ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

School of Mechanical, Chemical and Materials Engineering

DESIGN AND MODELING OF LADDER CHASSIS FRAME FOR TOYOTA PICKUP

A Thesis Submitted to Adama Science and Technology University in Partial Fulfillment of the Requirements for the Award of the Degree of Master of Science in Automotive Engineering

by

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APPROVED BY BOARD OF EXAMINERS

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CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in the thesis entitled **"Design and Modeling of Ladder Chassis Frame for Toyota Pickup"** in partial fulfillment of the requirements for the award of the degree of Master of Science in Automotive Engineering is an authentic record of my own work carried out from November 2017 to September 2018 under the supervision of Melesse Haile (Assi. Prof), Department of Mechanical systems and Vehicle Engineering, Adama Science and Technology University, Ethiopia.

The matter embodied in this thesis has not been submitted by me for the award of any other degree or diploma. All relevant resources of information used in this thesis have been duly acknowledged.

Yohannes kefale	--------------------------------	------------------------------
Student's Name	Signature	Date

This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief. This thesis has been submitted for examination with my approval.

Melesse Haile (Assi. Professor)	--------------------------------	---------------------------
Advisor's Name	Signature	Date

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ACYRONOMY, ABBREVIATION AND SYMBOL

A	Area of frame above neutral axis
AISI	American Iron and Steel Institute
Al	Aluminum
AMCE	Automotive Manufacturing Company of Ethiopia
B	Width
C	compression
CFD	Chassis Frame Design
CFRP	Carbon Fiber strengthened polymer
E	Modulus Elasticity of Material
EVCF	Electric vehicle chassis frame
F	Force in Newton
FBD	Free body diagram
FEA	Finite Element Analysis
FEM	Finite Element Method
FOH	Front over Hang
G	Modulus of Rigidity of Material
H	Height
HRCS	Hollow Rectangular Cross-Section
HSCS	Hollow Square Cross-Section
I	Moment of Inertia of the Cross-Section
LD	Load Distribution
LHS	Left hand side
Mpa	Mega Pascal
MOENCO	Motor Engineering Company of Ethiopia
N	Factor of Safety
RHS	Right hand side
ROH	Front over Hang
SAE	Society of Automotive Engineering
SOP	Standard operational procedure
Sy	Yield strength
T	Tension
Ute	Australian utility truck

V	shear force
W	Weight in Newton per Millimeter Square
WIP	Weight in Percent
Z	Section of Modulus
$\bar{Y}$	Distance b/n the C.G of area and the neutral axis
σ_v	Von-miss Stress
τ_{xy}	Shear Stress
σ_{sy}	Tensile Strength
σ_{yt}	Yield Stress
σ_x	Axial Stress
δ	Deflection

ABSTRACT

Chassis means, the French word that has double meanings. It means that either get-together of the structural part of the vehicle or the assembly of declared structural elements plus the mechanical parts, that provide to vehicle motion in automotive. Chassis frame of pickup truck is frequently damaged due bumping and riding problem during driving. This problem resulted in reducing vehicle performance and durability. In existing pick-up deflection and weight reduction of truck frame does not fit the length of truck frame. Therefore, improvement is done in this design. The main objective of this work is to perform the Design and Modeling of Ladder Chassis Frame for Toyota Pickup. The methods used in this work are mainly included analytical analysis, C++ computer programing, and three-D AutoCAD software ANSYS result validation. The static characteristics included, recognized place of high stress area and deflection for both HRCS and HSCS. Enhanced weight, strength, and cost are obtained. The total load acting on the chassis frame is 27664.42N and the load distribution at front hang is 38% whereas rear hang is 62%. The maximum bending moment occurred on the chassis frame is 4386121.5Nmm and maximum shear force is -7570.49N. A model is developed after chassis frame is modeled by AutoCAD. Computer method C++ is used for generated bending moment and shear force diagrams as well as the result was effectively better. The result of reduction in weight is 42.6% for HRCS and 57.5%.for HSCS. the deflections was also 4mm and 2mm respectively and the existing one about 50mm which is greater than span ratio method 50 mm >16 and it is better and safe when deflection is <16. Therefore by comparing weight reduction and deflection 4mm or HRCS were selected in this paper. Result is validated by ANSYS and the deflection is measured 3.58mm which is almost similar with analytical. Important recommendation is use experimental test during preparing the prototype. Using this title, cost analysis and material optimization is recommended for future researchers.

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Key words: *truck, chassis, frame, Auto-CAD, static, weight, deflection, design and ANSYS*

CHAPER ONE

1 INTRODUCTION

The word chassis in motor vehicle is the main structural components which provide engine of vehicle, powertrain such as clutch, transmission, suspension, steering system, chassis frame, vehicle tire or wheel and other parts without body of vehicle. Chassis means, the French word that has double meanings. It means that either get-together of the structural part of the vehicle or the assembly of declared structural elements plus the mechanical parts, that provide to vehicle motion in automotive.

Generally, this work can be providing the design and model of chassis frame for pickup truck. Specifically, the computer program like C++ and ANSYS is used to generate the moment and shear force diagram. 3D model is provided by using the AUTOCAD software. Chassis frame of pickup truck is frequently damaged due bumping and riding problem during driving. This problem resulted in reducing vehicle performance and durability. Therefore to resist these problems, it needs improvement of the design to overcome a better handling and riding comfort ability as well as increase performance and durability of the vehicle.[1]

1.1 Background

The word chassis, explanation from the French language, has in English a double meaning: it suggests that either the assembly of the structural part of the vehicle or the assembly of the mentioned structural parts and the mechanical elements that give to the vehicle motion (suspensions, wheels, steering, brakes, etc.).The structure of early cars consisted in a very chassis and a body. The chassis was the most structural frame on that all mechanical elements, like the engine, transmission, suspensions and steering mechanism, were mounted. It had been stressed by relevant reaction forces because of these focused hundreds.

The body was the instrumentality process house for passengers and luggage; in early cars it had been mounted on the chassis just like the alternative mechanical elements whereas, in trendy cars, it's integrated with the chassis, contributive during this thanks to structural strength and stiffness of the vehicle. In its latter that means, the chassis is thus a vehicle subassembly which will be truly accessible at a given stage of the collection method, as happened till concerning the tip of the Nineteen Forties for many cars, or will exist solely just about, as is that the case for more modern vehicles.

These days the chassis includes identical elements as at the start of engineering, however it cannot be disassembled as an entire entity from the vehicle. At the dawn of the motor automotive era, the innovators World Health Organization dedicated their intellectual and money efforts to the event of this new product, targeting the elements that were a lot of directly concerned within the motion of the vehicle, like engine, transmission, suspensions, steering and braking systems.

They became thus designers and makers of chassis. At that point body technology wasn't thought of to be basic and was directly taken from horse driven carriages and coaches, while not important modifications; several coach builders became body builders, because the initial makers of automotive bodies were known as. This example determined a major separation between these 2 industrial branches. This chassis frame is separately its own function. The whole separation of the chassis from the body collection method was conjointly even by the requirement to forestall varnish from being broken by mechanical elements throughout the advanced collection method.

Several hundred operating hours were needed for finishing the painting of an automotive body, solely to use the various layers of varnish; to the present figure the drying time of every layer should be additional to get the entire time needed for the painting cycle. The supply of a complete chassis was so even by the prevailing technology and industrial organization. The chassis manufacturer might therefore ship a finished product to the ultimate client or to a body builder. In several cases, the ultimate client bought a chassis, which was later on shipped to the body builder for more works, beneath a unique contract. This example was common till the start of war One. The requirements of production inspired several automotive makers to develop their own body style and production capability, besieged to scale back prices. This favored a swish transition from wood to steel technology, with hybrid wood steel structures.

The introduction of artificial enamels, additionally, shortened the painting time by Associate in nurture order of magnitude and favored a deeper integration between chassis and body grouping. This new organization was developed in the main within us and imitated by the most important makers in Europe, ranging from the start of the Twenties. Concerning twenty years later, the primary unitized bodies began to be applied in Europe. The evolution of chassis and body is delineate by considering 3 partly overlapping periods, together with severally the divisible chassis, the partly integrated chassis and therefore the unitized bodies[2].

1.2 Problem Statement

The main problem of pickup chassis frame is problem of deflection and weight reduction of pick-up frame does not fit the length of pick-up truck frame. The deflection is not proportional according to deflection span ratio. This consequence is going to bend the frame structure of pick-up truck. Most chassis frame of pick-up development is varied in design, weight, complexness and costs. Pick-up frame are not well understood in terms of auto response throughout riding particularly on jolty and off road conditions.

The most criteria within the analysis were the behavior of design and modeling of ladder chassis frame for Toyota pickup truck. This study is to enhance the present condition for betterment of riding quality and resisting deformation. There are major areas established within the study to come back out with correct investigation on the design and modeling of ladder chassis frame for Toyota pickup truck. Particularly calculation methodology on design and process evaluated.

Generally, the three classes of the major problems were assisted by the information taken from MOENCO and AMCE Company of Ethiopia is provided according to the next steps. The first is economic decline, like decrement of infrastructures in Ethiopia due to importing of pickup truck from foreign. This will cause decline of market demand due to cost as well as community satisfaction. The second, no design improvement of the pickup truck in Ethiopia depending up on customer needs. Third one is design problems of the pickup truck such us high deflection, low reduction in weight and low strength of material selection.

1.3 Objectives of the Study

1.3.1 General objective

The main objective of this work is to design and modeling of ladder chassis frame for Toyota pickup.

1.3.2 Specific objectives

The specific objectives of this thesis work are as follows.

- To determine static analysis of ladder chassis frame for Toyota pickup
- To back scale or reduce weight, compromise cross-section and evaluate its deflection
- To confirm goop or maximum bending moment and shear force diagram of pick up chassis using C++ computer programing
- To develop 3D model using AutoCAD and validate the results using ANSYS

1.4 Scope of the Study

The scope of this works includes static analysis of ladder chassis frame for Toyota pickup. Further, the design and model include deflection and weight reduction by compromising HRCS and HSCS. The software includes in this analysis are C++ computer programming, 3D AutoCAD and ANSYS to check result validation. Percentage analysis of distributed load is also included to know front and rear load distribution on pickup chassis frame. Determination of maximum shear force and maximum bending moment is also the main analysis in this work.

1.5 Limitation

This work is limited to determine deflection for hollow rectangular cross-section and hollow square cross section. The other limits are determination of stress produced on the chassis frame of pick-up truck. Constructing prototype is not fit with material properties of this design because it needs maximum budget to use exact material. Therefore prototype is limited to simple metal selection. However, construction of prototype fits the exact dimensions of 3D model generated by AutoCAD.

1.6 Significance of the Study

Pickup truck chassis frame could be a standard product vehicle for construction work and society services. It’s a vital part of goods transport for rulers and concrete category population of Ethiopia.

It is also significant to move goods for long distance and consultants or the employee of onsite and different functions service for carrying products in our population. However there's improper use of those vehicles in Ethiopia, which is overloading it on the far side its carrying capability. Therefore this study attracts a good contribution on impact of overloading to chassis frame. As results of this study the subsequent vital are obtained. To present attention, the homeowners to use it properly and cargo it at its carrying capability so as to extend the lifetime of the most elements of the vehicle, particularly the chassis frames. It’ll scaled back energy consumption and greenhouse emission as a result of avoiding overloading it. The chassis frame is to be rigid enough to support weight and stress

1.7 Beneficiaries

Automotive industries, vehicle homeowners, society and future researchers are benefitted. Especially Adama science and technology university communities are benefited from this thesis work.

1.8 Organization of the Study

The studies are organized into 5 chapters. It starts with the background, which has, statement of the problem, objectives, scope of the study likewise because the significance of the study. The second chapter is review of literature that deals with ideas and past studies and knowledge pertinent to the study. The third chapter can make a case for analysis methodology together with materials used and strategies to be followed to accomplish in this thesis work. Further, the fourth chapter resulted verification and discussion are provided. The last chapter includes conclusion and recommendation are carried out.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Introduction

This chapter deals surveying of different researcher data's as well as historical development of chassis frame with its classification. Reviewing deferent literature is used to identify their problems and improvement analyzed through their works. Generally, literature review, historical development, types of chassis frame, types of trucks, material properties and overall discussion on pickup truck chassis frame analysis is provided under this chapter.

2.2 Literature Review

Design Improvement and Analysis of automobile Chassis frame which include Static and Dynamic Characteristics are performed. The target investigation of static and dynamic characteristic like Torsional stiffness and natural frequency of automobile chassis, the analysis has been completed by Finite component technique and Experimental approach[3].

The works can be provides Finite component Analysis under static load conditions of TATA Chassis in two dimensions are conducted. Modeling of chassis was done using computer code CATIA V5 once destroying benchmarks and the results are analytically verified by using Macaulay's technique to calculate deflection of the beam[4].

Optimization of forty Feet Trailer Chassis supported Structural Static Simulation. The works shows the model of associate degree existing truck chassis and modifies the bar dimensions still because the range of cross members used supported the strain and strain values. The solid work used for the model[5].

The study was Experimental Analysis and Quasi-Static Numerical Idealization of Dynamic Stresses on an important Truck Chassis Frame Assembly that helps in understanding prevailing stresses in truck frame rails particularly throughout cornering and braking operations and brings out all geometric locations which will be potential failure initiation locations[6].

Structural analysis of ladder chassis with high strength cross section is required to attenuate the failures as well as issue of safety in design. Primarily C cross section variety of chassis is employed in buses and that i cross section sort in serious trucks wherever high strength is needed [7].

Modeling and structural analysis of serious vehicle chassis made from compound material by 3 totally different cross sections. The three different composite serious vehicle chassis are provided by considering 3 different cross-sections. Namely C, I and box sort cross sections. For validation the design is finished by applying the vertical load engaged on the horizontal totally different cross sections. Software is used in this work pro – e 5.0 for modeling, ANSYS 12.0 for analysis [8].

The value Effective resolution for Twist Free Chassis design of 3 Wheeler Vehicle is provided. His work includes through the mechanism of twist in chassis and analysis in terms of twist restoration, personnel value, voltage consumption, stresses is evaluated. The personnel value reduction is by 48.34 %, whereas the voltage value is reduced by 42.69%. By planning the SOP (Standard operational procedure) at work stations results in increase in awareness for quality and reduce of process rate by seventy five to check out work stage, wherever main beam subassembly is created [9].

The optimizing was considering various factors like weight, stress-strain values and deformation. By varied cross sections for modeling and analysis. thus their work are describes the design and Structural analysis of the serious vehicle chassis with constraints of most stress, strain and deflection of chassis below most load by using CATIA model ANSYS and FEM [10].

The contribution on structural analysis of chassis to produce insight into truck chassis analysis and act as a guide for researchers functioning on finite Element analysis is done using (FEA) [11].

The descriptions were preserved to review the investigations that are created on the various fatigue analysis techniques of automobile frames. Variety of analytical and experimental techniques area unit on the market for the fatigue analysis of the car frames. Their Determination of the various Analysis around modified condition in an automobile frames has been delineated in literature [12].

The static and dynamic load characteristics are analyzed using metal models. The analysis is characteristic location of high stress space, analyzing vibration; natural frequency and mode form by mistreatment finite part methodology on the far side their analysis. Natural frequency prediction and mode form are determined by mistreatment ANSYS package. The cad pure mathematics of chassis is generated in solid works and model and static analysis is completed in ANSYS worktable [13].

The work was offer Static and Modal Analysis of Truck Chassis to look at natural frequency and modal form through analysis. Additionally administrated design of the Chassis is carried by using finite element analysis are determined by using ANSYS fourteen [14].

The conduct was on the Role of pc power-assisted Engineering in Mitigation of Automotive Chassis Failures to gauge The checks embody the vertical bending test, lateral bending check, 3D bending check, the torsional check, modal analysis, accelerated sturdiness check, tow hook check and engine and transmission mount check [15].

The work was provided Applications of Finite component Stress Analysis of serious Truck Chassis to explain the Survey and up to date Development chassis. It was targeting stress analysis of the serious truck chassis frame [16].

The work was done on Finite component Static Structural Analysis of 4x2 Truck Chassis Frame. Determination of chassis frame stress is decided through analysis [17].

The work was develops the design of associate innovative chassis created in bio-composite to exchange the hollow steel chassis of the four-wheeler named the pit-car taken as reference by a bio-composite chassis [18].

The work was access on stress Analysis of Automotive Chassis with varied thicknesses to attain a discount within the magnitude of stress at the crisis of the chassis frame, face member thickness, cross-member thickness and position of cross-member from the bottom were varied and likewise as reducing the deflection [19].

This would perform Chassis Torsional Rigidity Analysis for a Formula SAE Racecar. The target of deign goal is to design the torsional stiffness of racecar chassis. Therefore the theoretical design target for chassis torsional rigidity is decided that's designable, whereas taking into consideration that the improvement should be buildable and utilized in future Formula SAE racecars [20].

This would perform Crash check Simulation and Analysis of a traveler Bus Frame. The target of this work was to review the impact of frontal, side, torsional and change impact on the bus bodily structure to gauge vehicle sturdiness. Then using the pc simulation in deigns analysis to scale back the value and increase the lifetime of the chassis frame of the bus was achieved [21].

The conduction was achieved on modeling and structural analysis of car chassis frame product of chemical compound material for constraints were stresses and deflections [22].

This work was perform structural and modal analysis of a ladder frame chassis and their work is usually giving towards the study of deformation, natural frequency and stress induced in an automotive chassis of Ashok Leyland Vikings model under most load for various cross section of cross-members particularly C, I, and Rectangular Box (hollow) kind cross sections[23].

The determination was on relying Static and Dynamic on Analysis of a Ladder Frame Truck Chassis for the modification of the updated iron truck chassis model to scale back the vibration, improve the strength and optimize the burden of the truck chassis. Modifications to vary natural frequencies were offered by increasing the thickness of the chassis center section by a pair of millimeters and extra filler members placed at the middle of the bottom plate with a thickness of ten millimeters. The general weight of the new truck chassis was enhanced by seven-membered [24].

This work was performed on design and analysis on flat frame chassis for off-road vehicle. Work is providing with roll cage structure design and development with the validation of the flat joints of the chassis frame. Thus, the results of a Flat frame structure with new design are verified with engineering formulation. Largely to pull apart things on roll cage became terribly straightforward if we tend to use this sort of flat body frame a minimum of the inside of a cage [25].

The work was performed on modeling & finite component analysis (FEA) of automotive chassis to boost potency to develop and design a Chassis for automotive by conduct its Finite component Analysis [26].

Conduction of work was done on Structural Analysis of Pick-up Truck Chassis victimization Fem for evaluating and investigation static characteristics and additionally the fatigue life prediction of the chassis frame. Static analysis may well be providing within the determinative the situation during which most stress happens and to gauge torsional stiffness of the chassis frame of the motor truck. Torsional stiffness of the chassis frame made up our minds. Foretold worth's were valid with the results on the market within the literature and also the most value of error was found to be seven.83% [27].

The work was conduct Stress Analysis of Ladder Chassis with varied Cross Sections determination with constraints of most shear stress and deflection of chassis underneath most loads are going to be obtained through the researches. Austenitic subjected to the identical load. Vehicle chassis are sculptured by considering 3 different cross-sections. Namely C, I, and Rectangular Box (hollow) are the kind cross sections utilized in the works [28].

This work was provides Chassis calculations for Frame design. The focus of analysis is a six-wheeled articulated truck, and the load cases under study are Lateral Loading, Frame Torsion and Vertical Load on Kingpin. Making robust deformation and stress models with a calculation time succinctly short and accuracy consistently high for efficient design work is a difficult task. By means of simplifying contemporary modeling approaches and methods and automating the setup process, a method that enables short calculation iterations on a chassis frame of a truck is achieved cad are obtained for analysis [29].

BBG body builder guide was provides. The body builder guide of hilux acquire that indicates overall part, therefore, the pickup. They additionally embody the technical specification and code model of the trucks with the manufacturing country are going to be delineated during this body guide [30].

The work was achieved Strength analysis of 3 wheeled vehicle's chassis and body frame assembled in Ethiopia. The most objective of this project is to document procedural details of such reworking, with a read to presenting additional analysis and development destined investigations within the future. CATIA and ANSYS are used for developing the model of the three vehicles [31].

2.2.1 Overall discussion on pickup truck chassis frame analysis

It is often all over that, several of the truck structures found within the analysis are subjected to internal and external load, which affected the ride quality of the car. These loads and behaviors are often determined through a series of processes particularly, Modal Analysis. The correlation and modal changes in technique is additionally necessary. Most of researcher uses similar software but know C++ computer programing is added in this analysis to make it better. Using C++ is easy to selecting material that fit the design.

The other researchers are not compromise the HRCS and HSCS but in this research it is added. In previous compromising of channel, rectangular, I-cross section is analysis but the deflection and cost are not reduced simply they analysis only for the purpose of nothing. According to literatures or many researchers the design problem is also not improved well and it going too deformed and failure due to lack of proportional fit of length with carrying load during design. Therefore it needs design improvement on chassis frame of pickup truck.

2.3 Overview of Chassis Types

2.3.1 Definition of a chassis

The chassis is the framework that is everything attached to it in a vehicle. In a modern vehicle, it is expected to fulfill the following functions:

- Provide mounting points for the suspensions, the steering mechanism, the engine and gearbox, the final drive, the fuel tank and the seating for the occupants.
- Provide rigidity for accurate handling;

- Protect the occupants against external impact.
- While fulfilling these functions, the chassis should be light enough to reduce inertia

And offer satisfactory performance. It should also be tough enough to resist fatigue loads that are produced due to the interaction between the driver, engine, power transmission and road conditions.

2.4 Chassis Design and History

Earlier, race cars were constructed on massive lines, a design trait that reflected bridge-building more than performance engineering. Prior to World War II, almost all car chassis was of the girder type, a construction of beams, usually I-shaped or Z-shaped. Mercedes-Benz introduced tubular beams in 1937. In such a chassis, the beams were parallel, from axle to axle, and the construction was known as a twin-tube. It remained in trend for racing cars until the early 1950s, when chassis with space frame principles started appearing with the Lotus Mark Six and Mercedes-Benz 300SL.

2.5 Separable Chassis

The chassis, in its structural which means, was the bearing structure of a vehicle and had to support all mechanical elements and also the complete body that during this case was solely ballast with none explicit structural perform. Additionally, the chassis had to supply a straightforward organization of the collecting method, being much the mounting fixture for all mechanical components.

Figure 2.1 grillage chassis of a car at the beginning of 20 century, made of stamped steel

2.6 Types of Truck

There are a unit many varieties of truck altogether over the planet. Majority of truck's makers receiving order from several industries for transportation functions in varied varieties and specifications in term of size and truck capability. Supported that, there are a unit 3 types or categories that area unit presently available within the market specifically, the compact truck, full size truck and mid-size truck [22].

2.6.1 Compact truck

The compact truck is that the most widespread sort of motor truck worldwide. it's designed sort of a mini version of a two-axle significant truck, with a frame providing structure, a traditional cab, a spring suspension on the rear wheels and a little I4 or V6 engine, typically mistreatment gas. The compact truck was introduced to North America within the Sixties by Japanese makers. Datsun (Nissan 1959) and Toyota dominated underneath their own nameplates through the top of the Nineteen Seventies.

2.6.2 Full size truck

A full size truck could be a massive truck appropriate for trucking significant masses and acting different functions. Most life-size trucks will carry a minimum of 450 kilogram within the rear bed, with some capable of over 5 times that abundant.

2.6.3 Mid-size truck

In North America, trucks were unremarkably used as general purpose traveller cars. They were standard not solely with construction staff, however additionally with housewives and workplace staff. Therefore arose the requirement for a motor truck that was larger than a compact and smaller and a lot of fuel economical than the life-size pickup.

2.7 The Cultural Vital of the Truck

There are units many varieties of truck that are developed within the market particularly for the cultural wants. The analysis and development have continually found the new technologies, which have extremely contributed to their wants particularly for personal use likewise as organization and country [24].

2.7.1 The Australian truck

The Australian utility truck, or a lot of heart ally known as “ute”, is that the mainstay type of truck in Australia. Since the fashionable style of the ute 1st rolled off the line at the Ford works in Geelong in 1934, that Ford represented because the “kangaroo chaser”. There have been 2 common varieties exist, that is that the yank vogue truck, unremarkably popular farmers. It’s typically Japanese or Australian designed model, like the Isuzu Rodeo or the

Toyota Hilux. These are a unit standard during a type of forms, 2 and 4 wheel drive, single or twin cab integrated receptacle or flat bed. These types of vehicles also are common in New Zealand, wherever they're additionally brought up as “utes”. The opposite sort of vehicle unremarkably brought up as a “ute” is sort of different-a motorcar gaudy version of typical saloon cars, which includes a “ute”-type integrated receptacle back.

2.7.2 Truck in Europe

In Europe, pickups truck is taken into account light-weight industrial vehicles for farmers. Till the Nineteen Nineties, pickup trucks were most well-liked chiefly as individual vehicles in rural areas, whereas vans and enormous trucks were the popular technique of transportation for merchandise [25].

2.7.3 Military use

Pickup trucks are used as troop transport in several elements of the planet, particularly in countries with few civilian roads of terribly rough piece of land. Pickup trucks have additionally been used as fighting vehicles, usually equipped with a machine-gun mounted on the bed.

2.8 Ladder Frame

The history of the ladder frame chassis dates back to the times of the horse drawn carriage. It was used for the construction of ‘body on chassis’ vehicles, which meant a separately constructed body was mounted on a rolling chassis. The chassis consisted of two parallel beams mounted down each side of the car where the front and rear axles were leaf sprung beam axles. The beams were mainly channeled sections with lateral cross-members, hence the name. The main factor influencing the design was resistance to bending but there was no consideration of torsion stiffness.

A ladder frame acts as a grillage structure with the beams resisting the shear forces and bending loads. To increase the torsion stiffness of the ladder chassis, cruciform bracing was added in the 1930s. It can use straight or curved members. The lateral and cross-members provide rigidity to the structure because it provides resistance to lateral forces and further increase torsion rigidity. Body mounts are usually integral outriggers from the main rails, and suspension points can be well or poorly integrated into the basic design [26].

