Design and Analysis of Mobile Hydraulic Scissor Type Light Duty Vehicle Loading and Unloading Lift

Esa Hussen Hamu

A Thesis Submitted to the Department of Mechanical Engineering

School of Mechanical, Chemical and Material Engineering

Presented in Partial Fulfillment of the Requirement for the Degree of Master in Automotive Engineering

Office of Graduate Studies

Adama Science and Technology University

June, 2024

Adama, Ethiopia

Design and Analysis of Mobile Hydraulic Scissor Type Light Duty Vehicle Loading and Unloading Lift

Esa Hussen Hamu

Adviser: Geleta Fekadu (PhD)

A Thesis Submitted to the Department of Mechanical Engineering
School of Mechanical, Chemical and Material Engineering

Presented in Partial Fulfillment of the Requirement for the Degree of Master in Automotive Engineering

Office of Graduate Studies

Adama Science and Technology University

June, 2024
Adama, Ethiopia

DECLARATION

I declare that this master thesis entitled "Design and Analysis of Mobile Hydraulic Scissor Type Light Duty Vehicle Loading and Unloading Lift'' is my original work. That is, it has not been submitted for the award of any academic degree, diploma, or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

________________________ ______________________ ____________________

Name of student	Signature	Date

RECOMMENDATION

I/we, the advisor(s) of this thesis, hereby certify that I/we have read the revised version of the thesis entitled “Design and Analysis of Mobile Hydraulic Scissor Type Light Duty Vehicle Loading and Unloading Lift” prepared under my/our guidance by Esa Hussen Hamu submitted in partial fulfillment of the requirements for the degree of Master of Science in Automotive Engineering. Therefore, I/we recommend the submission of the revised version of the thesis to the department following the applicable procedures.

____________________	__________	____________________
Major Advisor	Signature	Date
____________________	__________	____________________
Co-advisor	Signature	Date

APPROVAL PAGE

I/we, the advisors of the thesis entitled “Design and Analysis of Mobile Hydraulic Scissor Type Light Duty Vehicle Loading and Unloading Lift” and developed by Esa Hussen Hamu, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

______________________	____________	______________
Major Advisor/Supervisor	Signature	Date
______________________	____________	______________
Co-advisor/Co-supervisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Esa Hussen Hamu have read and evaluated the thesis entitled “Design and Analysis of Mobile Hydraulic Scissor Type Light Duty Vehicle Loading and Unloading Lift " and examined the candidate during the open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Automotive Engineering.

______________________	____________	______________
Chairperson	Signature	Date
______________________	____________	______________
Internal Examiner	Signature	Date
______________________	____________	______________
External Examiner	Signature	Date

Finally, approval and acceptance of the thesis are contingent upon the submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department of Graduate Council (DGC) and School Graduate Committee (SGC).

______________________	____________	______________
Department head	Signature	Date
______________________	____________	______________
School Dean	Signature	Date
______________________	____________	______________
Office of Postgraduate Studies, Dean	Signature	Date

ACKNOWLEDGEMENT

First, I would want to express my gratitude to Almighty Allah for the wisdom he has bestowed upon me, as well as the strength, health, and chance to complete my thesis. I'd like to express my heartfelt gratitude and appreciation to Alemayehu Wakjira (PhD) my thesis proposal advisor who gave me motivation, useful comments, suggestions, and constructive criticisms during proposal preparation, and to Geleta Fekadu (PhD), my thesis advisor who gave me useful comments, suggestions, and for providing me with immense supports as well as for guiding and supervising my work during the entire period of the research and for shaping the final write-up of the thesis. I'd want to thank all my friends and those of you who did not leave your names but contributed to the completion of this thesis.

Nobody has been more important to me in the pursuit of this undertaking than my family members. I'd like to thank my parents for their love and guidance in whatever I do. They are the ideal role models. Most significantly, I want to thank my beloved wife Tayiba shanko for her unending support and patience throughout my years of study.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

NOMENCLATURE AND ACRONYMS

A	Area
CAD	Computer-aided design
C	Spring index
D	Diameter
di	Inner diameter
do	Outer diameter
dw	Wire diameter
E	Modulus of elasticity
ECC	Ethiopian Construction Corporation
F	Force
FEA	Finite Element Analysis
Fn	Natural frequency
G	Shear modulus of material
GVW	Gross Vehicle Weight
GVWR	Gross Vehicle Weight Rating
hs	Solid height
I	Moment of inertia
ISO	International Standard Organization
kPa	Kilopascal
L	Length
LDV	Light Duty Vehicle
M	Mass
Ms	Mild steel
N	Number of coils
P	Pressure
SUV	Sport Utility Vehicle
t	thickness
W	Weight

ABSTRACT

Scissor type systems are frequently used as lifting systems in the industry. These systems are mainly preferred to do maintenance, repair, and clean. It is a portable, easily extended and compressed, safe operating machine used for lifting significant loads at required height safely and efficiently. There are different types of scissor lifts, Hydraulic, Pneumatic, and mechanical scissor lift. Hydraulic scissor lifts are the type of lifts used in industries, workshops, or maintenance centers for purposes of lifting a load or providing at unreachable heights, and for vehicle maintenance. The hydraulic scissor lifts that existed in some automotive industries occupy more space in the maintenance shop and simply cannot move from place to place for use and also not comfortable to load/unload vehicles on a truck or use the crane to load/unload the vehicle on the truck is not safe and, high space, etc. The main investigation of this project is, to design a hydraulic scissor lift that has a carrying capacity to load light duty vehicles that have GVWR below 3200kg and to design a moveable wheel mechanism used to move the machine from one place to another and a static and dynamic analysis by using finite element methods. Depending on the maximum load carrying allowed and the maximum height at which it rises, the type of hydraulic cylinders have 650mm stroke and 63mm cylinder diameter, directional control valve, pump the maximum working pressure of 160 bar, and 12.5kW electric motor was selected. Drafting & drawing of the mobile hydraulic scissor type light duty vehicle loading and unloading lift was done using SOLIDWORKS 2022 with suitable modeling and the analysis including total deformation, equivalent stress, and strain, was done in ANSYS 2022R1 software. The maximum equivalent (von-mises) stress 712.17Mpa and 242.94MPa are less than the maximum allowable stress (1287.18MPa). The result shows that it can resist the applied load safely or can carry without failures and its safe and the maximum total deformation 62.169mm and 0.40242mm are at optimum range that is in the acceptable range of value. Furthermore, each and every part does not beyond their yield stress values of the material. As a result of the analyses, it was concluded that the system designed could safely be used during load/unload operations. Final design of the mobile hydraulic scissor type lift assembly analysis results shows that, it is considered safe to use targeted weight carrying (3200 Kilograms) purpose.

Keywords: ANSYS 2022 R1, Scissor arms, SOLIDWORKS 2022, Wheel mechanisms

CHAPTER ONE
INTRODUCTION

1.1 Background

Any machine part cannot be moved to a desired position with an application of less amount of external force, for placing a component in the required location, the motion of component follows commonly horizontal or vertical direction. Before car lifts were invented, mechanics would often have to deal with cramped and dangerous conditions while working on motor vehicles. They would often use ramps or jacks to lift vehicles and accidents were common. Pits offered a safer option for working on vehicles, but very often these pits did not allow a mechanic to stand comfortably while working on a vehicle and also people lift objects with the help of ropes and rollers. Due to the revolution and development of science and technology, these days many upgraded technologies are used to lift stuff. Many machines such as aerial lifts, boom lifts, scissor lifts, man lifts, telehandler, and towable lifts are used to move machines and manpower in different directions based on the requirement (Gnanabharathi G. 2017).

1.1.1 Lifting System

Lifting systems are used for purposes of lifting a load or providing at unreachable heights. A lift is a very simple device or mechanism used for raising any elements or objects or load from ground level to a specific height to perform a particular task or work with the maximum possible load carrying capacity and minimum efforts of a workman. These systems can be used in multi-purpose applications and a range of services such as cleaning services, maintenance-repair activities, and load lifting and lowering activities (Cengiz G. et al, 2018).

