ADDIS ABABA UNVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF MECHANICAL AND INDUSTRIAL ENGINEERING

(MECHANICAL DESIGN)

The Effect of Stiffener Plate Thickness on Stress of Truck Chassis Using Finite Element Method

A Thesis Submitted to the Graduate School of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Mechanical Engineering (Mechanical Design).

By: Getahun Derbie

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DECLARATION

This is to certify that the thesis prepared by ***Getahun Derbie Zenebe*** entitled: ***''The Effect of Stiffener Plate Thickness on Stress of Truck Chassis Using Finite Element Method ''***, do here, by declare this thesis is my original work and that it has not been submitted partially or in full for degree in any university/institution, which compiles with the regulations of the university and meets the accepted standards with respect to originality and quality.

Getahun Derbie

Signature _______________

Date____________________

Advisor: _______________________ Signature _______________ Date__________________

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Abstract

In this study, the effect of stiffener plate thickness on stress of truck chassis using finite element method focusing on Volvo truck chassis is performed. The main goal of the research is optimization of stress on joints of the chassis by adding stiffener plates between joints of side member, cross member and on top of connector plate flanges. The stiffeners are fastened by means of bolt and rivet. In order to achieve reduction in magnitude of stress on joints of the chassis stiffener plate thickness are varied (3mm to 8mm). For analysis, High strength low alloy steel existing truck chassis structural steel material is used.

Analytical analysis of maximum stress and maximum deformation are done on existing chassis to select the cross member for further modeling and analysis. Both existing and modified truck chassis drawings are modeled using CATIAV5R19 and the finite element analysis is done using ANSYS14.5.

Then, the finite element analysis result showed that the magnitude of equivalent (von-miss) stress using stiffener plates thickness of (3mm-8mm), the value of the stress reduced (190Mpa-77.6Map) respectively and according the result (36.9% - 59.0%) of stress optimized. The magnitude of deformation using stiffener plates thickness of (3mm-8mm), the value of deformation reduced (0.34mm-0.266mm) respectively and according the result (11.8% - 22%) of deformation optimized as compared with existing chassis. Due to stiffener plate thickness of (3mm-8mm) added to existing chassis weight of modified chassis is increased (72.69kg - 89.52kg) respectively and according the result (9%-18%) of weight is increased. Finally, the finite element analysis results comparable with literature results and the difference is less than 10%.

Keywords: *Stiffener, Chassis, HSLA, CATIAV5R19, ANSYS 14.5,*

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Nomenclature

GVW-Gross vehicle weight

W_{max} -Maximum Weight of chassis

W_d- Uniform Distributed Load of chassis

g- Gravity

t =thickness

L-Over all chassis length

W_s-Load acting on single beam

M_{Max} –Maximum Bending moment

R-Reaction Forces

I_{xx}-Moment of Inertia

E-Module of elasticity

h-hight of side member

b-width of the flange

Z-Section Module

δ-Stress

m=meter

N = Newton

W = weight

M = Mass

EBG-Equatorial Business Group

CHAPTER-ONE

INTRODUCTION

1.1.Background

Chassis is a French term initially used to denote the frame parts or basic structure of the vehicle. Vehicle without body is called chassis. A chassis consists of an internal framework that supports a manmade object in its construction and use. It is analogous to an animal's skeleton. An example of a chassis is under part of a motor vehicle, consisting of the frame on which the body is mounted. The components of the vehicle like Power plant, Transmission System consisting of clutch gearbox, propeller shaft and rear axle, Wheels and Tires, Suspension, Controlling Systems like Braking, Steering etc. and electrical system parts are also mounted on the Chassis frame. It is the main mounting for all the components including the body. So it is also called as Carrying Unit .The main functions of the chassis are to support the chassis components and the body to withstand static and dynamic loads without excessive deflection or distortion [7].

Types of chassis

- **Ladder Frame chassis**

Ladder chassis is considered to be one of the oldest forms of automotive chassis or automobile chassis that is still used. It's also resembles a shape of a ladder which having two longitudinal rails inter linked by several cross members [8][20].

Figure 1.1.1.Ladder frame chassis.

❖ **Backbone chassis**

Backbone chassis which has a rectangular tube like backbone and simple in structure. It usually made up of glass fiber that is used for joining front and rear axle together and responsible for most of the mechanical strength of the framework. The space within the structure is used for positioning the drive shaft in case a rear-wheel drive. This type of chassis is strong enough to provide support smaller sports car besides it is easy to make and cost effective [8].

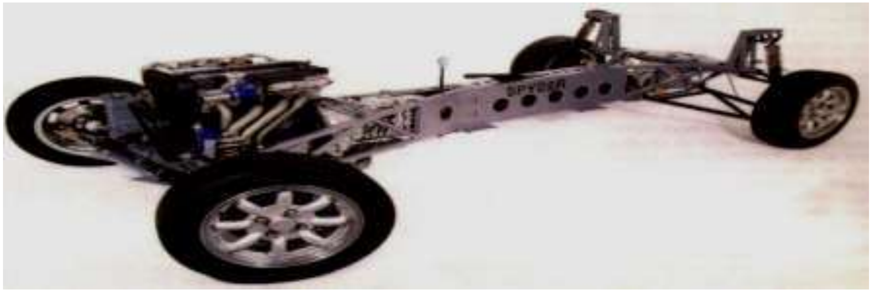


Figure 1.1.2. Backbone chassis

❖ **Monocoque Chassis**

Most of modern cars use this type of chassis. A monocoque chassis is a single piece of framework that gives shape to the car. A one-piece chassis is built by welding several pieces together. It is different from the ladder and backbone chassis as unlike them incorporated with the body in a single piece, whereas the former only support the stress members. The demanding of a monocoque chassis highly increased since it is cost effective and suitable for robotized production [8].

Figure 1.1.3. Monocoque Chassis

❖ **Tubular space frame chassis**

Tubular space frame chassis is used for the urban car. Since ladder chassis is not strong enough, motor racing engineers have developed a 3-dimensional design which known as tubular space frame. Tubular space frame chassis employs dozens of circular-section tubes (some may use square section tubes for easier connection to the body panels though circular provides the maximum strength), position in different directions to provide mechanical strength against forces from anywhere. These tubes are welded together and form a complex structure [8].

Figure 1.1.4 Tubular space frame chassis

❖ **Stress Optimization technique of truck chassis.**

Reinforcement technique is the practice of providing a stiffener plates on external or internal side members at high stressed regions [3][5].Stiffeners are attached to the beams to give chassis stiffness against plane deformation. Stiffeners are two types' transverse stiffeners and longitudinal stiffeners. The transverse stiffeners are support the beams in standing vertical position and normal to the span direction of the beam. The longitudinal stiffeners are support the beams by horizontal position and aligned with the span direction of the beams. Stiffeners are attached to the beams by one side or both side of the beam to optimize stress [2][3].

So, in this study we use ladder type of chassis containing two main longitudinal members with C-Channel sections throughout the length of the truck and eight cross members supporting the two longitudinal members are bolted in place shown below in *figure 1.1*.5. The general objective of the research work is to study the effect of stiffener plate thickness on stress of truck chassis using finite element method. Modification of existing truck chassis will be carried by adding stiffener plate between the side member and cross member, on the top of connector plate and cross member flange; the stiffeners are fastened by means of bolt and rivet. Depending on actual measurement of connector plate length and cross member height decided to use stiffener plate-1, size 225mm*550mm*(3mm-8mm) and stiffener plate -2, size 100mm*100mm*5mm to study the effect of stiffener plate thickness on stress of truck chassis. So, to fulfill the objectives of the study, modeling and analysis of truck chassis carried out using CATIAV5R19 and Finite element method of ANSYS 14.5respectively.

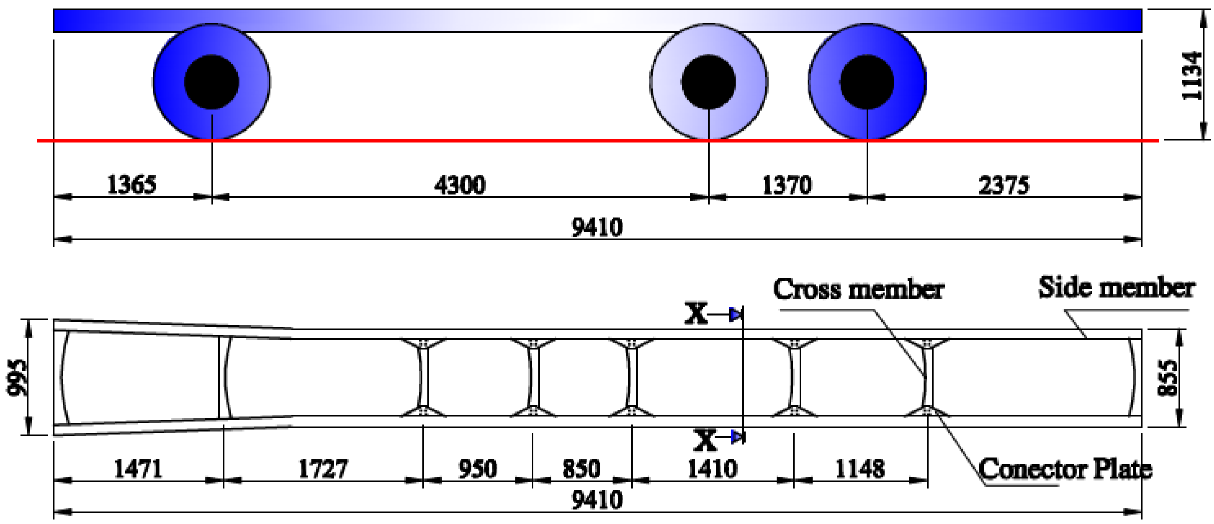


Figure 1.1.5..Side and top view of truck chassis.

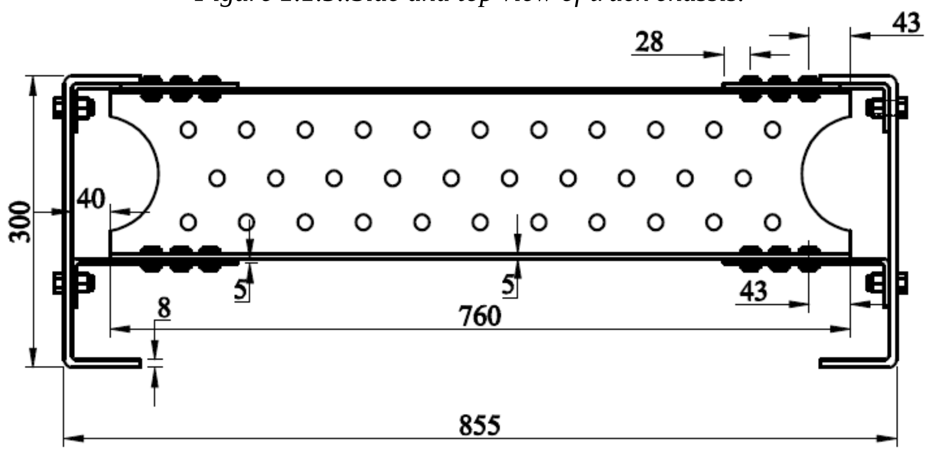


Figure 1.1.6. section x-x view of truck chassis.

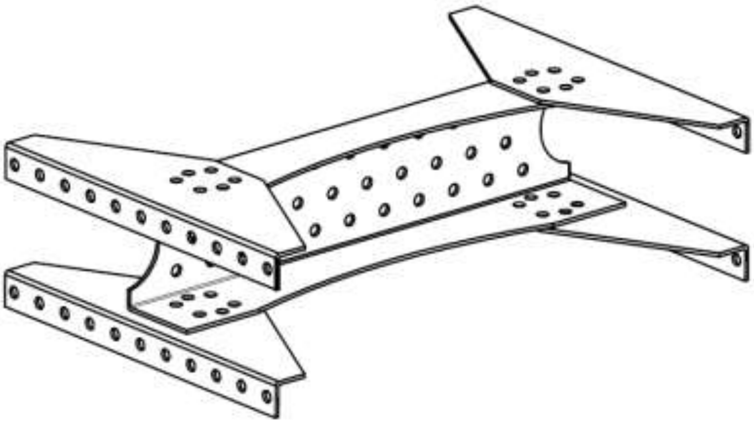


Figure 1.1.7.Isometric view of Existing chassis cross mebers.

1.2. Statement of the Problem

The purpose of the cross member connected with side member has to bear the force of all bending and torsion of loading conditions as shown above in *fig.1.1.5 and fig.1.1.6*. Even though, the cross member ,connector plate and side member joints are riveted and bolted to hold all forces of bending and torsion of loading conditions, the load ultimately leads to development of cracks around the riveted hole and the crack growth to cross member. In routine run and loading, the connector plate and cross member fails and the chassis tends to excess load. As a reference of Volvo trucks maintenance shop of EBG, the failure is happened on 11 trucks from total 50 trucks in one overhauled season. This failure is the biggest downtime contributor for the truck chassis. So, to reduce the stress on joints of the chassis, this research is conducted on optimization of stress by inserting stiffener plate between the side member and cross member and, on the top of connector plate flange. Modeling and analysis of existing and modified truck chassis is done using CATIAVR19 and ANSYS14.5 respectively

1.3. Objectives

1.3.1 General Objective

To study the effect of stiffener plate thickness on stress of truck Chassis using Finite Element Method.

1.3.2 Specific Objective

1. Development of suitable model for existing and modified truck chassis using CATIA, V5R19 Software.
2. Analysis of equivalent (Von-misses) stress and Deformation of existing and modified truck chassis using finite element method of ANSYS 14.5.
3. Analyzing the effect of thickness on stress and deformation
4. Comparison of results, equivalent stress, deformation and weight is conducted for existing and modified chassis.

1.4. Methodology

The methods to achieve the objectives of the research are:

- Relevant data collected from literature review.
- An actual data will be collected by observing specification and measuring of actual dimension from Volvo-truck chassis.
- Analytical analysis performed on existing truck chassis to identify maximum bending moment point or stressed area of chassis under loading condition.
- Selection of cross member around high stressed area for modeling and analysis.
- 3D modeling of existing and modified truck chassis using CATIA V5 R19.
- Analysis of existing and modified truck chassis using FEM of ANSYS 14.5.
- Comparison of ANSYS 14.5 results for existing and modified truck chassis.
- Finally, conclusion and recommendation from FEA of ANSYS 14.5 results.

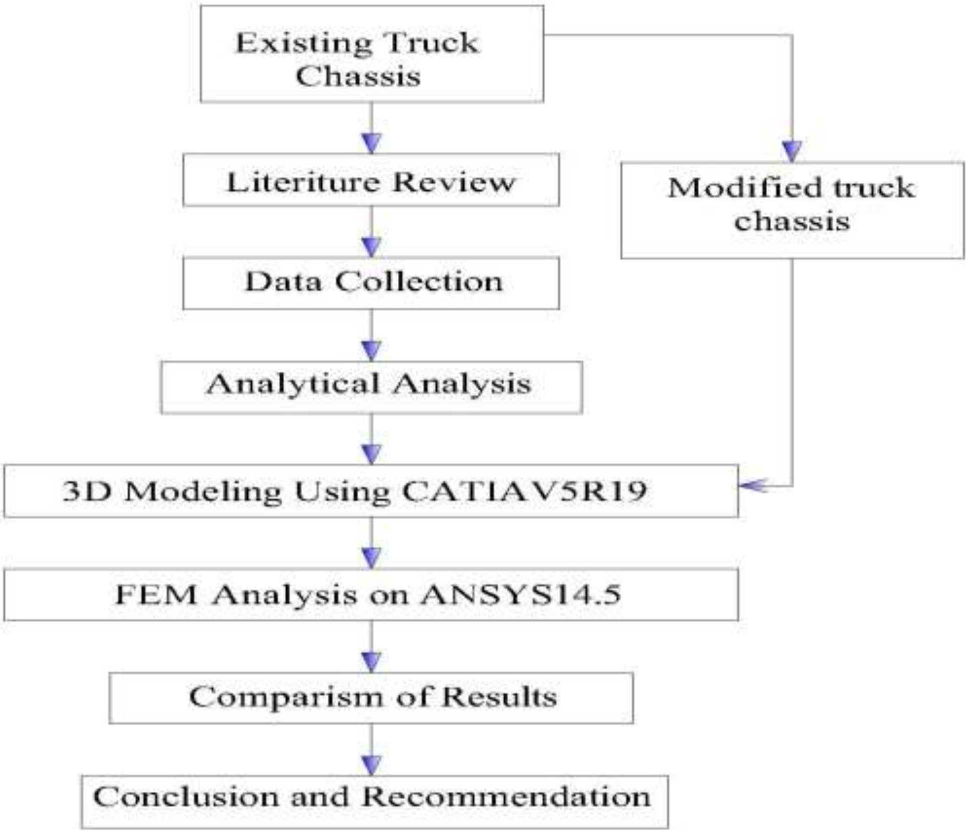


Figure. 1.4.1. Work flow of the study.

1.5.Limitation of the Study

The study has some limitations:

1. The study is conducted on existing truck chassis to optimize stress based on stiffener plate thickness.
2. Literatures are used for validation of the finite element analysis results.

1.6. Organization of the study

The study is organized in five chapters, the first chapter containing thesis background, statement of the problem, General and specific objective, limitation of the study and methodology of the study. The second chapter presents literature review. The third chapter deals with materials, methods and conditions. The fourth chapter addresses ANSYS 14.5 workbench software results and discussion. And the last chapter states the conclusions, recommendations and future works of the study.

CHAPTER- TWO

LITERATURE REVIEW

Many researchers are published a lot of literatures, journals and articles related to design, analysis, and stress optimization of truck chassis considering of different methods, some of them are discussed below here:

2.1 Pervious Work Related to Chassis.

2.1.1 Method

Finite Element Analysis (FEA)

Finite element analysis (FEA) is one of the efficient and well-known numerical methods for various engineering problems. FEA first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variation calculus to obtain approximate solutions to vibration systems [29]. For the last 30 years it has been used for the solution of many types of problems. FEA has become an integral part of design process in automotive, aviation, civil construction and various consumer and industrial goods industries, cut throat competition in the market puts tremendous pressure on the corporations to launch reasonably priced products in short time, making them to rely more on virtual tools (CAD/CAE) accelerate the design and development of products. FEA tools are being used to analyze multi-disciplinary problems, including structures, thermal and fluid flow, NVH applications, biotechnology etc. [34]. FEA is used to predict multiple types of static and dynamic structural responses. For example, companies in the automotive industry use it to predict, stress, strain, deformations, and failure of many different types of components. FEA reduces the need for costly experiments and allows engineers to optimize parts before they are built and implemented. There are many software packages available to industries that use finite element analysis and computer aided engineering. The wide and universal propagation of commercial finite element packages (ANSYS, ABAQUS, COMSOL, ALGOR, HYPERVIEW, LS DYNA, NASTRAN etc) for computations in design of mechanical structures made possible to define more accurately the stress analysis of truck chassis. The advent of faster computers and robust FEA software allows design engineers to build larger, more refined and complex models resulting in timely, cost-effective, accurate, and informative solutions to customer problems [33]. In the following section, finite element package ANSYS will be discussed in more details.

Analysis and Modeling of Truck Chassis

The commercial software package ANSYS used as a FEA tool in the stress analysis. The ANSYS program is a powerful, multi-purpose analysis tool that can be used in a wide variety of engineering disciplines. Using ANSYS software can avoid expensive and time-consuming development loops, so the design period is shortened [34]. The stress analysis of a truck chassis using ANSYS software carried out by many researchers to reduce the magnitude of stress and deformation of the chassis frame.

This researcher investigated stress analysis of a truck chassis using the commercial finite element package ANSYS version 5.3.They examined the effect of the geometrical modification through varying the side member thickness from 8 to 12 mm, and the thickness of the connection plate from 8 to 12 mm by local plate, the connection plate thickness from 7 to 10 mm, and the length of the connection plate (L) from 390 to 430 mm. They conclude that if the change of the side member thickness using local plates is not possible, due to increase weight of chassis then choosing an optimum connection plate length (L) seems to be best practical solutions for decreasing the stress values [1]. However, in our study to achieve the stress reduction in chassis we use optimum local plate size and thickness between side member and angle connector, on the top of cross member and angle connector. Analysis of truck chassis will be done using ANSYS latest version of 14.5 finite element packages and modeling of the chassis will be done using latest version of CATIAV5R19.

In order to reduce the magnitude of stress on truck chassis this paper Investigated the von misses stress, stress intensity and deformation of truck chassis by adding transverse stiffener (standing vertical position) along with side member of truck chassis and the result compared a chassis without stiffener plate. The analysis is done using finite element method of ANSYS version 14 package and the Model is developed on proe-5. the analysis result showed that there is reduction in von misses stress in chassis with stiffener of 37.11% compared to without stiffener while stress intensity reduced up to 36.23% and deflection reduced by 36.16% [2].

However, in our study the stiffener plate is inserted on longitudinal direction of the side member, and on the top of cross member. The Analysis of truck chassis will be done using ANSYS latest version of 14.5 finite element packages and modeling of the chassis will be done using latest version of CATIAV5R19.

In order to optimization stress on chassis researchers are used different reinforcement techniques. Adding stiffeners in external side member of chassis on highly stressed regions [3][4]and adding of thick plate in both sides of cross members are stress optimization technique [14][28].After modification of the chassis modeling prepared in PRO-E and CATIA. The analysis were done using finite element method of ANSYS workbench [3][4][14].Analytical analyses were carried out to validate the static finite element analysis [3]. Finally, they conclude that the maximum von-misses stress and stress intensity reduced 37.9% and total deformation reduced to 40.7% [3].And the maximum von-misses stress reduced to 31.42% and total deformation reduced to 4.7% [4], and adding of thick plate in both sides of cross member technique equivalent stress 35.5%, Stress intensity 37% and total deformation 3.6% are optimized after adding thick plate on the cross member [14].

However, in our study the stiffener plate is inserted on internal of the side member, and on the top of cross member using optimized size and thickness of stiffener. The Analysis of truck chassis will be done using ANSYS latest version of 14.5 finite element packages and modeling of the chassis will be done using latest version of CATIAV5R19.

In order to achieve a reduction in the magnitude of stress at critical point of the chassis frame, the finite element analysis and modeling of the chassis are done using ANSYS and CATIAV5R10 respectively by varying side member thickness, cross member thickness and by changing position of cross member from rear end. The ANSYS results were compared to analytical calculation. Finally, they concluded that it is better to change the thickness of cross member at critical stress point than changing the thickness of side member and position of chassis for reduction in stress values and deflection of chassis [5][6]. However, in our study the changing of cross member thickness is increase weight of the chassis, and then it is better to insert stiffener plate on internal side member, and on the top of cross member using optimized size and thickness of stiffener. The

Analysis of truck chassis will be done using ANSYS latest version of 14.5 finite element packages and modeling of the chassis will be done using latest version of CATIAV5R19.

Recently a research done on Design, Analysis, and Optimization of Truck chassis by considering three different cross-sections, namely C, I, and Rectangular Box (Hollow) type cross sections on the Eicher 407 and TATA 2518TC models using finite element method. 3D-model of chassis modeled in CATIA V5R19, Meshing will be carried out in hyper mesh, and ANSYS will be used for solutions [7][8]. In addition Studies shows that Design and analysis of ladder frame chassis considering support at contact region of leaf spring and chassis frame using finite element method. The chassis is modeled in Creo Parametric 3.0 and static structural characteristics are analyzed using Finite Element models of ANSYS [9].

However, in our study modeling will be done using latest Version of CATIAV5R19 commercial software and meshing will be done using latest Version of ANSYS14.5 commercial software.

In order to study the effect of Torque on Ladder Frame Chassis of Eicher 20.16 modeling and analysis were done on ANSYS software by considering the same loading condition and varying side member thickness. For Validation of Finite element analysis analytical method for cantilever beam was taken of same length as that of main member of chassis also the cross section is same [10].however, we use latest version of CATIAV5R19 for modeling of the chassis.

Recent study on Structural Analysis of Pick-Up Truck Chassis using finite element method was done on design modification of the chassis frame by incorporating X-type member within the side members (the Side member is Rectangular hollow section the modification was done inside the section with X-type stiffener) the results were validated against the results available in the literature and the maximum error was found to be 7.83% [11]. The Finite element analysis of the chassis is done using ANSYS and modeling done using CATIA.[11][12][15][17][24] However, in our study we make modification using a stiffener plate by inserting on longitudinal direction of the side member, and on the top of cross member. The Analysis of truck chassis will be done using ANSYS latest version of 14.5 finite element packages and modeling of the chassis will be done using latest version of CATIAV5R19.

The research focused on design improvement and analysis of car chassis using Finite element method. modification of chassis has been performing by changing the geometry and structure without changing functional dimension of the existing model by trial and error method under the static structural analysis. PRO-E software is used for modeling and finite element package ANSYS 14.5 is used for analysis [13][18]. However, in our study we make modification using a stiffener plate by inserting on longitudinal direction of the side member, and on the top of cross member. Modeling of the chassis will be done using latest version of CATIAV5R19.

This paper explained stress analysis of heavy duty truck chassis for fatigue and life prediction of chassis components. Finite element analysis was done using commercial finite element packaged of ABAQUS [16].

In order to stress optimization on automobile chassis a lot of researchers are analysis done using finite element method of, ANSYS7.1 and Opti-struct and for modeling pro/engineer 2001 , Creo (Pro-E) 2.0 software are used[25][27]. During the study they introduced local stiffeners plate to reduce the magnitude of the stress on the critical location. The modified chassis stress values was reduced by 44% [26].

Experimental Method Analysis

A literature focused on design, Load carrying improvement and frame optimization of truck chassis the analysis has been done using Finite Element Method. The finite element Analysis result validated using Experimental analysis of the truck chassis [13][19][22][23].

Most of the above literatures studied on stress analysis of a truck chassis by considering different methods (techniques) are summarized below.

- They examined the effect of the geometrical modification through varying the side member thickness, connection plate thickness, length of the connection plate, cross member thickness, changing position of cross member and adding of thick plate in both sides of cross members.
- They studied on stress optimization using different reinforcement techniques by adding stiffeners on external and internal side member of chassis on highly stressed regions.

- They studied on analysis and optimization of Truck chassis by considering different cross-sections, namely C, I, and Rectangular Box (Hollow).
- They studied on design modification of chassis by incorporating X-type member within the side members (the Side member is Rectangular hollow section the modification was done inside the section with X-type stiffener).

Most of the above literatures

- For analysis old version of ANSYS and ABAQUS package of Finite element method are used.
- For modeling old version of CATIA, Pro/engineer 2001 and Creo (Pro-E) 2.0 software are used.
- They validate the Finite element result with Experimental analysis, analytical analysis and literature reviewed.

Therefore, from the above different methods, we are conclude that,

- To insert a stiffener plate on internal of the side member, and on the top of cross member using appropriate thickness of plate.
- The Analysis of truck chassis will be done using ANSYS latest version of 14.5 finite element packages.
- Modeling of the chassis will be done using latest version of CATIAV5R19.
- The Finite element analysis result will be validating using analytical analysis and Literature reviewed.

2.1.2 Improvement of load carrying capacity

This researcher Investigate the modeling and analysis of truck chassis using FEM to improve load carrying capacity and reducing the failure of chassis with bending by adding stiffener in transverse direction of side member. Transverse direction means the stiffeners are support the beams in standing vertical position [2]. In addition, Design improvements are made to improve the chassis stiffness of the structure and to improve load carrying capacity. Series of modifications and tests were conducted by adding one more cross beam stiffener at the centre of the wheel base in order to strengthen and improved the chassis stiffness as well as the overall chassis performances. Finally, they conclude that bending stiffness increased 48.2%, torsion stiffness increased 51.3% and at the same time weight also increased by18% [6].

This paper deals with the analysis of chassis frame for improving its payload by adding stiffener plate and C- channel at maximum stress region of chassis frame. This has been carried out with limited modifications by adding stiffeners and C- channel high stress region. The necessary design changes required to enhance the load carrying capacity of the vehicle has been recommended successfully [17].

The above literatures are studied on improvement of load carrying capacity and stiffness of the chassis the main points are summarized below.

- To improve load carrying capacity and stiffness of the chassis Transverse direction stiffener plate on side member is used.
- To improve load carrying capacity design improvements are made by adding one or more cross member stiffener at the center of wheel base.
- To improve payload of the chassis stiffener plate and C- channel added at maximum stress region of chassis frame.

Therefore, in our case to, improve load carrying capacity and stiffness of truck chassis. We use longitudinal type stiffener plate along the side member and top surface of the cross member.

2.1.3 Materials

This Paper Studied on Design, Analysis, and Optimization of Truck chassis- Rail & Cross member on the Eicher 407 model using finite element method. Optimizations carried out on high strength and low alloyed steel (HSLE) cross member replaced by aluminum material. For modeling and analysis around rear leaf spring mounted side rail and cross members are selected. Total load is collectively applied as uniformly distributed load throughout the rail and cross member. Therefore, finally they conclude that by keeping total deformation and maximum stress weight of the chassis is reduced by 14.9% using aluminum [7].

This research paper explains optimization of the truck chassis by changing material. Firstly, FEA analysis carried out in existing chassis later they changed the material with three different alloys and perform the same analysis. The three-material used are grey cast iron, AISI 4130 alloy steel and ASTM A710 steel. From the analysis AISI 4130 giving better results and compared others it is lighter than that[15]. In addition, a paper presents the stress analysis of heavy duty truck chassis using material of chassis of ASTM Low Alloy Steel (A710 C) [16].

This researcher investigated modeling and structural analysis of Mahindra bolero vehicle chassis using polymeric composite material. Three different composite materials of Carbon/Epoxy, E-glass/Epoxy and S-glass Epoxy subjected to the same load as that of a steel chassis is used and for shape optimization three different composite C, I and Box type chassis cross sections are used. From results, the rectangular hollow section has less deformation, where as I cross section has high deformation and C-cross section has highest deformation. Carbon fiber has least deformation with superior strength among all the three. Finally they conclude that, the polymeric composite vehicle chassis is lighter and more economical than the conventional steel chassis with similar design specifications [20].

This researcher Studied on the static structural analysis of chassis frame EICHER 11.10 by considering three different materials of St52, Ni-Cr Steel and CFRP. Finally, From Finite element Result they conclude that, when CFRP material used instead of St52 deflection reduced by 63.24%, stress reduced by12.61%.and when CFRP material used instead of NI-Cr deflection reduced by 64.7%, stress reduced by12.40% [21].

