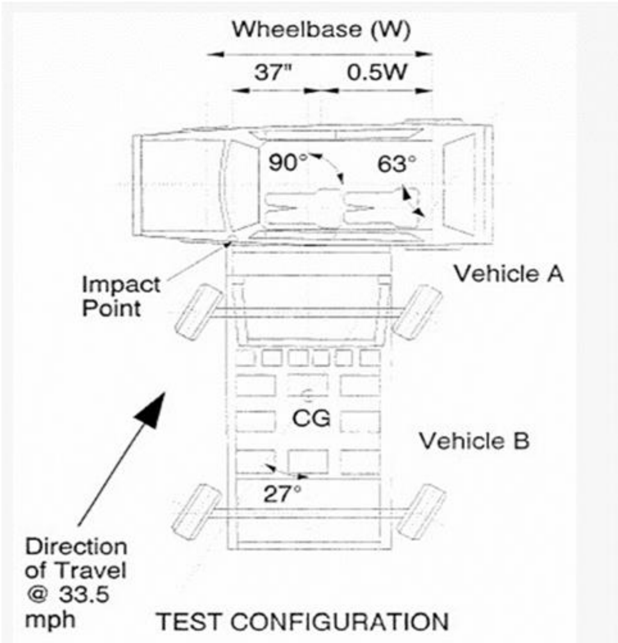

Figure 1.2 FMVSS 214 Test Configuration [5]

After many years research, they developed the passenger car which reduces the injuries and manufactured the vehicle with less harmed from the side impact during the struct from another vehicle which collision on the side door. The NHTSA standard is developed by the United States and international community researched together for the safety standard [5].

1.3.3 Insurance Institute for Highway Safety, Side Impact Test Protocol

The Insurance Institute for Highway safety test is most critical to the vehicle which leads to injuring the occupant serious level, so it is good using the side impact protection occupant can survive from the collision with injuries. It is same as Federal Motor Vehicle Safety Standard (FMVSS 214) crash test but in this procedure, wheels are aligned in the moving deformable barrier (MDB) on longitudinal axis of the cart is zero degree which allows for 90-degree impact on the vehicle at the velocity of 50 kmph (31 mph) [6].

The moving deformable barrier which has a total mass of 1500 kg and impact velocity of 50km/hr at the angle of impact is 90 degrees to the vehicle which cause damage to the occupant at the serious condition. The objective of the safety standard to test the vehicle it is suitable for

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the occupants which increase the regulation to reduce the side impact, prevent from the damage, avoided injuries in the collision [6].

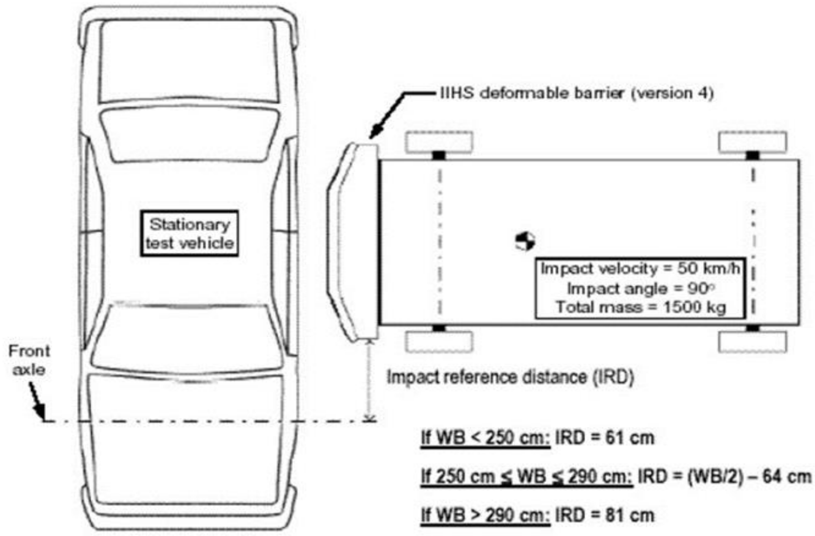

Figure 1.3 IIHS Test Configuration [7]

1.3.4 Euro – NCAP side impact test

Euro – NCAP side impact test evaluating the research at the carriage of 950 kg (Aluminium foam in frontal part) impacts at the displacement of 50km/hr hit against the vehicle at the stationary condition with dummies as driver and passenger in the seats. In the side impact test which the car is fixed on the carriage against a pole and moves against to the stationary fixed pole with the speed of 29km/hr. In this test, they added dummies in driver's seat which directed towards the pole near to the driver's head with the diameter of 254 mm during the impact which enters into the car cabin which affects the occupant so evaluate the research in Human head injury criteria (HIC).

Side impact beam is attached on the car side door parts which protect passengers in a collision with side obstacle. There is no separate beam standard test or regulation test for the side impact beam testing.

After finished the car production model are tested and fitted the side impact to test in this condition. The research should be determined in the experimental or computational method to analysed the result of the side impact test with intersecting of the safety bags, occupant head and passenger of the rear seat moving is analyzed in dynamic condition [8].

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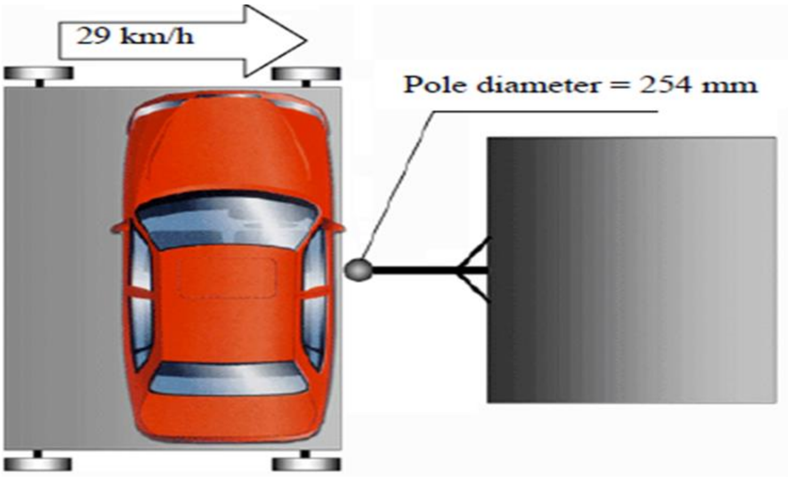

Figure 1.4 Test of a side impact to the pole according to Euro-NCAP [8]

1.4 Collision of side impact facts

1.4.1 crash data

In the present day-day injuries take place every hour around the world and most of these are very unstable. The side-impact crash is the second most severe crash scenario after frontal-impact. It may be found that the frontal impact is higher than the side-impact. However, the space required for any structure in the event of a side-impact to absorb strength can be very less than the frontal-impact. The occupant injuries inside the side-impact crash are severe while compared with the frontal crash. different crashes concerned are the rollover and rear impact. Many researchers have executed a significant study on frontal and side impact crash evaluation and have been a success in decreasing the risk of the injuries sustained by the occupant [2].

The commission has observed an ambitious road safety program which targets to reduce road deaths in Europe between 2011 and 2020. The program sets out a mixture of initiatives, at the European and countrywide stage, specializing in improving automobile safety, the protection of infrastructure and road customers' behavior [10].

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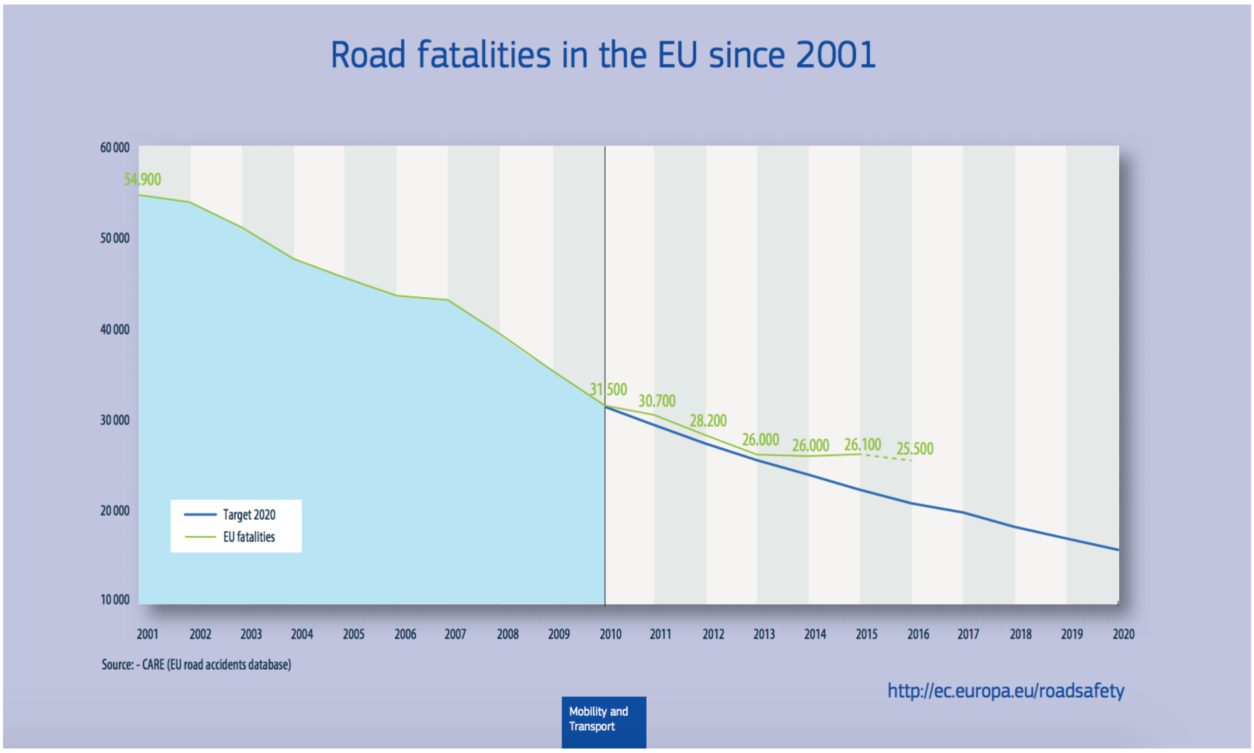

Figure 1.5 Road fatalities in the EU since 2001 to 2020 [10]

1.4.2 Injury pattern of side impact protection

Intrusion most usually will increase the threat of chest, stomach and pelvic injuries. Door panel intrusion remains the most considerable contributor to occupant injuries. Earlier than the implementation of the side impact standard, it turned into probably that the lower door panel could interfere and result in pelvic fracture [11].

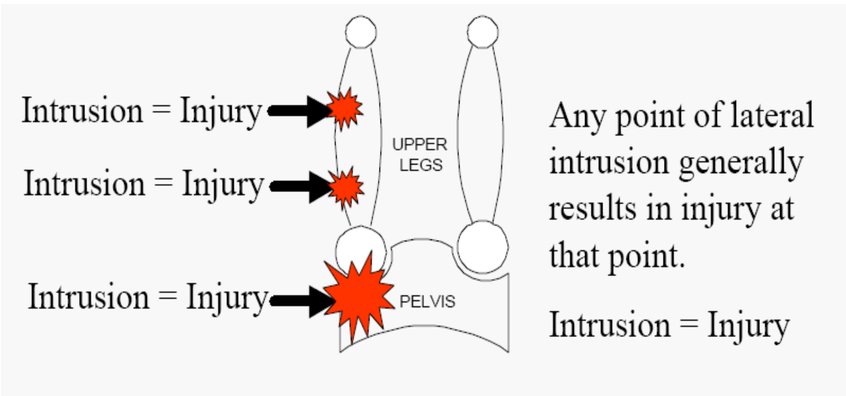

Figure 1.6 Injury Pattern in Side Impact [11]

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Chapter-2

Literature Review

In past years from different researches of the side impact beam mentioned that design of the beam should withstand any condition. The material of the beam should be high in strength, stiffness, and damping properties. From upcoming years development and usage of the composite material in automobile parts, beams are increasing rapidly. The modern development design of composite beam which absorbs the energy and more deformation.

"Crashworthiness Evaluation of Low Weight Recyclable Intrusion Beam for Side Impact" analysed the research project by Avinash P. Pawar [1] given that intrusion beam is attached to the car doors which absorb the kinetic energy to prevent the passenger from the collisions. From many types of research proves that without intrusion beam are very dangerous by direct contact with the occupant in a crash collision. If the side intrusion beam is made of the composite material which reduces the injuries of the occupant and reduces the weight than the Aluminium. In this research project, the side intrusion beam is made up of thermoplastic glass fiber composite material are analyzed by FEA (Finite Element Analysis) and obtained results are validated by the safety standards in Federal Motor Vehicle Safety Standard (FMVSS) – 214 for occupant cars.

The Finite element analysis results are differed from the experimental results by percentage of 23.2%. The rectangle cross section of the side impact beam with the composite material of glass epoxy fiber has high resistance than the high strength steel and it has 41.4% of weight reduction when compared with high strength steel and Aluminium.

"Development of Side Door Intrusion Beam of Passenger Car for Maximum Bending Load" analysed the research project by Yogesh K. Nichit, Prof. Arun. K. Battu [19] given that the cross-section beam is determined from the Finite Element Analysis (FEA) for side intrusion beam. It is the main part which absorbs the energy from the crash impact and gives the major role to prevent the passenger from the major accidents. From the different cross, section beams are developed from the FEA to test the three-point bending test. The parameters should be modified so it will determine the load capacity of maximum bending.

From different section of the bending force are compared and valuated the beams. Optimization the design of side impact beam which has good result performance should be decided.

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- The cross section of I shape, and Square shape has a maximum bending force than the circular shape beam, but I shape has maximum bending when compared to the square shape beam will be good.
- The bending force of the I cross section impact beam has 8.6 KN but the weight of the beam is 17% less than the circular beam and 34 % increased the load carrying capacity.
- If the square section beam is replaced to circular section beam can reduce 10% of weight and 24% of load carrying capacity.

"Design and Analysis of a composite beam for side impact protection" analysed the research project by K. Veeraswamy, V. VenkataSudheerBabu [20] given that the side impact beam is made up of composite material which reduces the weight of the beam and increases the fuel efficiency. In this research project, the side impact beam is made up of Carbon/Epoxy AS4/3051-6 which has high load carrying capacities, high stiffness and absorb more strain energy compared with steel. The side door is made in the Finite Element Analysis of solid structure are obtained in this project. They designed the new side impact beam using CATIA and removed the current the beam in the car and they modified the new beam which is attached to the driver side door of the car. Comparing the total energy absorption result of the new beam and current beam with the steel and composite material. The side impact beam is analyzed with the FMVSS 214 safety methods for the side impact. Executing the new side impact beam which reduces the injury of the occupant from the collision and absorbs the energy from the impact. The composite material beam is the most effective in FMVSS 214 standard for the side impact protection and absorbs the displacement energy than the steel from the impact. The weight reduction of the beam is 65%. Therefore, the composite side impact beam fails in the buckling because of impact load, proper design, fiber matrix and fiber orientation combination reduce the failure of the buckling.

"Study and Advanced Concept for Side Impact Protection Beams to Reduce the Injury of the Occupant Using CAE " analysed the research project by DHANEESH K P, B. PRABAKARAN [21] given that aim of the project work to change the current beam to modified beam with use of high strength steel of yield stress is 1200 Mpa when compared with low strength steel of yield stress is 366 Mpa so this high strength of the material is better to withstand the impact from collision which reduces the impact to the occupant with low injuries.

In this research removing the current beam attaching the new beam with high strength steel material on the car side doors which will impact the collision and analyzing with the help

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of CAE (Computer Aided Engineering). Analysed the total energy absorbing of current side impact beam and new side impact beam with the high steel material comparing the results of the beams with the standard regulation of FMVSS 214. This Newly modified side impact beam which reduces the impact of the car side door structure which absorbs the energy from the side impact collision. Simulating the crash test in the side impact beam in the computational method of CAE which analysis the result of the current side impact beam in high strength steel material is

- The deformation of the side impact beam is reduced randomly at 25%.
- In the safety standard regulation of FMVSS 214, High strength steel material beam is effectual in this safety regulation.
- The energy absorption of the new high strength steel material beam increased 40% than the current side impact beam.
- When compared to the low strength steel material beam to the high strength steel material beam are more stiffness and strength of the beam is high.
- Automobile manufacturing company can change the mechanical properties of the steel by using the method of heat treatment process.
- The experimental car needs to test in practical condition whether it can withstand the impact of the collision.
- The occupant can verify the injury parameters of the new side impact beam using test dummies in LS dyna.

"Design Study of a Side Intrusion Beam for Automotive Safety" analysed the research project by Pedro Mota Rebelo in Instituto Superior Tecnico, Lisboa, Portugal [22] given that the protective components of the safety system which prevent the collision and the protective components are sided intrusion beam is installed in the vehicle side doors to prevent the occupant from the accident. Design of the side impact beam which absorbs the impact energy between the elasto-plastic deformation process. The beams with the thinned walled structure which absorb more deformation energy from the impact. This research work focuses on the cross section of the beams to find the bending performance. If the beam has high bending performance installed in the car side doors and tested in different crash test regulations.

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Improvement of bending performance in side intrusion beam which tested in crash condition and it shows the thickness variation in the beam. Mainly the selection of the material for the beam is important to specify the yield stress σy, finding the maximum bending load act on the beam which can sustain.

"Design and analysis of a composite beam for side-impact protection of occupants in a sedan" analysed the research project by Hamid M. Lankarani [3] given that aim of the research is to investigate the composite material of side impact beam attached on the car side doors which helps to reduce injuries of the passenger. The structure of the composite tube is researched in the different test to find out the maximum energy obtained from the material, thickness, and orientation. The safety standards of FMVSS and IIHS test to find out the acceleration and beam sustained on the vehicle before and after use of composite beam. Researched about the occupant kinematics ae discussed in detail process. The side impact composite tube tested in axial and transverse direction. From the different materials and orientation of the beam used to find out the highest energy absorption. The composite structure beam is fitted on the doors of the vehicle to find the acceleration, displacement, and injuries to the passenger should be reduced.

- Composite side impact beam absorbs more energy, but the beam will obtain more deformation which minimizes the displacement and car acceleration will be 55%. The composite material which reduces the weight of the beam up to 60%.
- The composite material beam is stronger than the present beam which randomly decreases the injury level of the occupant from the collision.
- The side impact beam is so effective in both IIHS and FMVSS regulation standard with the percentage of IIHS – 71% and FMVSS – 83% in reduction of acceleration.

"Investigation of anti-intrusion beams in vehicle side doors" analysed the research by E. Černiauskas, A. Keršys, V. Lukoševičius and J. Sapragonas [8] presented a paper on the impact beam by considering the FMVSS 214 regulation standard. Analysed the side impact beam with different cross sections and different steel grade standard material.

- The stiffness of anti-intrusion beams uses in various car model at many times. After investigation of the experimental and numerical methods of the beam strength with sufficient rigid closed profile beams at different materials and in open profile beams has minimum stiffness requirements.

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- The side door intrusion beams are designed in the CAD model to evaluate the structure stiffness while during the collision against the obstacle. Analysed the side vehicle impact beam against the obstacle developed from FE models of the force-power characteristics of non-isolated beams and dynamic investigation of the beams.
- Calculation of the experimental beam and FEM results of the open profile side door beams with different cross section and different materials of the mechanical properties.
- The results are depending on the mechanical properties of the material which is used to perform in mechanical testing of the side impact beams.

"Crashworthiness Evaluation of Side Door Beam of Vehicle" analysed the research by T. L. Teng, K. C. Chang, T. H. Nguyen [23] given that aim of the research study full scale side impact beam test are in the FEA models are obtained and test models are based on the FMVSS-214. the crash test is simulated in LS-DYNA of finite element code. Analysed the performances of the side impact beam crashes on the collision which finds the displacement of the beam and injuries obtained on the dummies. The main objective of this research studies is to investigate the effectiveness of the side impact beam in the computational method with the standard regulation of FMVSS-214. Optimize the design of the beam which absorbs more energy from the impact of fewer injuries to the occupant.

"Improved Side Impact Protection" analysed the research by Tom Gibson, MONASH University [24] given that developments of the side impact protection explained and discussed the severity of the accidents and injuries in side impact crashes. The real time accidents data from the year 1989 to 1997 in Victoria. In real time crashed vehicle can analysis data from the National accident analysis sample (NAAS) and provided all injuries of side impact crash.

"Preliminary Design of Side Door Impact Beam for Passenger Cars Using Aluminium Alloy" analysed the research studies by Mohd Fadzli Abdollah, Rafidah Hassan [2] shows that the Finite Element Analysis (FEA), to determine the cross-section of the side-door impact beam. The energy absorption of Aluminium alloy and high-strength steel were investigated using a Charpy impact test.