1.1.2 Hydraulic scissor lift

Vehicles have always been heavy and require regular transportation and repairs. That was the most important equipment for any automotive industry, garage, or equipment maintenance service center is the hydraulic scissors lift. A hydraulic scissor lift is a mechanical device used for various applications for the lifting of loads to a height or level. Scientific developments in the field of hydraulics were vital to the invention of the car lift. In the 17th century, French mathematician, Blaise Pascal, first described how a hydraulic jack might function. Pascal developed Pascal’s Principle, also known as the principle of transmission of fluid pressure. In layman’s terms, it means that within closed systems, the pressure exerted on an incompressible fluid will result in equal pressure in all directions. The first hydraulic car lift was patented in 1925 by Peter Lunati, for lifting vehicles. By

1945, many companies were making hydraulic lifts for the motor vehicle industry. Since the invention of the first hydraulic car lift, many other lifts have been patented including the scissors type hydraulic car lift in 1989, a 4-post hydraulic platform vehicle lift for multiple cars in 2000, and an above-the-floor hydraulic lift in 1982 (Dishant G. and Yogesh D. 2018).

The hydraulic scissor lift developed is very useful for garages and various industries as it is easy to install and safe to use compared to other hydraulic scissor lifts, electric lifts, pits, ramps, or jacks. In this thesis, a mobile hydraulic scissor lift that extends or rises to the desired height for a given load reduces manpower, and safe workplace, increases the safety protection of personnel and moveable to a safe workspace.

1.2 Statement of the Problem

In many automotive industries, and equipment maintenance service centers or garages the lifting or loading mechanism still uses labor-intensive and time and space consuming procedures. The hydraulic and electric car lifts that existed in equipment maintenance service centers or garages and some automotive industries occupy more space in the maintenance shop and simply cannot move from place to place for use and to create a comfortable working area and shop for technicians (inspector) and also not comfortable to load and unload vehicles on other truck. The limitations encountered in the use of mechanical scissor lift, hydraulic scissor lift, electric lift, and different scissor lifts in getting to an elevated height such as the amount of load to be carried, comfortability (elderly, women, etc.), time consumption, much energy expended, and also using the crane to load and unload the vehicle on the truck is not safe, require high operating cost, space, etc.

1.3 Objectives of the Study

1.3.1 General Objective

The general objective of this research is to design and analyze mobile hydraulic scissor type light duty vehicle loading and unloading lift using the finite element method.

1.3.2 Specific Objectives

- ☞ To gather the detail information about the existing scissor lift of the light duty vehicle.
- ☞ To design and model the top platform, scissor arms, base platform, and wheel mechanism of a mobile hydraulic scissor type lift by using SOLIDWORK 2022 software.

- To select appropriate materials for mobile hydraulic scissor lift components design.
- To analysis the static and dynamic load of scissor arms and wheel mechanism of the mobile hydraulic scissor lift by a finite element analysis.

1.4 Scope of the Study

The scope of the research is to design and analyze of mobile hydraulic scissor type light duty vehicle loading and unloading lift that has the capability of lifting up to 2m height from the ground and a carrying capacity of up to 3200kg. The other parameter of the scope of the design is its mobility by using manpower or another machine directly pushing/pulling on its handle to create a comfortable working area in service shops or for other uses. In addition to this, the scope of this design project is analyzing and calculating the applicable dimensions of the mechanical parts of the lift, how to design the scissor lift arms, upper plate, lower plate, frames, wheel mechanisms, and hydraulic drive for the above same criteria, and deformation, bending and shear stress analysis by using ANSYS 2022 R1 software.

1.5 Significance of the Study

The significance of the study includes the benefits and beneficiaries of the study and they discussed below:

The economic benefit of this thesis is to reduce the maintenance and manufacturing costs since the machine does not require routine maintenance. This work helps other researchers to investigate this type of lifting system for the application of lifting and loading objects at the required height. This lifting system minimizes construction costs and operating costs, and also it reduces working time and saves space. Since this mobile hydraulic scissor type lift is used for a long time without maintenance, and not requires much skilled labor, and easily replacement is possible.

The beneficiaries of this study is to helps for manufacturing companies, automobile industries, and for vehicle maintenance centers or shops on how to design hydraulic scissor lifts for light duty vehicles from different materials by using SOLIDWORKS software and its performance and static analysis using ANSYS software. It also gives a better understanding about mobile hydraulic scissor type light duty vehicle loading and unloading lifts for users and researchers.

1.6 Limitations

The prototype of a mobile hydraulic scissor type light duty vehicle loading and unloading lift is not manufactured due to a lack of budget. An experimental investigation has not been done due to the unavailability of a proper laboratory.

1.7 Organization of the Thesis

The first chapter is an introduction that comprises the background of the study, a statement of the problem, objectives, scope, significance of the study, organization of the thesis, and limitations. The second chapter presents a review of literature related to the study that emphasizes the study design and analysis of a mobile hydraulic scissor type light duty vehicle loading and unloading lift. The third chapter describes the materials and methodology followed during the research work and design. The fourth chapter contains design analysis results and discussion and the last chapter, chapter five contains conclusions of the research work as well as recommendations and directions for future works.

CHAPTER TWO

LITERATURE REVIEW

Marketing work always requires developments in behavioral sciences and process and man’s wants have never been satisfied, and they go through many steps and processes to get greater scientific and technological outcomes. Before now, several engineers have done much research on scissor lifts. It reviewed some of the research that was done on scissor lift design and construction. Generally, this chapter included a scissor lift overview, types, working principles, and critical comments.

2.1 Scissor Lifting System

The most popular lifting systems in the industry are scissors lifting systems. These systems are especially used for maintenance-repair and cleaning. A scissor lift is a portable, easily extended and compressed, safe operating machine used for the transportation of medium sized components to its expected position. A scissor lift is a machine which moves in vertical direction using criss-cross 'X' pattern scissor arms. The required elevation of the lift is achieved based on the number of criss-cross 'X' pattern scissor arms attached. Scissor lifts are generally preferred because of its ease of use, cost effectiveness as compared to the other heavy duty lifts available in the market (Gnanabharathi G., 2017).

The mechanism to achieve this is the use of linked, folding supports in a criss-cross "X" pattern, known as a pantograph (or scissor mechanism). The upward motion is achieved by the application of pressure to the scissor arms, elongating the crossing pattern, and propelling the work platform vertically. The contraction of the scissor action can be hydraulic, pneumatic or mechanical (via a lead-screw or rack and pinion system) (Venkatesh S, 2018).

Its compact ability is also one of the reasons why scissor lifts are preferred over others. The frame is very sturdy & strong enough with increase in structural integrity. A multiple height scissor lift is made up of different leg sets. The basic mechanism used in the scissor lift is inspired by Pantograph Mechanism. A pantograph mechanism is a linkage based on the arrangement in which parallelograms are attached in a way in which one-point trace the path of another point in a scale defined by the length of the sides of the parallelogram. These types of lifts are used to achieve high travel with relatively short platform (Puneet et. al, February 2021).

2.2 Classification of Scissor Lift Platform

The scissor lifts can be classified as a hydraulic lift, pneumatic lifts and mechanical lifts. Pneumatic and hydraulic lifts are two types of lifts that are widely used throughout industry due to their high load capacities, large extension ranges, and environmental versatility. While several classifications of lifts are available, in the majority of residential, commercial, and industrial applications, the lifting action is typically performed by a pneumatic or hydraulic mechanism. However, mechanical lifts are also available for applications unsuited for pneumatic or hydraulic lifts, such as those requiring limited range but precise movement and quiet operation. Hydraulic scissor lifts are very powerful tool for applying a ton of force on the platform plate of component, which is equally distribute on scissor arms. Hydraulic lifting mechanisms are capable of producing up to and greater than 25x the force produced by comparable pneumatic lifting mechanisms. Additionally, they can hold both force and torque constant without the need for a continuous fluid flow as with pneumatic mechanisms. The most common industrial lift is the hydraulic scissor lift (Manoharrao and S, 2016).