The lateral and cross members provide rigidity to the structure (Wakeham, 2009) as shown below in Figure 2.1 [31].

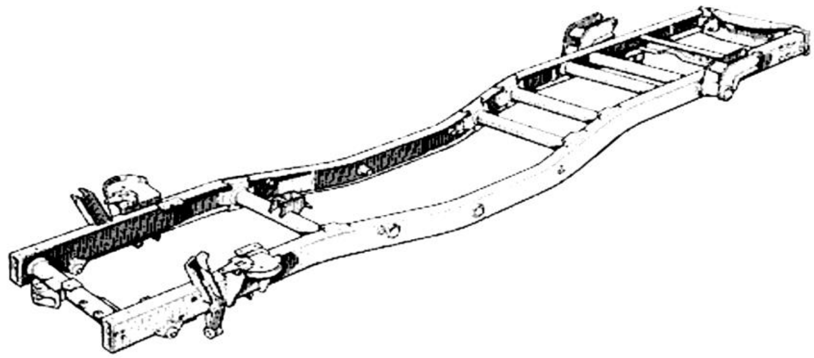


Figure 2.1 Ladder frame chassis

2.8.1 Twin tube

The ladder frame chassis became obsolete within the middle 1930's with the appearance of all-around freelance suspension, pioneered by Mercedes Benz and automobile Union. The suspension was unable to work effectively thanks to the dearth of torsion stiffness. The ladder frame was changed to beat these failings by creating the facet rails deeper and boxing them. A closed section has some one thousand-fold the torsion stiffness of associate open section. The potency of dual tube chassis' is sometimes low thanks to the load of the massive tubes. They were still in use into the 1950's, the 1958 Lister-Jaguar being associate example of this kind. A typical twin-tube chassis is shown in Figure 2.2.

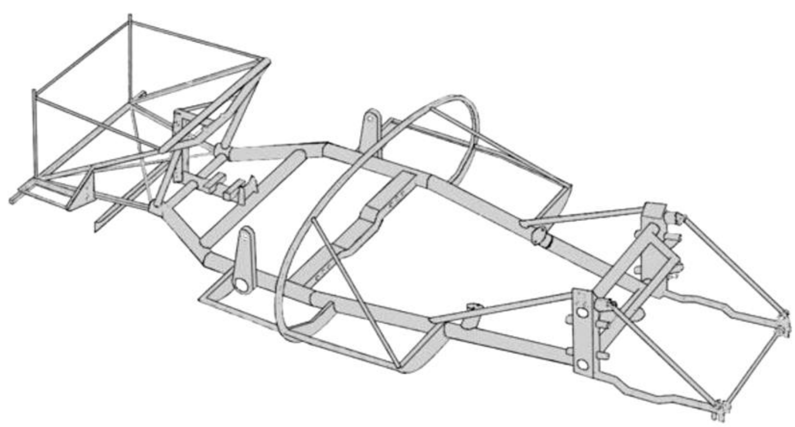


Figure 2.2 Twin-tube chassis

2.8.2 Multi-tubular chassis

In theory the term multi-tubular refers to a chassis that's designed up with quite 2 bearing beams (figure 2.3), that may be wont to describe all chassis sorts beside the twin-tube represented on top of. In observe, the term is maybe best applied to those chassis, which utilizes four main facet rails however can't be classified within the true area frame class.

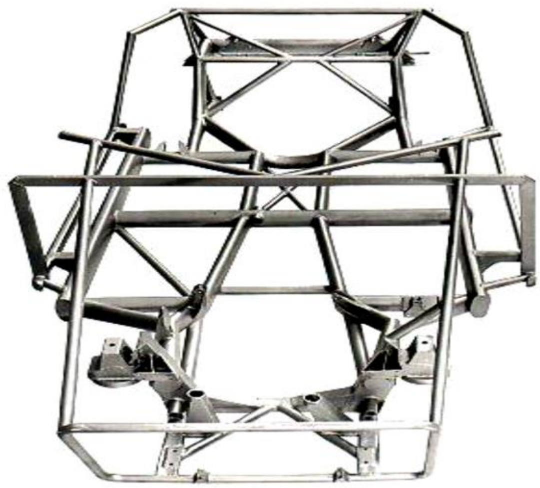


Figure 2.3 A multi-tubular sports car chassis [Maserati Alfieri 2013]

Essentially, this chassis offers poor performance, however has established to be a roaring compromise between the twin-tube chassis and also the area enclose terms of stiffness and cost. Often, the frame member diameter, that the outer diameter of the frame should be augmented to achieve an acceptable torsional stiffness. This leads to a heavier chassis, as compared to for instance, an area frame which will be introduced within the next paragraph.

2.8.3 Space frame

The body on frame is that the oldest structure system used and today it solely applies within the Construction of business vehicles and off-road vehicles. It consists of 2 totally different structures: the frame and the bodywork. The frame cans a structure consisting of 1 or additional metal beams on the vehicle, connected by crossbars welded, screwed or riveted, organized transversally or diagonally. This part features a high strength and therefore the mechanical parts and therefore the bodywork is hooked up on that frame.

The body forms the outer shell of the vehicle and is screwed to the frame. It’s not any strength feature. It’s a good strength to hold significant masses and a high rigidity to face up to high elastic and dynamic stresses. Reforms within the body can even be performed simply.

Altogether frames until currently length in one dimension is extremely less compared to the opposite 2 dimensions. Increasing depth will increase bending strength. Beam parts carry either tension or compressive masses [31].

Though the area frame (Figure 2.4) incontestable a logical development of the four-tube chassis, the area frame differs in many key areas and offers huge blessings over its predecessors. The space frame is one during which several straight tubes are organized for the hundreds intimate with all act in either tension or compression. This is often a serious advantage since none of the tubes are subject to a bending load. Since area frames are inherently stiff in torsion, little material is required so that they may be light-weight.

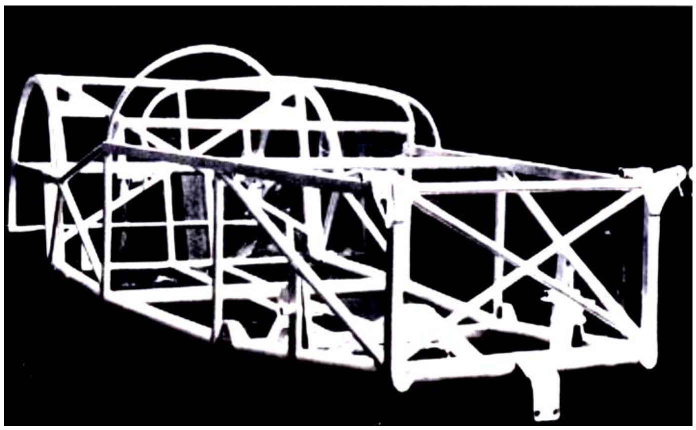


Figure 2.4 1952 Lotus space frame

2.8.4 Monocoque

A monocoque chassis, figure 2.5, may be a one-piece structure that defines the form of the automotive. Monocoque was initial wide employed in craft within the Thirties. The Sixties race cars, that used monocoque chassis, had a cylindrically fashioned construction to boost the torsional rigidity.

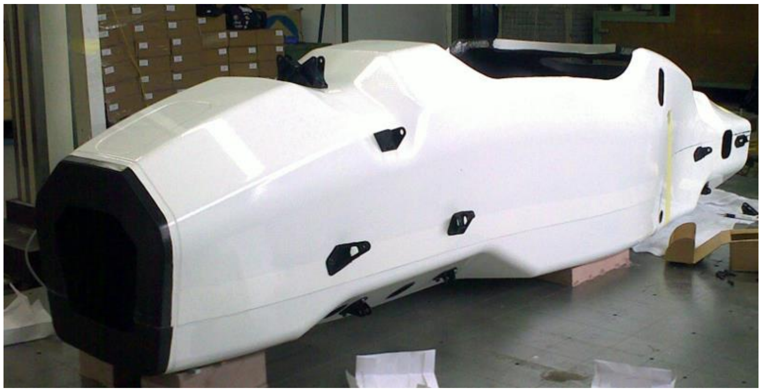


Figure 2.5 Monocoque chassis. [Kohoch3 2013]

The monocoque chassis provides the most structural support and therefore absorbs all the hundreds touching the automotive. In race cars these days, the foremost common variety of monocoque chassis are manufactured from differing kinds of composites, as an example Carbon Fiber strengthened Polymers (CFRP). The advantages of monocoque chassis (in specific, composite monocoque chassis) embrace high torsional stiffness and light-weight weight. There are some disadvantages, like the difficult style and high value. Alternative materials will be employed in monocoque constructions are as an example optical fiber and Al.

2.8.5 Box - No box

There are 2 totally different style solutions for the rear of a formula automobile chassis, a box and a no box resolution. The distinction between the 2 is that within the box resolution (figure nine left) the rear frame encloses the differential and elements of the drive shaft since within the no box (figure 2.7) resolution the rear frame ends before the differential and drive shaft. It’s easier to design the box resolution; however, it adds a lot of weight to the development over the no box resolution. Also, the no box resolution makes it easier to use the various elements within the tail and could be a lot of compact resolution, however, is a lot of advanced to design [33].

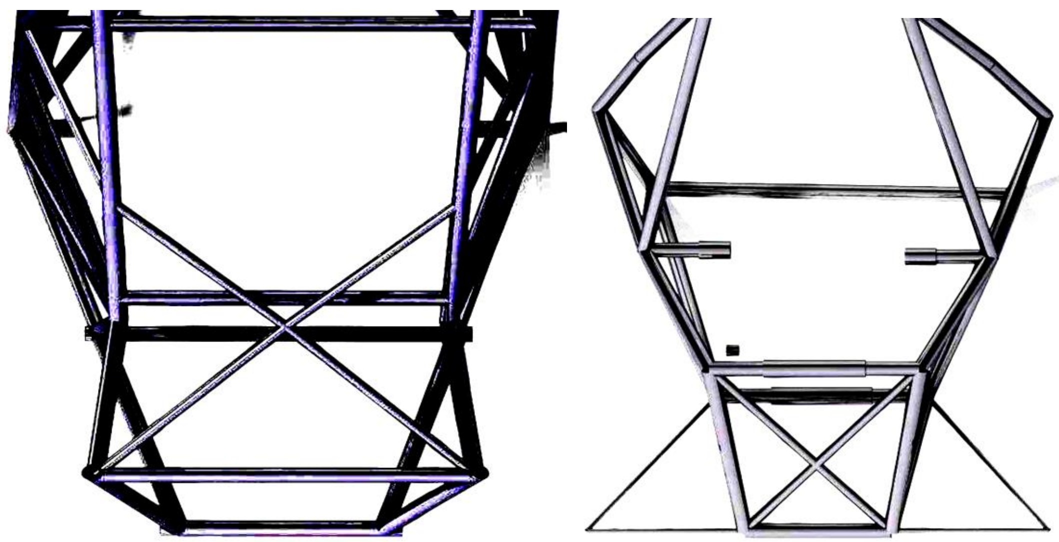


Figure 2.6. Left Frame with box and Right Frame with no box

2.9 Electric Vehicle’s Chassis Frame

The participation in Shell Eco Marathon has mandatory regulations that concern the design of all vehicle parts, including: Safety, Dimensional, Technical and Ergonomic rules. At the same time, the vehicle cover design and dimensional specifications also affected and shaped the constraints that must be met during the development of chassis. This type of chassis frame is only limited to sport car. It is not used for the puropse of carring goods. They use safety factor about 4 which is used on off road only[30].

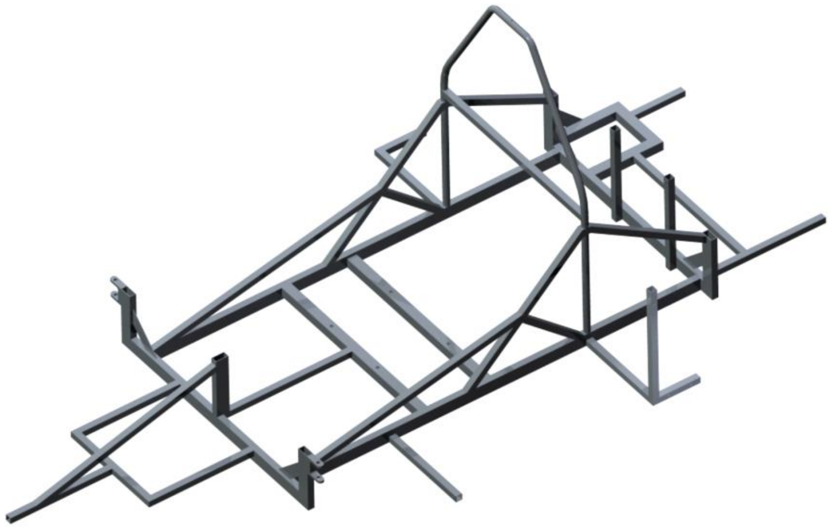


Figure 2.7. Electric vehicle chassis frame (EVCF)

2.10 Material Properties

AISI steel specifications stockholders and suppliers, delivering to the full of the United Kingdom. Yankee Iron & Steel Institute AISI specifications cowl a good vary of steel varieties, together with steel, steel, alloy steel and stainless steel. AISI steel grades have become more and more fashionable within the United Kingdom, primarily because of their use within the oil and gas industries. AISI grades area unit generally spoken as SAE designations. We have a tendency to hold a comprehensive vary of stock in AISI material and AISI equivalent specifications. AISI steel grades obtainable the bulk is as carbon steels and alloy steels [33].

It’s potential that AISI grades area unit quoted as SAE grades and it's usually that AISI/SAE has same steel positive identification. Carbon steels area unit selected by a consistent AISI or SAE four-digit variety, during which the last 2 numbers show them about the middle of the carbon varies. AISI 1010, as an example, includes a carbon content of 0.08 to 0.13%. The initial 2 digits of the AISI! SAE numbers also are important.

The amount ten indicates non-re-sulfurized grades. Similarly, grade numbers starting with eleven denote re-sulfurized grades. Re-sulfurized and re-phosphatized grades are indicated by the amount twelve, and non-re-sulfurized grades with a most metallic element content of over 1.00%, by the amount fifteen. The suffix H when the four digits indicate steel made to prescribed hardenability limits. Types throughout the manufacture of steel, gas is employed to get rid of excess carbon from the liquid metal and to do the carbon content desired for the finished steel. Carbon and gas mix to make carbon monoxide of surface soften. If the surplus gas isn't removed, the vaporific product continues to evolve because the steel solidifies. If very little or no gas evolves throughout the natural process, the steel is oxidized. This oxidized steel is termed killed, as a result of it lies quietly within the metal bar mold.

2.10.1 Mechanical properties of carbon and alloy steel

Mechanical properties of carbon and steel alloy will include the parameters like; as rolled, normalize, annealed, Austenitizing temperature, elongation, reduction, brinell robustness, Izod impact strength, Shear Strength, Elastic (Young's, Tensile) Modulus and Shear Modulus. As rolled: rolling may be a metal forming method during which metal stock is more matured one or a lot of pairs of rolls to cut back the thickness and to create the thickness uniform. Hardening; Annealing is employed to induce softness, to change malleability, toughness, electric, magnetic or mechanical properties; or to give a precise microstructure.

Steel is toughened by heating the steel to a temperature on top of the higher important temperature, holding it there till the temperature is uniform throughout the half, then slow cooling the half through the transformation vary. The heating and cooling rates rely on the composition, form, and size of the half. Standardization is hardening method applied to metal alloys to grant the fabric an even fine-grained structure and to avoid excess softening in steel.

It involves heating the steel to 20-50°C on top of its higher crossroads, soaking it for a brief amount at that temperature then permitting it to cool down in the air. Heating the steel simply on top of its higher crossroads creates primary solid solution grains (smaller than the previous ferritic grains), that throughout cooling, kind new ferritic grains with an extra refined grain size. The method produces a harder, a lot of ductile material, and eliminates columnar grains and nerve fiber segregation that typically happens throughout casting. Normalizing improves of a part and provides dimensional stability if subjected to added heat treatment processes [27].

The coefficient of elasticity may be a mechanical property that measures the stiffness of a solid material. It defines the connection between stress (force per unit area) and strain (proportional deformation) in a very material within the linear snap regime. In materials science, shear modulus or modulus of rigidity, denoted by G, or typically S or μ, is outlined because of the magnitude relation of shear stress to the shear strain. The aim of austenitizing steel and alternative metal alloys is to rework them into the desired form and to supply strength and resistance to the fabric.

The temperature at that the steel and metal alloys are heated on top of their important temperature is termed the austenitizing temperature. usually, the austenitizing temperature ranges from 400°C (752°F) to 800°C (1472°F) for various grades of carbon, alloys and power steels. Once the austenitizing temperature is earned, correct microstructure and full hardness of steel in additional heat treatment processes may be earned. The impact may be an important development in governing the life of a structure. Impact tests are employed in finding out the toughness of fabric. A material's toughness may be an issue of its ability to soak up energy throughout plastic deformation. Brittle materials have low toughness as a result of the tiny quantity of plastic deformation that they'll endure. The impact price of a fabric cans even amendment with temperature [31].

Generally, at lower temperatures, the impact energy of a fabric is attenuated. The dimensions of the specimen may additionally have an effect on the worth of the Izod impact take a look at as a result of it should permit a distinct range of imperfections within the material, which may act as stress risers and lower the impact energy. A ductile material (most metals and polymers) can record a high elongation. Brittle materials like ceramics tend to point out terribly low elongation as a result of they are doing not elastically deform. Rubber extends by an oversized measure before failure; however, this extension is usually elastic and is recovered. Elongation is vital in parts that absorb energy be deforming elastically (e.g. crash barriers, automotive bumpers). High elongation to failure is vital for "plastic hinges" (e.g. video container boxes). Elongation is vital in producing - it measures what quantity bending and shaping a cloth will face up while not breaking. Elongation is a permanent stretch of specimen once a failure. The figure exist below shows the elongation of materials for d/f material sorts.

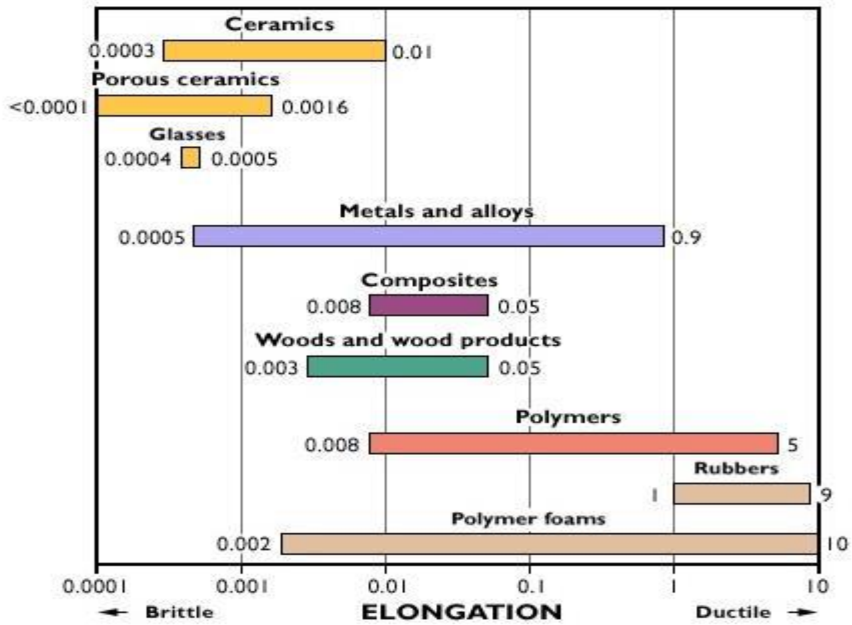


Figure 2.8. Elongation for different material

Reduction of space is live of the malleability of metals obtained in an exceedingly tensile check. It's the distinction between original cross-sectional space of a specimen and therefore the space of its smallest cross-section once testing. It's typically expressed at least decrease in original cross-section. The littlest cross-section will be measured at or once fracture. For metals, it always is measured once fracture and for plastics and elastomers, it's measured at fracture. Typically the fabric select have high strength and sensible mechanical properties. The properties of AISI 1020 with G 10200 of carbon and steel has indicates; low prices, high sturdiness, high strength, low deformation [32].

CHAPTER THREE

3 MATERIALS AND METHODS

3.1 Materials

Materials accustomed carry out this design are software system like C++, ANSYS and AutoCAD Instruments like, meter and calipers; Flash; digital Camera; stationery materials; books and journals; pc and different complimentary services the other material used for epitome preparation for demonstrations are, ingot 4x4, wire, electrode, paint material, bench work, c-lamp, welding machine, grinding machine plate disc, sheet, paraflex polyester putty, and hardener paste etc.

Table 3.1. Materials used to accomplish the research

	Materials used to accomplish the research	
No	Materials	Interpretations
1	measuring Instruments like, meter and calipers	Used to calculate the exact dimensions of material
2	Computer, Flash and digital Camera	Used for preparing the paper
3	CAD software's and c++ programming	Used to model parts and generate the graphs
4	metal bar 4x4, wire, electrode, and sheet metal	Materials used to construct prototype and the model.
5	bench work and c-lamp	Supports and tights the parts to constructed
6	welding machine	Welding machine AC power source and controls
7	Grinding and cutting machine	Used to remove the metals and cut in to apart
8	paraflex polyester putty	ParaFlex has a hard wearing surface that can be used in Exposed situations.
9	hardener paste	It is used for all types of mastics and polyester resins; add in the measure of 3%.
10	Cutting-Off and Grinding Wheels	The wheel used for hand grinding

3.1.1 Para flex polyester putty

Top Putty could be two-component polyester putty, particularly developed to fill pinholes, sand scratches, hail injury or little dents on cars surfaces and different vehicles. It's characterized by simple application and sanding, superior filling properties and quick-drying as it is indicated on figure 3.1 the paraflex is white in color and mixed with hardener paste to fill the puncture and welded a part of chassis frame.

Figure 3.1. Para flex polyester putty

3.1.2 Hardener paste

Acts as the catalyst for the polymerization of unsaturated polyester resins, particularly for the polyester putties and fast polyester rosin. Peroxide Hardener, Wholesale many top quality peroxides. Automotive refinishing paint usage and top quality peroxide hardener. Peroxide hardener for up rosin, peroxide paste five hundredths and it's red, pink and white.

3.2 Methods

In order to finish this task, there square measure many steps that had been followed through the work. First knowledge assortment has been done from manuals of native aggregation company and by the activity of the important Toyota vehicle frame of structural parts. Then CAD modeling of the structure had created by victimization the info recorded from the prevailing vehicle chassis and suspension. AUTOCAD software package was accustomed build the 3D computer model. The analytical answer has been performed for analyzing of the prevailing frame and structure for the desired results i.e. static thought of the pickup chassis frame design and model bending moment and shear force. After that, Re-modeling of the vehicle frame of structural parts victimization new size of parts and new chassis frame. When this works Comparison of the first and improved structure In terms of various parameters of the first and improved structure is going to be performed. Lastly, analysis has been validated by ANSYS software. Recommendations are going to attack the prevailing chassis frames and spring or on of relevant enhancements of the planning of recent Toyota vehicle chassis frame and spring. The project method within the type of a flowchart is given as follows.

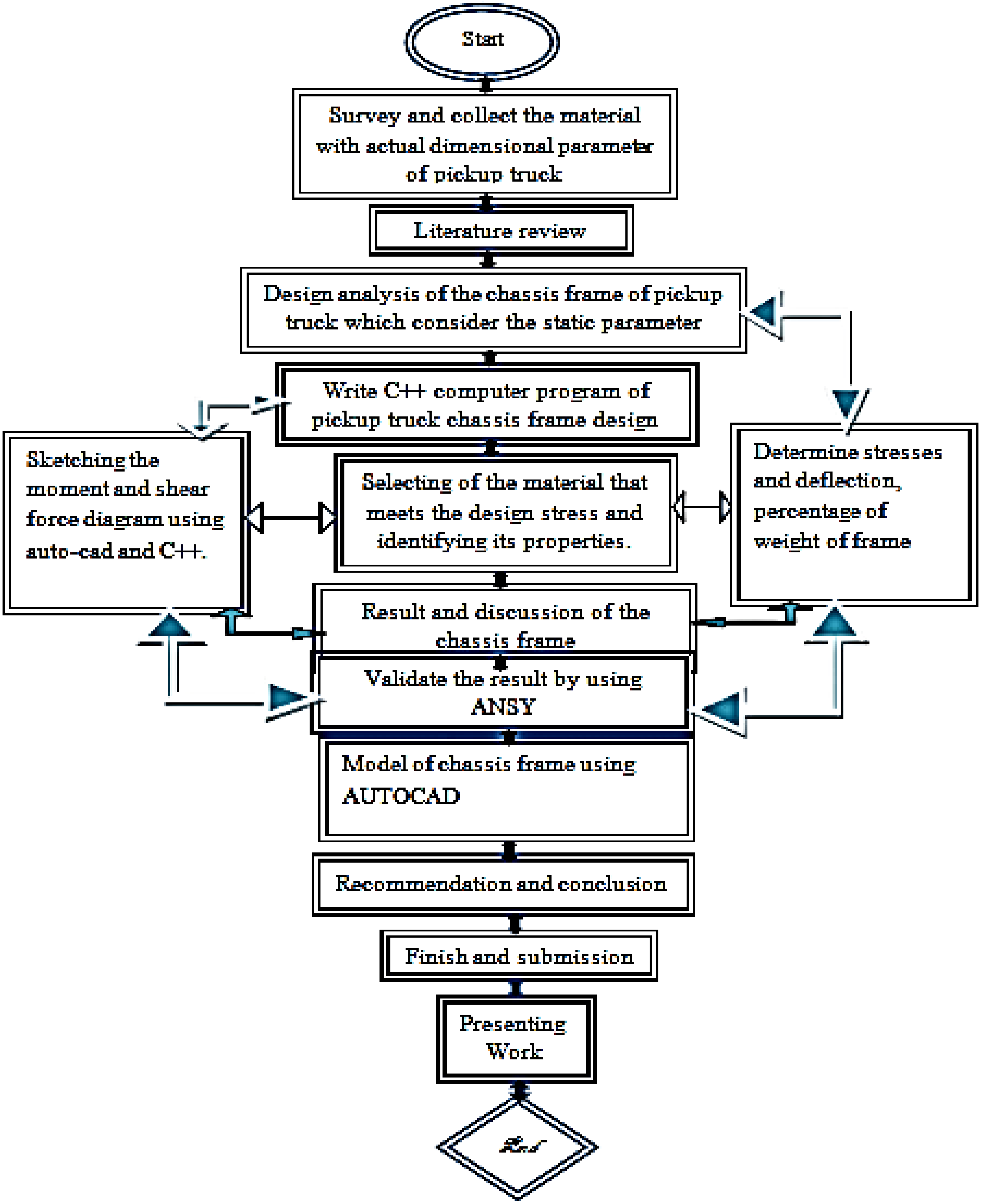


Figure 3.2. Flow chart of the design

3.3 Chassis Frame Design (CFD) and Modeling of Toyota Pickup Truck

The chassis frame is that the basic framework of the car. It supports all the elements of the car hooked up to that. It’s manufactured from drop solid steel. All the elements associated with vehicles are hooked up to that solely. All the systems associated with automobile like the power station, transmission, steering, suspension, braking system etc. are hooked up to and supported by it solely. “Chassis” a French term which implies the entire vehicles while not Body and it includes all the systems like the power station, transmission, steering, suspension, wheels tires, machine electrical system etc. while not body. If body is additionally hooked up to that them it's called the real vehicle as per the form and style of the body.