Both materials of differential fractures and surface contours after impact testing, which directly indicates that Aluminium alloy experienced a ductile fracture and higher impact energy absorption than the high-strength steel.

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Structural design was studied using FEA, determine a suitable cross-section for the side-door impact beam. Observation of the fractures and surface of both materials, after the Charpy impact test, shows that the Aluminium alloy experienced a ductile fracture profile and the high-strength steel fractured in a brittle fracture profile.

"TAGUCHI BASED DESIGN OPTIMIZATION OF SIDE IMPACT BEAM FOR ENERGY ABSORPTION" analysed the research studies by Radha Krishna Nemani, Dr. Rachayya Arakerimath [26] shows that the three different cross sections of the side impact beam are obtained. Side impact collisions are the second largest cause of death and injury in the collision after frontal crashed. Side impact beams are used in the doors to absorb the impact energy and reduce the depth of door intrusion, thus help protect the occupant. In a full vehicle test of side impact against a pole, the intrusion characteristics of the complete door assembly are assessed. 'Side impact beams' plays a major role in the behavior of the complete door assembly.

In this work, three different cross-sections of the side impact beam are considered. The Finite element method models to develop the three-point bend test (quasi static load test). The investigation performed using LS-DYNA explicit finite element which absorbs the energy absorption in different design of beams and optimized the parameters using Taguchi method. Performing the vehicle side doors to the location of the punch at 450mm energy absorption is minimum. It's very high sensitive to punch displacement at 100 mm energy absorption is minimal.

"Modeling, Analysis and Comparative Study of Side Impact Beam" analysed the research studies by Harijono Djojodihardjo, Soo Lin Khai [21] shows that the objective of the work is to obtain a fail-safe impact beam with an example of an impact beam for the door panel of a passenger car to provide a high level of safety for passengers towards side impact without breaking.

The present work attempts to obtain the minimum possible weight of impact beam while maintaining the level of safety. Fiber Reinforced Polymer (FRP) material is used to analysis the procedure of the computational method. The thickness of the composite structure of fiber material with better stiffness, less weight and absorb deformation energy. In the linear static analysis, the composite beam of E-glass/Epoxy with the thickness of 6mm and orientation performs well than the steel. It has 5.71% less weight and deformation of the material will be low and absorb the deformation energy up to 57.2% more than the steel beam.

`

The simulation of the impact beam in computational method with impact load can withstand. The composite has low density, high specific modulus and strength of the beam are high. The properties of composite materials have both typical static or dynamic loads. The replacement of steel beam with composite material is good for the side impact beam which prevents the occupant from the side crash collision.

From previous different research studies show that the composite material is used in the automobile parts and efficient design which gives safety to the car and weight of the vehicle is less and absorbs more deformation energy. The composite material has high specific stiffness and strength. It also has high impact load absorbing and damping properties of the composite material beam.

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Chapter 3

Theoretical Background

Side impact vehicle injuries are most risky accidents to the occupant higher than the frontal crashes. side impact crashes are directly impacted by the automobile structure which affects the occupant due to the fact there may be no large area required for the deformation to save you the occupant from the collusion. The car structure which absorbs the impact power from the aspect effect which passes the restricted injuries to the occupant from the coincidence and aspect impact beam has to withstand from the crash impact forces, absorb the strength which reduces the effect to the passenger compartment. side effect car injuries end in critical accidents to the passenger because of time loss of aspect air bags and plenty of coincidence cases the sufferer will do the mistakes to have an effect on the collision with the side of the cars.

3.1 Side-Impact Beam

Vehicle side doors are the most imported components of the frame because this element has to conform with a lot of requirements and specifications. The gap between the door and the occupant may be very less in a side impact when in comparison to the frontal impact. The protection member referred to as the side impact beam is generally located inside the door and this is answerable for offering high stage of safety for the occupant in the event of side impact by another car. For the structural analysis of the side door impact beam, Finite element method becomes used considering it is the maximum widely used computational method within the automotive industry [9].

3.2 Types of crash test investigation

3.2.1 Quasi-Static testing

In quasi-static testing, the test specimen is overwhelmed at a consistent velocity. Quasi static tests won't be a real simulation of the crash situation because, in a real crash situation, the structure is subjected to a decrease in crushing speed from an initial impact speed finally to relaxation.

The following are some advantages of quasi-static testing:

- Quasi-static tests are easy and smooth to manipulate.

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- To observe the crushing method, impact tests require a very high-priced device, because the complete process occurs in a split second. therefore, quasi-static tests are used to study the failure mechanisms in composites, by using a selection of suitable crush speeds [13].

The following is the main drawback of quasi-static testing.

- Quasi-static tests won't be a real simulation of the actual crash situations since certain materials are strain rate sensitive.

3.2.2 Impact testing

The crushing velocity decreases from the initial impact velocity to relaxation because the specimen absorbs the energy.

The following is the main advantage of impact testing

- It is a real simulation of the crash situation because it takes into consideration the stress rate sensitivity of materials.

The following is the main drawback of impact testing.

- In impact testing, the crushing method takes place in a fraction of a second. consequently, it is encouraged that crushing is studied with high-speed camera [13].

3.2.3 Dynamic Collision test (FMVSS 214)

In this test process, a deformable barrier set up on a sled impacts a vehicle side door angularly. this is, all four wheels of the barrier-sledge are inclined at an angle of 27° in the front, an aluminum honeycomb barrier is fixed, and this is at the peak of the bumper in order that the real simulation of the crash is simulated. inside the automobile, a US-side impact Dummy is placed in the front seat and this dummy measures the injury ranges sustained [12].

3.2.4 Composite test procedure (CTP) for automobile side impact testing

The terminology should suggest, this test method is not most effective for a composite. This test begins with the displacement of the barrier into the side of the vehicle until the internal door is in contact with the dummy. At this point, the barrier face is half on this position until the internal wall of the door is loaded using the frame forms. enough force-deflection information is received for the computer model. [12].

`

Chapter 4

Research Methodology

The methodology of this research is to design, and analysis of the side impact beam fitted inside car side doors to prevent the occupant from the side collision. side impact is the threat of injury better than the frontal crashes because there's no huge area for the displacement to prevent passenger from the crash impact. Front structure which absorbs energy five times greater than the side structure from the crash impact. side impact beam has to be a high static strength, stiffness is a most essential factor for the collision impact.

- Design the side impact beam with different types of cross section profile with different materials and tested in the static, dynamic test.
- Nonlinear plasticity materials are used in the side impact beam have high strength, stiffness and impact energy.
- The density of the material will be low, so the weight of the material will be low in this condition with reinforcement of high modulus and absorbs more deformable energy than the steel, Aluminium.
- The side impact beams are analysed in static (Implicit) structural and explicit structural analysis in the CAE software of ANSYS Workbench and LS DYNA Prepost to find the reaction force, displacement, and energy absorption in the beams.
- Comparing the Results of the Implicit and Explicit Structural Analysis method of three-point bending test which method is better for the side impact beams.
- Comparing the results of the different cross section beams with different materials which compare the beams has high energy absorption from the impact and displacement, Force reaction of the beam.
- Side impact beam should resist the crash impact, absorb the energy which minimizes the impact to the passenger compartment and prevent the injuries.

`

4.1 Research Methodology Methods

In this Research methodology methods, Design and Analysis of the side impact beam in car side doors which are tested in three-point bending test in static and explicit dynamic analysis with the regulation methods. This research thesis is processed into the methods of the methodology are listed in the flow chart below:

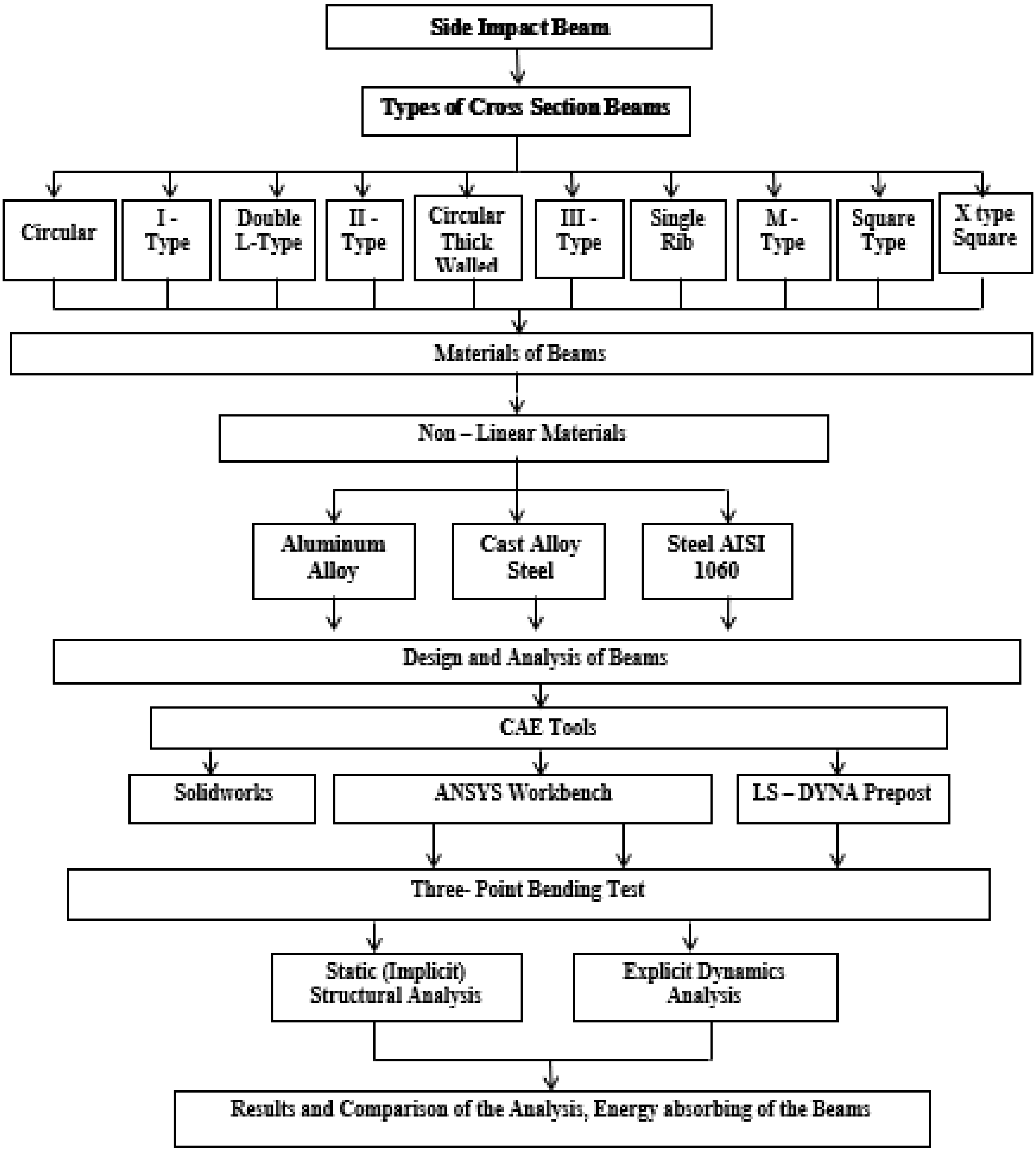

Figure 4.1 Methodology of research methods flowchart

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4.2 Problem Identification

This research project is based on the literature review about the side impact beam of the car side doors and identified the problems from the research literature review are:

- The side impact beam design from the literature review is not able to withstand the high deformation from the side collision and selection of material is steel so the energy absorption is less, and weight of the side impact beam will be an increase.
- Most of the side impact beam from the literature review preferred the National Highway Safety Administration (NHTSA) and Insurance Institute for Highway Safety (IIHS) regulation standard from experimental testing which includes the time, cost and human effort.
- Most of the researches from the literature review, the side impact beam is not tested in the 3 - point bending test. This test which performs the bending simulation at a low cost.
- In the Previous research studies, the side impact beam is fitted in the car side doors which tested in the safety standard of NHTSA and IIHS which takes more time to be analysed and computer simulation for the side impact beam are the major drawbacks lack of a faster way for performing than the experimental test.
- In the previous research studies from the literature review, the side impact beam is not compared with the implicit (static) structural analysis and Explicit dynamics from the CAE software.
- The cross section of the side impact beam wants to be designed in a proper manner which can withstand the deformation from the collision and rigidity of the beam should be high.
- The combination of high ductility and strength of the metal material is high which large deformation is performed and the material weight should be reduced in the side impact beam.
- Finally, selection of the material should be in nonlinear material, so the strength of the material will be high and absorb the more energy absorption from the impact, so the weight of the side impact beam will be reduced and prevent the occupant from the injuries.

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4.3 Computer Aided Engineering Tools

4.3.1 ANSYS

ANSYS Mechanical is a finite element analysis device for structural analysis, along with linear, nonlinear and dynamic studies. This computer simulation product offers finite factors to model behavior and helps material models and equation solvers for a huge variety of mechanical design issues. The ANSYS simulation platform delivers the broadest suite of high-quality-in-class simulation technology and unifies it together with your custom programs, CAD software program and company enterprise method equipment along with PLM. It's open and flexible framework connects engineering teams, equipment, and information. ANSYS is a standard-purpose software program, used to simulate interactions of all disciplines of physics, structural, vibration, fluid dynamics, heat transfer and electromagnetic for engineers. So ANSYS, which allows to simulate assessments or running conditions, allows to test in some virtual surroundings earlier than production prototypes of products. moreover, determining and improving weak factors, computing existence and foreseeing probably issues are possible by way of 3D simulations within the virtual surroundings [16]. ANSYS software with its modular structure as visible in the table below gives a possibility for taking only needed features. ANSYS can work included with different used engineering software program at the desktop via including CAD and FEA connection modules. ANSYS Mechanical organization is the flagship mechanical engineering software program answer that makes use of finite element analysis (FEA) for structural evaluation the usage of the ANSYS Mechanical interface [16].

Material: an entire range of material models covering the whole thing from hyper elastics, form memory alloys, soils, concrete, plastic and metal structures may be as it should be modeled; you could even upload user-defined fabric models if needed [15].

Dynamics: Mechanical corporation can cover all your needs for dynamic analysis, which includes harmonic, spectrum reaction and random vibration with pre-stress, and advanced solver options for fast solutions. within the transient domain, each implicit and explicit solver allow you to model time structured scenarios. The rigid body Dynamics functionality helps you to clear up mechanisms rapidly. It also allows you to include element Mode Synthesis (CMS) components to feature flexibility to models while still accelerating the simulation [15].

`

4.3.2 LS-DYNA

LS-DYNA is a preferred purpose transient dynamic finite element application able to simulate complex real-world issues. it is optimized for shared and distributed memory UNIX, Linux, and windows-based systems. it is an explicit 3-D finite element software for studying the large deformation dynamic reaction of the elastic and inelastic solids and structures. the program is significantly used by many top vehicle, aerospace and research organizations. A wide range of material types and interfaces permit the efficient mathematical modeling of many engineering troubles. It consists of more than one hundred and fifty material models along with metal, nonmetallic and composite models which allow to define any material in the real world. The contact competencies along with touch between deformable bodies, between deformable and inflexible our bodies supplied in LS-DYNA can resolve any contact issues which very useful in crash testing [3].

The main software regions of LS-DYNA are as follows:

- Crashworthiness simulations: vehicles, airplanes, trains, ships, etc.
- Occupant safety analysed: LS-DYNA included with MADYMO is used for dummy interaction with airbag, seat belts, foam padding, etc.
- To simulate bird strike to airplanes.
- analysis and optimization of metallic forming technique.
- Biomedical programs and many more [6].

LS-DYNA computes on leading UNIX machines, supercomputers mad massively Parallel Processing (MPP) machines. computers configuration depends on processing time and problem length. excellent computers and MPP takes the advantage of a couple of processes when the code is relatively efficient. LS-Dyna is used to simulate the crushing method of a composite tube and it is used to compare the unique composite materials in determining the maximum energy absorbing material. three-point bending test is likewise done the use of this FEA solver. The side-impact beam designed is placed in the side door of a car and then the side-impact analysis is carried in LS-Dyna [14]

4.4 Modeling of Side Impact Beam

4.4.1 Different types of cross section profile side impact beams

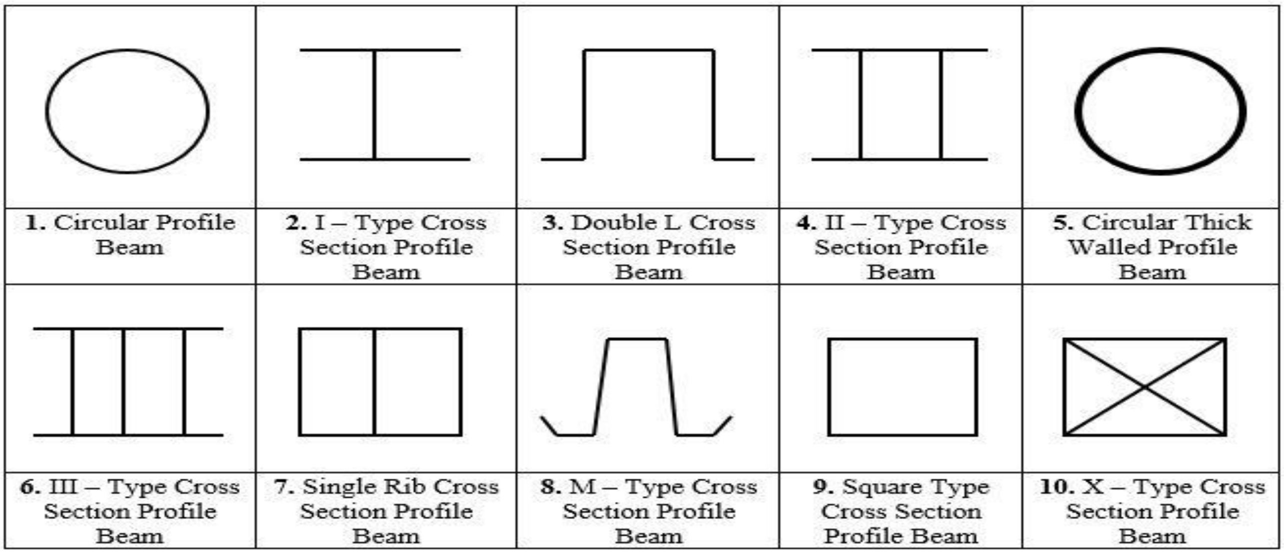

Figure 4.2 Types of Cross section side impact beams

- In these types of side impact beams, 1 and 5 – Different wall thickness circular profile beam which 1st beam is 2mm thickness profile beam and 5th is a 4mm thickness profile side impact beam.
- The 2nd profile beam is I type cross section profile beams which has a flat surface with edges and 3rd profile beam is Double L cross section profile beam which has flat at the upper side with the edge cornered beam.
- From 4th and 6th profile, the beam has II and III type cross section profile beams with the flat surface which transfers the force distribution uniformly.
- In the 7th and 8th profile, the beam has single rib cross section profile beam which absorbs the load uniformly and M-type cross section beam has cornered edges which affects the force distribution.
- The 9th and 10th profile beams have Square type and X-type square cross section beams have a flat surface which absorbs the load with high strength at the middle surface of the beams.

`

4.4.2 Dimensions of Different Cross Section Beams

Table 4.1 Dimensions for different cross section profile beams

NO	CROSS SECTION OF PROFILE BEAMS	THICKNESS, MM	DISTANCE BETWEEN SUPPORTS, MM
1	Circular cross section profile beam	2 mm	1000 mm
2	I – Type cross section profile beam	2 mm	1000 mm
3	Double L cross section profile beam	2 mm	1000 mm
4	II – Type cross section profile beam	2 mm	1000 mm
5	Circular thick-walled profile beam	4 mm	1000 mm
6	III – Type cross section profile beam	2 mm	1000 mm
7	Single rib Cross section profile beam	2 mm	1000 mm
8	M – type cross section profile beam	2 mm	1000 mm
9	Square type cross section profile beam	2 mm	1000 mm
10	X – type cross section profile beam	2 mm	1000 mm

`

4.5 Material Description

The materials used in the side impact beam are described in this methodology are Aluminium Alloy, cast alloy steel, Steel AISI 1060.

4.5.1 Material Properties of side impact beam

The process of plasticity conduct in ANSYS. This effective BISO and MISO models. The Bilinear Isotropic Hardening (BISO) option makes use of the stress yield standards coupled with an isotropic of hardening assumption, it is known as bilinear because just two lines defined the stress-strain curve: one to explain the linear elastic region and any other to the plastic. The Multilinear Isotropic Hardening (MISO) is like the preceding model, except that multiple curves are used rather than a bilinear curve. to enter the data in ANSYS, to define the material's behavior in both the elastic and plastic region. to perform this, general strength specimens have been produced and submitted to a tension test [17].