2.2.1 Hydraulic Scissor Lifts

The hydraulic scissors lift is operate using the fluid pressure that raises the platform via power with pressurized hydraulic oil. Slight speed variation is possible owing to temperature fluctuations that can alter the viscosity of the hydraulic oil. Hydraulic scissors lifts has developed overtime, and at each stage of its development, critical problems solved and produces greater force than pneumatic.

Figure 2.1 Hydraulic Scissor Lift (https://www.industrialmanlifts.com).

2.2.2 Pneumatic Scissor lift

The pneumatic scissor lifts operated using air pressure and they are very efficient because the power supply carried out by compressing the atmospheric air. Most of the units do not require electricity and thus can be used at any place where the air is available (Thorat, et. al., 2017).

Figure 2.2 Pneumatic Scissor Lift Table (https://www.industrialmanlifts.com)

2.2.3 Mechanical Scissor Lifts

The mechanical lifts extended through a rack and pinion system or power screw, both of which can convert rotational motion. The benefit of mechanical lift is that the teeth of its gear system prevent from slippage essentially. Mechanical scissor lift it needs more power to lift the required object. So it is more complicated to design and the cost of manufacturing is low when it is compared to the hydraulic and pneumatic system.

Figure 2.3 Mechanical scissors lift (Amr Awadelkarim, et. al 2017)

2.3 Components of Hydraulic Scissor Lift

The hydraulic scissor lift has different system part contains a different component to build the whole hydraulic scissor lift. The main component of the hydraulic scissor lift is listed below:

a) Top platform: it is required to design a platform that should serve under heavy load applications and withstand high stresses.

b) Scissors arms: This component is subjected to buckling and bending loads that tend to break or cause bending of the components.

c) Base platform: This component is subjected to the weight of the top platform, hydraulic cylinder, and scissor arms.

d) Hydraulic cylinder: It is one of the power sources that used to lift the link to the required height and retract the link in the closed position.

e) Hydraulic pump: used to push incompressible oil from the oil reservoir to the cylinder. This pushes the piston upward, providing the force necessary to raise the lift.

f) Motor: Most hydraulic scissor lifts are powered by an electric motor. These provide power to the hydraulic pump, which actuates the lift table.

g) Hydraulic oil tanker: used to contain or store the hydraulic oil.

h) Hydraulic hoses: hydraulic hoses are used to transfer hydraulic oil from the oil tanker to the hydraulic cylinder.

i) Hydraulic control Valve: A hydraulic control valve properly directs the flow of liquid oil through the hydraulic system. The direction of the hydraulic flow is determined by the position of a spool. A hydraulic system can only function as per requirements by using valves. The example of main component of the hydraulic scissor lift is shown in the following figure.

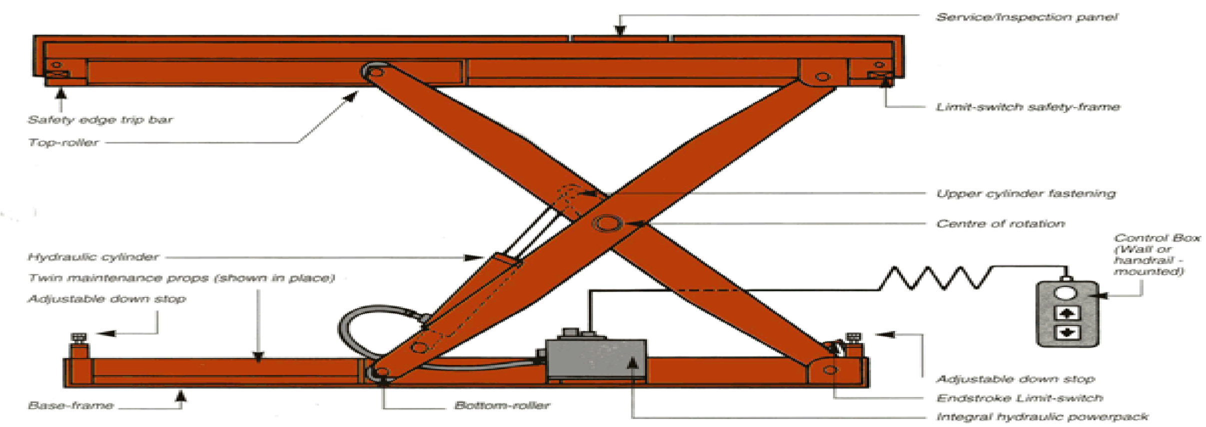


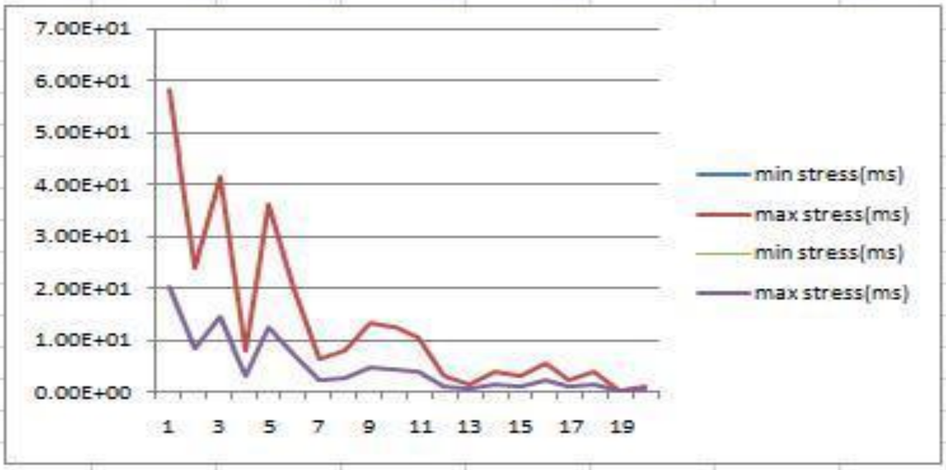
Figure 2.4 Basic components of hydraulic scissor lift (https://manualdiagramholzman..net/)

2.4 Literature review related with mobile hydraulic scissor type lift

The design and analysis of a hydraulic scissor lift use a hydraulic hand pump to power the cylinder without consuming any electric power. The analysis of the scissor lift was done in ANSYS, and all responsible parameters were analyzed in order to check the compatibility of the design values. It is found that they are facing some problems regarding hydraulic scissor lifts, like the job of being lifted is heavier, which causes more deformations in the hydraulic lift frame, and checking the deformations and stresses induced in it is a major objective of this project. It is also found that the weight of the present lift is high; weight optimization is also a prime objective of this project (Gaffar G. et al., 2015).

Design, analysis, and development of multi-utility home equipment using a scissor lift mechanism that focuses on various aspects related to the lifting mechanism and its design. This paper is to design and analyze and construct multi-utility home equipment for senior citizens so that they can carry out their daily activities efficiently. Also, the equipment should be compact and cost effective. The lifting height achieved by the scissor mechanism is 1 m from the bottom level. Buckling and bending failure analysis of scissors is also done in this paper. This project aims at making equipment multifunctional, easy to use or operate, cost effective and portable so that it can be used conveniently at home and may be used in hospitals, hotels, and other common places. All safety considerations are taken into account while designing equipment. A scissor lift mechanism is a device used to extend or retract a platform by hydraulic means. The extension or displacement motion is achieved by the application of force by a hydraulic cylinder to one or more supports. The portable work platform is operated by a hydraulic cylinder, which is operated by a motor. Also, the whole device is motorized, which, with the help of a control panel, allows users to travel from one place to another. In this paper, they carried out a detailed analysis of scissor mechanism members against bending and buckling failure (Divyesh P. et al. 2015).