Primarily chassis is taken into account as a framework to support the body, engine and alternative elements that conjure the vehicle. Chassis lens the total vehicle support and rigidity. Chassis sometimes includes a combination of long ways extending channels and multiple cross members that run across the channels. The cross members have a reduced cross-section so as to let for a long way extending space for storing. The chassis has to contain the assorted parts needed for the auto still as being primarily based around a driver’s cockpit. The protection of the chassis could be a major side within the style and will be thought of through all stages. Generally, the fundamental chassis sorts merge backbone, ladder, house frame and monocoque. Differing kinds of chassis style result in the various performance.

3.3.1 Purpose of frame

The frame is used to:

- Support the element components of the chassis and the body.
- Face up to torsional vibration caused by the movement of the vehicle.
- Face up to the force caused by cornering of the vehicle.
- Control of the vibration caused by the running of the vehicle.
- Face up to bending stresses because of rising and fall of the front and rear axles.

3.3.2 Construction of frame

The frame is constructed to possess; the side-members and cross-members. The cross-section can be of: box, channel, tubular. This first stage of 3D model plotted by Auto-CAD to show the parts of chassis frame and connected parts.

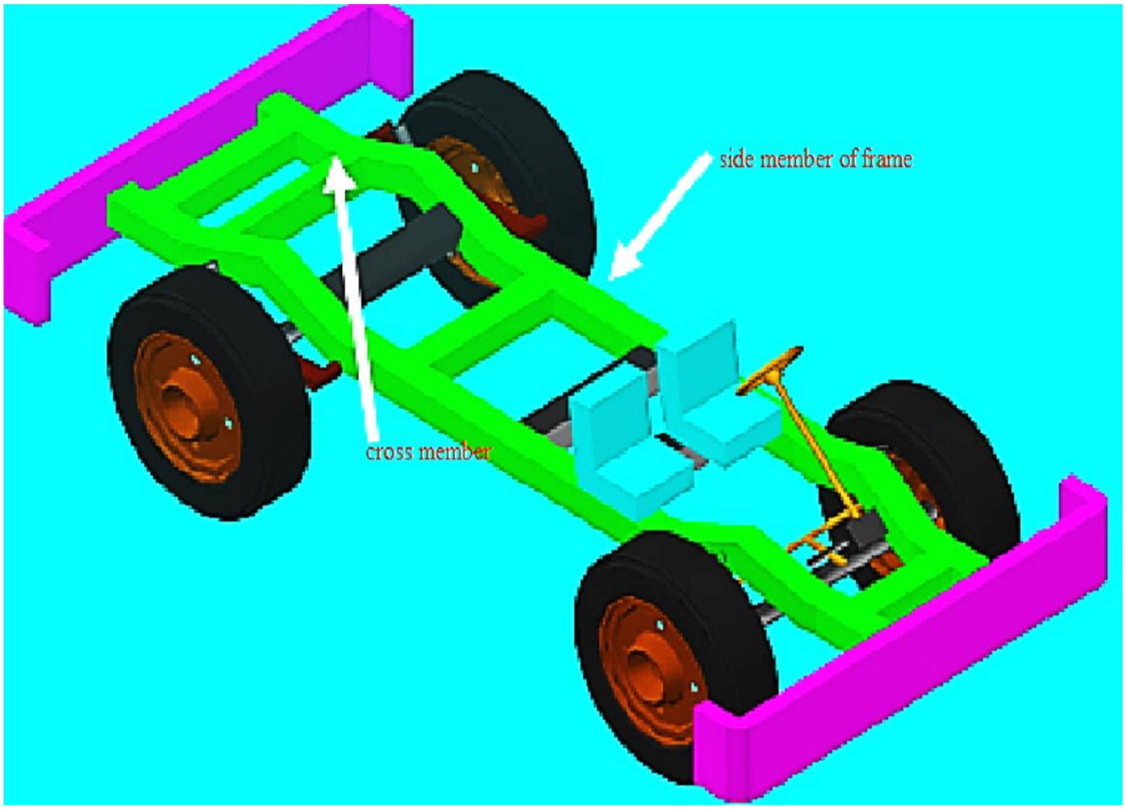


Figure 3.3. Construction of frame

3.3.3 Design Consideration of frame

As the frame supports numerous parts, it's subjected to static and dynamic masses, such as bending, shear, fatigue, shock, and twisting of the frame. The design provides of chassis frame of a pick-up truck and therefore the additional thought during this design could be a static load. Under static load, determination of shear force and bending moment with their diagram is taken into consideration. By using C++ computer program, the shear force and bending moment diagram can be generated.

The determination of the deflection initially purpose and largest purpose of the aspect frame is taken into account. The choice of fabric is taken into account once the design stress is decided. Thus determination of the design stress or operating stress is calculated by fixing the security mill from a regular specification of chassis frame manufacturer. The von-miss is employed in decisive of style stress. Parameters of the trucks are obtained from technical specifications document and real. Then using the parameter dimension the model is obtained by means of AutoCAD software system because it is expressed below the drawing. connected components that are connected to chassis frames such, spring, tire, axle, coil-spring, steering, damper, and bush are model using AutoCAD however the analytical calculation are solely restricted to the chassis frame of a truck. Generally, the design of chassis frame of truck flows from live to the design stress, shear, forces, deflection, and extra.

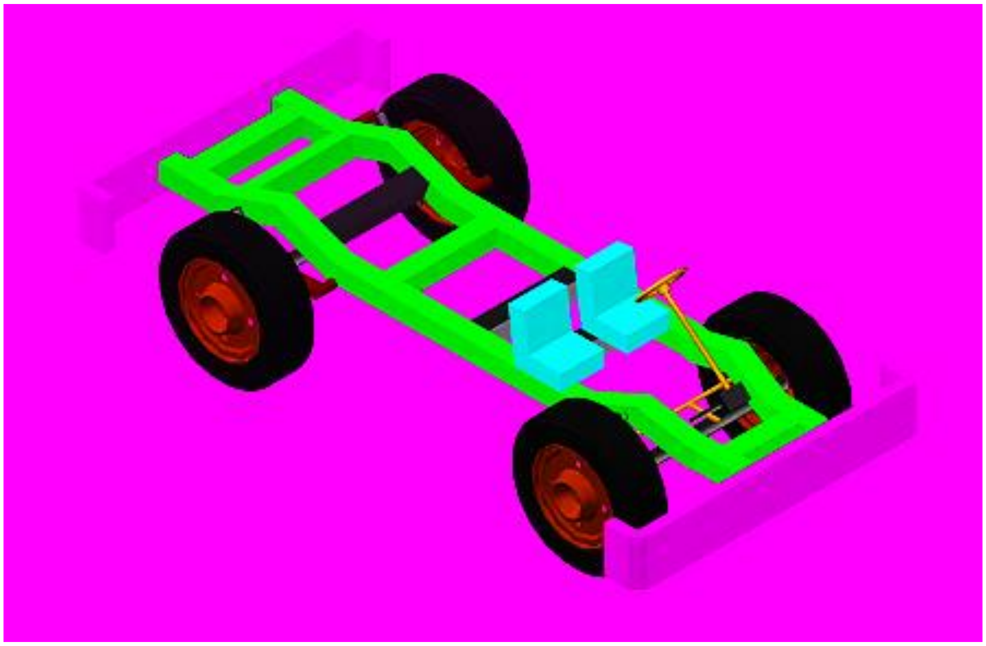


Figure 3.4. Model of chassis frame and some connected parts of pickup chassis frame

3.3.4 Dimensional parameters

Table 3.2. Specification of Toyota vehicle ggn15r-trdmkl3 pickup chassis frame #1[30]

Total load (W)	7640 kg
Total length of the side frame (L)	4864mm
Width of the chassis	1140mm
Wheel basa (b)	3085mm
Rear hang	1005mm
Front hang	774mm

Table 3.3. Height of gravity center

Height of Gravity Center		
Model		Gravity Center Height of Base Vehicle (C&C) Mm
	Single Cab	560
	Extra Cab	570
2WD	Double Cab	585
	Single Cab	660
	Double Cab	685
Pre-runner	Extra Cab	670

Table 3.4. Specification of Toyota vehicle ggn15r-trdmkl3 pickup chassis frame #2

	Body type					Single cab
	Drive system					4x2
	Model code					GGN15R-TRMDKQ3
		Length			mm	5130
		Width			mm	1760
		Height			mm	1680
	Wheel base				mm	3085
		Front			mm	1510
		Rear			mm	1510
	Cab end to rear axle				mm	1310
	Fuel tank capacity				Liters	76
	Seating capacity				Persons	3
Weights	Unsprung weight axle			Front	Kg	90
				Rear	kg	180
	Chassis and cab curb weight			Front	kg	865
				Rear	kg	660
	Growth vehicle weight			Front	kg	1070
				Rear	kg	1750
	Max. permissible axle capacity			Front	kg	1125
				Rear	kg	1750
Chassis	Chassis frame			Length	mm	4864
				Front over hang		774
				Rear over hang		1005
	Leaf spring	Size	L*W*H*n-1		mm	1270*60*8-1

Table 3.5. Specification of Toyota vehicle ggn15r-trdmkl3 pickup chassis frame #3

Chassis	Minimum Turning Radius				M	5.9
	Transmission	Model				R150
		Gear Ratio		1^{st}		3.83
				2^{nd}		2.062
				3^{rd}		1.436
				4^{th}		1
				5^{th}		0.838
				Rev		4.22
	Differential	Gear Ratio				3.583
	Front Suspension	Coil Spring	Size	Diameter	mm	156.4
				Height(Set)	mm	191
				Diameter of Wire	mm	16.4
				Rate	N/mm	77.9
Engine	Engine	Type				1GR-FE
		Displacement			Cc	3956
		Max. Power			kw/rpm	175/5200
		Max. Torque			N.m/rpm	343/2400-4800

The sidebar of the present chassis frame is made up of “rectangular cross-sectional and C Channel in some case” during this design hollow rectangle and square cross-section is provided b/c of thought of deformation and price reduction within the style. In a number of the researchers, the I-section is additionally used however it's abundant price. If the value is redoubled the client flow becomes weakened. C-channel the reduction in weight is extremely medium however this can cause most deformation and medium price. So the deformation goes to fail the vehicle chassis frame.

The customers will not satisfied if the failure has occurred frequently. Usually to extend the lifetime of the vehicle chassis frame by reducing the deformation and prices the customer become glad. So to full fill the costumer wants, the hollow rectangular cross-sectional is taken into account during this design.

3.3.5 Basic Calculation for Chassis Frame

Model No. = Toyota pickup

Capacity of Truck = 7.64 ton (Kerb Weight+ Payload)

= 7640 kg = 7640×9.81=74948.4 N

Capacity of Toyota with 1.2% = 74948.4 × 1.2 N = 89938.08N

But the gross vehicle weight is measured by kg units which is equal to 2820 kg.

The load distribution of front hang is the ratio of front hang to the vehicle gross weight.

Load distribution by percentage = front hang/vehicle gross weight ×100 %.

$$\text{Load distribution by percentage} = \frac{\text{front hang}}{\text{vehicle gross weight}} \times 100\%.$$

$$W_f = \frac{Fo}{Wv1} \times 100\% \quad \text{......3.1}$$

Where; W_f = load distribution on front overhang of Hilux pick up

Fo = front overhang of Hilux chassis

Wv1= vehicle gross weight.

Fo = 1070 kg

Wv1 = 2820 kg

Then; W_f = 1070/2820×100%

W_f = 0.38×100%

= 38%

The load distribution on the rear over hang is equals to the total percentage of the Hilux pick up chassis minus of the front overhang of the chassis Hilux.

Rear over hang is denoted by Ro.

Ro = 100%-38%

Ro = 62%

Total load acting on the frame is the product of vehicle gross weight by the total GRAVITY of Hilux pickup chassis frame.

W = wv1×g

W = 2820 kg × 9.81m/s^2

W = 27,664.42N

The load distribution on single frame is equal to the half of total load distribution of the Hilux pick up chassis frame.

W_s = 0.5×W

= 0.5×27,664.42N

= 13832.1 N

3.3.6 Load analysis of frame

Static analysis calculates the consequences of steady load conditions on a structure of chassis frame of pickup truck, whereas ignoring inertia and damping effects, like those caused by time variable masses. A static analysis, however, includes steady inertia masses like gravity and motility speed, and time-varying masses that may be approximated as static equivalent masses like the static equivalent tire reaction masses and vehicle weight and payload.

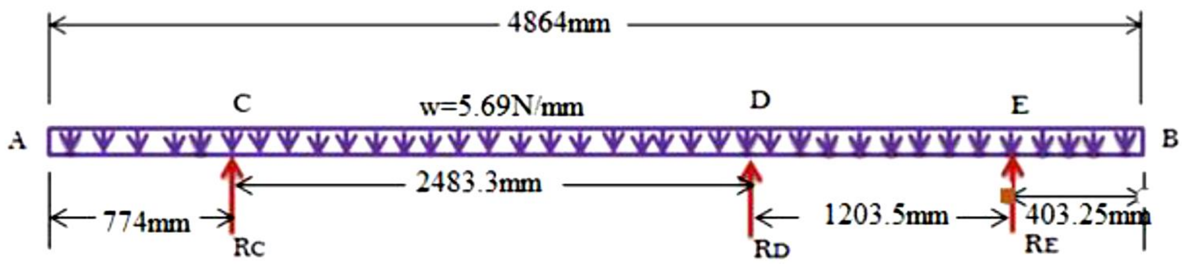


Figure 3.5. Free body diagram of chassis components

3.4 Loading Conditions

Beam is just clamp with shock and spring. Thus Beam could be a merely Supported Beam with uniformly distributed load. Load performing on Entire span of the beam is 27,664.42N. Length of the Beam is 4.864 m. The chassis frame of the pickup is connected to reaction forces at the front of the truck and reaction force at the rear end of the truck. The reaction force at the front of the frame is supported by coil spring of the pickup and also the reaction at the rear is supported by the leaf spring of the pickup. The end point of the leaf spring is denoted by the reaction at point D and reaction at point E that are connected to the chassis frame at the end point. The reaction are expressed on the below chassis frame of the truck.

Therefore;

R_C = reaction at the front side of point C

R_D = reaction at the rear side of point D

R_E = reaction at the rear side of point E

$$W = \frac{F}{L} \quad \ldots\ldots 3.2$$

Where;

W = Uniformly Distributed Load

F = Force acting on the chassis frame

L = Length of pickup frame

$W = \frac{27,664.42 \text{ N}}{4864 \text{ mm}}$ = 5.69 N/mm

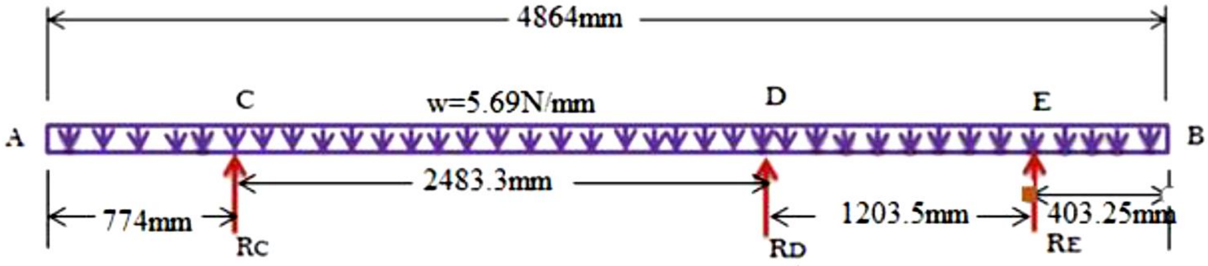


Figure 3.6. Total load generated on the beam

3.5 Fixed End Moment

This is the indeterminate structure of beam. A structure during which the laws of statics don't seem to be comfortable to see all the unknown forces or moments is claimed to be statically indeterminate. Such structures area unit analyzed by writing the acceptable equations of static equilibrium and extra equations touching on the deformation and constraints referred to as compatibility condition. The statically indeterminate structures are used for many benefits.

It is comparatively a lot of economical within the demand of fabric because the most bending moments within the structure are reduced. The statically indeterminate are a lot of rigid resulting in smaller deflections. The disadvantage of the indeterminate structure is that they're subjected to stresses once subjected to temperature changes and settlements of the support. The development of indeterminate structure is tougher if there are dimensional errors within the length of members or location of the supports.

3.5.1 Calculation of bending moment

Shear force and bending moment of the chassis frame of pickup diagram can be calculated analytically and generate exploitation c++. Remained that from mechanics of materials the interior forces P (generic axial), V (shear) and M (moment) indicates the resultant of stress distribution performing on the cross section of the beam. Internal Axial Force (P) ≡ equal in magnitude however opposite by direction to the algebraic sum of total (resultant) of the parts within the direction parallel to the axis of the beam of all external masses and support reactions performing on either aspect of the section being thought of. T ≡ Tension C ≡ Compression

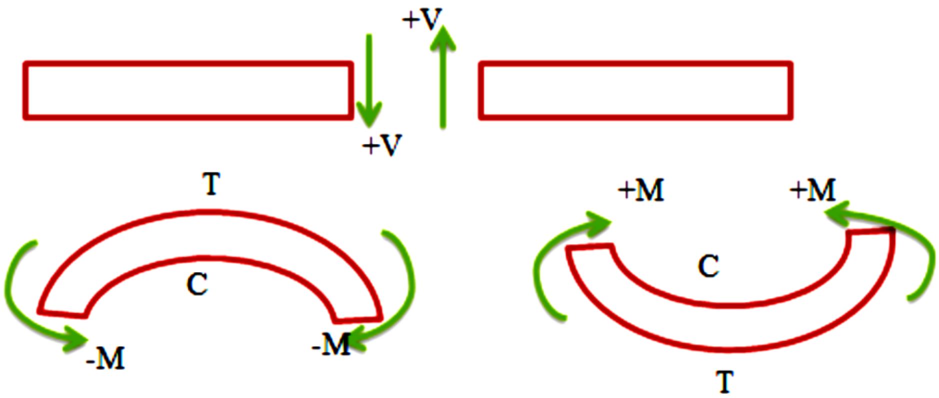
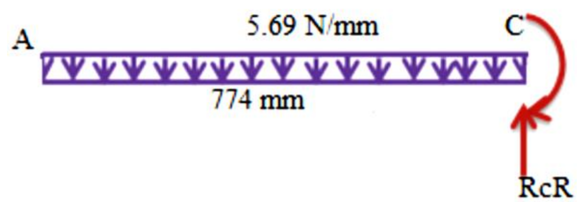


Figure 3.7. Beam sign convention for shear and moment

Internal Shear Force (V) ≡ equal in size or magnitude however opposite in direction to the algebraic sum (resultant) of the elements within the direction perpendicular to the axis of the chassis frame of all external loads and support reactions performing on either aspect of the section being thought-about. Internal Bending Moment (M) ≡ equal in size however opposite in direction to the algebraic add of the moments about (the center of mass of the cross-section of the beam) the section of all external loads and support reactions performing on either aspect of the section being thought-about. Positive Sign Conventions: Tension axial force on the section Shears that produce clockwise moments and bending moments that produce compression within the high fiber and tension within the bottom fibers of the beam as shown on the above figure. Shear and bending moment diagrams are represent the dissimilarity of those quantities on the length of the member. Continuing from one finish of the member to the opposite, sections are passed. when every sequential modification in loading on the length of the member, a FBD (Free Body Diagram) is drawn to see the equations expressing the shear and bending moment in terms of the gap from a convenient origin. Plotting these equations produces the shear and bending moment diagrams. Bending moment may be a torsion applied to every aspect of the beam if it had been cut in 2 anywhere on its length. The hinge applies a clockwise (+) direction of moment (torque) to the RHS, and a counter-clockwise (-) direction of moment to the LHS. Procedure to seek out BM at any cross-sectional within the beam: Cut beam through that section, then add moments for the correct or left aspect solely. Ignore + or - sign, and use the later definition for +/-

a)



$$M_{ca} = -\frac{w(a)^2}{2}$$

Where;

W = uniformly distribution load in Newton per meter

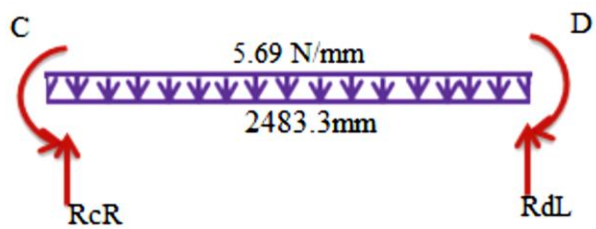
a = length at point AC in meter

M_{ca} = moment at point ca

$$M_{ca} = \frac{5.69\times774\times774}{2}$$

= -1704371.22 Nmm

b)



$$M_{CDL} = -\frac{wb^2}{12}$$

$$M_{CDR} = \frac{wb^2}{12}$$

Where;

W = uniformly distribution load in Newton per meter.

M_{CDL} = moment at the left side of point CD in newton meter.

$M_{DCR =}$ moment at the right side of point CD in newton meter.

b = length between C and D.

$$M_{CDL} = -\frac{wb^2}{12}$$

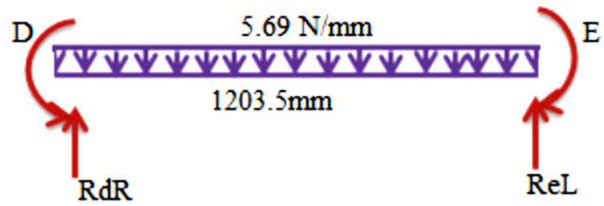
$$M_{CDL} = \frac{-5.690\times2483.3\times2483.3}{12}.$$

$$M_{CDL} = -2924080.99 \text{ Nmm}.$$

$M_{DCR} =_{+} M_{CDL}$

M_{DCR} = 2924080.99 Nmm

c)



$$M_{DE} = -\frac{\mathbf{wc^2}}{\mathbf{12}}$$

Where; W = uniformly distribution load in Newton per meter.

M_{DE} = moment point DE in newton meter.

M_{ED} = moment at the right side of point ED in newton meter.

c = length between D and E.

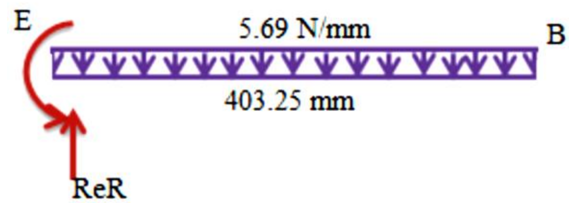
$M_{DE} = \frac{-5.69 \times 1203.5 \times 1203.5}{12}$.

M_{DE} = - 686788.80 N mm.

$M_{ED} = +M_{DE.}$

M_{ED} = 686788.80 N mm

d)



$M_{EB} = -\frac{wd^2}{2}$

Where;

M_{EB} = moment point EB in newton meter.

d = length between E and B.

$M_{EB} = \frac{-5.69 \times 403.25 \times 403.25}{2}$

M_{EB}= -462627.05 Nmm.

Total restraint at point C

$M_C = M_{CA}+M_{CD}$……………………………………………………………….…….3.3

M_C = (1704371.22-2924080.99) Nmm.

M_C = - 1219709.77 Nmm

Total restraint at E

$M_E = M_{ED}+M_{EB}$…………………………………………………..……...…………3.4

M_E = 686788.80-462627.05

M_E = 640521.75 Nmm

For span CD

$M_{CD} = -M_{CA}$

M_{CD} = -1704371.22Nmm.

$M_{DC} = M_{DC}-M_{C/2+}$3EIib/l

M_{DC} = 2924080.99+1219709.7 /2+3EIib/2483.3

MDC = 3533935.88 Nmm +0.001208069EIib……………………..…...…………...3.5

For span DE

$M_{DE} = -M_{EB}$……………………………………………………………….………3.6

M_{ED} = -(-462627.05Nmm)= 462627.05 Nmm

$M_{DE} = M_{DE}-M_E$/2+3EIib/l

M_{DE}= 686788.80 Nmm - 640521.75 Nmm /2+3EIib/403.25m.