The paper deals on Design and analysis of chassis using FEM. The stress and deformation are calculated for the chassis frame and the analysis has been done for the validation on the chassis frame using mild steel and HSLA materials. Finally the optimized result showed that stress (9%), deformation (4.5%) and Weight 0.63% are reduced using HSLA material [27].

The above literatures are studied on material properties of truck chassis the main points are summarized below.

- Weight optimization of truck chassis are done by replacing of High strength low alloy steel (HSLA) using Aluminum material.
- The polymeric composite vehicle chassis is lighter and more economical than the conventional steel chassis with similar design specifications.
- CFRP chassis material has better in strength than High strength Low alloy steel (HSLA).
- High strength low alloy steel (HSLA) materials are better strength than Mild steel.

Therefore, in our case for analysis of the truck chassis:-

We use existing truck chassis material of high strength low alloy steel (HSLA) from Specification of truck chassis.

CHAPTER-THREE

MATERIAL, METHODS AND CONDITIONS

3.1.Chassis Material

The Material property is taken from existing chassis of technical Specifications Volvo truck chassis. Automotive structure steel of high strength low alloyed steel (HSLA) shown below in *table 3.1.1, E-46.*

Table 3.1.1.Mechanical properties of truck chassis.

Sr.no	Parameters	Values
1	Module of Elasticity	210Gpa
2	Density	7850Kg/m2
3	Yield Strength	410Mpa
4	Poisson ratio	0.3

(Source: Technical Specifications of Volvo FH truck chassis)

3.2Analytical Data

the specification of the truck chassis and the actual measurement taken from the truck is shown below *table 3.2.1.*

Table.3.2.1.Specifications of truck chassis (Model: Volvo FH Truck)

Sr.no	Parameters	Value
1	Overall Length of frame	9410mm
2	Front Width of frame	893mm
3	Wheel Base distance	4300mm
4	Front over hung	1365mm
5	Back over hung	2375mm
6	No. of cross members	8
7	Side member size (C-Section)	300x80x8x9410mm
9	Cross member size (C-section)	175x90x5mm
10	Angle Connector size(Angle Plate)	550x40x120x5mm
11	CG from Front Axle	4076mm
12	CG from Rear Axle	224mm
13	Front Axle weight	4805kg
14	Rear Bogie weight	3655kg
15	Kerb Weight at front axle	4649kg
16	Kerb Weigh at Bogie weight	4091kg
17	Pay Load(Including Body, driver, fuel,etc)	17260
18	Capacity (Gross vehicle weight) -*GVW*	26000kg

(Source: Technical Specifications of Volvo- FH truck chassis)

3.3. 2D-Sketch and Measurement of Truck Chassis

The dimension required for 2D-CAD drawing are obtained by taking reading (measurement) directly from rail and cross member of Volvo FH truck chassis as shown in *fig.3.3.1*

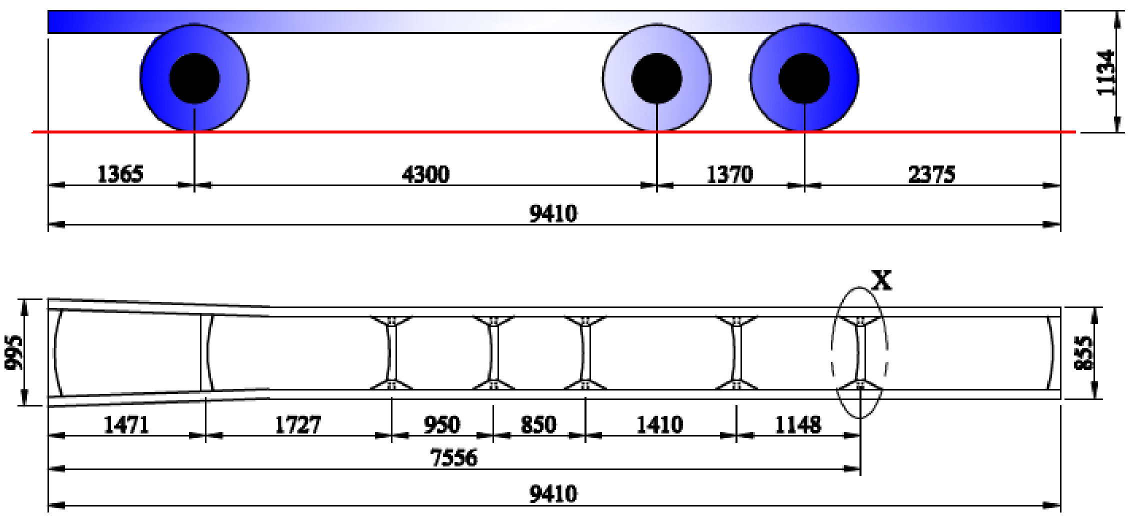


Figure.3.3.1.Actual measurement of Volvo-FH truck Chassis.

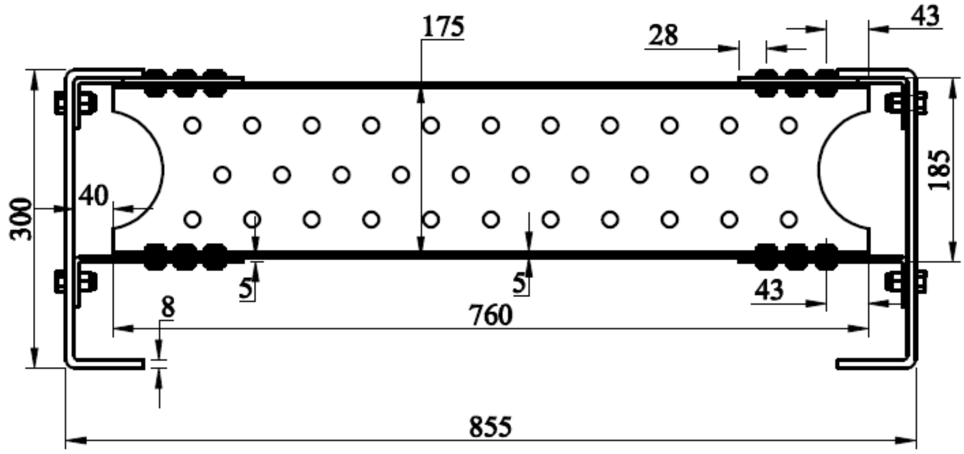


Figure.3.3.2.Actual measurement of Volvo-FH truck Chassis @detail-X

3.4.Analytical Analysis of Existing Truck Chassis

This analytical analysis is done on the existing truck chassis to know the maximum bending moment of the chassis at which point will be occurred and to select the cross member at maximum stressed region for further analysis .Basically, the main objective of the research is to study the effect of stiffener plate thickness on stress of truck chassis using finite element analysis of ANSYS.

3.4.1 .Loading Condition

According loading conditions of beam ,Chassis is a Simply Supported Beam with uniformly distributed load and Chassis has three point supported beam, due to three axle [9][15].

Capacity of the truck = (Pay load + Kerb Weight)= 26000kg

Maximum Weight carrying capacity of the chassis (W_{max}):

$$W_{max} = GVW * g \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.1)$$

Where: GVW-Gross Vehicle weight

g -Gravitational acceleration

$$W_{max} = 26000kg * 9.81 \, {}^{m}/_{s^2} = 255060N$$

Uniformly distributed Load (W_d) throughout the length of chassis, $L = 9410mm$

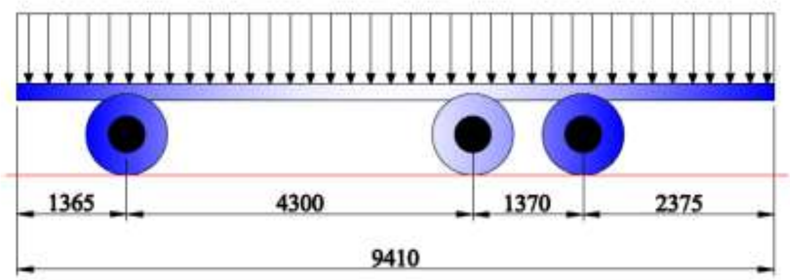
$$W_d = \frac{W_{max}}{L} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.2)$$

Where: L-Over all chassis length

$$W_d = \frac{255060N}{9.41m} = 27 \, {}^{KN}/_{m}$$

Therefore, $W_d = 27 \, {}^{KN}/_{m}$ load is uniformity distributed throughout length and width of the chassis shown in *figure.3.4.1*

$$W_d = 27 \, {}^{KN}/_{m}$$



Figuer.3.4.1.loding condition of truck chassis.

3.4.2 .Analytical Analysis of Bending moment and Reaction forces

The truck chassis has three wheels with axles at point of C, D and E shown in *figure 3.4.1*.the load is uniformly distributed through the longitudinal member and cross members. The chassis are made up of two C-channels side members but for analytical analysis, we will consider single beam. So, the load acting in each beam is half of the total load acting on the chassis [15].

Load acting on single beam (W_s):

$$W_s = \frac{\text{Total Uniformly distributed Load (} W_d)}{2} \quad \text{……………………………………… (3.3)}$$

$$= \frac{27}{2} \boldsymbol{KN/m}$$

$$= \mathbf{13.5} \boldsymbol{KN/m}$$

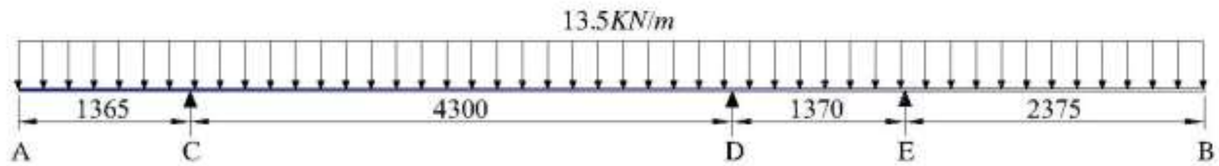


Figure.3.4.2. Uniformly distributed load on single Side member beam.

3.4.2 Bending moment Analysis and Bending Moment Diagram

Indeterminate structure of beam with fixed end moment and reaction forces at point C, D, E, $\overline{\boldsymbol{M}}_{\boldsymbol{CA}}$,$\overline{\boldsymbol{M}}_{\boldsymbol{CD}}$, $\overline{\boldsymbol{M}}_{\boldsymbol{DE}}$, $\overline{\boldsymbol{M}}_{\boldsymbol{EB}}$,$\boldsymbol{R_C}$, $\boldsymbol{R_D}$, $\boldsymbol{R_E}$ as shown below in the fig.3.4.2[9][15].

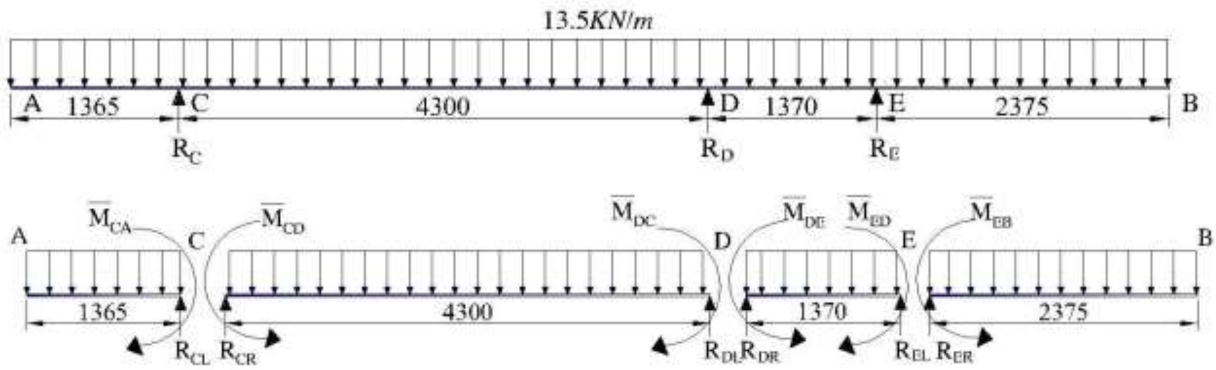


Figure.3.4.2.1. Rreaction forces and moments at point C,D,E.

❖ Calculation of restraint moment at point C,D,E :-

$$\bar{M}_{CA} = \frac{W_s * L_{CA}{}^2}{2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.4)}$$

$$= \frac{13.5*10^3*(1.365)^2}{2}$$

$$=+12.58KNm$$

$$\bar{M}_{CD} = -\frac{W_s * L_{CD}{}^2}{12} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.5)}$$

$$= \frac{13.5*10^3*(4.3)^2}{12}$$

$$= -20.8kNm,$$

$$\bar{M}_{DC} = +20.8KNm$$

$$\bar{M}_{DE} = -\frac{W_s * L_{DE}{}^2}{12} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.6)}$$

$$= \frac{13.5*10^3*(1.37)^2}{12}$$

$$=-2.11kNm,$$

$$\bar{M}_{ED} = +2.11KNm$$

$$\bar{M}_{EB} = -\frac{W_s * L_{EB}{}^2}{2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.7)}$$

$$= \frac{13.5*10^3*(2.375)^2}{2}$$

$$=-38.4kNm$$

❖ **Total restrainet moment at 'C'**

$$\bar{M}_C = \bar{M}_{CA} + \bar{M}_{CD} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.8)}$$

$$= (+12.58KNm-20.8kNm)$$

$$=-8.22KNm$$

- **Total restraint moment at 'E'**

$$\bar{M}_E = \bar{M}_{ED} + \bar{M}_{EB} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.9)}$$

= (2.11KNm-38.1kNm)

=-36KNm

- **Moment for Span "CD"**

$$M_{DC} = -\bar{M}_{CA} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.9)}$$

$$= -12.58KNm$$

$$M_{DC} = \bar{M}_{DC} - \frac{\bar{M}_C}{2} + \frac{3EI}{L_{CD}} i_b \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.10)}$$

$$M_{DC} = 24.91kNm + 0.697EI\, i_b \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.11)}$$

- **For the Span "DE"**

$$M_{DE} = \bar{M}_{DE} - \frac{\bar{M}_C}{2} + \frac{3EI}{L_{DE}} i_b \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.12)}$$

$$M_{DE} = 2kNm + 2.189EI\, i_b \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.13)}$$

- **At equilibrium condition of point "D"**

$$M_{DC} + M_{DE} = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.14)}$$

From equation 3.11 and 3.13

$$EI_{ib} = -9.324x10^3$$

Substituting the value of EI_{ib} , in to equation 3.11 and 3.13

$$M_{DC} = 18.4kNm\,,$$

$$M_{DE} = -18.4kNm$$

❖ **Calculation for Bending Moment Diagram:**

$$M_A = 0\ ,$$

$$M_C = \overline{M}_{CA} = -12.58KNm$$

$$M_P = \frac{W_s * l_{CD}{}^2}{8} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.15)}$$

$$= \frac{13.5 * 4.3^2}{8}$$

$$= 31.2kNm$$

$$M_D = M_{DE} = -18.4kNm$$

$$M_Q = \frac{W_s * l_{DE}{}^2}{8} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.16)}$$

$$= \frac{13.5 * 1.37^2}{8}$$

$$= 3.2kNm$$

$$M_E = \overline{M}_{EB} = -38.4kNm$$

$$M_B = 0$$

So, The Bending Moment diagram due to the above calculation as follows.

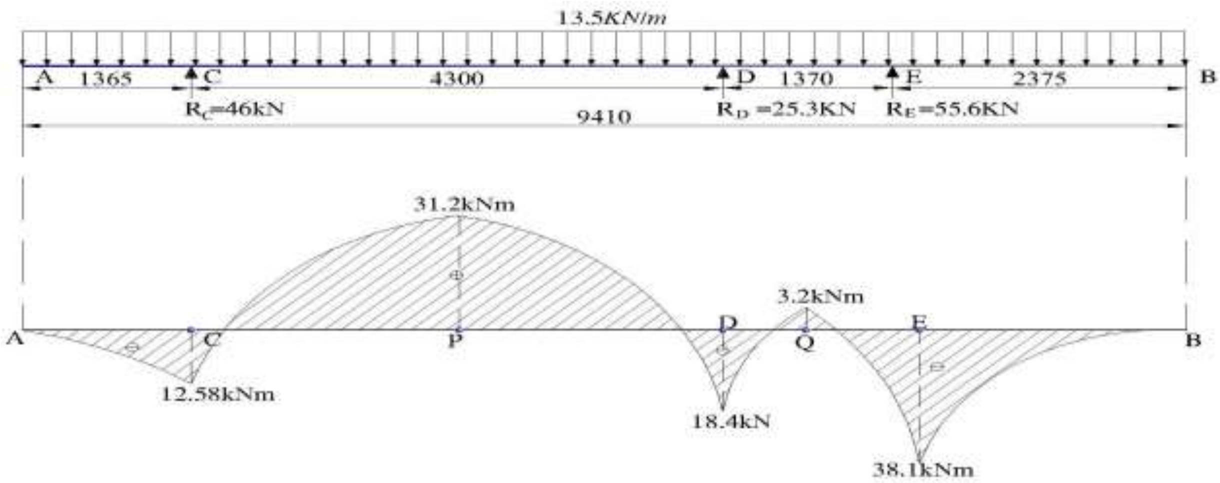


Figure. 3.4.2.2.Bending Moment diagram.

So,the maximum bending moment occures at ''E''

$$M_{Max} = M_E = -38.4kNm$$

3.4.3 .Reaction Force Analysis and Shear forces Diagram

$$R_{CL} = W_s * l_{AC} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.17)$$

$$= 13.5K\,{}^{N}/_{m} * 1.365m$$

$$= 18.4KN(\uparrow)$$

$$R_{CR} = \left(\frac{W_s * l_{CD}}{2}\right) + \left(\frac{\bar{M}_{CA} + M_{DE}}{l_{CD}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.18)$$

$$= \left(\frac{13.5*4.3}{2}\right) + \left(\frac{12.58-18.4}{4.3}\right)KN$$

$$= 27.7KN(\uparrow)$$

$$R_{DL} = (W_s * l_{CD}) - R_{CR}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.19)$$

$$= (13.5 * 4.3 - 27.7)KN$$

$$= 30.4KN(\uparrow)$$

$$R_{DR} = \left(\frac{W_s * l_{DE}}{2}\right) + \left(\frac{M_{DE} + \bar{M}_{EB}}{l_{DE}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.20)$$

$$= \left(\frac{13.5*1.37}{2}\right) + \left(\frac{18.4-38.1}{1.37}\right)KN$$

$$= -5.13KN$$

$$R_{EL} = (W_s * l_{ED}) - R_{DR}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.21)$$

$$=(13.5 * 1.37) + 5.13)KN$$

$$= 23.6KN(\uparrow)$$

$$R_{ER} = (W_s * l_{EB}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.22)$$

$$=(13.5 * 2.375)KN$$

$$= 32KN(\uparrow)$$

Therefore :- $\boldsymbol{R_C = R_{CL} + R_{CR}}$ …………………………… *(3.23)*

$$= (\mathbf{18.4\ KN + 27.7KN})$$

$$= \mathbf{46KN}(\uparrow)$$

$\boldsymbol{R_D = R_{DL} + R_{DR}}$ ………………………………… *(3.24)*

$$= (\mathbf{30.4\ KN - 5.13KN})$$

$$= \mathbf{25.3KN}(\uparrow)$$

$\boldsymbol{R_E = R_{EL} + R_{ER}}$ ………………………………… *(3.25)*

$$= (\mathbf{23.6KN + 32KN})$$

$$= \mathbf{55.6KN}(\uparrow)$$

The shear force diagram due to the above calculation as follows

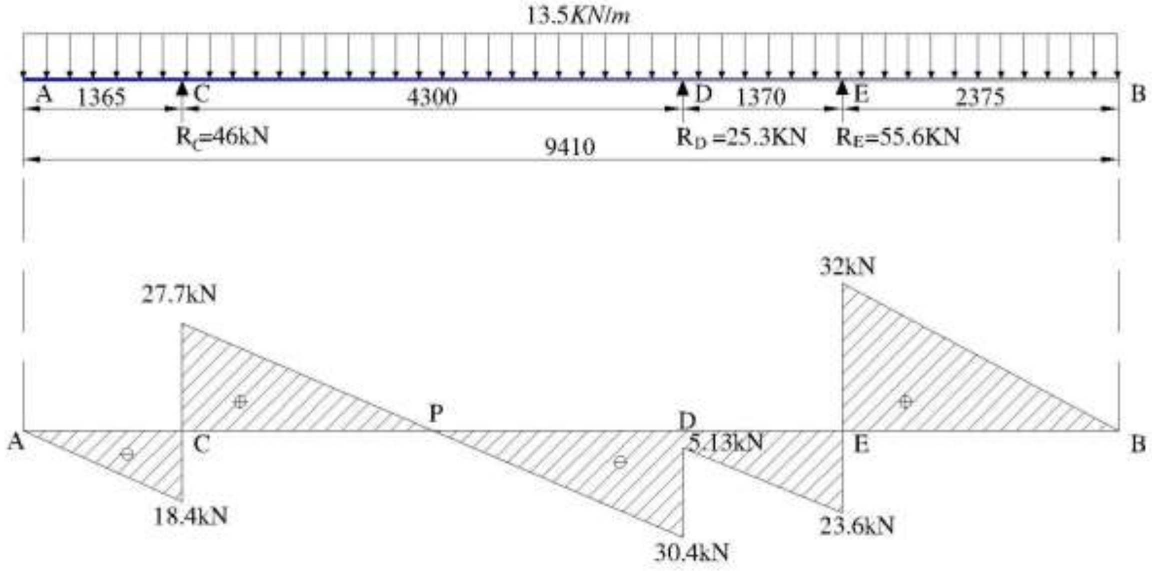


Figure. 3.4.3.1.Shear force diagram.

3.4.4 .Maximum Stress and Deflection Analysis

Due to maximum moment at point'E'we consider a section x-x in 'EB'span at- x,distance from A Taking moment of all forces about x-x section[15] shown below in fig.3.4.4.1.

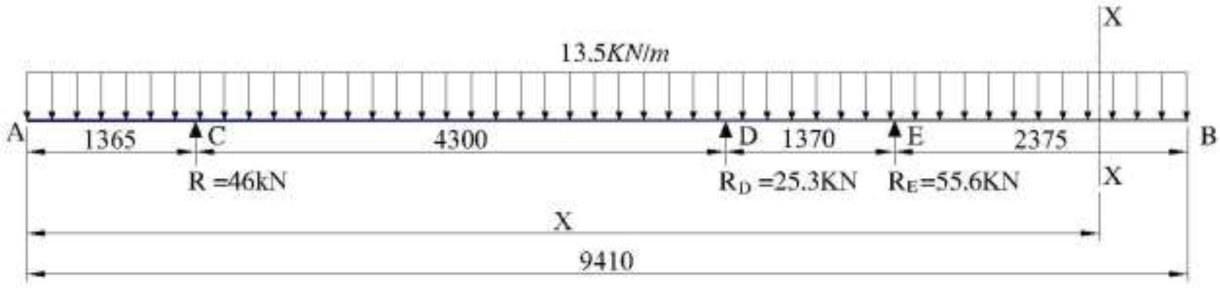


Figure. 3.4.4.1.Reaction generatrd on the Beam.

So,the moment generated at point x-x,

$$M_{xx} = \frac{-W_s * l_{AX}{}^2}{2} + R_C\,(x - l_{AC}) + R_D\,(x - l_{AD}) + R_E\,(x - l_{AE}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.25)$$

Macaulay's method (The double integration method) is a technique used in structural analysis to determine the deflection of Euler-Bernoulli beams. Use of Macaulay's technique is very convenient[15].

$$M_{xx} = EI\frac{d^2y}{dx^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.26)$$

Therefore, from equation (3.25) and (3.26)

$$M_{xx} = EI\frac{d^2y}{dx^2} = \frac{-W_s * L_{AX}{}^2}{2} + R_C\,(x - L_{AC}) + R_D\,(x - L_{AD}) + R_E\,(x - L_{AE})$$

$$EI\frac{d^2y}{dx^2} = -6.75x^2 + R_C\,(x - 1.365) + R_D\,(x - 5.665) + R_E\,(x - 7.035)$$

By Integrating with respect to x we get

$$EI\frac{dy}{dx} = \frac{-6.75x^3}{3} + C_1 + R_C\,\frac{(x-1.365)^2}{2} + R_D\,\frac{(x-5.665)^2}{2} + R_E\,\frac{(x-7.035)^2}{2}$$

Again Integrating with respect to x we get

$$EIy = \frac{-6.75x^4}{12} + C_1\,x + C_2 + R_C\,\frac{(x-1.365)^3}{6} + R_D\,\frac{(x-5.665)^3}{6} + R_E\,\frac{(x-7.035)^3}{6}$$

Appling boundary conditions :

$@x = 1.365m, y = 0, and \quad @x = 5.665m, y = 0$

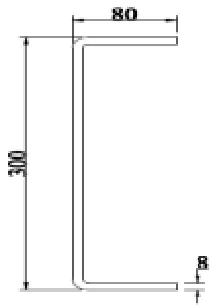
$$325.4x10^3 + 1.365C_1 + C_2 = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.27)}$$

$$-597.96x10^3 + 5.665C_1 + C_2 = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.28)}$$

From the above sumiltinious equation we get: $C_1 = -63.4x10^3$, $C_2 = 957.12x10^3$

$$y = \frac{1}{EI}\ (-616.7x^4 + 8611.7(x - 1.365)^3 + 4120(x - 5.665)^3 + 893720 \ldots\ldots\ldots \text{(3.29)}$$

❖ **Calculation for moment of inertia (I $_{xx}$)**



Figuer.3.3.8 Section of side member.

For C-section

$$R(radius\ of\ gyration) = \left(\frac{300}{2}\right) = 150mm, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.30)}$$

$b = 80mm, h = 300mm$

$b_1 = 72mm, h_1 = 284mm$,

$$y = \frac{h}{2} = 150mm, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.33)}$$

Moment of inertia around x-x axis (I_{xx})

$$I_{xx} = [\frac{bh^3 - b_1 h_1{}^3}{12}] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.34)}$$

$$I_{xx} = 4 * 10^{-5} m^4$$

Section of modules around the x-x axis $(\boldsymbol{Z}_{xx})$

$$\boldsymbol{Z}_{xx} = [\frac{I_{xx}}{y}] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.35)$$

$$\boldsymbol{Z}_{xx} = \left[\frac{\mathbf{4 * 10^{-5}}}{\mathbf{0.15}}\right]$$

$$= \mathbf{2.6 * 10^{-4}} \boldsymbol{m}^{3}$$

Basic bending equations are as follow:-

$$\frac{M}{I} = \frac{\delta}{y} = \frac{E}{R} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.36)$$

Maximum bending moment acting on the beam

$$\boldsymbol{M}_{Max} = \boldsymbol{M}_{E} = -\mathbf{38.4} \boldsymbol{kNm}$$

$$\boldsymbol{Z}_{xx} = \mathbf{2.6 * 10^{-4}} \boldsymbol{m}^{3}$$

Therefore , the Normal bending stress produced on the beam due to maximum moment will be at point ‘’E’’ be:

$$\boldsymbol{\delta} = \frac{M}{Z} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.37)$$

$$= \frac{-\mathbf{38.4 * 10^{3}}}{\mathbf{2.6 * 10^{-4}}}$$

$$= -\mathbf{148} \boldsymbol{Mpa}$$

From equation 3.29.deformation at point E will be ,X~7.556m

$$\boldsymbol{y} = \frac{1}{EI} \left(-\mathbf{616.7}\boldsymbol{x}^{4} + \mathbf{8611.7}(\boldsymbol{x} - \mathbf{1.365})^{3} + \mathbf{4120}(\boldsymbol{x} - \mathbf{5.665})^{3} + \mathbf{893720}\right.$$

$$\boldsymbol{Y}_{E} = \mathbf{0.30} \boldsymbol{mm}$$

Table.3.4.4.1. Analytical result of Existing chassis Normal stress and deformation @point ‘E’

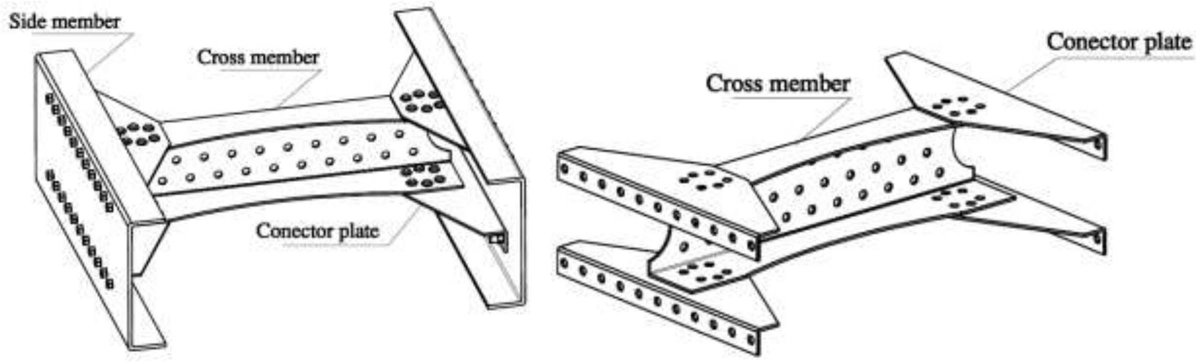
Sr.no	Normal Stress (Mpa)	Deformation(mm)
1	148	0.30

3.5.Modeling of Truck Chassis

From previous analytical analysis of existing truck chassis the maximum bending moment is occurred around point ‘’E’’. So, to study the effect of stiffener plate thickness on stress of truck chassis, we will take a cross member around point ‘’E’’ of *figure 3.3.1* at detail-x for further modeling and analysis of the chassis.

On this research, 3D modeling of existing and modified truck chassis is done using CATIAV5R19, based on the actual measurement taken from Volvo truck and analysis is done using ANSYS14.5 software.

The aim of the research is to study the effect of stiffener plate thickness on stress of truck chassis using finite element method by adding stiffener plate thickness between the side member and cross member, and, between connector plate and cross member flange; the stiffeners are fastened in between by means of rivet and bolt joints as shown *Fig.3.5.1 and Fig.3.5.2.*



Figuer.3.5.1 existing chassis with cross member and conector plate @detail- X.

