Design and modeling of three wheeler chassis for Sheller/Thresher farm machines

By

Wariso Heyi

A THESIS SUBMITTED TO THE

DEPARTMENT OF MECHANICAL SYSTEMS AND VEHICLE ENGINEERING
SCHOOL OF MECHANICAL CHEMICAL AND MATERIALS ENGINEERING

Presented in the Partial Fulfillment of the Requirements for the Award of the Degree of Master of Science in Automotive Engineering

Office of Graduate Studies

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

ADAMA; ETHIOPIA

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Advisor: Ramesh Babu Nallamothu (PhD)

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DECLARATION

I hereby declare that the work which is being presented in the thesis entitled "Design and Modelling of Three Wheeler Chassis for Sheller/Thresher Farm Machines'' 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 October 2018 to May 2020 under the supervision of Ramesh Babu Nallamothu (PhD), Department of Mechanical system and vehicle Engineering, at Adama Science and technology university, Ethiopia. Any portion 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.

Name	Signature	Date
Wariso Heyi		
(Candidate)	________________	_______________

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

Name	Signature	Date
Dr. Ramesh Babu Nallamothu (PhD)		
(Adviser)	______________________	___________________

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Approved by Board of Examiners

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Internal Examiner	Signature	Date
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External Examiner	Signature	Date
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Advisor	Signature	Date

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ACRONYMS

RHS	rectangular hollow section
A	cross-sectional area
I	moment of inertia
S	section modulus
r	radius of gyration
M	bending moment
y	distance from the neutral axis to the extreme fibre
E	young's modulus of the material of the beam
R	radius of curvature of the beam
V	shear force
Q	first moment of area in mm^3
t	width of cross-sectional area
N.A	neutral axis
σ	bending stress
τ	shear stress
$\bar{y}$	Distance of the C.G. of the area **A** from the neutral axis.

Abstract

Three wheeled vehicle is a compromise between two-wheeled and four-wheeled vehicles. That, it has the various advantage in aspects of cost, load-carrying capacity, fuel consumption, space occupation and weight. Hence, it is convenient and widely used as a common means of transportation of peoples and goods for shorter distances over many countries especially in developing one. However, the existing Three-wheeled vehicles are successful means of transportation for people and goods but since it is limited to urban areas only, people in rural area of Ethiopia yet, has no such access for transportation people, goods and for performing their farming activities properly too. To minimize this, a new three-wheeled chassis can be used to transport Sheller/thresher machines easily, was designed and modelled. This also helps to make the transportation of people and goods easily, economically and to perform farming activities simultaneously using such machines. The purpose of this thesis work is to Design, and Model three-wheeled chassis which would be convenient to transport farm machines, such as Sheller/thresher at farm sites or rural area. This had achieved by design and modelling three-wheeled chassis of ladder frame using structural steel of rectangular hollow section, Air-cooled Diesel Engine of 9HP and components of TAGRO Bajaj (Bajaj Re-4 stroke) such as: steering column, braking systems, suspension systems, wheel and tyre, by using AutoCAD 2007 and ANSYS R18 software for modelling chassis structures and verification of static analysis respectively. The results that obtained of static analysis was better in strength and stiffness, easy to manufacture and cost effective.

Keywords: *Three-wheeled chassis, static analysis, Auto CAD, Frame, Sheller/Thresher*

CHAPTER ONE
INTRODUCTION

1.1. Background

Three-wheeler vehicles have been popular in many countries as a means of transportation of goods and peoples for shorter distances. Using Three-wheelers are convenient and cost-effective. Nowadays this resulted, the three-wheeler vehicles being disseminated throughout almost all Ethiopian towns and it has been playing a great role in transporting people and goods.

Unlike this, about 85 % of the Ethiopian population who gains their livelihood directly or indirectly from agricultural production in a rural area of Ethiopia yet, had a big constrain in terms, of accessing such transportation options for their products and assisting technology to perform their farm activities as well. However, farmer's demands have been increasing to use farm machines like, Sheller/thresher technologies which could be assist in performing their farm activities, in contrast to this the existing machines are heavy (about 300 kg), bulk size and constructed with no transportation mechanisms. Moving such machines even in shorter distance and loading, unloading to carts, car etc. is difficult and needs minimum of four to eight (4/8) manpower in transporting process as indicated in the figure 1.1 and figure 1.2 below, which had been labor intensive and incurring farmers to additional financial burden. The Sheller shown in figure 1.2, weighs 274 kg. To alleviate this design and modelling of simple and economic three-wheeled chassis is a better solution.

etc.

Figure 1. 1 loading of the Thresher to the car

Figure 1. 2 Sheller

Pictures Source: Melkasa Agricultural Research Center(MARC)

"Chassis" a French term which means the complete automobiles without body and it includes all the systems like power plant, transmission, steering, suspension, wheels tyres, auto electric system etc.

If body is also attached to it then it is known as the particular vehicle as per the shape and design of the body.

The chassis of an automobile is defined as frame supported on springs and attached to the axle that holds the body and engine of vehicle. Chassis is a French word and was initially used to denote the frame parts or basic structure of an automobile. It is the backbone of the vehicle. It is the main mounting for all the components. So, it is also called as Carrying unity.

The chassis is possibly the most important part of any vehicle. Its main role is to provide the vehicle with a main structure which all other components can be fixed to. The chassis must be rigid in both torsion and bending and must be able to resist twisting and sagging. The chassis must be able to accommodate and support all the components of the vehicle and any occupants and must absorb all loads without excessive deflection (Bhande Akshay S et al., 2018).

Components of Chassis

Frame: A frame is the main structure of vehicle chassis to which all other components fasten.

The frame is defined as a fabricated structural assembly that supports all functional vehicle systems. This assembly may be a single welded structure, multiple welded structures, or a combination of composite and welded structures. It is the most crucial element that gives strength and stability to the vehicle under different load conditions Depending upon the application of loads and direction, chassis frame is deformed to vertical bending, longitudinal torsion, lateral bending and Horizontal lozenging this may causes chassis frame to loss its function and handling problem, to avoid such problems chassis frame should design with sufficient strength and stiffness it is the strong metal structure that provides a mounting place for the other parts of the vehicles.

- Engine or Power plant: it provides the source of power
- Clutch: it connects and disconnects the power from the engine flywheel to the transmission system.
- Gear Box, U Joint, Propeller Shaft and Differential.

Functions of the chassis frame:

- To carry load of the passenger or goods carried in the body.
- To support the load of the body, engine, gear box etc.,
- To withstand the forces caused due to the sudden braking or acceleration
- To withstand the stresses caused due to the bad road condition.
- To withstand centrifugal force while cornering

There are several types of chassis structures. Structural selection is an important point since it will define all the following stages of chassis development. There are different choices, monocoque, semi-monocoque body on frame. Backbone and ladder chassis. With advantage and disadvantage of each. (Book reference).

Hence**,** this thesis work had been carried out to **Design** and **Model** a **Three Wheeled Chassis of ladder frame** of payload capacity about 1000 kg (1 ton) which is able to assist farmers in transporting Sheller/thresher machines from location to location with less effort and economically. This minimizes transporting problems and simultaneously enables such machines using for farming activities too.

The input required like weight and dimensions etc. which used to embark on three-wheeled chassis design and modeling have been gathered from the existing Sheller/thresher.

The materials had been selected based on the required strength, stiffness, and availability in the market.

Finally, Design analysis have been carried out using analytical method and ANSYS R18.0 have been used for verification of static analysis. 3D Modelling and structural analysis of the chassis had been carried out using AutoCAD and ANSYS software, respectively.

1.2 Statement of the problem

Ethiopia has a long history of agricultural practices, but due to the development of agricultural mechanization is minimal, still farm power is mainly dependent on manpower, even operating and utilizing of existing maize Sheller/multi-crop thresher is difficult. This caused due to those machines are heavy in weight (about 300 kg) and didn't incorporate driving mechanism in their design and construction therefore, Moving of those machines from place to place for farming activities is labor intensive (even to move it in a short distance 4-8 people are needed) and inconvenient. This causing additional expenditure and effort to the farmers.

1.3 Objectives

1.3.1 General Objective

The general objective of this thesis work is to Design and Modeling of three wheeled chassis of ladder frame for transporting of Sheller/thresher farm machines from location to locations easily.

1.3.2. Specific Objectives

The specific objectives are:

- To collect the data related to the Sheller/Thresher and material properties of rectangular hollow section (RHS).
- To design three-wheeler chassis.
- To develop model of chassis structure
- To analyse the developed model for stresses and deflections using ANSYS.

1.4. Significance of the work.

The significance of this thesis work is as follows:

This thesis work provides information for technology users, manufacturers, higher education and farm machineries research institutes.

1.5. Beneficiaries

The project is expected to benefit the following bodies.
Farmers, Local Manufacturers, Service providers, Investors, Research institutes, higher institution for teaching aid/purposes and all individuals of the society and the country as a whole.

1.6. Delimitation (Scope)

This thesis work is limited to the Design and Modelling of three wheeled ladder frame chassis.

1.7. Limitation

Due to pandemic of Covid-19 the thesis work has the limitation of prototype construction since, construction of prototype requires different manufacturing machines available at different companies.

1.8 Organization of the study

The thesis is organized with the following chapters.

Chapter one: Introduction, includes background of the study, statement of the problem, general and specific objectives, significance of the study, beneficiaries and delimitation (scope) of the study.

Chapter two: Literature review, includes introduction of chassis, literature review, components of chassis, types of chassis frame, three-wheeled vehicles, types of chassis structures, and requirements of chassis structures.

Chapter three: Materials and methods, includes materials, methods, design and modeling of three-wheeler chassis, basic calculation for chassis frame structure, analysis for stresses, shear stresses in beams, calculation for deflection, design chassis frame using factor of safety, and analytical verification Via ANSYS software.

Chapter four: Result and discussion, includes theoretical and analytical comparison results of maximum stress, deflection and equivalent (von-Mises) stress and simulation.

Chapter Five: Summary, Conclusion and Recommendation

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

Chassis is the most integral part of the vehicle. It is the frame of the chassis on which the entire body of the vehicle is built. The entire external load of the vehicle including its self-weight is on the chassis. Thus, this chassis design and its analysis forms the most important part of the vehicle manufacturing. To design a chassis of the vehicle which gives the most appropriate desired results is the most tedious task. The chassis has the most complex design and it also doesn't have a proper loading pattern and thus its design and analysis is complex. Thus, the most accurate and widely used method of analysis, which is the numerical method of analysis using ANSYS package is used. During the design and analysis of the chassis. The manufacturers of todays are more towards developing a chassis which could carry more payload than it usually does. The chassis has to not only carry the vehicle's own load like cabin, engine, transmission system but also the body of the vehicle including the passengers and their payloads (Ramesh Kumar, 2018).

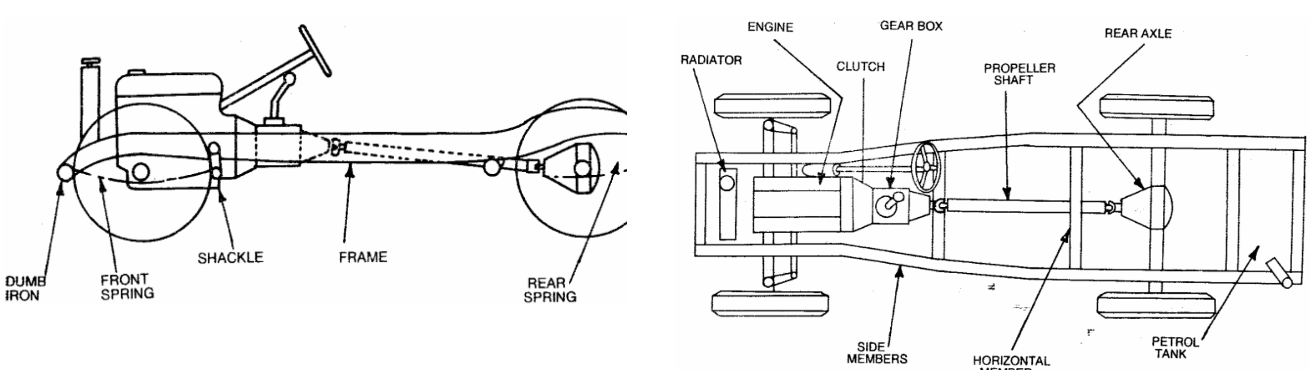

Figure 2. 1 Layout of chassis and its main components

Source: Sri. N.R.Hema Kumar

2.2. Literature review

Manish M. Patil et al., (2017) had developed three-wheeler chassis of payload capacity about 150 kg to transport physically disable peoples and fright as well. As the chassis withstand necessary loads as well as absorbs shocks, structural strength, dimensions, geometry and load of intended three wheeler chassis had been taken into consideration while developing this three wheeler chassis from existing two wheeler chassis and the frame structure had designed using mild steel pipes reinforced with angle bars where necessary. The chassis frame was modelled with 3D dimensional as beam elements using circular hollow sections. FEA software ANSYS was used. In determination of static analysis of displacements, strains, stresses, and reaction forces.

Sharad Patel et al., (2016) had designed and developed three-wheeled vehicle of load capacity about 200 kg for indoor mobility in large campuses, airport, industries, recreational parks, museums, palace etc. where walking consumes a lot of time.
A chassis frame was made up of mild steel pipe of 38 mm diameter. Compare to other available frame structures such solid bar section, square section, I section the hollow pipe structure has minimum weight and enough strength. Stress and strength results were taken by considering a weight of 200 kg on it. So the vehicle was safe against load condition of max. 200 kg.

Damtie Enawgew et al., (2013) investigated shortcoming of existing three wheeled vehicle chassis frame structure assembled in Ethiopia and improved strength of chassis frame structures. The Load capacity of the structure were about 330 kg or 3237. 3 N. this had been applied at the center of gravity of the frame. And maximum payload including driver is about 320 kg applied at seat points of each passenger and driver each had estimated 80 kg (784.8N) weights. The chassis of semi-monoque type of the existing structure was improved to a space frame by using rectangular hollow section (RHS) of 40×40×3 mm steel beam welded together, with the same length, width and height values as existing one, the result obtained was also such a better in strength and stiffness, easy to manufacture and cost effective.

A. Hari Kumar et al., (2016) stated that chassis is to be considered as one of the significant structures of an automobile. It is the frame which holds both the car body and the power train. Various mechanical parts like the engine and the drive train, the axle assemblies including the wheels, the suspension parts, the brakes, the steering components, etc., are bolted onto the chassis. The chassis provides the strength needed for supporting the different vehicular components as well as the payload and helps to keep the automobile rigid and stiff. Consequently, the chassis is also an important component of the overall safety system. Furthermore, it insures low levels of noise, vibrations and harshness throughout the automobile. Chassis should be rigid enough to withstand the shock, twist, vibration and other stresses. Along the strength, an important consideration in chassis design is to have adequate bending and torsional stiffness for better handling characteristics. So, strength and stiffness are two important criteria for the design of chassis. The load carrying structure is the chassis, so the chassis has to be designed that it has to withstand the loads that are coming over it.

B.Ramya et al., (2014) studied that, as the chassis design in general is a complex methodology and to arrive at a solution which yields a good performance is a tedious task. Since the chassis has a complex geometry and loading patterns, there is no well- defined analytical procedure to analyze the chassis. So, the numerical method of analysis is adopted, in which Finite Element Technique is most widely used method. Vehicle chassis is an important part which supports the major load of the Vehicle assembly. As Vehicle chassis plays a vital role, its design has to be subjected to Structural Analysis to validate against all the possible cases of load applications and failures to strengthen the design. Static analysis calculates the effect of steady load conditions on structure while ignoring inertia and damping effects, such as those caused by time varying loads. A static analysis therefore can include steady inertia loads (such as gravitational and rotational velocity). Static analysis is used to determine the displacement, stresses, strains and forces in the structures or components caused by loads that do not induce significant inertia and damping effects. The kind of loading that can be included in static analysis are 1. Externally applied forces and pressure 2. Steady state inertia forces (such as gravity and rotational velocity)

ANSYS solver formulates the governing structural stress strain equations for each and every element and these formulated governing equations are for solving the deformations from which all the other quantities such stresses, strain etc. can be calculated.