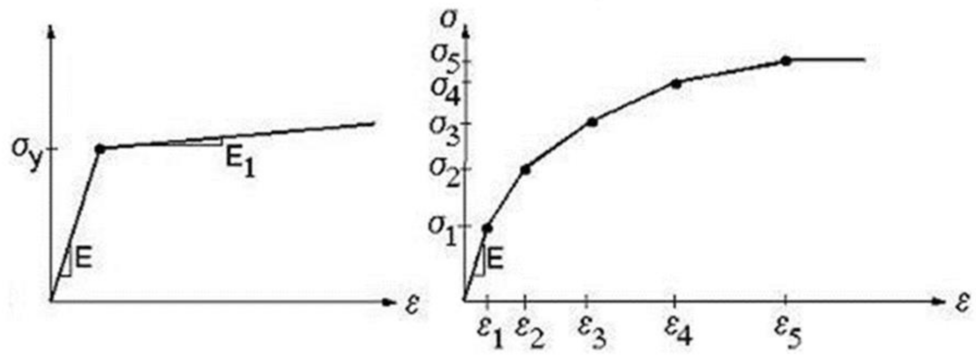

Figure 4.3 Uniaxial behavior for a) MISO and b) BISO model [17]

In this thesis, the side impact beam materials are deals with the Bilinear Isotropic Hardening (BISO) plasticity which the stress and strain curve has linear elastic region and plastic region added to the materials used in the side impact beams. The stress and strain curve have the elastic, plastic state and facture point.

From the ANSYS software its necessary to obtain the stress and strain curve of the elastic, plastic region of the Bilinear isotropic hardening of the yield stress and young's modulus of the materials in the side impact beam [17].

`

Table 4.2 Material Properties of the side Impact beams

	Aluminium Alloy	**Cast Alloy Steel**	**Steel AISI 1060**
Young's modulus, MPa	71000	1.9E+05	2.05E+05
Poisson's ratio	0.33	0.26	0.28
Density, Kg/m^3	2770	7300	7860
Tangent modulus, MPa	500	780	1468
Yield strength, MPa	280	241	430

4.6 Model Description

In this Research, Side impact beam is attached the Ford fiesta car side doors are analysed and tested the side impact beam in LS DYNA software. For this purpose, Ford Fiesta car side doors are chosen in this research work. The dimensions of the car are given below.

Table 4.3 Dimensions of the Ford Fiesta [18]

Side Doors Length	1000 mm
Length	3924 mm
Width	1685 mm
Height	1468 mm

Figure 4.4 Ford fiesta model [18]

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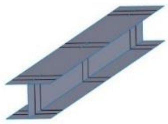
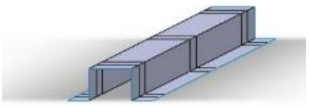
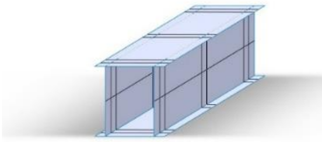
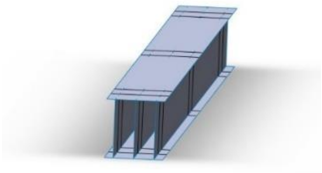
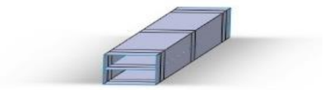
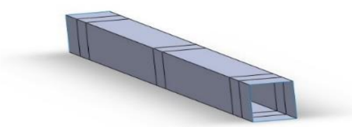
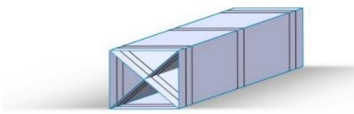
4.7 SOLIDWORKS Model

4.7.1 Beam Models

Table 4.4 Types of cross section beam models

	
1. Circular cross section profile beam	2. I – Type cross section profile beam
	
3. Double L cross section profile beam	4. II – Type cross section profile beam
	
5. Circular thick-walled profile beam	6. III – Type cross section profile beam
	
7. Single rib Cross section profile beam	8. M – type cross section profile beam
	
9. Square type cross section profile beam	10. X – type cross section profile beam

`

Solidworks design software is used to design the side impact beam developed by the Dassault Systems French company. Solidworks is the Computer Aided Three-Dimensional Interface Application. The dimension of the side impact beam length is 1000mm and design of the beam is shell is extruded in the Surface Extruded.

This type of cross section beams is designed in the Solidworks with the specific thickness and dimensions. This side impact beam is attached to the car side doors which absorbs the deformation energy from the side collision and prevents the passenger from the impact without any major problems

4.8 LS DYNA PREPOST Model

4.8.1 Side impact Beam in the model door

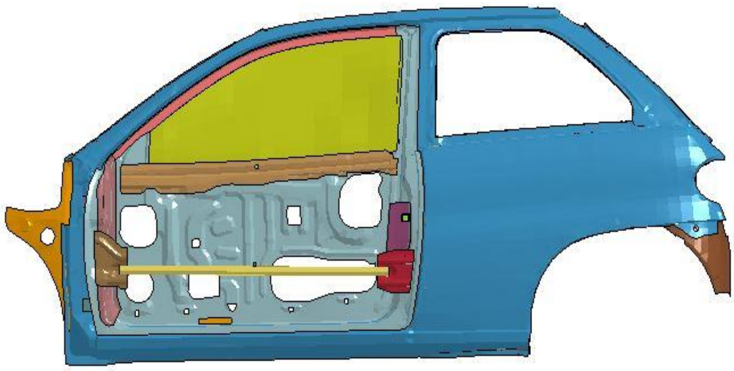


Figure 4.5 Side impact beam in the door without panel

The side impact beam is fitted in to the side doors with the dimensions of 1000mm with the two fixture supports on the edge of the side impact beam. The beam is tested the material in Aluminum Alloy, Cast alloy steel and Steel AISI 1060. The figure shows the side impact beam in the door with panel and figure shows the side impact beam in the door without door panel.

`

Chapter 5

Design Model Analysis

5.1 Model analysis in ANSYS

Side impact beams are Analysed in ANSYS is used to determine to find the deformation, reaction force and energy absorption of the beam. The model of the beam is designed in SOLIDWORKS used to Import into the ANSYS Workbench model. In ANSYS workbench, they are different analysis systems choose the static structural analysis and Explicit dynamics system. In static structural and Explicit dynamics, Select the materials from the engineering data they are various materials in the Engineering data sources. In the Geometry, the process can import the side impact beam from the design modeler. The materials used for the side impact beams are Aluminum Alloy, cast alloy steel, Steel AISI 1060.

5.1.1 Model of Static (Implicit) structural and Explicit Dynamics Analysis in ANSYS

In this Model of side impact beam are imported from the solidworks in the analysis system of ANSYS software in the static structural and Explicit dynamics analysis system with a different cross section of beams with different materials of the beam.

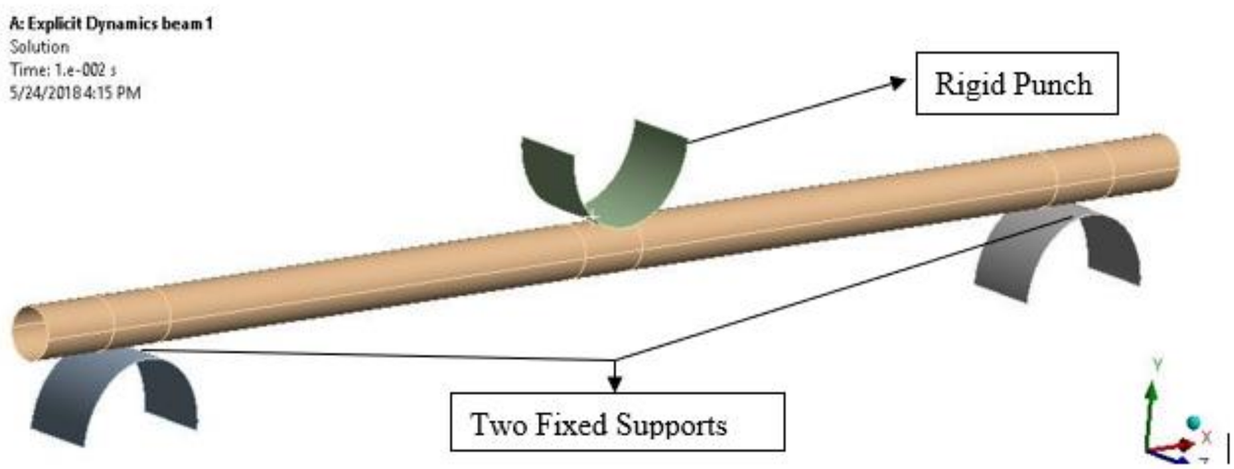


Figure 5.1 Circular cross section profile beam with a rigid punch and two fixed supports

The beam which is similar to other 9 cross section beam with a rigid punch and two fixed supports.

`

5.1.2 Model setup

In the ANSYS software Model setup which the imported model is overwritten in the Geometry od design modeler and analysis in the static structural implicit analysis and Explicit dynamics analysis.

Contacts for both static and explicit dynamic analysis:

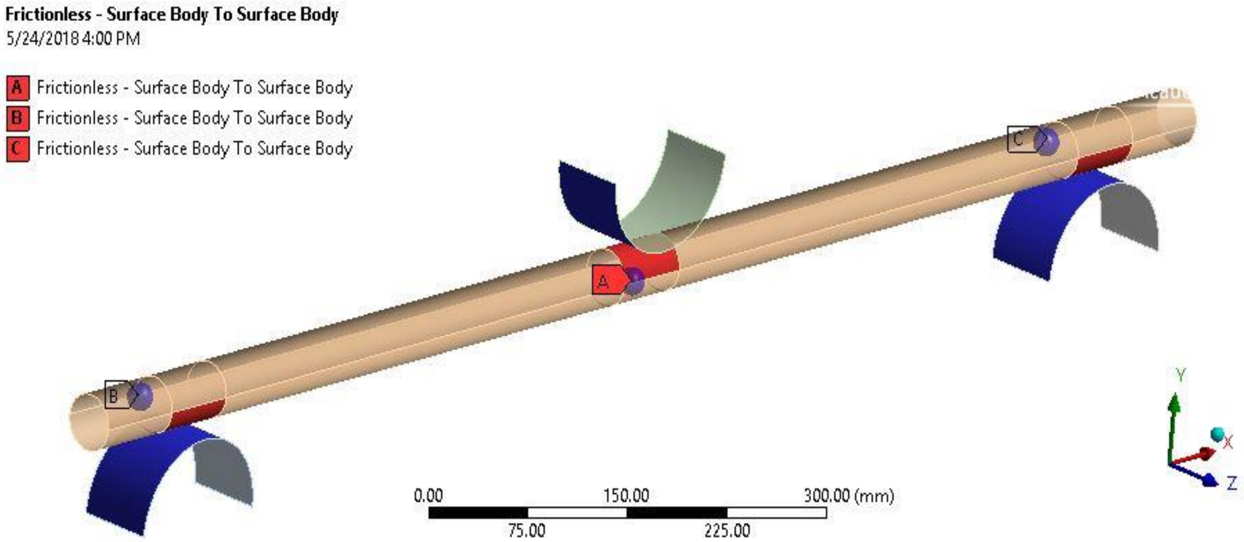


Figure 5.2 Frictionless contacts for the beam, rigid punch, and two fixed supports

In the beam connection, the contacts for the contact the contact bodies and target bodies in the Frictionless type method. This beam is contacted using two supports on the corner of the beam similarly other 9 cross section beam models are in the same manner.

Fixtures and Displacement in Static structural (implicit) and Explicit analysis:

In the side impact beam, they are two fixed supports below the beam and distance between the two supports is 1000mm and the displacement will be free in the Y direction and fixed in the X, Z direction of the beam on the four edge corners in the center of the beam. Now the displacement of the rigid punch will be 150mm on Y-direction axis and X, Z direction of the axis is fixed in the beam.

`

Table 5.1 Displacement and velocity of Axis components

Axis Component	Displacement (mm)	Velocity (m/s)
X	0	0
Y	-150mm	-14.7m/s
Z	0	0

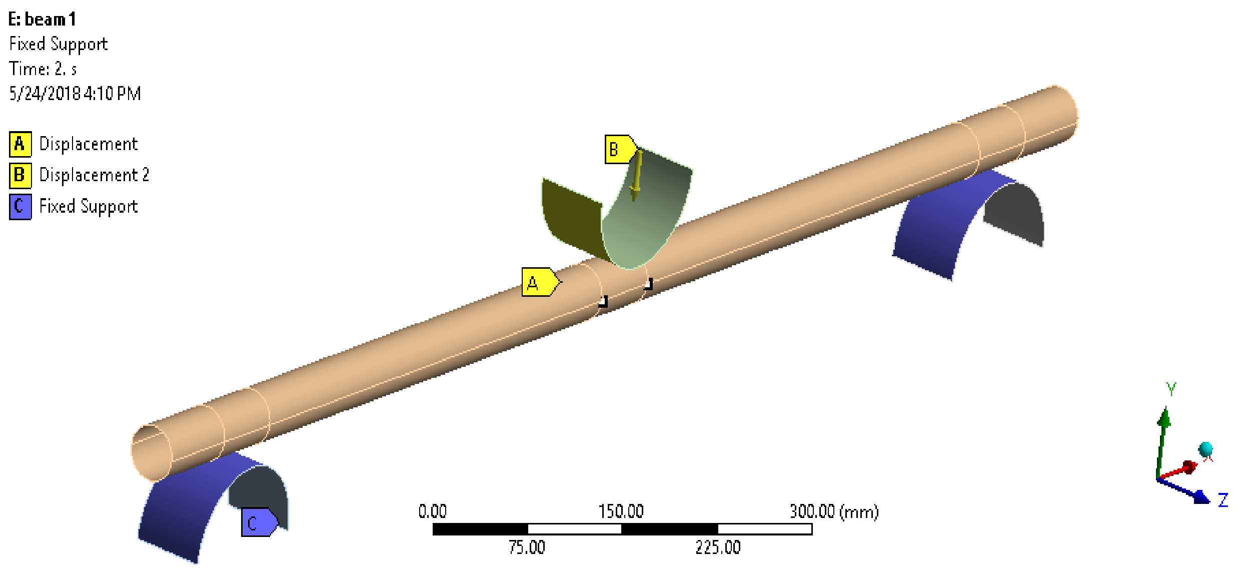


Figure 5.3 Beam with fixtures in the x direction, displacement on the y axis

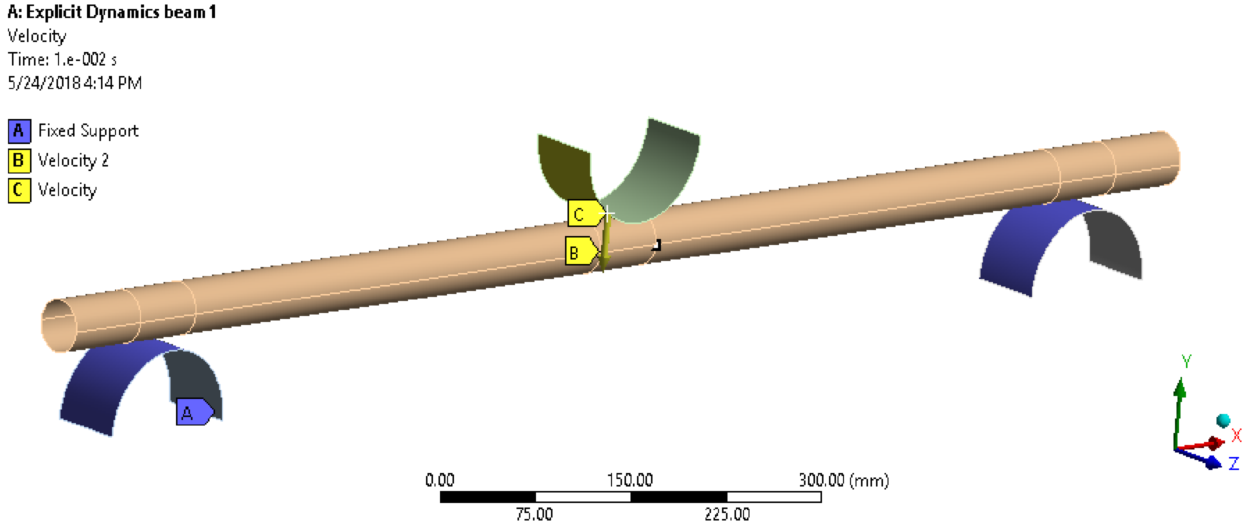


Figure 5.4 Beam with fixtures in the x direction, velocity on the y axis

Now the velocity of the rigid punch will be -14.7 m/s on Y-direction axis and X, Z direction of the axis is fixed in the beam which is similar to other 9 cross section beam with same velocity condition.

5.1.3 Meshed beam

The finite element analysis depends the accuracy of meshing. A coarse mesh is chosen, and the entire beam meshes. The following table shows the mesh data in detail:

Table 5.26 Meshing details

Element size	8.0mm
Size function	Uniform
Behavior	Soft
Methods	Quadrilaterals
Number of nodes	2736
Number of elements	2657

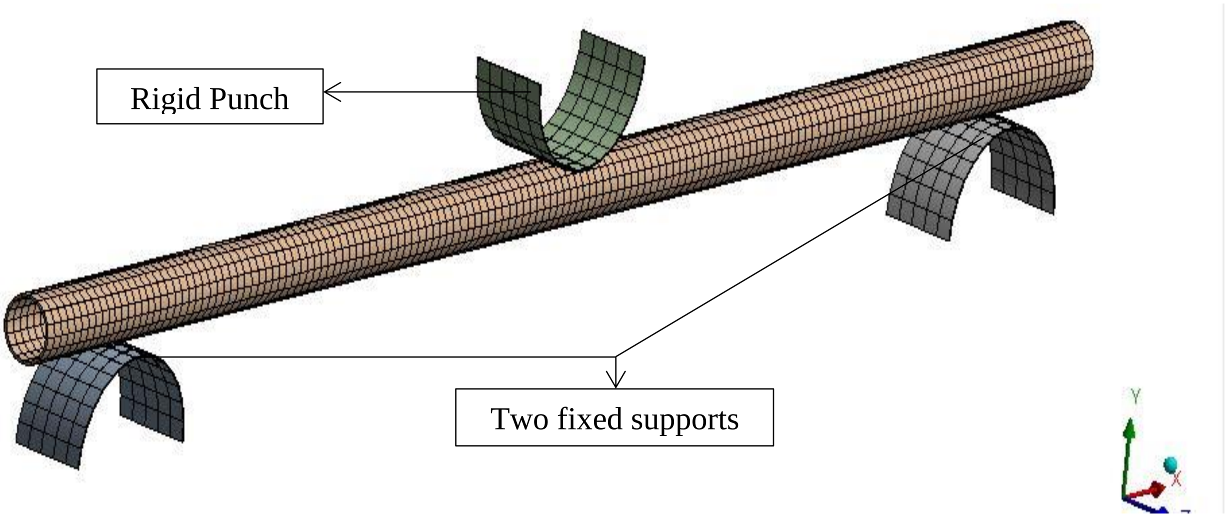


Figure 5.5 Meshed beam in ANSYS

The meshed beam which is similar to other 9 cross section beam with the same element size of 8 mm in coarse condition.

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5.2 Model analysis in LS DYNA PREPOST

Side impact beams are analysed in LS PREPOST is used to determine to find the reaction force of the beam model. The impact beam is designed in SOLIDWORKS used to Import into the LS PREPOST model. In LS PREPOST, chosen the Explicit dynamics system.

5.2.1 Model of Explicit Dynamics Analysis in LS DYNA PREPOST

In this Model of side impact beam are analysed in Explicit dynamics of LS DYNA PREPOST. The circular profile beam with materials of Aluminum Alloy, cast alloy steel and Steel AISI 1060 are attached in to the side doors to analysed the force reaction of the beam.

5.2.2 Model Setup

In the LS DYNA PREPOST software Model setup which the imported model is overwritten in the Geometry and analysis in the Explicit dynamics analysis. Boundary condition and load: The boundary condition on the rigid punch applied the degree of freedom, velocity, load curve scale factor. Constrained and contacts: In the constrained condition applied the node set, joint revolute, spot weld in the side door which the side impact beam is fitted. In the contacts, the two fixture supports are contacted in the side door and the Rigid punch also contacted in the side doors which the displacement will act on the side door.