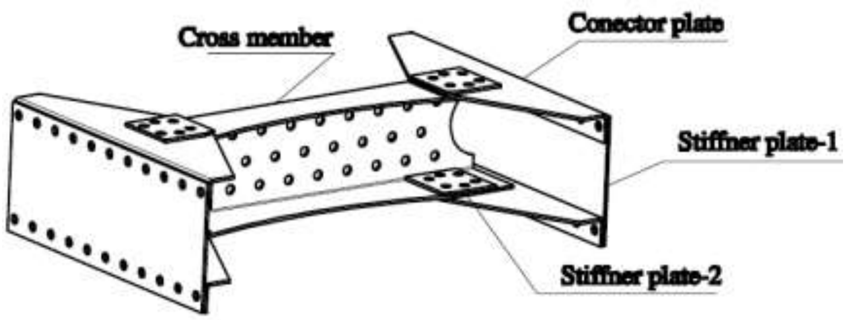


Figure.3.5.2 New proposed modified Cross member with stiffeners.

3.5.1 . 3D-Modeling of Existing Truck Chassis

Detail component measurements are taken from existing truck chassis of Volvo-FH and modeling of all parts are done in CATIAV5R19 as shown below Figures.

N.B. length of side member at detail-X of point 'E' 800mm considered [6].

Table.3.5.1. Component of existing cross member chassis

It.no	Description	Quntity	Size	Remark
1	Connector Plate	02	50x170x550x5mm	
2	Cross Member	01	120x175x760x5mm	
3	Longitudinal member	02	300x800x80x8mm	
4	Bolt with nut	44	M14x40mm	
5	Rivet	24	Ø12x24mm	

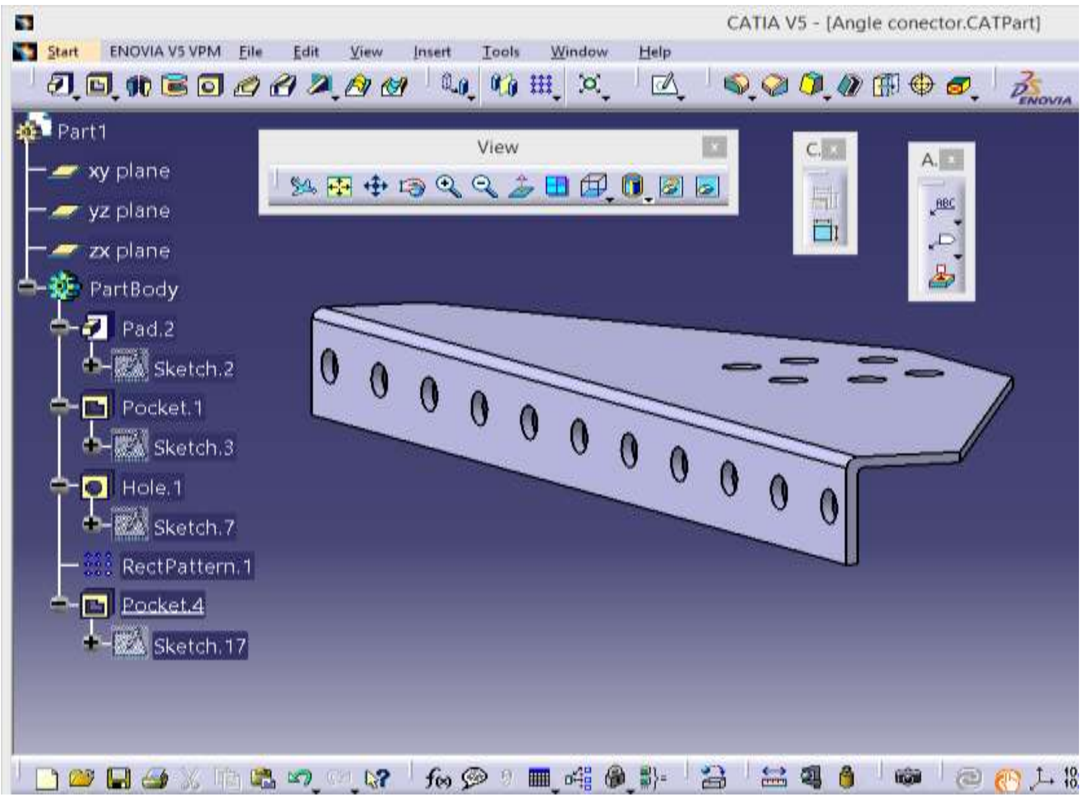
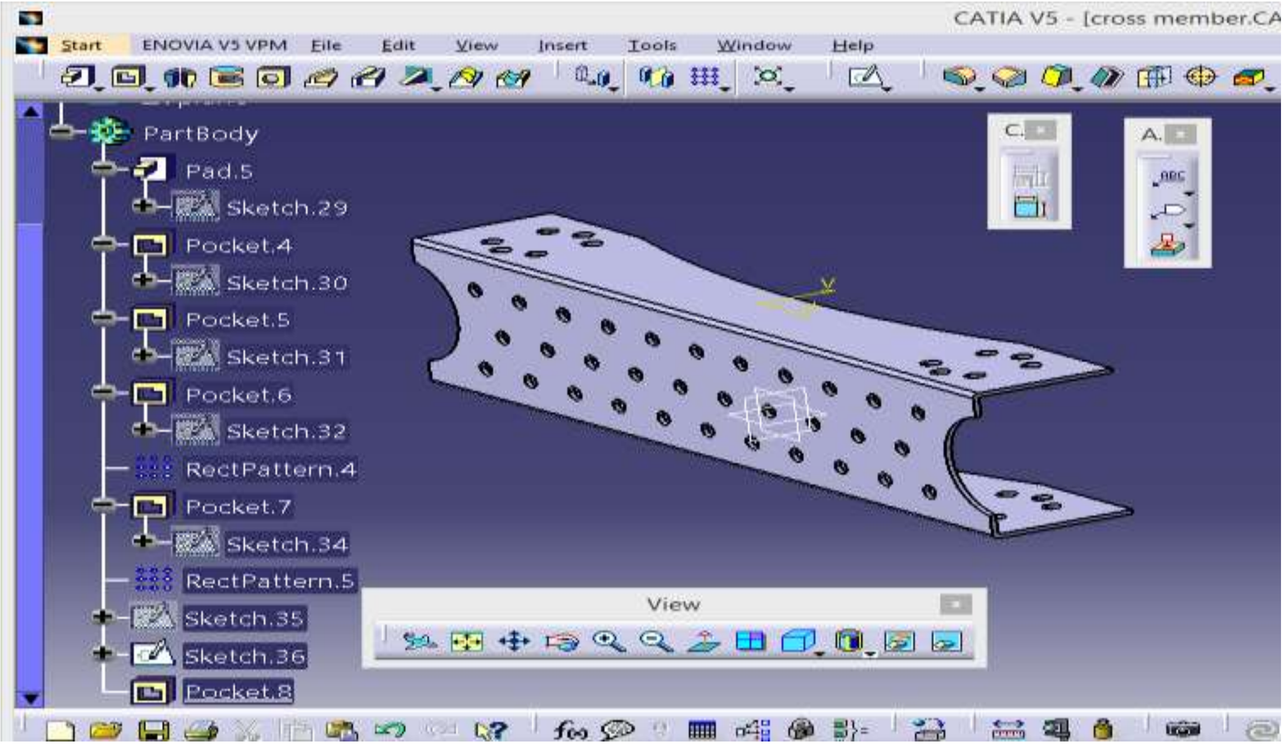
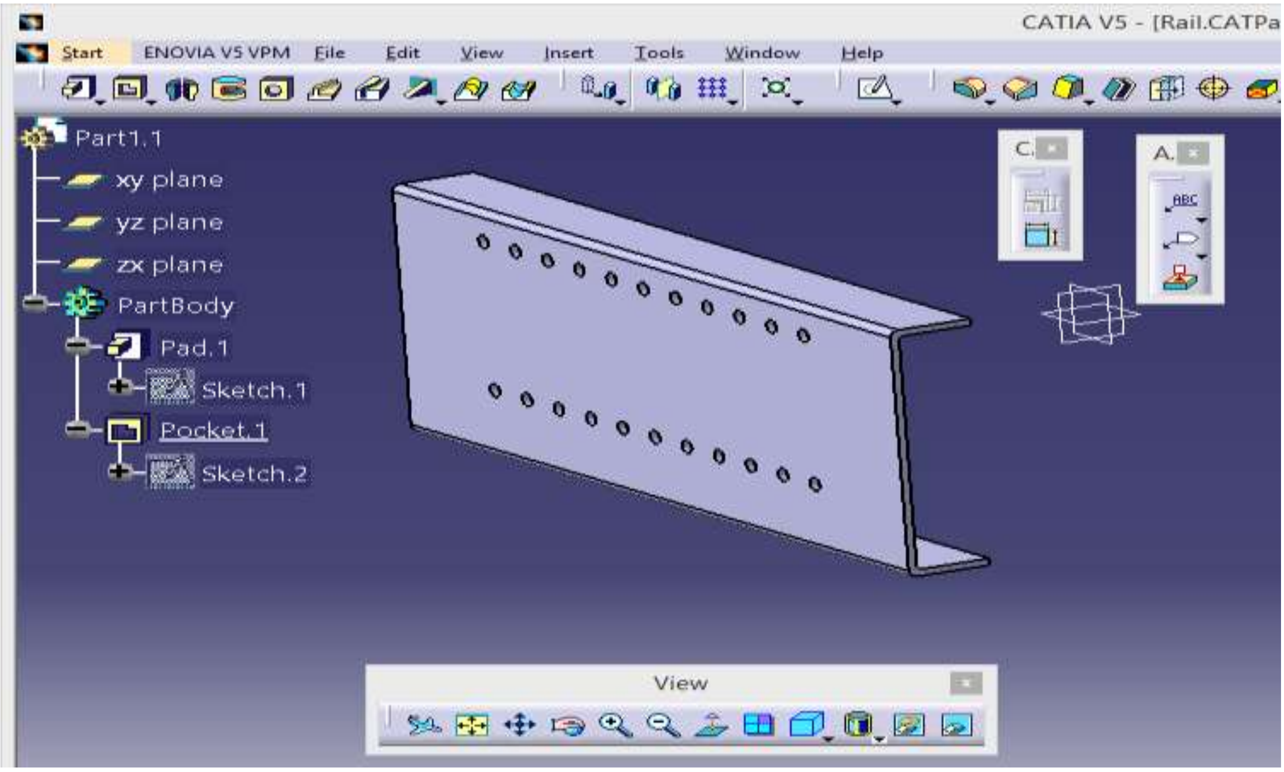


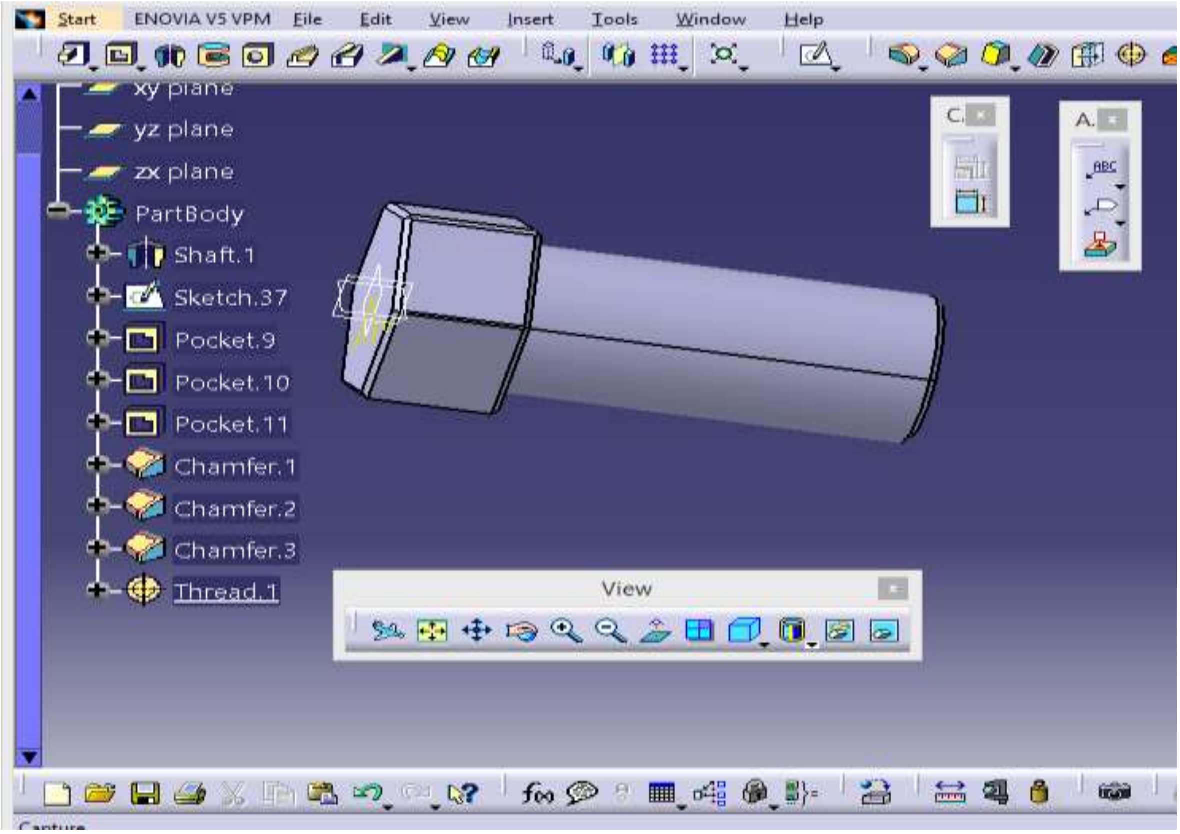
Figure.3.5.1.1. 3D modeling of Angle connector plate using CATIAV5R19.



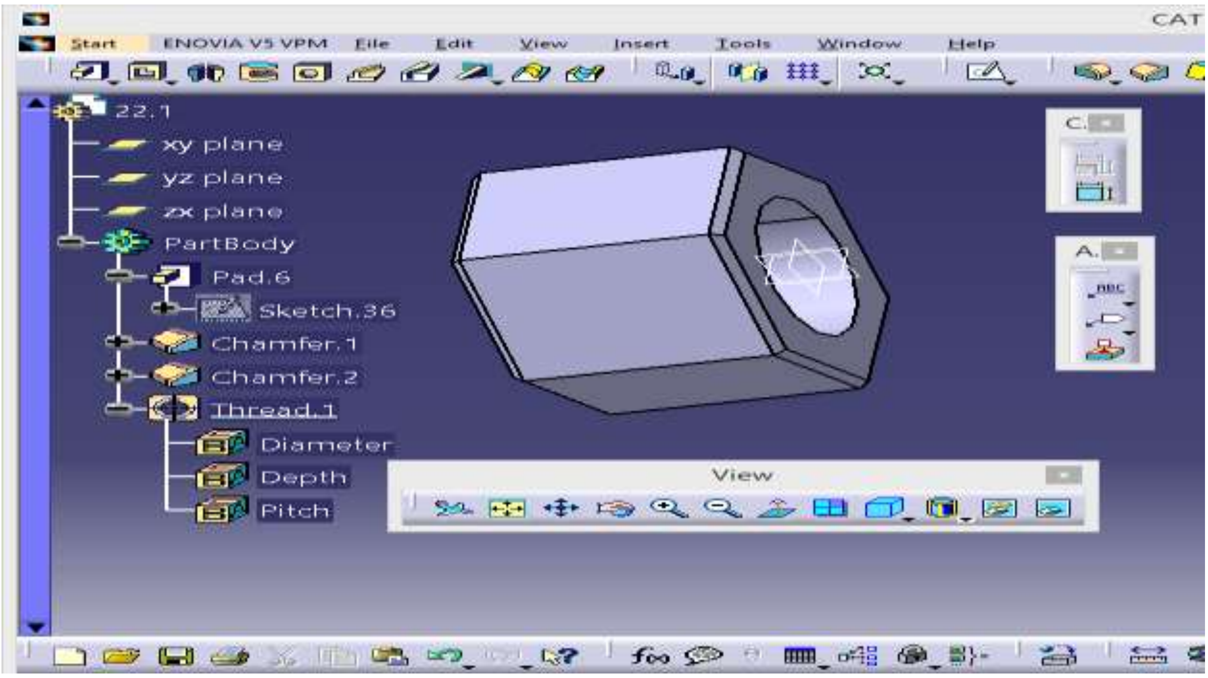
Figuer.3.5.1.2. 3D- modeling of cross member using CATIAV5R19.



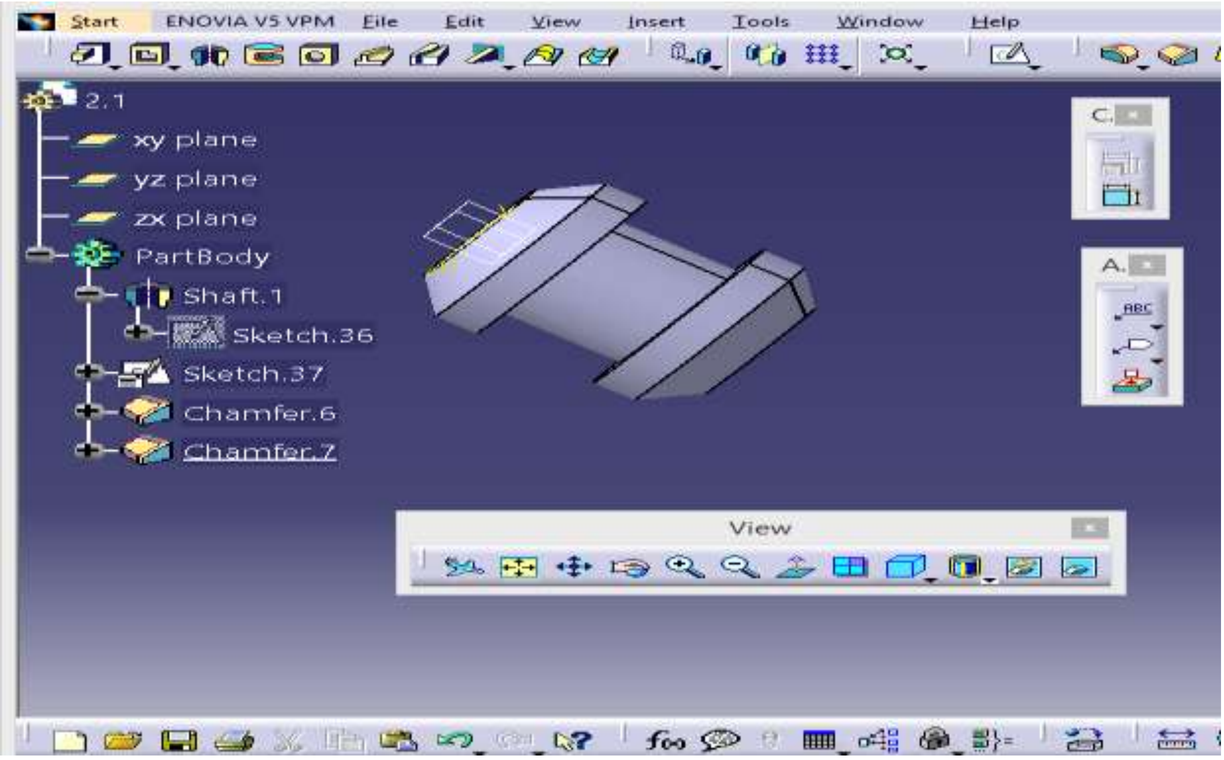
Figuer.3.5.1.3. 3D- modeling of side member using CATIAV5R19.



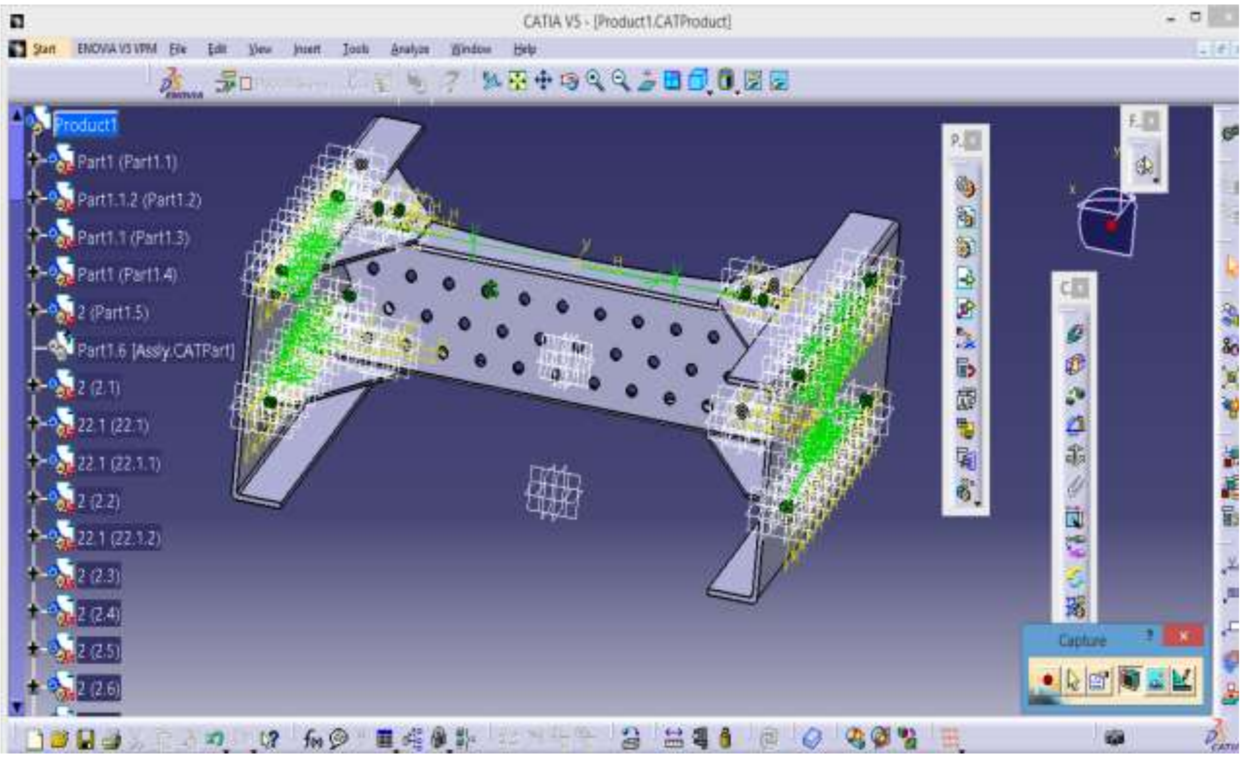
Figuer.3.5.1.4. 3D- modeling of Bolt using CATIAV5R19.



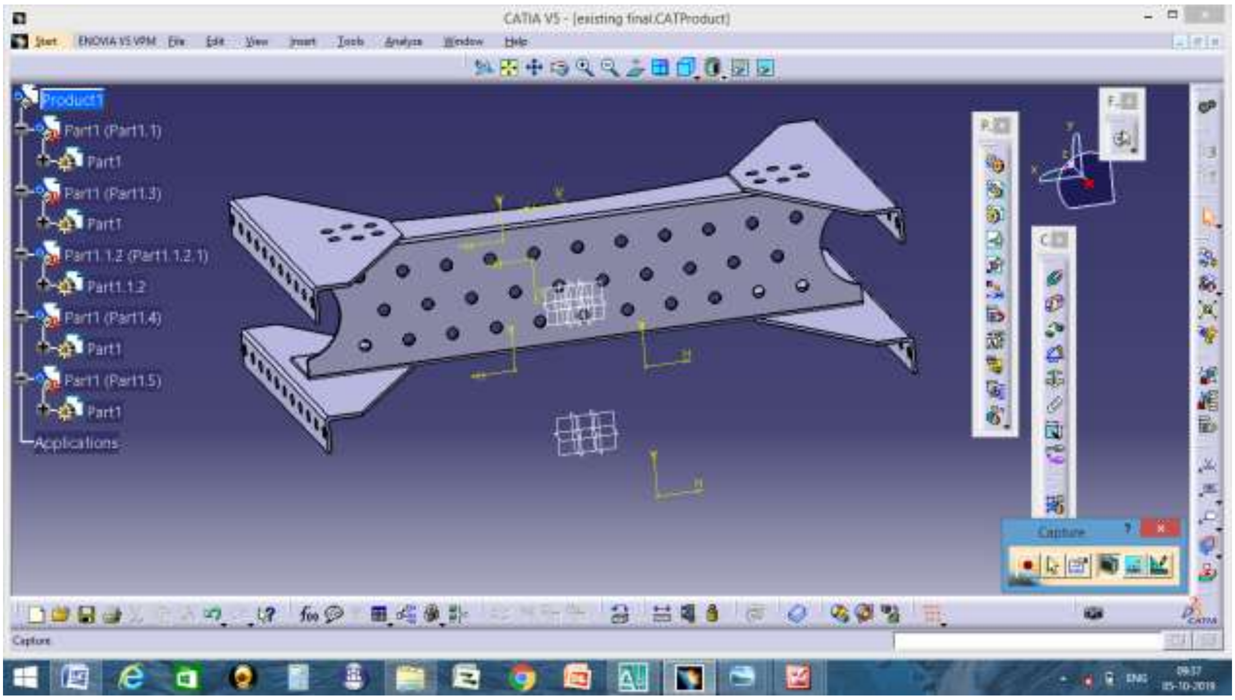
Figuer.3.5.1.5. 3D- modeling of Nut using CATIAV5R19.



Figuer.3.5.1.6. 3D- modeling of Rivet using CATIAV5R19.



Figuer.3.5.1.7.3D- modeling of existing cross member assembly using CATIAV5R19.



Figuer.3.5.1.8. 3D- modeling of existing cross member using CATIAV5R19.

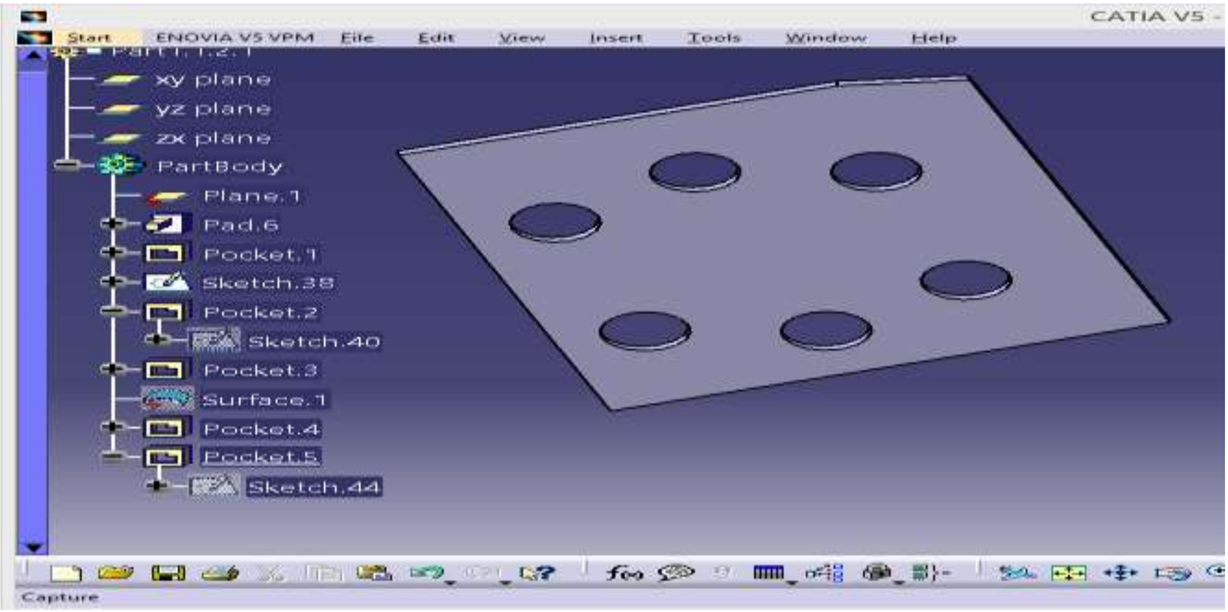
Figuer.3.5.1.9. 3D- Render modeling of existing cross member using CATIAV5R19.