Ravinder Pal Singh et al., (2010) stated that, good chassis design allow a light, stiff and extremely safe and to be produced at a reasonable manufacturing cost since, it is an indispensable structural backbone of an automobile

Depending upon application of loads and their direction, chassis is deformed in respective manner briefed as follows.

Chassis loads

i. Vertical bending
ii. Longitudinal torsion
iii. Lateral bending
iv. Horizontal lozenging

Vertical bending: the weight of vehicle components mounted on the frame and driver's weight etc. under an effect of gravity produce sag in the frame. Frame is assumed to act as simply supported beam and four wheels as supports tend to produce reactions vertically upward at the axles. Vertical dynamic forces due to acceleration/deceleration further increase the vertical deflection, hence stresses in chassis.

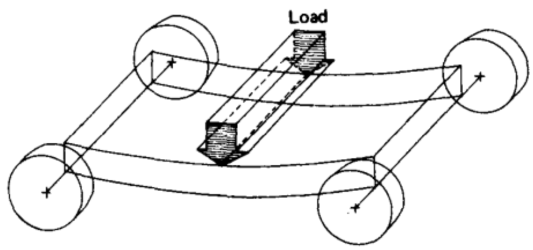

Figure 2. 2 Vertical bending

Longitudinal torsion: Application of equal and opposite forces act at a certain distance from an axis tends to rotate the body about the same axis. Vehicles also experience torsion while moving on road subjected to forces of different magnitudes acting on one or two oppositely opposed corners of the vehicles. The frame can be thought as a torsion spring connecting the two ends where suspension loads act. Torsional loading and resultant momentary elastic or permanent plastic deformation and subsequent unwanted deflections of suspension springs can affect the handling as well as performance of vehicle. The resistance to torsional deformation is called as stiffness and it is expressed in Nm/degree in SI units. Torsional rigidity is a foremost and primary determinant of frame performance of vehicles.

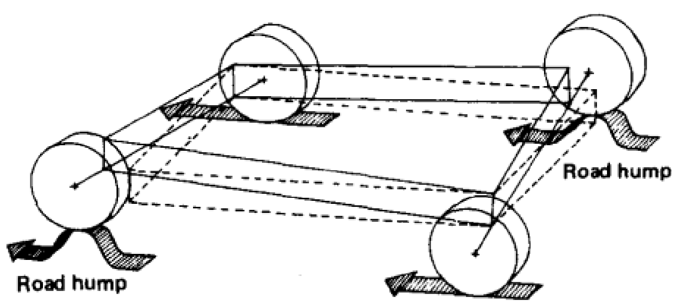

Figure 2. 3 Longitudinal torsion

Lateral bending: lateral bending deformation occurs mainly due to the centrifugal forces caused during cornering and wind forces to some extent. Lateral forces act along the length of chassis and is resisted by axles, tires and frame members.

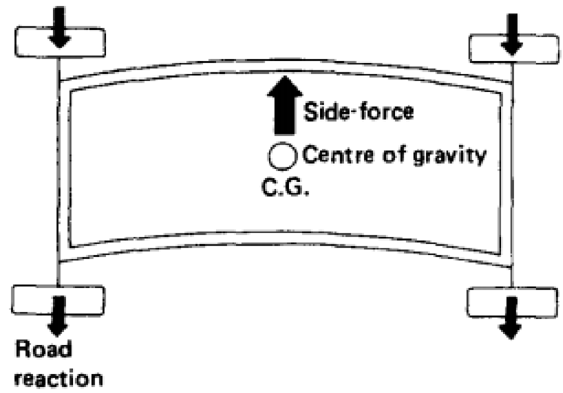

Figure 2. 4 Lateral bending

Horizontal lozenging: this deformation is caused by forward and backward forces applied at opposite wheels. These forces may be caused by vertical variations in the pavement or the reaction from the road driving the car forward. These forces tend to distort the frame into a parallelogram shape. The magnitude of these loads changes with the operating mode of the vehicle.

It is generally thought that if torsional and vertical bending stiffness is satisfactory, then the chassis structure is expected to perform well. But torsional stiffness is given more weightage as the total cornering traction is the function of lateral weight transfers.

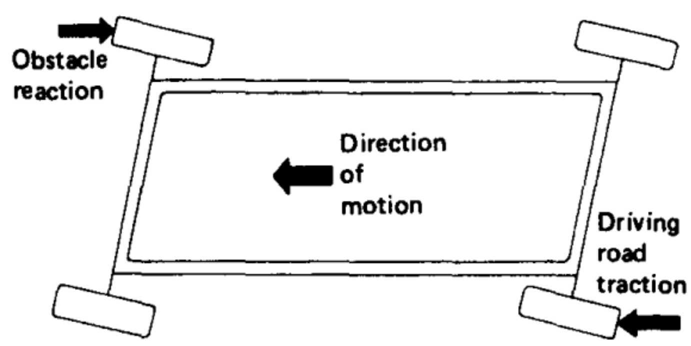

Figure 2. 5 Lozenging

2.3. Components of Chassis

Frame: A frame is the main structure of vehicle chassis to which all other components fasten.

The frame is defined as a fabricated structural assembly that supports all functional vehicle systems. This assembly may be a single welded structure, multiple welded structures, or a combination of composite and welded structures. It is the most crucial element that gives strength and stability to the vehicle under different load conditions Depending upon the application of loads and direction, chassis frame is deformed to vertical bending, longitudinal torsion, lateral bending and Horizontal lozenging this may causes chassis frame to loss its function and handling problem, to avoid such problems chassis frame should design with sufficient strength and stiffness it is the strong metal structure that provides a mounting place for the other parts of the vehicles.

- Engine or Power plant: it provides the source of power
- Clutch: it connects and disconnects the power from the engine flywheel to the transmission system.
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Functions of the chassis frame:

- To carry load of the passenger or goods carried in the body.
- To support the load of the body, engine, gear box etc.,
- To withstand the forces caused due to the sudden braking or acceleration
- To withstand the stresses caused due to the bad road condition.
- To withstand centrifugal force while cornering

2.4. Types of Chassis Frames

There are three types of Frames:

Conventional Frame: it has two long side members and 5 to 6 cross members joined together with the help of rivets and bolts to prevent torsional deflection and maintain geometry.

The frame sections are used generally.

- Channel Section – Good resistance to bending
- Tabular Section – Good resistance to torsion
- Box Section – Good resistance to both bending and torsion

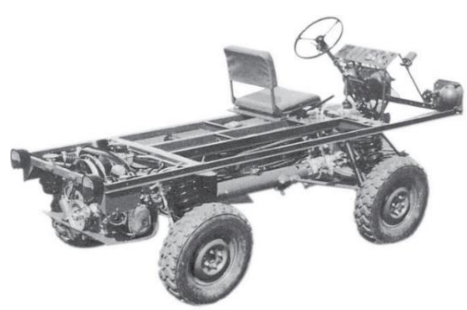


Figure 2. 6 Conventional Frame (Body-over Frame)

Integral Frame: this frame is used now a days in most of the cars. There is no frame and all the assembly units are attached to the body. All the functions of the frame carried out by the body itself. Due to elimination of long frame it is cheaper and due to less weight most economical also. Only disadvantage is repairing is difficult.

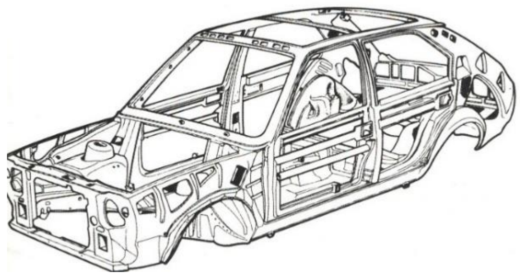


Figure 2. 7 Integral Frame (Unibody)

Semi – integral Frame: in some vehicles half frame is fixed in the front end on which engine gear box and front suspension is mounted. It has the advantage when the vehicle is met with accident the front frame can be taken easily to replace the damaged chassis frame. This type of frame is used in FIAT cars and some of the European and American cars.

There are also several types of chassis structures. Structural selection is an important point since it will define all the following stages of chassis development. There are different choices, monocoque, semi-monocoque body on frame. Backbone and ladder chassis. With advantage and disadvantage of each. (Book reference).

- Ladder chassis frame which is a concern of this thesis project.

2.5. Three Wheeled Vehicles

Some common three wheeled vehicles on the market and their suspension solutions are discussed below.

Piaggio Ape

The first "**auto rickshow**" was produced in 1948 by the Italian company Piaggio & C. SpA. The model was named Ape and they are produced in three different types: van, pick-up and rickshaw. It has got a semi-monocoque frame and a steel body in the front that fits either one or two peoples, while the rear is built as a single load-bearing chassis in sheet metal. The rear suspension consists of trailing arms, spring coils and shock absorbers and in the front, there is a leading link suspension (Thomas Gyllendahl, and David Tran 2012).

Bajaj

Bajaj Auto is the fourth largest manufacturer of two- and three-wheelers in the world and the largest three wheeled vehicle producer in India. The Bajaj auto rickshaws are very common on the Ethiopian market. One common version is the Bajaj RE. The first rickshaw built by Bajaj was licensed under Piaggio/Vespa and appeared on the market in 1950. They used same mechanics as the Piaggio Ape but changed its appearance and even introduced a taxi version which Piaggio Ape did not have. This means that they still used the trailing arms together with shock absorbers and springs as rear suspension and leading link as front suspension (Damtie Enawgew et al., 2013).

TVS King

The first auto rickshaw developed by TVS Motor was named TVS King and was introduced in 2008, it was the first auto rickshaw model in India with a four stroke 200 cc engine. The TVS King uses trailing link as front suspension and individual trailing arms as rear suspension and it has got constant rate coil springs with co-axial hydraulic dampers

Both Bajaj and TVS Kings were taken as my concern in this thesis project (Thomas Gyllendahl, and David Tran 2012).

Mahindra & Mahindra

Mahindra & Mahindra is a company that doesn’t just aim for the commercialized vehicle but also to personal vehicle such as SUV, tractors, two-wheelers etc. the company was started in 1945 and is an underlying company of Mahindra group. The first three-wheeler to reach the market was the Alfa which was introduced in 2008. The Alfa is equipped with leading link, coil spring and hydraulic shock absorber as the front suspension. The rear suspension consists of independent trailing arms together with hydraulic shock absorbers and rubber springs (Thomas Gyllendahl, and David Tran 2012).

Monika Motors

Second largest company that specializes on auto rickshaws in Thailand, it is a part of the B.Grimm concern and was founded in 1883. First auto rickshaw came into production in 1960 and was named Monika L5. The L5 uses the same suspension combination as Tuk Tuk Forwarders auto rickshaws, i.e. a dual telescopic fork and a rigid rear axle with leaf springs. In other hand it can be said that trailing arms are common as a rear suspension and trailing and leading link are common in the front. Those equipped with leading link has the advantage of anti-dive (Thomas Gyllendahl, and David Tran 2012).

Tuk Tuk Forwarder Co., Ltd

This company is only aimed on rickshaws and was founded in 1993. They did not start their production until 1996 where they had a yearly capacity of 12000 units. In 1994 the first two electrical Tuk Tuks were produced. Suspension wise this company goes in another direction than the rest as they use leaf springs and double shock absorbers together with a rigid axle for the rear suspension. In the front they use a telescopic fork with coil springs and dual shock absorbers (Thomas Gyllendahl, and David Tran 2012).

2.6. Types of Chassis Structure

Monocoque or Integral Structure

Monocoque structures consists of sheets, beams or other kinds of metal components united by welding and resulting in a rigid structure in one piece. Monocoque chassis are used now a day for majority of the vehicles. It is efficient in terms of using space, so the interior space is wide. It is not cost effective to manufacture them in small quantities. However, it is easy to mass produce. They might be economically produced due to the high automation which allows their manufacture. Monocoque structure uses more metal material than any other type of structure, consequently, it is heavier. This structure is the best configuration to protect the passengers in rollover, and generally in any kind of collision because it provides more stability in case of an accident. Nevertheless, after having an accident the reparation is quite difficult. Less noise and vibration are produced compared with any other type of structure. One disadvantage is that is difficult to design different bodyworks from the same vehicle and any kind of reform in the structure are almost impossible to implement. Because it is geometrically very complicated, sheet steel pressings and spot welds used to form an integral structure. Side frames + depth + roof give good bending and torsion stiffness. Stress distribution is function of applied loads and relative stiffness between components. Stress distribution can be analysed by FEM. Its advantages are stiffer in bending and torsion, lower weight, less cost and quite operation (Jornsen Reimpell et al., 2001).

Sami Monocoque

Sami monocoque structure is quite similar to monocoque structure. The only difference is that semimonocoque has longerons and stingers to make up a strength base. The other components are attached to this base. Sometimes, it is difficult to differentiate it from monocoque structure. Nowadays auto-rickshaws have a semi-monocoque chassis. It is a very simple structure that consists on a combination of longerons and stingers supporting the weight of the metal sheets, and the round tubes where the roof is attached. The chassis of the current auto-rickshaws is not monocoque or independent chassis (Damtie Enawgew et al., 2013).

Space Frames or Body on Frame

Body on frame is the oldest structure system used and nowadays it only applies in the construction of commercial vehicles and off-road vehicles. It consists of two different structures: the frame and the bodywork. The frame is a structure consisting of one or more metal beams along the vehicle. Connected by crossbars welded, screwed or riveted. Arranged transversely or diagonally. This element has a high strength and the mechanical components, and the bodywork are attached on it. The body forms the outer shell of the vehicle and is screwed to the frame. It has not any strength feature. This system allows some advantages. It has a great strength to carry heavy loads and a high rigidity to withstand high elastic and dynamic stresses. This system also protects the bodywork from bending or torsion efforts. The body on frame system has a great facility to use different bodies in the same frame. Reforms in the body can also be performed easily. In all frames till now length in one dimension is very less compared to the other two dimensions. Increasing depth increases bending strength. Beams elements carry either tension or compressive loads (Jornsen Reimpell et.al, 2001).

Backbone

A backbone chassis is the simplest structure design. It consists of a sturdy tubular backbone that joints the front and rear axle. These chassis is fully enclosed to be rigid structure and handle all loads. It should be noted that the backbone chassis can be built through many types of construction. The space within the structure is used to place the driveshaft in case of front-engine, Rear-wheel drive layout. Further, the drive train, engine and suspensions are all connected to each of the ends of the chassis.The body is built on the backbone usually made of glass-fiber. Almost rear wheel drive and front engine vehicles use backbone chassis. Main backbone is a closed box section. Splayed beams at front and rear extent to suspension mounting points. Transverse beams resist lateral loads, backbone frame bending and torsion beam, splayed beams, bending, transverse beams tension or compression (Jornsen Reimpell et al., 2001).

Ladder Frame

A ladder frame is the simplest and oldest frame used in modern vehicle construction. It was originally adapted from “horse and buggy” style carriages as it provided sufficient strength for holding the weight of the components. Larger beams could be used if there were higher weight capacity required. The engine of the vehicle using this ladder frame is placed in the front or sometimes in the rear and supported at suspension points. Their constructions consist of two longitudinal rails interconnected by many lateral/cross braces, typically made from round or rectangular tubing or channel. The longitudinal members are the main stress member. They deal with the load and also the longitudinal forces caused by acceleration and braking. 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. Most SUV’s are still use ladder chassis (Jornsen Reimpell et al., 2001).