The design and analysis of a hydraulic scissor lift focused on the force acting on the lift when it is extended and contracted. Generally, a hydraulic scissor lift is used for lifting and holding heavy-weight components. Material selection plays a key role in designing a machine and also influences several factors such as durability, reliability, strength, and resistance, which finally lead to an increase in the life of the scissor lift. The design is performed by considering the hydraulic scissor lift as portable, compact, and more suitable for medium-sized load applications. Drafting and drawing of a hydraulic system scissor lift is done using solid work with suitable modeling and imported to the ANSYS workbench for meshing and analysis. Hence, the analysis of the scissor lift, including total deformation load and equivalent stress, was done in the ANSYS 14.0 version, and all responsible parameters were analyzed to check the compatibility of the design value. The computational values of two different materials, such as aluminum and mild steel, are compared for the best results in figure 2.5.



time step	min stres:	max stres	min stres:	max stress(ms)
0.35	7.94E-09	58.146	1.87E-09	20.424
0.55	1.22E-08	24.195	2.99E-09	8.416
0.75	4.46E-09	41.878	2.43E-09	14.687
0.875	3.14E-09	7.9902	1.02E-09	2.9308
1	2.36E-08	36.245	5.84E-09	12.649
1.2	5.79E-09	20.161	4.93E-09	7.1358
1.4	8.82E-09	6.337	3.48E-09	2.3517
1.6	1.23E-08	8.0552	3.38E-09	2.7071
1.8	6.62E-09	13.552	4.95E-09	4.6914
2	1.26E-08	12.657	3.98E-09	4.4355
2.2	1.22E-08	10.615	9.26E-09	3.7607
2.4	5.49E-09	3.1174	1.16E-09	1.1544
2.6	1.40E-08	1.5416	3.49E-09	0.60398
2.8	3.33E-08	3.8816	1.07E-08	1.3121
3	2.25E-08	3.2491	1.24E-08	1.1091

Figure 2.5 Stress Analysis of Mild Steel & Aluminum Alloy

Both mild steel and aluminum alloys are good at their different aspects. Mild steel has greater durability and strength, and it is also cheap and easily available. These properties play an important role in designing a scissor lift. So in designing the scissor lift, mild steel was selected as of greater importance (M. Kiran K. et al., June 2016).

The objective of the analysis and optimization of the hydraulic scissor lift used for lifting purposes is to make the table adjustable to a desired height. A scissor lift provides the most economical, dependable, and versatile method of lifting loads; it has few moving parts that may only require lubrication. This lift table raises the load smoothly to any desired height. The scissor lift design is used because of its ergonomics as compared to other heavy lifting devices available on the market. It is found that they are facing some problems regarding the hydraulic scissor lift, like a job to be lifted being heavier, which causes more deformations in the hydraulic lift frame. Checking the deformations and stresses induced in it is a major objective, and the weight of the present lift is high. Weight is also the prime objective of this project. As loading and unloading are repeated, there may be a chance of fatigue failure. To check the life of the lift and the vibration of the hydraulic lift during working time by modal analysis, Vibrations were studied during the lifting of the tower by using modal analysis (Sabde A. M. and Prof. Jamgekar R.S. 2016).

Finite Element Analysis of Frame of Hydraulically Operated Beam Lifting Machine focused on beam lifting device designed for textile industries that operated hydraulically and has two frames, one horizontal and another vertical. The horizontal frame is mounted with two telescopic cylinders used for beam lifting to the required height. The mobility of the structure is provided by using castor wheels. Finite element analysis of the frames is done by ANSYS software. Considering the needs of the textile industries, a special-purpose machine has been designed to lift the beams in textile industries. The finite element analysis of the frame of this machine is done to get an idea of the stresses and deformation of the structure and to modify it if needed (S. B. Naik et al.).

The aim is to design and conduct a strength analysis of the scissor lift that is elevated by the mechanical drive (lead screw and bevel gear) for household applications. In this research, an attempt is made to evaluate the strength according to the stress analysis of the scissor lift developed for household application. This project proposal is an inspiration for an attempt to develop carry machines that do not use advanced systems; however, mechanical drive scissors, which can overcome the higher than declared limitations, are employed. The design of the scissor lift is to elevate up to a height of about three meters and carry a weight of 300 kilograms. The prime goal is an analysis of the strength of the conditions of the structural elements. They analyzed the scissor lift model and obtained favorable results. Apart from this model being feasible, it also has various attributes that add to its value. In contrast to hydraulic lifts, their daily use consists of a mechanical drive. It paves the way for many advantages: ease of use, weight (the absence of the hydraulic cylinder resulted in a reduction in the weight of the model, which weighs 300 kg and can go up to a height of 2.9 meters), storage space, Price factor, operational costs, and maintenance costs are very low compared to the other lifts in the market (Gnanabharathi G. 2017).

To design and analyze car lifts to fit the given parameters, the history and types of car lifts are studied, and several research papers are referred to. In the case of their lift, it had to be more stable and have a higher capacity to lift loaded mini-trucks. The project uses SOLIDWORKS for design and ANSYS for analysis of the CAD model of the lift. After the design is analyzed, the parts are ordered, and the lift is assembled. As per the load requirements, available hydraulic cylinders, design of the lift, and budget, two hydraulic cylinders are chosen. They are connected to a power pack, which supplies pressurized oil to the cylinders through hoses. Pneumatic cylinders were considered, but they are expensive and not very efficient, raising the chances of failure. The design and fabrication of a portable work platform elevated by a hydraulic cylinder was carried out in accordance with the required design standards. The portable work platform is operated by a hydraulic cylinder. Ergonomics, material handling, and providing comfort to the operator were the motives behind developing this lifter (Dishant G. and Yogesh D. 2018).

The scissor lifting machine is hydraulically operated, which makes lifting simple by eluding bending onward to lift manually because the table is regulated to be lifted at a preferred height. The overall objective of this paper is to design and manufacture a double scissors lift device elevated by one hydraulic cylinder that can be used in the automobile sector. The machine is tested by lifting different weights, and it is successful and can lift up to the recommended weight of 270 kg efficiently without any problem. Drafting and drawing of the hydraulic system scissor lift is done using SOLIDWORKS. This device will make use of the power generated from a hydraulic cylinder to raise or lower a platform. Research carried out in the automobile industry reveals that one of the heaviest components of the automobile is the car engine, which has an average weight of 272 kg. By this factor, the control weight would be 280 kg for a safer design of the scissor lift table platform for assembly purposes in the automotive industry. For the given dimensions, the scissor lift can hold a load of up to 280 kg at a height of 1000 mm (Wubshet D. et. al., November 2019).

2.5 Research gap

From the literature review, it has been observed that many researchers have done research on mechanical and hydraulic scissor lifts that lift the parts of vehicles and entire households' man that lift high heights but limited load carrying capacity. A mobile hydraulic scissor lift done by different researchers does not have capacity to lift light duty vehicles and also is not used as ramps to load and unload light duty vehicles. Different scissor lifts are designed to occupy more space in the maintenance shop, and fixed lifts simply cannot move from place to place for use. And it also takes more time to lift, and the material used is not determined according to the exact mechanical properties and necessary material for each component. When it comes to the mechanism by which the lifts are operated, most of them fall into the mechanical system category, which makes the lifts heavy and requires high operating costs. The previous researcher didn't consider balancing and minimizing the vibration when holding the load at a certain height. This all are the gap. So based on this research gap, it was decided to do the design and analysis of a of a mobile hydraulic scissor type light duty vehicle loading and unloading lift and also to determine the exact mechanical properties and necessary materials like structural steel and stainless steel for each component that has been selected for increased life of the machine and a safe working area.

CHAPTER THREE
MATERIALS AND METHODOLOGY

This chapter contains materials used and methods followed to design and analyze of mobile hydraulic scissor type light duty vehicle loading and unloading lift. The selection of appropriate materials that satisfy design specifications is deeply defined. In addition to this, define the theory of the design procedure and then at the end design each component of the mechanical parts of the system. The materials required for this design and the methodology to be followed are given below.

3.1 Data collection

To achieve the objective, primary and secondary sources were used.