3.6. 3D-Modeling of Modified Truck Chassis

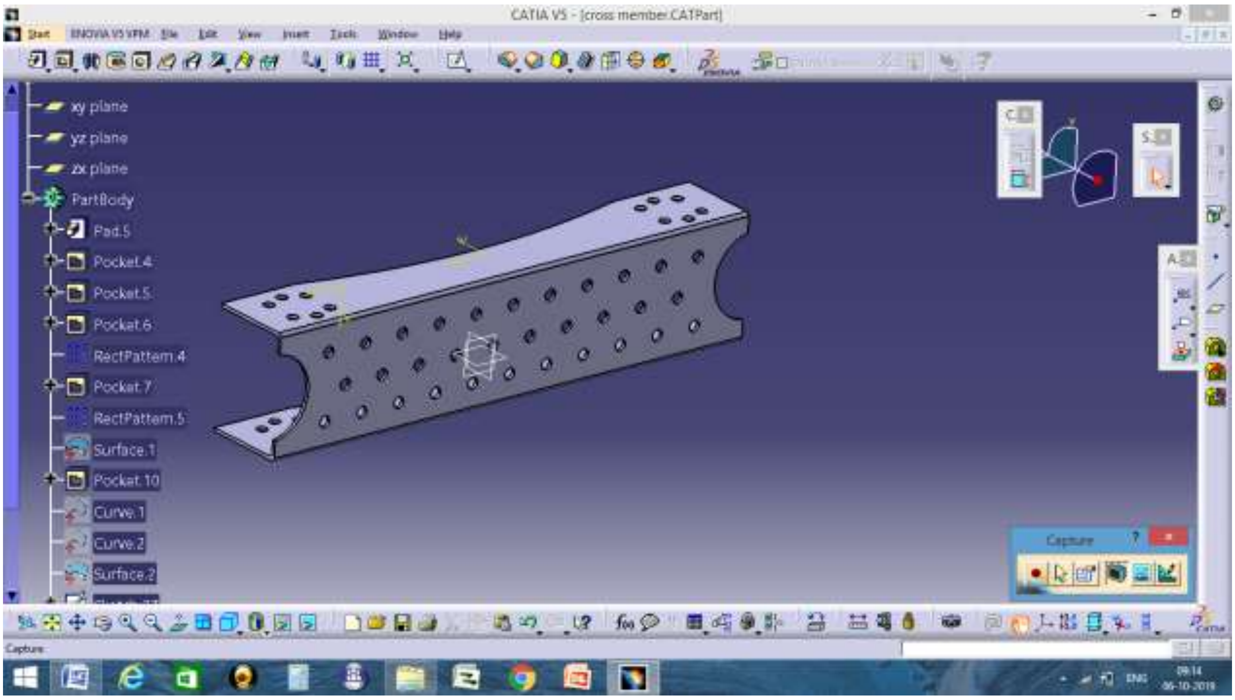
During the modification of existing truck chassis stiffener plate-2 inserted between side member and connector plate using bolt connection, stiffener plate -1 riveted on the top of cross member and connector plate using rivet connection. Then, when stiffener plate-2inserted the Cross member rivet hole positions are shifted (5-8mm) from original position of existing cross member due to the stiffener plate thickness. The detail description of modified cross member assembly are shown below in *table.3.6.1*

Table.3.6.1. Component of modified truck chassis@ detail-x:

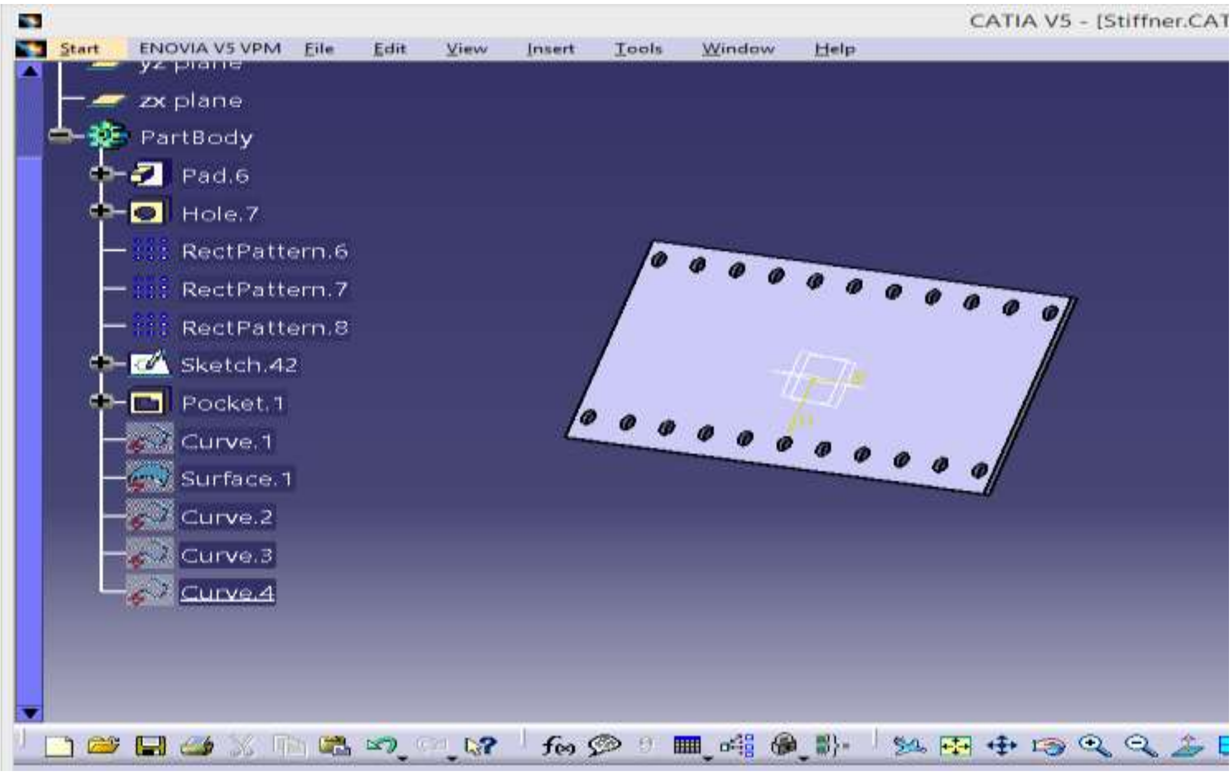
It.no	Description	Quntity	Size	Remark
1	Connector Plate	02	50x170x550x5mm	
2	Cross Member	01	120x175x380x5mm	
3	Longitudinal member	02	300x800x80x8mm	
4	Bolt with nut	44	M14x40mm	
5	Rivet	24	Ø12x30mm	
6	Stiffener Plate-1	04	100x100x5mm	
7	Stiffener Plate-2	02	550x225x(3-8)mm	



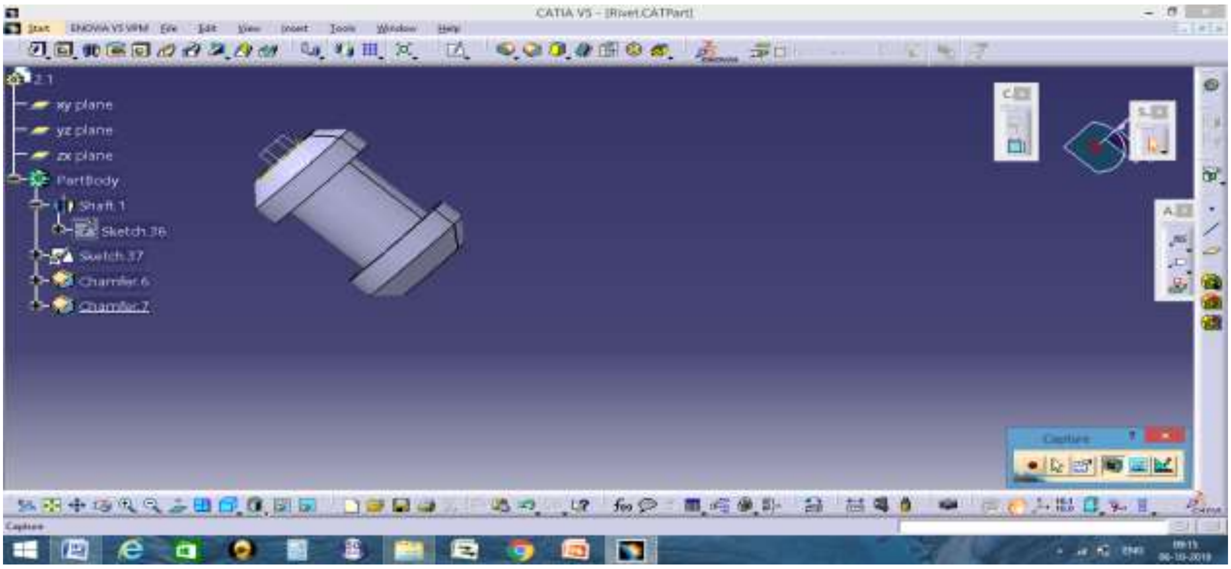
Figuer.3.6.1.3D- modeling of stiffener plate-2 using CATIAV5R19.



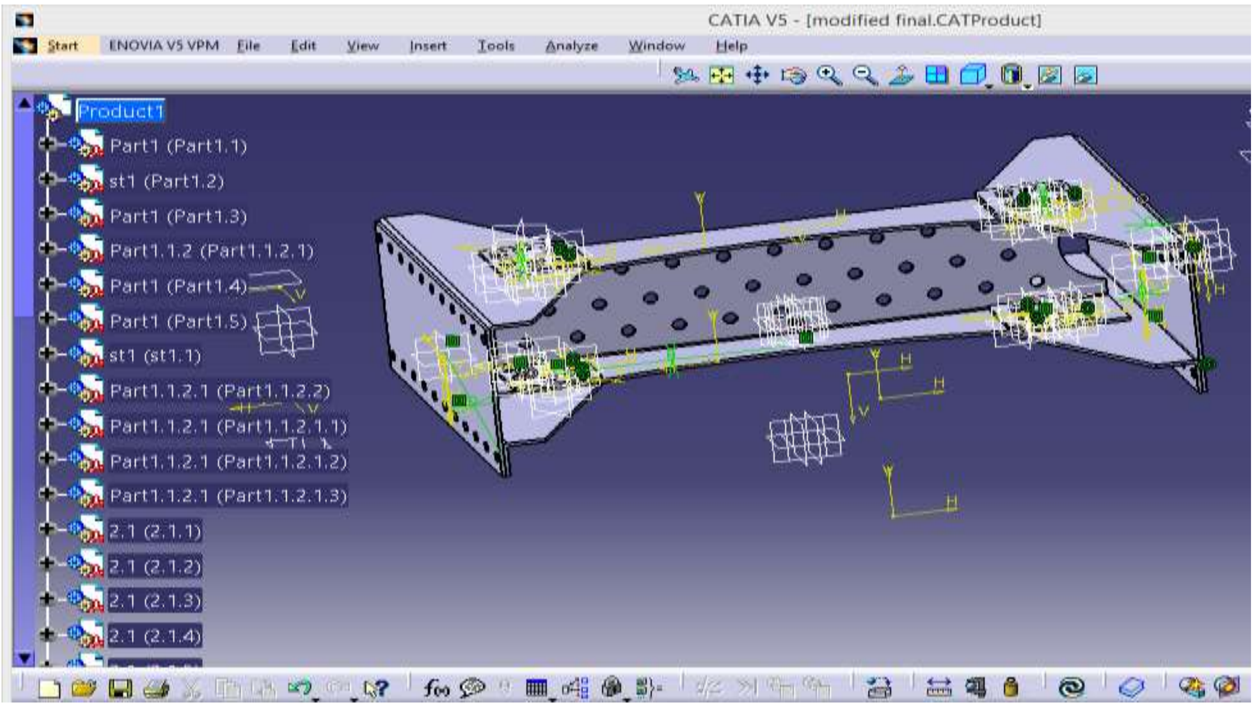
Figuer.3.6.2.3D- modeling of modified cross member using CATIAV5R19.



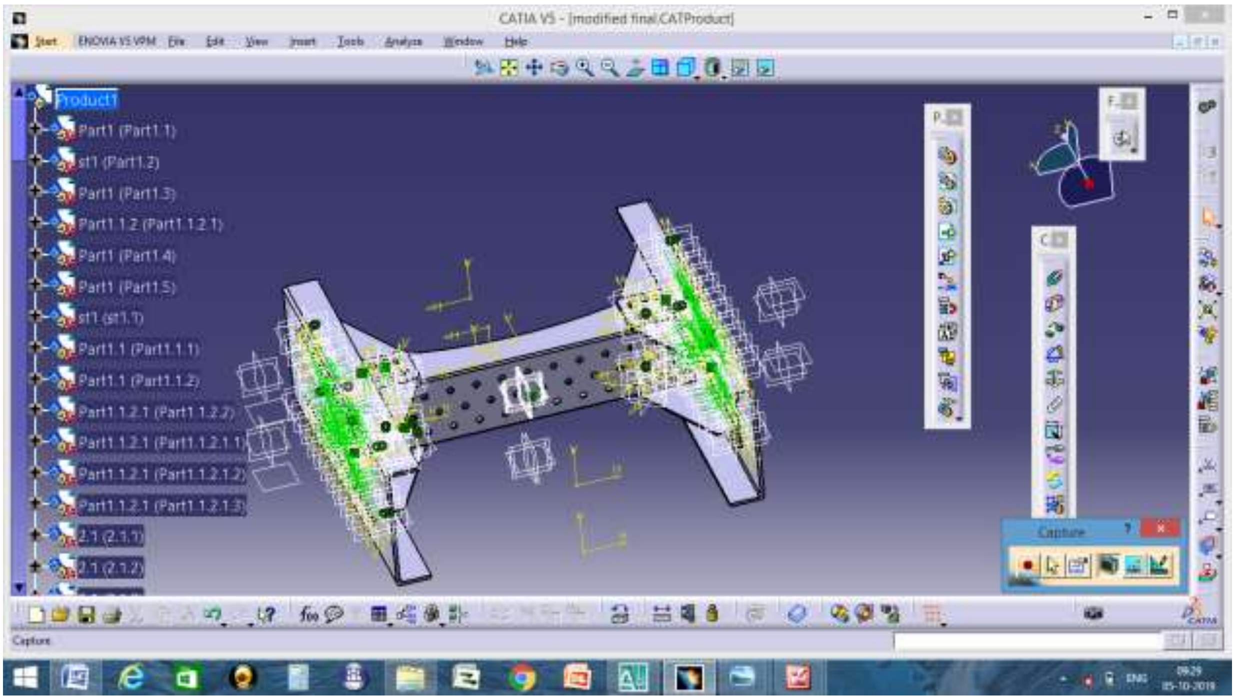
Figuer.3.6.3.3D- modeling of stiffener plate-1 using CATIAV5R19.



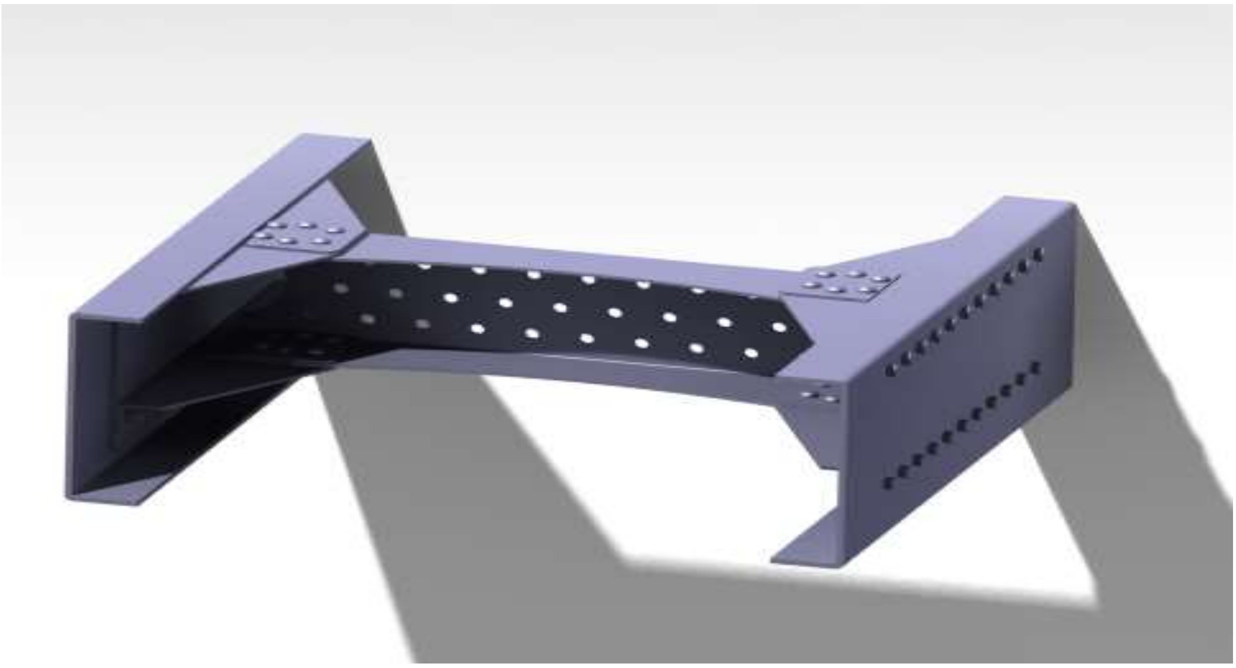
Figuer.3.6.4.3D- modeling of Rivet using CATIAV5R19



Figuer.3.6.5.3D- modeling of modified cross member with stiffeners Assembly using CATIAV5R19.



Figuer.3.6.6. 3D- modeling of modified cross member assembly using CATIAV5R19.



Figuer.3.6.7.3D-render modeling of modified cross members assembly using CATIAV5R19.

3.7.Analysis of Truck Chassis Using ANSYS 14.5

ANSYS work bench is one of finite element analysis (FEA) software package .Finite element structural analysis is a method of study of the behavior of a structure under particular load and displacement conditions. The finite element modeling is generalization of the displacement or matrix method of structural analysis to two and three-dimensional problems. The basic concept of FEM that structure to be analyzed is considered to be an assemblage of discrete pieces called "elements" that are connected together at a finite number of points or nodes. The finite element is a geometrically simplified representation of a small part of the physical structure. Discrediting the structure requires experience and complete understanding of the behavior of the structure can behave like a beam, truss, plate, and shell [2]. Therefore, the finite element analysis of ANSYS 14.5 work bench of truck chassis is as follows.

3.7.1.Static Structural Analysis of Existing Truck Chassis.

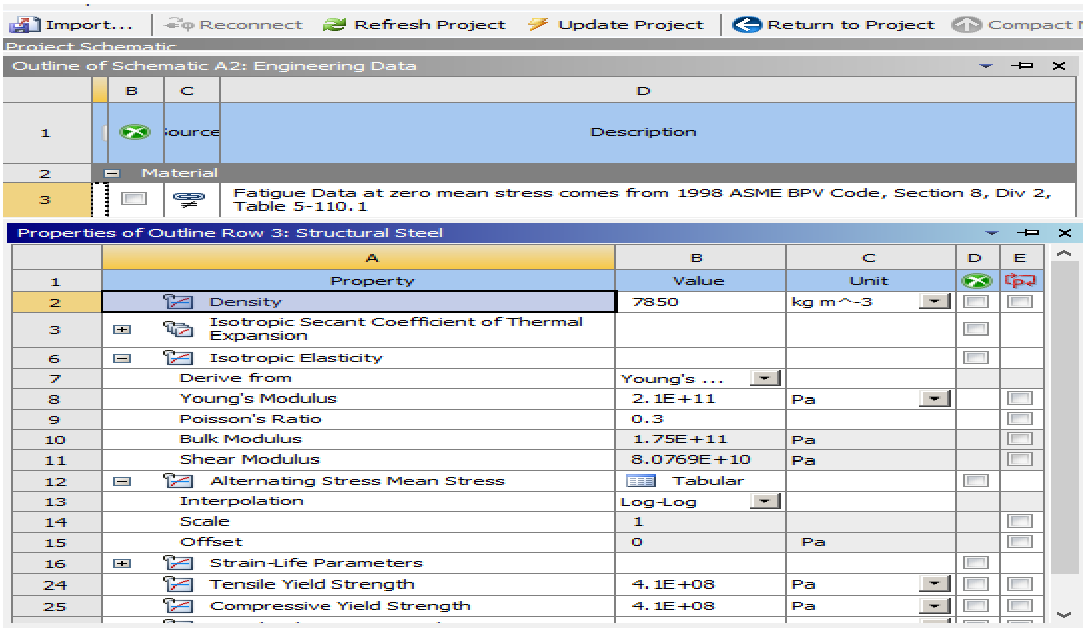
A static structural analysis used to determines the displacements, stresses, strains, and forces in structures or components caused by external loads that do not induce significant inertia and damping effects.

Steps to do Static structural analysis on ANSYS14.5 work bench are.

- Engineering data defining
- Modeling
- Geometry
- Mesh
- Constraints and Load Application
- Generating Solutions

- **Define Engineering Data**

The specific material property of high strength low alloy steel (HSLA) are shown below in *Figure.3.7.1*.



Import... | Reconnect | Refresh Project | Update Project | Return to Project | Compact

Project Schematic

Outline of Schematic A2: Engineering Data

	B	C	D
1		Source	Description
2	Material		
3			Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1

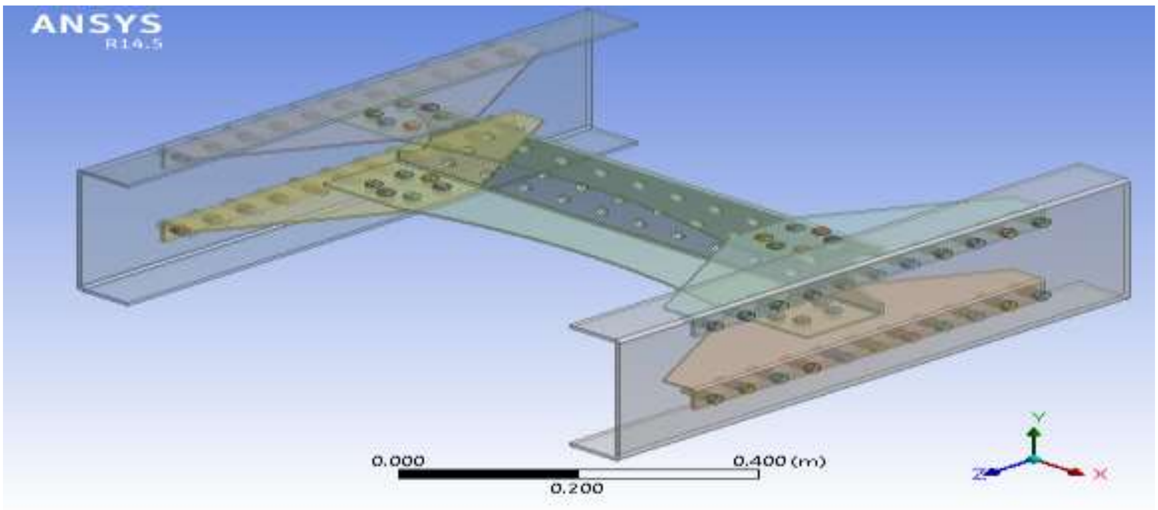
Properties of Outline Row 3: Structural Steel

	A	B	C	D	E
1	Property	Value	Unit		
2	Density	7850	kg m^-3		
3	Isotropic Secant Coefficient of Thermal Expansion				
6	Isotropic Elasticity				
7	Derive from	Young's ...			
8	Young's Modulus	2.1E+11	Pa		
9	Poisson's Ratio	0.3			
10	Bulk Modulus	1.75E+11	Pa		
11	Shear Modulus	8.0769E+10	Pa		
12	Alternating Stress Mean Stress	Tabular			
13	Interpolation	Log-Log			
14	Scale	1			
15	Offset	0	Pa		
16	Strain-Life Parameters				
24	Tensile Yield Strength	4.1E+08	Pa		
25	Compressive Yield Strength	4.1E+08	Pa		

Figuer.3.7.1. work bench material property of existing truck chassis.

- **Modeling**

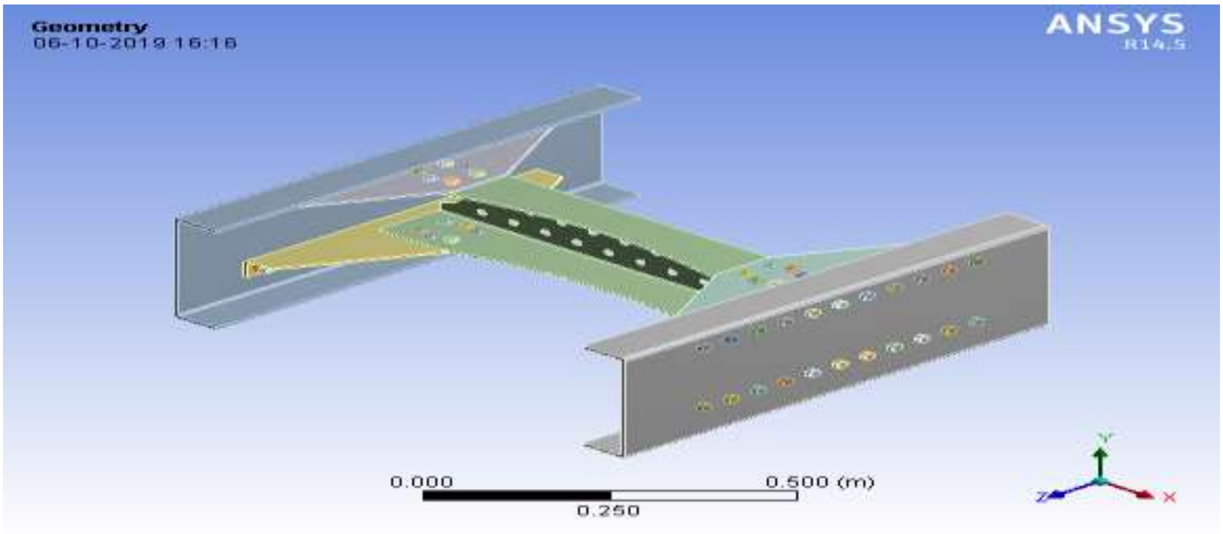
Modeling of the chassis is done in CATIAV5R19 and imported to ANSYS14.5 work bench total 119 parts and 119Bodies are considered shown below in the *Figure.3.7.2*



Figuer.3.7.2. Imported model of existing chassis in ANSYS14.5.

- **Geometry**

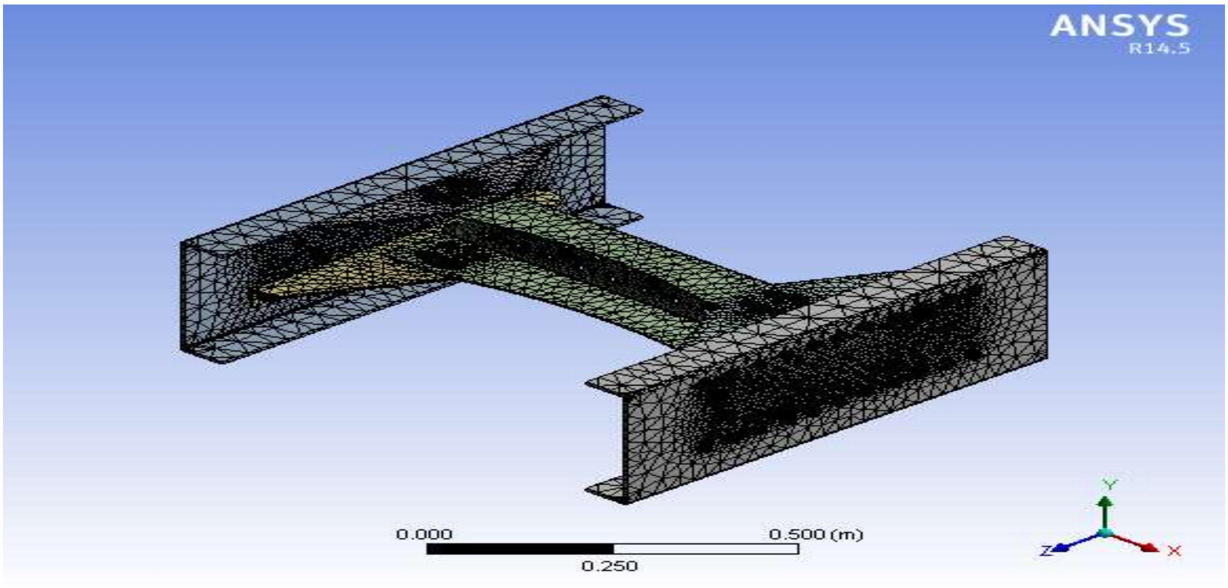
The model is imported and generated Geometry in ANSYS14.5 workbench shown below in *figure.3.7.3.*



Figuer.3.7.3. Generated Geometry in ANSYS14.5 workbench.

- **Mesh**

Medium element size mesh option used to generate mesh with 455721 nodes and 194690 numbers of elements sown below in *figure3.7.4*.



Figuer.3.7.4. meshed model of existing chassis.