2.7. Requirements of chassis structure

The purpose of the structure is to maintain the shape of the vehicle and to support the various loads applied to it. The structure usually accounts for a large proportion of the development and manufacturing cost in a new vehicle programme, and many different structural concepts are available to the designer. It is essential that the best one is chosen to ensure acceptable structural performance within other design constrains such as cost, volume and, method of production, product application, etc. Assessments of the performance of a vehicle structure are related to its strength and stiffness. A design aim is to achieve sufficient levels of these with as little mass as possible (Jason C, 2002).

Strength: The strength requirement implies that no part of the structure will lose its function when it is subjected to loads. Loss of function may be caused by instantaneous overloads due to extreme load cases, or by material fatigue. Instantaneous failure may be caused by

(a) Overstressing of components beyond the elastic limit, or

(b) By buckling of items in compression or shear, or

(c) By failure of joints.

The strength may be alternatively defined as the maximum force which the structure can withstand. Different load cases cause different local component loads, but the structure must have sufficient strength for all load cases (Jason C, 2002).

Stiffness: The stiffness K of the structure relates the deflection Δ produced when load P is applied, i.e. $P = K\Delta$. it applies only to structures in the elastic range.

The stiffness of a vehicle structure has important influences on its handling and vibrational behaviour. It is important to ensure that deflections due to extreme loads are not so large as to impair the function of the vehicle, for example, so, that the doors will not close, or suspension geometry is altered. Low stiffness can lead to unacceptable vibrations, such as "scuttle shake". Again, different load cases require different stiffness definitions, and some of these are often used as 'benchmarks' of vehicle structural performance. The two most commonly used in this way are:

a. Bending stiffness K_B, which relates the symmetrical vertical deflection of a point near the centre of the wheelbase to multiples of the total static loads on the vehicle. A simplified version of this is to relate the deflection to a single, symmetrically applied load near the centre of the wheelbase.
b. Torsion stiffness K_T, relates the torsional deflection θ of the structure to an applied pure torque T about the longitudinal axis of the vehicle. The vehicle is subjected to the 'pure torsional load case' (where the torque is applied as equal and opposite couples acting on suspension mounting points at the front and rear), and the twist θ is measured between the front and rear suspension mountings. Twist at intermediate points along the wheelbase is sometimes also measured in order to highlight regions of the structure needing stiffening.

   These two cases apply completely different local loads to individual components within the vehicle. It is usually found that the torsion case is the most difficult to design for, so that the torsion stiffness is often used as a ‘benchmark’ to indicate the effectiveness of the of the vehicle structure (Jason C, 2002).

Vibrational behavior: The global vibrational characteristics of a vehicle are related to both its stiffness and mass distribution. The frequencies of the global bending and torsional vibration modes are commonly used as benchmarks for vehicle structural performance.

Bending and torsion stiffness K_B and K_T influence the vibrational behaviour of the structure, particularly its first natural frequency (Jason C, 2002).

2.8 Design consideration of Chassis frame

Bending Case: The bending conditions depend upon the weights of the major components of the vehicle and the payload. The first consideration is the static condition by determining the load distribution along the vehicle. The axle reaction loads are obtained by resolving forces and taking moments from the weights and positions of the components (i.e. the equations of statics). The structure can be treated as a two-dimensional beam as the vehicle is approximately symmetric about the longitudinal x- axis. A typical medium size passenger carload distribution is shown in figure 2.10 below. Examination of figure shows a typical list of the major components of the vehicle that are considered. The distributed loads are estimates of the weight per unit length for the body of the vehicle including trim details. The unsprung masses consisting of wheels, brake discs/drums and suspension links are of course not included as they do not impose loads on the structure. (Julian Happian – Smith, 2002)

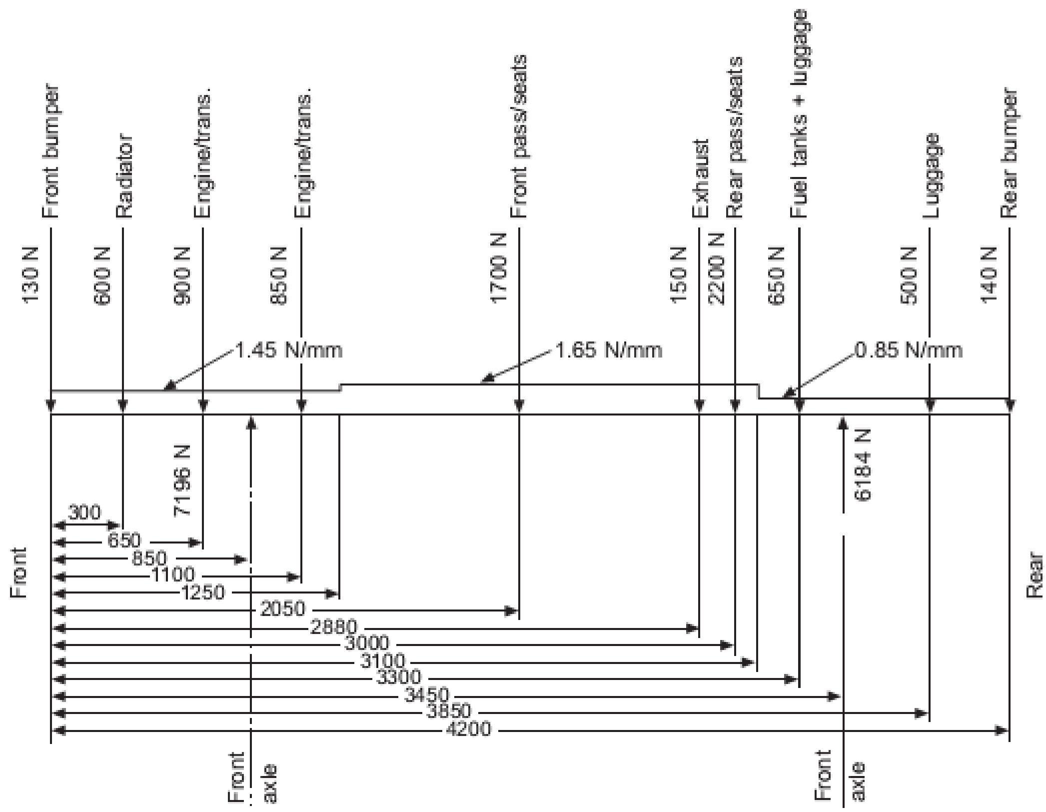


Figure 2.8 Typical Passenger Vehicle Bending Loads

Source: Julian Happian Smith, 2002

From the load diagrams of figure 2.11. And 2.12. The bending moment diagram and shear force diagram can be constructed in the normal way. As shown below.

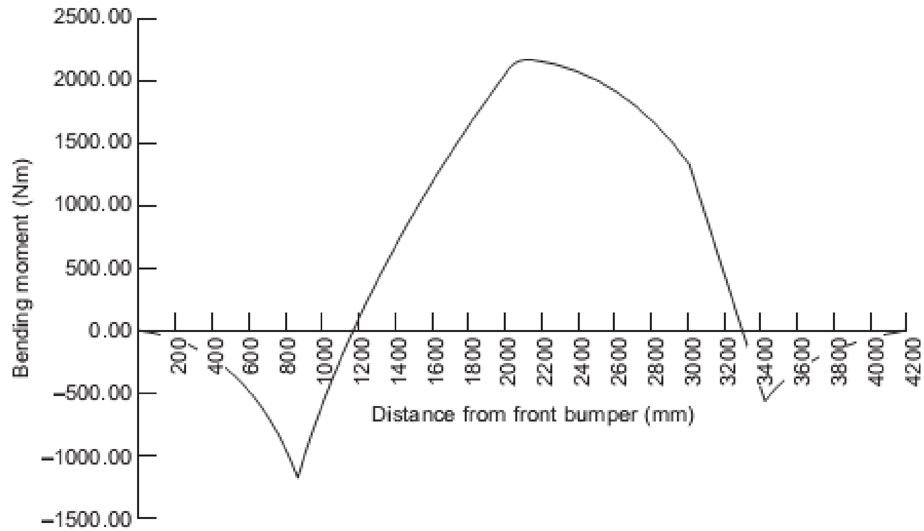


Figure 2.9 Passenger car bending moments

Source: Julian Happian Smith, 2002

Figure 2.10 Passenger car shear force diagram

Source: Julian Happian Smith, 2002

The dynamic loading must be considered as the vehicle traverses uneven road surfaces. For example, the vehicle may pass over a hump-back bridge at such a speed that the wheels leave the ground. The resulting impact of the vehicle returning to earth is cushioned by the suspension system but inevitably causes a considerable increase in loading over the static condition. Experience gained by vehicle manufacturers indicates that the static loads should be increased by factors of 2.5 to 3.0 for road going vehicles. Off-road or cross-country vehicles may be designed with factors of 4 (Pawlowski, 1964).

Torsion case: The case of pure torsion can be considered simply as being applied at one axle line and reacted at the other axle. The condition of pure torsion cannot exist on its own because vertical loads always exist due to gravity. The maximum torsion moment is based on the loads at the lighter loaded axle, and its value is the wheel load on that lighter loaded axle multiplied by the wheel track.

The torsion moment $\frac{R_F}{2} t_f = \frac{R_R}{2} t_r$

The front and rear track t_f and t_r respectively may be slightly different and the rear axle load R_R is usually smaller then R_F for a modern passenger car even when fully laden. In this situation R_R is the load on the rear axle for the fully laden case R_F will be less than the front axle load for the same fully laden condition.

Once again these loads are based on static reaction loads but dynamic factors in this case are typically 1.3 for road vehicles (Pawlowski, 1964). For trucks which often go off road 1.5 and for cross-country vehicles a factor of 1.8 may be used.

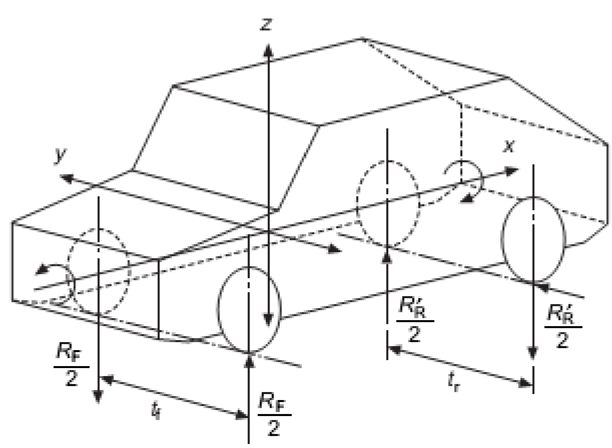


Figure 2.11 Vehicle torsion case

CHAPTER THREE

MATERIALS AND METHODS

3.1. Materials

Selection of materials for accomplishment of this thesis work was carried out on the basis of availability of materials in the market, resistance to both bending and torsion under application of loads and its mechanical and physical properties. Table 3.1 and 3.2 below show the lists of materials and mechanical properties of structural steel used in this work, respectively.

Table 3.1 Materials used

Materials	**Specification**
Structural steel	- Rectangular hollow section - size 40mm×60mm×3mm - ASTM A501
TAGRO Bajaj (Bajaj Re-4 Stroke) components - Steering column - Braking systems - Suspension systems - Wheel - Tire	Standard existing spare parts
Diesel Engine	- 4-stroke - Air cooled - 9 HP

Structural steel of Rectangular hollow section (RHS),

$$40 \times 60 \times 3mm$$
$$40 = width/base\ (mm)$$
$$60 = vetical\ depth (mm)$$
$$3 = wall\ thickness (mm)$$

Table 3.2 Mechanical properties of structural steel

Parameters	Values
Yield strength	250 min MPa
Tensile stress	343 min (MPa)
Young’s modulus	207 GPa
Poisson’s ratio	0.30
Density	7850 kg/m^3
Elongation	30(%)

Structural Steel: Most structural steels are designated by ASTM standards established by the American Society for Testing and Materials. One common grade is ASTM A36. Which has a minimum yield point of 248 MPa and is very ductile. It is basically a low-carbon. Hot-rolled steel available in sheet, plate, bar and structural shapes such as some wide-flange beams. American Standard beams, channels and angles.

Most wide-flange beams (W-shapes) are currently made using ASTM A992 structural steel. Which has a yield point of 345 to 448 MPa and a minimum tensile strength of 448 MPa. An additional requirement is that the maximum ratio of the yield point to the tensile strength is 0.85. This is a highly ductile steel. Having a minimum of 21% elongation in a 2.00-inch gage length. Using this steel instead of the lower strength ASTM A36 steel typically allows smaller, lighter structural members at little or no additional cost.

Hollow structural sections (HSS) are typically made from ASTM A500 steel that is cold-formed and either welded or made seamless. Included are round tubes and square and rectangular shapes. There are different strength values for round tubes as compared with the shaped forms. Also, several strength grades can be specified. Some of these HSS products are made from ASTM A501 hot-formed steel having properties similar to the ASTM A36 hot-rolled steel shapes.

Many higher strength grades of structural steel are available for use in construction, vehicular and machine applications. They provide yield points in the range from 290 – 700 MPa. Some of these grades, referred to as high-strength, low-alloy (HSLA) steels are ASTM A242, A440, A514, A572 and A588. (Robert L. Mott, P.E.2004)

Steel Structural Shapes

Steel manufacturers provide a large array of standard structural shapes that are efficient in the use of material and that are convenient for specification and installation into machine frames.

Designations for steel and aluminium shapes are:

Standard angles (**L**- shapes), channels (C- shapes), wide-flange beams (**W**-shapes), American Standard beams (S-shapes), structural tubing, and pipe.

Note that the **W**-shapes and the **S**-shapes are often referred to in general conversation as "**I**- beams" because the shape of the cross section looks like the capital letter **I**.

Table 3.3 below gives geometric properties of rectangular hollow sections among others structural shapes. This geometric properties rectangular hollow section gives data for the area of the cross section (***A***), the weight per meter of length, the location of the centroid of the cross section, the moment of inertia**(*I*),** the section modulus(***S***), and the radius of gyration(***r***). The values of ***I*** and ***S*** are important in the analysis and design of beams. Whereas ***I*** and ***r*** are needed for column analysis.

Geometric properties of structural steel used for chassis frame design

Outside Corner Radius

The radius of any outside corner of the section is between the limits of $\mathbf{0.5}\ to\ \mathbf{2.5}$ times the nominal wall thickness

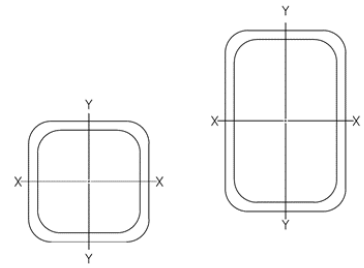


Table 3. 3 Geometric properties of Rectangular hollow sections

SECT. INDEX	Dimensions			Properties							Plastic section modulus		Torsional constant		Superficial area per meter length
	NOMI SIZE	WALL THICK NESS	WEIGHT PER METER	AREA	X-axis			y-axis			X-axis	Y-axis			
					I_x	S_x	r_x	I_y	S_y	r_y	Wplx	Wply	I_t	C_t	
	mm	**mm**	**kg**	**cm^2**	**cm^4**	**cm^3**	**cm**	**cm^4**	**cm^3**	**cm**	**cm^3**	**cm^3**	**cm^4**	**cm^3**	**m^2/m**
RT 64	60×40	2.0	2.93	3.74	18.41	6.14	2.22	9.83	4.92	1.62	7.47	5.65	20.7	8.12	0.19
		2.5	3.60	4.59	22.07	7.36	2.19	11.74	5.87	1.60	9.06	6.84	25.14	9.72	0.19
		3.0	4.24	5.41	25.38	8.46	2.17	13.44	6.72	1.58	10.53	7.94	29.28	11.17	0.19
		3.5	4.86	6.19	28.35	9.45	2.14	14.95	7.48	1.55	11.90	8.96	33.13	12.48	0.19
		4.0	5.45	6.95	30.99	10.33	2.11	16.28	8.14	1.53	13.16	9.89	36.67	13.65	0.19

Sources: Kaliti Metal Products Factory "Products Technical Specification Manual" and (Robert L. Mott, P.E. 2004)

Note: Hollow structural shapes (HSS) are most readily available in ASTM A500.