Among the primary sources used, primary data was collected by observing commercial automotive sales and services shops and the governmental maintenance shops and personal interview by asking technicians and shop foreman to identify what kind of light duty vehicle lift they are using and the problems are being faced. During visiting Moenco Southern Addis Branch, many electric lifts existed in the maintenance shop; all are fixed and used only for maintenance services as shown in figure 3.1.

Figure 3.1 Moenco Southern Addis Branch Electric Lift in Vehicle Maintenance Shop

While observing ECC governmental maintenance shops and when measuring the dimension of vehicles as shown in figure 3.2, one an electric light duty vehicle lift and a hydraulic type heavy duty lift exist. Both are fixed and not moveable. They are used only for maintenance services.

Figure 3.2 In ECC Maintenance Shop Vehicles Dimension Measurements

In general the problems identified during observing different governmental and private vehicles' sales and maintenance shops are shown as follows:

- Different electrical and hydraulic car lifts used in the shop was not moveable and didn't make the working space free or comfortable for other works.
- Hydraulic and mechanical jacks used in some shops are not convertibly for technicians like elders, women's etc.
- The ramp used to load/unload vehicles in different maintenance shops requires a large space
- Using a crane to load/unload vehicles is not safe for the vehicle's body and high costs, and also requires large space.

Among the secondary sources data: Secondary data collected from various research papers, browse websites, manuals, textbooks, literature reviews, and media sources are:

- Different jack design are not appropriate for use by everybody
- Different light duty vehicle lifts designed are not moveable.
- The designed fixed car lifts only to lift the entire vehicle's body for every task of maintenance not used as loading/unloading is not moveable.
- Different small size moveable scissor lifts are designed not to have the carrying capacity to lift the entire vehicle's body, only lift parts or components of vehicles.

3.2 Components used to design

Components used to design a mobile hydraulic scissor lift are divided into three major systems, such as mechanical system parts, hydraulic system parts, and electrical system.

3.2.1 Mechanical System Parts

The mechanical system contains the major parts or components of the whole system or the part which do the main task of the system (lift loads). It includes the upper platform, the scissor arms, the lower or base platform, Ramp extensions, ground supports and the wheel mechanism. This system enables the extension of the system to the required height and it uses a specific type of power. The materials used for different components of the mechanical system parts are as follows:

• Top Platform and Ramp extension: This component is subjected to the weight of the gross vehicle weight (GVW) which includes total vehicle weight, passengers, and some cargo. Hence strength is required; the frame of the platform is structure steel and the top plate and ramp plate is Stainless Steel.

• Scissor arms: This component is subjected to buckling load and bending load tending to break or cause bending of the components. Hence based on strength, stiffness, plasticity and hardness a recommended material is structural steel.

• Base Platform: this component is subjected to the weight of GVW, top platform, scissors arms and hydraulic Cylinder parts. It is also used for the stability of the whole assembly. Therefore strength, Hardness and stiffness are needed mechanical properties. Structural steel is used.

• Wheel mechanisms: The wheel mechanism is the mechanism used to move the lift machine from one place to other. The components of wheel mechanism is wheel, springs, two types of u shape plates and stand plate. Wheel is a circular block of a hard and durable material at whose center has been bored a circular hole through which is placed an axle bearing about which the wheel rotates when a moment is applied by gravity or torque to the wheel about its axis. Structural steel material is used except stand plate and spring stainless steel. The mobility for the structure is provided by using castor wheels.

• Connecting Shaft/Pins, nuts, bolts and bearings: Links, base and other components are connected to each other by using pin, nuts, bolts where, which are made of hard steel material that is structural steel.

Finally, the mechanical properties of the necessary component for the design of a mobile hydraulic scissor type light duty vehicle loading/unloading machine are strength, ductility, toughness, hardness, and stiffness, depending on a component and tasks, the selected material for these purposes is stainless steel and structure steel.

3.2.2 Hydraulic System Parts

Hydraulic system is not a source of energy. It used to control and transmit power. Some components of hydraulic system are hydraulic cylinder, hydraulic pump, drive motor, control valve, hydraulic oil tanker and hoses. In this system a pump driven by a prime mover such as an electric motor creates a flow of fluid, in which the pressure, direction and rate of flow are controlled by values. An actuator is used to convert the energy of the fluid back into mechanical power.

• Hydraulic Cylinder: is considered as a support with both ends pinned. It is subjected to direct compressive force which imposes a bending stress which may cause buckling of the component. It is also subjected to internal compressive pressure which generates circumferential and longitudinal stresses all around the wall thickness. Hence necessary material property must include strength, ductility, toughness and hardness.

• Hydraulic Pump: is a mechanical source of power that converts mechanical power into hydraulic energy. It generates flow with enough power to overcome pressure included by the load at the pump outlet. Used to actuate scissor arms to extract and contract.

• Hydraulic Control Valve: A hydraulic control valve properly directs the flow of a liquid medium, usually oil, through your hydraulic system. The direction of the hydraulic flow is determined by the position of a spool. A hydraulic system can only function as per requirements by using valves.

• Hydraulic Tank: is a container for holding the fluid required to supply the system including a reserve to cover any losses from minor leakage and evaporation. The tank can be designed to provide space for fluid expansion, permit air entrained in the fluid to escape, and to help cool the fluid.

• Hydraulic hoses: Two hydraulic hoses are used to transfer hydraulic oil from tanker to hydraulic cylinder and returned oil to hydraulic cylinder.

3.2.3 Electrical System Parts

The electric power is a source of power and implements an electrical motor that will operate the hydraulic pump applying pressure on hydraulic cylinders, which reciprocate by lifting the scissor arms and the load. The management of the elevator is carried out by the control panel switch which has three buttons: the main switch, lowering, and rise.