- **Apply Load and Supports**

Calculation of applied load on length of rail member, L_s = 800mm,from equation.3.2. $W_d = 27\,{}^{KN}/_{m}$ Load is uniformity distributed throughout length of the chassis, then for selected cross member with rail element total applied load will be (W_s)

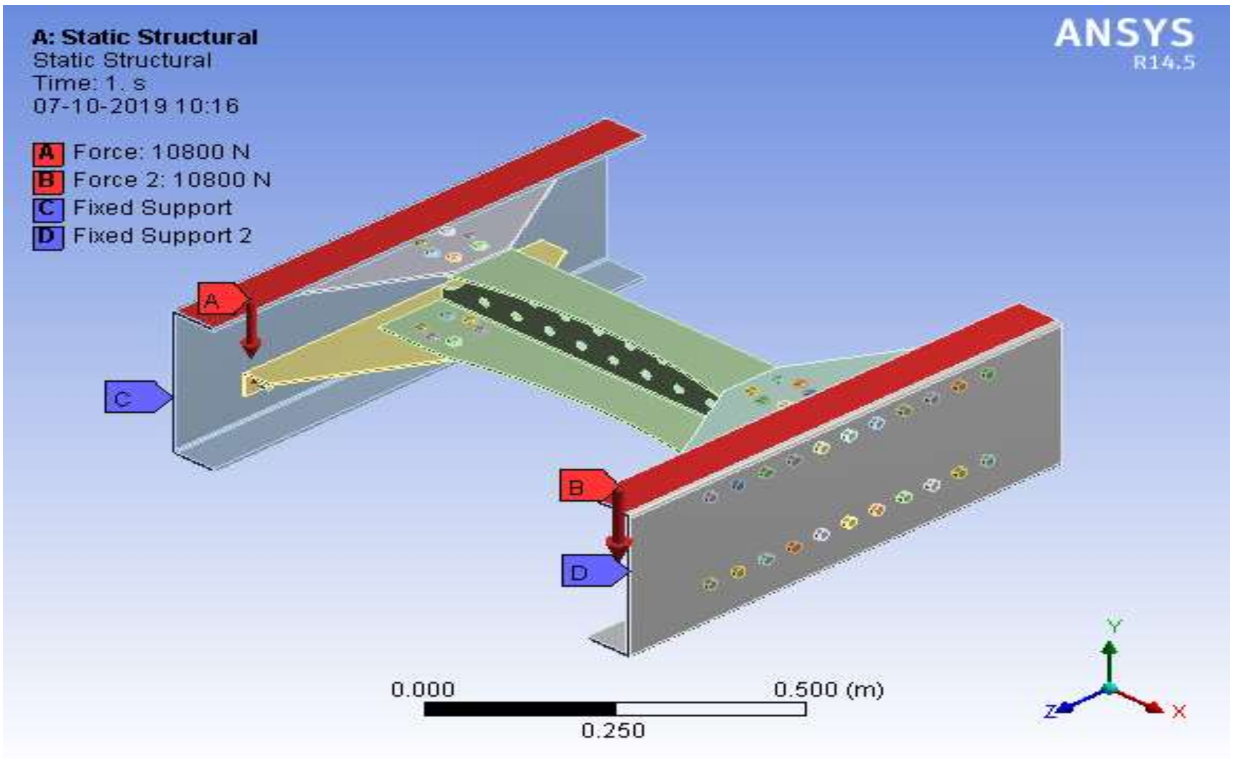
$$W_s = W_d * l_s \quad \text{……………………. (eqn. 3.3.29)}$$

$$W_s = 27\,{}^{KN}/_{m} * 0.8m$$

$$W_s = 21.6KN$$

So, the load applied on single side member is half of $\mathbf{W_s}$=21600N, then the applied load for this analysis is **10800N** as shown in the *figure 3.7.5.*

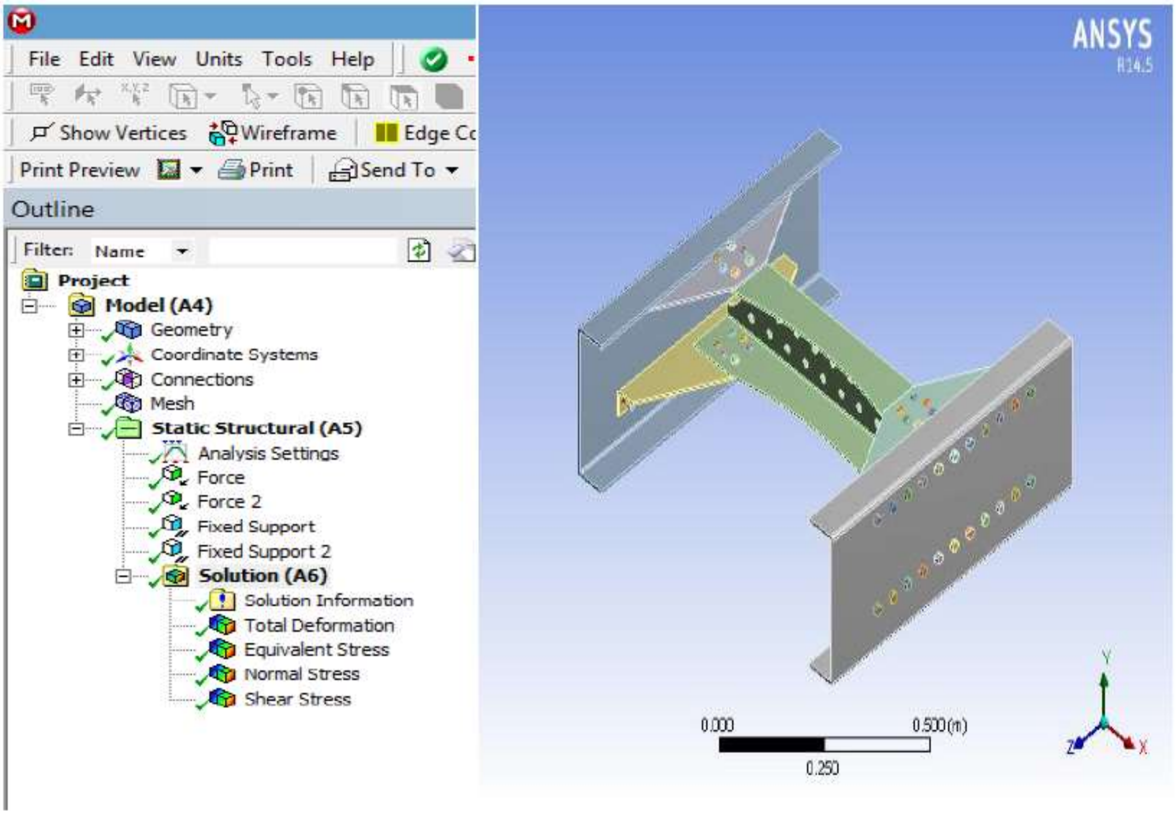
N.B. Conditions of supports are considered the cross member as cantilever of Fixed-free beam conditions due to the third wheel of chassis is fixed and free end.



Figuer.3.7.5. Load and fixed support of chassis.

- **Generating Solution**

The solution is generated from the input parameters. Equivalent (Von Misses) stress, total deformation; normal stress and shear stress are the basic variables to be solved using ANSYS14.5 software analysis.

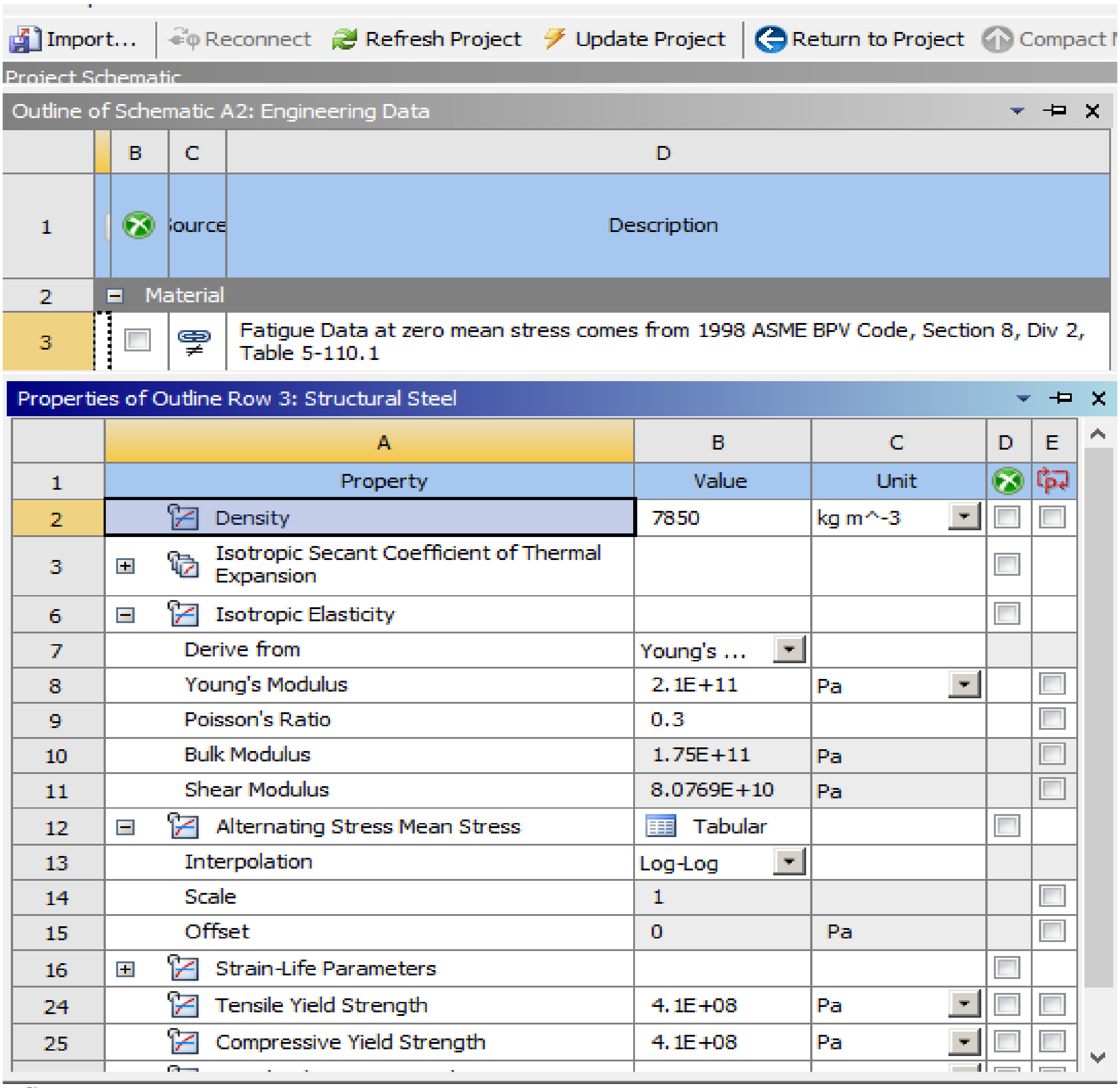


Figuer.3.7.6. Generating solution of existing chassis.

3.7.2. Static Structural Analysis of Modified Truck Chassis

Define Engineering Data

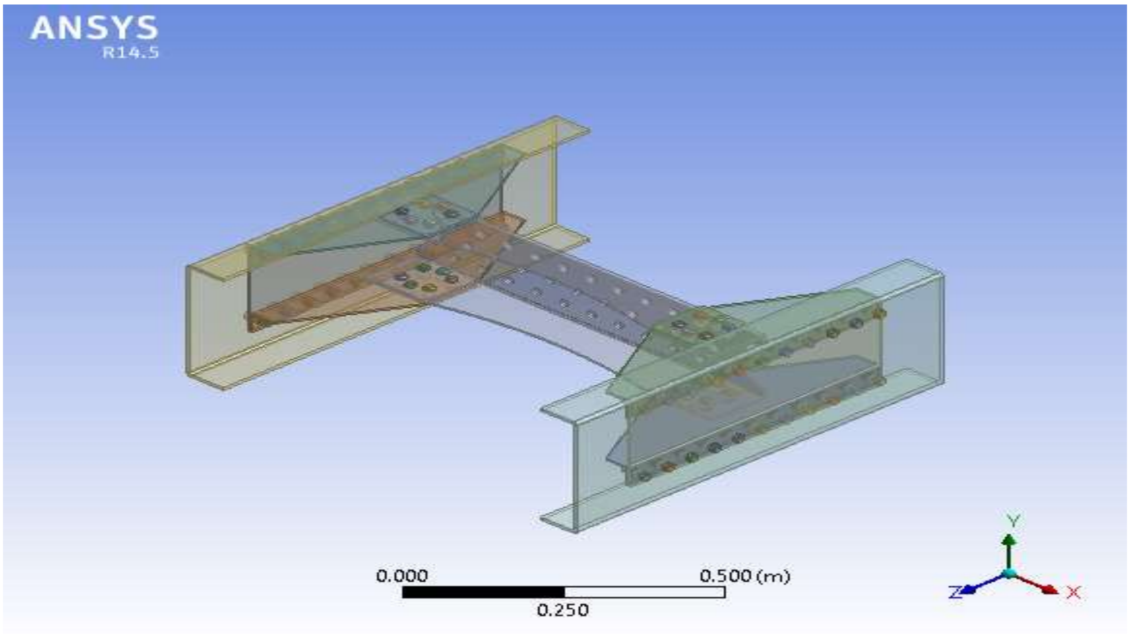
The specific material property of high strength low alloy steel (HSLA) are shown below in *Figure.3.7.2.1.*



Figuer.3.7.2.1. work bench material property of modified chassis.

Modeling

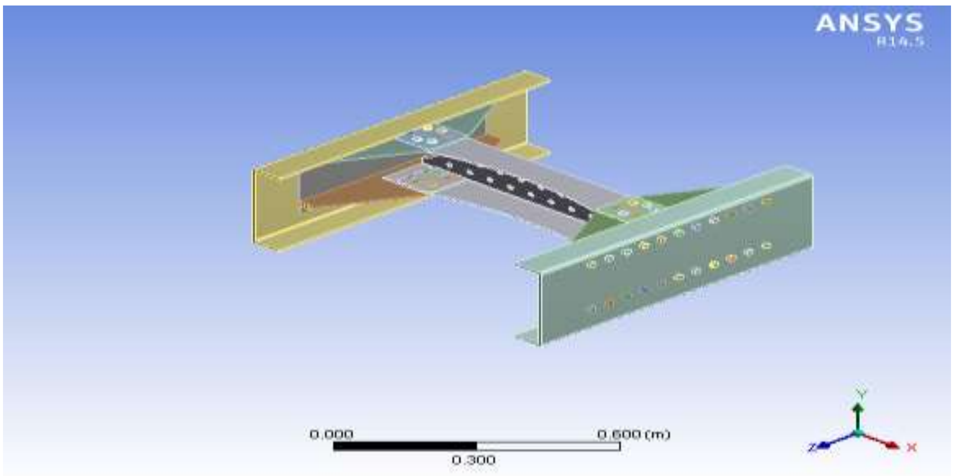
Modeling of the chassis is done in CATIAV5R19 and imported to ANSYS14.5 work bench total 125 parts and 125Bodies are considered shown below in the *Figure.3.7.2.2*



Figuer.3.7.2.2.Imported model of modified chassis in ANSYS14.5.

Geometry

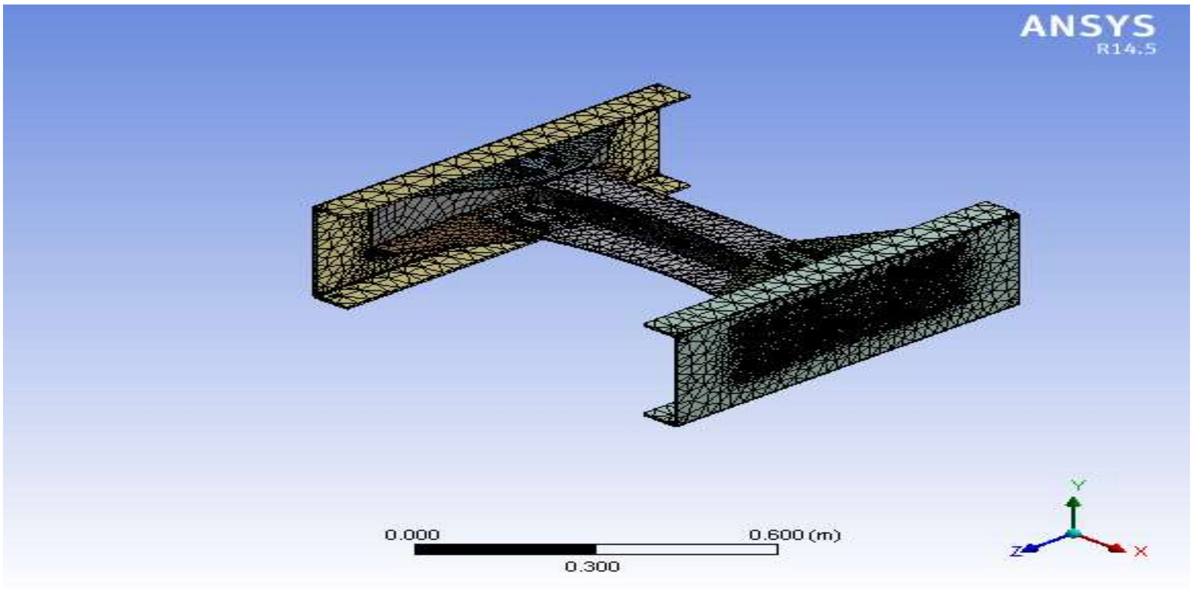
The model is imported and generated Geometry in ANSYS14.5 workbench shown below in *figure.3.7.2.3.*



Figuer.3.7.2.3. Generated modified Geometry in ANSYS14.5 workbench

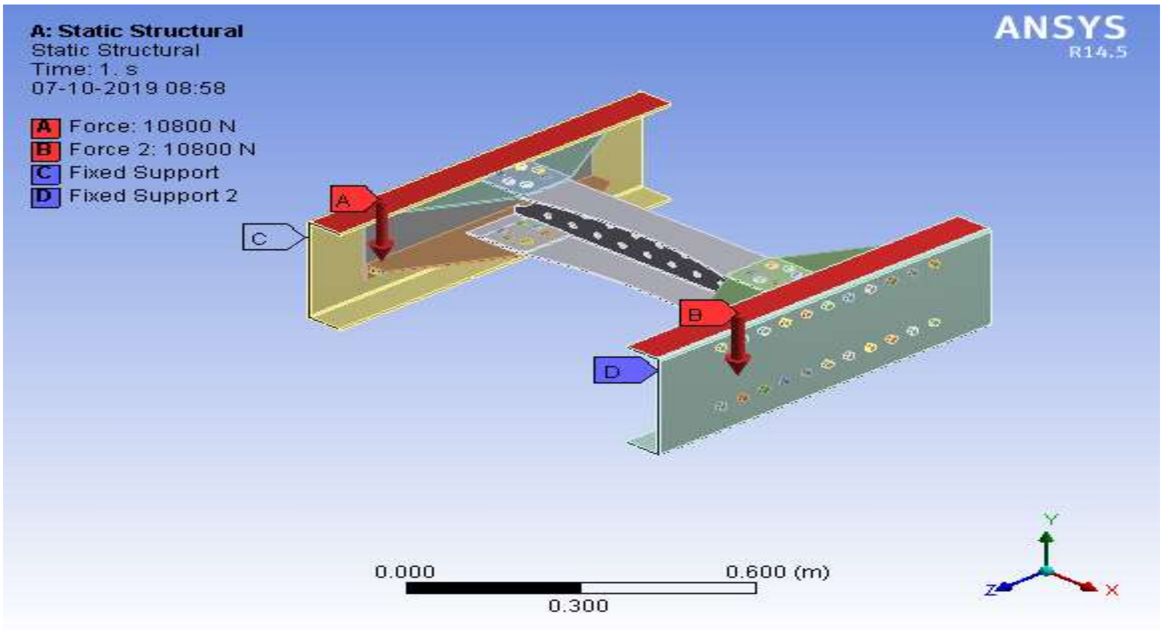
Mesh

Medium element size mesh option used to generate mesh with 492526 nodes and 211552number of elements sown below in *figure3.7.2.4.*



Figuer.3.7.2.4. meshed model of existing chassis.

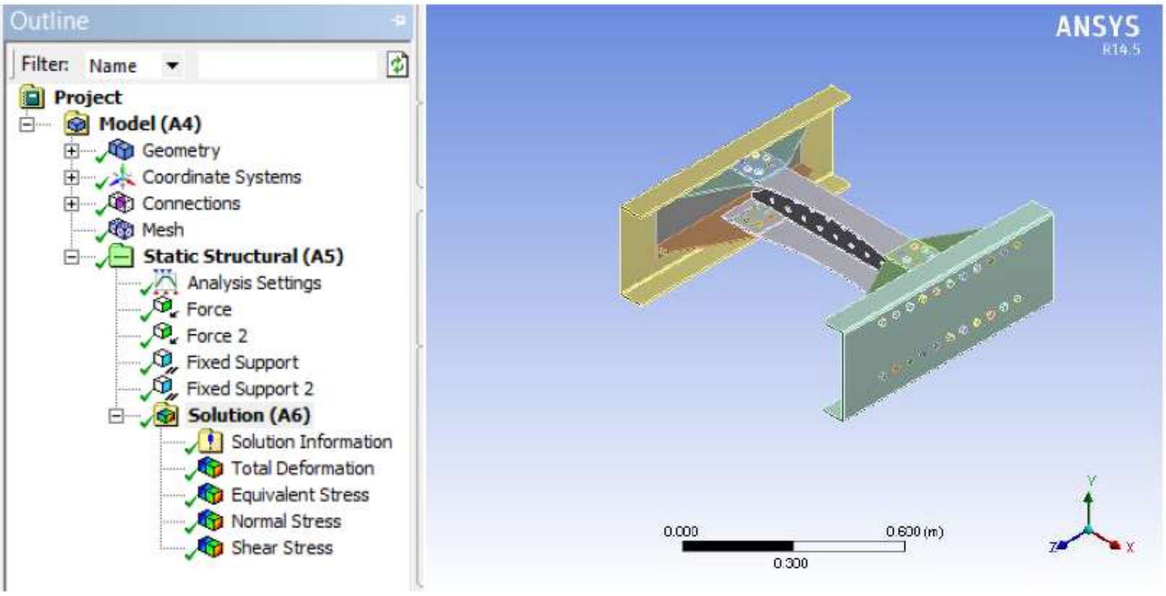
Apply Load and Constraints



Figuer.3.7.2.5. Load and fixed support of chassis.

Generating Solution

The modified chassis solution is generated from above input parameters. Equivalent (Von Misses) stress, total deformation; normal stress and shear stress are the basic variables to be solved using ANSYS14.5 software analysis.



Figuer.3.7.2.6. 3D- modeling Assembly with stiffener plate thickness-5mm using CATIAV5R19

CHAPTER-FOUR

RESULT AND DISCUSSION

In this chapter the results of both existing and modified chassis obtained from the static structural analysis of equivalent (Von Misses) stress, total deformation and calculated weight at different stiffener plate thickness are clearly discussed, the remaining results of the analysis which means normal stress and shear stress and mass of existing and modified chassis calculated on *CATIAV5R19* are displayed and summarized in *appendix–A.* The most related literature results are briefly discussed to validate and to select optimized Equivalent stress and deformation results of the modified chassis on *Appendix-A* and analytical and Finite Element analysis of *ANSYS14.5* results of normal stress and deformation at point *–E of figure 3.3.1of* existing chassis is compared at *appendix–A, Table A.6.8.*

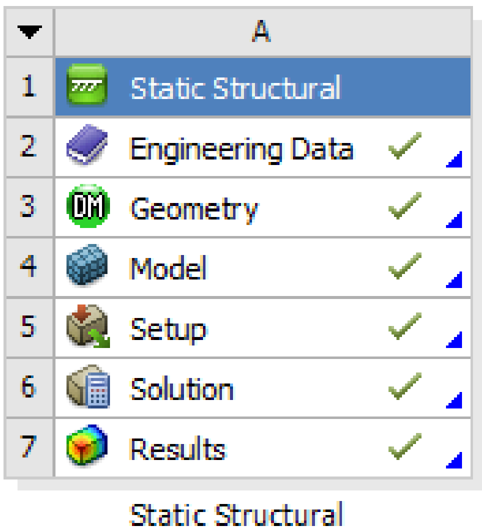


Figure.4. ANSYS 14.5 Workbench static structural analysis system

4.1. Results

4.1.1. Equivalent (Von-Misses) Stress existing chassis

The Equivalent (Von Misses) stress values of existing chassis as the result shown in *figure 4.1.1.1* the maximum equivalent stress value is 190Mpa and weight of the chassis from *CATIA V5R19* model of existing chassis assembly from *Appendix-A Figure.A.3.2. is 72.69kg.*

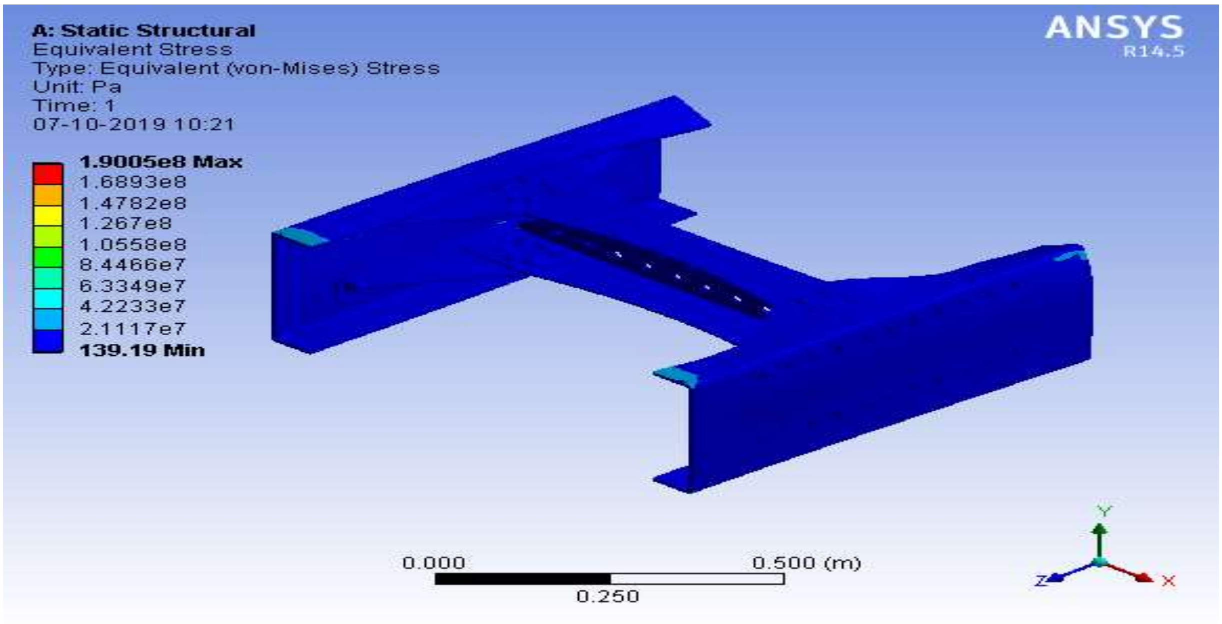


Figure.4.1.1.1 Equivalent (Von-Misses) Stress of Existing chassis

4.1.2 .Equivalent (Von-Misses) Stress Modified Chassis

- **Equivalent (Von-Misses) Stress result modified chassis with stiffener Plate thickness (t1=3mm and t2=5mm)**

The Equivalent (Von Misses) stress result shown below in *figure 4.1.2.1* the maximum equivalent stress is 119.8Mpa. Then, the equivalent stress is reduced to 36.9% and 7kg of stiffeners are added to existing chassis then the total weight is79.95 kg .so, weight is increase 9%.(Calculated weight from *Appendix-A Figure.A.4.2*)

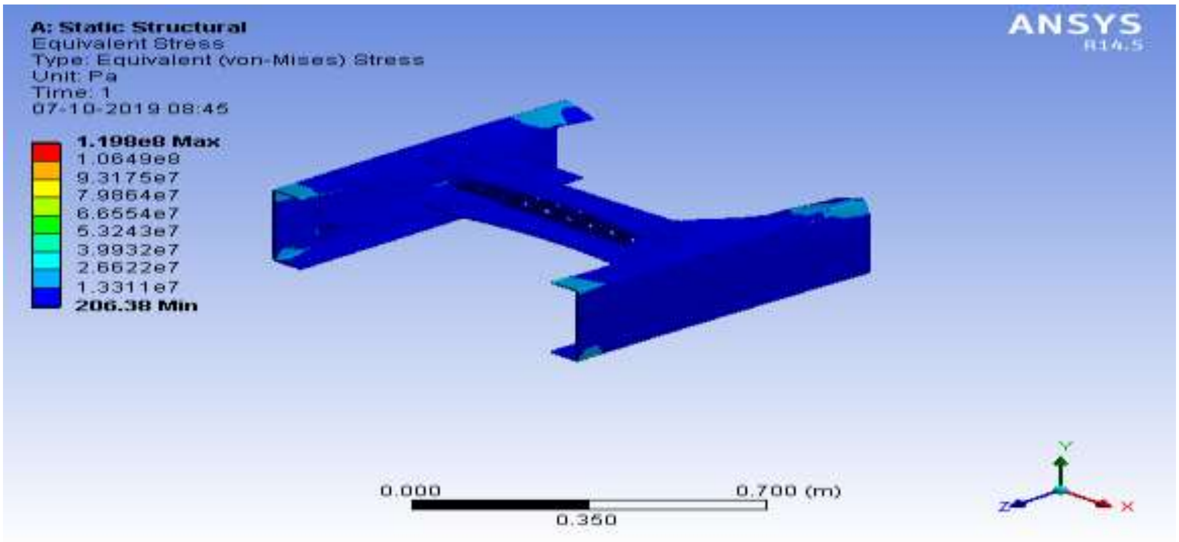


Figure.4.1.2.1.Equivalent (Von-Misses) of Stress modified chassis at stiffener plate (t1=3mm and t2=5mm)

- **Equivalent (Von-Misses) Stress result modified chassis with stiffener Plate thickness (t1=5mm and t2=5mm)**

Equivalent (Von Misses) stress result shown below in *figure 4.2.1.2*. The maximum equivalent stress is 91.3Mpa. Then, the equivalent stress is reduced to 51.9% and 13kg of stiffeners are added to existing chassis then the total weight is 83.9kg .so, weight is increase to 13.3 %.(calculated weights from *Appendix-A Figure.A.4.3*)

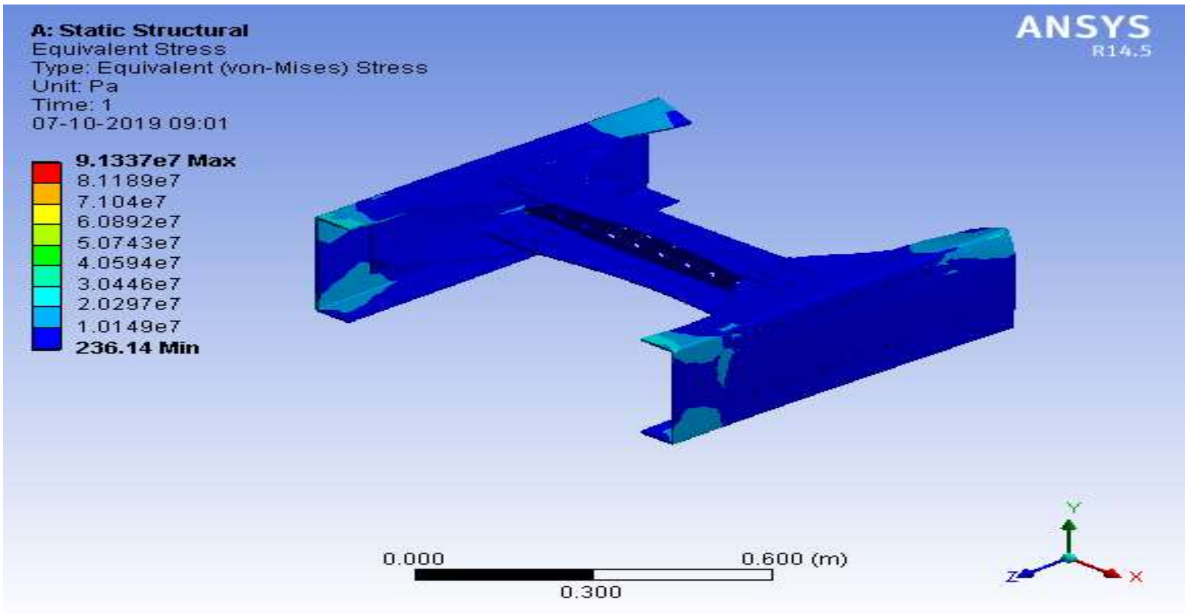


Figure.4.1.2.2.Equivalent (Von-Misses) Stress of modified chassis at stiffener plate (t1=5mm and t2=5mm)

- **Equivalent (Von-Misses) Stress result modified chassis with stiffener Plate thickness (t1=6mm and t2=5mm)**

The Equivalent (Von Misses) stress result shown in *figure 4.2.1. 3*. The maximum equivalent stress is 88.38Mpa. Then, the equivalent stress is reduced to 53.5% and 13.08kg of stiffeners are added to existing chassis then the total weight is 85.77kg .so, weight is increase to 15%.(calculated weights from *Appendix-A Figure.A.4.4*)

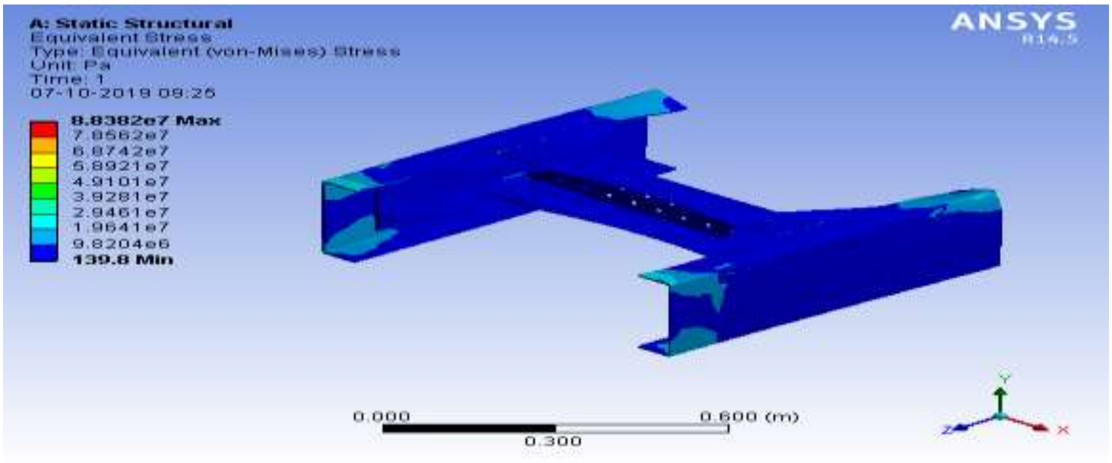


Figure.4.1.2.3 Equivalent (Von-Misses) Stress of modified chassis at stiffener plate (t1=6mm and t2=5mm)

- **Equivalent (Von-Misses) Stress result modified chassis with stiffener Plate thickness (t1=7mm and t2=5mm)**

The Equivalent (Von Misses) stress result shown in *figure 4.2.1. 4*. The maximum equivalent stress is 85.8Mpa. Then, the equivalent stress is reduced to 54.8% and 14.96kg of stiffeners are added to existing chassis then the total weight is 87.65kg .so, weight is increase to 17%.