5.2.3 Meshed the side impact beam in side doors

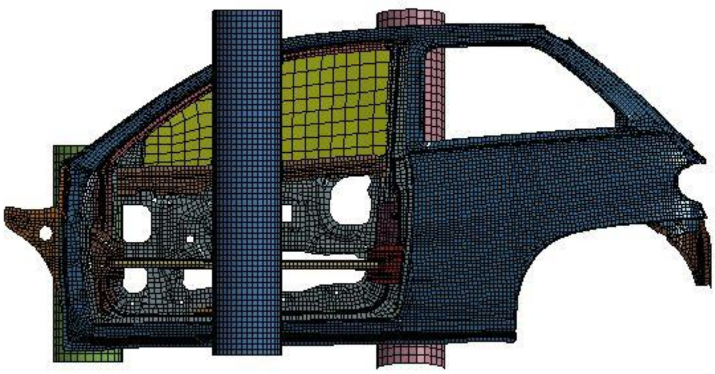

Figure 5.6 Meshed side impact beam in the side door

The side door is meshed with the standard mesh size and the side impact beam, two fixture supports, the rigid punch meshes in the same standard size of 8mm.

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Chapter-6

Results and Discussion

The Side impact beam model is imported into the ANSYS workbench. Comparison of the different cross section beam with different materials is obtained to find the force reaction and energy absorption of the side impact beam.

6.1 Finite Element Analysis Results

The side impact beam is obtained in the Finite element analysis are

- Directional Deformation of static implicit analysis in ANSYS Workbench
- Energy Absorption of explicit analysis in ANSYS Workbench
- Force reaction Vs Displacement – Implicit static Analysis in ANSYS Workbench
- Energy Absorption Vs Displacement – Explicit dynamic Analysis in ANSYS workbench
- Force reaction and Energy absorption - Explicit analysis in LS-DYNA PREPOST

6.2 Directional Deformation

Directional deformation is the most important results to analysis the Cross section beams to withstand the impacts from the displacement. They are static implicit analysis are obtained with the different types of beams with different materials comparing the result of the deformation of the beam.

6.2.1 Static structural implicit Analysis

Directional deformation of 10 cross section beams in Aluminum Alloy which is a similar way to Cast alloy steel and Steel AISI 1060:

The 10 Cross-section beams are analysed in the static implicit analysis which deforms the beam in the material of Aluminium Alloy which the methods are similar to the Cast alloy steel and Steel AISI 1060.

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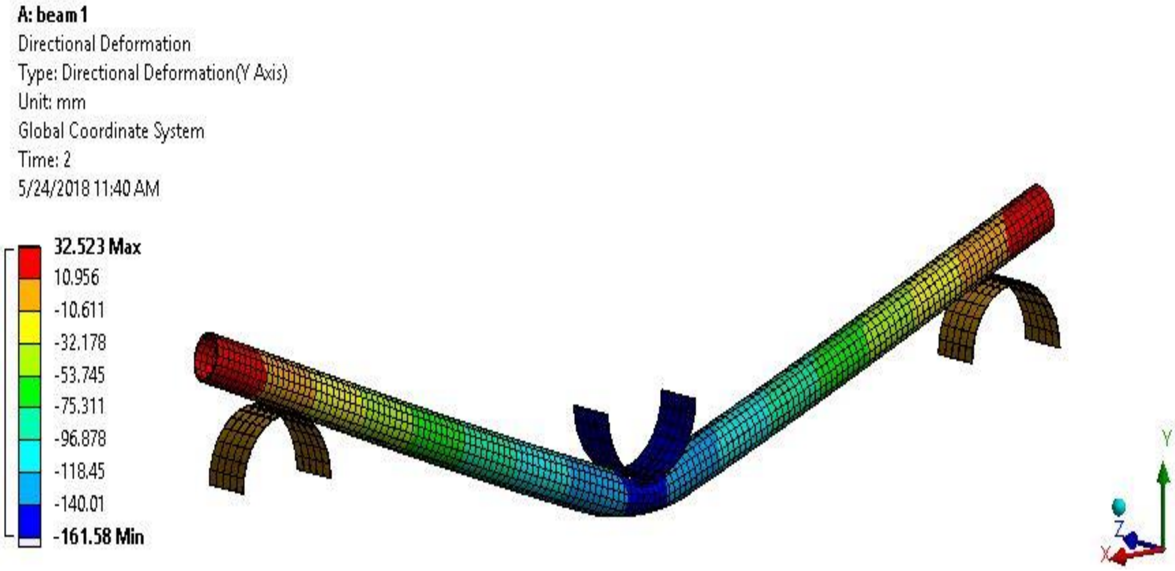

Figure 6.1 Deformation of circular profile beam

In the circular profile beam which the deformation act on the Y axis is -150mm so the maximum deformation takes place in the beam is -161.58 mm**.**

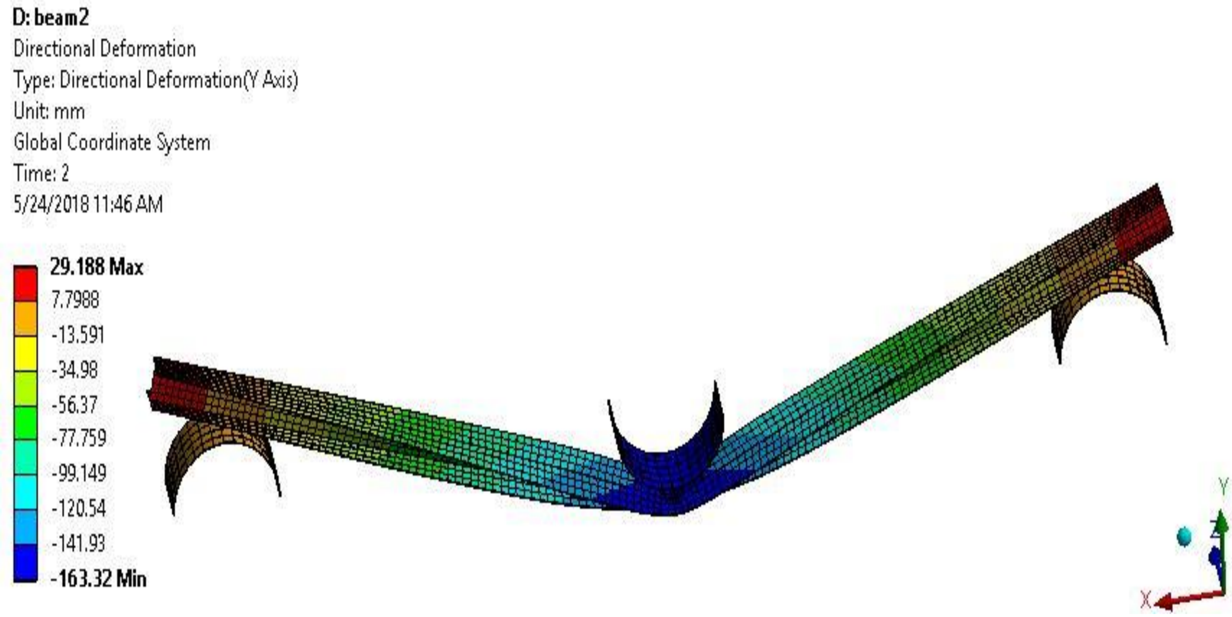

Figure 6.2 I – Type cross section profile beam

In the I – Type cross section profile beam which the deformation act on the Y axis is -150mm so the maximum deformation takes place in the beam is -163.32 mm.

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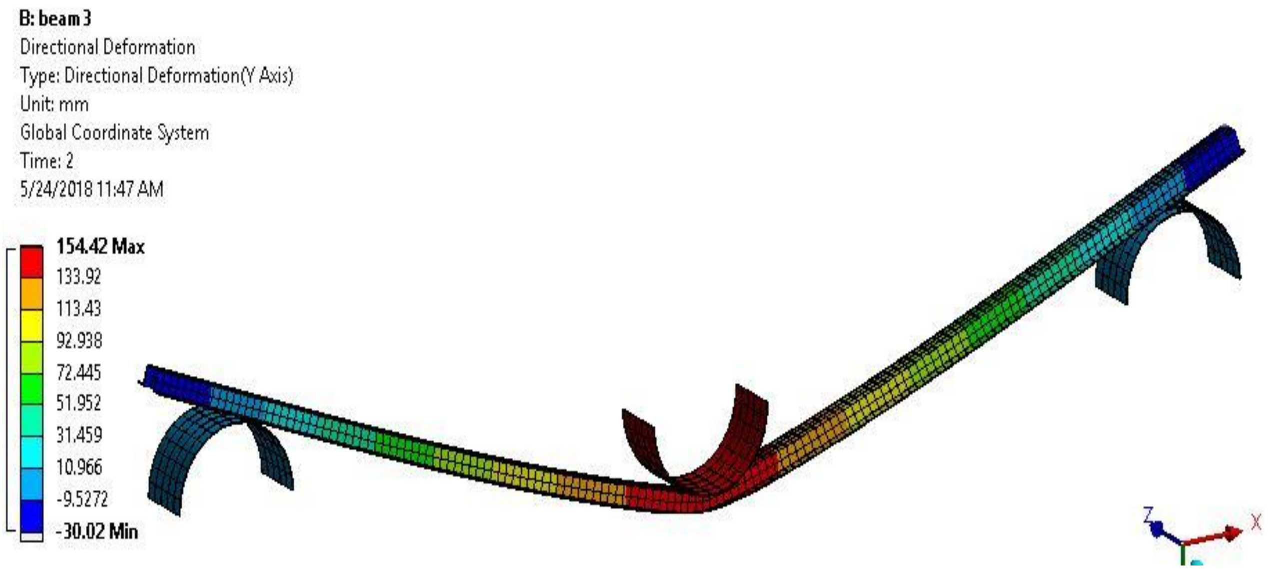

Figure 6.3 Double L cross section profile beam

In the Double L type cross section profile beam which the deformation act on the Y axis is 150mm so the maximum deformation takes place in the beam is 154.42 mm.

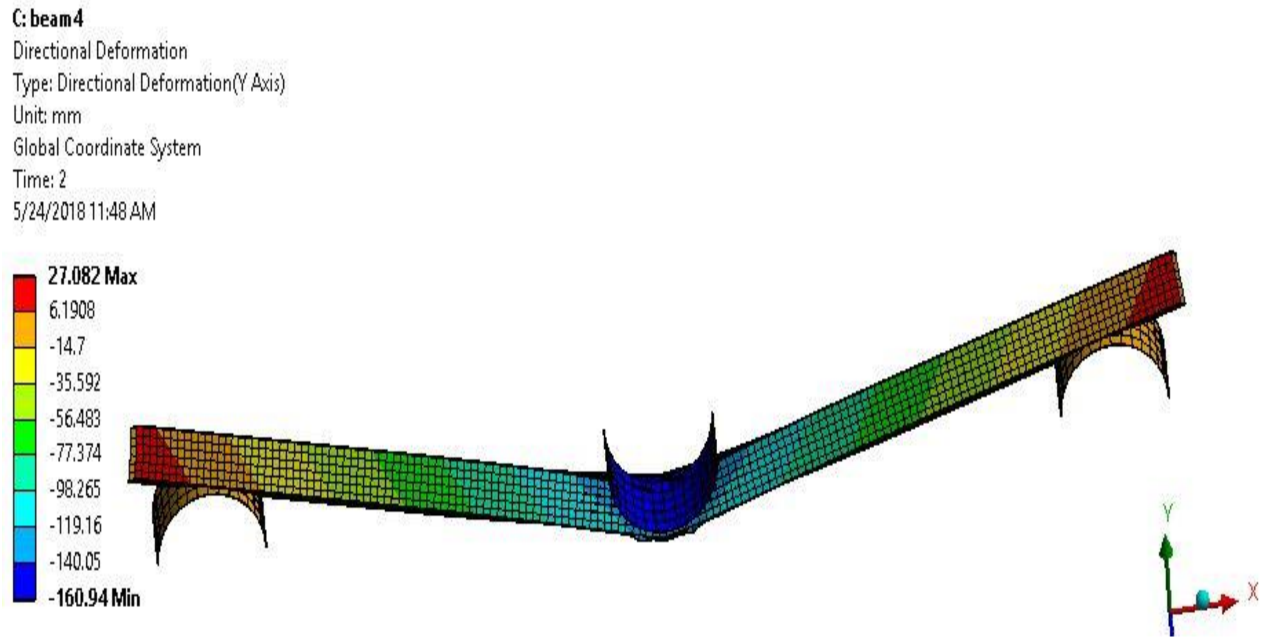

Figure 6.4 II – Type cross section profile beam

In the II – Type cross section profile beam which the deformation act on the Y axis is -150mm so the maximum deformation takes place in the beam is -160.94 mm.

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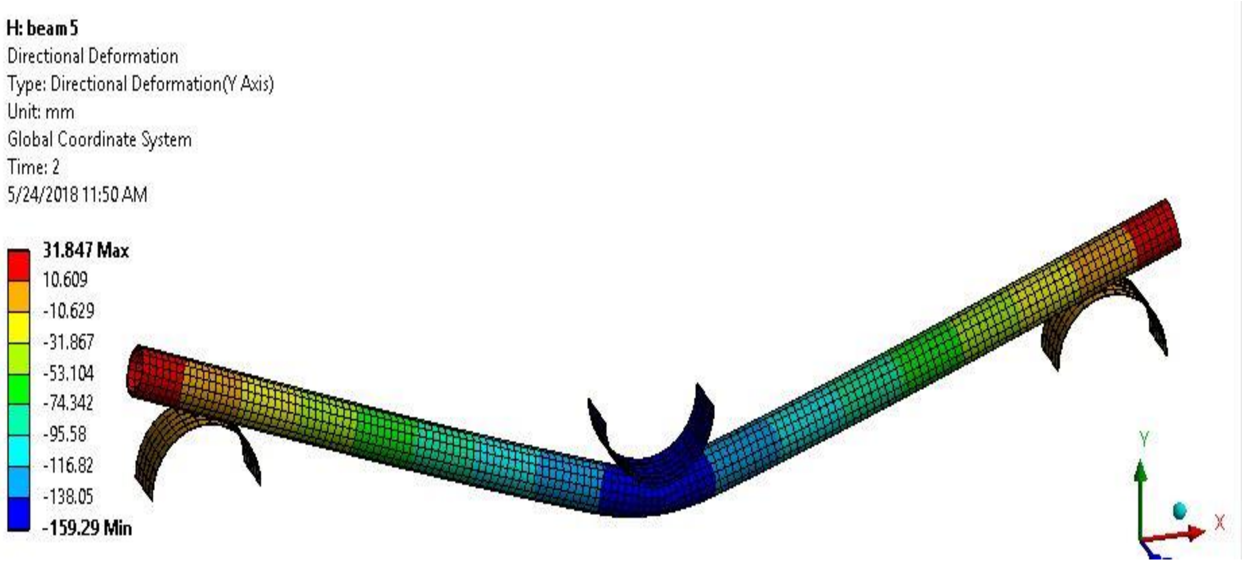

Figure 6.5 Circular thick-walled profile beam

In the Circular thick-walled profile beam which the deformation act on the Y axis is -150mm so the maximum deformation takes place in the beam is -159.29 mm.

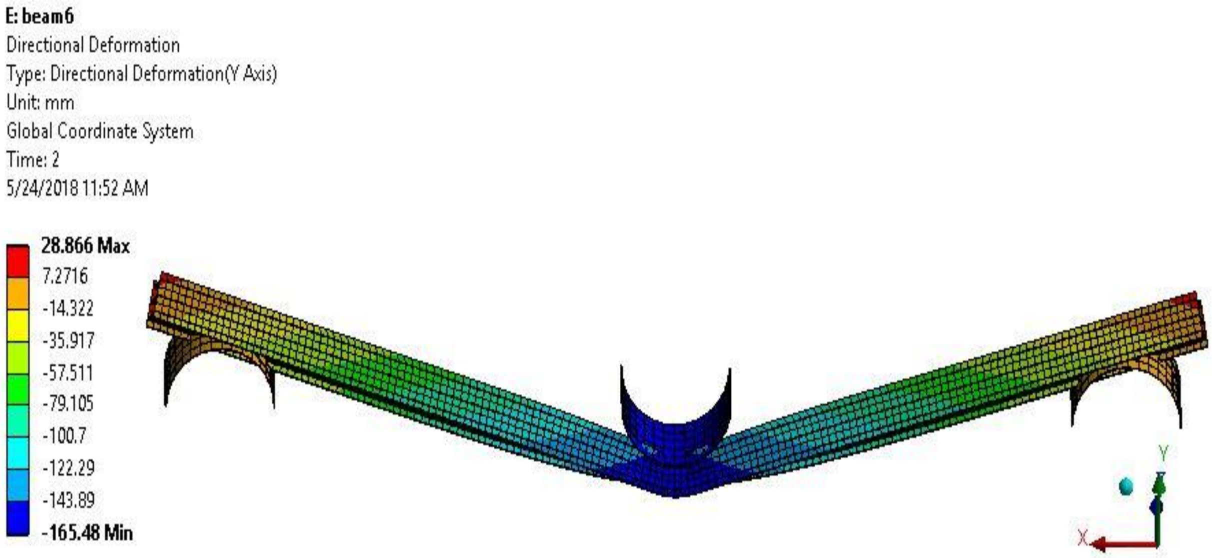

Figure 6.6 III – Type cross section profile beam

In the III – Type cross section beam which the deformation act on the Y axis is -150mm so the maximum deformation takes place in the beam is -165.48 mm.

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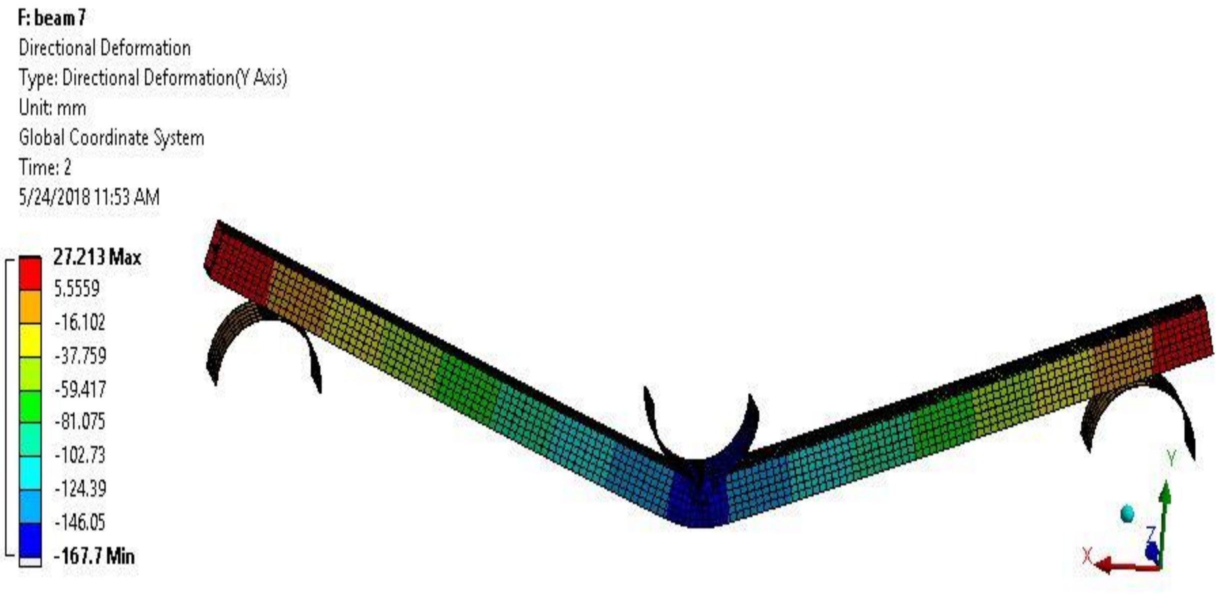

Figure 6.7 Single rib cross section beam

In Single rib beam which the deformation act on the Y axis is -150mm so the maximum deformation takes place in the beam is -167.7 mm.