M_{DE}=366527.92Nmm+0.00744 EIib…………………………………....………...3.7

Then, by solving equation 3.3 and 3.5

$M_{DC} + M_{DE} = 0$

3533935.88 Nmm + 0.001208069EIib + 366527.92 Nmm+0.00744 EIib =0

3900483.8 = - 0.008647622EIib

EIib = 3900483.8 /- 0.008647622

EIib = -451044668.7……………………….……………………………………3.8

Substitute equation 3.6 in to 3.3 and 3.5 respectively for determining M_{DE} and M_{DC}

M_{DC}= 2988762.70 Nmm.

M_{DE}= -3124557.81 Nmm.

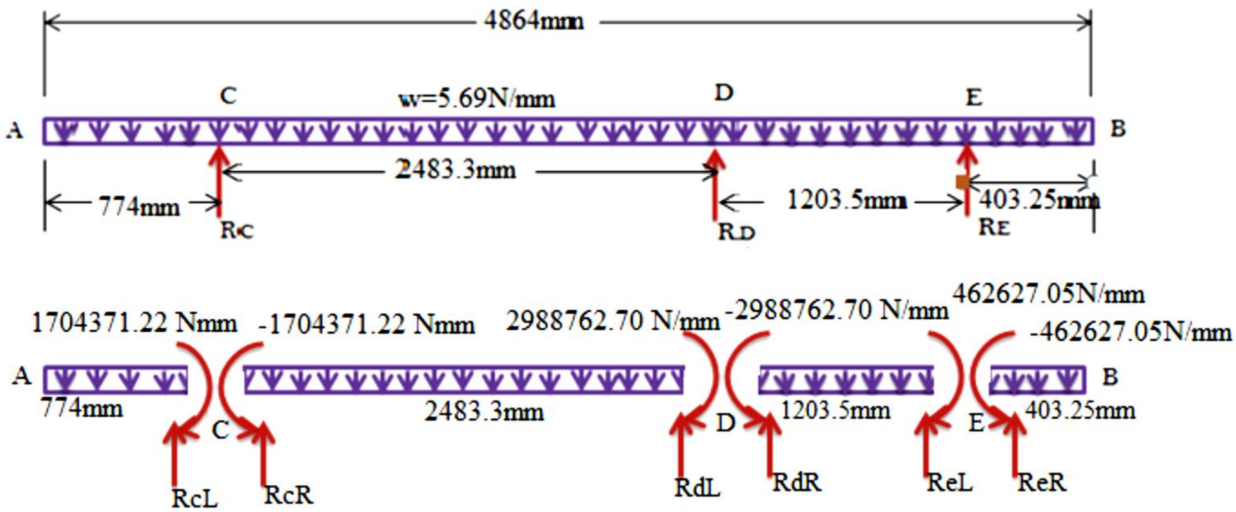
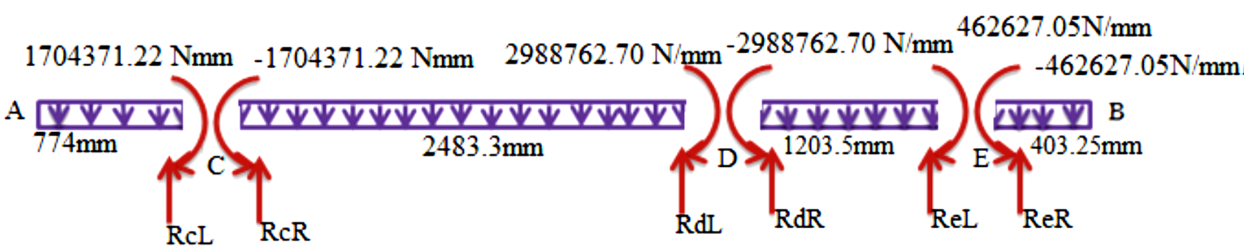


Figure 3.8. Fixed end moment

3.5.2 Calculation for reaction forces and shear force

Determine reaction force; Reactions Structural elements are typically control in equilibrium by being secured to rigid fixing points; these are typically alternative components of constant structure. The fixing points or supports can react against the tendency of the applied forces (loads) to cause the member to maneuver. The forces generated within the supports are referred to as reactions. In general, a support needs to be control or supported at a minimum of two points.

3.5.2.1 Determine reaction force



Where;

R_{cL} = Reaction at left side of point C

R_{cR} = Reaction at right side of point C

R_{dL} = Reaction at left side of point D

R_{dR}= Reaction at right side of point D

R_{eL} = Reaction at left side of point E

R_{eR} = Reaction at right side of point E

$a = 774$ mm

$b = 2483.3$ mm

$c = 1203.5$ mm

$d = 403.25$ mm

$L = a + b + c + d = 4864$ mm.

<u>For point of C, D, E</u>

$\sum F_Y = 0$……………………………………………………………………………………3.9

Where;

F_Y = The sum of all vertical forces

$R_C + R_D + R_E - W = 0.$

$R_{cL} = W \times a.$

$R_{cL} = 5.69 \times 774$

R_{cL}= 4404.06 N

$R_{cR} = \frac{W\times b}{2} + \frac{MCa-MDC}{b} = \frac{5.69\times2483.3}{2} + \frac{1704371.22 - 2988762.70}{24833}$

$R_{cR} = 6559.48$ N

$R_{dL} = W \times b - R_{cR} = 5.690 \times 2483.3 - 6559.48$

$R_{dL} = 7570.497$ N

$R_{dR} = \frac{W\times C}{2} + \frac{MDE-MED}{C} = \frac{5690\times1203.5}{2} + \frac{686788.80 - 3124557.81}{1203.5}$

$R_{dR} = 5498.82$ N

$R_{eL} = W \times c + R_{dR} = 5.69 \times 1203.5 - 5498.82$

$R_{eL} = 1349.09$ N.

$R_{eR} = W \times d = 5.690 \times 403.25$

$R_{eR} = 2294.49$ N

$R_C = R_{cL} + R_{cR}$…………………………………………………………….……..…….3.10

$$R_C = 10963.54 \text{ N}$$

$R_D = R_{dL} + R_{dR}$…………………………………………………………….………......….3.11

$$R_D = 13068.58 \text{ N}$$

$R_E = R_{eL} + R_{eR}$……….…………………..…………………...…………..……….3.12

$$R_E = 3643.98 \text{ N}$$

Hence, the summiting of total force along F_Y direction is equals to zero

$$\sum F_Y = R_C + R_D + R_E - W \ldots\ldots\ldots\ldots\ldots 3.13$$

$$\sum F_Y = 10963.54 + 13068.58 + 3643.98 - 5.69 \times 4864.$$

$$\sum F_Y = 0.$$

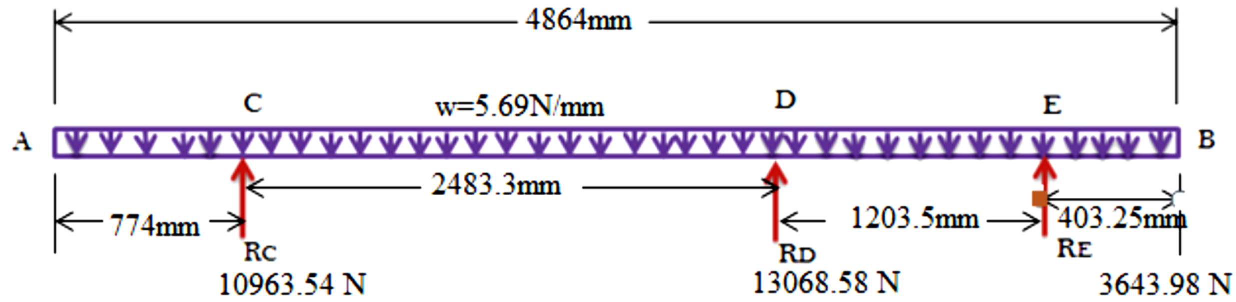
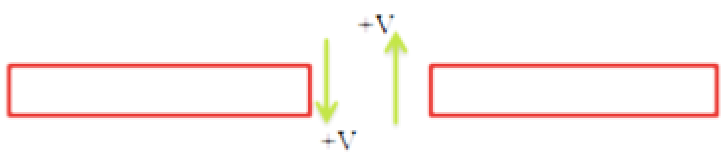
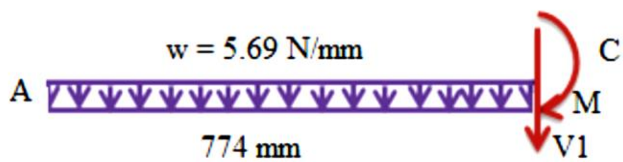


Diagram of reaction beam of single chassis frame

3.5.2.2 Calculation of the shear force on side of chassis frame





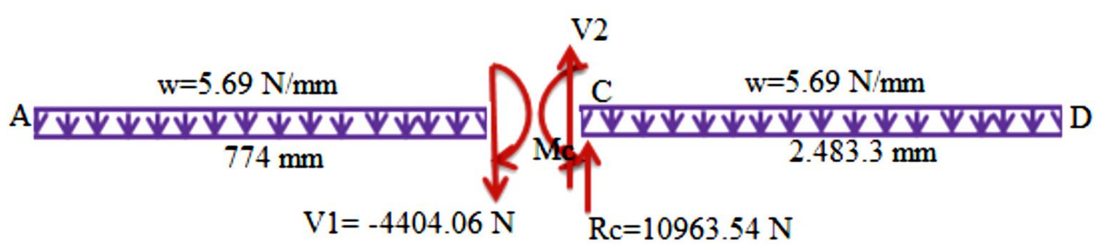
$$V1 = -W \times a$$

$$V1 = -5.69 \times 774$$

$$V1 = -4404.06N$$

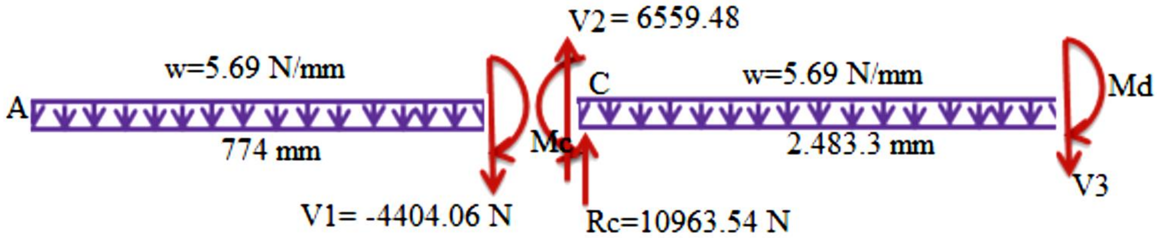
$$V2 = V1 + RC$$

.



$$V2 = 10963.54 - 4404.06.$$

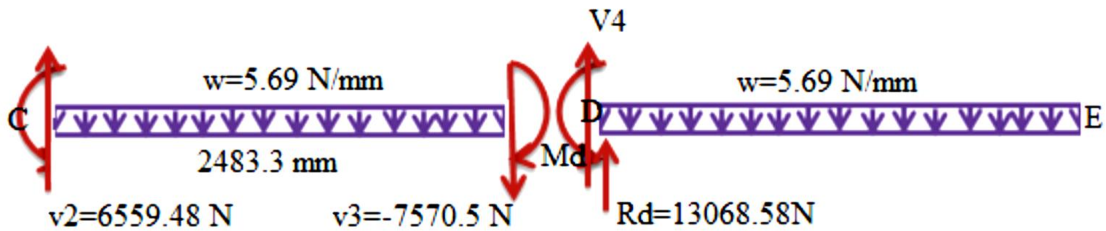
$$V2 = 6559.48N.$$



V3 = V2-Wb

V3 = 6559.48-5.6×2483.3

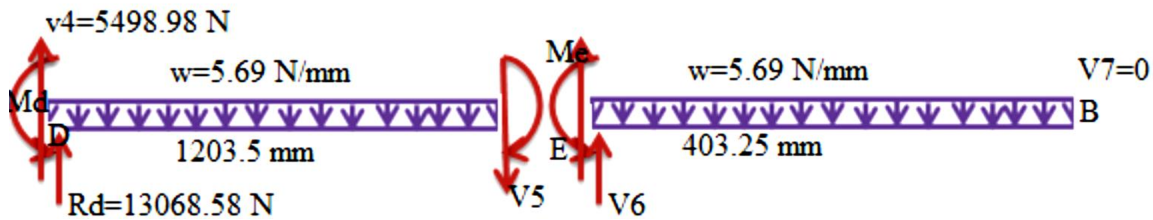
V3= -7570.49 N



V4 = V3 + RD

V4 = -7570.49 +13068.58

V4 = 5498.89 N



V5 = V4-W×C

V5 = 5498.89-5.69×1203.5

V5 = -1349.83 N

V6 = V5+RE

V6 = -1349.83+3643.98

V6 = 2299.14 N

V7 = V6-W×d

V7 = 2299.14-5.69×403.25

V7 = 2299.14-2299.14

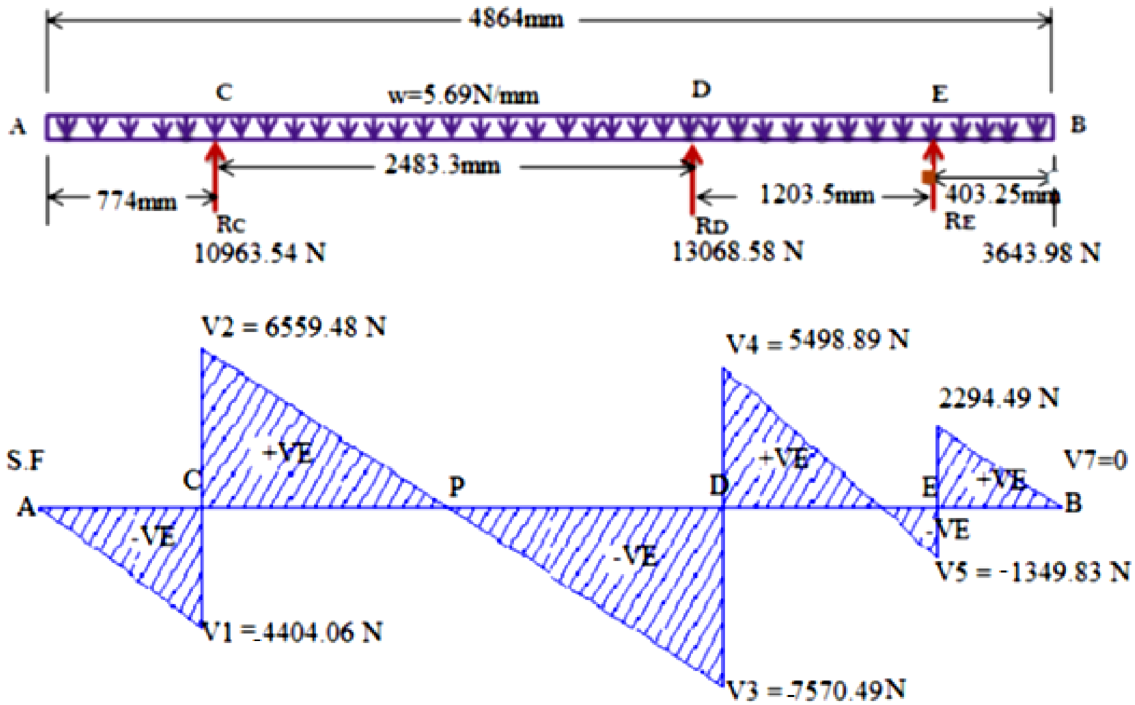


Figure 3.9 shear force diagram

3.5.3 Designs for bending moment diagram

M_A=0 N-mm

M_C= - M_{CA}= -1704.37 Nm

M_P= $Wb^2/8$

M_P=5.69N/mm×$2483.3^2/8$

= 4386121.49 Nmm

M_D= M_{DE}= = -2959.68 Nm

MQ=$Wc^2/8$

MQ=5.69N×1203.5^2m/8

MQ= 1030183.21Nmm

ME=MEB

ME=-462.62 Nm

M_B= 0 Nm

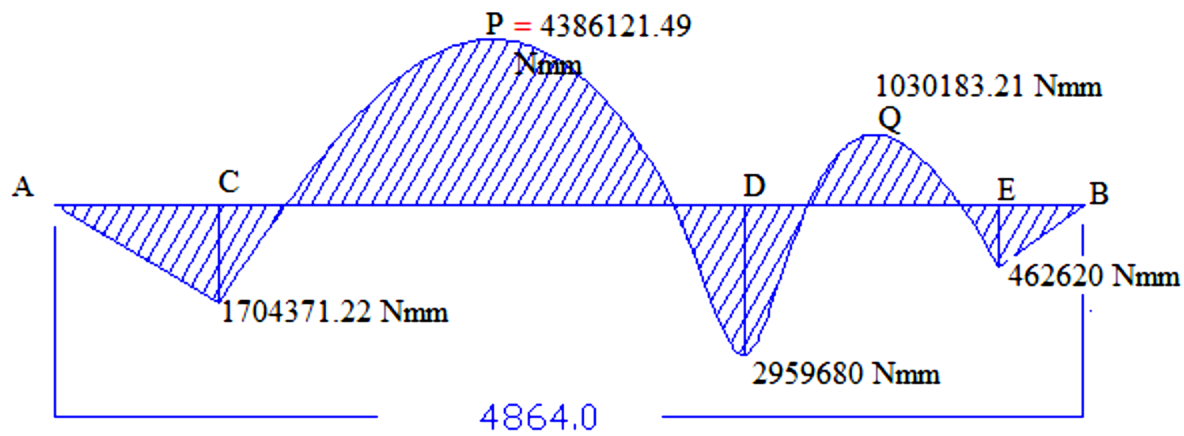


Figure 3.10. Bending moment diagram of Toyota pick up

3.6 Calculations for the Chassis Frame Deflection

When a chassis is subjected to the action of applied loads, every member undergoes deformation because of that the axis of frame structure is deflected from its original position. The deflections conjointly occur because of temperature variations and lack-of-fit of members. The deflections of frame structures are vital for making certain that the designed structure isn't overly versatile. The big deformations within the structures will cause injury or cracking of non-structural parts. The deflection in chassis frame depends on the acting bending moments and its flexural stiffness. The computation of deflections in frame structures is additionally needed for finding the statically indeterminate structures.

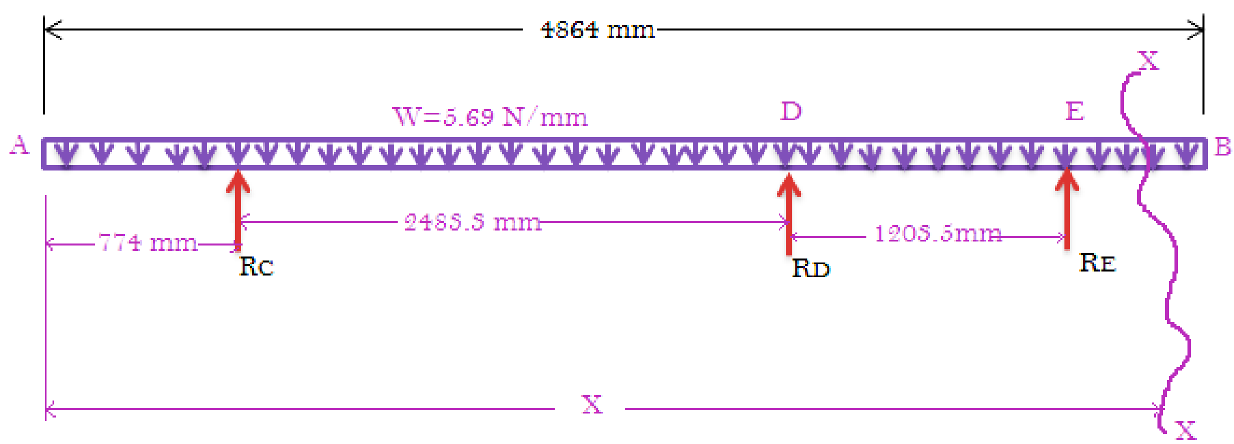


Figure 3.11. Supporting force generated on the beam

We consider a section x-x in "EB" span at x distance from A. Taking moment of all forces about x-x section

M_{XX} = 5.690x^2 + RC(x-774) + RD(x-3257.3) + RE (x-4460.8)…………………….……..3.14

According to Macaulay's theorem

M_{xx}= EI$\frac{d2y}{dx2}$=5.690/2$\mathbf{x^2}$ + RC(x-774) + RD(x-3257.3) + RE (x-4460.8)…………..……..3.15

Then; integrated with respect to x and you get

$$EI\frac{dy}{dx} = -5.690\frac{x^3}{6} + \frac{Rc(x-774)^2}{2}+\frac{Rd(x-3257.3)^2}{2} + \frac{Re(x-44608)^2}{2}+c$$

Again the second integration equation 3.12 of with respect x value will be give the following result

$$EIy = -5.690\frac{x^4}{24} + \frac{Rc(x-774)^3}{6}+\frac{Rd(x-3257.3)^3}{6} + \frac{Re(x-4460.8)^3}{6}+cx+c2$$

$$Y = \frac{1}{EI}[-5.690\frac{x^4}{24} + \frac{Rc(x-774)^3}{6}+\frac{Rd(x-3257.3)^3}{6} + \frac{Re(x-4460.8)^3}{6}+c1x+c2] \text{…..……3.16}$$

Choose the boundary conditions to evaluate the value of c1, c2 and the general deflection of the chassis frame.

$$EIy = -5.690\frac{x^4}{24} +cx+c$$

When x = 774mm and y = 0

$$0 = \frac{1}{EI}[-5.690\frac{x^4}{24} +c1x+c2]$$

$$0 = \frac{1}{EI}[-5.690\times \frac{774^4}{24} +774c1+c2] \text{………………...…………...………..……………3.17}$$

$$0 = -8.50873244\times 10^{10}+774c_1+c_2$$

When x = 4460.8 and y = 0

$$0=\frac{1}{EI}[-5.69\times \frac{4460.8^4}{24}+\frac{Rd\times(4460.8-3257.3)^3}{6} +c1\times4460.8+c2] \text{....................................3.18}$$

$$0=-9.38754503 \times 10^{13} +4460.8\ c_1 + c_2 +10963.54 \times \frac{(4460.8-774)^3}{6} +13068.58 \times \frac{(4460.8-3257.3)^3}{6}$$

Solve equation 3.14&3.15 to compute the value of c1&c2.

C1= 4.4148×10^{08}

C2 = -2.5661819×10^{11}

Then, put the value of c1&c2 in to equation 3.13

$$Y = \frac{1}{EI}\left[-5.690 \times \frac{x^4}{24}\ 4.4148 \times 10^{08}x\ -2.5661819 \times 10^{11} + \frac{13068.58N \times (x-3.2573)^3}{6} + \frac{3643.98 \times (x-4.4605)^3}{6}\right] \qquad 3.19$$

The above equation is the common or the general equation for deflection in the chassis of the pickup. The deflections at the reaction or the supports of point (C, D, and E) are zero.

3.7 Analysis for Stress

Macaulay's methodology is employed to seek out the bending moment at any general section X-X of the beam. The Macaulay's methodology helps to seek out one expression for bending moment throughout the whole span of the beam. It's accustomed cowl all loading conditions. Finding moment at x—x, taking clockwise direction as positive,

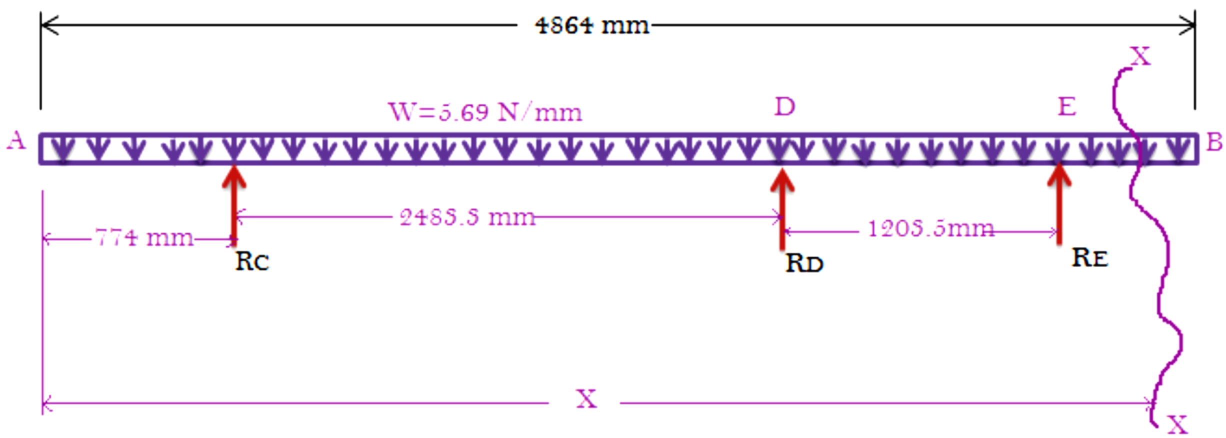


Figure 3.12. Section X-X of beam

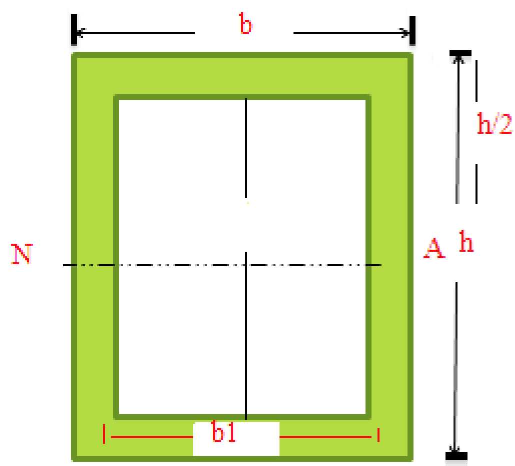


Figure 3.13 Hollow rectangular cross-section

where as;

y_{max} = Distance of the outmost layer from the neutral axis.

Y = Distance of C.G of area from neutral axis.

I = Moment of inertia about neutral axis.

Z =Section modulus.