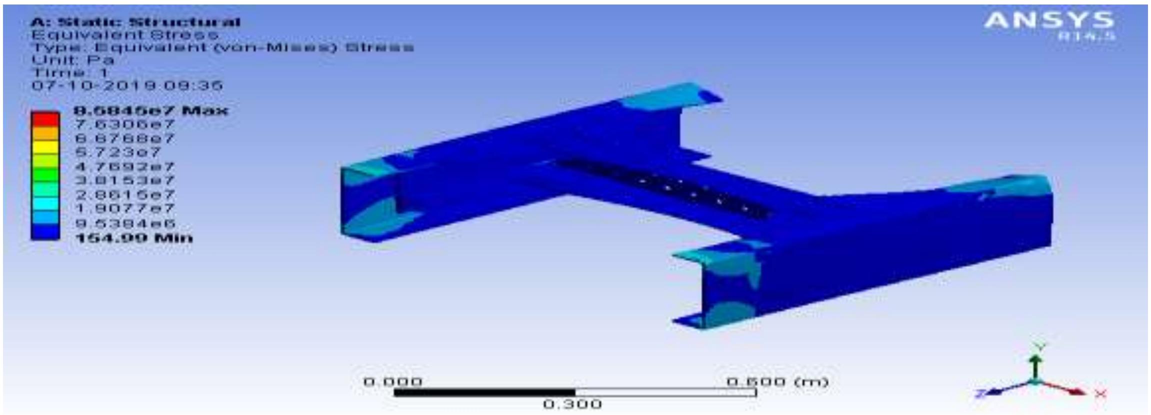


Figure.4.1.2.4 Equivalent (Von-Misses) Stress of modified chassis at stiffener plate (t1=6mm and t2=5mm)

- **Equivalent (Von-Misses) Stress result modified chassis with stiffener Plate thickness (t1=7mm and t2=5mm)**

The Equivalent (Von Misses) stress result shown in *figure 4.2.1. 5*. The maximum equivalent stress is 77.6Mpa. Then, the equivalent stress is reduced to 59% and 16.8kg of stiffeners are added to existing chassis then the total weight is 89.52kg .so, weight is increase to 18.8%.

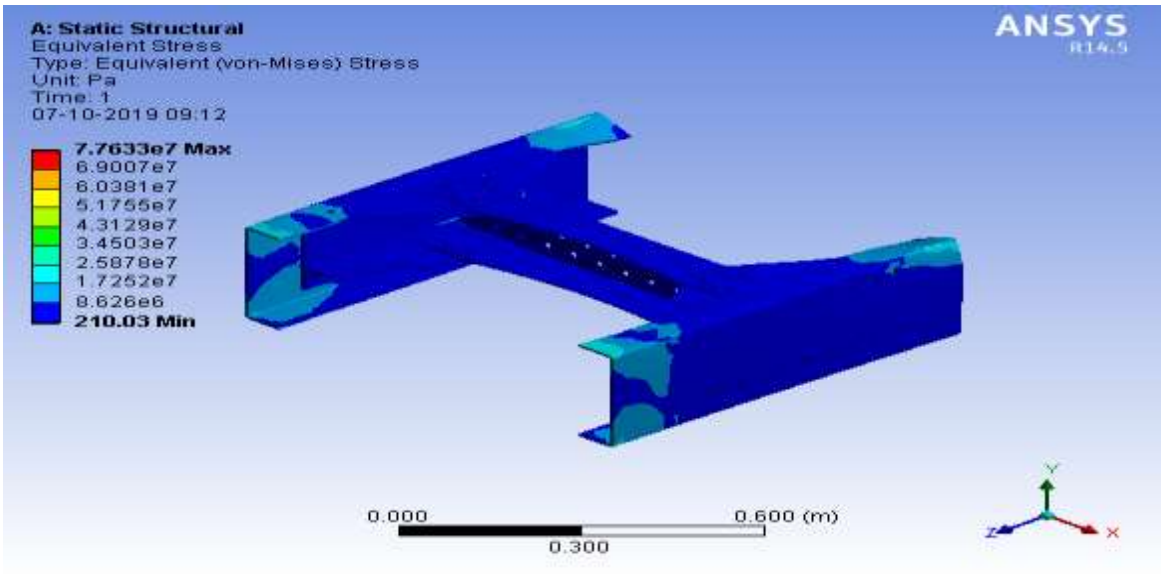


Figure.4.1.2.5 Equivalent (Von-Misses) Stress of modified chassis at stiffener plate (t1=8mm and t2=5mm)

4.1.3. Total Deformation of Existing Chassis.

The total deformation of existing chassis result shown in *figure 4.1.3.1*.the value of total deformation is 0.34mm.

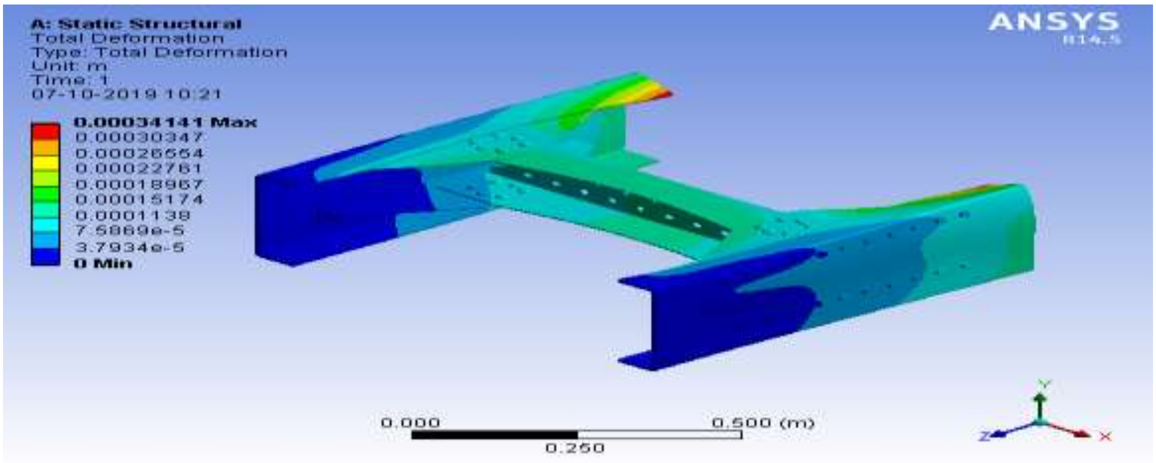


Figure.4.1.3.1. Total deformation of Existing chassis

4.1.4. Total Deformation of Modified Chassis.

- **Total Deformation result of modified chassis with stiffener Plate thickness (t1=3mm and t2=5mm)**

The total deformation result shown in *figure 4.1.4.1.* The value of total deformation is 0.30mm then, the total deformation is reduced to 11.8%.

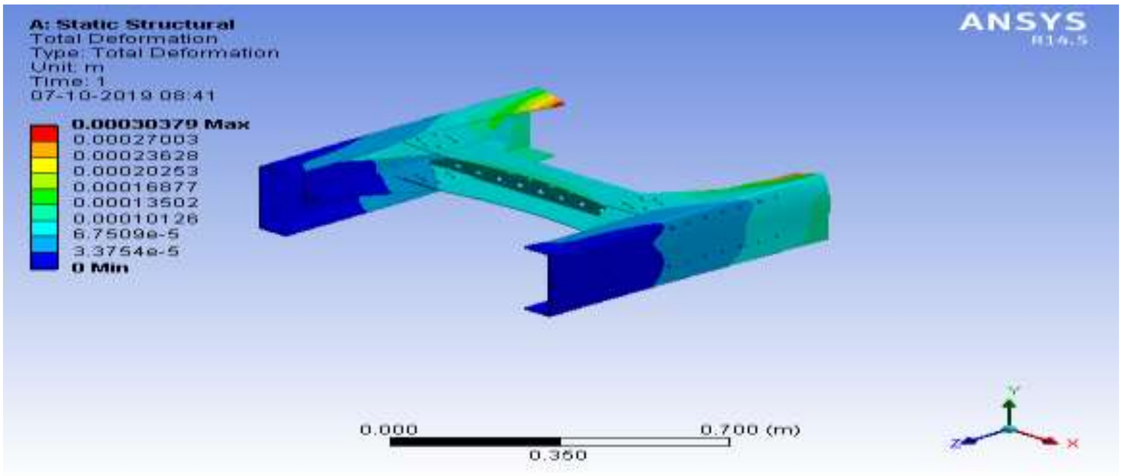


Figure.4.1.4.1. Total deformation of modified chassis at stiffener plate (t1=3mm and t2=5mm)

- **Total Deformation result of modified chassis with stiffener Plate thickness (t1=5mm and t2=5mm)**

The total deformation result shown in *figure 4.1.4.2.* The value of Total deformation is 0.29mm then, the total deformation is reduced to 14.7%.

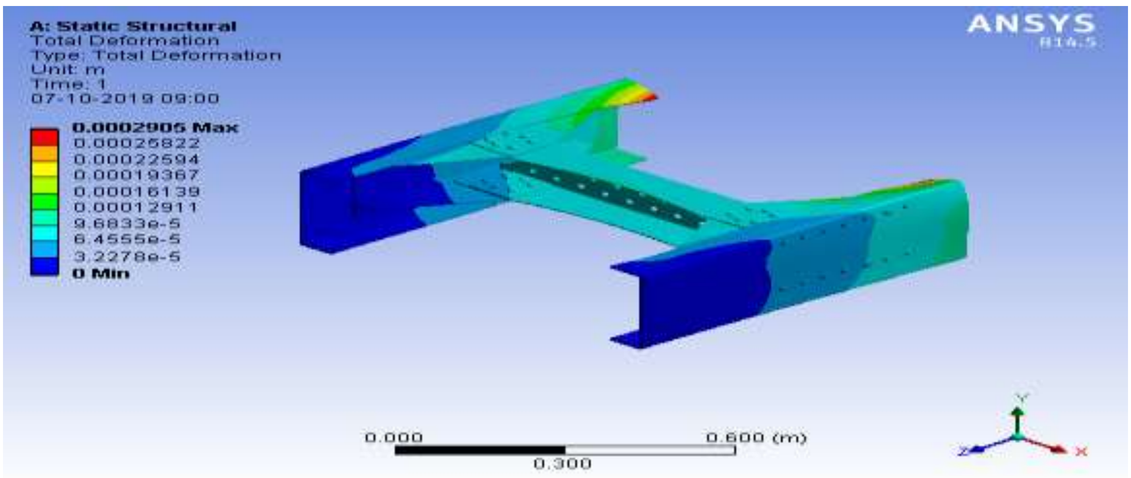


Figure.4.1.4.2. Total deformation of modified chassis at stiffener plate (t1=5mm and t2=5mm)

- **Total Deformation result of modified chassis with stiffener Plate thickness (t1=6mm and t2=5mm)**

The total deformation result shown in figure 4.1.4.3. The value of Total deformation is 0.28mm then, the total deformation is reduced to 17.6%.

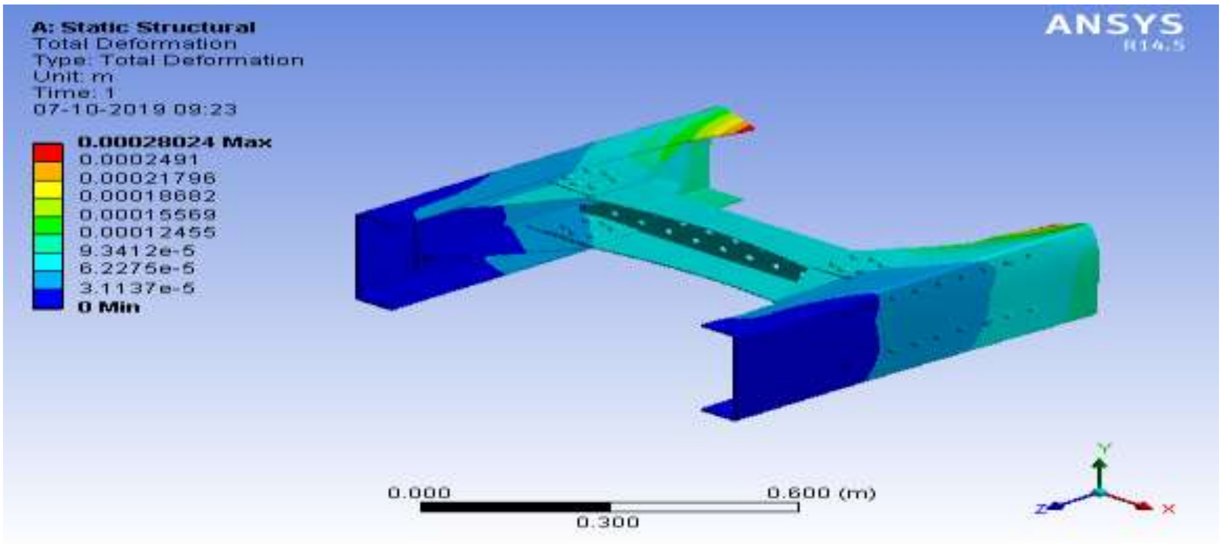


Figure.4.1.4.3. Total deformation of modified chassis at stiffener plate (t1=6mm and t2=5mm)

- **Total Deformation result of modified chassis with stiffener Plate thickness (t1=7mm and t2=5mm)**

The total deformation result shown in figure 4.1.4.4. The value of Total deformation is 0.27mm then, the total deformation is reduced to 20.6%.

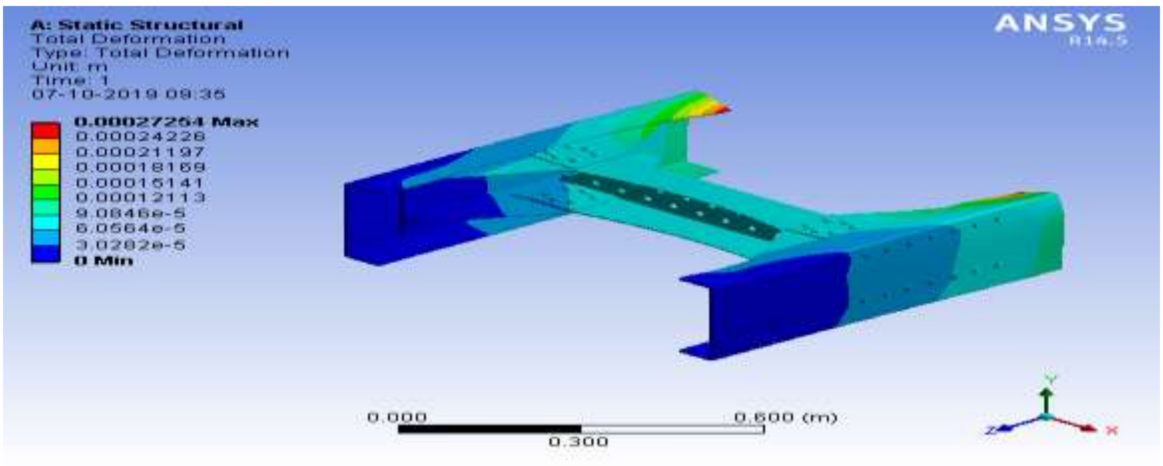


Figure.4.1.4.4. Total deformation of modified chassis at stiffener plate (t1=7mm and t2=5mm)

❖ **Total Deformation result of modified chassis with stiffener Plate thickness (t1=8mm and t2=5mm)**

The total deformation result shown in figure 4.1.4.5. The value of Total deformation is 0.266mm then, the total deformation is reduced to 21.8%.

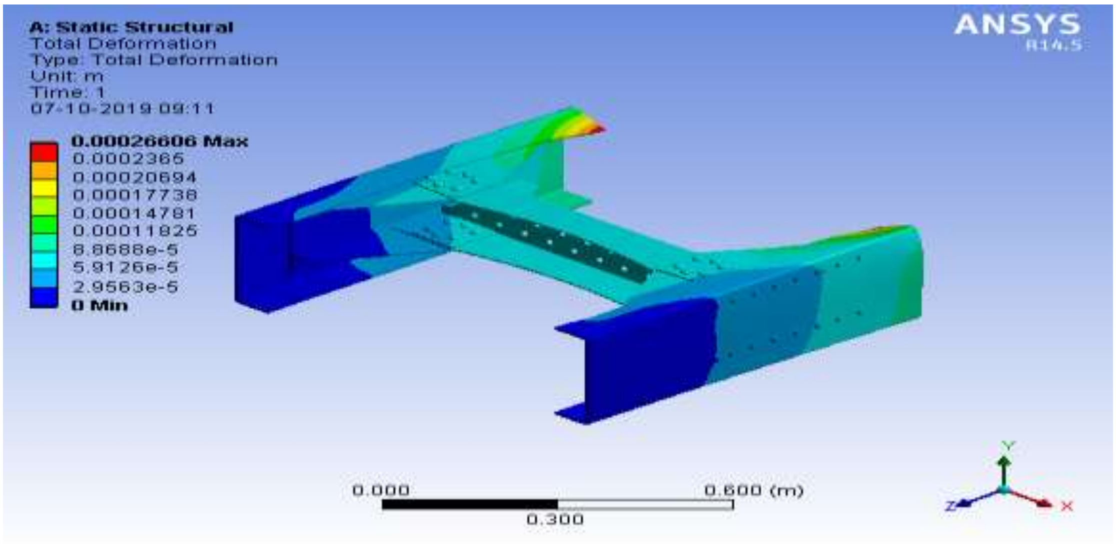


Figure.4.1.4.5. Total deformation of modified chassis at stiffener plate (t1=8mm and t2=5mm)

4.2. Discussion

4.2.1 Equivalent (Von-Misses) Stress, Deformation and weight.

Using ANSYS 14.5 Workbench software, the values of equivalent (Von-Misses) stress and the maximum total deformation found along existing and modified chassis by considering of the same given boundary conditions and applied load of 10800N. The maximum Equivalent (Von-Misses) stresses, Deformation and weight of existing and modified chassis are summarized in *Table.4.2.1.1 and Table.4.2.1.2* below.

T he static structural Finite Element analysis of modified chassis result shows that the equivalent (Von-Misses) stress is reduced (36.9%-59 %.), the maximum displacement reduced from (11.8%-21.8%) and weight of modified chassis is increased (9%-18.8%), when the stiffener plate thickness is varied (3-8) mm.

So, stress optimization using reinforcement technique is the main goal of the research and during optimization weight of chassis is increased. But, due to weight increment carrying capacity or, loading condition and stiffness of modified chassis is increased to some extent [23].

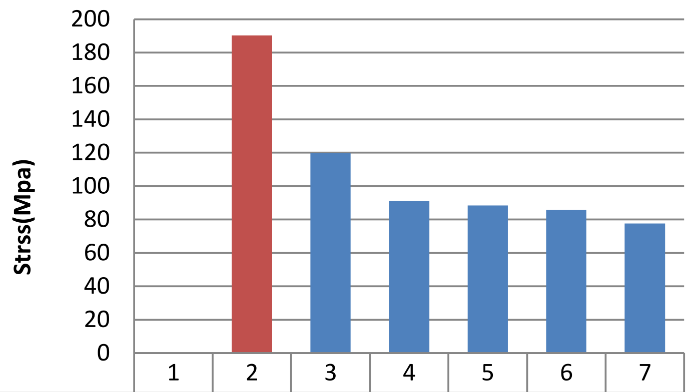
Table.4.2.1.1. Summarized Finite Element analysis results of ANSYS14.5.

Sr.No	Type	Max. Von-Miss Stress (Mpa)	Total Deformation (mm)	Weight (Kg)	Stress reduced (%)	Deformation reduced (%)	Weight increased (%)
1	Existing Chassis	190	0.340	72.69	------	------	-----
2	Modified chassis with Stiffener thickness (t_1=3mm and t_2=5mm).	119.8	0.300	79.95	36.9%	11.8%	9%
3	Modified chassis with Stiffener thickness (t_1=5mm and t_2=5mm).	91.3	0.290	83.90	51.9%	14.7%	13.3%
4	Modified chassis with Stiffener thickness (t_1=6mm and t_2= 5mm).	88.38	0.280	85.77	53.5%	17.6%	15%
5	Modified chassis with Stiffener thickness (t_1=7mm and t_2=5mm).	85.8	0.270	87.65	54.8%	20.6%	17%
6	Modified chassis with Stiffener thickness (t_1=8mm and t_2 =5mm).	77.6	0.266	89.52	59.0%	21.8%	18.8%

4.3. Result Comparison

4.3.1. Comparison of equivalent stress

The Von-miss stress is linearly decreased due to the stiffener plate thickness increased shown below *Figure 4.3.1.1.and Figure 4.3.1.2.*



	1	2	3	4	5	6	7
Von-Miss Stress in (Mpa) - Existing Chssis		190					
Von-Miss Stress in (Mpa)- Modified Chassis			119.8	91.3	88.38	85.8	77.6

Figure 4.3.1.1.comparison of equivalent stress existing and modified chassis.

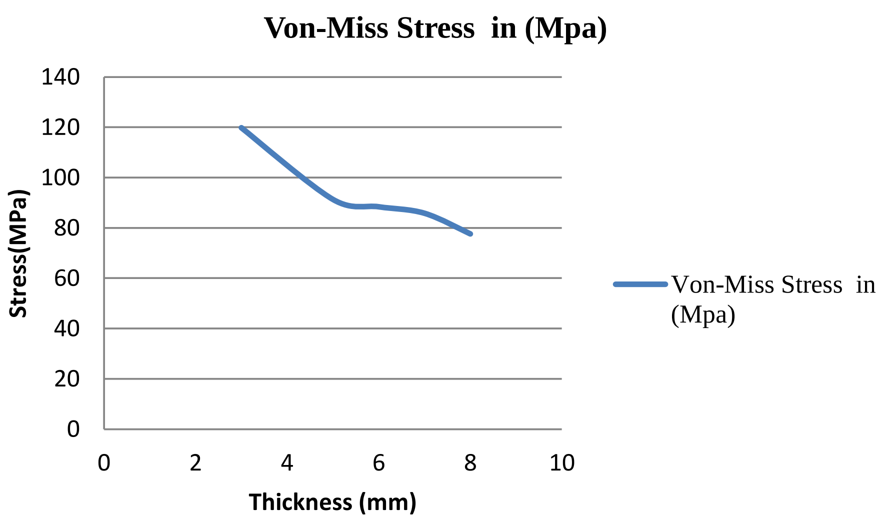


Figure 4.3.1.2.equivalent stress vs thickness.

4.3.2. Comparison of Deformation

The deformation is linearly decreased due to the stiffener plate thickness increased shown below *Figure 4.3.2.1.and Figure 4.3.2.2.*

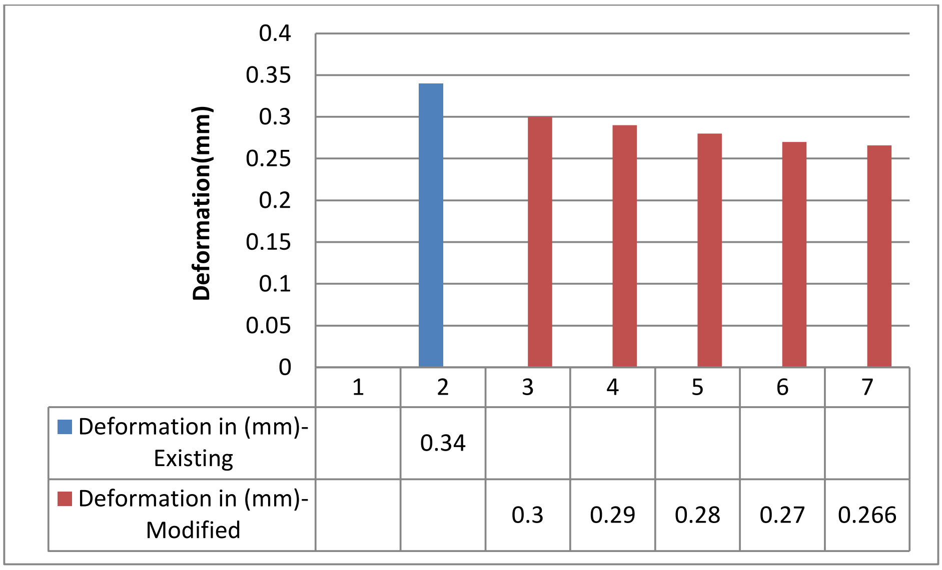


Figure 4.3.2.1.comparison of deformation existing and modified chassis.

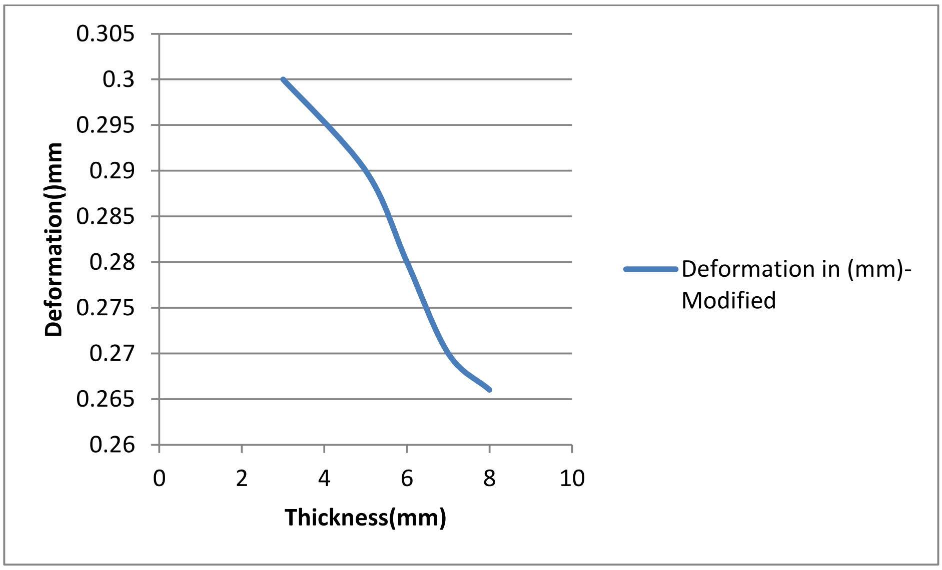


Figure 4.3.2.2. Deformation Vs thickness.

4.3.3. Comparison of Weight

The Weight is linearly decreased due to the stiffener plate thickness increased shown below *Figure 4.3.3.1.and Figure 4.3.3.2.*

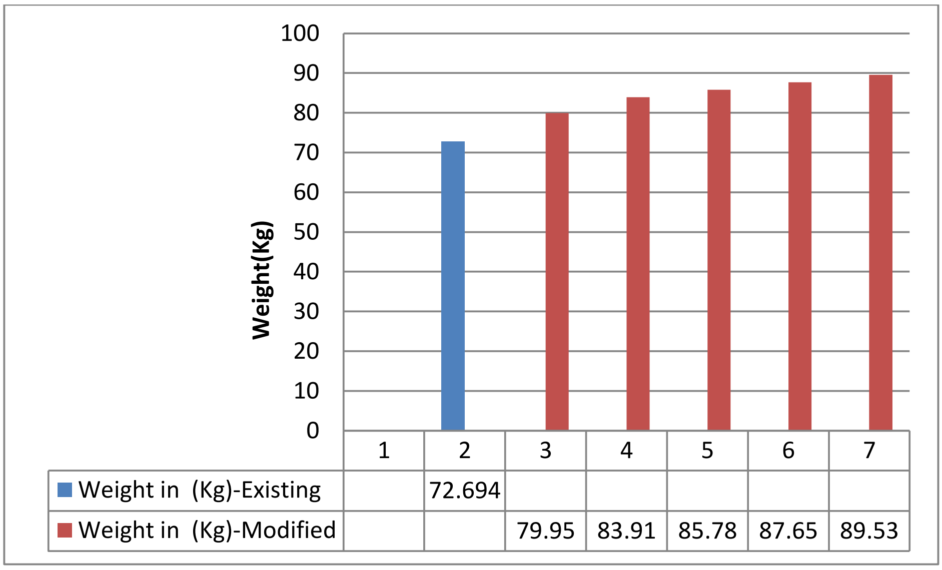


Figure 4.3.3.1.comparison of weight existing and modified chassis.