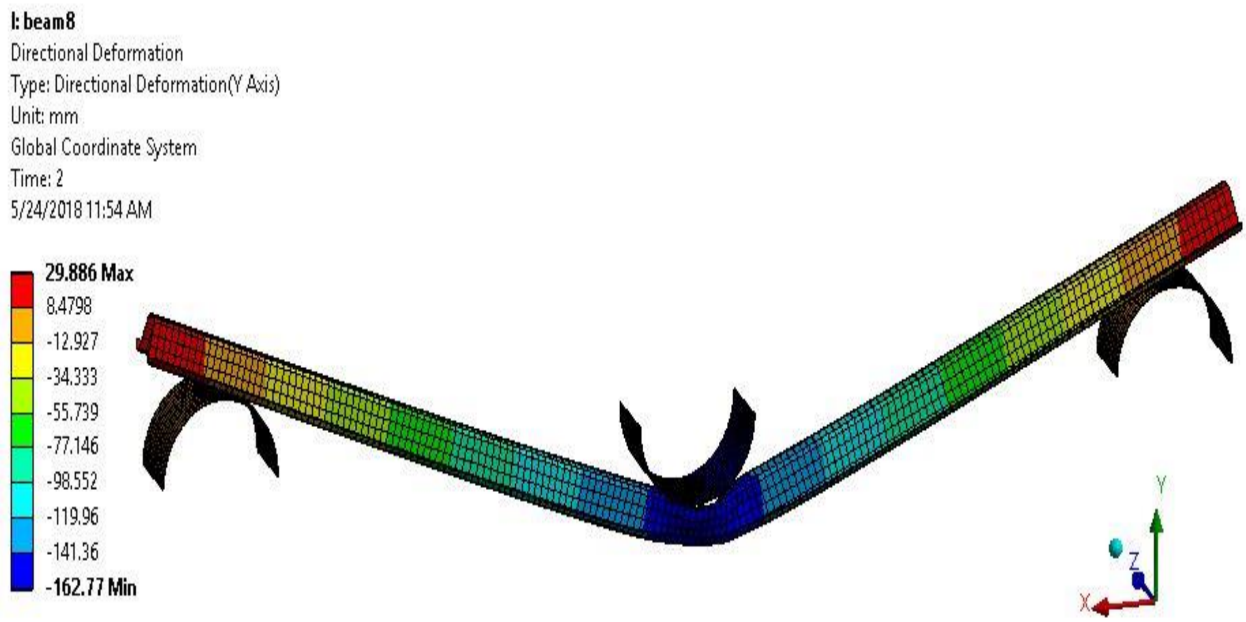

Figure 6.8 M – Type cross section beam

In M – Type cross section beam which the deformation act on the Y axis is -150mm so the maximum deformation takes place in the beam is -162.77 mm.

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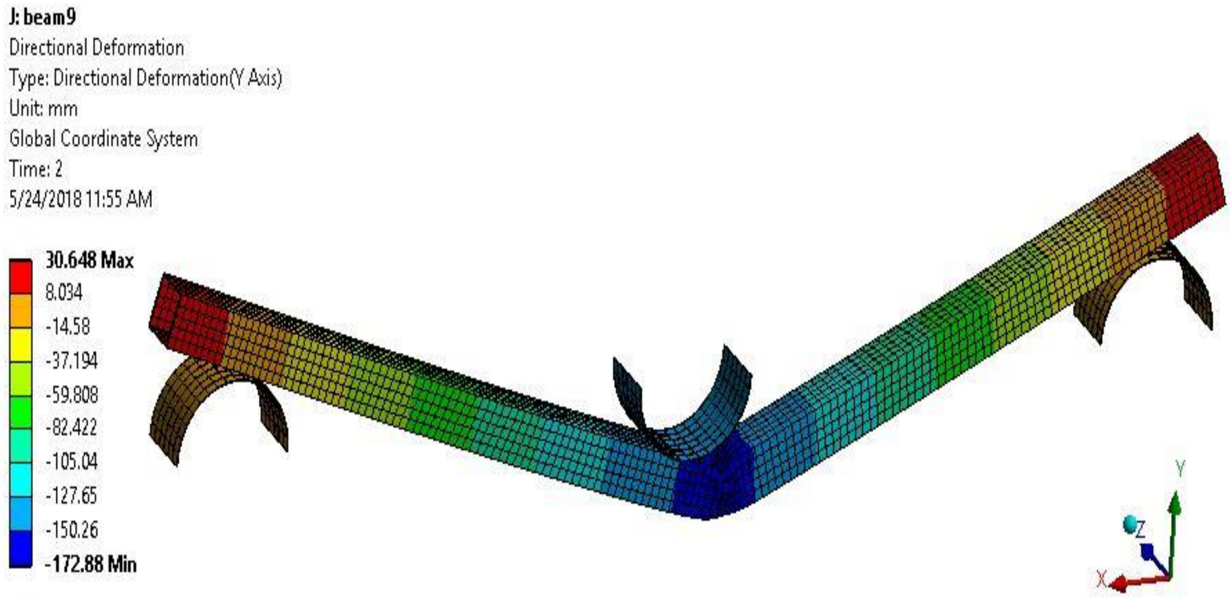

Figure 6.9 Square type cross section beam

In square type beam which the deformation act on the Y axis is -150mm so the maximum deformation takes place in the beam is -172.88 mm.

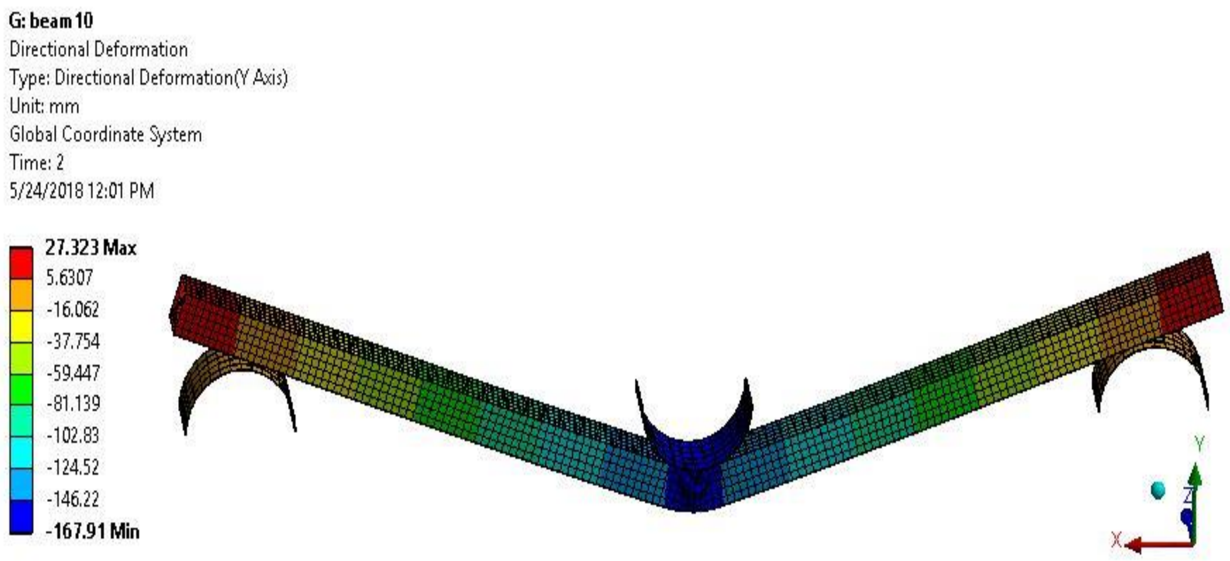

Figure 6.10 X – Type Square cross section beam

In X – Type beam which the deformation act on the Y axis is -150mm so the maximum deformation takes place in the beam is -167.91 mm.

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6.3 Energy absorption

6.3.1 Explicit Analysis

Energy absorption of 10 cross section beams in Aluminum Alloy which is a similar way to Cast alloy steel and Steel AISI 1060:

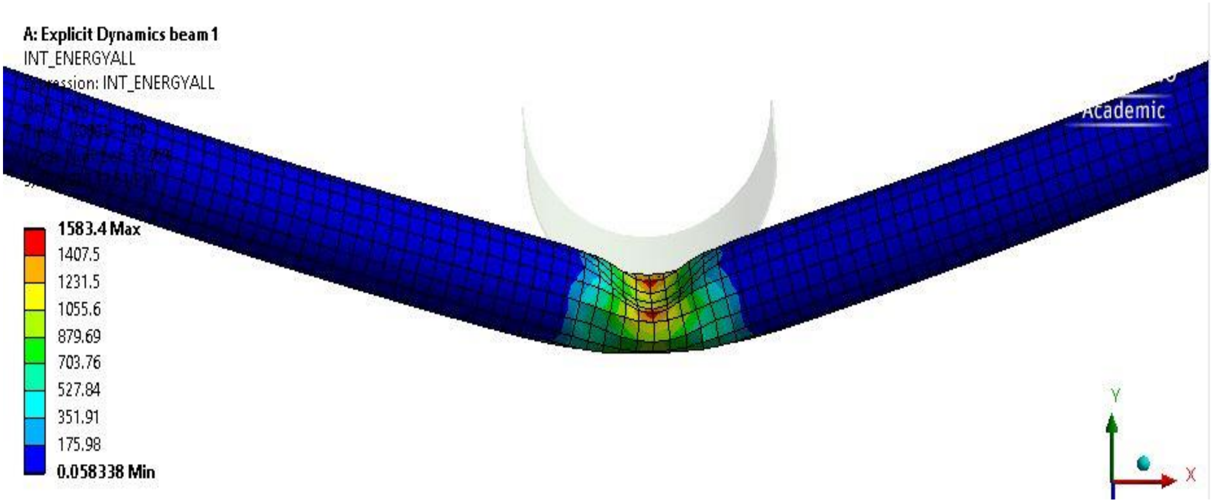

Figure 6.11 Energy absorption of circular profile beam

In the circular profile beam which the velocity act on y axis is -14.7 m/s on the rigid punch, so the maximum energy absorption is 1583.4 J/kg.

Figure 6.12 I – Type cross section profile beam

In the I – type cross section profile beam which the velocity act on the y axis is -14.7 m/s on the rigid punch, so the maximum energy absorption is 3450.8 J/kg.

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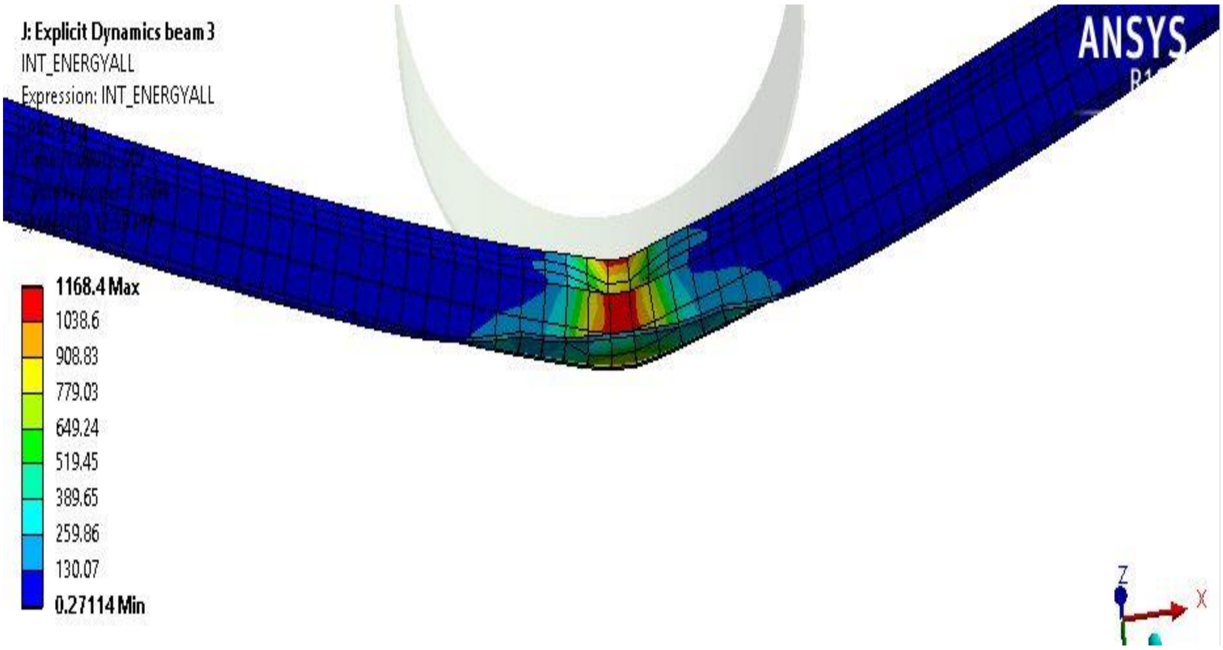

Figure 6.13 Double L cross section profile beam

In the Double L cross section beam which the velocity act on y axis is -14.7 m/s on the rigid punch, so the maximum energy absorption is 1168.4 J/kg.

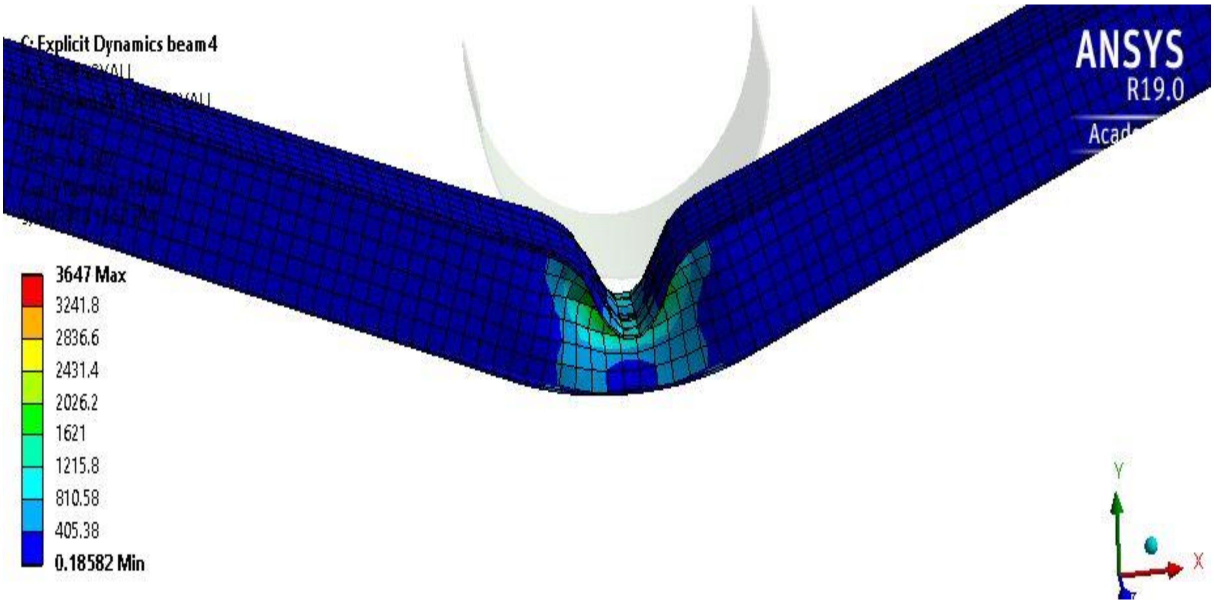

Figure 6.14 II – Type cross section profile beam

In the II – type cross section profile beam which the velocity act on the y axis is -14.7 m/s on the rigid punch, so the maximum energy absorption is 3647 J/kg.

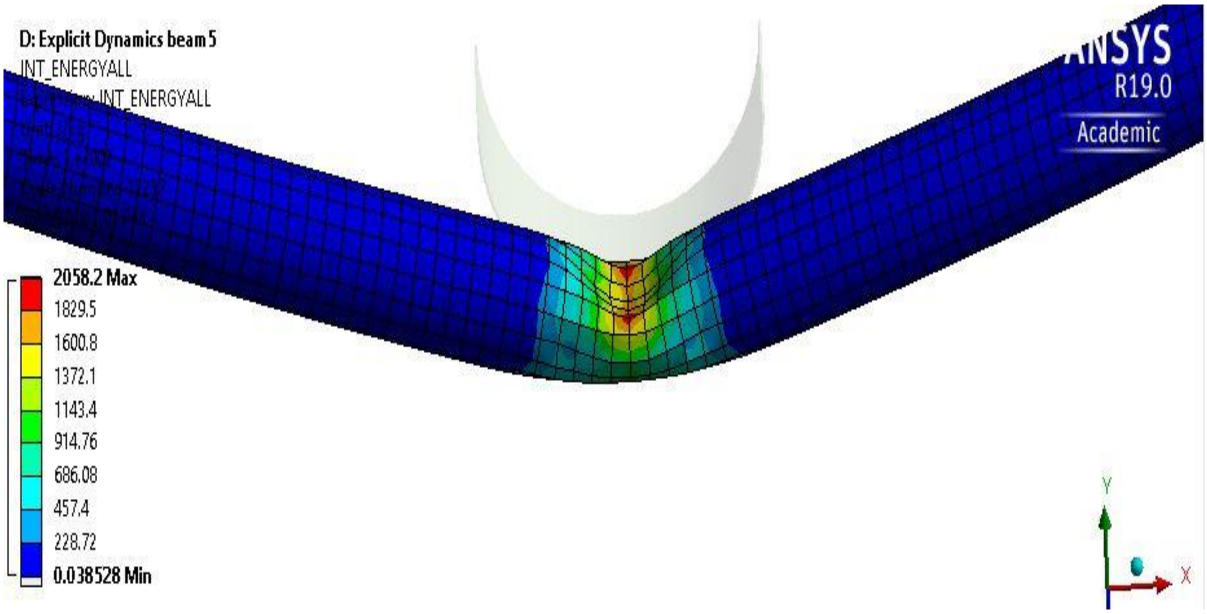

Figure 6.15 Circular thick-walled profile beam

In the circular thick – walled profile beam which the velocity act on y axis is -14.7 m/s on the rigid punch, so the maximum energy absorption is 2058.2 J/kg.

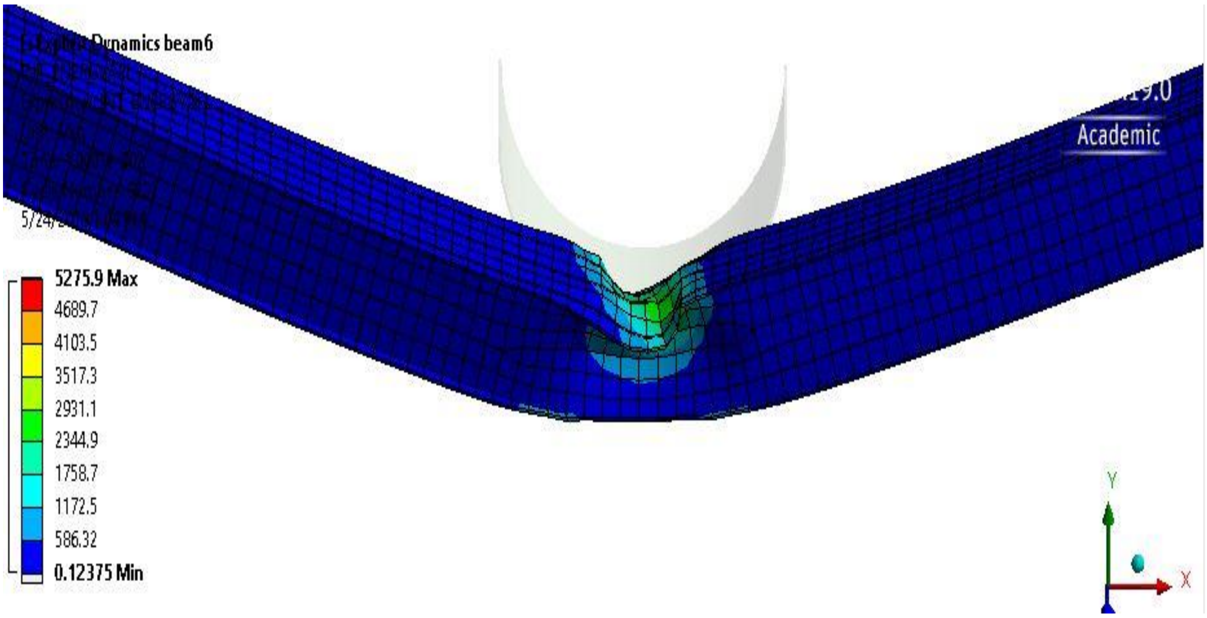

Figure 6.16 III – Type cross section profile beam

In the III – type cross section profile beam which the velocity act on the y axis is -14.7 m/s on the rigid punch, so the maximum energy absorption is 5275.9 J/kg.