F- Vertical shear force acting on the section

Stress due to bending moment (σx) Where;

b = 70mm, h = 140mm, b_1 = 65mm and h_1 = 130mm

$I = \frac{b \times h^3 - b_1 \times h_1^3}{12} = \frac{70 \times 140^3 - 65_{1\times} 130_1^3}{12}$ mm4

I = 4106250 mm^4 $\quad ymax = \frac{h}{2} = \frac{140 \text{ mm}}{2} = 70$ mm

$Z = \frac{I}{Ymax} = \frac{4106250 \text{ mm4}}{70 \text{ mm}}$, Z = 58660.70 mm^3

$\sigma = \frac{M}{I} \times y = \frac{M}{I/y} = \frac{M}{Z}$

$\sigma = \frac{M}{Z}$

$\sigma = \frac{4386121.49 \text{ Nmm}}{58660.70 \text{ mm3}}$

$\sigma = 75 \text{ N/mm}^2$

3.7.1 Shear stress

When the chassis frame is loaded the shear force at a district invariably comes in to play beside the bending moment it's been determined that the impact of shear stress, as compared to the bending stress, is sort of negligible and is that if not importance. However typically the shear stress at a district is far of importance within the style it's going to be noted that the shear stress within the beam isn't uniformly distributed over a crosswise however varies from zero at the outer fibers to a most at as a neutral surface. The shear stress of parallelogram is given as shear stress at any section acts within the plane right angle to the plane of the bending stress. Its value is given as

$\boldsymbol{\tau} = \frac{\mathbf{F \times A \times \bar{y}}}{\mathbf{I \times b}}$……………………………………………………………………………...…….3.20

Where;

F = vertical shear force acting on the section,

A = area of beam above neutral axis,

I = moment of inertia of section about neutral axis,

b = width of section under consideration and

$\bar{y} =$ Distance b/n the C.G. of the area and the neutral axis.

Since the shear stress is that the 0.5 the axial stress, the applied shear force is increased by one point one four to satisfy sensible yield strength. This information is declared in step with the principal stress from strength of materials and failure theories 2010 state of stress [30]. so the most shear force applied on rectangular cross-sectional of the frame is given as -7570.49N from the diagram shear force and it will be 5 range of crosswise are provided which supplies in step with this design. The fruitful of those parameters are offers the shear force cause on the frame chassis of the pickup trucks can measure 55437.69 N on all range of frame cross section.

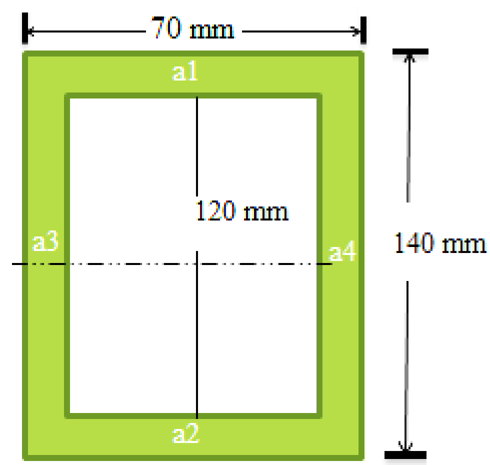


Figure 3.14. Cross-section of frame

From the above rectangular cross-section we can determine the total area to solve the distance b/n the C.G. of the area and the neutral axis.

$$a_T = a1 + a2 + a3 + a4$$

Where; a_T is the sum of area of the rectangular cross-section

$a_T = [70 \times 10 + 70 \times 10 + 140 \times 10 + 140 \times 10]\ mm^2$

$a_T = 3800\ mm^2$

` $\tau = 174580.65 N/m^2 = 174.6 KN/m^2$

$$\bar{y} = \sum \frac{ya}{a_T}$$

$$\bar{y} = \frac{[70 \times 10 \times 5 + 120 \times 10 \times 60 + 70 \times 10 \times 135 + 120 \times 10 \times 60]\mathrm{mm3}}{3800\ \mathrm{mm2}}$$

$$\bar{y} = 63.68\mathrm{mm}$$

To determine shear stress use equation the formula on equation 3.17

$$\tau = \frac{55437.69\ \ \mathrm{N} \times 3800\ \mathrm{mm2} \times 63.68\mathrm{mm}}{4106250\ \mathrm{mm4} \times 70\ \mathrm{mm}}$$

$$\tau = 46.67\ \mathrm{N/mm2}$$

3.7.2 The Von-mise stress

$$\boxed{\sigma_v = \sqrt{\frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_1 - \sigma_3)^2}{2}}}$$

When σ_3=0, the von Mises stress is:

$$\sigma_v = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2}$$

When only $\sigma_x$and τ_{xy} are present (as in combined torsion and bending/axial stress or pure torsion), there is no need to calculate the principal stresses, the Von-Misses stress is:

$$\sigma_v = \sqrt{\sigma_x^2 + 3\tau_{xy}^2}$$

$$\sigma_v = \sqrt{75^2 + 3 \times 46.67^2}.$$

$$\sigma_v = 110.3\ \mathrm{N/mm2}.$$

Note that in pure shear or pure torsion σ_x=0. If σ_x=0, then

$$\sigma_v = \sqrt{3\tau_{xy}^2} = \sqrt{3}\tau_{xy}$$

According to distortion energy theory, yielding occurs when σ_v reached the yield strength Sy. Thus in pure shear, yielding occurs when τ_{xy} reaches 58% of Sy. The Dynamic Loading should be thought of because the vehicle traverses uneven road surfaces. As an example, the vehicle could leave out a hump-back bridge at such a speed that the wheels leave the bottom. The ensuing impact of the vehicle returning to earth is cushiony by the suspension however inevitably causes a substantial increase in loading over the static condition. Expertise gained by vehicle makers indicates that the static masses ought to be enlarged by factors of 2.5 to 3.0 for road going vehicles. Cross-country or cross-country vehicles could also be designed with factors of four (Pawlowski, 1964). Thus looking on the expertise of manufacturer, the manufactory of safety is often thought of as 3 n = three within the style of chassis frame for pickup trucks.

3.8 Design Chassis Frame Using Factor of Safety

Working stress is fascinating to stay the strain under the most or final stress at that failure the materials takes place. This stress is thought because the working stress or design stress.it is additionally referred to as allowable stress or safe. Factory of safety is outlined because the quantitative relation of maximum stress to the working stress. However just in case of ductile materials issue of safety is expressed because the quantitative relation of yield point stress to the operating or design stress. Shut in brittles material issue of safety is represented because the final stress to the working stress. Known by victimization the working stress value and ratio yield point stress are often determined as follow. Factor of safety is often denoted by n symbol.

$$\text{factor of safety} = \frac{\text{yielding point stress}}{\text{working stress or design stress}}$$

$$\mathrm{n} = \frac{\mathrm{sy}}{\sigma\mathrm{all}}$$

sy = n × σall $\mathrm{sy} = 3 \times 110.3\ \mathrm{N/mm2}$

$$\mathrm{sy} = 330.9\ \mathrm{mpa}$$

3.9 Design of Chassis Frame Using C++ programing phase one when the force on the rear springs is combined together

The purpose of C++ programming is employed to generate bending moment diagram and shear force diagram by writing analysis on computer programing. Additionally it is used to verify the design stress. Generally it provides the output of reaction forces by writing its input. Advantage of the C++ programming is employed to evaluate each point without any error. The written programs of this work exist in appendix of this paper. Selection of material and properties is obtained by using c++ programing.

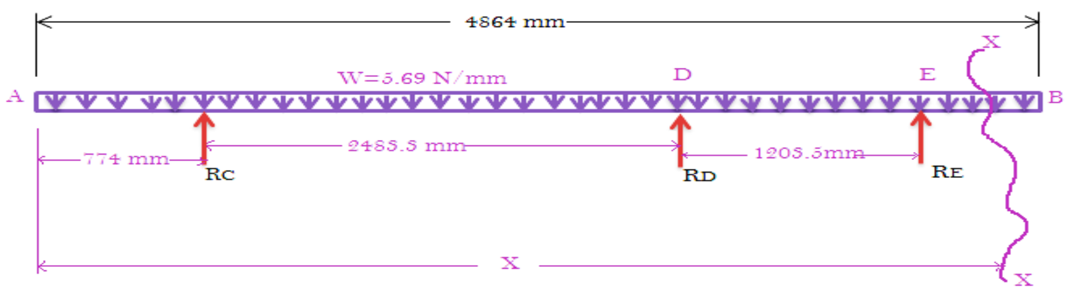
In the starting, design of the chassis frame of the motor truck is often thought of as the particular factor taken from the work search and technical specification of the guide manual of the motor truck. Thus the fabric choice is taken into account when the allowable stress is often determined. The allowable stress was calculated by exploitation analytical calculation and pc primarily based C++ programming. The yielding strength of the material shows 330.9 mpa and tensile strength is 448.2 mpa. Then the materials often exist in carbon and steel alloy that is indicated within the customary material specification of AISI 1020 with the UNS variety of G10200 as rolled, normalized and tempered.

Table 3.6. Material specification

material specification				
mechanical properties of carbon and alloy steel				
AISI no			1020	
Uns.no			G10200	
Treatment	as rolled	Tensile strength, σst	448.2	Mpa
		Yield strength, σsy	330.9	Mpa
	Normalized	Tensile strength, σst	441.3	Mpa
		Yield strength, σsy	346.5	Mpa
	Annealed	Tensile strength, σst	394.7	Mpa
		Yield strength, σsy	294.8	Mpa

3.10 Calculation of Max and Min Deflection of the Chassis Frame Pickup Truck

The frame of the pickup is supported by the reaction at the purpose c, d and e thus the deflection at subsidiary reaction area unit becomes zero. This may cause the deflection at purpose a is minimum and most deflection has occurred at purpose b. this shows worth of x at purpose a is live zero and the value of x at purpose b is live 4864 millimeter.



Generally; YA = minimum deflection of chassis frame and YB = maximum deflection of chassis frame. The values are determine by the using the equation of 3.16

$$Y = \frac{1}{\mathrm{EI}}\left[-5.690 \times \frac{x^4}{24}\ 4.4148 \times 10^{08}x - 2.5661819 \times 10^{11} + \frac{10963.54\mathrm{N} \times (x-0.774)^3}{6} + \frac{13068.58\mathrm{N} \times (x-3.2573)^3}{6} + \frac{3643.98 \times (x-4.4605)^3}{6}\right] \ldots\ldots 3.21$$

Deflection at point c,d&e are zero

Deflection at point “A” (i.e. x = 0)

$$Y_A = \frac{-2.5661819 \times 10^{11}}{\mathrm{EI}} \ldots\ldots 3.22$$

Where, E = young modulus of elasticity and can be obtained after the material properties are known

I = moment of inertia for rectangular cross-section

$$Y_A = \frac{-2.5661819 \times 10^{11}}{EI}, \ E = 200000 \text{ N/mm and } I = 4106250 \text{ mm}^4$$

$$Y_A = -0.31 \text{ mm} .$$

Deflection at “B” (i.e. x = 4864 mm)

$$Y_B = \frac{1}{EI} [-5.690 \times \frac{x^4}{24} - 4.4148 \times 10^{08} x - 2.5661819 \times 10^{11} + \frac{10963.54N \times (4864-0.774)^3}{6} + \frac{13068.58N \times (4864-3.2573)^3}{6} + \frac{3643.98 \times (4864-4.4605)^3}{6}$$

$$Y_B = \frac{3.29 \times 10^{12}}{EI} \ldots\ldots 3.23$$

$$Y_B = \frac{3.29 \times 10^{12}}{200000 \times 4106250}.$$

$$Y_B = 4 \text{ mm}.$$

According deflection span ratio is allowable for simply supported beam is 1/ 300

According to 1 / 300 for 4864 length is equal to $\frac{4864}{300}$ = 16 mm.

$$Y_B = 4 \text{ mm is safe} .$$

3.10.1 Deflection for hollow square section

This consideration is the thickness of the section is the same and the material for both is the same.

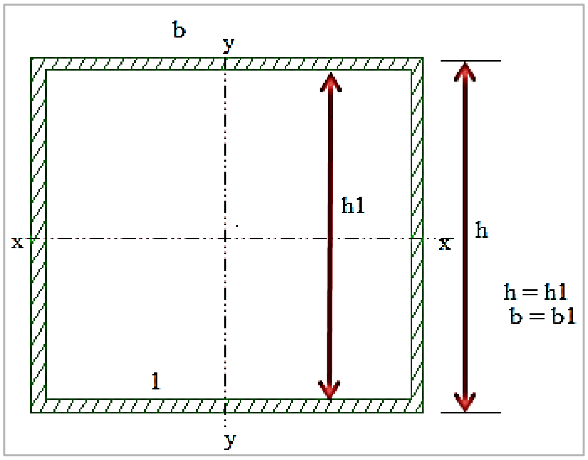


Figure 3.15 Hollow square cross-section

B = b1 = 140 mm and h = h1 = 130 mm

Moment of inertia for the square section is given as;

$$I_{xx} = \frac{b}{12}^4 - \frac{h}{12}^4.$$

$$I_{xx} = \frac{140^4}{12} - \frac{130^4}{12}.$$

$$I_{xx} = 8212500 \text{ mm}^4.$$

$$Z = \frac{I_{xx}}{y} \quad \ldots\ldots 3.24$$

Where;

"Z" is denoted as section modulus

$$Z = \frac{8212500}{70}.$$

$$Z = 117321.43 \text{ mm}^3.$$

The stress produced on the frame of the pickup truck is given as;

$$\sigma = \frac{M}{Z} \quad \ldots\ldots 3.24$$

Where;

"M" is denoted as maximum bending moment acting on the frame of the pickup truck.

$$\sigma = \frac{4386121.49}{117321.43}.$$

$$\sigma = 37.4 \ \frac{N}{mm^2}.$$

Then maximum deflection produced on the chassis frame of pickup is given as

$$Y_{max} = \frac{3.29\times10^{12}}{200000\times8212500}.$$

$$Y_{max} = 2 \text{ mm}.$$

CHAPTER FOUR

4 RESULT AND DESCTION

4.1 Introduction

The load distribution of front hang is the ratio of front hang to the vehicle gross weight.

Load distribution by percentage = front hang/vehicle gross weight $\times 100\ \%$. $\mathrm{Fo} = \text{front overhang of Hilux chassis and Fo} = 38\%$. The load distribution on the rear over hang is equals to the total percentage of the Hilux pick up chassis minus of the front overhang of the chassis Hilux. Rear over hang is denoted by Ro. And Ro = 62% Total load acting on the frame is the product of vehicle gross weight by the total gravity of Hilux pickup chassis frame were, W = 27,664.42N. The load distribution on single frame is equal to the half of total load distribution of the Hilux pick up chassis frame. Percentage distribution indicates best result because of the load distribution of the rear hang must be greater than the front over hangs for pickup trucks and the results also satisfies this condition. The maximum bending moment, maximum shear force, deflections for hollow rectangular and square cross-section, prototype, three-D modeling of the frame and connected parts, strength stress, yield stress and design stress and other design calculations results are generated and discussions are well described in this chapter. The table, figure, diagram, drawings and charts are generated using excel, AutoCAD, and computer programming system. Comparisons of different parameter of pickup chassis frames are also obtained by comparing the existing pickup model with the new design of chassis model.

Table 4.1 Percentage of load distribution of the pickup truck

WIP	LD 100%
FOH	38
ROH	62
FOH	Front over hang
ROH	Rear over hang
LD	Load distribution
WIP	Weight in percent

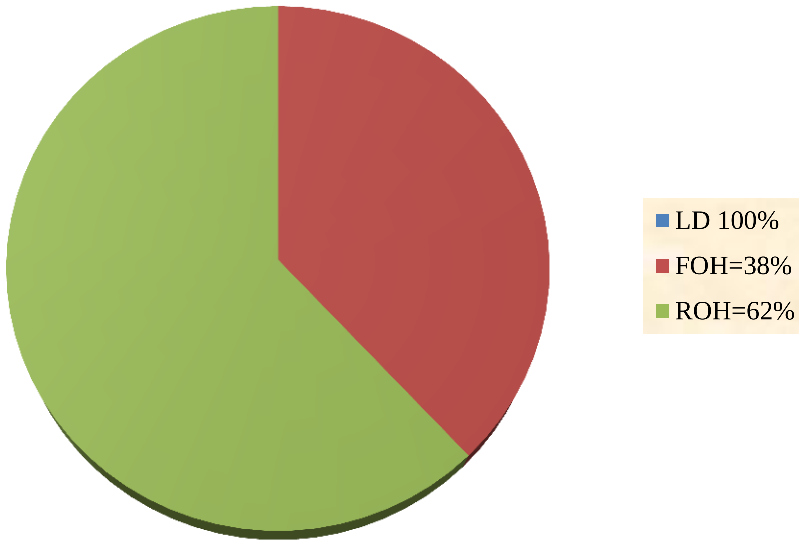


Figure 4.1 Load distribution chart of pickup truck

4.2 Generating the Diagrams and Table using excel from C++ data

The C++ programming will be written in two forms. The primary one is just by considering two reaction forces and the second is by considering three reactions. Just in case of two reactions the summation of force on leaf spring can be assumed as one force and it is taken at the center of leaf spring. This means the reaction force at the primary point of shackle spring and the secondary point of shackle spring are combined together which produce one force. Any ways the total forces are equal in each case. However the shear force and moments are varies as the reaction force of chassis frames are varied. For each case C++ computer programming generates better result. generally reaction at point C and at point D is given as 6.4E+03 N and 7.43E+03 N. However, this numerical is rad due to pc languages. The uniformly distributed load on the frame will tell the similar result with design calculation. It is denoted by wp1 for C++ and the result is 2.84E+03 or 5.7 N/mm2 but analytical design is 5.69 N/mm2 which vary by error of 0.01 N/mm. The value for each one is taken in table 4.2 as well as bending and shear force diagram also provided on the fig 4.2.

Table 4.2. Shear force and bending moment results for case no one

X(m)	Fs(N)	Mb(Nmm)
0	0	0
0.97	3.63E+03	-73.63
1.95	865.35	2.11E+03
2.92	-1.90E+03	1.61E+03
3.89	2.77E+03	-1.35E+03
4.86	0	0

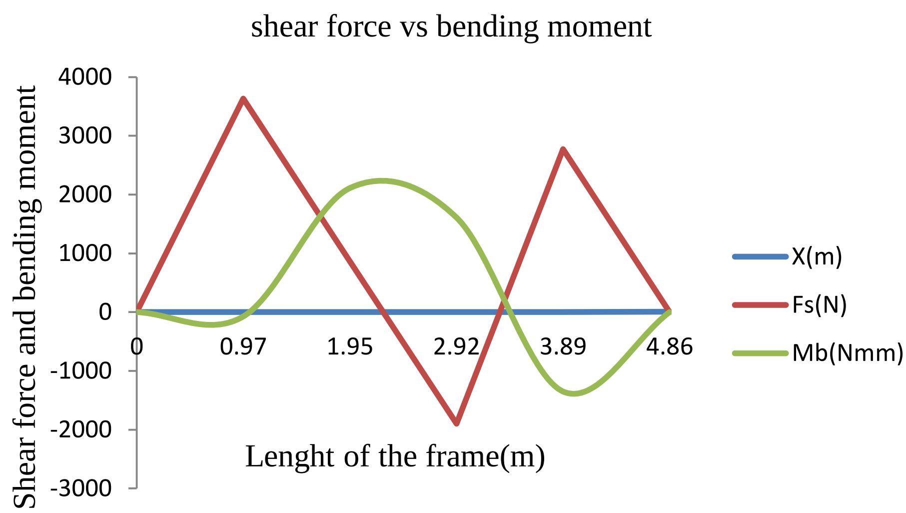


Figure 4.2. Shear force and bending moment diagram with only two supportive forces

4.2.1 Shear force diagram using AutoCAD cad system

According to the result of shear force calculation the maximum and the minimum point of shear force are plotted using cad system. The diagram show as the shear force v1, v3 and v5 are negative sign and the shear force at v2, v5 and v6 are positive. But at point A and point B the shear became zero. The maximum shear force not depends on sign convection only the high magnitude value is the maximum shear forces. Therefore the shear force at the v3 indicates the maximum shear force from the result and below diagram of shear force.

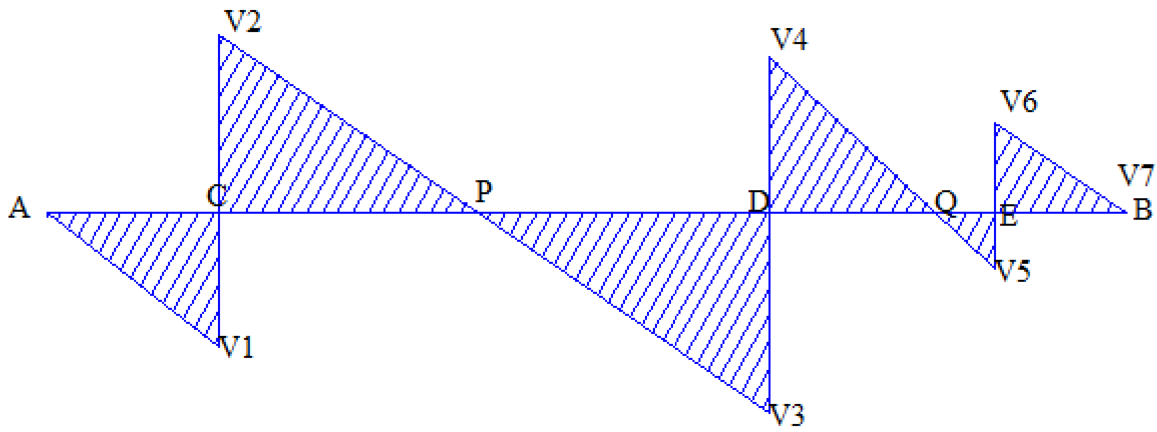


Figure 4.3. Shear force diagram using the cad system

4.2.2 Shear force and shear force diagram of pickup chassis frame

The maximum and minimum point of the shear force is additionally drawn within the table and on the figure of 4.4. The fore the maximum shear force is live -7570.49 N from the results as indicated within the table 4.3 and minimum live -1349.49 N the reaction force is zero at shear vo and shear v7. This result shows there's no reaction force at shear vo and shear v7.generally the shear force is named the distinction forces on the chassis frame and might be indicated in table and figure exploitation diagram that's generated exploitation stand out and C++ computer programing. Typically the shear forces generated on obtain chassis frame is drawn on figure 4.4 and table 4.3.

Table 4.3 Shear force result at each point of pickup chassis frame

Value of (x) mm		Shear force (FS= V)N		Units
xo	0	V0	0	N
X1	700	V1	-4404.60	N
X2	2000	V2	6559.48	N
X3	3000	V3	-7570.49	N
X4	3500	V4	5498.89	N
X5	4300	V5	-1349.49	N
X6	4500	V6	2294.49	N
X7	4870	V7	0	N

Shear force diagrams are plotted using AutoCAD and each point are indicated by symbol letter as shown in figure 4.3. Figure 4.4 also same with 4.3 but the only difference is that the below figure 4.4 is generated by using computer programming and excel. This shows, that, using computer programming and excel together is more accurate than the other. Generally the shear force at point A and point B is zero as it is represented in figure 4.3 and 4.4.

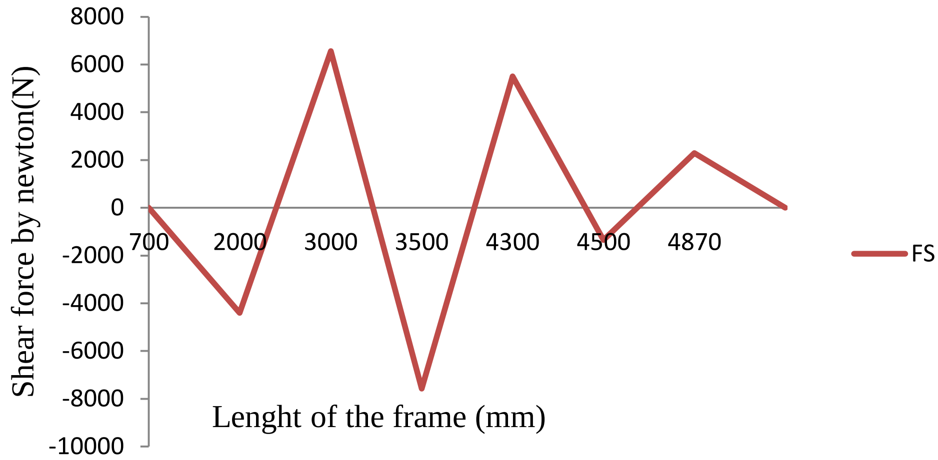


Figure 4.4 Shear force diagram of pickup chassis frame with three supportive forces

4.2.3 Bending moment and moment diagram of chassis frame

A bending moment is that the response introduced concerning associate degree exceedingly in a very structural issue. Bending moment is additionally occurred once an external force is applied at a given distance faraway from a part of reference; inflicting a bending impact. Within the best terms, a bending moment is that if truth be told a force that causes one thing to bend. If the item is not well-restrained the bending force can purpose the item to rotate a couple of bound purpose.

Moment of The truck chassis frame is obtained from the look result and its value are drawn on the below table 4.4. Bending moment at purpose A and B is zero as shown in table 4.4 and therefore the moment at purpose C, D, P, alphabetic character and E are drawn from in table 4.4 and therefore the results area unit taken from analytical style and computer programing. Every purpose is drawn using AutoCAD drawing in chapter 3 on figure 3.10. Similarly as every moment result's showed on table 4.4

Table 4.4. Bending moment result at each point of pickup truck chassis frame

Value of (x) mm		Bending moment(Mb)		Units
xo	0	MA	0	Nmm
X1	700	MC	-1704371	Nmm
X2	2000	MP	4386121.5	Nmm
X3	3000	MD	-2959680	Nmm
X4	3500	MQ	1030183.2	Nmm
X5	4300	ME	-462620	Nmm
X6	4870	MB	0	Nmm

The bending moment diagram is used to represent the maximum value of bending moment and as well as minimum. Moment diagram is also told as the sign convection of moment and its magnitude. According to the moment diagram on figure 4.5 the maximum bending moment are 4386121.5 Nmm and -462620 Nmm respectively as denoted by Mp and Mq in table 4.4 and the diagram on the figure 4.5. Generally the diagram of moment diagram is generated using the results in analytical calculation and computer programming data generated by excel as well as AutoCAD. It's also zero at starting and ending points.