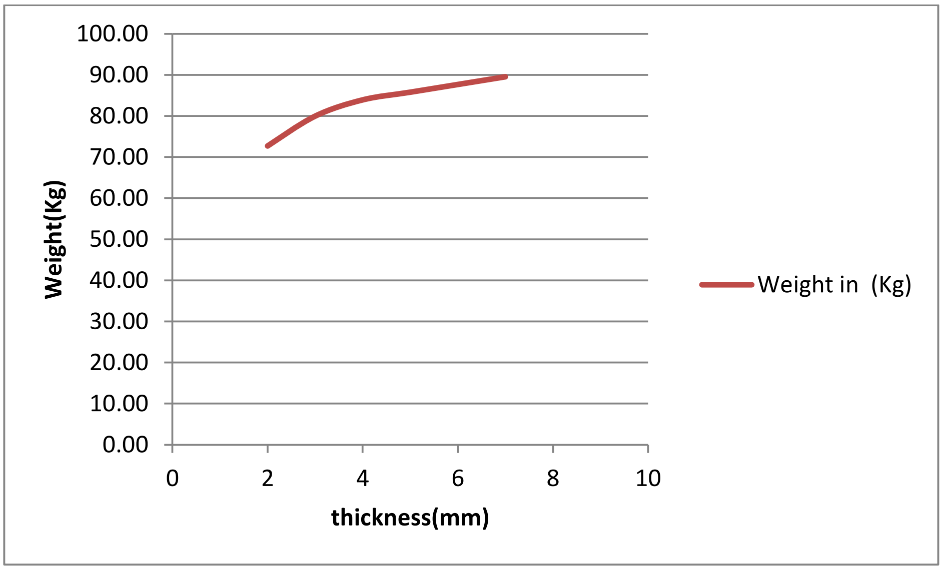


Figure 4.3.3.2.comparison of weight vs Thickness.

CHAPTER-FIVE

CONCLUSION AND RECOMMENDATION

5.1.CONCLUSION

In this thesis, finite element analysis of existing and modified truck chassis carried out and the following results are achieved.

Table.5.1.1. Summarized Finite Element analysis results of ANSYS14.5.

Sr.No	Type	Max. Von-Miss Stress (Mpa)	Total Deformation (mm)	Weight (Kg)	Stress reduced (%)	Deformation reduced (%)	Weight increased (%)
1	Existing Chassis	190	0.340	72.69	------	------	-----
2	Modified chassis with Stiffener thickness (t_1=3mm and t_2=5mm).	119.8	0.300	79.95	36.9%	11.8%	9%
3	Modified chassis with Stiffener thickness (t_1=5mm and t_2=5mm).	91.3	0.290	83.90	51.9%	14.7%	13.3%
4	Modified chassis with Stiffener thickness (t_1=6mm and t_2= 5mm).	88.38	0.280	85.77	53.5%	17.6%	15%
5	Modified chassis with Stiffener thickness (t_1=7mm and t_2=5mm).	85.8	0.270	87.65	54.8%	20.6%	17%
6	Modified chassis with Stiffener (t_1=8mm & t_2 =5mm).	77.6	0.266	89.52	59.0%	21.8%	18.8%

Then, from the finite element analysis result we conclude that, increasing stiffener plate thickness is reducing the stress and deformation of the chassis, but it's important to know that the overall weight of the chassis increases. Therefore, to prevent excessive weight of the chassis, we use optimum stiffener plate thickness to reduce the stress and deformation.

5.2.RECOMMENDATION

From ANSYS 14.5 static structural analysis results and literature reviewed. We recommend that, it's suitable to modify the existing truck chassis using stiffener plate size of 175x550x3mm between the side member and connector plate, and stiffener plate size 100x100x5mm on the top of cross member .then, equivalent stress optimized up to 36.9%, deformation optimized upto11.8%, and weight is increased up 9%. Even, if weight of the chassis increased carrying capacity of the chassis is increased [5].Recommended finite element result is validated using literature with difference less than 10% is shown in *Appendix-A table.A.6.7.*

5.3. FUTURE WORK

The following research areas are recommended for Future studies on truck chassis,

- The effect of rivet position and joints on stress of chassis.
- The effect of connector plate length on stress of chassis.
- The effect of material properties on stress of chassis.

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APPENDIX –A

A.1. ANSYS 14.5 Results of Normal and shear stress for existing chassis.

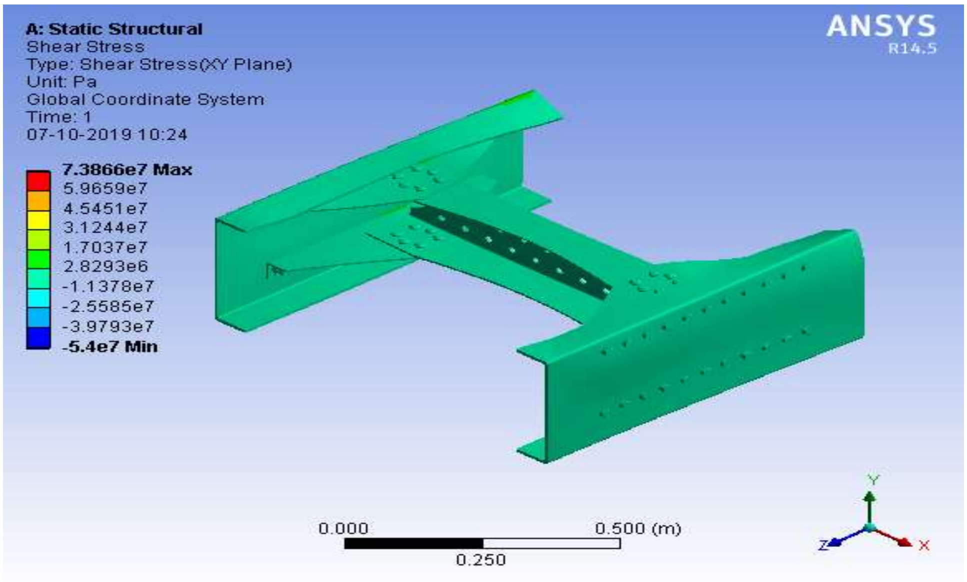

Figure.A.1.1.Shear stress result for existing chassis

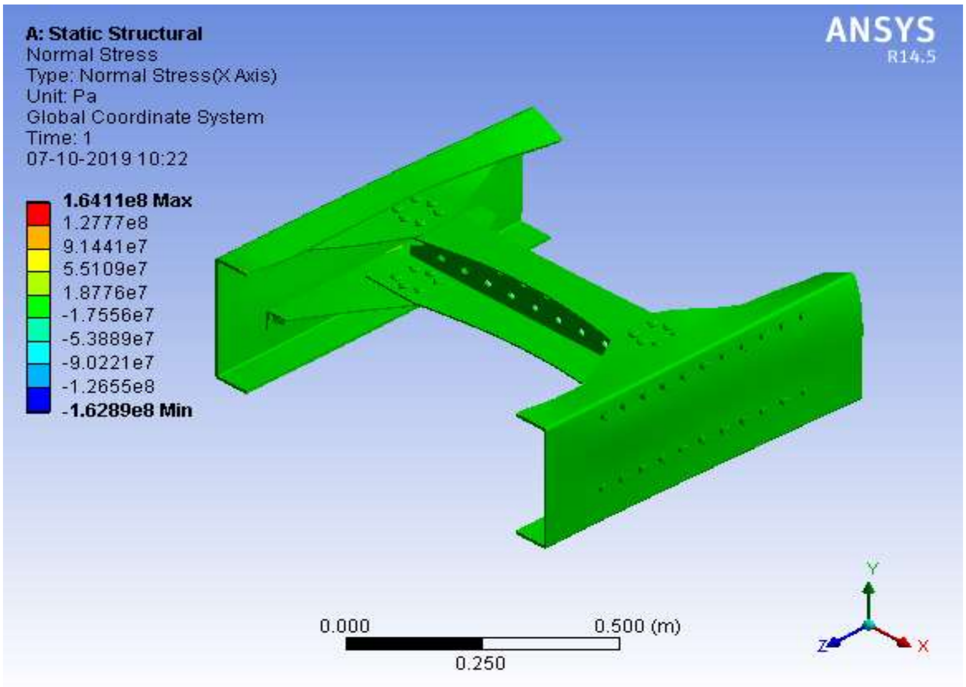

Figure.A.1.2.Normal stress result for existing chassis

A.2. ANSYS 14.5 Results of Normal and shear stress for Modified chassis.

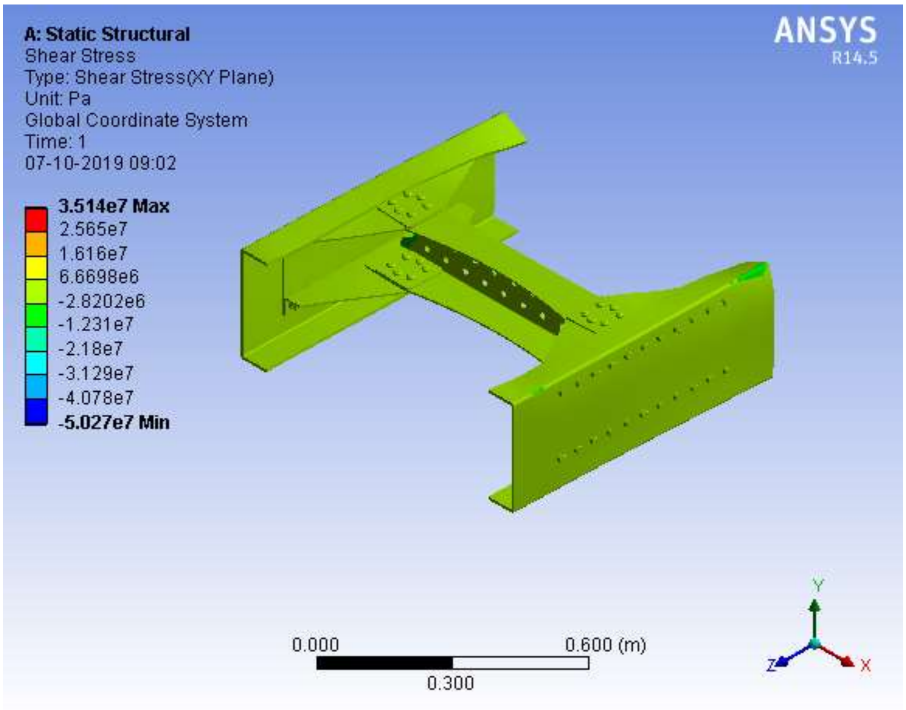

Figure.A.2.1.Shear stress result for modified chassis with stiffener plate thickness (t1=3mm and t2=5mm)

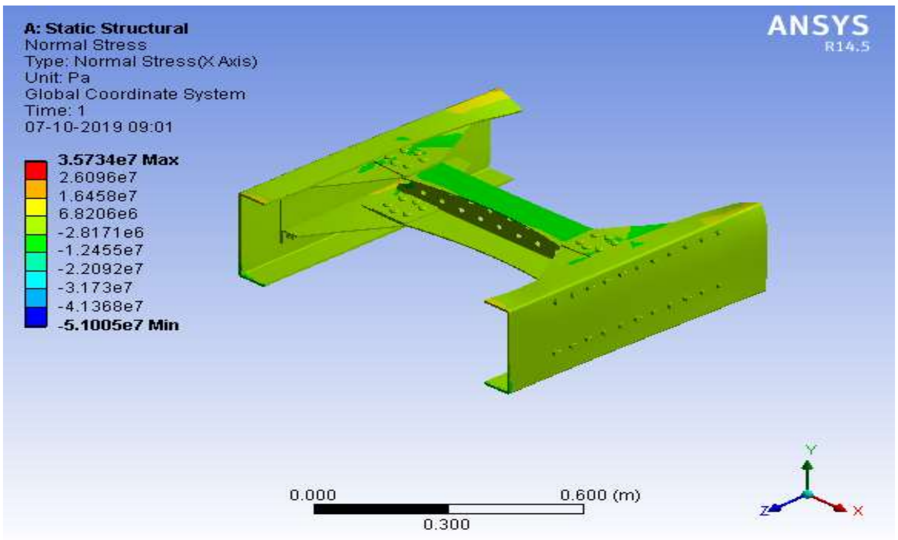

Figure.A.2.2.Normal stress result for modified chassis with stiffener plate thickness (t1=3mm and t2=5mm)

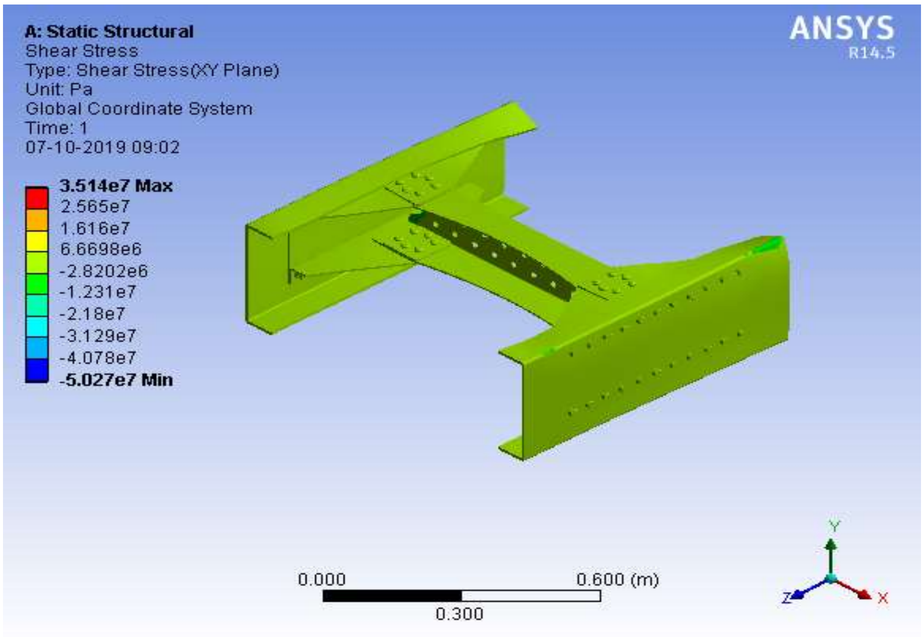

Figure.A.2.4.Shear stress result for modified chassis with stiffener plate thickness (t1=5mm and t2=5mm)

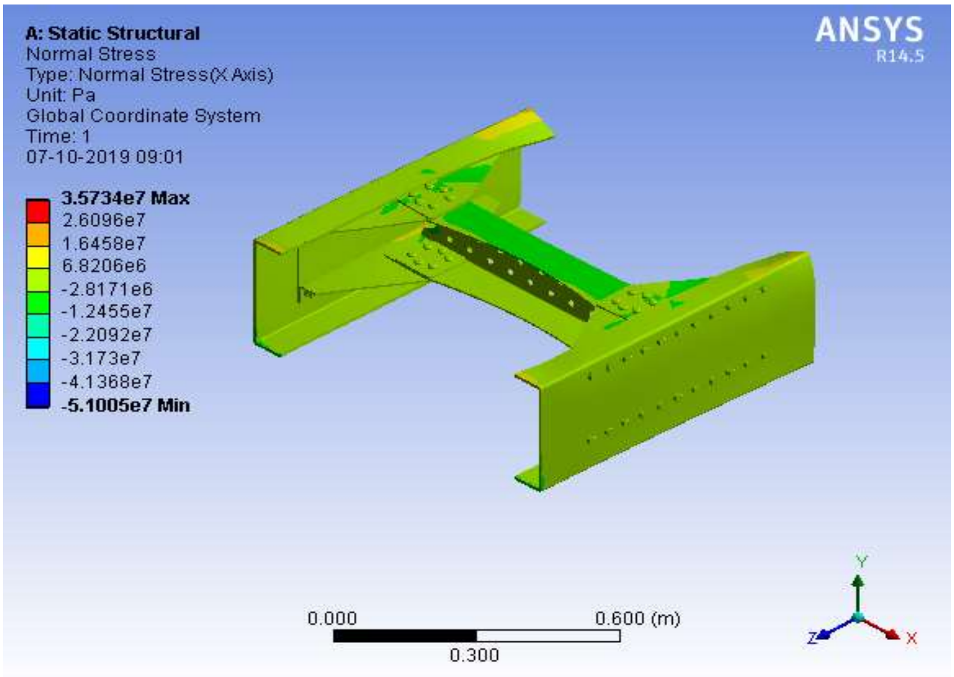

Figure.A.2.5.Normal stress result for modified chassis with stiffener plate thickness (t1=5mm and t2=5mm)

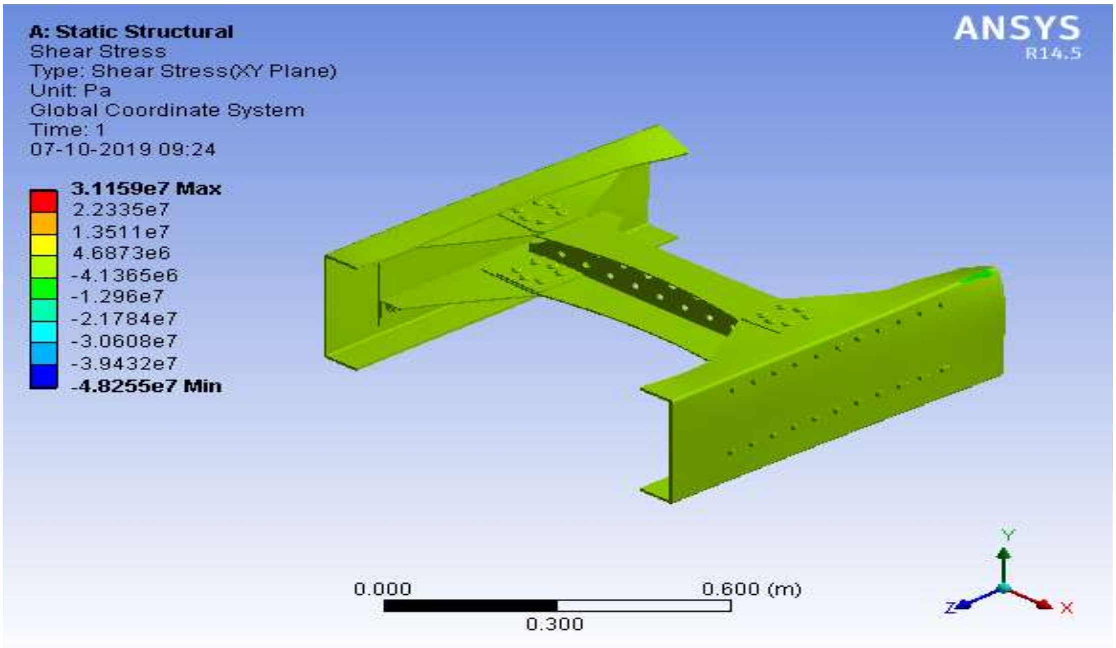

Figure.A.2.6.Shear stress result for modified chassis with stiffener plate thickness (t1=6mm and t2=5mm)

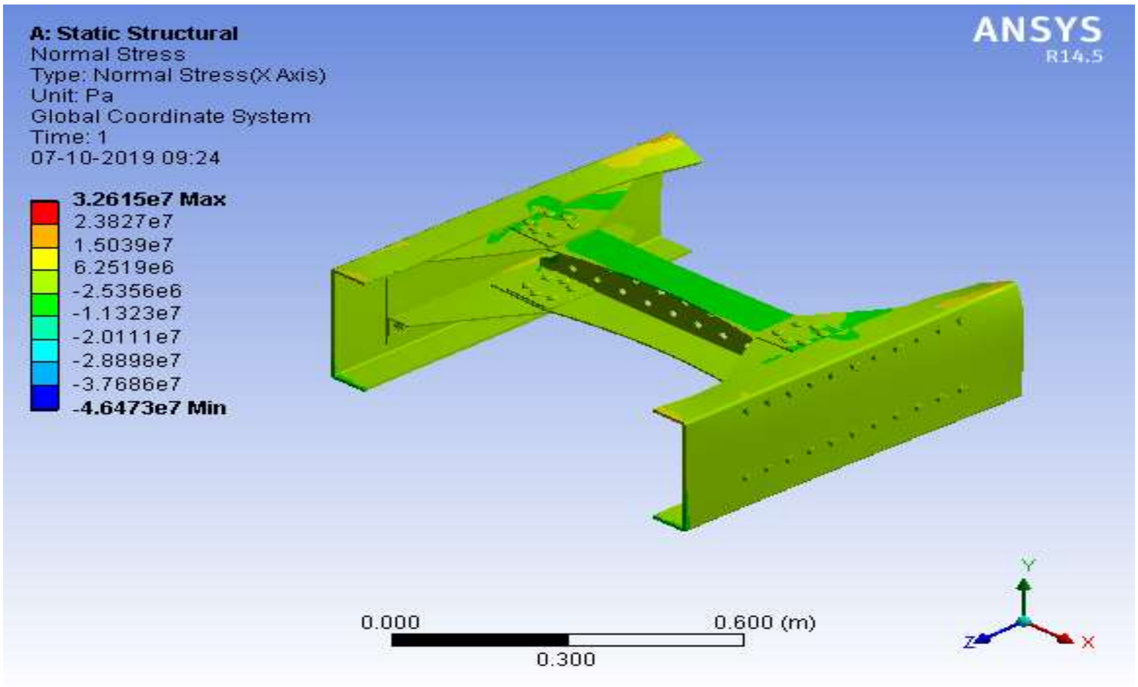

Figure.A.2.7.Normal stress result for modified chassis with stiffener plate thickness (t1=6mm and t2=5mm)

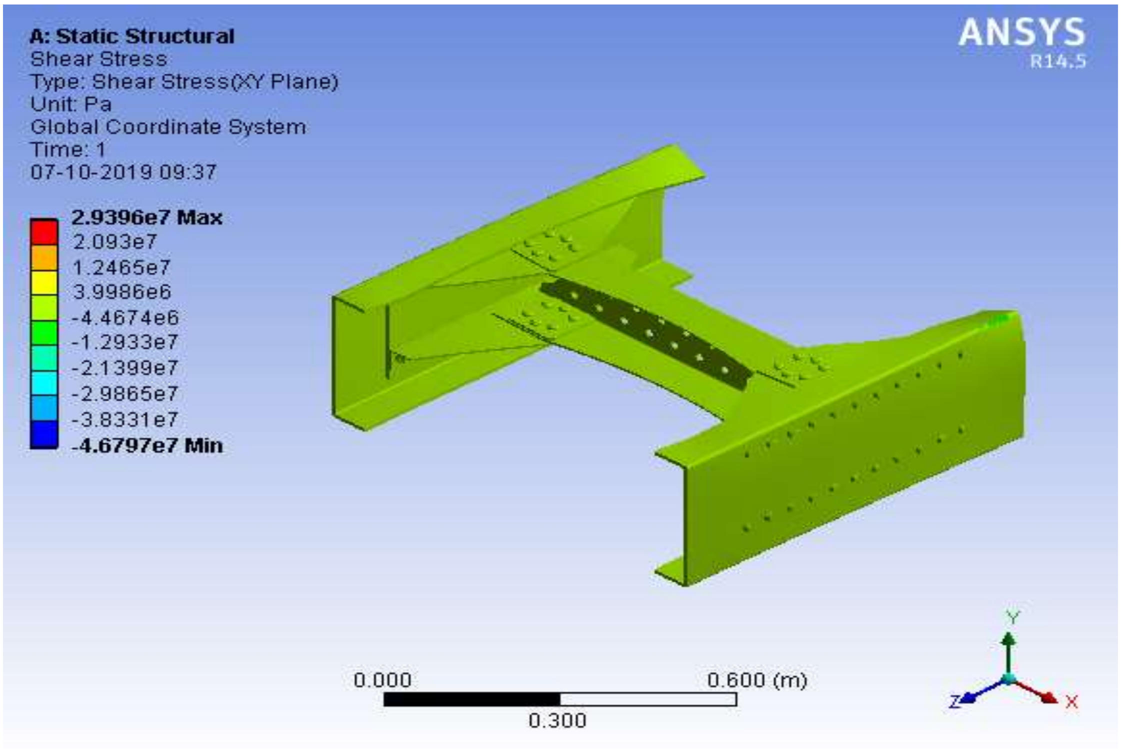

Figure.A.2.8.Shear stress result for modified chassis with stiffener plate thickness (t1=7mm and t2=5mm)

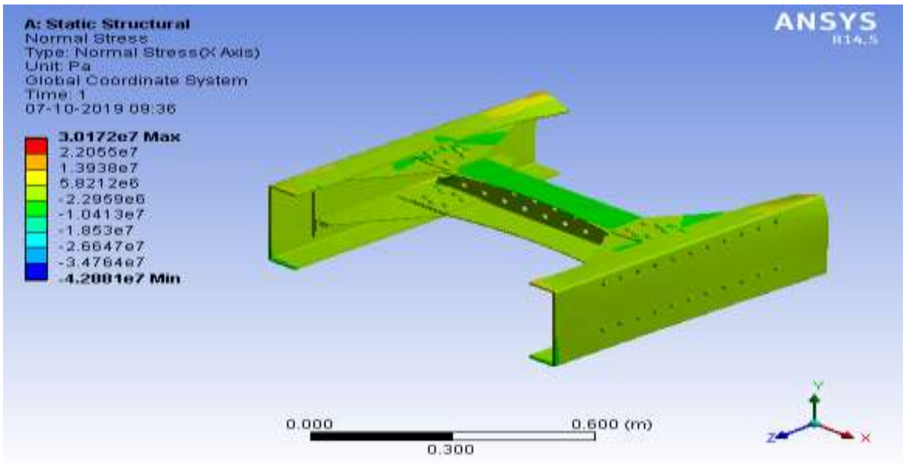

Figure.A.2.9.Normal stress result for modified chassis with stiffener plate thickness (t1=7mm and t2=5mm)

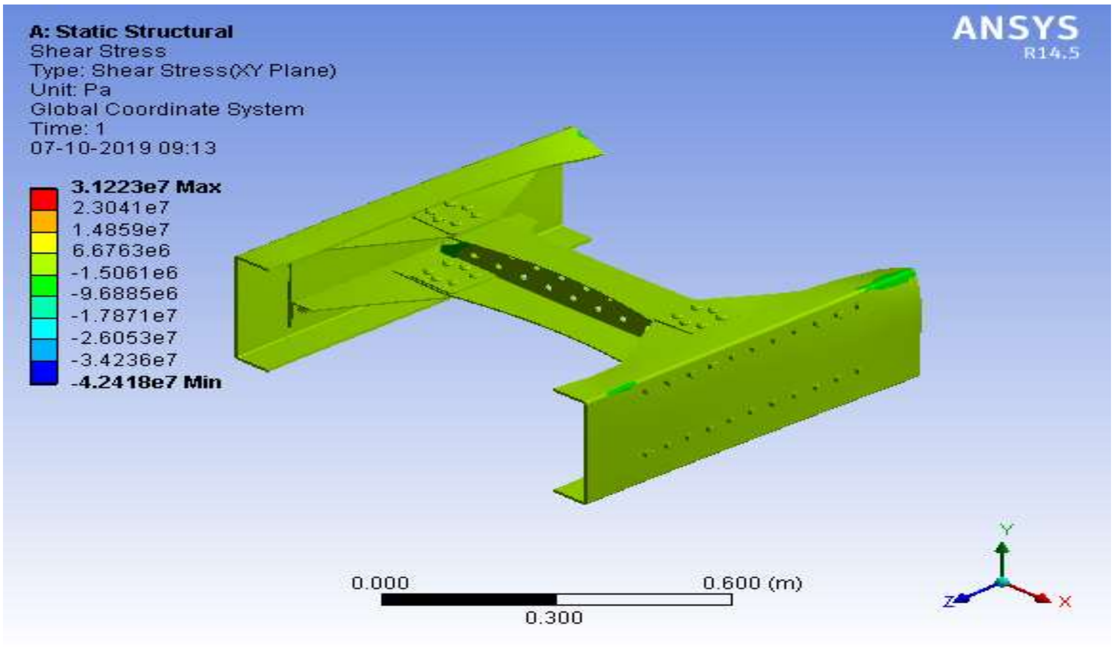

Figure.A.2.10.Shear stress result for modified chassis with stiffener plate thickness (t1=8mm and t2=5mm)

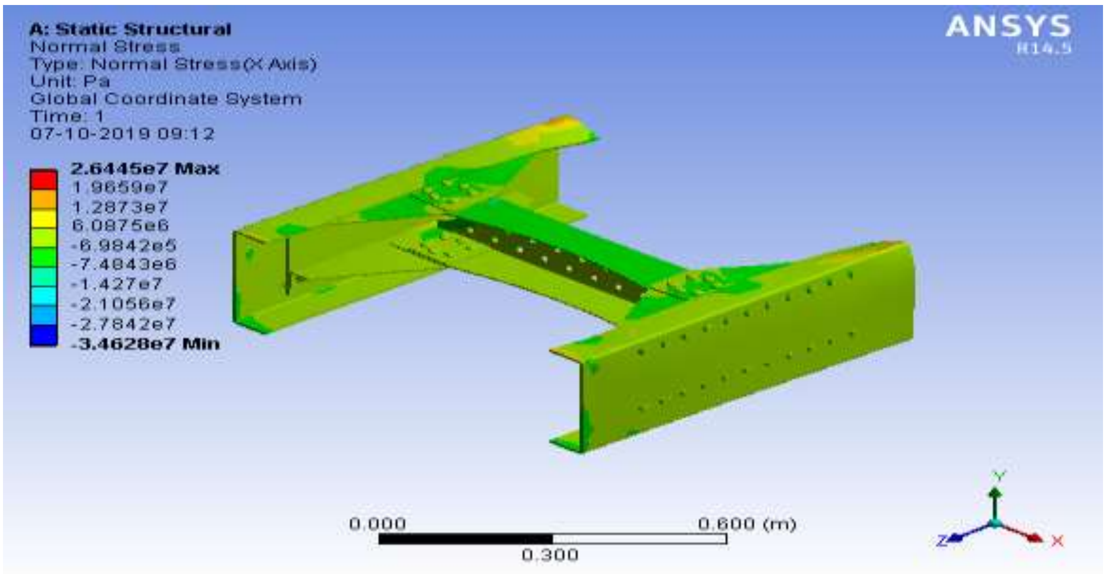

Figure.A.2.11.Normal stress result for modified chassis with stiffener plate thickness (t1=8mm and t2=5mm)

A.3.Weight Calculation of Existing Truck Chassis on CATIAV5R19

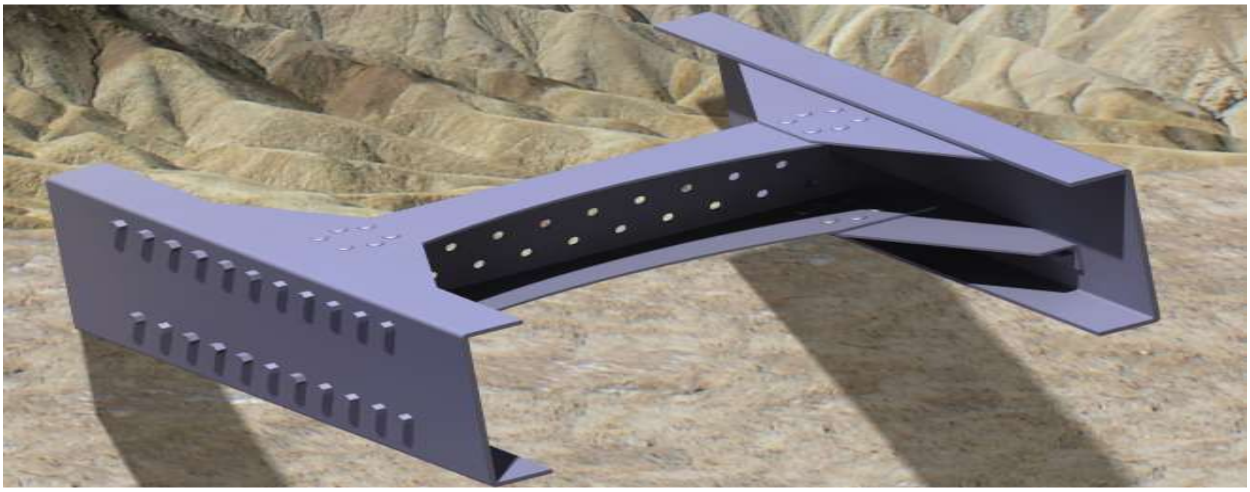

Figure. A.3.1.Modeling of Existing Truck chassis.