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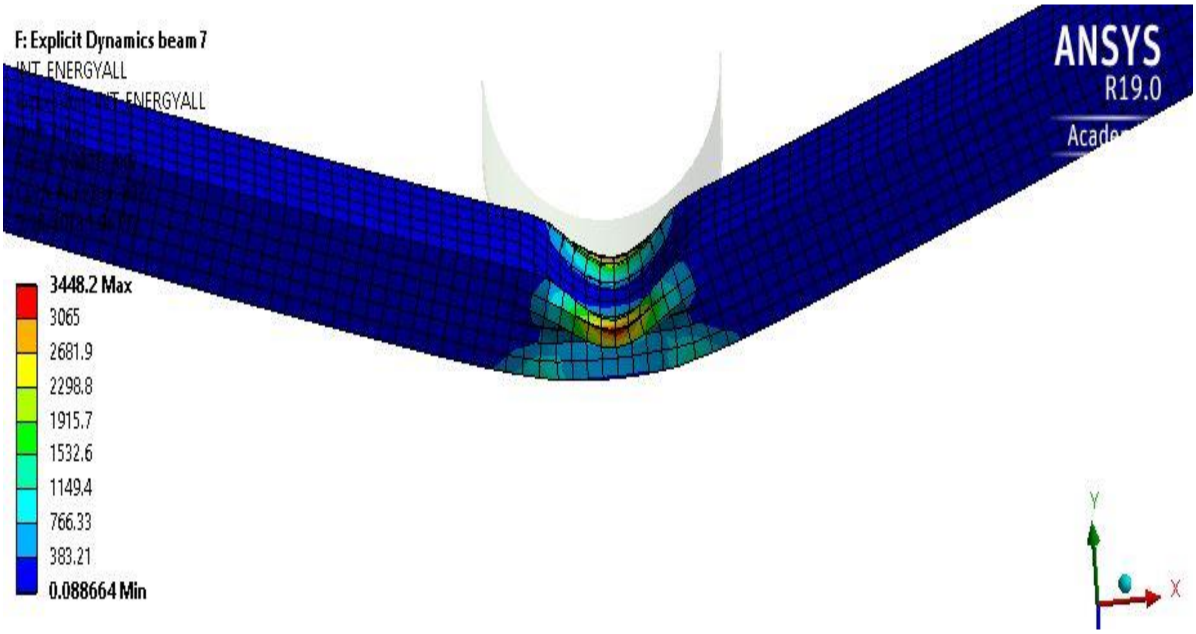

Figure 6.17 Single rib cross section beam

In the single rib profile beam which the velocity act on y axis is -14.7 m/s on the rigid punch, so the maximum energy absorption is 3448.2 J/kg.

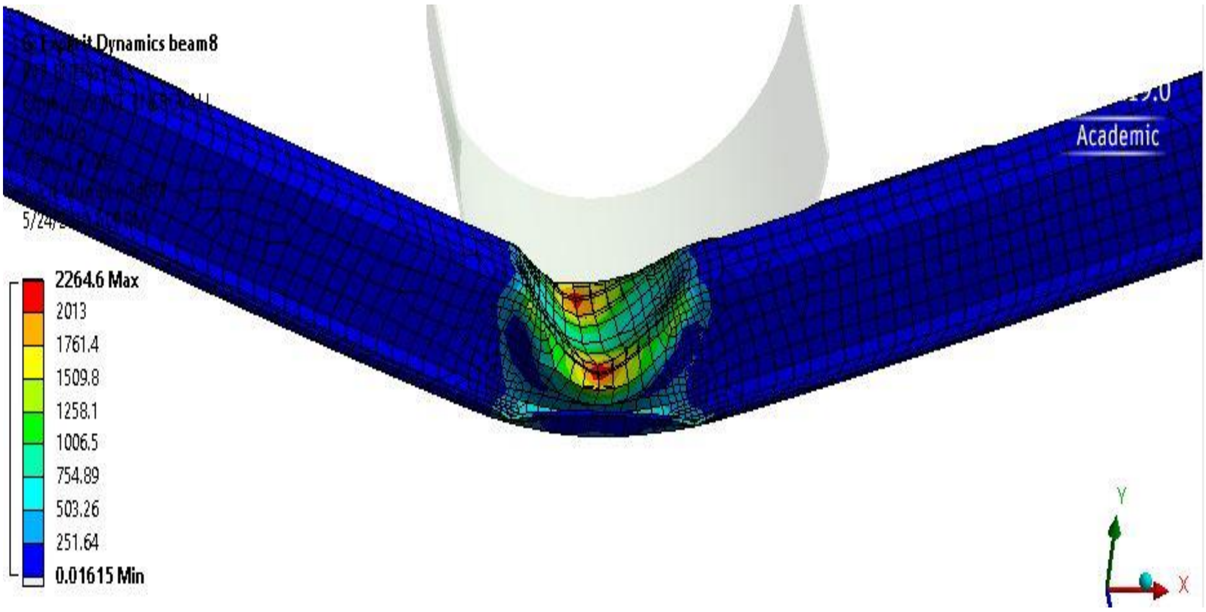

Figure 6.18 M – Type cross section beam

In the M – type cross section profile beam which the velocity act on the y axis is -14.7 m/s on the rigid punch, so the maximum energy absorption is 2264.6 J/kg.

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zzzzzzz

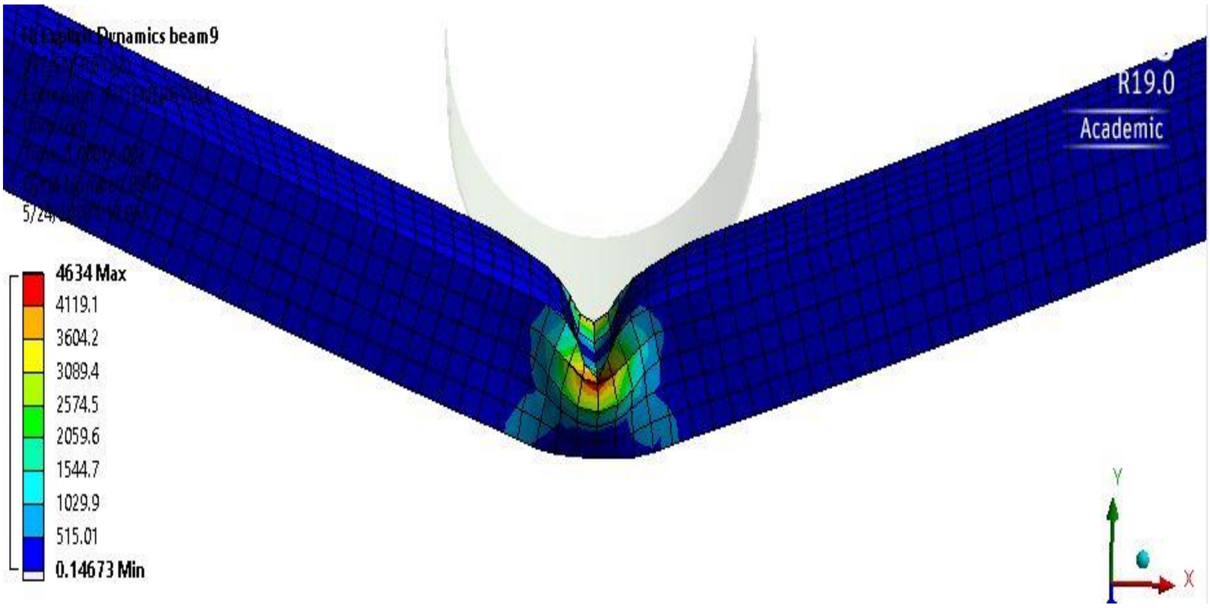

Figure 6.19 Square type cross section beam

In the square type cross section beam which the velocity act on y axis is -14.7 m/s on the rigid punch, so the maximum energy absorption is 4634 J/kg.

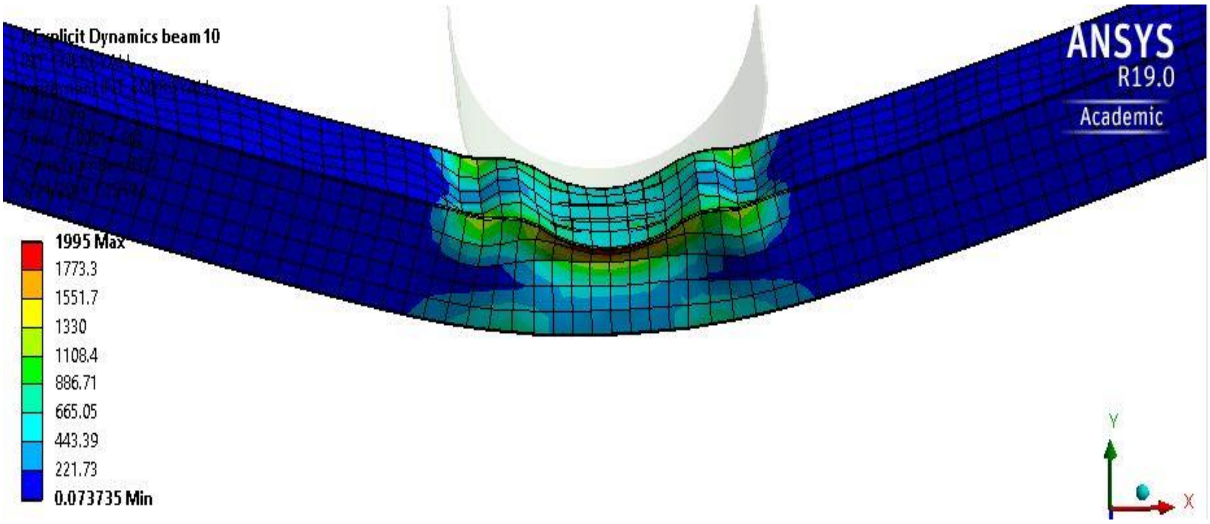

Figure 6.20 X – Type Square cross section beam

In the X – type square cross section profile beam which the velocity act on the y axis is -14.7 m/s on the rigid punch, so the maximum energy absorption is 1995 J/kg.

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6.4 Force Reaction Vs Displacement

In this analysis, the static implicit and explicit dynamics are obtained with the different types of beams with different materials comparing the result of the force reaction in the different cross section beams which has more reaction force from the displacement.

6.4.1 Static structural implicit analysis

In this analysis, Aluminium alloy material is used in this 10 cross section beams to find the Force reaction and displacement of the side impact beams. In this static analysis, the displacement will be obtained on the rigid punch with the displacement of 150 mm on the beam.

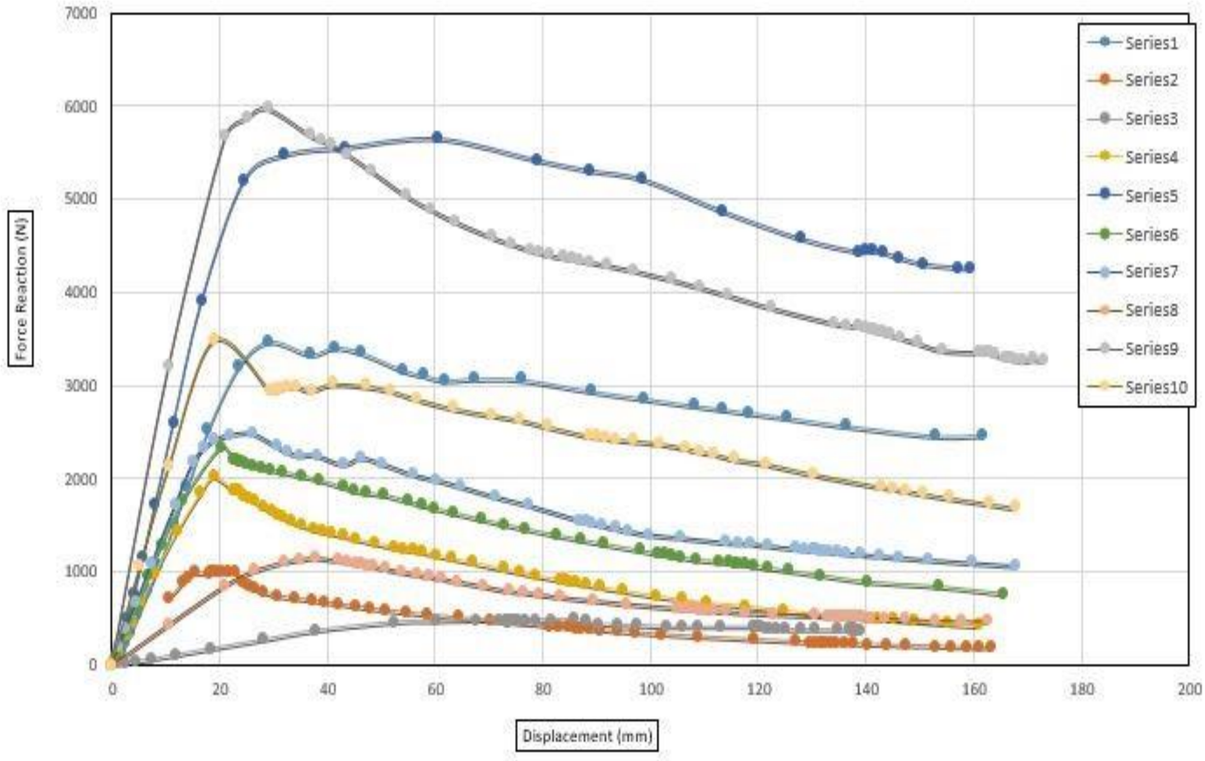

Figure 6.21 Force Reaction Vs Displacement graph in the side impact beams in Aluminum Alloy material [1 – Circular profile beam curve, 2 – I type cross section profile beam curve, 3 – Double L cross section beam curve, 4 – II type cross section beam curve, 5 – Circular Thick-walled profile beam curve, 6 – III type cross section profile beam curve, 7 – Single rib cross section beam curve, 8 – M type cross section beam curve, 9 – Square type cross section beam curve, 10 – X type square cross section beam curve]

In this figure, the force reaction vs displacement of the 10 cross section beams in the material of Aluminum alloy is shown. In this figure, the curve 9 has the high reaction force and

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displacement which the beam has high strength and stiffness than the other beams. In the curve, the 5^{th} beam has constant force reaction and displacement that the other material. The 2^{nd} curve beam has lightly increased and dropped the reaction force and displacement. In the 3^{rd} curve has low reaction force and displacement than the other beams and it is the weakest beam. In the curve, 4^{th} and 6^{th} beam have lightly increased than the 2^{nd}, $3^{rd,}$ and 8^{th} curve beam. In the curve 1^{st} and 10^{th} beam has the moderate reaction force and displacement.

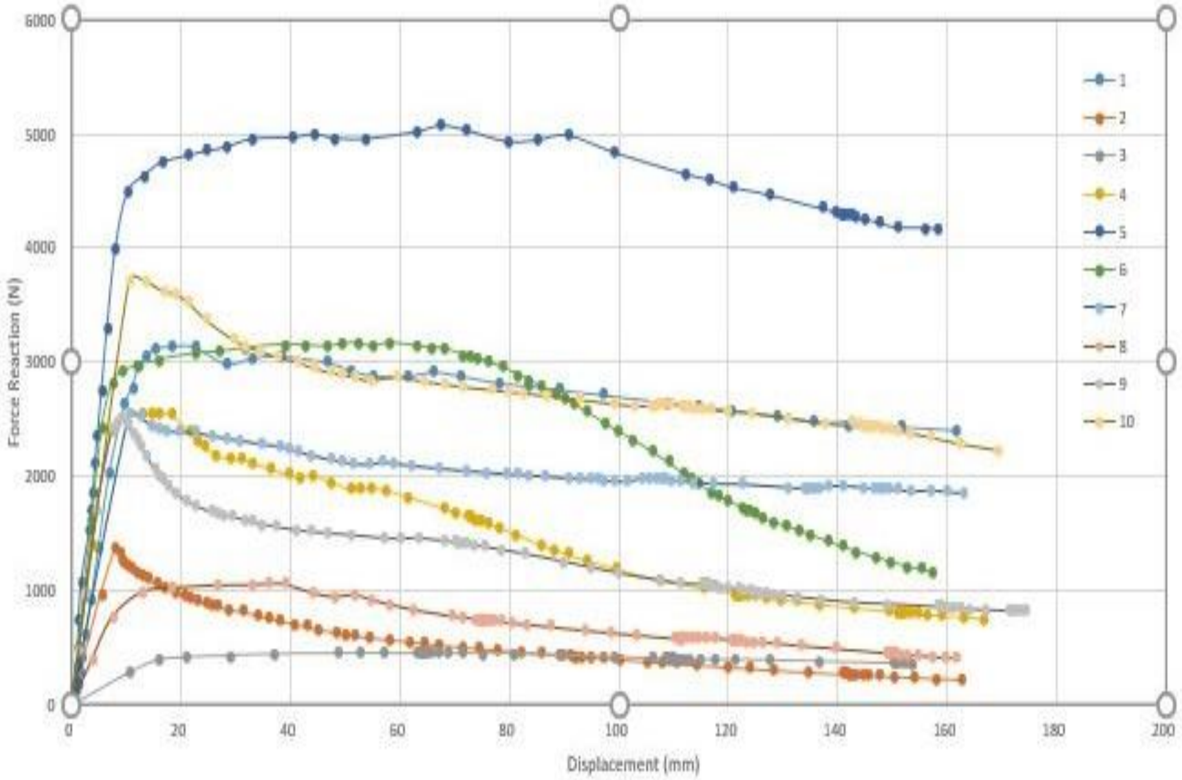

Figure 6.22 Force Reaction Vs Displacement graph in the side impact beams in Cast Alloy Steel material [1 – Circular profile beam curve, 2 – I type cross section profile beam curve, 3 – Double L cross section beam curve, 4 – II type cross section beam curve, 5 – Circular Thick walled profile beam curve, 6 – III type cross section profile beam curve, 7 – Single rib cross section beam curve, 8 – M type cross section beam curve, 9 – Square type cross section beam curve, 10 – X type square cross section beam curve]

In this figure, the 5^{th} curve beam has the high reaction force than any other beams. In the 4^{th} curve, the beam has slightly high reaction force and dropped slightly. In the 6^{th} curve, beams have constant reaction force and displacement. In the curve 1^{st}, the $7^{th}$and 10^{th} beam has slightly lower than the moderate reaction force. The curve 2^{nd} and 3^{rd} beam have low reaction force than

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any other beam in which the beam strength is low. The curve 8th a 9th beam has a moderate constant flow of the reaction force and displacement curve.

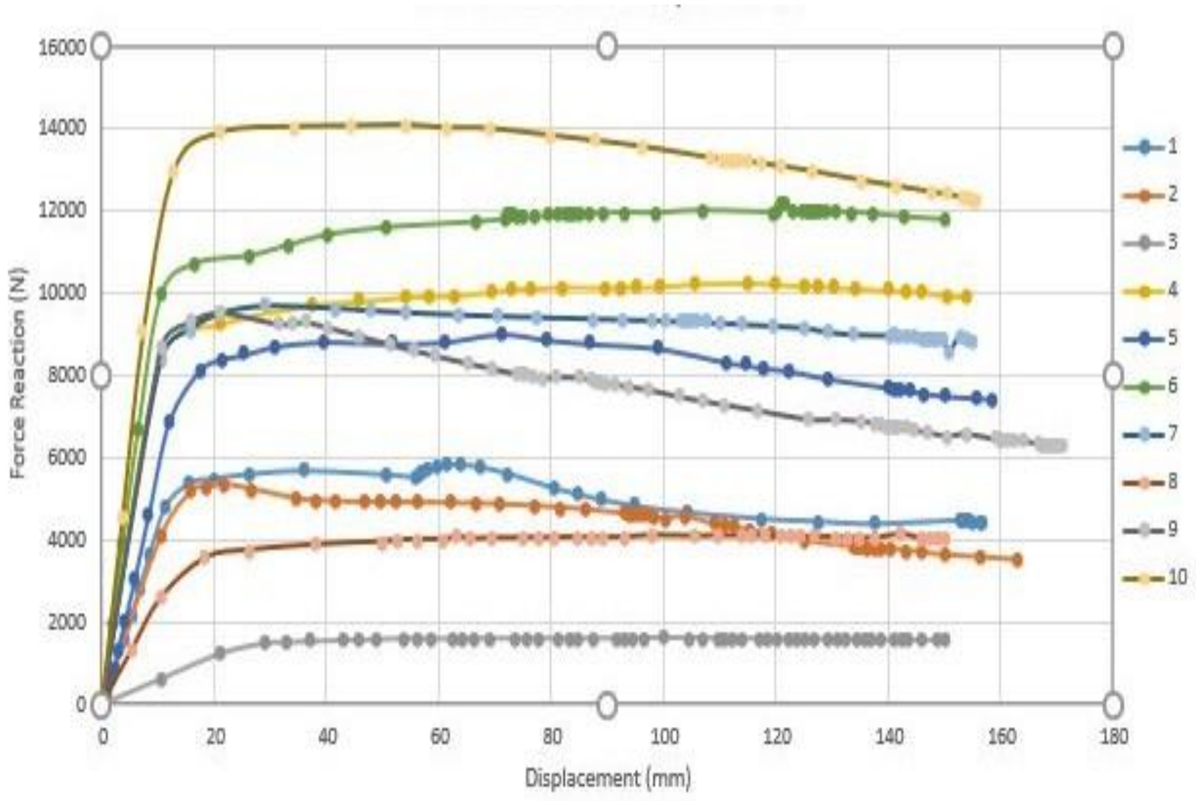

Figure 6.23 Force Reaction Vs Displacement graph in the side impact beams in Steel AISI 1060 material [1 – Circular profile beam curve, 2 – I type cross section profile beam curve, 3 – Double L cross section beam curve, 4 – II type cross section beam curve, 5 – Circular Thick walled profile beam curve, 6 – III type cross section profile beam curve, 7 – Single rib cross section beam curve, 8 – M type cross section beam curve, 9 – Square type cross section beam curve, 10 – X type square cross section beam curve]

In this figure shows that the curve 10th and 6th beam has increased randomly the force reaction and displacement flow which the beam absorbs the high displacement. The curve 1st, 4th, 5th, 9th beams have a constant flow of the force reaction and displacement which can withstand the moderate bending beams. The 2nd, 3rd, 7th,8th curves beam have less reaction force and displacement, so the beam has low bending and stiffness of the beam has low.