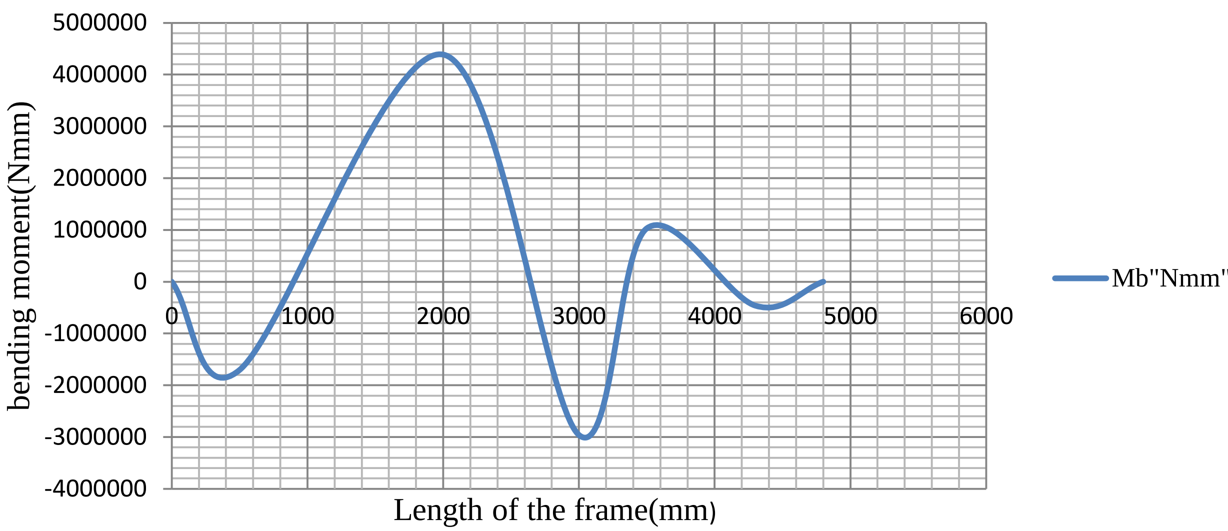


Figure 4.5 Bending moment diagram of pickup chassis frame with three supportive forces

4.3 Static result of pick up chassis frame chassis frame

The strength of chassis frame of pickup truck is calculated and the result is known from data calculation. The tensile strength of a material is the maximum amount of tensile stress that it can take before failure. As a result shows the tensile strength that can be designed by using the parameter is represents 448.2 MPa for both inner and outer of the side frame .the yield point of the frame can be show as 330.9 MPa the design criteria of the deflection span ratio is allowable for simply supported beam is 1/ 300. According to 1 / 300 for 4864mm, the deflection is limited to 16mm. as a result shows the maximum deflection for pick truck chassis frame design is 4mm which is better and acceptable. When only $\sigma_x$and τ_{xy} are present (as in combined torsion and bending/axial stress or pure torsion), there is no need to calculate the principal stresses, the Von-Misses stress is equals to 110.3MPa. In case pure torsion, the bending/axial stress is zero and $\sigma_v$is 132.67MPa. Shear stress in the beam is not uniformly distributed over a cross-section but varies from zero at the outer fibers to a maximum at as a neutral surface which is 46.67 MPa. The factory of safety can be considered as three n = 3 in the design of chassis frame for pickup trucks. The static loads should be increased by factors of 2.5 to 3.0 for road going vehicles. Static result of chassis frame of pickup truck are represented in the below table.

Table 4.5. Static results of pick up chassis frame design

No	Static calculation	Result	Units
1	tensile strength	448.2	MPa
2	yield point	330.9	MPa
3	Von-Misses stress	110.3	MPa
4	Deflection HRCS	4	Mm
5	Deflection HSCS	2	Mm
6	. Shear stress	46.67	MPa
7	factory of safety	3	−
8	σ_v for pure shear stress	132.67	MPa
9	Poisson's ratio	0.29	−
10	Shear strength	280	MPa

Area of hollow rectangular cross-section is equals to 2000m^2 and for hollow square cross-section is 2700m^2. The sum of area for both cross-sections is 4700m^2 so the weight reduction by percentage is calculated by the area of each cross section to the total area of the cross-section. Therefor the percentage of reduction in weight for rectangular cross-section is given as $\frac{2000}{4700} \times 100\% = 42.6\%$. The percentage of reduction in weight for square cross-section is given as $\frac{2700}{4700} \times 100\% = 57.5\%$. Therefore rectangular cross-section has better than the square cross-section and acceptable in the design of chassis frame of pick-up and result and parameters are shown in table 4.6

Table 4.6. Result of new model chassis frame parameter with different cross-sections

parameters	Hollow RCS	Hollow SCS	Remark
Outer base b	70mm	140 mm	Better
Inner base b1	60mm	130 mm	Better
Outer height h	140mm	140 mm	Better
Inner height h1	130mm	130 mm	Better
thickness	5mm	5 mm	Better
Section modulus	58660.7mm^3	117321.43mm^3	Better
Moment of inertia	4106250mm^4	8212500mm^4	Better
deflection	4mm	2mm	Better
Weight reduction	42.6%	57.5%	Suggestion SCS is expensive
Total length	4864 mm	4864 mm	Better
Note that, hollow RCS is economically safe and better than hollow square CS			

4.4 Comparison of the result with literatures and the existing design

In previous design many chassis frame results have generated by ANSYS, CATIA and SOLID works. But in this design the results has generated using C++ programming, AutoCAD model and ANSYS which is the easiest and visible and additionally excel is also provided. The deflection result of chassis frame design of pickup in literature was 50mm but in this design the 4mm. Therefore deflection result in literature review is not better when compared with the new of pickup chassis frame. The tensile strength and yield point of chassis frame of pickup for the previous one is 440 mpa and 305 mpa and the material they used is structural steel. In case of the new design of pickup chassis frame the tensile strength and the yield point is 448.2 mpa and 330.9 mpa and the material used is carbon and steel alloy. The density of the existing is 7850 kg/m^3 with Poisson's ratio ratio of 0.3 and the density of the new design is 7900$kg/m^3$with the Poisson's ratio of 0.29.

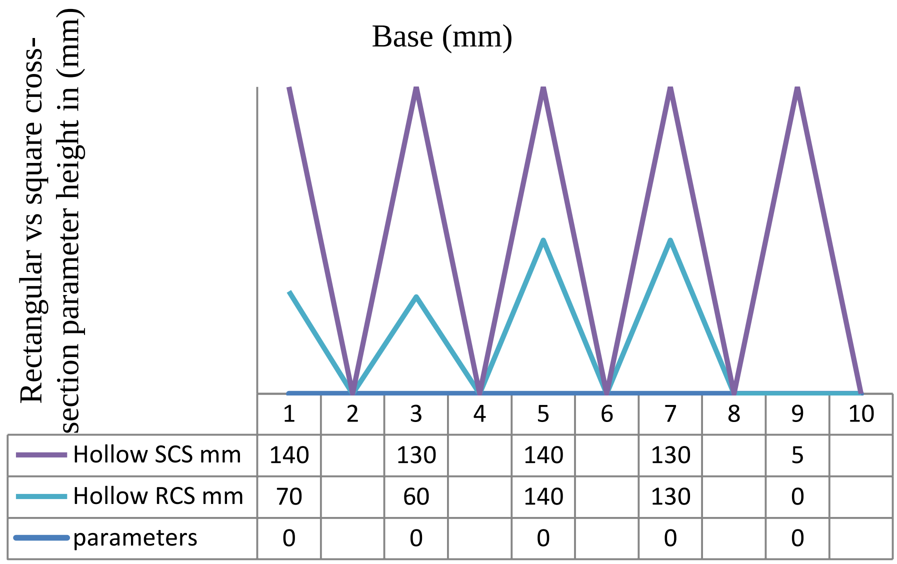


Figure 4.6 Cross-sectional relation HRCS and HSCS

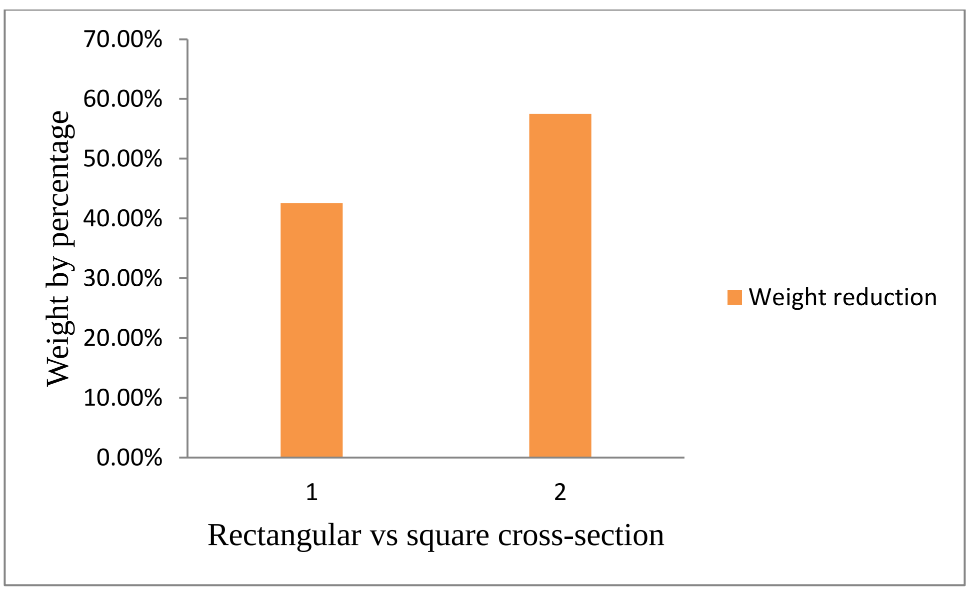


Figure 4.7. Weight reduction by chart

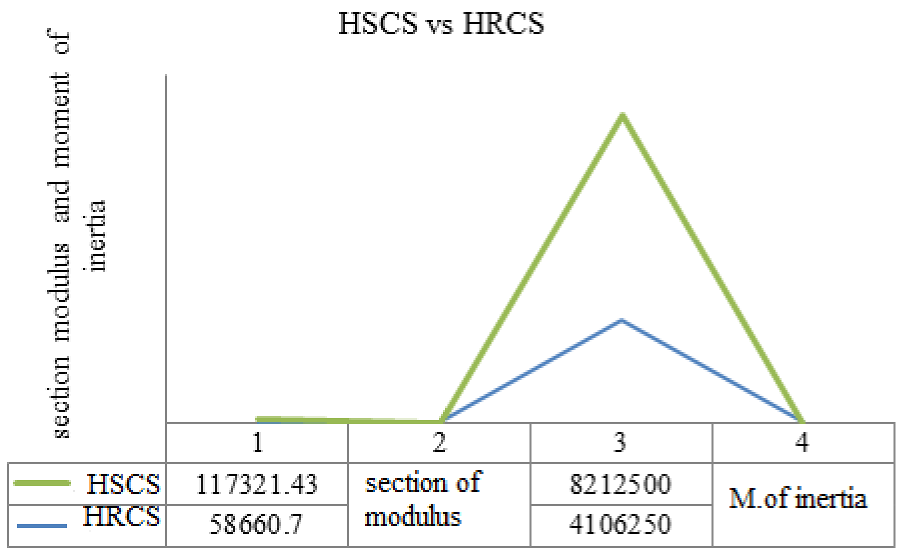


Figure 4.8. Moment of inertia and section modulus HRCS and HSCS

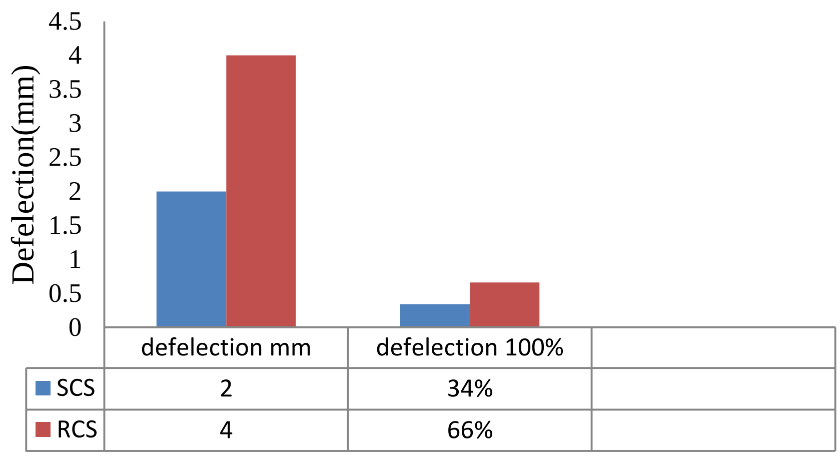


Figure 4.9. Deflection comparison between HRCS and HSCS

4.5 ANSYS APDL Validation of Static Analysis for Chassis Frame of Pickup

This ANSYS validation is used to confirm the result of analytical analysis with ANSYS results and the result is comparatively better. The validation of static analysis of chassis frame design by using the ANSYS software can be consider two types of analysis system for force to compare the bending moment, shear force, stress and deflection. The first consideration on this result validation of ANSYS can be consider the two supportive force on the beam of chassis frame and the result is validated when it compared with analytical analysis. The second consideration in this result is achieved by applying three reaction forces on the beam of pick up chassis frame. One force supported on the front side of the pickup and the other two forces are supported on the rear primary with ending point of leaf spring

Table 4.7. Comparison of analytical with ANSYS result for different parameter on double reaction

No	Analytical design result of cfd	asnys result of cfd	Remarks
Shear force N	0		
	-4404.60	-4423.54	Better
	6559.48	6323.81	Better
	-7570.49	7128.07	Better
	5498.89	5202.80	Better
	-1349.49	1352.27	Better
	2294.49	-2497.27	Better
	0	0	Better
moments Nm	0	0	Better
	-1704.37	-1820.39	Better
	4386.12	4439	Better
	-2959.68	-2844.72	Better
	1030.18	1201	Better
	-462.62	-416.42	Better
	0	0	Better
Stress	61	51	Better
deflection	4mm	5.5 mm	Better>16mm

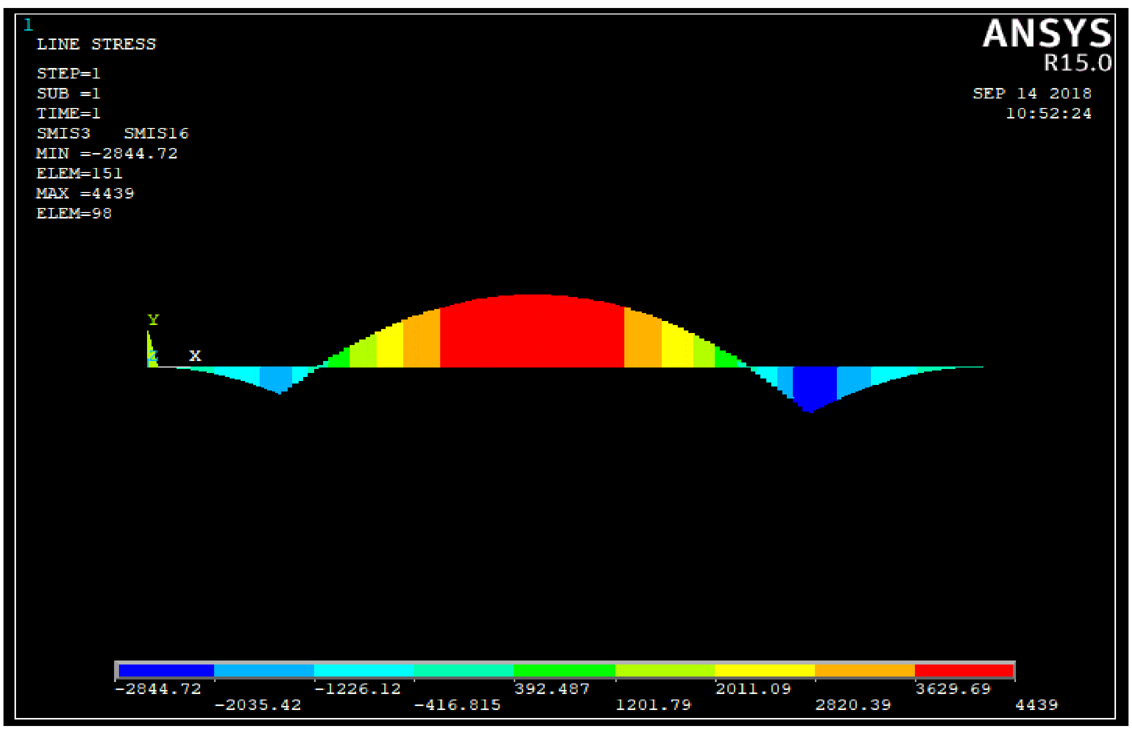


Figure 4.10. Double reaction bending moment diagram using ANSYS validation

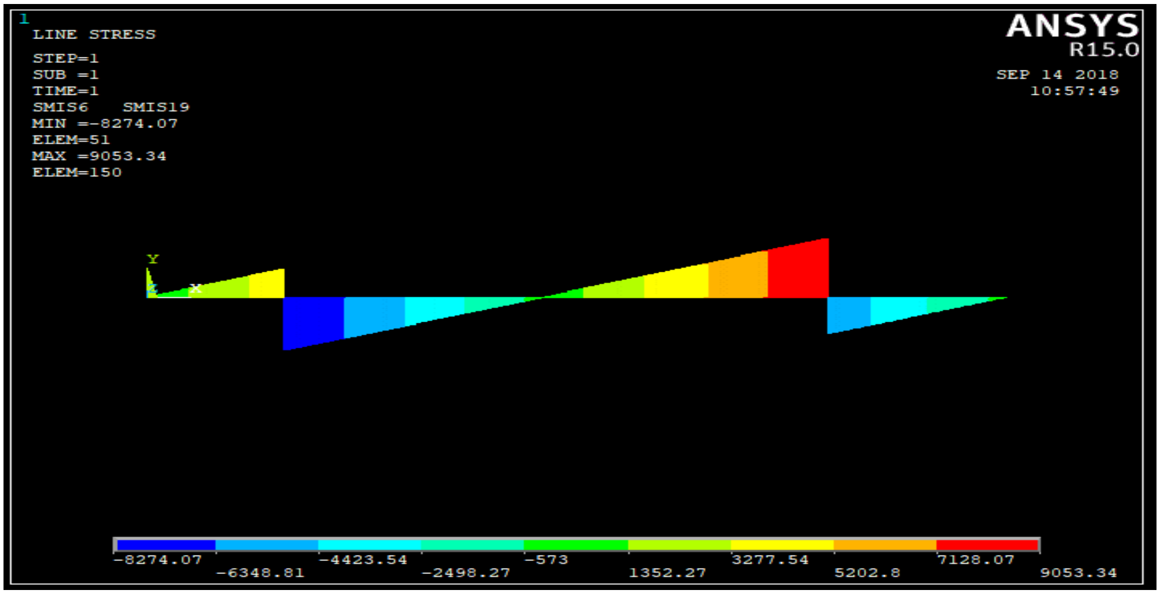


Figure 4.11. Double reaction bending moment diagram using ANSYS validation

4.6 Chassis frame validation for triple reaction force of pickup truck using ANSYS APDL

Three reactions on chassis frame beam of pickup truck is more better than the double reaction. The deflection obtained by ANSYS is measure 0.00358 by meter and analytical deflection measure 0.004 by meter. Therefore using three reaction forces is confirmed than double reaction force for this work. The other parameters are discussed on the below table.

Table 4.8. Comparison of analytical with ANSYS result of parameter on triple reaction

No	Analytical design result of cfd	asnys result of cfd	Remarks
Shear force N	0	0	
	-4404.60	4214.33	Better
	6559.48	-6550.76	Better
	-7570.49	7290.08	Better
	5498.89	5752.20	Better
	-1349.49	1138.59	Better
	2294.49	2676.46	Better
	0	0	Better
moments Nm	0	0	Better
	-1704.37	-1820.39	Better
	4386.12	4439	Better
	-2959.68	-2844.72	Better
	1030.18	1201	Better
	-462.62	-416.42	Better
	0	0	Better
stress	75	0	Better
deflection	0.004m	0.00358m	Better>0.016

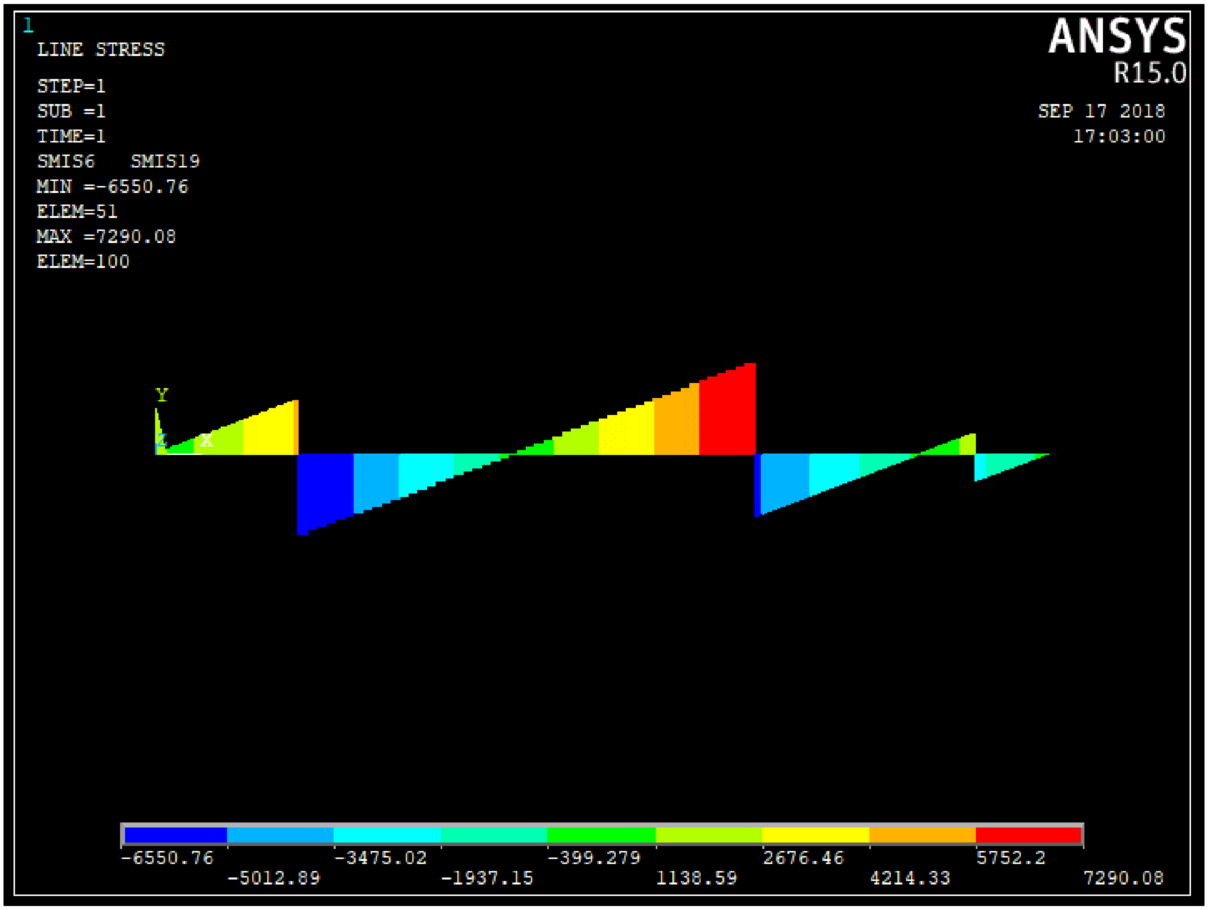


Figure 4.12. Shear force Result diagram using ANSYS

PRRSOL Command

File

```
PRINT REACTION SOLUTIONS PER NODE

 ***** POST1 TOTAL REACTION SOLUTION LISTING *****

 LOAD STEP=     1  SUBSTEP=     1
  TIME=    1.0000      LOAD CASE=   0

 THE FOLLOWING X,Y,Z SOLUTIONS ARE IN THE GLOBAL COORDINATE SYSTEM

   NODE       FX           FY           FZ           MX           MY           MZ
      2    0.0000       11095.     0.22426E-15-0.40514E-06 0.39148E-13
     52    0.0000       12644.     0.53496E-16-0.26482E-07-0.45410E-13
    152    0.0000       3905.3    -0.24819E-16 0.82602E-07-0.56015E-16

TOTAL VALUES
VALUE     0.0000       27644.     0.25294E-15-0.34902E-06-0.63185E-14  0.0000
```