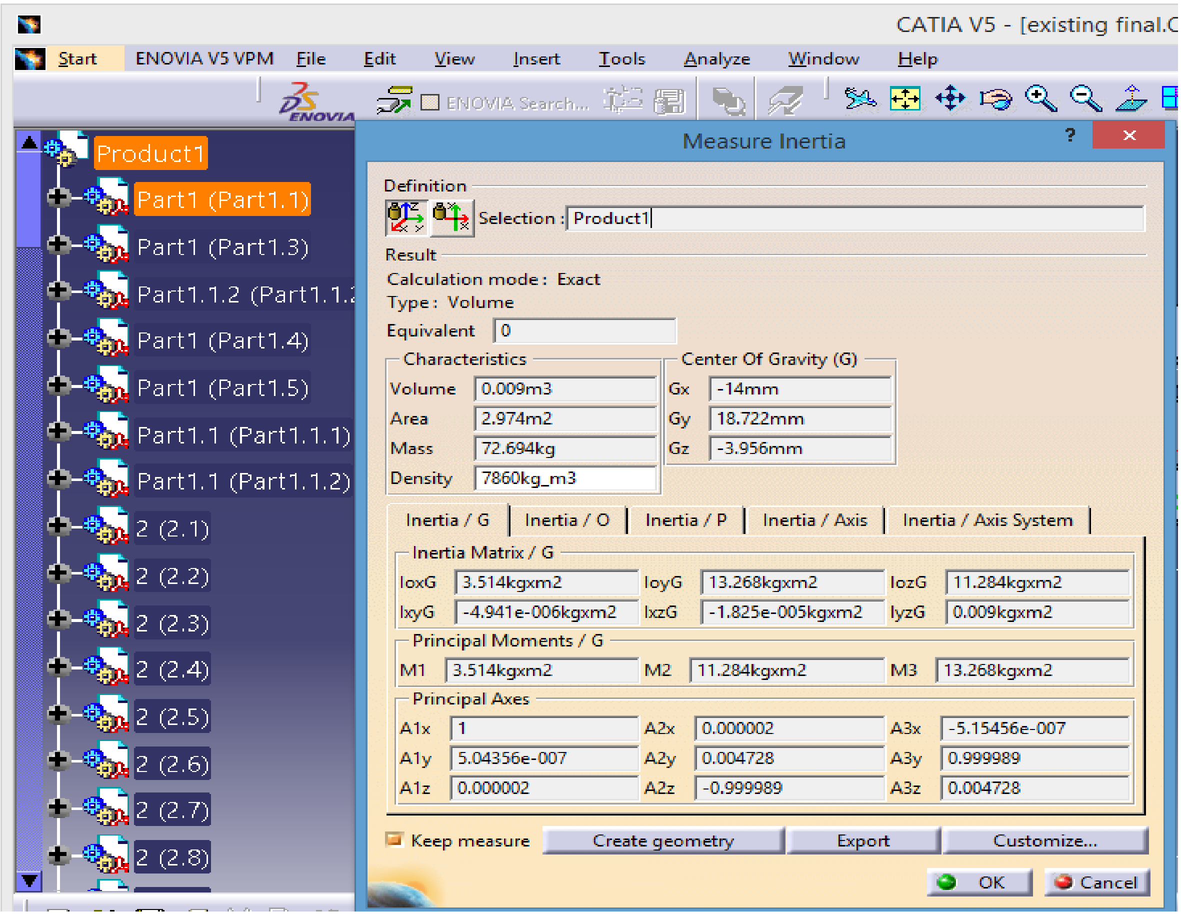

Figure.A.3.2.Calculated mass of Existing truck Chassis on CATIAV5R19.

(Mass =72.694kg)

A.4. Weight Calculation of Modified truck Chassis on CATIAV5R19

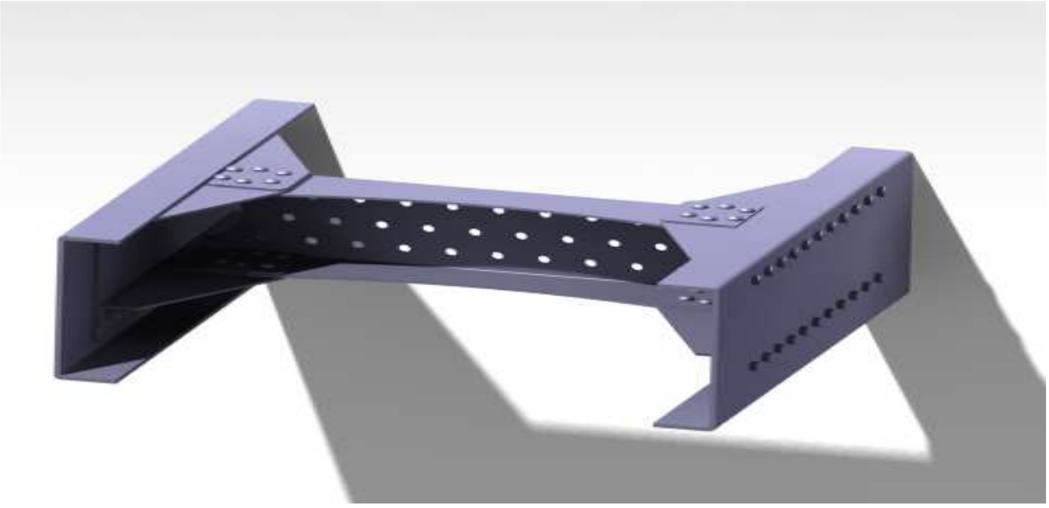

Figure.A.4.1.Modeling of Modified truck Chassis on CATIAV5R19.

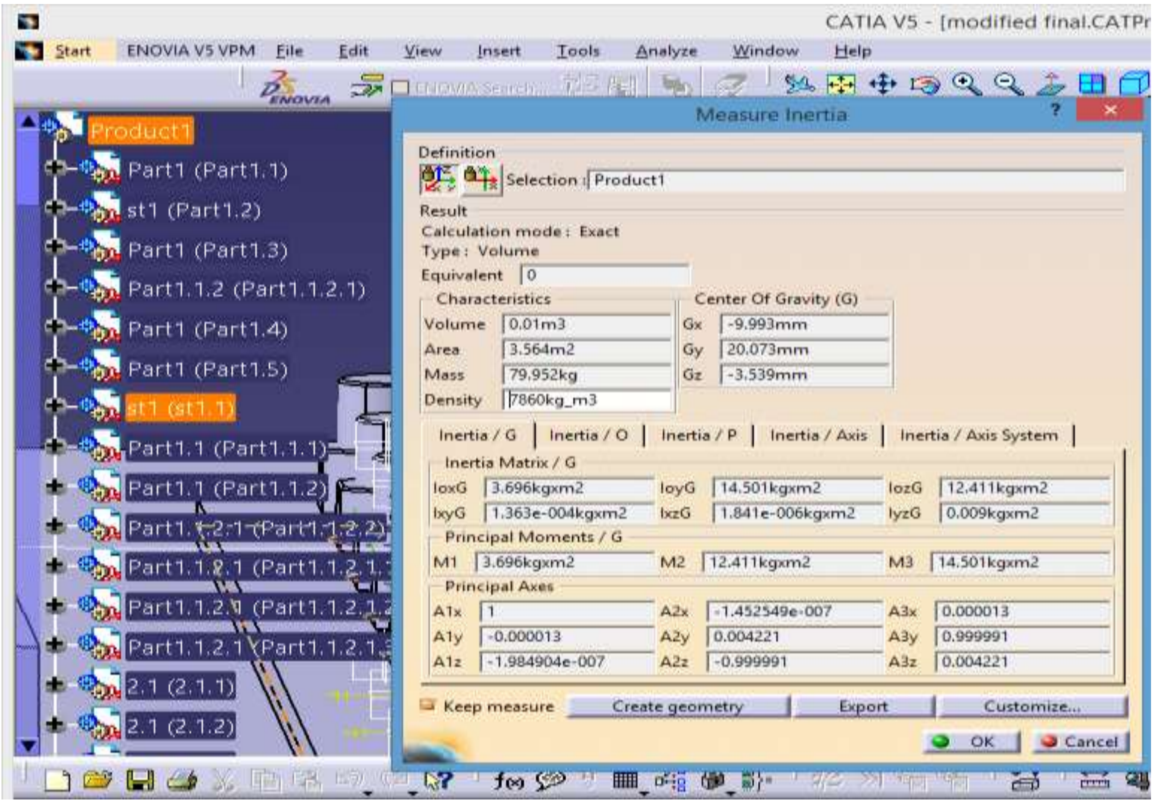

Figure.A.4.2.Calculated mass of modified truck Chassis on CATIAV5R19.

(@ stiffener plate thickness of t1=3mm and t2=5mm)

(Mass =79.952kg)

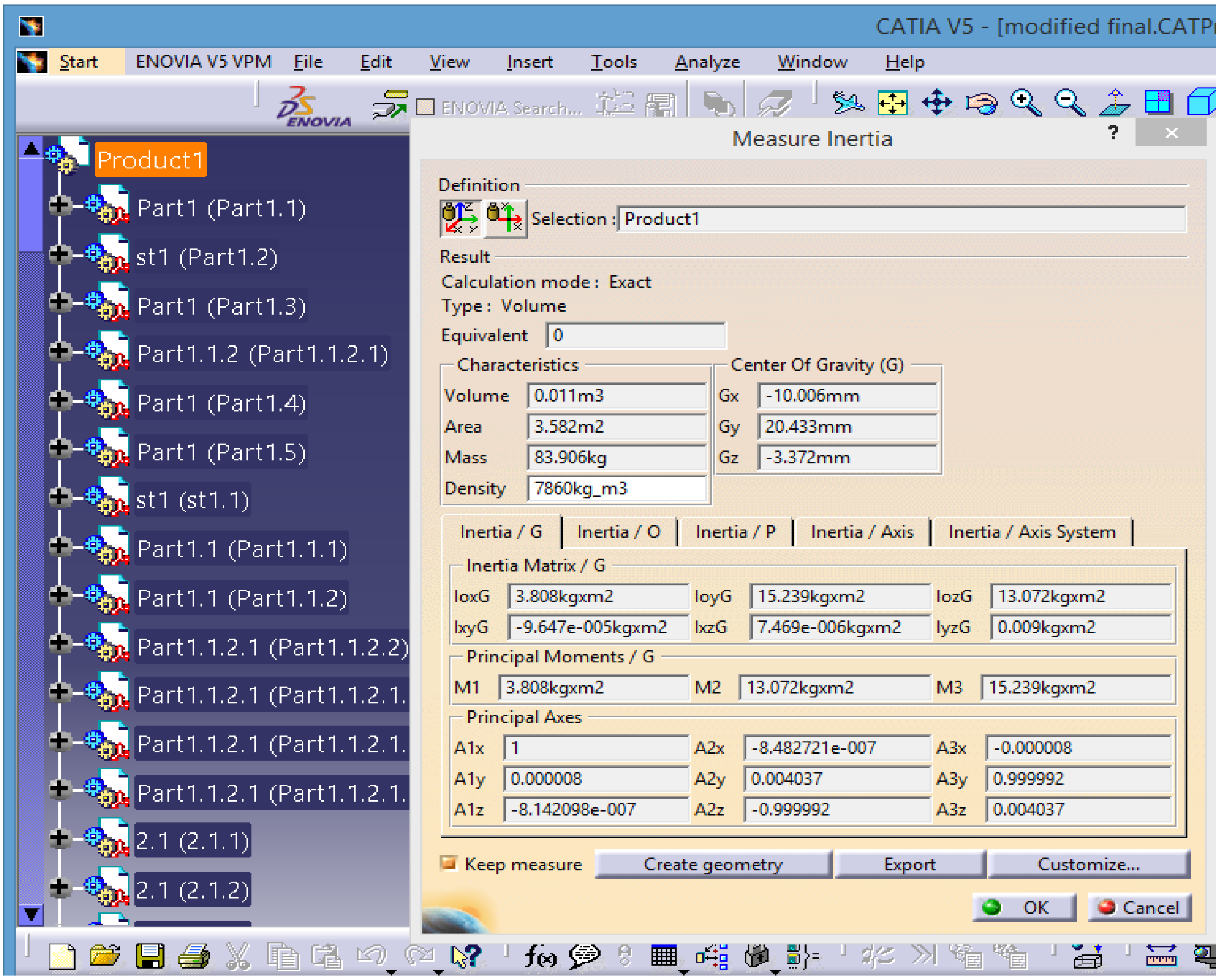

Figure.A.4.3.Calculated mass of modified truck Chassis on CATIAV5R19

(@ stiffener plate thickness of t1=5mm and t2=5mm).

(Mass =83.906kg)

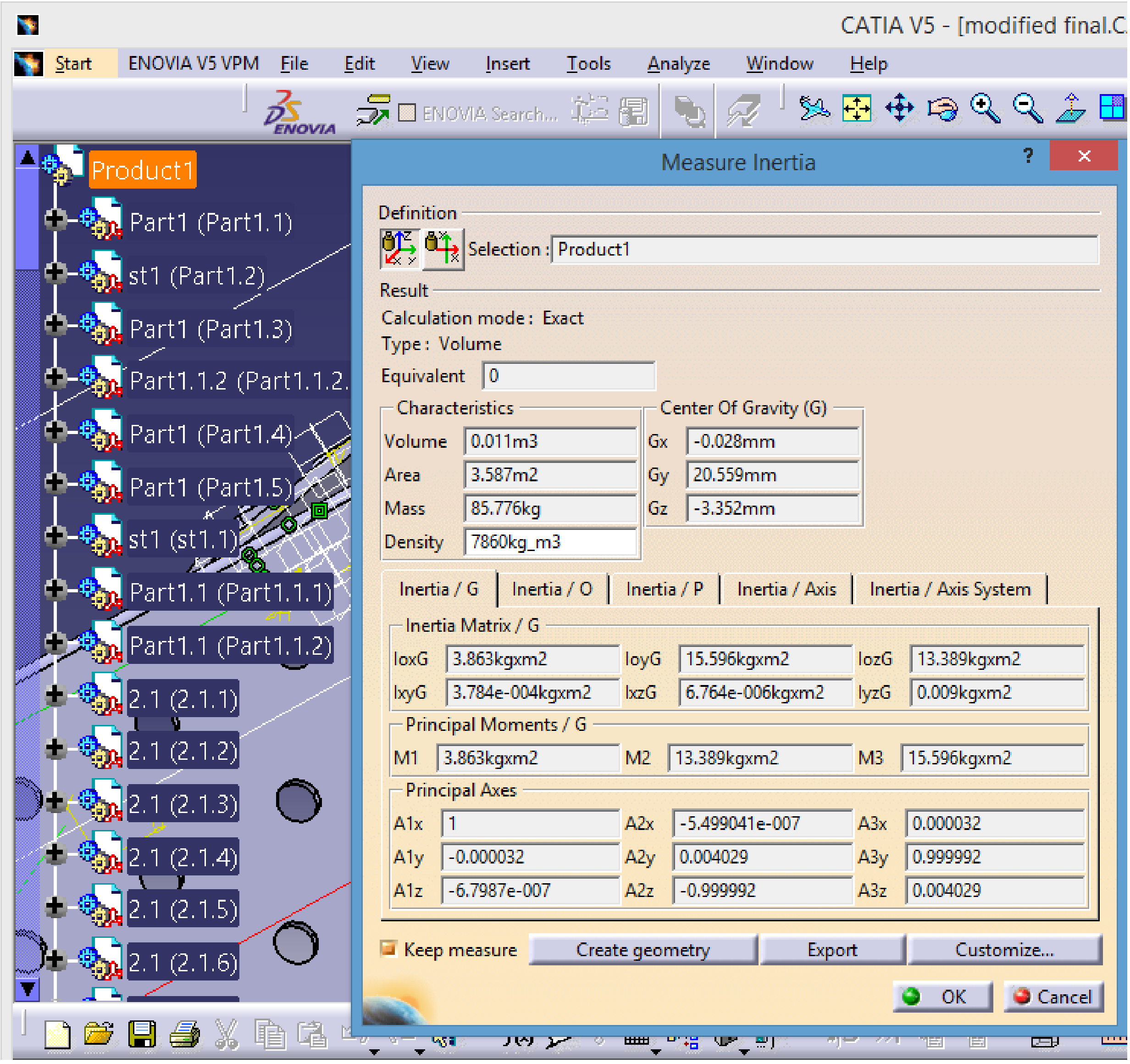

Figure.A.4.4.Calculated mass of modified truck Chassis on CATIAV5R19.

(@ stiffener plate thickness of t1=6mm and t2=5mm).

(Mass =85.776kg)

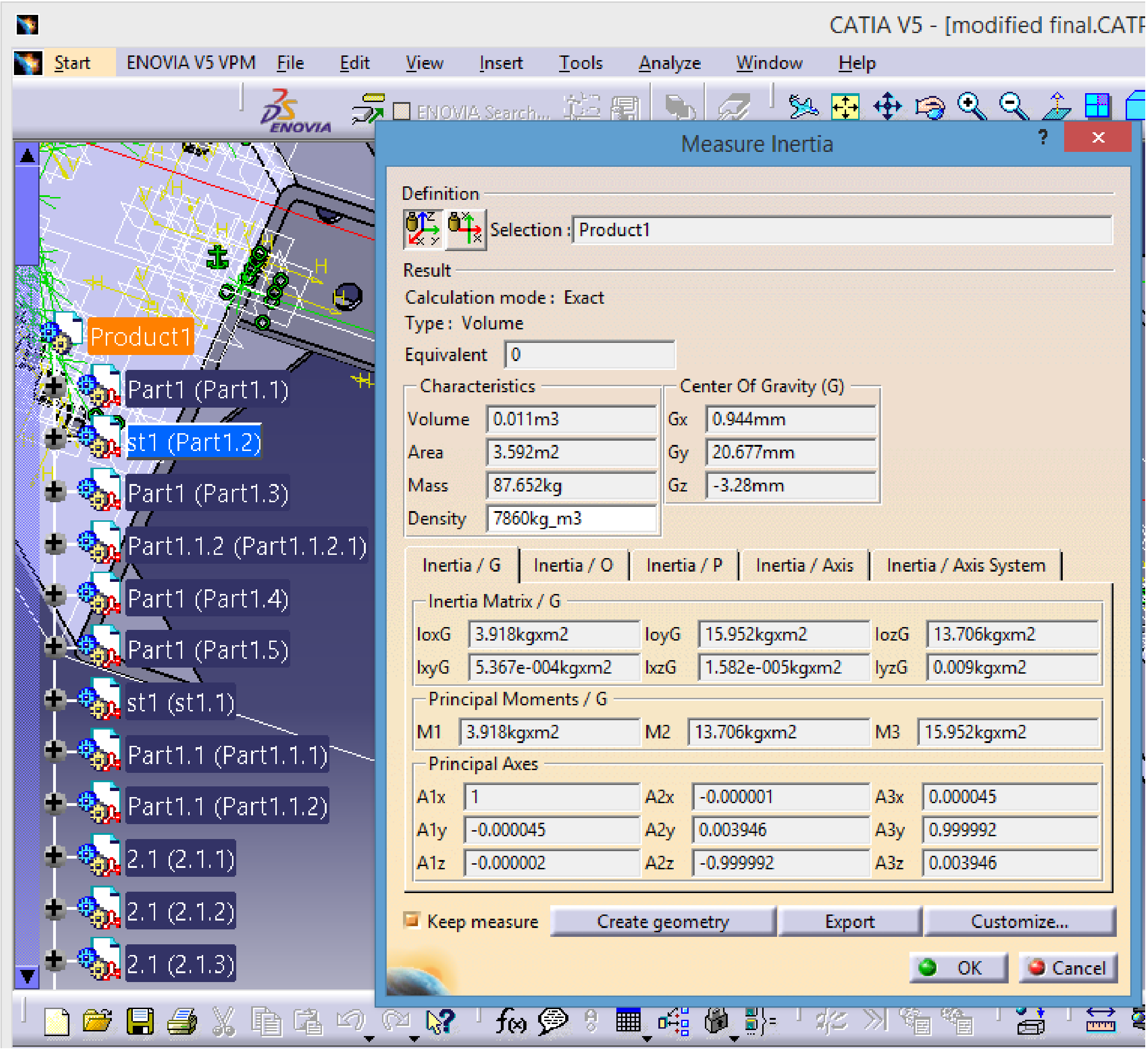

Figure.A.4.5.Calculated mass of modified truck Chassis on CATIAV5R19 (Measured Inertia)

(@ stiffener plate thickness of t1=7mm and t2=5mm)

(Mass =87.652kg)

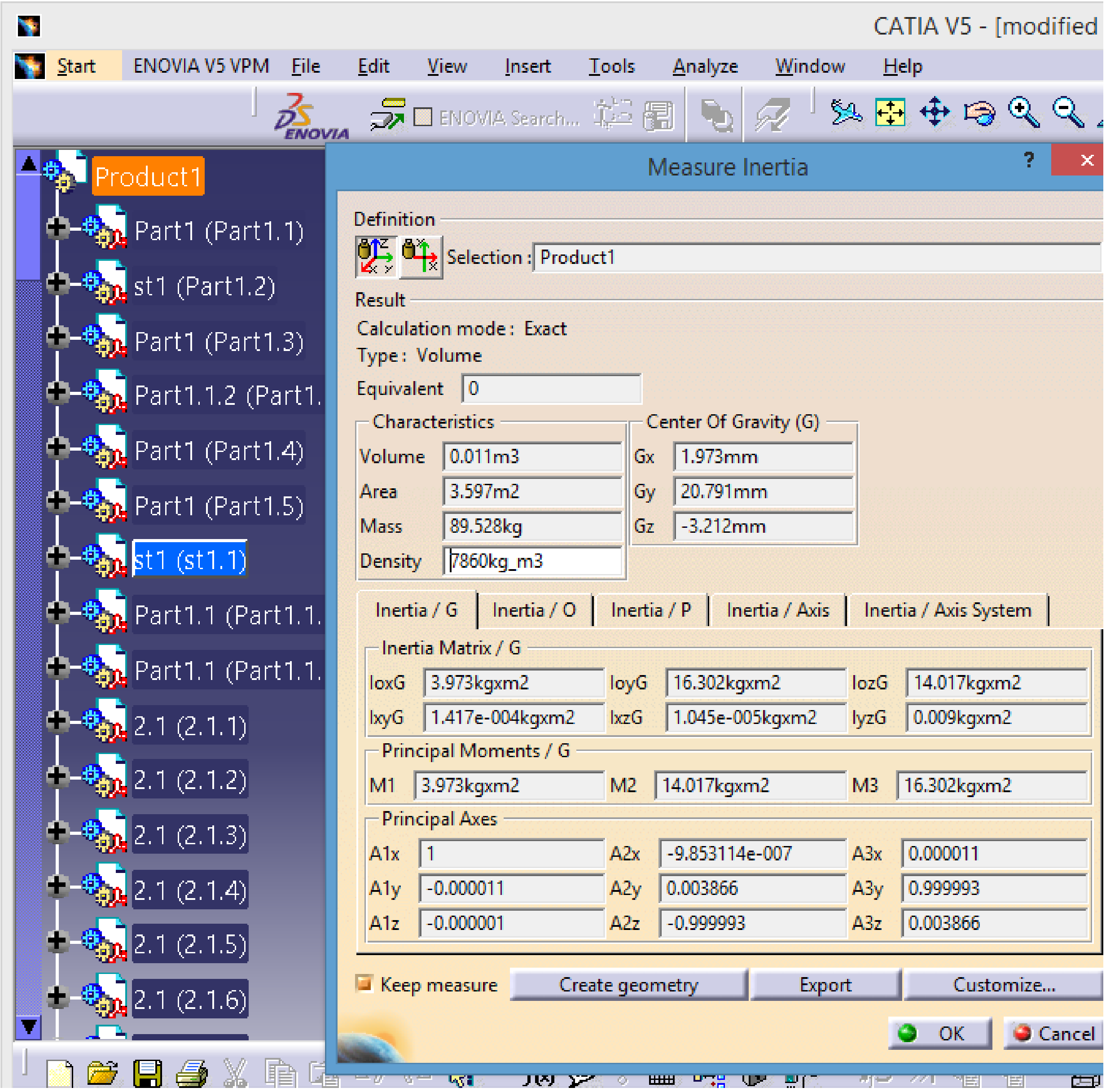

Figure.A.4.6.Calculated mass of modified truck Chassis on CATIAV5R19 (Measured Inertia)

(@ stiffener plate thickness of t1=8mm and t2=5mm)

(Mass =89.528kg)

A.5. Summarized Results for normal stress, shear stress and Weight of chassis.

Table.A.5.1.Summurized result of normal and shear stress

Sr.No	Type	Normal Stress in (Mpa)	Shear Stress In (Mpa)
1	Existing Chassis	164	73.8
2	Modified chassis with Stiffener thickness (t_1=3mm and t_2=5mm).	116.8	56.7
3	Modified chassis with Stiffener thickness (t_1=5mm and t_2=5mm).	35.7	35.1
4	Modified chassis with Stiffener thickness (t_1=6mm and t_2= 5mm).	32.6	31.2
5	Modified chassis with Stiffener thickness (t_1=7mm and t_2=5mm).	30.2	29.4
6	Modified chassis with Stiffener thickness (t_1=8mm and t_2 =5mm).	26.4	31.2

A.6. Summarized Literature Reviewed Results.

Table.A.6.1.

Result for 'Modeling and Analysis of container chassis using finite element method [2]''.

Sr.no	Type	Von-misses stress (Mpa)	Total deformation in (mm)	Stress reduced in (%)	Total deformation reduced in (%)
1	Chassis Without Stiffener	1.3	9.76		
2	Chassis With Stiffener	0.82	6.23	36.9%	36%

Table.A.6.2.

Result for 'Static Load Analysis Of Tata Ace Ex Chassis And Stress Optimisation Using Reinforcement Technique [3].''

Sr.no	Type	Von-misses stress (MPa)	Total deformation (mm)	Stress reduced (%)	Total deformation reduced (%)
1	Original chassis	37.09	1.08		
2	Chassis with reinforcement	28.74	0.64	22.5%	40%

Table.A.6.3.

Result for ''Stress Analysis of Automotive Chassis with Various Thicknesses [5].''

Sr.no	Type	Max principal Stress (MPa)	Total deformation (mm))	Stress reduced (%)	Total deformation reduced (%)
1	Main Frame	295.21	5.0671		
2	Reinforcement frame	200.45	4.8307	32%	4.7%

Table.A.6.4.

Result for ''Static Load Analysis of TATA super ace Chassis and Stress optimisation using Standard Techniques [14].''

Sr.no	Type	Max principal Stress (MPa)	Total deformation (mm))	Stress reduced (%)	Total deformation reduced (%)
1	Original chassis	146.31	1.6471		
2	Chassis with boxing	94.641	1.588	35.3%	3.6%
3	Chassis with reinforcement	74.203	1.4976	49.3%	9%

Table.A.6.7.Validation of recommended ANSYS14.5 Result with literature Reviewed Result.

Sr.no	Type	Max.Von miss Stress Reduced (%)	Total deformation (%)	Remark
1	Modified chassis with Stiffener plate thickness (t_1=3mm and t_2=5mm).	36.9%	11.8%	Recommended Result
2	Chassis with Boxing Plate ,t=3mm[14]	35.5%	3.6%	
	Difference < 10%	1.6%	8.2%	accepted
3	Chassis With Stiffener [2].	36.9%	36%	
	Difference < 10%(Stress) >10%(Deformation)	0%	24.2%	The stress is accepted but deformation is high (>10%).
4	Chassis with reinforcement[5]	32%	4.7%	
	Difference < 10%	4.9%	7.1%	Accepted,
5	Chassis with reinforcement[3]	22.5%	40%	
	Difference >10%	14.4%	28.2%	Both are > 10%

Table.A.6.8.Comparison of Analytical analysis and FE Result of existing chassis.

Sr.no	Type of Results	Normal Stress (Mpa)	Deformation (mm)
1	Analytical result	148	0.30
2	ANSYS14.5 Result	164	0.34
	Difference	9.7%	11.7%