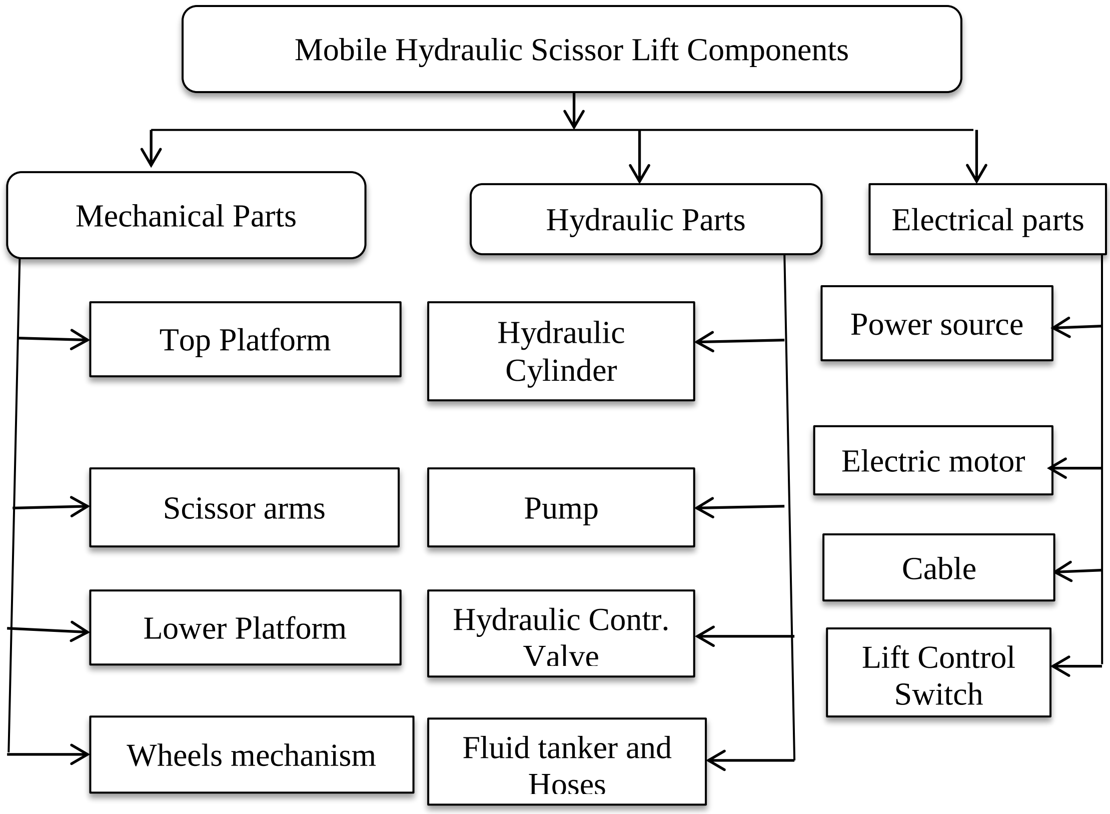


Figure 3.3 Mobile Hydraulic Scissor Lift Components

3.3 Vehicles Physical Appearance Assessment

Before starting to design a mobile hydraulic scissor type lift machine that was compatible with all light duty vehicles the physical appearance of vehicles like dimension of aerodynamically shape of the vehicles takes into consideration. The measurement that was taken from the light duty vehicles should be in the range of the lifting machine. There are so many different types of light duty vehicles depending on their aerodynamic shape, usage and dimension. Such as automobile, pick up, van, suv, station wagon. Such vehicle types have their dimension of aerodynamic shape, load and center of mass. The following table provides the physical properties of the different light duty vehicles.

Table 3.1 Vehicles Specifications (https://www.toyota-gib.com/eng/models/dual-purpose-type/hilux/hilux-lhd-30l-diesel - 5-seater- LAN125L-DNMSEN.html, https://www. Edmunds.com)

Vehicle type	**Toyota Pick up**	**Ford Pick up**	**Toyota S/wagon**	**Toyota S/wagon**
Model code	LAN125L-DNMSEN	2022 Ford F-150	VDJ200L-GNTVZ, VX-R	VDJ200L-GNTVZ, VX
Drive	4WD	4WD	4WD	4WD
Transmission	Manual	Automatic	Automatic	Automatic
Speed	5	10	6	6
Number of seats	5	6	8	8
Color	White	White	White	White
Engine model	5L-E	Flex-fuel (FFV)	lVD-FTV	lVD-FTV
Displacement	2986		4461	4461
Number of cylinders	4	V-6	8	8
Maximum power (kw/rpm)	70/4000	216/ 6,500 rpm	173/3200	173/3200
Maximum torque (Nm/rpm)	197/2400	265 lb-ft @ 4,000 rpm	615/1800-2200	615/1800-2200
Fuel Type	Diesel	Diesel	Diesel	Diesel
Fuel tank capacity (Lit)	80	98	93	93
Kerb weight. kg	1859	2134	2620	2620
Gross Vehicle Weight, kg	2820	2935	3,200	3.150
Payload, kg	961	801	780	730
Length, mm	5,330	5,885.18	4,985	4,950
Width, mm	1800	2,430.78	1,980	1,980
Height, mm	1,855	1,960.88	1,945	1,945

Wheelbase, mm	3,085	2,693.16	2,850	2,850
Ground clearance, mm	310	238.76	230	230
Front tires	205R16C	265/70R17	285/50R20	285/60R18
Rear tires	205R16C	265/70R17	285/50R20	285/60R18
Tire type	Radial	Radial	Radial	Radial

Generally, the technical Specification of vehicles selected to design a mobile hydraulic scissor type light duty vehicle lift was described in table 3.2.

Table 3.2 Vehicles Technical Specification

Vehicles Dimension	Maximum vehicles standard dimension	Selected vehicles dimension
Length	5,885.18mm	5,000mm
Width	2,430.78mm	2,500mm
Wheel base	3,085mm	3,085mm
Gross Vehicle Weight	3,200kg	3,200kg

3.4 Methodology

In order to address the general and specific objectives of this work a well-designed methodology was followed. Various steps included in the methodologies are listed below and summarized in the figure 3.4.

- Important data used to design mobile hydraulic scissor type lift was collected through a literature review.
- Some crucial characteristics of materials and the analysis of lift components which was done by the experimental investigation were collected.
- Actual data was collected by observing and measuring different types of light duty vehicle specifications.
- Performed theoretical calculation for components of mobile hydraulic scissor type light duty vehicle lift.
- The 3D model of parts of the mobile hydraulic scissor type lift was done by SOLIDWORKS 2022 and analyze of materials used to design lift.
- Finally, stated the conclusion of ANSYS 2022 R1 workbench results.

In general the overall work flow of the study methodology of the thesis was described in figure 3.4.

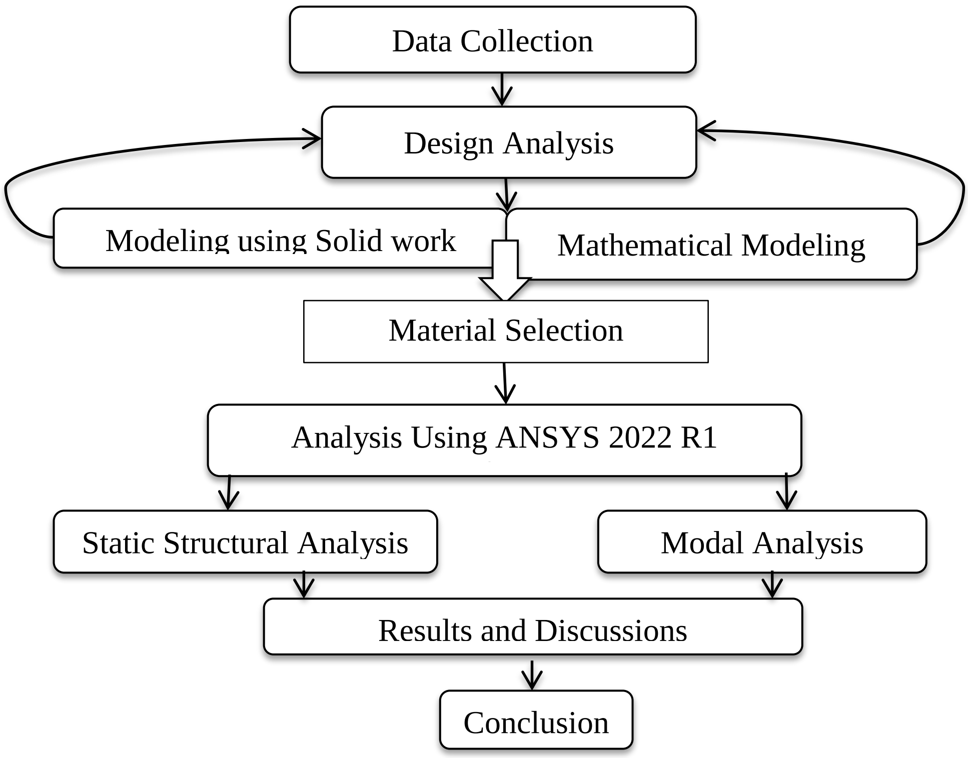


Figure 3.4 Work flow of study

3.4.1 Design of mechanical system part

Before designing of mechanical part of a mobile hydraulic scissor type light duty vehicle loading and unloading lift knowing the dimensions and weight of materials used to design is essential. Therefore some of the standard dimension and weights of steel materials is described in table 3.3.