$Nominal\ size\ 60mm \times 40mm \times 3mm$

$60 = vetical\ depth\ (mm)$
$40 = width/base\ (mm)$
$3 = wall\ thickness\ (mm)$
$I = moment\ of\ inertia$
$S = section\ modulus$
$r = radius\ of\ gyration$

3.2. Methods

In order to accomplish the objectives, there were several steps which followed while the project was under way. The methods that followed were encompassed of:

Data collection

Data collection was the first job of this thesis work, thus primary data which are useful to determine the overall dimensions of the chassis, capacity of chassis, and required material, physical and mechanical properties of materials for the design of chassis going to be developed were collected as follows:

- **Primary data:**

  Primary data were collected by measuring, weighing, and observing existing Sheller/threshers machines and relevant resources related to dimensions, weight, systems, gaps regarding heaviness and inconvenience to transport, loading, unloading and to determine engineering solution as well.

- **Secondary data:**

  Secondary data like, size and working principles of systems of existing three-wheeler vehicles were collected from technical specification and manuals. Journals and Books from different sources also used as a source of data of designing consideration such as: load conditions, stress analysis, material mechanical properties, availability and etc.

  Design and Structural Analysis

  Next to collecting necessary data design and structural analysis is the one which to be done carefully to make the project successful according to intended work. Thus, following the data collection of loads and load conditions, structural dimensions like, structure length, width, wheel base, front and rear overhang, wheel track etc. on the basis of mechanical properties of selected materials were determined and Loads such as:

  - bending force and shear force
  - bending stress and shear stress
  - Structural deflection was analytically analysed by using standard equations and for verification ANSYS software 18 was used.

Modelling and model Verification

- AutoCAD 2007 software was used for modelling 3D chassis structure.
- Structural analysis was carried out using ANSYS software R18.

-

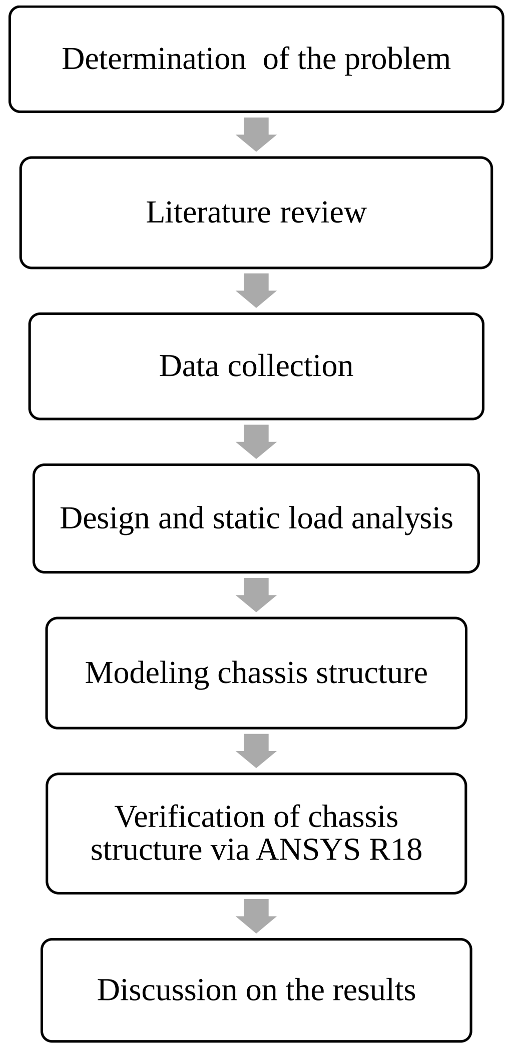


Figure 3.1 Research Methodology flow chart

3.2.1. Specification and overview of existing Sheller/Thresher machines

The existing Sheller/Thresher machines have difficulty of transporting from location to location, loading and unloading. They are disseminated widely and serving farmers, service providers and investors in Ethiopia for harvesting crops like, maize, wheat, barley, teff etc.

Therefore, in this thesis work a three-wheeled chassis was designed and developed, which can be used to eliminate the problems like transportation, loading and unloading problems of the existing machine.

The specifications of existing multi-crop thresher are given in table 3.4 and specifications of maize Sheller are given in table 3.5.

Table 3. 4 Specification of existing Multi-crop Thresher

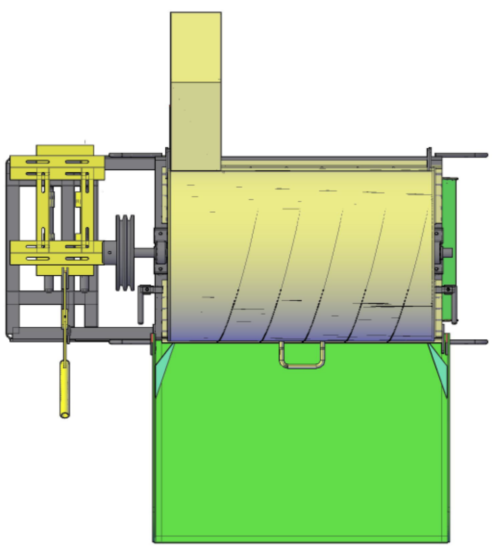
S/N	Item	Dimensions (mm) L.W.H			Volume (mm^3)	Weight kg
01	Thresher	1400	1600	1360	1453.33	227

Table 3. 5 Specification of existing Maize Sheller

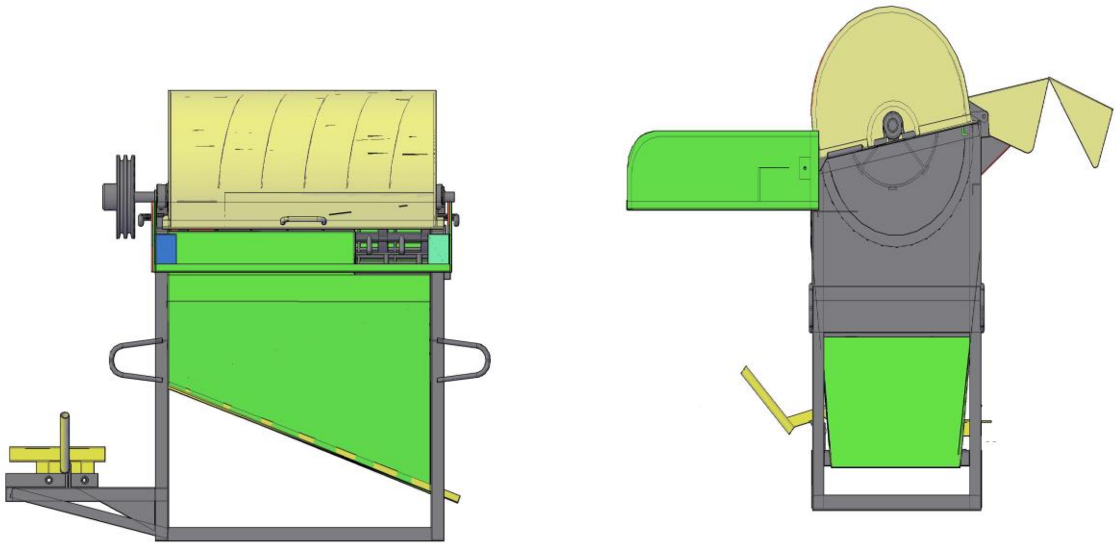
S/N	Item	Dimensions (mm) L.W.H			Volume (mm^3)	Weight kg
01	Sheller	1460	1830	1230	1507	271.3

3.2.2. Model of existing Multi- crop Thresher

The following 2D and 3D models of existing multi-crop thresher including all components such as: drum, concave, frame structure, cover, body, engine set, feeding table, straw outlet, seed-out let and pulley were prepared using AutoCAD 2007 software as shown in figure 3.2 and 3.3 respectively. This was prepared for the sake of having overview about machine.



Top View



Front View R.Side View

Figure 3. 2 Orthographic view of existing Thresher

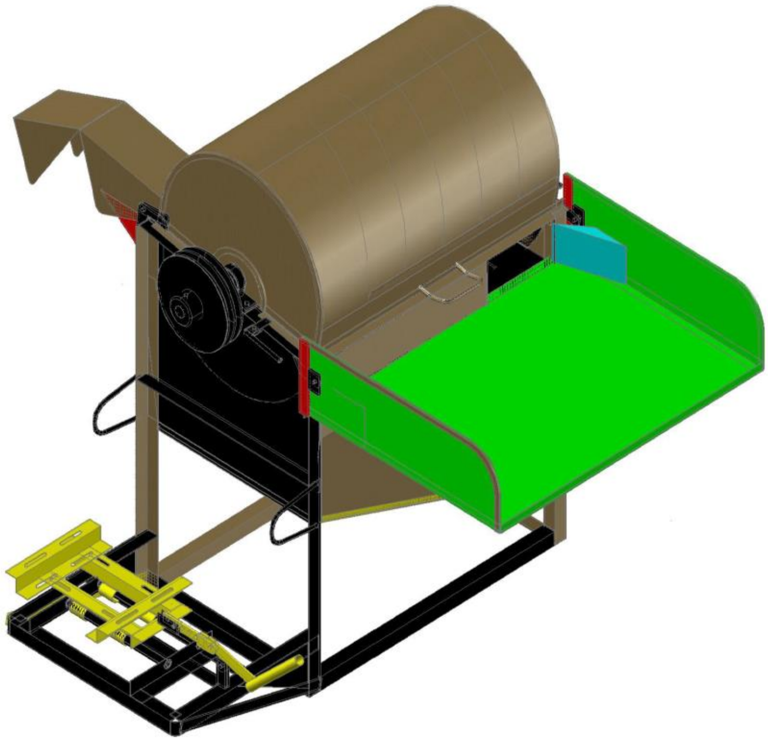


Figure 3.3 Isometric view of existing Thresher

3.3. Design and Modelling of three-wheeler chassis

3.3.1. Chassis Frame Design

As the chassis frame supports numerous parts, it is subjected to static and dynamic forces, such as bending, shear, fatigue, shock and twisting of the frame. The design provides of chassis frame of a three-wheeler and therefore the additional thought during this design could be a static load. Under static load, determination of shear force, bending moment and deflection with their diagram is taken into consideration. The shear force, bending moment and deflection diagrams were plotted using Auto-CAD software.

The stresses developed in the chassis were estimated by considering, the chassis frame as a simply supported beam of uniformly distributed load and clamped with shock absorber, coil spring and also considering specification and parameters of chassis frame obtained from technical document/manual and real one. Dimensioning and modeling of chassis components such as: frame, suspension system, shock absorber, engine sample, steering system, tires, axle, driver set and power transmission system assembly as shown below in figure 3.4, 3.5, and 3.6 respectively, The three-wheeler chassis assemble with combination of Thresher assembly were modelled by using AutoCAD 2007 software system. However, the analytical calculations are solely restricted to the chassis frame of three wheeler.