Figure 4.13 Total Reaction solution generated by ANSYS

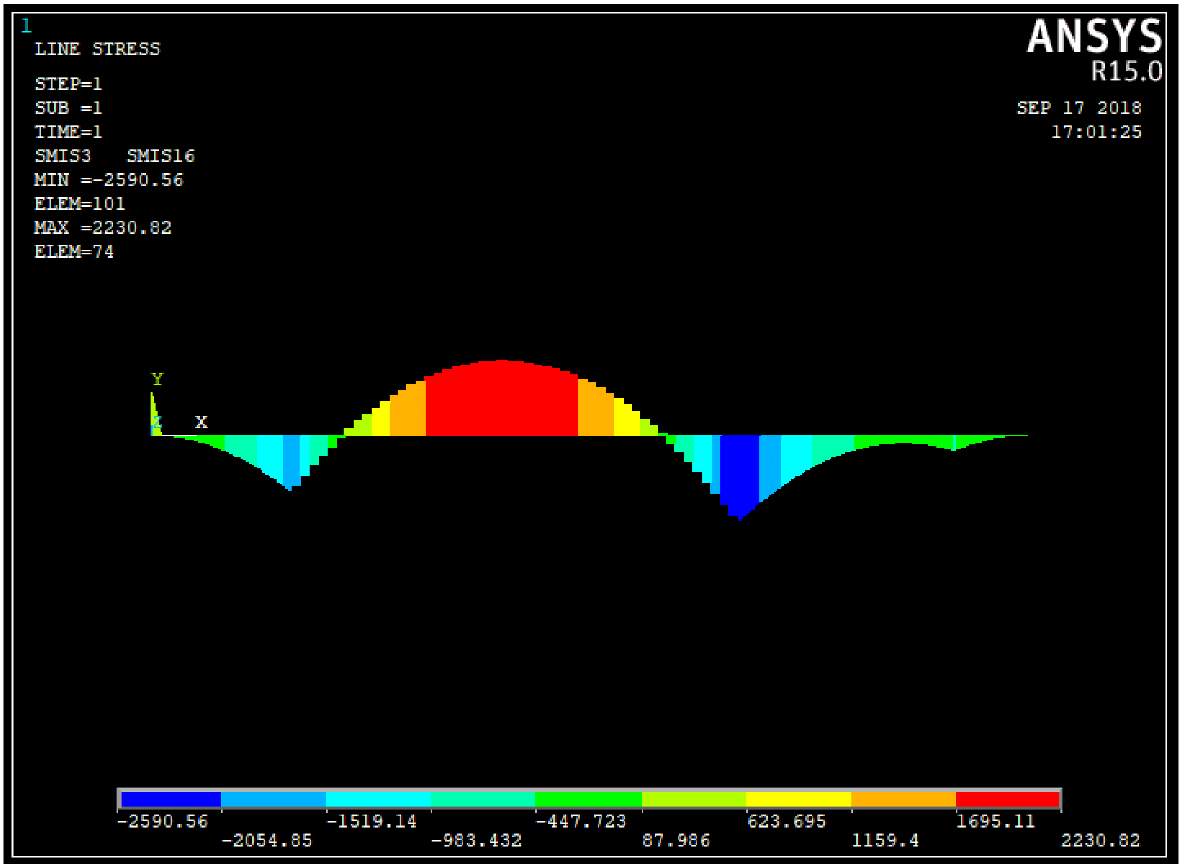


Figure 4.14. Bending moment Result diagram using ANSYS

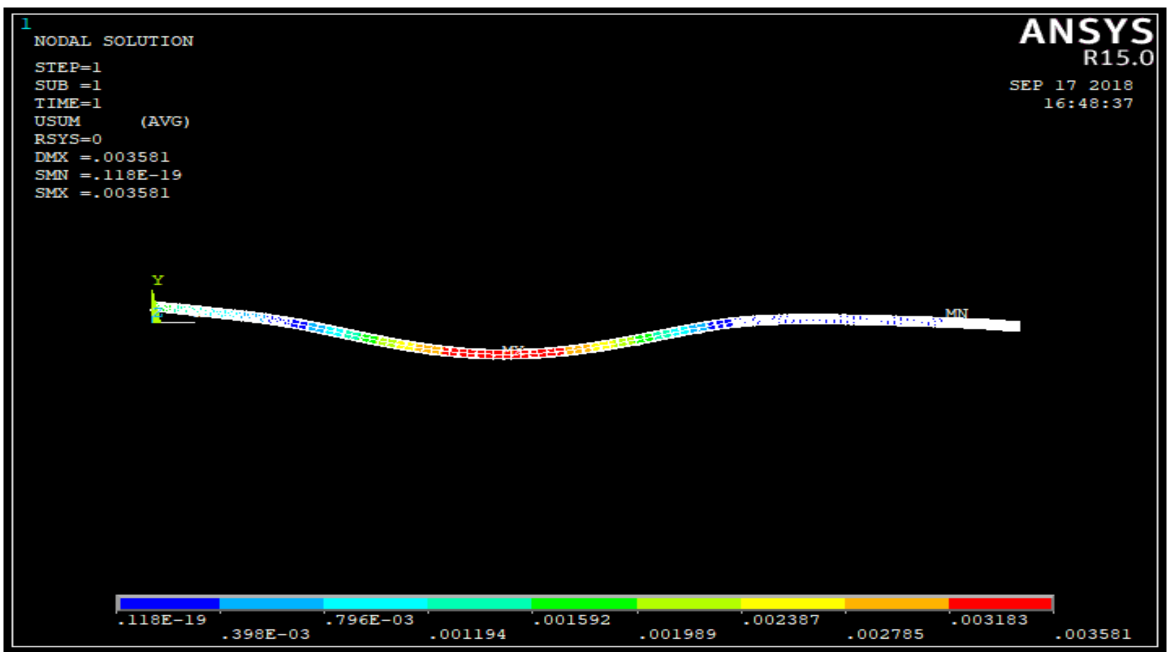


Figure 4.15. Deflection result of model solution using ansys software

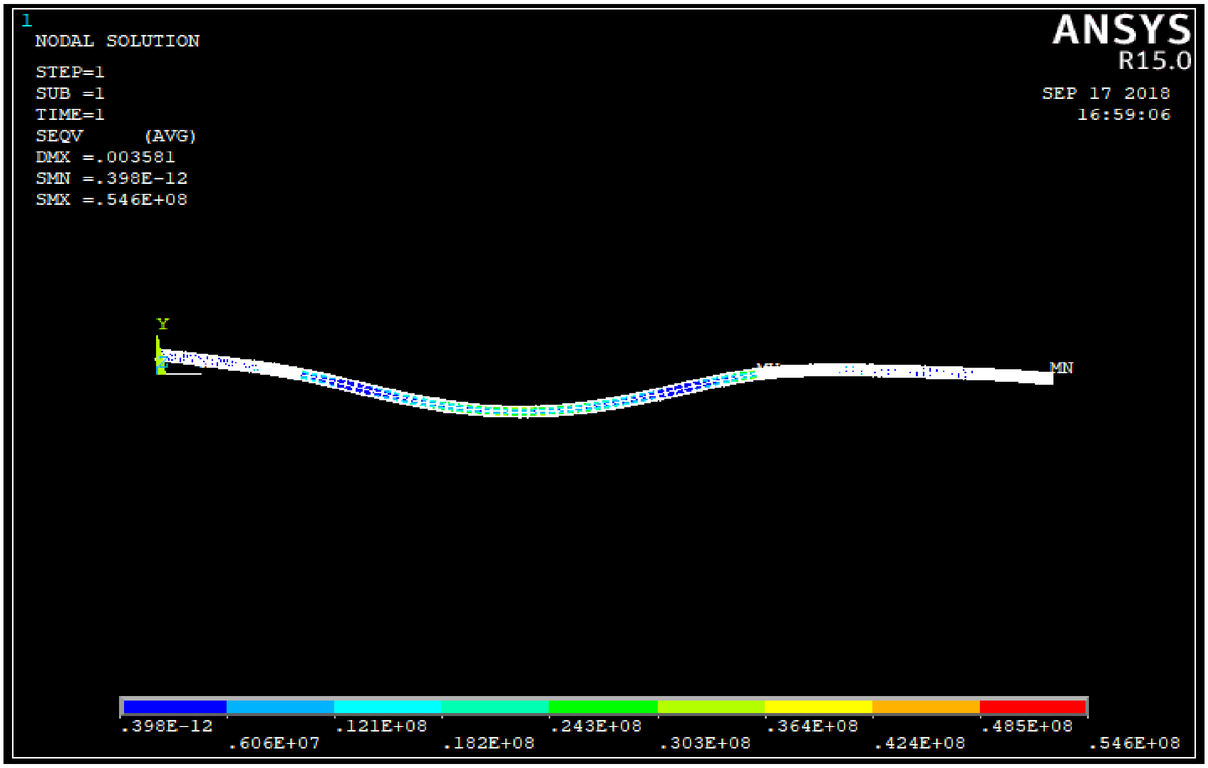


Figure 4.16 Deflection result of model solution using ansys

4.7 Three-D Modeling of Chassis Frame of Pickup Truck Using AUTOCAD

Three-D AutoCAD modeling has modified the approach we have a tendency to design; for the higher. Not solely will Three-D AutoCAD modeling facilitate the designers and finish users visualize house needs, however additionally improve drawing effectiveness and accuracy. It offers the designer the power to physically see what proportion assets associate object chassis frame of pickup takes from all views. Modeling of pickup chassis border Three-D AutoCAD is completed in one model and style in 2nd is often done by generating the frame read from Three-D AutoCAD model. Once a style is completed in Three-D AutoCAD, it assists designers with coordination.

The designer will rehearse a Three-D AutoCAD model with the specialized software package and see the particular size and house of the planning. The Three-D AutoCAD walkthrough software package additionally permits to run interference checks to envision if the design clashes with alternative things within the Three-D AutoCAD model. By exploitation, the Three-D AutoCAD walk-through software package will simply see whether or not the design permits for instrumentality maintenance access and operational access, and addresses safety issues. So to permit the style to make a lot of easy design for the tip user the Three-D

AutoCAD model of the frame is generated as follow. We are able to place the model by 3 d wireframe visual vogue, realistic material and advanced metal by render system.

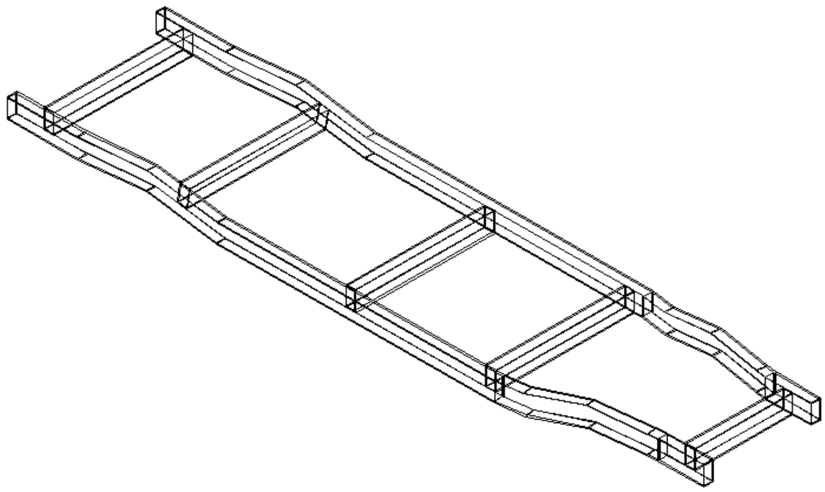


Figure 4.17. Three-D wireframe visual style for hollow rectangular section

The chassis frame of pickup truck shown on the Figure 4.21 is Three-D realistic material of frame. The realist material becomes obtained from the render of AutoCAD application. This cad application used to show the exact drawing of the three-model of the frame.

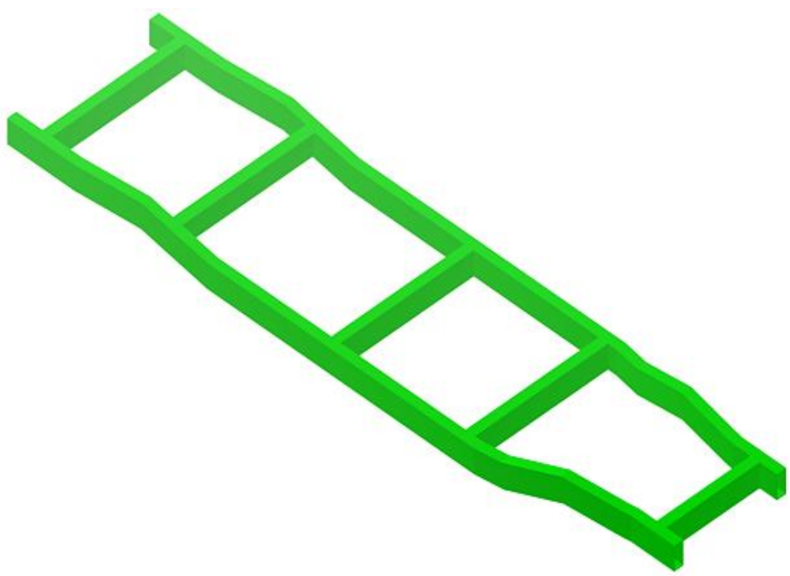


Figure 4.18. Three-D realistic material of chassis frame for hollow rectangular section

The chassis frame of pickup truck shown on the Figure 4.22 is Three-D advanced metal of frame. The three d render by advanced metal of chassis frame of pickup truck becomes obtained from the render of AutoCAD application. This cad application used to show the exact drawing of the three-model of the frame for hollow rectangular section.

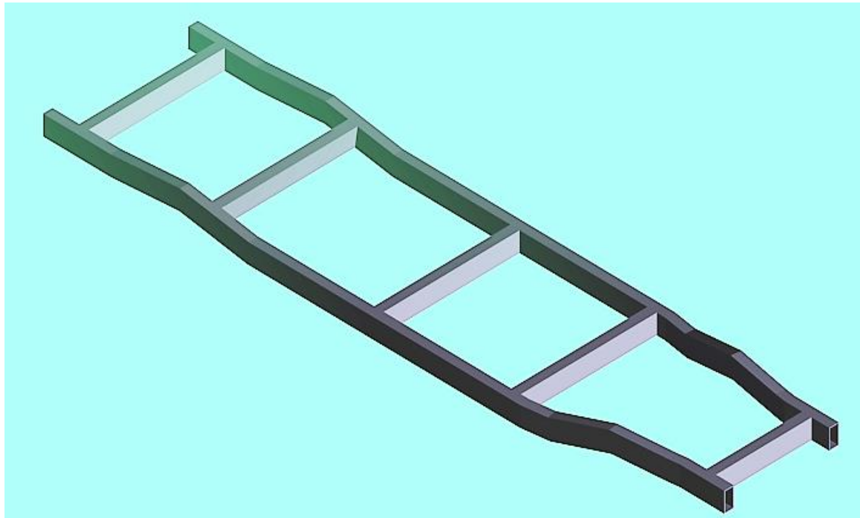


Figure 4.19. The three d render by advanced metal of chassis frame of pickup truck

It is important to draw the three-D model of the chassis parts that is related to the chassis frames. Therefore in my design only frame of the pickup truck designed but to know the part connected to the frame is importance therefore some of the parts are model in this paper for more information for future researchers.so the detail drawing for those parts are exist in appendix and 3D of all are model according to figure 4.20 and the frame of this model has rectangular cross-section as it is shown on the below the model

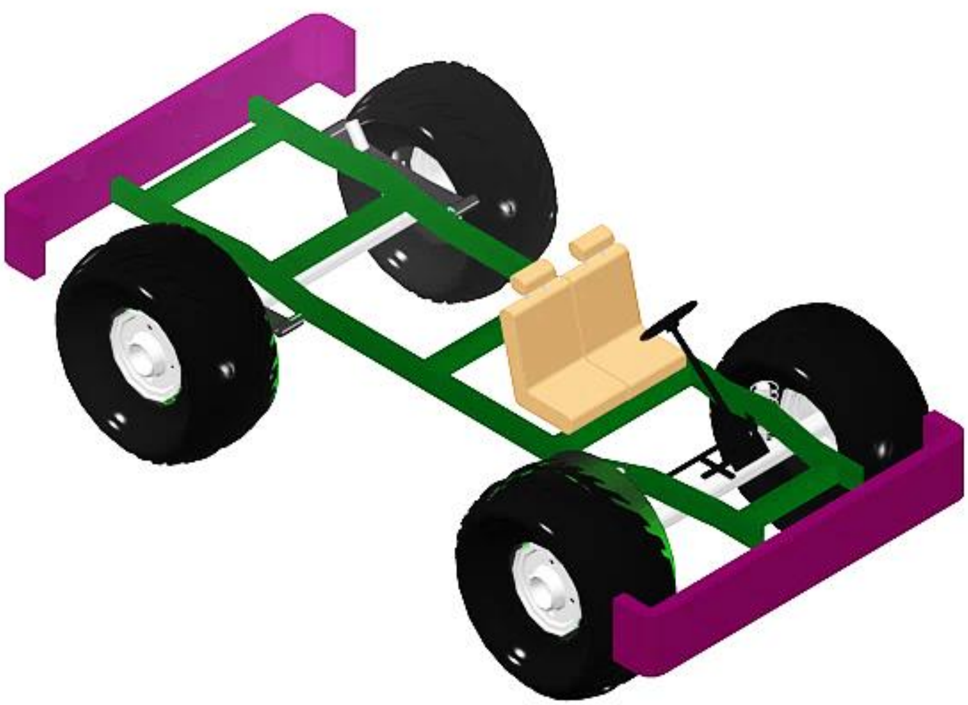


Figure 4.20 Rendered chassis frame with rectangular hollow cross-section

4.8 Chassis frame of pickup truck three-D AutoCAD for hollow square section frame

The chassis frame for the three-D wire frame can be indicated in the below figure 4.21. This visual three d wire frame is designated for the hollow square section of the pickup chassis frame of the pickup truck.

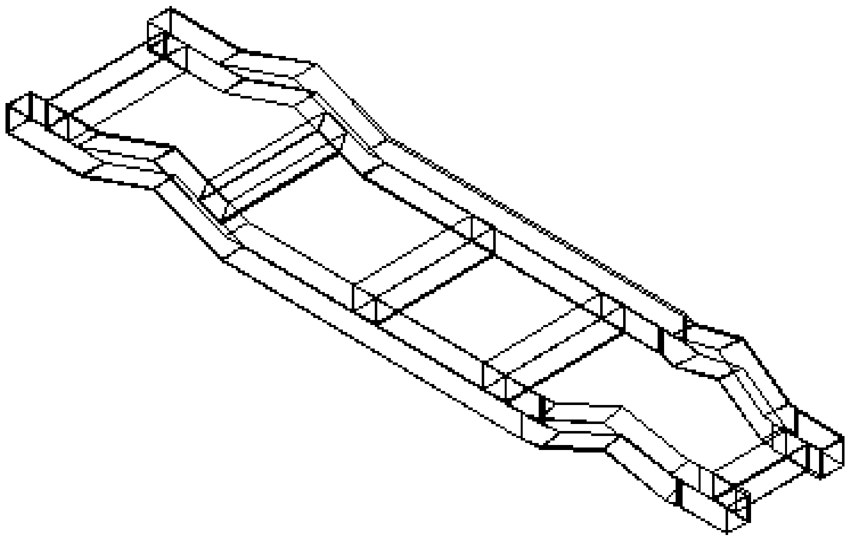


Figure 4.21. Three D wireframe visual style of hollow square-section

The chassis frame of pickup truck shown on the Figure 4.25 is Three-D advanced metal of frame. The three d render by advanced metal of chassis frame of pickup truck becomes acquired from the render of AutoCAD application for hollow square section frame. This cad application used to show the exact drawing of the three-model of the frame.

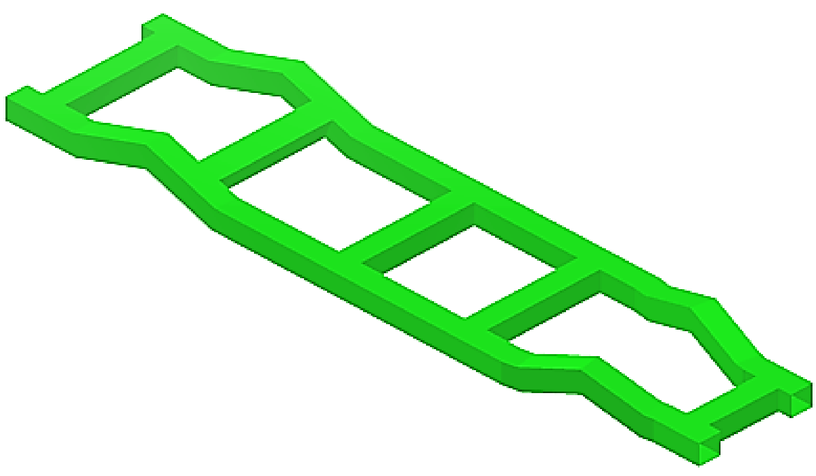


Figure 4.22. The three –D render by advanced metal of chassis frame of pickup truck

The weight reduction of the frame and increment of the strength are important criteria in this design. Optimization the frame cross-sectionals of the frame important to improve deflection, weight, cost and strength for customer satisfaction. The figure 3.26 Designate the square cross-section of the frame of pickup chassis frame three-D model.

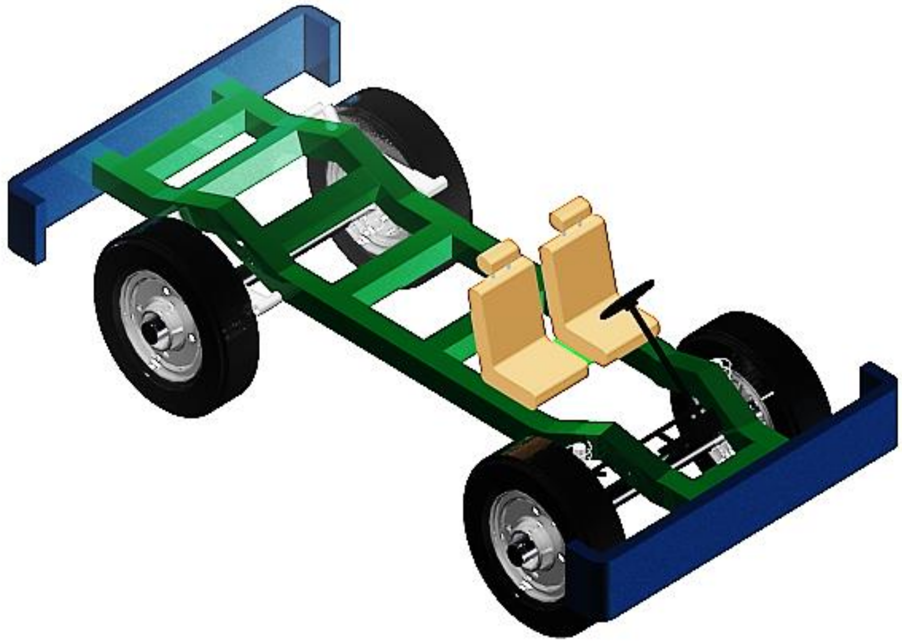


Figure 4.23. Rendered chassis frame with square hollow cross-section

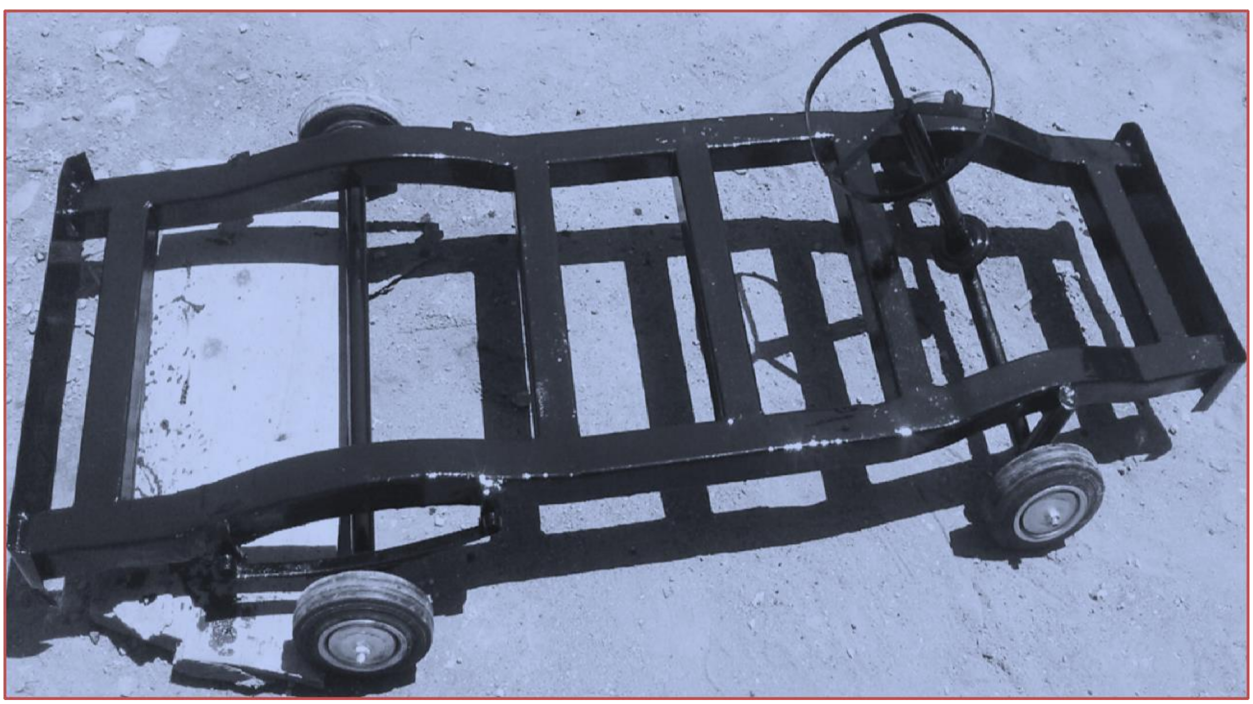


Figure 4.24 Prototype of Toyota chassis frame of pickup truck with related components

CHAPTER FIVE

5 CONCLUSION AND RECOMMENDATION

5.1 Summary of Finding

This study is summarizing on design and modeling of ladder chassis frame for pickup truck model through finding static analysis. The design was comparatively included comparison of hollow rectangular cross-section and hollow square cross-section of chassis frame for pickup. Analysis were done for determining weight, deflection, shear stress, bending moment, shear force, von-mise stress, safety factor, modeling, bending stress and writing of computer programming. Analyses were done by using analytical methods, software's like AutoCAD and ANSYS. C++ computer programming's also included in case for determining allowable stress, reaction forces, moment and shear force diagram. The total reaction is 27644N as well as load distribution at rear and front were 38% and 62%. Deflections at the supporting reaction were zero. Furthers the deflections for HRCS and HSCS remain measured as 4mm and 2mm. Machine, tools, and paint material was needed for developing prototype .Reaction forces are compromised by using ANSYS software. Bending and shear force diagrams as well as deflections ere determined by applying two or three reaction force on chassis frame.