Table 3.3.Dimensions and weight of steel materials (www.steelexpress.co.uk**)**

Item No.	Normal size (W x B)	Thickness (mm)	Weight per meter (kg)	Item No.	Normal size (W x B)	Thickness (mm)	Weight per meter (kg)
1	60x30	3.00	4.13	14	3000x1500	2.5	92.1
2	60x40	3.00	4.65	15		3.0	112.0
3	80x40	3.00	5.49	16		1.2	44.2
4		4.00	7.22	17	2000x1000	3.0	49.6
5	80x60	3.00	6.53	18	2500x1250	3.0	77.5
6	100x40	3.00	6.53	19	12D		0.89
7	20x20	3.00	3.16	20	15D		1.40
8	25x25	3.00	4.94	21	20D		2.48
9	30x30	3.00	7.11	22	25D		3.88
10	40x40	3.00	12.60	23	80x80	6	7.89
11	50x50	3.00	19.80	24		10	12.80
12	75x75	6	7.37	25	100x100	6	9.20
13		10	11.95	26		10	15.0

3.4.2 Design of Top Platform or Upper Base

This component is subjected to the weight of the GVW that the vehicle runway. The overall dimensions and 3D model are shown in table 3.4 and figure 3.5

Table 3.4 Dimensions of top platform components

Name	Qty. No	Length of each (mm)	Width of each (mm)	height of each (mm)	Thickness of each (mm)
Top Platform Plate (chequered plate)	02	5,000	775		4.0
Angle bar	02	5,000	100	100	6.0
Top Platform frame (rectangular tubing)	04	4,840	80	60	3.0
	06	615	80	60	3.0
	02	2,500	80	60	3.0
Ramp extension (chequered plate)	02	950	775		4.0
Frame	02	950	30	30	3.0
Ramp Roller	02	775	20D at the end of both side		

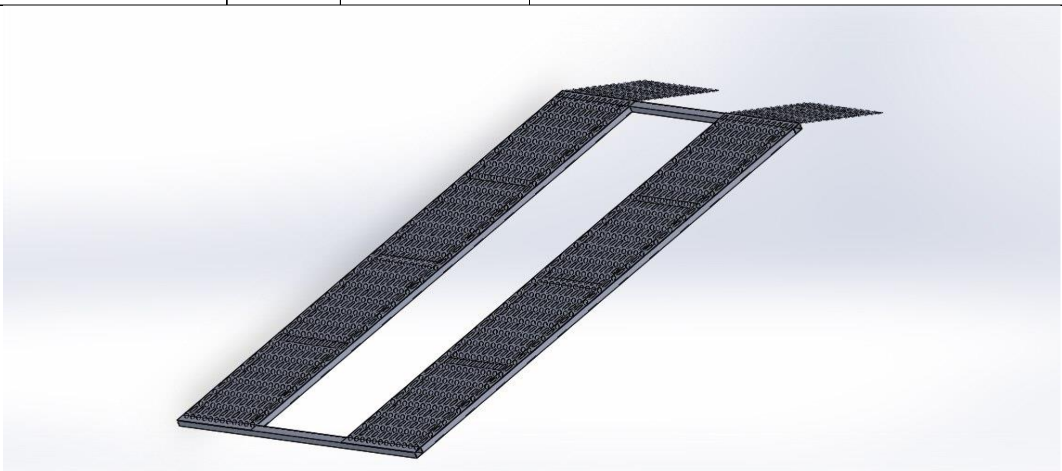


Figure 3.5 3D Model of Top platforms

The top platform was compatible with stand the entire light vehicle. The place where the vehicle tire was stand on had enough width, 775mm and in the middle, the beams had a 950mm hallowed section in order to create open space for the technician and make visible of the bottom of vehicles.

The cross section area of top platform was as follows:

$$A = L\ x\ W \quad 3.1$$

$$A_1 = L\ x\ W\ and\ A_2 = L\ x\ W$$

Where, L – Length

W- Width of the each top platform

A- Cross section area

$$A_1 = A_2 = (L\text{x}W)$$
$$= (5{,}000\text{x}775)$$
$$= 3.875m^2$$

So $3.875m^2$ is areas of the each top platform section vehicle stand on.

All objects, whether solids or fluids, are pulled toward the center of the earth by the force of attraction. This force is called the weight of the object and is proportional to the object's mass as defined by the following equation:

$$F = W = mg \qquad 3.2$$

Where, F = Force in N

W = weight of the object, N

m = mas of objects in kg

g = proportionality constant called the acceleration of gravity, which equals 9.81m/s^2

The total masses of the vehicles are the sum of payload + Curb weight which is 3,200kg (when take the maximum mass of vehicle) and acceleration due to gravity (g) = 9.81 m/s^2. Then the total load applied on top platform is calculated by equation 3.2:

$$F_v = W = m \text{ x } g = 3{,}200 \text{ x } 9.81x\ 1.5 = 47{,}088kgm/s^2$$
$$= 47.088kN$$

The total load applied on each top platform section is calculated as:

$$= \frac{47088N}{2} = 23{,}544N$$

The total pressure applied on the each sections of top platform from the vehicle weight was calculated as:

$$P = \frac{F}{A} = \frac{23544N}{3.875m^2} = N/m^2 = 6075.87Pa$$

The total mass of top platform m_T was calculated from top platform plates, (77.5kg), Frames, 36.65kg), and angle bars (25kg) (from table 3.3).

Where, $m_T =$ total mass of top platform

W_T= total weight of top platform

$$m_T = 77.5kg + 36.65kg + 25kg$$
$$= 139.15kg$$
$$W_T = 139.15kg\text{x}9.81m/s^2$$
$$= 1365.06N$$

3.4.3 Design of Base Platform or Lower Base

The base platform is subjected to the weight of GVWR, top platform, scissor arms and hydraulic cylinder parts. It is also equipped with outriggers to stabilize or balance the lift while the vehicle is loaded on it. The overall dimensions and 3D model of lower base components are shown in table 3.5 and figure 3.6

Table 3.5 Base platform components

Name	Qty. No	Length of each (mm)	Width of each (mm)	Height/ diameter of each (mm)	Thickness of each (mm)
Base Platform (Angle bar)	02	5,000	100	100	6.0
	02	2,500	100	100	6.0
	02	4800	100	100	6.0
Plate	02	763	200		6.0
Base Platform (Rectangular tubing)	02	950	80	60	3.0
out riggers (rectangular tubing)	04	500	80	40	3.0
Support Plate(U-shape)	12		80	60	10
stand legs(round bar)	04	400		24.85	4.0
Plate	04		100	100	4.0
stand legs end plate	04			60	10

Figure 3.6 3D model of lower base

The area of each base platform was calculated by equation 3.1.

$$A1 = A2 = LxW = 5{,}000x775$$
$$= 3.875m^2$$

The total mass of lower base m_B was calculated from base platform square tube, 21.96kg, stand legs, 10kg and end plate and pin 12kg, angle bar plate, 46kg and rectangular tube, 12kg (from table 3.3).

Where, $m_B =$ total mass of lower base

W_B= total weight of lower base

$$m_B = 21.96kg + 10kg + 12kg + 46kg + 12kg$$
$$= 89.96kg$$
$$W_B = 89.96kg\text{x}9.81m/s^2$$
$$= 882.51N$$

Outriggers: To reduce the risk of tilting, short metal legs called outriggers are attached to base work platforms. The purpose of outriggers is to keep the hydraulic scissor lift stable. Many scissor lifts, cranes, and heavy construction equipment have used outriggers. Popular scissor lifts with outriggers are the aforementioned scissor lifts that have a platform capacity of 1,000 lbs and a platform height of 32′ or 33′. In addition, the platform of each of these lifts can extend up to 60″. The outrigger to be used in our lift is attached to both sides of the lower base. If the work platform is low and the scissor lift is on solid ground, you might not need to use the outriggers. If a fully extended scissor lift is on soft ground or exposed to high winds, it’s a good idea to stabilize the lift by using its outriggers. When the outriggers are lowered down by hand to place them firmly on the ground or slab, at that time the scissor lift is supported by both its wheels and the outrigger’s four legs.