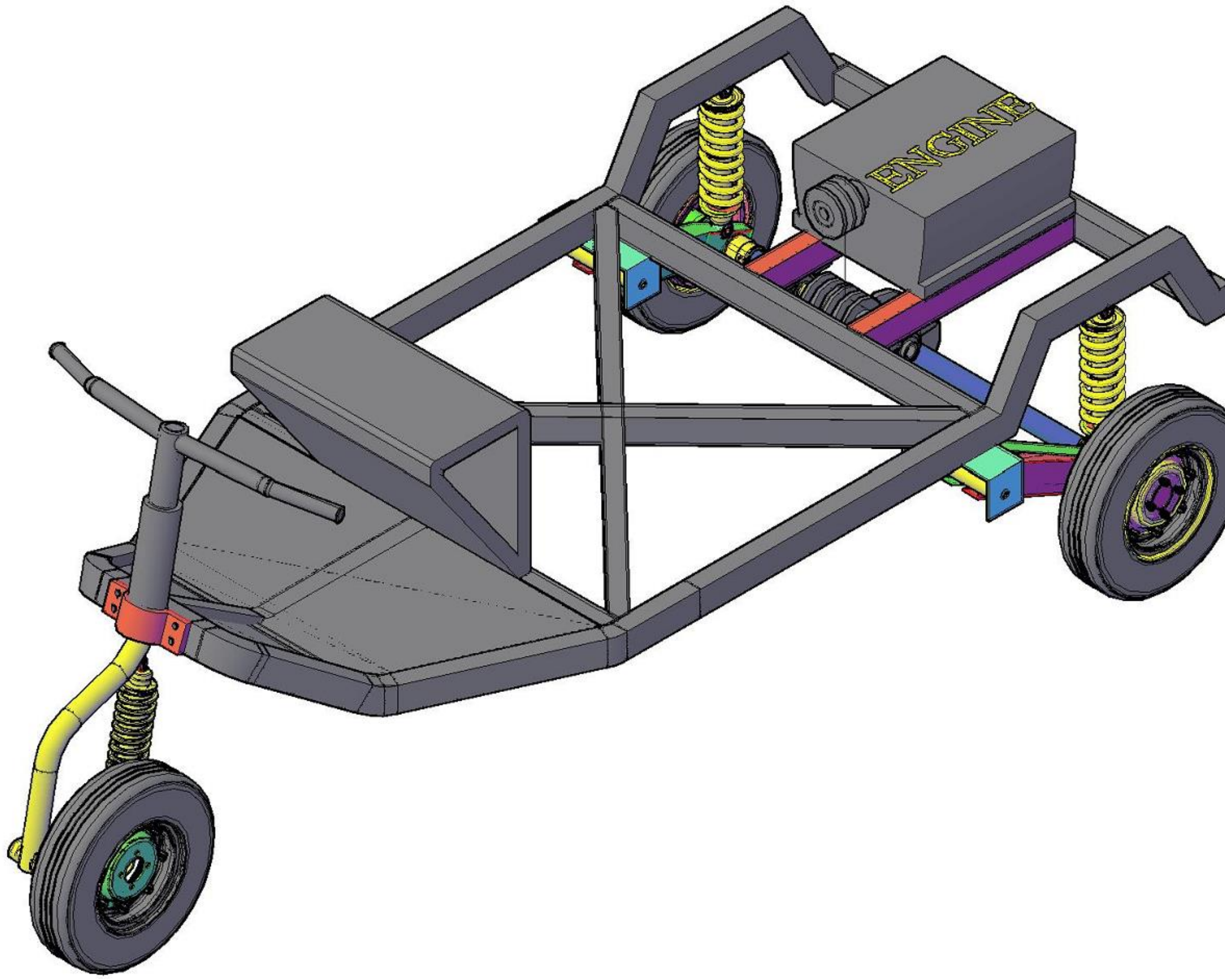


Figure 3.4 Model of three-wheeler chassis

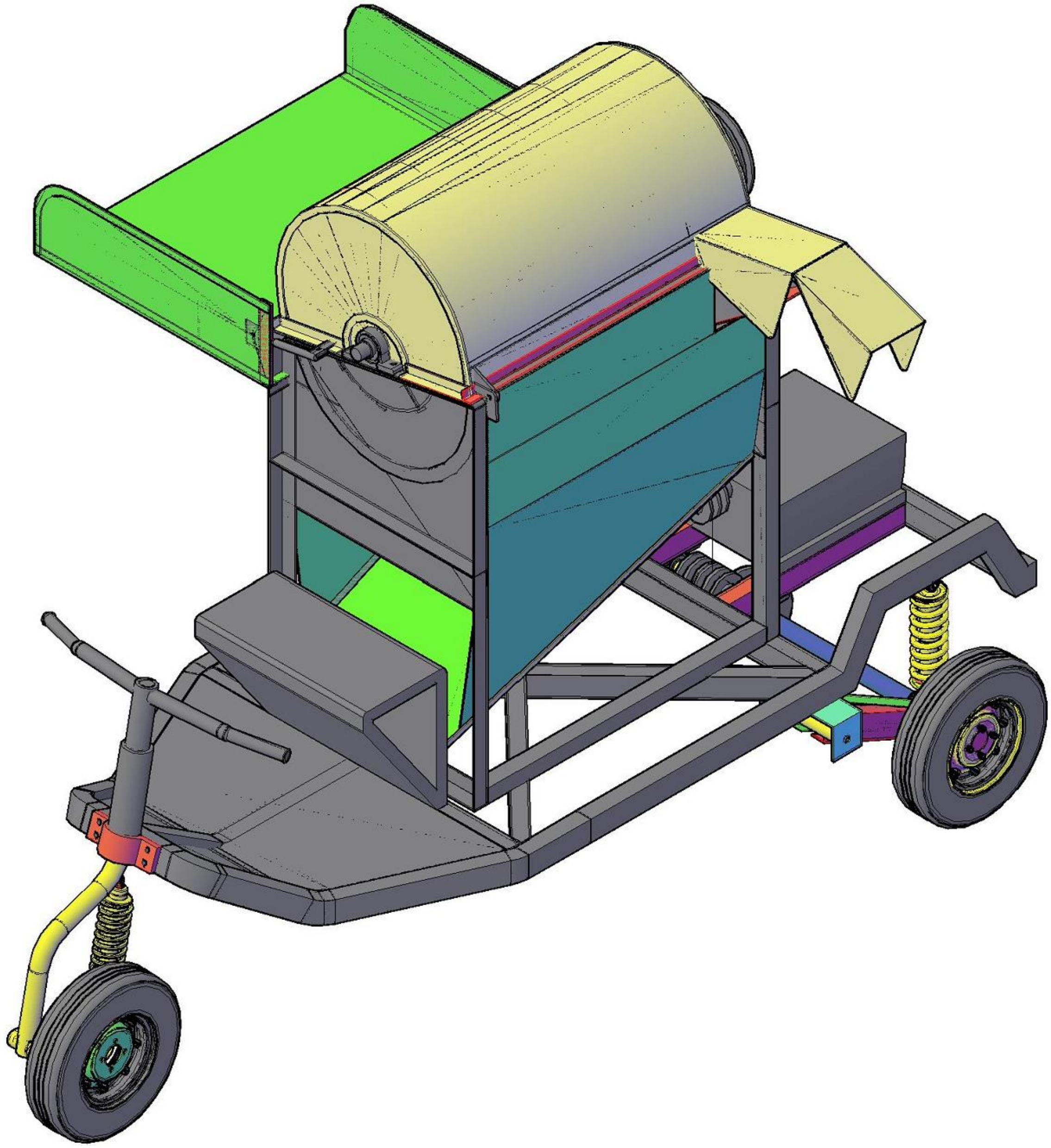


Figure 3.5 Model of Chassis assembled with thresher

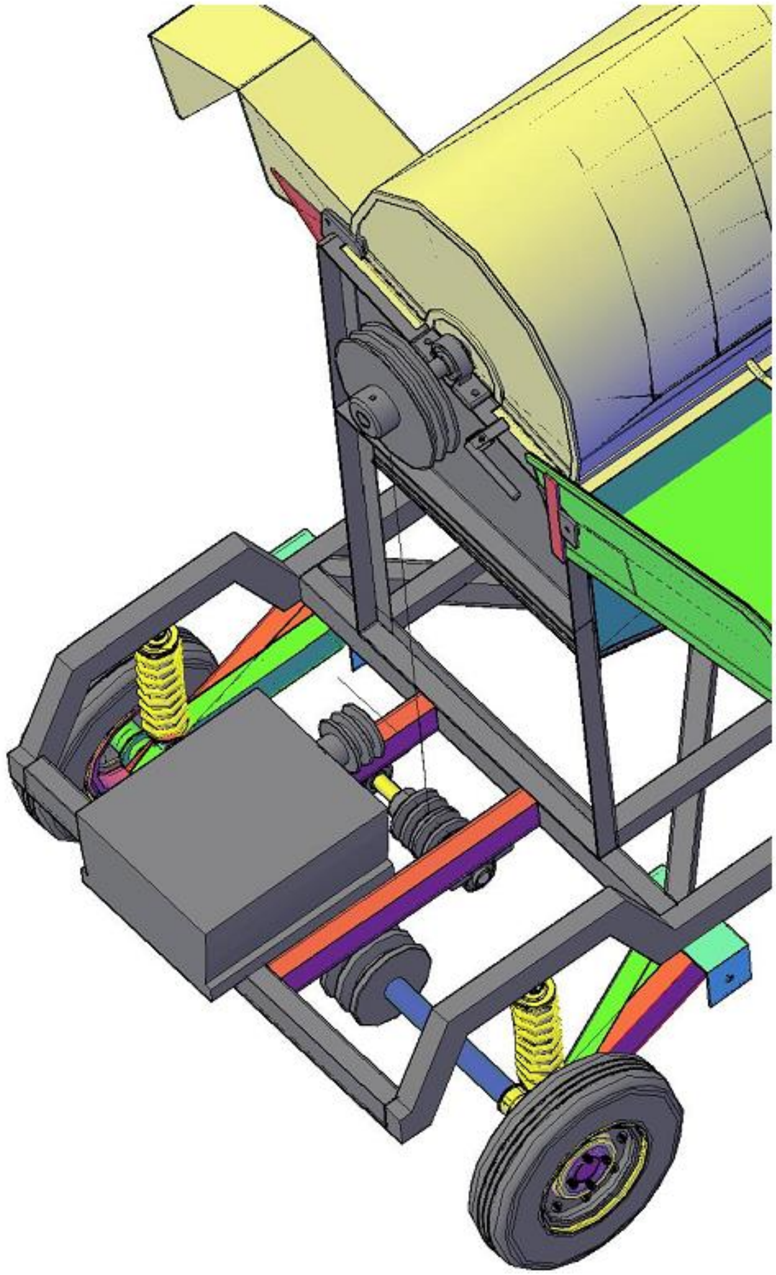


Figure 3. 6 Chassis rear power transmission unit

Table 3.6 Mechanical properties of materials

Parameters	Values
Yield strength	250 min MPa
Tensile stress	343 min (MPa)
Young's modulus	207 GPa
Poisson's ratio	0.30
Density	7850 kg/m^3
Elongation	30(%)

Source: *Kaliti Metal Products Factory "Products Technical Specification Manual" and Robert L. Mott, P.E. "Machine Elements in Mechanical Design" fourth edition university of Dayton*

Chassis Loads

The various loads which are acting on the chassis are estimated according to the center of gravity of the Chassis/vehicle. The various loads acting on the chassis are as listed in the table 3.7 below (Bhande Akshay S).

Table 3.7 Estimated loads of the chassis.

Components	Mass (kg)	Sources
Driver	60.7	WHO report
Engine	48	Measured
Drive train	20	Manual
chassis	60	Manual
Steering & Suspension	40	Manual
Sheller/thresher	271.3	Measured

Table 3.8 Specifications of Chassis Frame

Parameter	Value	Sources
Length	2625 mm	Specifications manual of TAGRO BAJAJ
Width	1300 mm	
Wheelbase	2000 mm	
Wheel track	1150 mm	
Front overhang(a)	325 mm	
Rear overhang(c)	300 mm	
Height	1710 mm	
Ground clearance	180 mm	
Gross vehicle weight	800 kg	Capacity of chassis frame
Kerb weight	330 kg	Estimated
Payload	470 kg	

Beam Cross Section

The chassis frame is constructed to possess; the side-members and cross-members. The cross section can be of: Box section, Channel section, tubular. Hence, based on the Multi-Criteria approach structural steel of rectangular hollow section (box-cross section) was selected with the listed Mechanical and geometrical properties for this particular project.

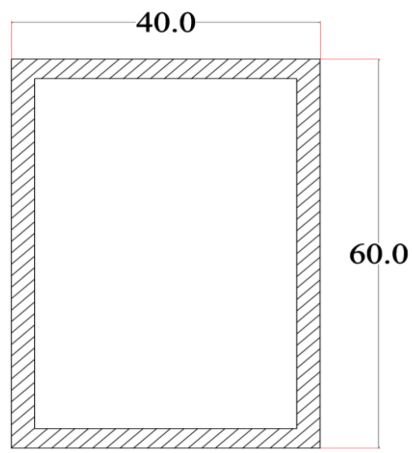


Figure 3.7 Beam cross section

3.4. Basic Calculations and considerations for Chassis Frame Structure

Factor of safety

It is common practice to size the machine elements, so that the maximum design stress is below the yield stress by an appropriate factor and it is used to provide a design margin over the theoretical design capacity to allow for uncertainty in the design process. Factor of safety is recommended by the conditions over which the designer has no control that is to account for the uncertainties involved in the design process.

Selection of factor of safety

The selection of the appropriate factor of safety to be used in design of components is essentially a compromise between the associated additional cost and weight and the benefit of increased safety or/ and reliability. Generally an increased factor of safety results from a heavier component or a component made from a more exotic material or/and improved component design. An appropriate factor of safety is chosen based on several considerations. Prime considerations are the accuracy of load and wear estimates. Components whose failure could result in substantial financial loss, serious injury or death usually use a safety factor of four or higher (often ten). Non- critical components generally have a safety factor of two, **dynamic load cases**.

Static load cases factor of safety (N) = 1.25 to 2 for design of structures under static loads for which there is a high level of confidence in all design data (Robert L. Mott, 2004).

Capacity of Chassis (G.V.W) = 800 kg (Kerb Weight + Payload)

$Factor\ of\ Safety = 1.25$

$\sigma_{all} = \frac{s_y}{N} = \frac{250}{1.25}$

$= 200\ N/mm^2$

Total Capacity of Chassis with Factor of safety:

800×1.25

$= 1000\ kg = 9810\ N$

Each Chassis Frame has two beams.

So, load acting on one beam = $\frac{9810}{2}$ = 4905 N per beam.

Load Conditions for Chassis Frame

Load acting on entire span = 4905 N

Length of beam = 2625 mm

The beam had subjected to slightly varying loads, yet it is homogeneous a maximum load had considered along its length as a uniform for sake of beam loads calculation.

$$\text{Uniformly Distributed Load} = \frac{4905}{2625} = \mathbf{1.9N/mm}$$

According to loading conditions of the beam, the beam has support of two axles at C and D. Total load acting on the beam has been shown below in figure 3.8

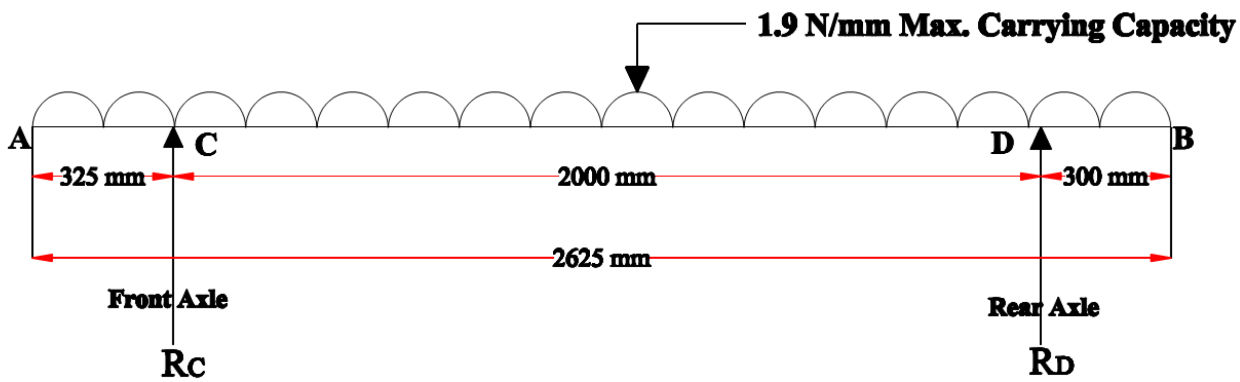


Figure 3.8 Total Load acting on the Beam

3.4.1. Fixed End Moments

Fixed end moments always develop as reaction moments in any member of a statically indeterminate beam under particular conditions of load having both ends fixed. The beam shown below in Figure 3.9 has indeterminate structure.

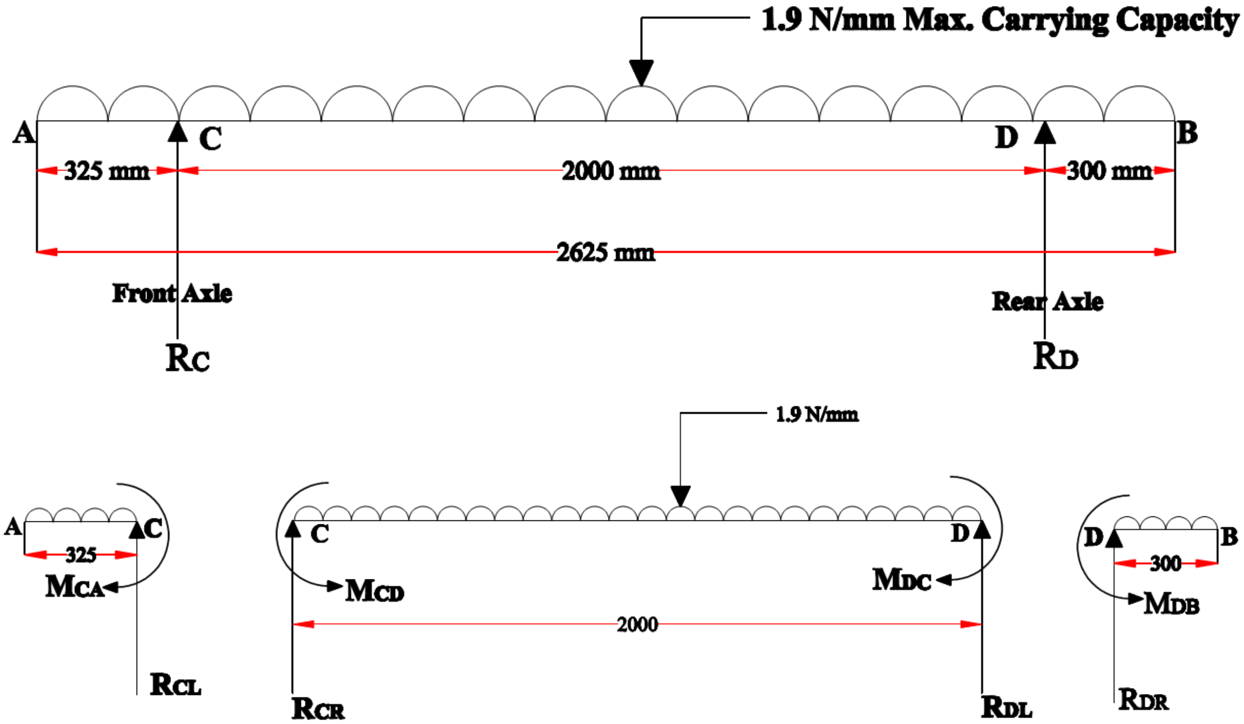


Figure 3. 9 Consideration of Fixed End Moments

$$M_{CA} = \frac{W \times a^2}{2} = \frac{1.9 \times 325^2}{2} = 100343.75 N/mm$$

$$M_{CD} = \frac{-W \times b^2}{12} = \frac{-1.9 \times 2000^2}{12} = -633333.33 N/mm$$

$M_{DC} = -M_{CD} = 633333.33$N/mm

$$M_{DB} = \frac{-W \times c^2}{2} = \frac{-1.9 \times 300^2}{2} = -85500 N/mm$$

Total restraint moment at C,

$M_C = M_{CA} + M_{CD} = 532989.583$N/mm

Total restraint moment at D,

$M_D = M_{DC} + M_{DB} = -547833.33$N/mm

Where:

- Front overhang (a) = 325mm
- Rear overhang (c) = 300mm
- Wheel base (b) = 2000mm
- Total length (l) = 2625mm

3.4.2. Calculations for Reactions, Shear Forces and bending moment

Shear forces acts in the beam perpendicular to the longitudinal axis and it has been usually generated due to the applied loads and support reactions. In designing, the ability of beam to resist shear force plays a vital role than the ability to resist an axial force. An axial force acts parallel to the longitudinal axis.