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6.5 Energy Absorption vs Displacement

6.5.1 Explicit dynamic analysis

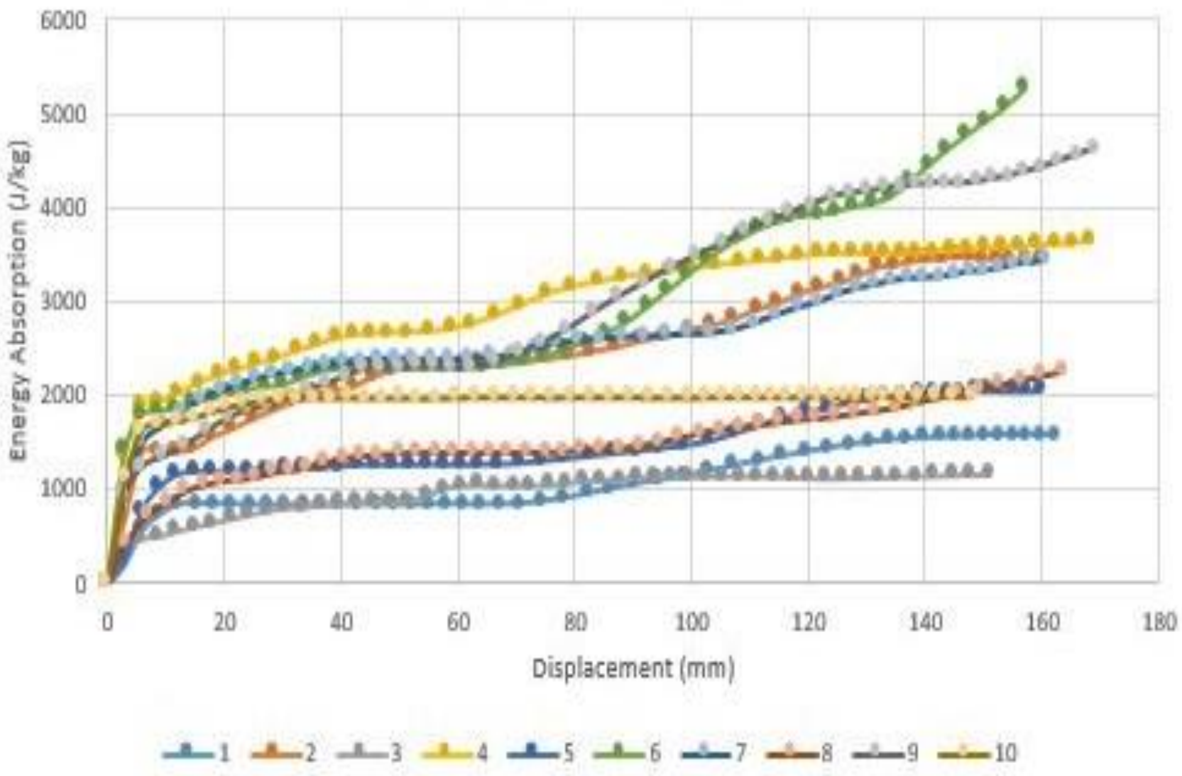

Figure 6.24 Energy Absorption Vs Displacement graph in the side impact beams in Aluminum Alloy material [1 – Circular profile beam curve, 2 – I type cross section profile beam curve, 3 – Double L cross section beam curve, 4 – II type cross section beam curve, 5 – Circular Thick walled profile beam curve, 6 – III type cross section profile beam curve, 7 – Single rib cross section beam curve, 8 – M type cross section beam curve, 9 – Square type cross section beam curve, 10 – X type square cross section beam curve]

In this figure shows that the 9th, 6th curve beam has high energy absorbing than any other beam. The curve 2nd, 4th, 7th, the 10th beam has the average energy absorption on the beams. The curve 1st and 3rd beam have a moderate change in energy absorption from the deformation.

The lower reaction force curve of 1st, 3rd, 8th beam has low energy absorption when compared to other beams. The 6th curve beam has high energy absorption from the displacement of this material. In this Aluminum Alloy steel material, the 6th III type cross section beam which can absorb huge energy than other beams.

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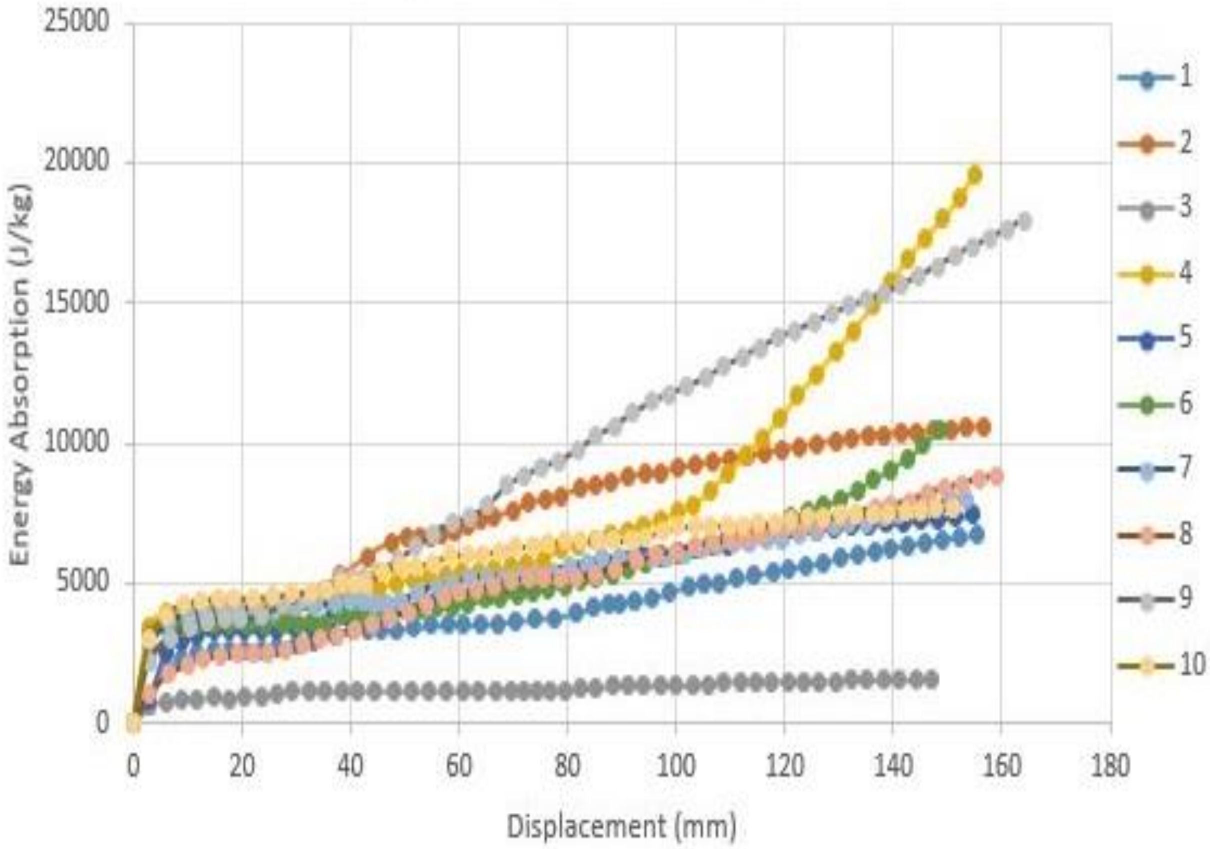

Figure 6.25 Energy Absorption Vs Displacement graph in the side impact beams in Cast Alloy Steel material [1 – Circular profile beam curve, 2 – I type cross section profile beam curve, 3 – Double L cross section beam curve, 4 – II type cross section beam curve, 5 – Circular Thick walled profile beam curve, 6 – III type cross section profile beam curve, 7 – Single rib cross section beam curve, 8 – M type cross section beam curve, 9 – Square type cross section beam curve, 10 – X type square cross section beam curve]

In this figure shows that the curve 4^{th} beam which absorbs the more deformation energy from the displacement. The 9^{th} curve beam absorbs the energy absorption slightly less than the 4^{th} beam. The 1^{st}, 2^{nd}, 5^{th}, 6^{th}, 7^{th},8^{th} 10^{th} curve beam has the average energy absorption which slightly differs from different beams. The 3^{rd} curve beam has low energy absorption from the displacement. In this Cast Alloy steel material, the 4^{th} II type cross section beam which can absorb huge energy than other beams.

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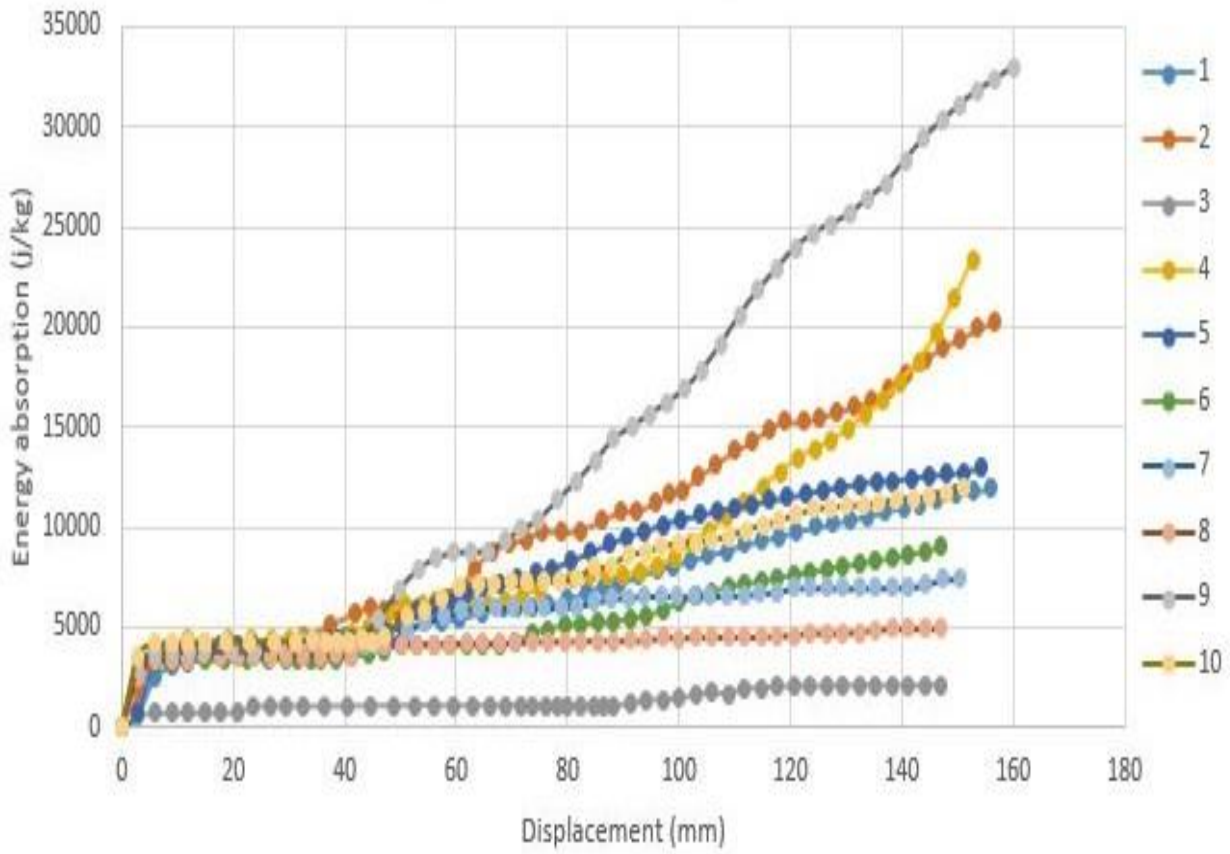

Figure 6.26 Energy Absorption Vs Displacement graph in the side impact beams in Steel AISI 1060 material [1 – Circular profile beam curve, 2 – I type cross section profile beam curve, 3 – Double L cross section beam curve, 4 – II type cross section beam curve, 5 – Circular Thick walled profile beam curve, 6 – III type cross section profile beam curve, 7 – Single rib cross section beam curve, 8 – M type cross section beam curve, 9 – Square type cross section beam curve, 10 – X type square cross section beam curve]

In this figure shows that the curve 9th beam which absorbs the more deformation energy from the displacement. The 9th curve beam absorbs the energy absorption slightly higher than the 4th beam. The 1st, 2nd, 5th, 6th, 7th,8th 10th curve beam has the average energy absorption which slightly differs from different beams. The 3rd curve beam has low energy absorption from the displacement. In this Cast Alloy steel material, the 9th Square type cross section beam which can absorb huge energy than other beams.

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6.6 Force reaction and Energy absorption in LS DYNA PREPOST

6.6.1 Force reaction

The side door with the side impact beam is analysed in the explicit of LS DYNA PREPOST to find the force reaction and energy absorption of the circular profile beam in the materials of Aluminium alloy, cast alloy steel and Steel AISI 1060 in Appendix A.

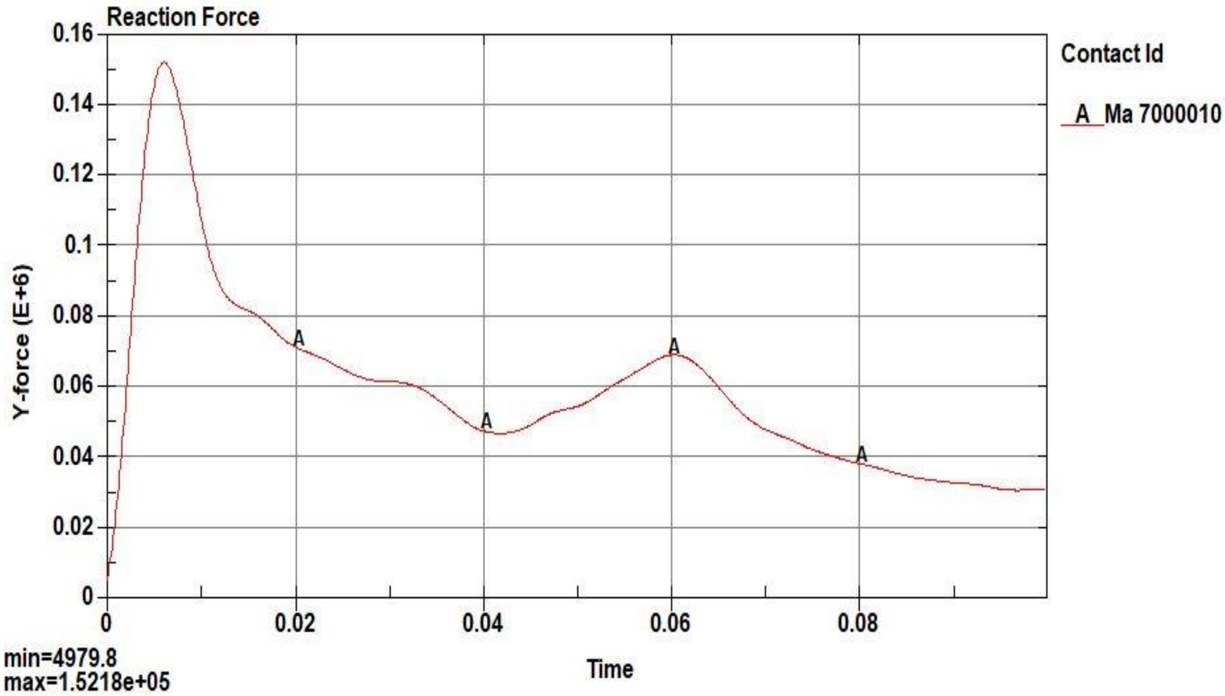

Figure 6.27 Force Reaction Vs Time of the circular profile beam in car side door Aluminum Alloy

In the force reaction Vs time graph of the circular profile beam in the material of Aluminium Alloy which flows to maximum reaction force is 1.5218e+05 N and the minimum reaction force is 4979.8 N.

In the force reaction Vs time graph of the circular profile beam in the material of cast alloy steel which flows to maximum and minimum bending force obtained on the beam.

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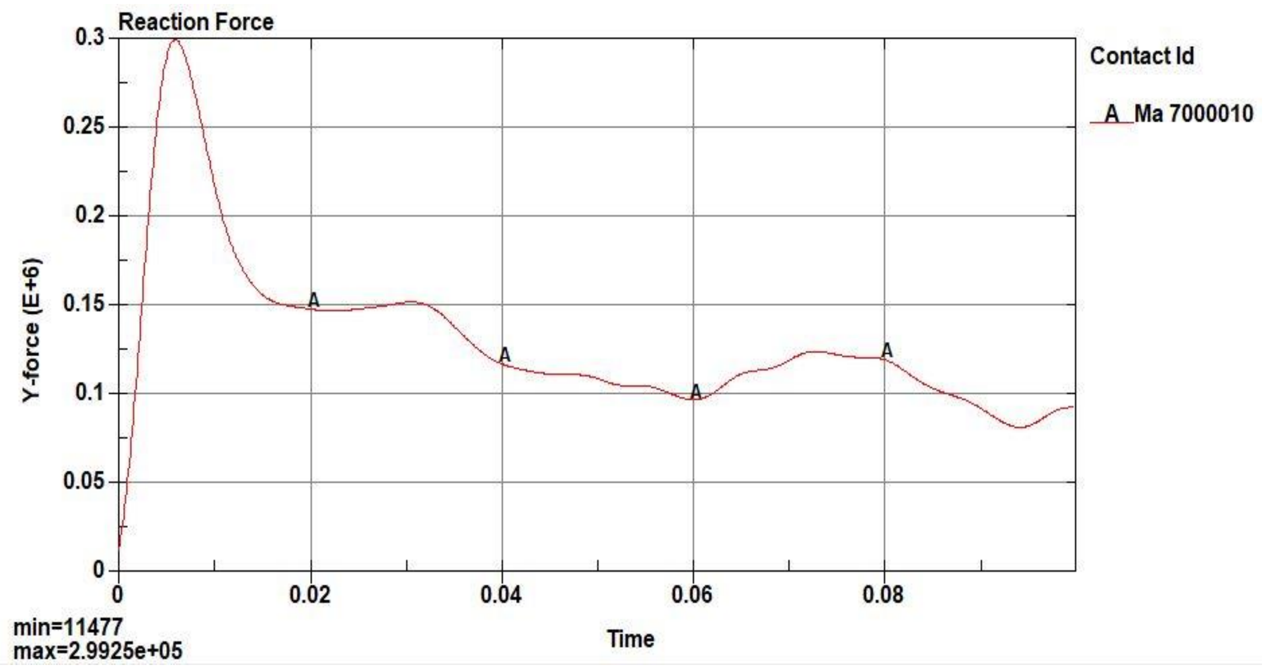

Figure 6.28 Force Reaction Vs Time of the circular profile beam in car side door of Cast alloy steel

The maximum reaction force is 2.9925e+05 N and the minimum reaction force is 11477 N is obtained in the circular profile beam of the car side doors.