5.2 Conclusion

Materials accustomed carry out this design are software system like C++, AUTOCAD, ANSYS, journals, books, measurement Instruments, machineries, tools and painting service. A bending moment is response introduced concerning associate degree exceedingly in a very structural issue. Tensile strength and yield strength are analytically concluded as 330.9 mpa and 448.2 mpa. Analytically Von-Misses stress is equals to 110.3MPa. For pure torsion, Von-Misses stress is 132.67MPa. Shear stress in the beam is not uniformly distributed over a cross-section but varies from zero at the outer fibers to a maximum at as a neutral surface which is 46.67 MPa. The factory of safety can be considered as three n = 3 in the design of chassis frame for pickup truck.

Analytically, the maximum shear force is -7570.49 N and minimum is -1349.49 N but as result of ANSYS the results are 7290.08 N and 6550.75N. The percentage of reduction in weight for HRCS is given as $\frac{2000}{4700} \times 100\% = 42.6\%$. The percentage of reduction in weight for

HSCR is given as$\frac{2700}{4700} \times 100\% = 57.5\%$. Therefore HRCS has better than the square cross-section and acceptable in the design of chassis frame of pick-up and result.

According to the moment diagram 4386121.5 Nmm and -462620 Nmm respectively as denoted by Mp and Mq is selected. The deflections was also 4mm and 2mm respectively and the existing one about 50mm which is greater than span ratio method 50 mm >16 and it is better and safe when deflection is <16. Therefore by comparing weight reduction and deflection 4mm or HRCS were selected in this paper as well as tested deflection by ANSYS is measured 3.58 mm and it's the best result all over this work. Generally the model is developed at the last and different comparisons were done through generating diagrams. The result is better and problem is solved as it's compared with deferent parameters. The result confirmation by ANSYS and C++ is acceptable as it compared with analytical analysis.

5.3 Recommendation

Any person can be doing his researches on design and modeling of ladder chassis frame of Toyota chassis frame. The title is more focus on static analysis of chassis frame which provides deflection and weight reduction. However, the future researchers can consider the dynamic analyses and other cross-sectional compromise through this title as recommendation. C++ and ANSYS are also provided and result is acceptable. Therefore, using computer programming is recommended to use it. Another important recommendation is use experimental test during preparing the prototype. Using this title, cost analysis and material optimization is recommended for future researchers.

5.4 Future Work

Premeditated future works through chassis frame of pickup truck can sustain the following future works;

- Dynamic analysis of pickup truck chassis frame for different cross-section
- Experimental investigation of chassis frame failure by considering different material
- Design optimization of static and dynamic analysis of pickup truck chassis frame
- Design and modeling of chassis components such as suspension parts and steering systems.

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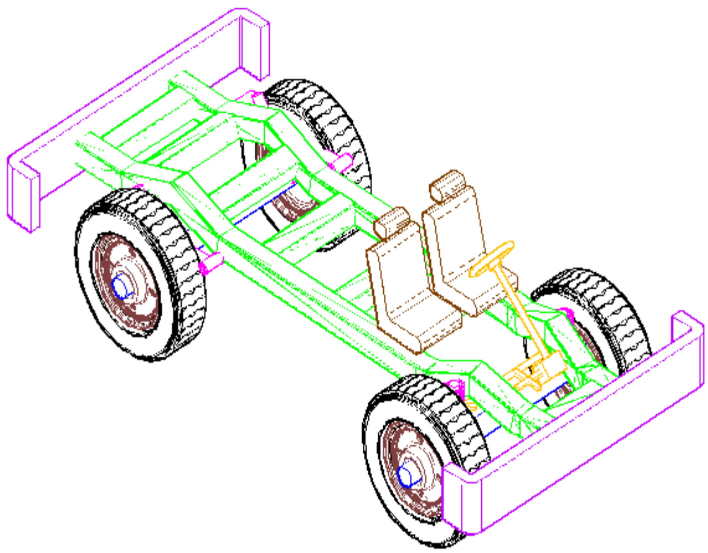
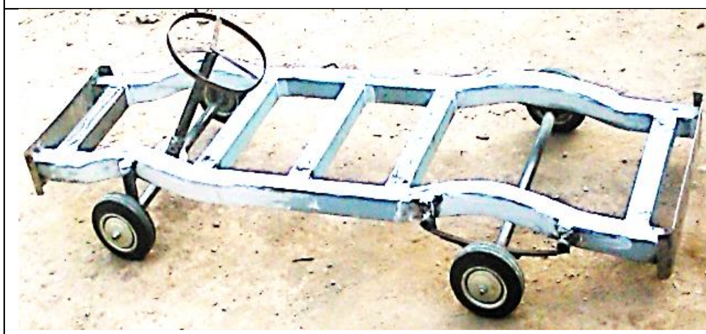
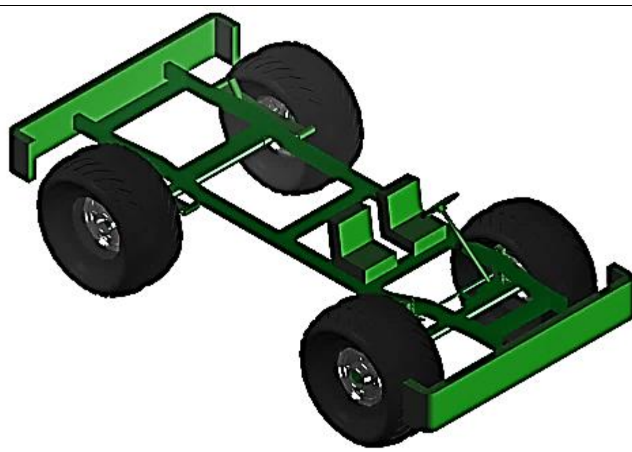
APPENDIXES

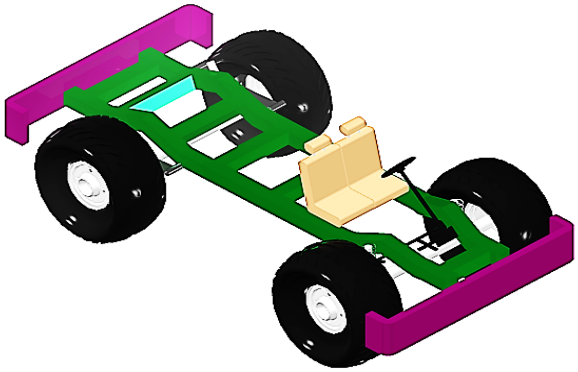
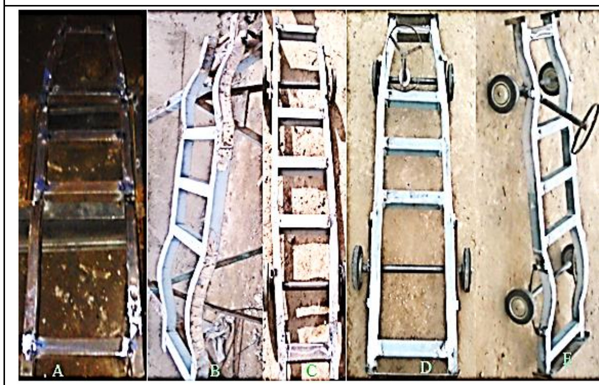
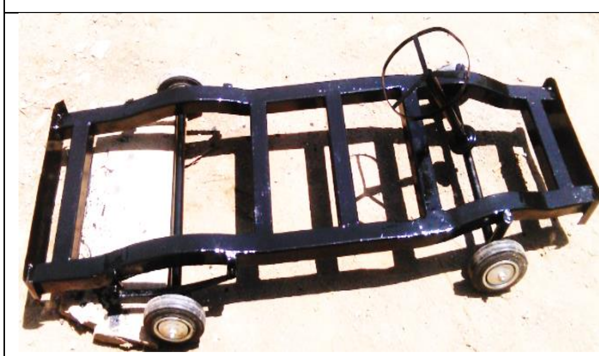
Different data photos and necessary materials for design chassis frame of pickup truck is obtained in this appendix.

Appendix-A model, tools and machines

model, tools and machines	Names and their functions
	Front and top view of chassis frame. The dimensions are indicated on view. Length of the side frame is 1216 mm. its length is the ratio denoted by one over four. therefore actual dimension is 1216×4=4864 mm
	Cut wheel This cut wheel is used to cut and grinding unwanted parts. During grinding chips are removed smoothly. This cut plate is broken due to high rotation and it needs replacement. therefore keep your self during using this cut wheel

	Portable gridding machine Hand gridding machine is used to grind and cut to smooth and remove unwanted part. the wheel is connected to hand machine
	Bench grinding and cutting machine. This machine is used to cut the material.
	Electric welding machine Electric welding machine is used to generate the electric source by using alternative current or direct current.
	Electrode Electrode is used for the purpose of welding and joining two parts.

	Wire Wire is used for purpose of joining. Also used to fill the pit hole.
	Pick up chassis frame This construction is obtained before painting the parts. Steering system, tire, wheel, leaf and coil springs, axle and dumper are the main parts connected to frame.
	Paraflex Paraflex is used to fill and smooth the broken part or the pit hole exist on the parts during preparing prototype.it uses for car
	3d chassis frame for HRCS This three d chassis frame is drawn by using AutoCAD software. As it is indicated on the model HRCS is used for this construction

	3d chassis frame for HSCS This three d chassis frame is drawn by using AutoCAD software. As it is indicated on the model HSCS is used for this construction.
	This is pre procedure during constructing the chassis frame of pickup truck.
	Chassis frame prototype This is the end result of this works. This prototype is generated by using different type of tools and machine. The dimension of the three d models is fit the constructed prototype.
	Synthetic paint It is black in color and paints are provided for finished prototype.

Appendix-B table of material properties		
Austenitizing		
Temperature	870	°C
Elongation	36,35.8&36.5	2% in
Reduction	59,67.9&66	area %
Brinell hardiness	143,131&111	HB
Izod impact ` strength	86.8,117.7&123.4	J
Shear Strength	280	Mpa
Elastic (Young's, Tensile) Modulus	200	Gpa
Shear Modulus	73	Gpa
Thermal Properties		
Latent Heat of Fusion	250	250 J/g
Melting Completion (Liquidus)	1460	1460 °C
Melting Onset (Solidus)	1420	°C, °F
Specific Heat Capacity	470	J/kg-K
Thermal Conductivity	52	W/m-K
Thermal Expansion	12	µm/m-K
Electrical Properties		
Electrical Conductivity: Equal Volume	11%	IACS
Electrical Conductivity: Equal Weight (Specific)	12%	IACS
Otherwise Unclassified Propertiesss		
Base Metal Price	1.80%	Relative
Density	7900	kg/m3
Embodied Carbon	1.4	kg CO2/kg material
Embodied Energy	18	MJ/kg
Embodied Water	45	L/kg

Appendix-C diagram of bending moment

```
// Chassis Frame Design (CFD)
#include<iostream.h>
#include<iomanip.h>
#include<conio.h>
#include<math.h>
#include<fstream.h>
 void main()
  {
   float Wv_N,Wv1_N,L_m,wb_m,FO_m,wpl1,nos,delx,x,Fs,Mb,RO_m,b_mo,h_mo;
```

```
   float Rb,Rc,Rf,Rr,x_min,x_max,x1,x2,x3,a,b,c,Mb_max,b_mm,h_mm,t_mm;
   float b_m,h_m,t_m,y_max,Izzo,b_mi,h_mi,Izzi,Izz,SIGMA_x,SIGMA_xMPa;
   float t_mo,SIGMA_all;
  clrscr();
  ofstream outfile ("CFD.dat");
  cout << " \n\t\t        Chassis Frame Design (CFD) in 'C++' ";
  outfile << " \n\t\t        Chassis Frame Design (CFD) in 'C++' ";
  cout << "\n................................................................................ \n";
  outfile << "\n...................................................................... \n";
  cout <<"\n Enter the 'Vehicle Gross Weight (Wv)' in 'N' = 27664 ";
  cin >> Wv_N;
  cout <<"\n Enter the 'Vehicle Length (L)' in 'm' =  ";
  cin >> L_m;
  cout <<"\n Enter the 'wheel base (wb)' in 'm' = ";
  cin >> wb_m;
  cout <<"\n Enter the 'Front Overhang (FO)' in 'm' = ";
  cin >> FO_m;
  cout <<"\n Enter the 'number of sections (nos)' = ";
  cin >> nos;
                        Wv1_N = Wv_N/2.0; wpl1 = Wv1_N/L_m; RO_m = L_m-(wb_m+FO_m);
                        a = FO_m; b = wb_m; c = RO_m;
                        Rf = (wpl1/(2.0*b))*((a*a)+(2.0*a*b)+(b*b)-(c*c));
                        Rr = (wpl1*a)+(wpl1*b)+(wpl1*c)-Rf;
                        x_min = 0.0; x_max = L_m; delx = L_m/nos;
                        x1 = FO_m; x2 = L_m-RO_m; x3 = L_m;
 cout <<"\n\n\t\tx\tFs\tMb\n";
outfile <<"\n\n\t\tx\tFs\tMb\n";
 for (x = x_min; x <= x_max; x = x+delx)
   {
    if (x >= x_min && x <= x1)
                        {
                         Fs = -(wpl1*x);
                         Mb = -(wpl1*x*x*0.5);
                          cout << setprecision(2)<<"\n\t\t"<<x;
                          outfile << setprecision(2)<<"\n\t\t"<<x;
                          cout <<setprecision(2)<<"\t"<<Fs<<"\t"<<Mb;
                          outfile <<setprecision(2)<<"\t"<<Fs<<"\t"<<Mb;
                          getch();
                           }
    if (x >= x1 && x <= x2)
                        {
                         Fs = Rf-(wpl1*x);
                         Mb = (Rf*(x-x1))-(wpl1*x*x*0.5);
```

```
                        cout << setprecision(2)<<"\n\t\t"<<x;
                        outfile << setprecision(2)<<"\n\t\t"<<x;
                        cout <<setprecision(2)<<"\t"<<Fs<<"\t"<<Mb;
                        outfile <<setprecision(2)<<"\t"<<Fs<<"\t"<<Mb;
                        getch();
                         }
    if (x >= x2 && x <= x3)
                       {
                        Fs = wpl1*(L_m-x);
                        Mb = -(wpl1*(L_m-x)*(L_m-x)*0.5);
                        cout << setprecision(2)<<"\n\t\t"<<x;
                        outfile << setprecision(2)<<"\n\t\t"<<x;
                        cout <<setprecision(2)<<"\t"<<Fs<<"\t"<<Mb;
                        outfile <<setprecision(2)<<"\t"<<Fs<<"\t"<<Mb;
                        getch();
                         }
                          }
                       cout << "\n\n\t\t" <<setprecision(2)<<"\tRf = "<<Rf;
                       cout << "\n\t\t" <<setprecision(2)<<"\tRr = "<<Rr;
                       cout << "\n\t\t" <<setprecision(2)<<"\twpl1 = "<<wpl1;
                       getch();
                       cout <<"\n\n Enter the 'maximum bending Moment (Mb_max)' in 'Nm' = ";
                       cin >> Mb_max;
                       cout <<"\n Enter the 'section width (b)' in 'mm' = ";
                       cin >> b_mm;
                       cout <<"\n Enter the 'section height (h)' in 'mm' = ";
                       cin >> h_mm;
                       cout <<"\n Enter the 'section thickness (t)' in 'mm' = ";
                       cin >> t_mm;
                        b_mo = b_mm*0.001; h_mo = h_mm*0.001; t_mo = t_mm*0.001;
                        y_max = h_mo/2.0; Izzo = (b_mo*h_mo*h_mo*h_mo)/12.0;
                        b_mi = b_mo-(2.0*t_mo); h_mi = h_mo-(2.0*t_mo);
                        Izzi = (b_mi*h_mi*h_mi*h_mi)/12.0; Izz = Izzo-Izzi;
                        SIGMA_x = (Mb_max*y_max)/Izz; SIGMA_xMPa = SIGMA_x*1.0e-6;
                       SIGMA_all = SIGMA_xMPa;
cout << "\n\n  Press 'Enter' twice, to 'proceed'.... ";
 getch();
 getch();
 clrscr();
 cout << "\n\n\n\t  The required 'allowable stress' is:  ";
 cout << "\n\n\t\t" <<setprecision(2)<<"\t\tSIGMA_all = "<<SIGMA_all<<" MPa";
 outfile << "\n\n\t  The required 'allowable stress' is:  ";
 outfile << "\n\n\t\t" <<setprecision(2)<<"\tSIGMA_all = "<<SIGMA_all<<" MPa";
```

```
  cout << "\n\n\n\t\t Press 'enter' twice to exit ! ";
  getch();
  getch();
  getche();
   }
```

Appendix-D chassis frame c++ programing for three reaction case

```
// chassis frame design1 (CFD1)
#include<iostream.h>
#include<iomanip.h>
#include<conio.h>
#include<math.h>
#include<fstream.h>
void main ()
{
float Wv_N,Wv1_N,L_m,FO_m,wp,nos,delx,x,Fs,Mb_Nm,RO_m,h_mo;
float Rc,Rd,Re,Rf,Rr,x_min,x_max,x1,x2,x3,x4,a,b,c,d,Mb_max,b_mm,h_mm,t_mm;
float mb,mc,md,me,wb_m,wp_N,rcl_N,rcr_N,rdl_N,rdr_N,rel_N,rer_N;
float b_m,h_m,t_m,y_max,Izzo,b_mi,Izzi,Izz,SIGMA_x,SIGMA_xMPa,b_mo,h_mi,Mb;
float t_mo,SIGMA_all,c_m, wp_Npermm,EIib;
float mac,mca,mcd,mdc,mde,med,meb,fsdc,fsde;
clrscr();
ofstream outfile ("CFD1.dat");
cout << " \n\t\t        Chassis Frame Design (CFD1) in 'C++' ";
outfile << " \n\t\t        Chassis Frame Design (CFD1) in 'C++' ";
cout << " \n\t\t adama science and technology university in ' c++' ";
outfile  << " \n\t\t    adama science and technology university in ' c++' ";
cout  <<  "  \n\t\t      departement  of  mehanical  system  and
vehicle engineringin                                          ' c++      ' ";
outfile  << "     departement of mehanical system and vehicle
engineringin '                                                 c++'       ";
cout << " \n\t\t yohannes kefyale ( ass.lecturer) in 'C++' ";
outfile  << "   yohannes kefyale ( ass.lecturer) in 'C++' ";
cout << "\n.............................................................                 \n";
outfile << "\n.............................................................              \n";
cout <<"\n Enter the 'Vehicle Gross Weight (Wv)' in 'N' = ";27664.2
cin >> Wv_N;
cout <<"\n Enter the 'Vehicle Length (L)' in 'm' = ";4.864
cin >> L_m;
cout <<"\n Enter the 'wheel base (wb)' in 'm' = ";
cin >> wb_m;
cout <<"\n Enter the 'Front Overhang (FO)' in 'm' = ";
cin >> FO_m;
cout <<"\n Enter the 'number of sections (nos)' = ";
```

```
cin >> nos;
cout <<"\n Enter the'rear over hang '(RO)' in 'm' = ";
cin >> RO_m;
  mca = wp*a*a*0.50 ;
  mcd = -wp*c*c*1.0/12.0;
  mdc = +mcd;
  mde = -wp*c*c*1.0/12.0;
  med = + mde;
  meb = -wp*d*d*0.50;
  mc = mca+mcd;
  me = med+ meb;
  fsdc;
  mcd = -mca;
  mdc = mdc-mc*0.5+ EIib/L_m;
  fsde;
med = -meb;
mde = mde-me*0.50+ EIib/L_m;
EIib        =        L_m*0.5*((-wp*c*c*1.0/12.0+(        12.0+(-wp*c*c*1.0/12.0-
wp*a*a*0.50+wp*c*c*1.0/12.0)*0.5+wp*c*c        *1.0/   wp*d*d*0.50)*0.5))*0.3333;
Wv1_N = Wv_N/2.0; wp = Wv1_N/L_m; RO_m = L_m-(wb_m+FO_m);
a = FO_m; b = wb_m; c = L_m-(a+b+d);d = RO_m, L_m = a+b+c+d ;
rcl_N = wp*a;
rcr_N=wp*b*0.5+((mcd/b)-(mdc/b));
Rc = rcl_N+rcr_N ;
rdl_N = wp*b-rcr_N;
rdr_N = wp*c*0.5+((mcd/b)-(mdc/b));
Rd = rdl_N+rdr_N;
rel_N = wp*c+rdr_N;
rer_N = wp*d;
Re = rel_N+rer_N;
Rf =  wp*a+wp*b*0.5+((mcd/b)-(mdc/b));
Rr = wp*b-rcr_N+wp*c*0.5+((mcd/b)-(mdc/b))+wp*c+rdr_N+wp*d;
Rf = Rc ;
x_min = 0.0; x_max = L_m; delx = L_m/nos;
x1 = FO_m; x2 = L_m-(RO_m+FO_m+c); x3 = L_m-(FO_m+wb_m+RO_m);
x4 = L_m-(FO_m+wb_m+c);
cout <<"\n\n\t\tx\tFs\tMb\n";
outfile <<"\n\n\t\tx\tFs\tMb\n";
for (x = x_min; x <= x_max; x = x+delx)
{
if (x >= x_min && x <= x1)
{
  Fs = -(wp*x);
```

```
  Mb = (wp*x*x*0.5);
   cout << setprecision(2)<<"\n\t\t"<<x;
   outfile << setprecision(2)<<"\n\t\t"<<x;
   cout <<setprecision(2)<<"\t"<<Fs<<"\t"<<Mb;
   outfile <<setprecision(2)<<"\t"<<Fs<<"\t"<<Mb;
   getch();
    }
if (x >= x1 && x <= x2)
{
  Fs = Rc+wp*x1;
  Mb = -wp*x1*x1*1.0/12.0 ;
   cout << setprecision(2)<<"\n\t\t"<<x;
   outfile << setprecision(2)<<"\n\t\t"<<x;
   cout <<setprecision(2)<<"\t"<<Fs<<"\t"<<Mb;
   outfile <<setprecision(2)<<"\t"<<Fs<<"\t"<<Mb;
   getch();
    }
if (x >= x2 && x <= x3)
{
  Fs =  Rc-wp*x2-wp*x2;
  Mb = wp*x2*x2*1.0/12.0;
   cout << setprecision(2)<<"\n\t\t"<<x;
   outfile << setprecision(2)<<"\n\t\t"<<x;
   cout <<setprecision(2)<<"\t"<<Fs<<"\t"<<Mb;
   outfile <<setprecision(2)<<"\t"<<Fs<<"\t"<<Mb;
   getch();
    }
if (x >= x3 && x <= x4)
{
  Fs =  Rc+Rd-wp*(x2+x3)-wp*x3;
  Mb = -wp*x3*x3*1.0/12.0;
   cout << setprecision(2)<<"\n\t\t"<<x;
   outfile << setprecision(2)<<"\n\t\t"<<x;
   cout <<setprecision(2)<<"\t"<<Fs<<"\t"<<Mb;
   outfile <<setprecision(2)<<"\t"<<Fs<<"\t"<<Mb;
   getch();
    }
if (x >= x4 && x <= x_max)
{
  Fs =  wp*x4;
  Mb = -wp*x4*x4*0.50;
   cout << setprecision(2)<<"\n\t\t"<<x;
   outfile << setprecision(2)<<"\n\t\t"<<x;
```

```
   cout <<setprecision(2)<<"\t"<<Fs<<"\t"<<Mb;
   outfile <<setprecision(2)<<"\t"<<Fs<<"\t"<<Mb;
   getch();
     }
 cout << "\n\n\t\t" <<setprecision(2)<<"\tRf = "<<Rc;
 cout << "\n\t\t" <<setprecision(2)<<"\tRr = "<<Rd;
 cout << "\n\t\t" <<setprecision(2)<<"\twp = "<<wp;
 cout << "\n\n\t\t" <<setprecision(2)<<"\tRf = "<<Rf;
 cout << "\n\t\t" <<setprecision(2)<<"\twp = "<<Re;
 getch();
 cout <<"\n\n Enter the 'maximum bending Moment (Mb_max)' in 'Nm' = ";
 cin >> Mb_max;
 cout <<"\n Enter the 'section width (b)' in 'mm' = ";
 cin >> b_mm;
 cout <<"\n Enter the 'section height (h)' in 'mm' = ";
 cin >> h_mm;
 cout <<"\n Enter the 'section thickness (t)' in 'mm' = ";
 cin >> t_mm;
     b_mo = b_mm*0.001; h_mo = h_mm*0.001; t_mo = t_mm*0.001;
     y_max = h_mo/2.0; Izzo = (b_mo*h_mo*h_mo*h_mo)/12.0;
     b_mi = b_mo-(2.0*t_mo); h_mi = h_mo-(2.0*t_mo);
     Izzi = (b_mi*h_mi*h_mi*h_mi)/12.0; Izz = Izzo-Izzi;
     SIGMA_x = (Mb_max*y_max)/Izz; SIGMA_xMPa = SIGMA_x*1.0e-6;
     SIGMA_all = SIGMA_xMPa;
 cout << "\n\n  Press 'Enter' twice, to 'proceed'.... ";
 getch();
 getch();
 clrscr();
 cout << "\n\n\n\t  The required 'allowable stress' is:  ";
 cout << "\n\n\t\t" <<setprecision(2)<<"\t\tSIGMA_all = "<<SIGMA_all<<" MPa";
 outfile << "\n\n\t  The required 'allowable stress' is:  ";
 outfile << "\n\n\t\t" <<setprecision(2)<<"\tSIGMA_all = "<<SIGMA_all<<" MPa";
 cout << "\n\n\n\t\t Press 'enter' twice to exit ! ";
 getch();
 getch();
 getche();
 }}
```

Appendix-E detail drawing of chassis frame pickup truck