Where;

W = load acting on the beam

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_C = reaction at point C

R_D = reaction at point D

$R_{CL} = -w \times a$

$= 1.9 \times 325$

$= \mathbf{-617.5\ N}$

$$R_{CR} = \frac{w \times b}{2} + \frac{M_{CA} - M_{DC}}{b}$$

$$= \frac{1.9 \times 2000}{2} + \frac{100343.75 - 633333.33}{2000}$$

$= \mathbf{-506340\ N}$

$R_{DL} = (w \times b) - R_{CR} = (1.9 \times 2000) + 506340 = \mathbf{510140\ N}$

$R_{DR} = w \times c$

$= 1.9 \times 300$

$= 570\ N$

Calculation for Reaction

Chassis frame is simply clamp with shock absorber and coil spring. So it is considered as simple supported beam with uniformly distributed load

Now taking the moment around the support D,

$$Rc = \frac{w \times l \times (l - 2 \times c)}{2 \times b}$$

$$= \frac{1.9 \frac{N}{mm} \times 2625 \times (2625 - 2 \times 300)}{2 \times 2000}$$

$$= \mathbf{2524.9\ N}$$

$$Rd = \frac{w \times l \times (l - 2 \times a)}{2 \times b}$$

$$= \frac{1.9 \times 2625 \times (2625 - 2 \times 325)}{2 \times 2000}$$

$$= \mathbf{2462.578\ N}$$

Calculation for Shear Force

$$V1 = w \times a$$

$$= 1.9 \times 325$$

$$= 617.5\ N$$

$$V2 = Rc - V1$$

$$= 2524.9 - 617.5$$

$$= \mathbf{1907.4\ N}$$

$$V3 = Rd - V4$$

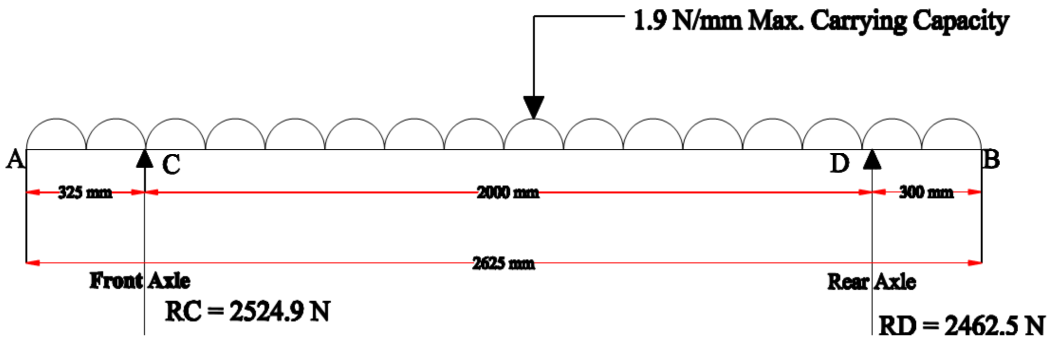
$$= 2462.578 - 570$$

$$= \mathbf{1892.578\ N}$$

$$V4 = w \times c$$

$$= 1.9 \times 300$$

$$= \mathbf{570\ N}$$



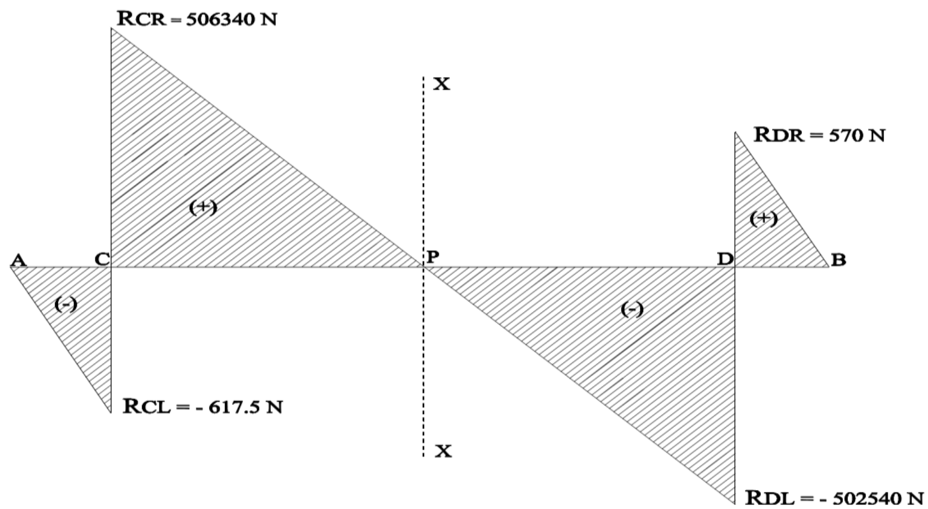


Figure 3.10 Shear Force Diagram

3.4.3. Calculations for Bending Moments

$M_A = 0$ N/mm

$M_C = -M_{CA} = -100343.75 N/mm$

$M_P = \dfrac{w \times b^2}{8} = \dfrac{1.9 \times 2000^2}{8} = 950000 N/mm$ or 0.95 kN m

$M_D = M_{DB} = -85500$ N/mm

$M_B = 0$ N/mm

Maximum Bending Moment Occurs at point P.

$M_{.\,Max} = M_P = 950000$N/mm or 0.95 kN-m

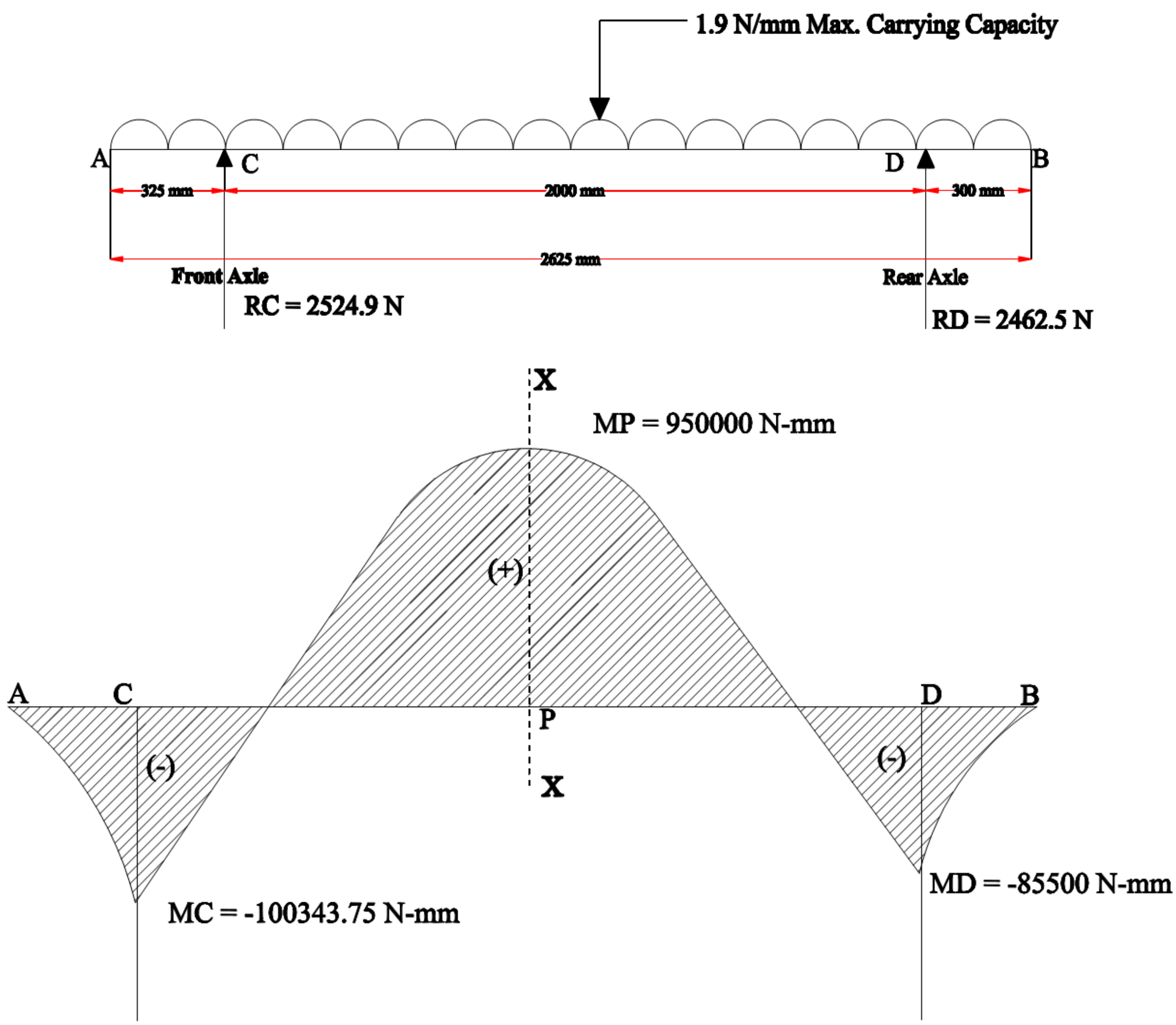


Figure 3.11 Bending Moment Diagram

3.5. Analysis for Stresses

Bending stresses: when some external load acts on a beam, the shear force and bending moments are set up at all sections of the beam. Due to the shear force and bending moment, the beam undergoes certain deformation. The material of the beam will offer resistance or stresses against these deformations. These stresses with certain assumptions can be calculated. The stresses introduced by bending moment are known as bending stresses. That, the bending stress of the beam used in the designing of **Three Wheeled Chassis Frame** was calculated as follows:

3.5.1. Calculations for Bending Stress

According to general bending equation,

$$\frac{M}{I} = \frac{\sigma}{Y} = \frac{E}{R}$$

From the above equation, the bending stress is given by

$$\sigma = y \times \frac{E}{R}$$

Since E and R are constant, therefore within elastic limit, the stress at any point is directly proportional to y, i.e. the distance of the point from the neutral axis,

Also from the above equation, **the bending stress**,

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

The ratio I/y is known as section modulus and is denoted by Z.

Where;

M = bending moment acting at the given section,
σ = bending stress,
I = moment of inertia of the cross-section about the neutral axis,
y = Distance from the neutral axis to the extreme fibre,
E = Young's modulus of the material of the beam, and
R = Radius of curvature of the beam.

Beam cross section

$base\ (b) = 40mm$

$depth(d) = 60mm$

$$y = \frac{d}{2} = \frac{60}{2} = 30mm$$

$$Iz = \frac{1}{12}(BD^3) - (bd^3)$$

$$Iz = 273852mm^4$$

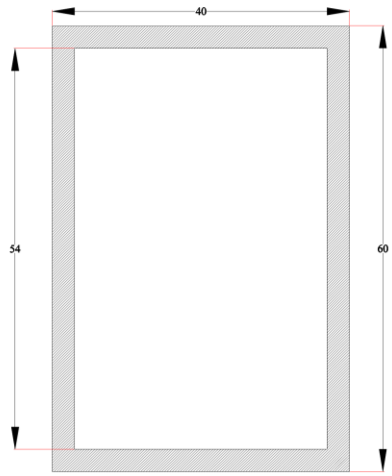


Figure 3.10 Beam cross section

Maximum bending moment acting on the beam,

$$M\max = \frac{w \times b^2}{8} =$$

$$= \frac{1.9 \times 2000^2}{8} = 950000N$$

$$Iz = \frac{1}{12}(BD^3 - bd^3)$$

$$Iz = \frac{1}{12}(40 \times 60^3 - 34 \times 54^3)$$

$$Iz = 273852mm^4$$

Note: The maximum tensile stresses occur at bottom periphery of the cross section, i.e. y = -30mm Whereas the maximum compressive stresses occur at the top periphery of the cross section, i.e. y = 30mm.

Stress produced in the beam,

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

$$= \frac{950000}{273852} \times 30$$

$$\boldsymbol{\sigma = 104\ N/mm^2}$$

$since, 104 \frac{N}{mm^2\ is}\ is\ with\ in\ the\ range\ of\ permissible\ stress\ of\ 200\ N/mm^2.$

$hence, the\ Design\ is\ Safe.$

Note: The compressive stress occurs at the top side of the cross section and its value is calculated to be $\boldsymbol{-104\ N/mm^2}$**.** while the tensile stress occurs at the bottom section of the beam's cross section and its value is found to be $\boldsymbol{+104\ N/mm^2}$**.**

3.6. Shear Stresses in Beam

The shear stress will be zero as shear stress is equal to shear force divided by the area. As shear force is zero, the shear stress will also be zero. But in actual practice, a beam is subjected to a bending moment which varies from section to section. Due to these shear forces, the beam will be subjected to shear stresses. These shear stresses will be acting across transverse sections of the beam. These transverse shear stresses will produce a complimentary horizontal shear stresses which will be acting on longitudinal layers of the beam. Hence beam will also be subjected to shear stresses. The beam shear stress formula is used to find the transverse shear stress on the beam's cross-sectional area.

$$\boldsymbol{\tau} = \frac{VQ}{It}$$

Where,

$\tau = \text{The shear stress in the member in N/mm}^2$

$\text{V} = \text{Internal resultant shear force in N. mm}$

$\text{Q} = \text{first moment of area in mm}^3$

$\text{I} = \text{Moment of inertia of the entire cross} - \text{sectional area in mm}^4$

$\text{t} = \text{Width of the member's cross} - \text{sectional area. in mm}$

$\text{N. A} = \text{beam neutral axis}$

$\text{Q} = \text{A} \times \bar{\text{y}}$

$\bar{\text{y}} = \text{Distance of the C. G. of the area } \mathbf{A} \text{ from the neutral axis.}$

$\mathbf{A} = \text{the top portion of the beam cross} - \text{sectional area.}$

$\boldsymbol{V} = 505722.5\ N$

$\boldsymbol{Q} = A \times \bar{\text{y}}$

$= \ 120mm^2 \times 28.5mm$

$= 3420mm^3$

$$I = \frac{1}{12}(BD^3 - bd^3)$$

$$= \frac{1}{12}(40 \times 60^3 - 34 \times 54^3)$$

$$= 273852mm^4$$

$$t = 40mm$$

$$\boldsymbol{\tau} = \frac{VQ}{It}$$

$$= \frac{505722.5N \times 3420mm^3}{273852mm^4 \times 40mm}$$

$$\boldsymbol{\tau} = 157.89\ N/mm^2$$

$$\boldsymbol{\tau}_{max} = 1.5\frac{V}{A}$$

$$= 1.5\frac{505722.5\ N}{564\ mm^2}$$

$$= 1345\ N/mm^2$$

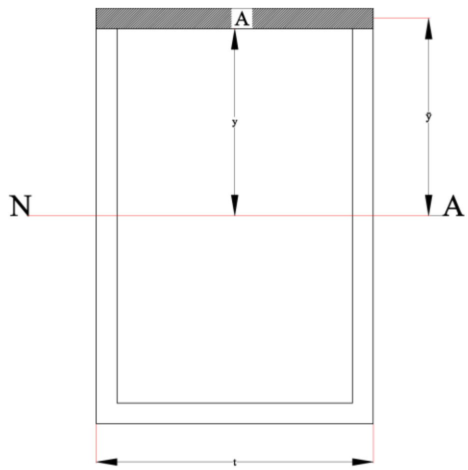


Figure 3.11 Shear stress in beam

Von Mises Stress (Equivalent Stress)

The von Mises stress:

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

When $\sigma_3 = 0$, the von mises stress is:

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

When only σ_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 Mises stress is:

$$\boldsymbol{\sigma_v} = \sqrt{\boldsymbol{\sigma}_x^2 + 3\tau_{xy}^2}$$

From the bending and shear stresses in the beam the following values had found.

$$\boldsymbol{\sigma_x} = 104\ N/mm^2$$
$$\tau_{xy} = 157.89\ N/mm^2$$

Therefore,

$$\boldsymbol{\sigma_v} = \sqrt{104^2 + 3(157.89)^2}$$
$$\boldsymbol{\sigma_V} = 292.58\ N/mm^2$$

Note that in pure shear or pure torsion $\boldsymbol{\sigma_x} = 0$. if $\boldsymbol{\sigma_x} = 0, then$

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

According to distortion energy theory, yielding occurs when $\boldsymbol{\sigma_v}$ reached the yield strengthS_y. Therefore, in pure shear, yielding occurs when $\boldsymbol{\tau_{xy}}$ reaches 58% of S_y.