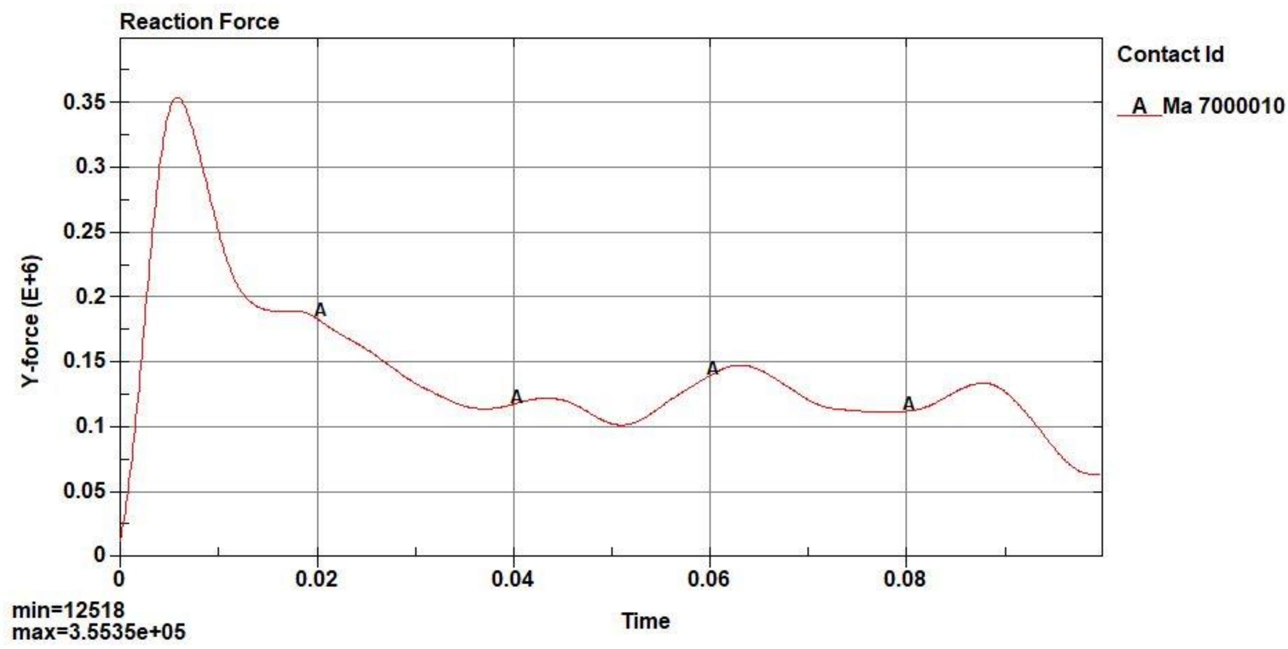

Figure 6.29 Force Reaction Vs Time of the circular profile beam in car side doors of Steel AISI 1060

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In the force reaction Vs time graph of the circular profile beam in the material of Steel AISI 1060 which flows to maximum reaction force is 3.5535e+05 N and the minimum reaction force is 12518 N.

6.6.2 Energy absorption

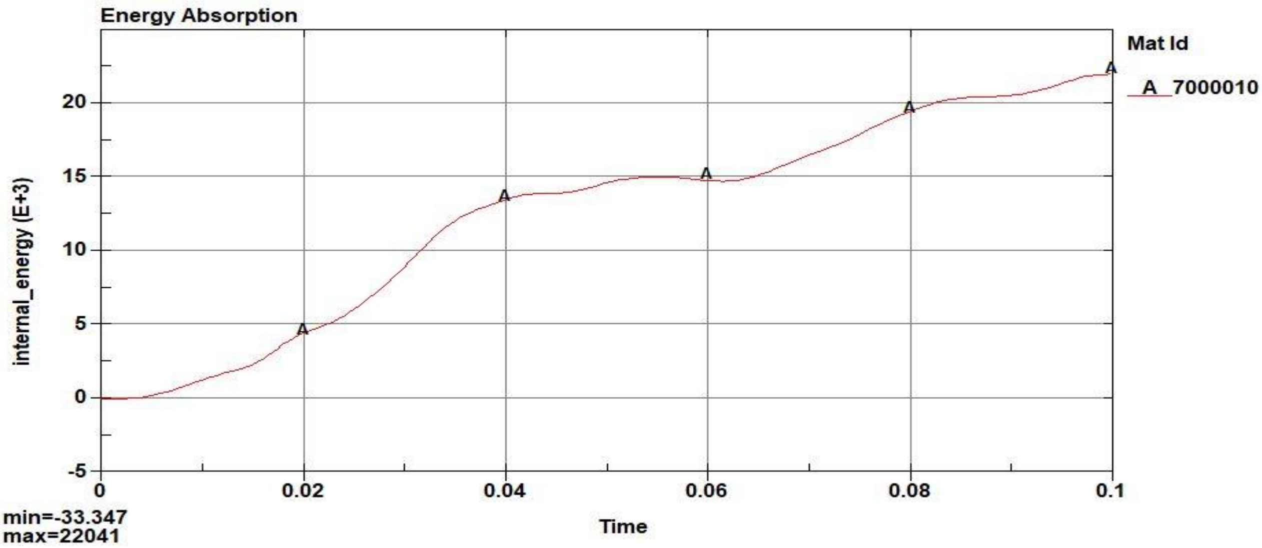

Figure 6.30 Energy absorption Vs Time of the circular profile beam in car side door of Aluminum Alloy

In the Energy Absorption Vs, time graph of the circular profile beam in the material of Aluminium Alloy which flows to maximum internal energy is 22041 J/kg.

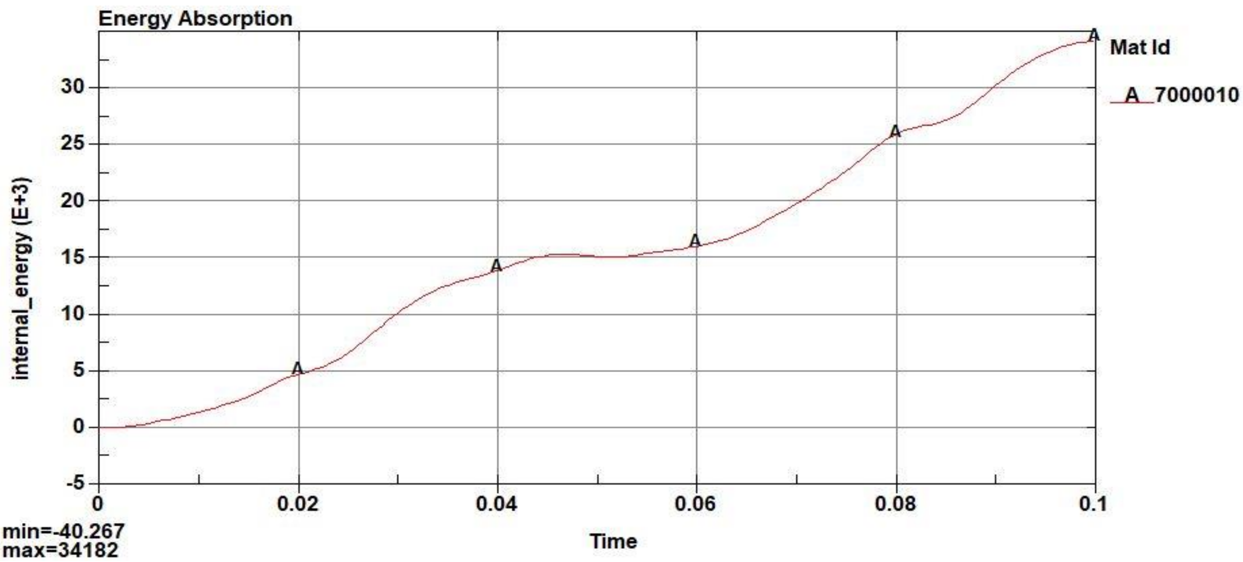

Figure 6.31 Energy absorption Vs Time of the circular profile beam in car side door of Cast alloy steel

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In the Energy Absorption Vs, time graph of the circular profile beam in the material of Cast alloy steel which flows to maximum internal energy is 34182 J/kg.

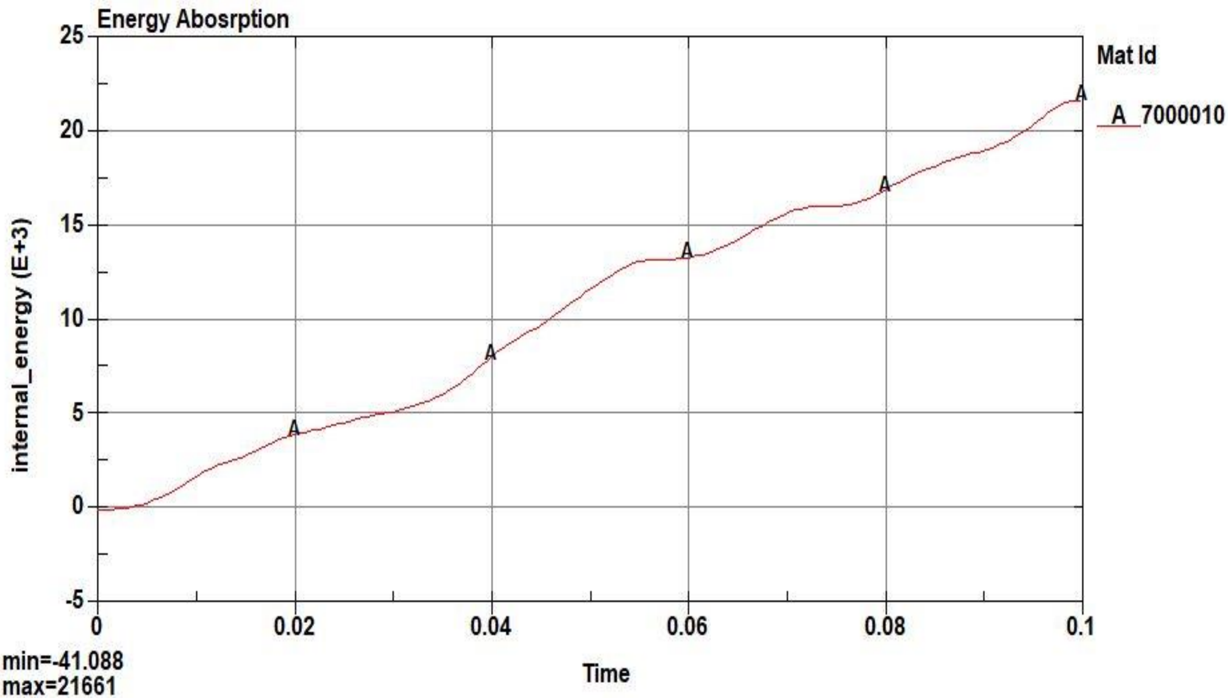

Figure 6.32 Energy absorption Vs Time of the circular profile beam in car side door of Steel AISI 1060

In the Energy Absorption Vs, time graph of the circular profile beam in the material of Steel AISI 1060 which flows to maximum internal energy is 21661 J/kg.

6.7 Discussion

- In the discussion of the static implicit analysis, directional deformation of the side impact beam is analysed in the material of Aluminum Alloy, cast alloy steel, Steel AISI 1060.
- In the Explicit dynamics analysis, Energy absorption of side impact beam are analysed in the material of Aluminum Alloy, cast alloy steel, Steel AISI 1060.
- Force reaction and energy absorption of the circular profile beam in side door are analysed in the material of Aluminum alloy, cast alloy steel, Steel AISI 1060 in LS DYNA PREPOST software.

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6.7.1 Comparison of the static implicit analysis - directional deformation and Explicit analysis – Energy absorption of the 10 different cross section beams in ANSYS Workbench

Table 6.1 Comparison of the static implicit analysis - directional deformation and Explicit analysis – Energy absorption of the 10 different cross section beams in ANSYS Workbench

Types of beam	Aluminium alloy	Cast alloy steel	Steel AISI 1060	Aluminium alloy	Cast alloy steel	Steel AISI 1060
	Directional Deformation (mm)			Energy Absorption (J/kg)		
Circular profile beam	161.58	161.42	156.84	1583.4	6729.9	11969
I-type cross section beam	163.32	162.69	163.09	3450.8	10611	20281
Double-L type beam	154.42	153.61	150.38	1168.4	1553.6	2142.5
II-type beam	160.94	166.8	153.83	3647	19614	23349
Circular thick walled	159.29	158.41	158.43	2058.2	7474.4	12969
III-type beam	165.48	157.5	150.41	5275.9	10530	9011.9
Single rib type beam	167.7	162.81	154.99	3448.2	8014.1	7402.4
M-type beam	162.77	161.52	150.26	2264.6	8836.8	4946.3
Square type beam	172.88	174.34	170.94	4634	17952	33000
X-type beam	167.91	169.46	155.65	1995	7679.9	11921

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6.7.2 Comparison of Force reaction and energy absorption of the circular profile beam in LS DYNA PREPOST

Table 6.2 Comparison of Force reaction and energy absorption of the circular profile beam in LS DYNA PREPOST

Results	Circular Profile beam		
	Aluminium Alloy	**Cast alloy steel**	**Steel AISI 1060**
Force Reaction (N)	1.5218e+05	2.9925e+05	3.5535e+05
Energy Absorption (J/kg)	22041	34182	21661

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Conclusion

In this study, side impact beam which attached in the car side door to protect occupant from a victim of the crash. Side impact beam should be high strength, stiffness is a most important factor for the collision impact. The Final results of this project are:

- The Force reaction Vs Displacement graph, Energy absorption Vs Displacement graph of the static implicit and explicit dynamic analysis in ANSYS workbench are already discussed which beam has high force reaction and energy absorption in the results.
- Comparison of the static implicit analysis - directional deformation and Explicit analysis – Energy absorption in ANSYS workbench of the 10 different cross section beams with materials of Aluminium alloy, cast alloy steel, Steel AISI 1060 which beam has low deformation and high energy absorption.

Materials	Directional Deformation (mm)	Energy Absorption (J/kg)	Results of the Directional Deformation Beam	Results of the Energy absorption beam
Aluminium Alloy	154.42	5275.9	**Double-L type beam**	**III-type beam**
Cast alloy steel	153.61	19614	**Double-L type beam**	**II-type beam**
Steel AISI 1060	150.26	33000	**M-type beam**	**Square type beam**

In this result, the Steel AISI 1060 material is good for the side impact beam which has high energy absorption and less deformation which protects the occupants form the side collision. Square type beam has high energy absorption than any beams and III type beam have standard energy absorption and deformation, so it is best for the side impact beam.

- Comparison of Force reaction and energy absorption of the circular profile beam in the material of Aluminium alloy, cast alloy steel, Steel AISI 1060 analysed in LS DYNA PREPOST. The cast alloy steel of the circular profile beam of the force reaction is 2.9925e+05 N of Force reaction and Energy absorption is 34182 J/kg is the best material which absorbs more energy absorption and force reaction which prevents the occupant from the side collision.

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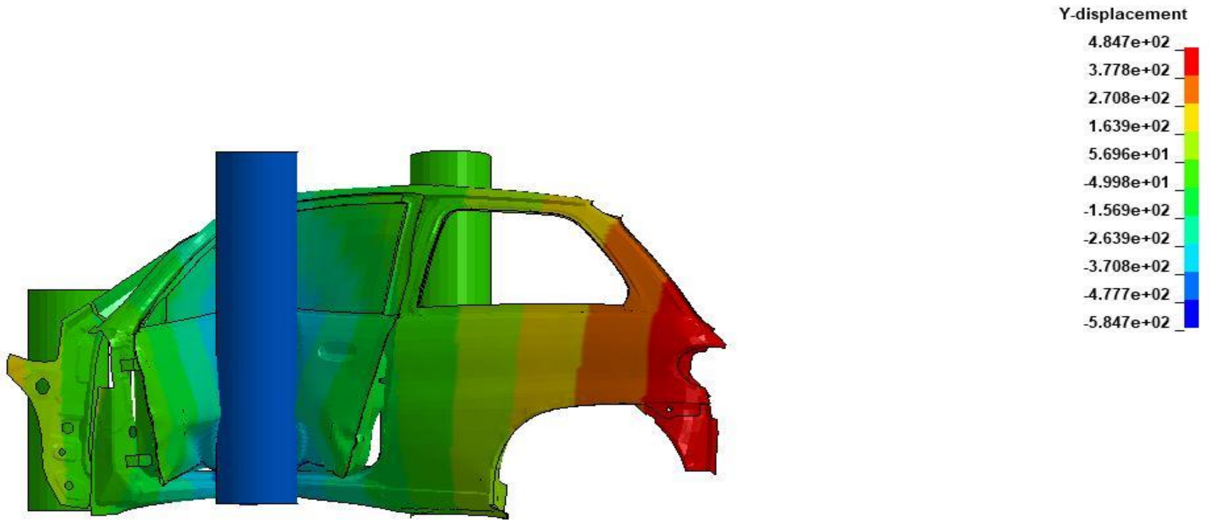
Appendix

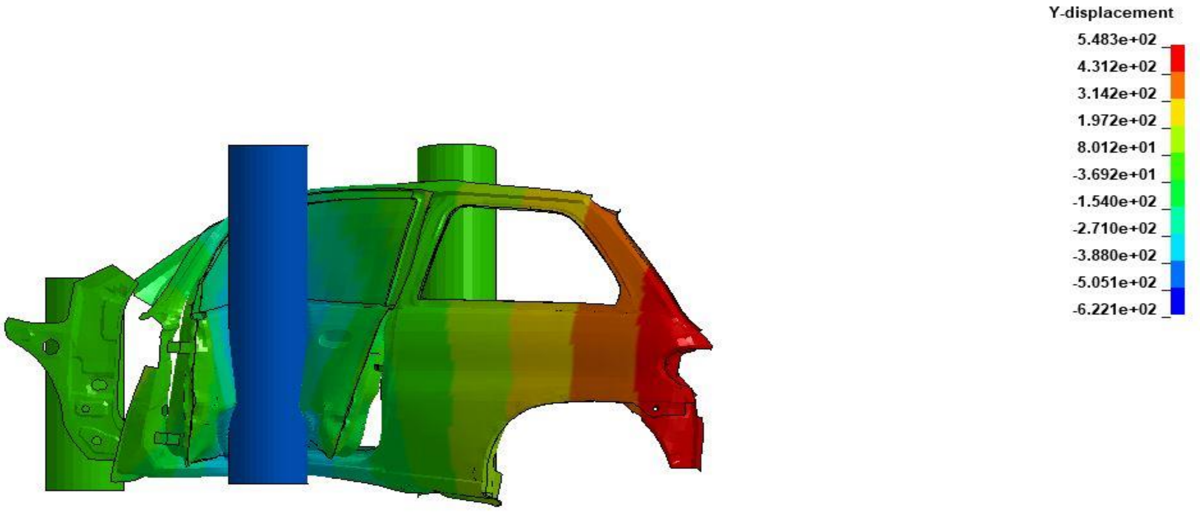
Deformation result of the side impact beam in the door by LSDYNA PREPOST

Aluminum alloy:



The circular beam attached in side door deformation is 5.847e+02 mm in the Aluminium alloy material.

Cast alloy steel:



The circular beam attached in side door deformation is 6.221e+02 mm in the Cast alloy steel material.

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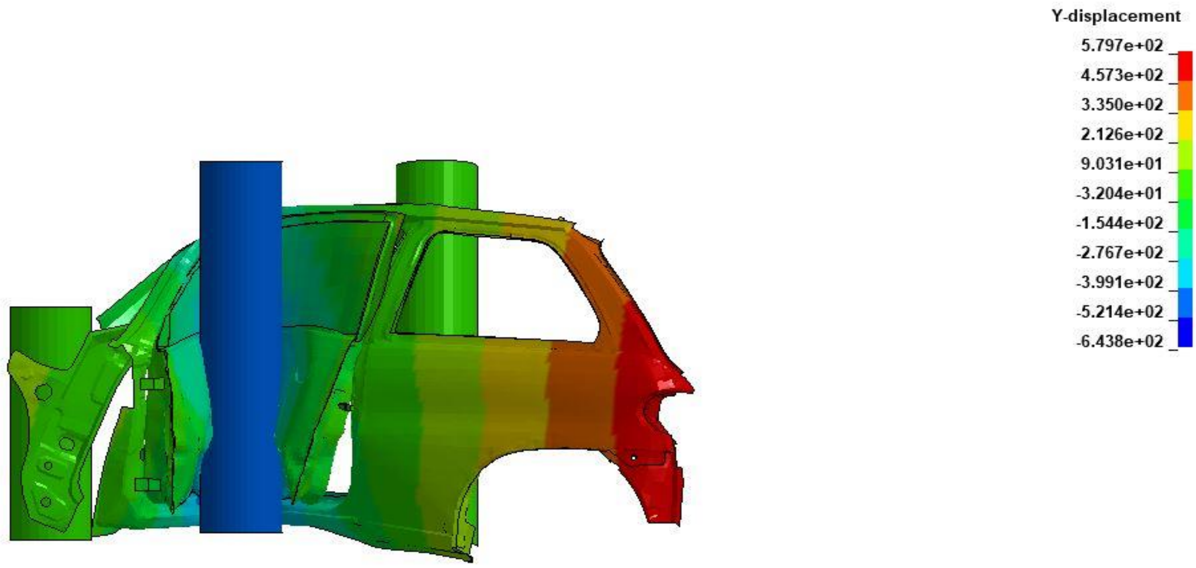
Steel AISI 1060:



The circular beam attached in side door deformation is 6.438e+02 mm in the Steel AISI 1060 material.