3.7. Calculations for 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.

Macaulay's method is used to find the bending moment at any general section X-X of the beam. The Macaulay's method helps to find a single expression for bending moment throughout the complete span of the beam. It is used to cover all loading conditions. Finding moment at x-x. Taking clockwise direction as positive (+) and anti-clockwise as negative (-).

Calculation for maximum deflection

R_C and R_D are reactions acting on the beam

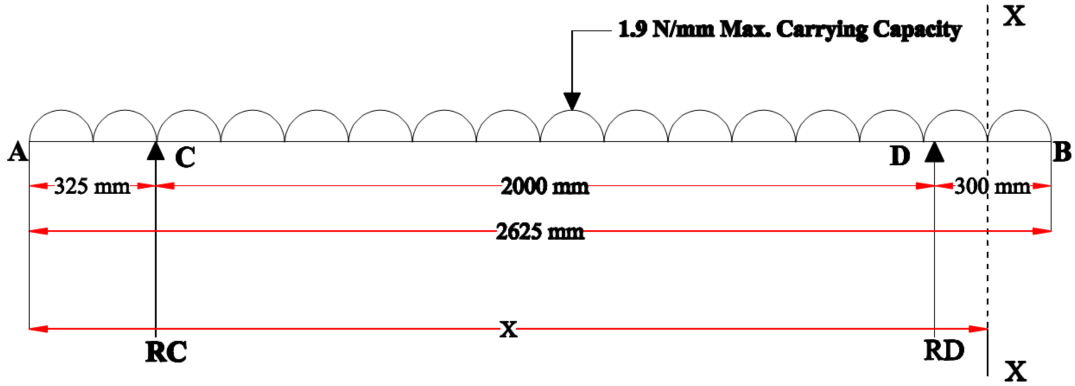


Figure 3.12 Reactions acting on the beam

A section X-X has been considered in span DB at a distance x from A

Taking moment of all forces about section x-x

$$Mxx = -\frac{1.9x^2}{2} + RC[x - 325] + RD[x - 2325]$$

According to **Macaulay's theorem** (double integration method)

$$Mxx = EI\frac{d^2y}{dx^2} = -\frac{1.9x^2}{2} + RC[x - 325] + RD[x - 2325]$$

Integrating once, we get

$$EI\frac{dy}{dx} = -\frac{1.9x^3}{6} + C1 + RC\frac{[x - 325]^2}{2} + RD\frac{[x - 2325]^2}{2} \qquad (1)$$

Integrating again, we get

$$EIy = -\frac{1.9x^4}{24} + C1x + C2 + RC\frac{[x - 325]^3}{6} + RD\frac{[x - 2325]^3}{6} \qquad (2)$$

$$y = \frac{1}{EI}\left[-\frac{1.9x^4}{24} + C1x + C2 + RC\frac{(x - 325)^3}{6} + RD\frac{(x - 2325)^3}{6}\right]$$

Choose the boundary conditions to evaluate the value of C1,C2 and the general deflection of the chassis frame structure.

$$\mathrm{EIY} = \frac{-1.9X^4}{24} + C1x + C2$$

when x = 325mm and y = 0

$$0 = \frac{1}{EI}\left[-1.9\frac{x^4}{24} + xC1 + C2\right]$$

$$0 = \frac{1}{EI}\left[-1.9 \times \frac{325^4}{24} + 325C1 + C2\right] \tag{3}$$

$$0 = -8.83234049 \times 10^8 + 325C1 + C2$$

$$when\ X = 2325mm\ and\ Y = 0$$

$$0 = \frac{1}{EI}\left[-1.9 \times \frac{2325^4}{24} + 2325C1 + C2 + Rc\frac{(2325 - 325)^3}{6}\right] \tag{4}$$

Solving equation (1) and (2) we get the value of:

$$C1 = 1.0870573 \times 10^7 and$$

$$C2 = -2.649702148 \times 10^9$$

$$substituting\ values\ of\ C1\ and\ C2\ in\ equation\ (2), we\ get$$

$$Y = \frac{1}{EI}\left[-1.9\frac{x^4}{24} + 1.0870573 \times 10^7 x \pm 2.649702148 \times 10^9 + RC\frac{(x - 325)^3}{6} + RD\frac{(x - 2325)^3}{6}\right] \tag{5}$$

Equation (5) is the general equation of deflection.

The deflections at the supports (C) and (D) are zero.

Deflection at points A, i.e, at $x = 0\ and\ x = l$

$$YA = -neglected$$

$$YB = neglected$$

$$Ymax\ occured\ between\ supports\ C\ and\ D, at\ x = 1325mm$$

$$\square\ ymax = \frac{1}{EI}\left[-1.9\frac{1325^4}{24} + (1325)1.0870575 \times 10^7 - 2.649702148 \times 10^9 + 510757.5\frac{(1325 - 325)^3}{6} - 510710\frac{(1325 - 2325)^3}{6}\right]$$

$$ymax = \frac{2.24338538905 \times 10^{11}}{EI}$$

$$where\ the\ value\ of, E\ and\ I = 207GPa\ or\ 207000\ MPa\ and$$

$$I = 273852mm^4\ respectively.$$

$\boldsymbol{ymax = 3.957mm\ Downward\ direction}.$

$$Maximum\ allowable\ deflection = \frac{span\ length}{300} = \frac{2625mm}{300}$$

 $Maximum\ allowable\ deflection\ in\ beam = 8.75mm.$

Since, 3.957mm is less than the maximum allowable deflection of 8.75mm.

Hence, the **Design is Safe.**

3.8. Design Chassis Frame Using Factor of Safety for dynamic load cases

The Dynamic Loading must be considered as the vehicle traverses uneven road surfaces. For example, the vehicle may pass over a hump-back bridge at such a speed that the wheels leave the ground. The resulting impact of the vehicle returning to earth is cushioned by the suspension system but inevitably causes a considerable increase in loading over the static condition. Experience gained by vehicle manufacturers indicates that the static loads should be increased by factors of 2.5 to 3.0 for load going vehicles. Off-road or cross-country vehicles may be designed with factors of 4 (Pawlowski, 1964)

Allowable stress

It is important that under the worst load conditions that the stresses induced into the structure are kept to acceptable limits. Consideration of the static loads factored by an appropriate amount should give a stress level certainly below the yield stress. For example, if the bending case for a road going passenger car is considered the maximum allowable stress should be limited as follows:

Stress due to static load × dynamic factor ≤ 2/3 × yield stress

This means that under the worst dynamic load condition the stress should not exceed 67% of the yield stress. Alternatively, the safety factor against yield is 1.5 for the worst possible load condition. A similar criterion is applied to other load conditions (Julian Happian-Smith, 2002).

$$allowable\ stress = \frac{\text{yield point stress}}{\text{factor of safety}}$$

$$yield\ piont\ stress = 250\ N/mm^2$$

$$N = static\ load\ factor + dynamic\ factor$$

$$N = 3.75$$

$$\sigma_{all} = \frac{250}{3.75}$$

$$\sigma_{all} = 66.66 \frac{N}{mm^2}\ for\ dynamic\ load\ cases$$

3.9. Analytical verification by using FEA method

3.9.1 Introduction to Finite Element Analysis (FEA) method.

The Finite Element Analysis (FEA) method, originally introduced by Turner et al. (1956), is a powerful computational technique for approximate solutions to a variety of “real-world” engineering problems having complex domains subjected to general boundary conditions. FEA has become an essential step in the design or modelling of a physical phenomenon in various engineering disciplines. A physical phenomenon usually occurs in a continuum of matter (solid, liquid, or gas) involving several field variables. The field variables vary from point to point, thus possessing an infinite number of solutions in the domain.

The basis of FEA relies on the decomposition of the domain into a finite number of subdomains (elements) for which the systematic approximate solution is constructed by applying the variational or weighted residual methods. In effect, FEA reduces the problem to that of a finite number of unknown by dividing the domain into elements and by expressing the unknown field variable in terms of the assumed approximating functions within each element. These functions (also called interpolation functions) are defined in terms of the values of the field variables at specific points, referred to as nodes. Nodes are usually located along the element boundaries, and they connect adjacent elements.

ANSYS Disciplines

The ANSYS program is capable of simulating problems in a wide range of engineering disciplines. However, this project focuses on the structural analysis.
Structural Analysis: deformation, stress, and strain fields, as well as reaction forces in a solid body.
The structural analysis type addresses several different structural problems such as:
Static analysis in which applied loads and support conditions of the solid body do not change with the time.

In general.

Analytical verification was carried out using ANSYS R18.0 software.
The method had verified by using a simply supported overhanging beam of cross section used in the structure. Total load acting on the chassis is the sum of capacity of the chassis and weight of

Sheller/Thresher machine, engine and operator which is 1000 kg. Since, Chassis has two beams. The load acting on each beam is half of the total load acting on the chassis that is 500 kg mass or 4905N.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Structural analysis using ANSYS.

Meshing: meshing is the basic processes of decomposition of the domain into a finite number of subdomains (elements) for which the systematic approximate solution is constructed by applying the variational or weighted residual methods. For the static structural analysis of deformation, stress, strain fields, as well as reaction forces in a solid body.

The verification process conducted using ANSYS:

Meshing elements: the following elements were used to mesh the chassis frame.

- Element size 200 mm.
- Elements 78085
- Nodes 361365

Engineering data

- Young's modulus 207000 Mpa
- Poisson's ratio 0.30

Material: structural steel

Mesh of chassis frame

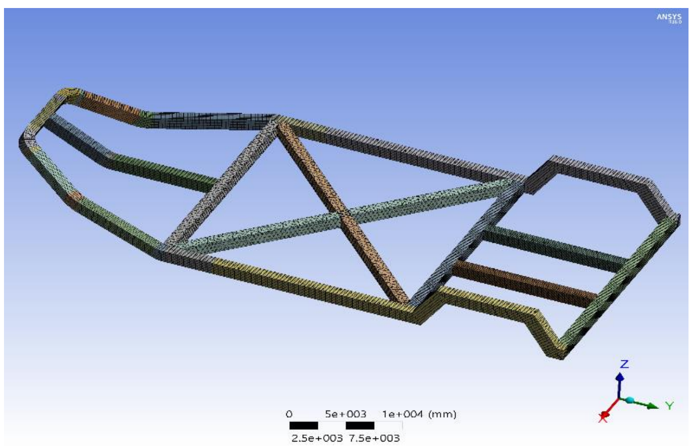


Figure 4.1 Meshed three-wheel chassis frame

4.2 ANSYS results of static analysis of beam and chassis frame structure

Normal stresses

Under normal working conditions, the beam was fixed at two points of wheel base and the load was applied along the length and chassis frame was fixed at 2, 4, 4 points of operator, Thresher and Engine respectively and the load of each was applied accordingly. The obtained stresses developed in the beam 104.04 Mpa and chassis 83.481Mpa as shown in the figure 4.2 below.

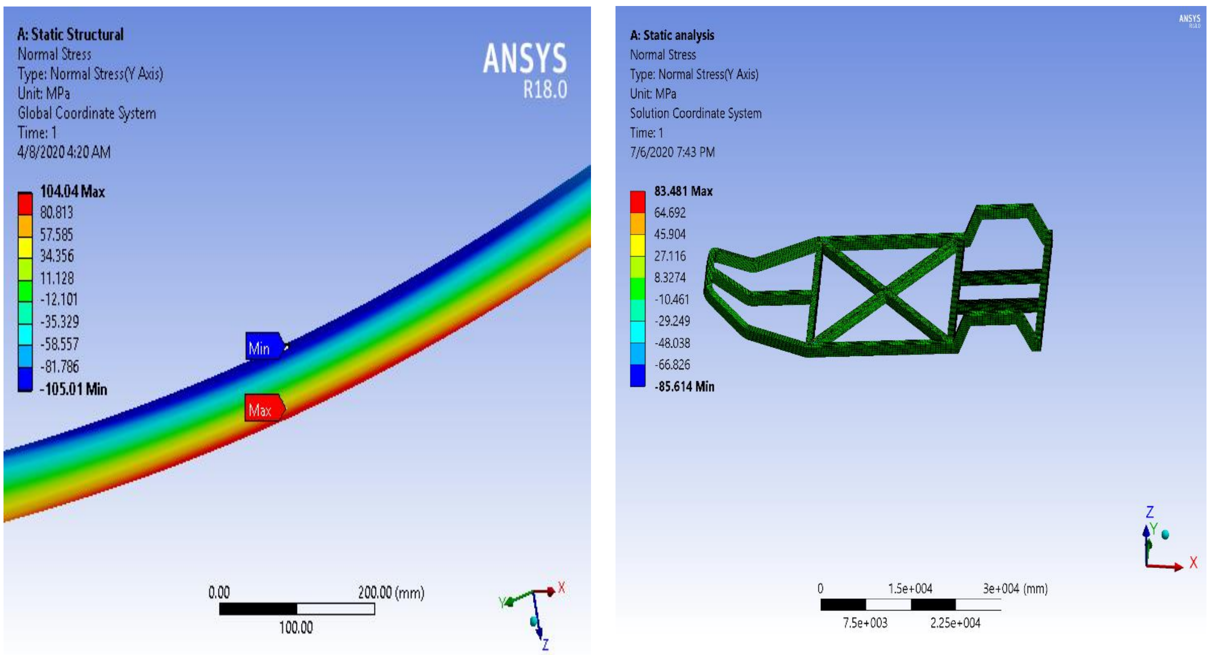


Figure 4.2 Normal stresses of beam and chassis frame

Deformation

Total deformation of beam and chassis frame after applying the load and simulating is 7.034 mm and 0.28979 mm respectively, which is desirable and safe as shown in figure 4.3 below.

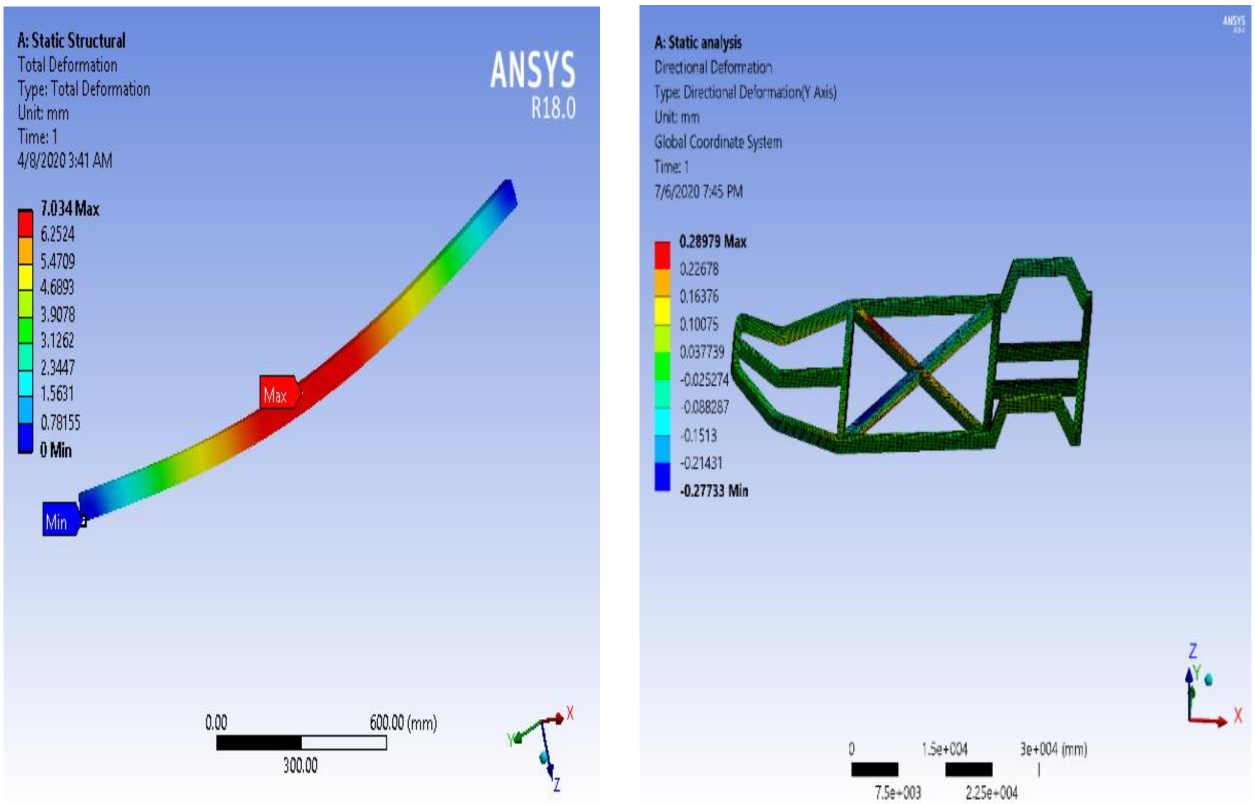


Figure 4.3 Beam and chassis frame deformations

Equivalent Stress

In this case, a material is said to start yielding when its von-Mises stress reaches a critical value known as the yield strength. The von-Mises stress is used to predict yielding of material under any loading condition from results of simple uniaxial tensile tests.

The found result of von Mises after applying load along beam and chassis frame, maximum stress is 104.26 Mpa and 367.56 Mpa as shown in figure 4.4 below.

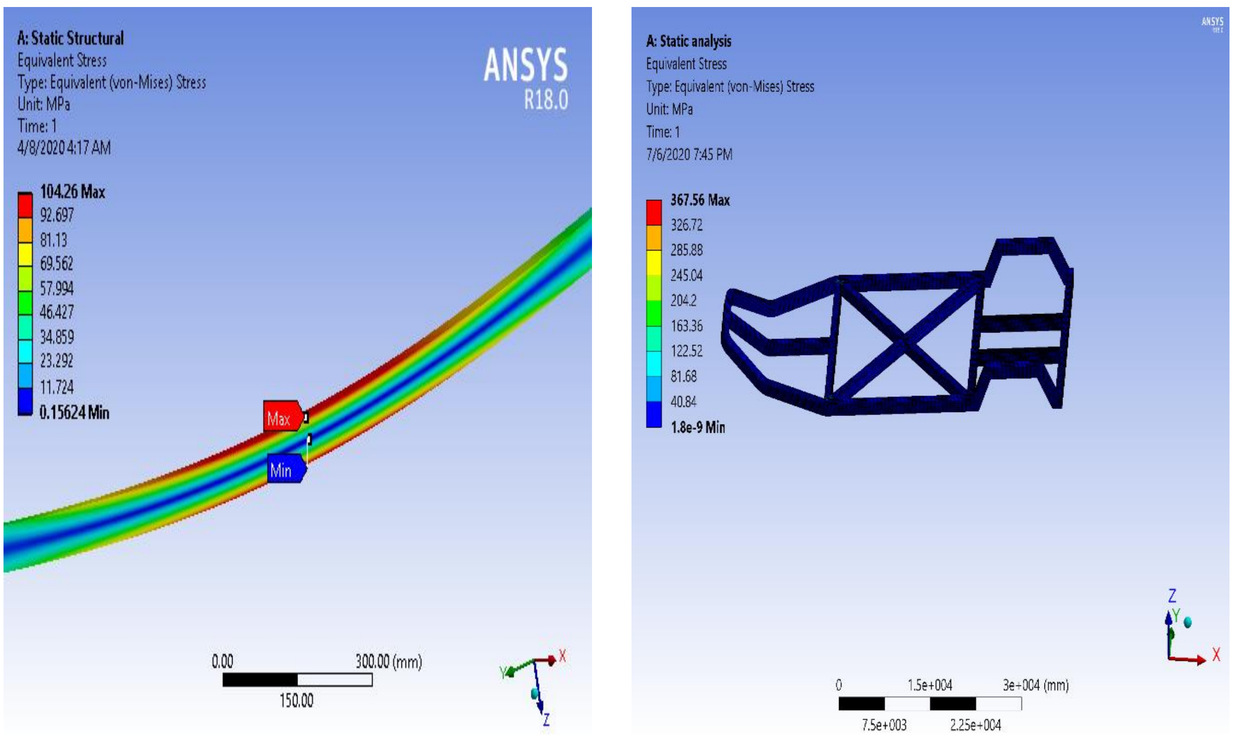


Figure 4. 4 Beam and chassis frame Equivalent (von-Mises) stresses

Load distribution along the chassis model

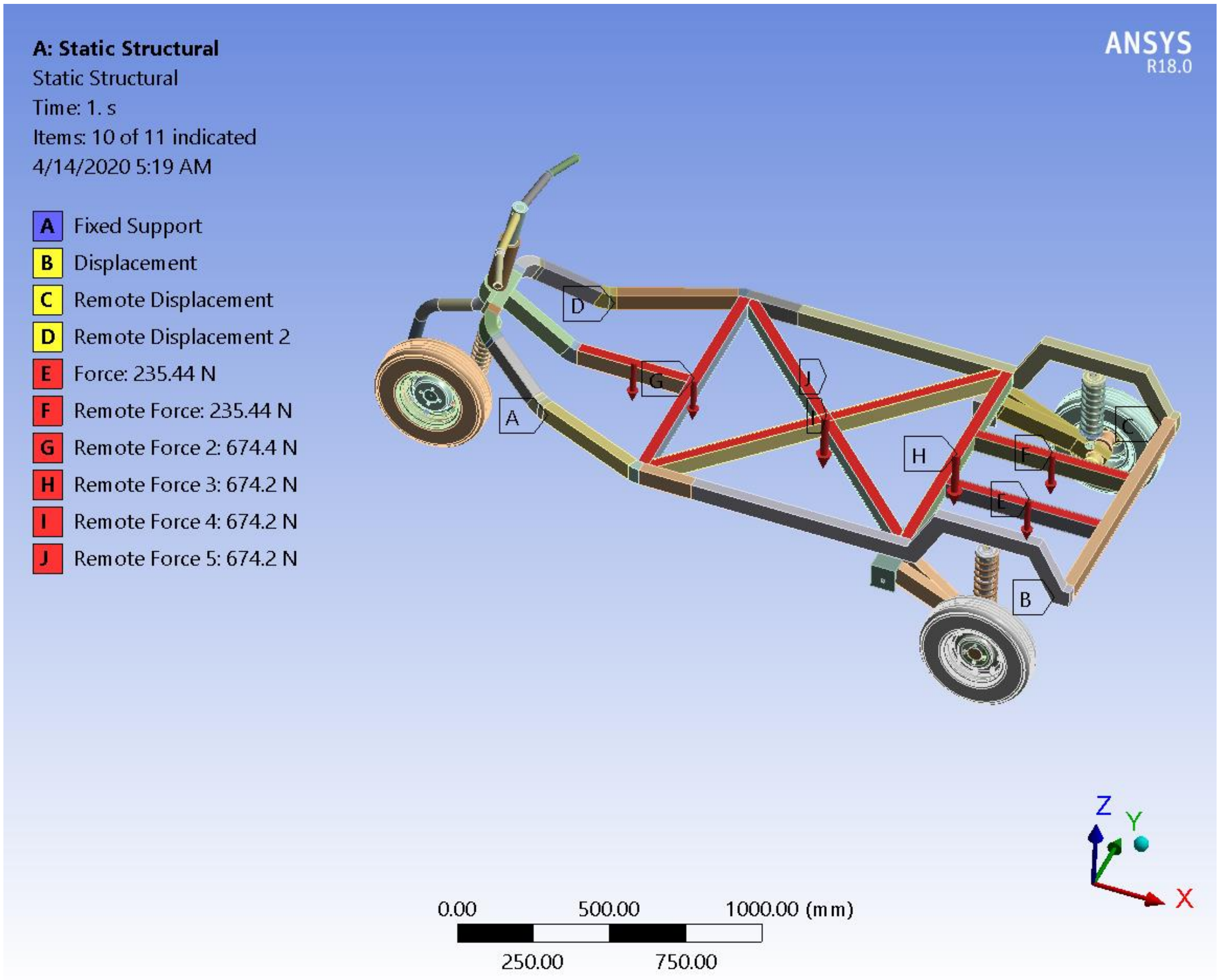


Figure 4. 5 Load distributions along chassis frame

Table 4.1 Summary of loads distribution along the chassis

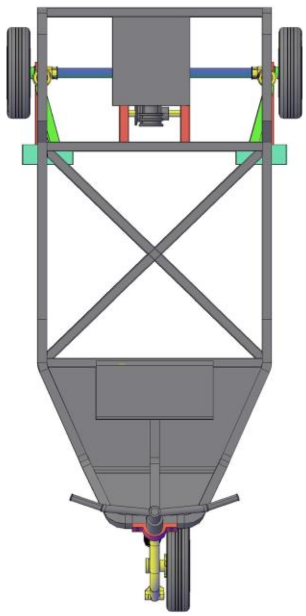
s/n	Load descriptions	Fixed points at	Represented letter	Loads location
1	Operator	A	G	Front
2	Thresher	B	G, H, I, J	Middle
3	Engine	C D	E, F	Rear

4.3. Results and discussion

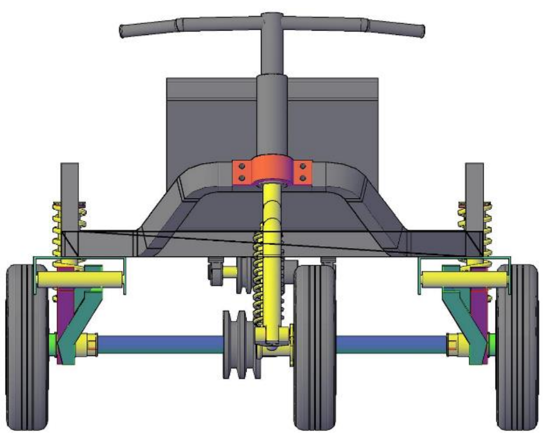
The beam and chassis frame structural analysis results of stresses, deformation and equivalent (von-Mises) which carried out analytically and using ANSYS in chapter 3 and chapter 4 respectively, are as a desirable and the design is also safe since, their values are within theoretical ranges. However, some variation was occurred between both analysing methods when compered each other results, especially deflection and von-Mises stress. Based on the results obtained from both analysing method, successful assembly of three-wheeled chassis with its components like, frame, suspension system, steering system, tires, wheels, shock absorber, power transmission unit at rear assembly and driver set were designed and modelled after the single longitudinal and frame structures checked with payloads. The three-wheel chassis developed is successful for the problem of Sheller/Thresher transporting easily and economically, as illustrated in figure 4.6 and the Table 4.1 shows the comparison of theoretical, analytical and ANSYS results of maximum stress, deflection and equivalent (von-Mises) stress of beam structural steel and chassis frame.

Table 4.2 comparison of results

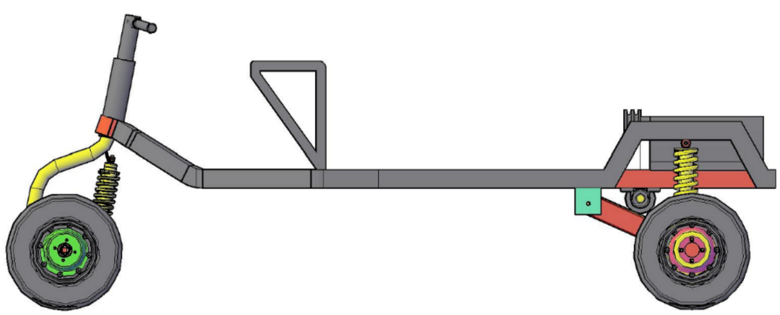
	Theoretical value	Analytical value	ANSYS value
Normal stress	200 Mpa	104 Mpa	104.04 Mpa
Deformation	8.75 mm	3.957 mm	7.034 mm
Equivalent(von-Mises) stress	< 350 Mpa	292.58 Mpa	104.26 Mpa



Top view of the chassis



Front view of the chassis



Side view of the chassis

Figure 4. 6 Chassis final orthographic drawing

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. Summary

In Ethiopia Farm power is mainly dependent on manpower, even operating and utilizing existing Sheller/Thresher farm machine is difficult. This caused due to those machines are heavy in weight (about 300 kg) and didn't incorporate driving mechanism in their design and construction. Moving those machines from place to place for farming activities is difficult and labor intensive.

The purpose of this thesis work is to Design, and Model engine driven three-wheeled chassis which would be convenient to transport those farm machines easily and economically. This had achieved by modelling three-wheeled ladder frame and merging together with some components of TAGRO Bajaj (Bajaj Re-4 stroke) and 9HP Air-cooled Diesel Engine, using AutoCAD 2007 and ANSYS R18 software for modelling chassis structures and verification of static analysis respectively.

The ANSYS structural analysis results of stresses, deflection and equivalent (von-Mises) stress also as safe as analytical and desirable.

5.2 Conclusion

This thesis work was carried-out on the basis of determination of specifications for newly designed and modelled of three-wheeler chassis for Sheller/thresher farm machine. The structural analyses results of stress 104MPa, deflection 3.957mm and von-Mises 292. 58MPa obtained in both analytical and ANSYS analysing methods are in safe ranges. The load capacity of the structure is about 800kg 7848N and thoroughly this newly developed three-wheeler chassis of ladder frame design the difficulty of transporting Sheller/thresher from place to place, loading and unloading also expected to be eliminated and the chassis can be constructed in home with low cost, since the selected components such as: rectangular hollow section (RHS), steering column, braking systems, tyre, wheel and suspension systems are available with low cost in market. Designing and modelling process are also successful however, further study is advisable to be performed on dynamic loads analysis and vibration test before prototype will be constructed.

5.3. Recommendation

As a recommendation for Ethiopian entrepreneurs, investors, researchers, vehicle body manufacturing companies to invest their money and knowledge for further research, constructing and evaluation of three wheeled chassis for non-movable farm machines like Sheller/Thresher to minimize challenges caused to farmers in transporting such machine from location to location.

5.4. Future works

- Dynamic analysis of three-wheeled chassis model should be performed in the future.
- Redesign of Sheller/thresher structure with consideration of developed three-wheeled chassis structure.
- Stability analysis should be performed.
- Vibration analysis should be performed.
- Ergonomic analysis should be performed.

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