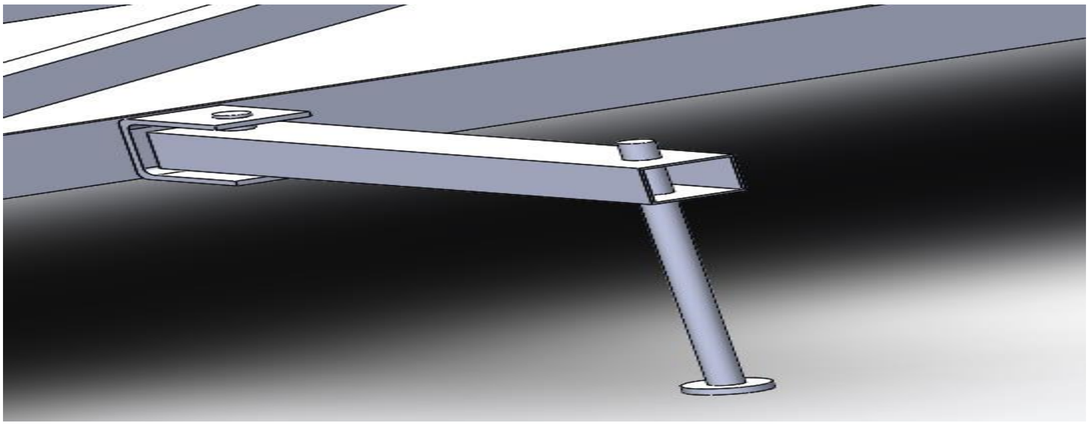


Figure 3.7 3D model of outrigger

3.4.4 Design of Scissor Legs (arms)

In this mobile hydraulic scissor lift scissor legs are the vertical individuals that permit the platform to change height. Legs are made of structural steel with the same scissor join height. The overall dimensions and 3D model are shown in table 3.6 and figure 3.7

Table 3.6 scissor arms components

Component Name	Qty. No	Length of each (mm)	Width of each (mm)	Diameter (mm)	height of each (mm)	Thickness of each (mm)
Scissor arms (rectangular tubing)	16	2500	80		60	3.0
	12	703	80		60	3.0
Scissor arms (tubing)-each other	02	763		20		3.0
Pin for mounting	04	80		20		

The total mass of scissor arms m_S was calculated from mas of each rectangular tubes, 52.24kg and connecting pins and rollers, 4.92kg (from table 3.3):

$$m_S = 52.24kg + 4.92kg$$

$$= 57.16kg$$

$$W_S = 57.16\text{x}9.81 = 560.74N$$

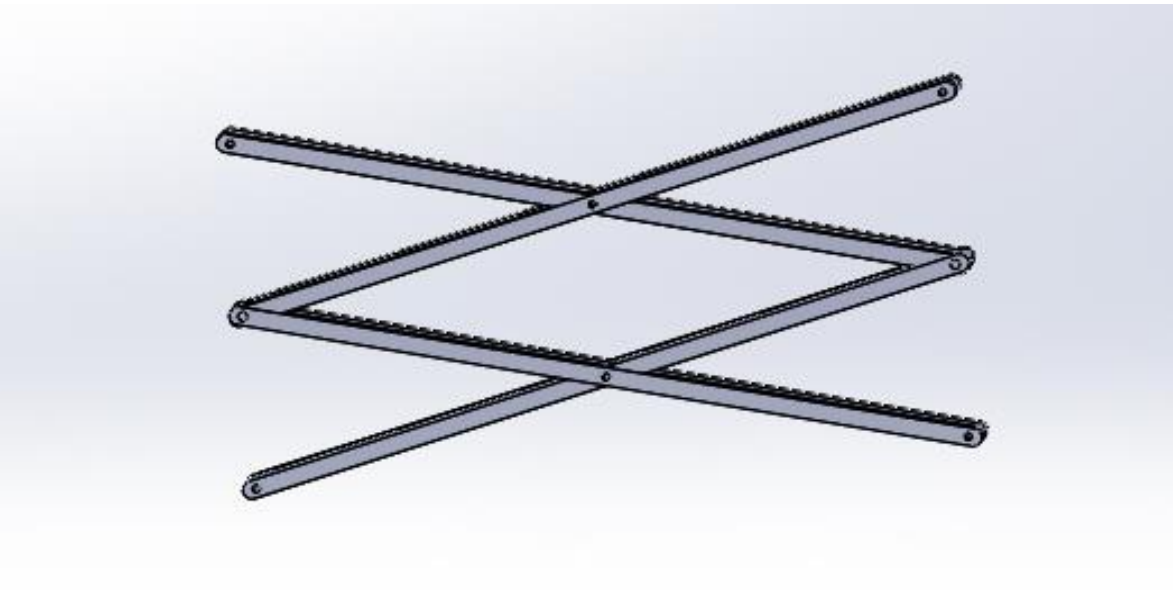


Figure 3.8 3D models of Scissor arms

3.4.5 Design of Wheel Mechanism Components

The wheel mechanism is a designed mechanism used to move the lift machine from one place to another. Its components are, castor wheels, supporting plates, stand plates, and compression springs. The dimensions of wheel mechanism components are shown in table 3.7

Table 3.7 Dimensions of wheel mechanism

Name of component parts	Qty. No	Length of each (mm)	Width of each (mm)	Diameter (mm)	height of each (mm)	Thickness of each (mm)
Wheel	04		40/80	60/300		
Wheel Bearing	04		40	35/59.9		
Wheel axle solid tubing	04	160		34.9		
Nut	04		40	35/60		
U-Shape H. Plate	04	480	130		200	10
U-Shape V. Plate	04	400	140		250	10
Stand plate	04	530	200			10
Spring Balance bolts	04	250		30		
Spring bolt support Plate	04			31/110		8

To establish the basic spring design, the desired deflection, and the desired forces should be known. Desired spring deflection is important in determining the maximum load that a spring can handle. The application of springs is the reduction of transmitted forces as a result of impact or shock loading and storage of energy.

The compression spring dimension sizes that must be taken into consideration are outer diameter, inner diameter, free length, and solid height. Free Length is the length of a spring when it is not loaded. Solid height is the length dimension of a compression spring at its maximum loaded condition.

Figure 3.9 Dimension of compression spring (Spring Engineers of Houston, Ltd.| http://www.springhouston.com)

Depending on the compression spring's dimensions, there is a limited amount of load the spring can carry. If the vehicle is loaded considering free length compressed to solid height and spring should take a permanent set and push the wheel to rise from the ground. When the wheel leaves the ground the lift stands by a stand plate.

According to the design of the wheel mechanism, the selected dimension of the spring is a free height of 240mm, Solid/loaded height of 200mm, Outer diameter of 110, and Inner diameter of 70mm.Solid height is influenced by the wire diameter and total amount of coils.

- Solid height = No. coils x wire diameter

  Wire diameter, d_w

$$= \frac{do - di}{2} = \frac{110 - 70}{2}$$
$$= 20mm$$

Number of coils, N

$$= \frac{hs}{dw} = \frac{200}{20} = 10$$

- Mean diameter = Inner diameter + wire diameter

$$= 70 + 20 = 90mm$$

- The pitch of a compression spring is the distance measured between the center of two coils or the space between each coils. It’s calculated by free height of coil of the spring divided by the number of turns. In this:

$$P = \frac{Free\ height}{No.coils} = \frac{240}{10} = 24mm$$

The pitch must never exceed the outside diameter of the compression spring, as this will result in winding difficulties in production. The greatest pitch recommended is 0.7x inside diameter.

Spring index is the ratio of mean diameter of spring to the wire diameter of spring.

$$Spring\ index, C = \frac{D}{dw} = \frac{90}{20} = 4.5$$

Increasing the coil diameter will make a spring weaker while decreasing it will make it stronger.

The overall dimensions of selected spring is shown as table 3.8

Table 3.8 Summary of Dimensions of Compressor spring

Overall dimensions	
Number of Coil, N	10
Mean Diameter, D	90mm
Wire Diameter, dw	20mm
Inner Diameter, d_i	70mm
Outer Diameter, d_o	110mm
Free height, h_f	240mm
Solid height, h_s	200mm
Pitch, p	24mm
Spring Index, C	4.5
Gross Vehicle Weight	3,200kg
Spring balancing bolt	Length(250mm)
	Diameter(40mm)

The overall 3D models of compression springs and wheel mechanism are shown as following figure.

Figure: 3.10 3D models of compression springs and wheel mechanism

“Load” is a force applied to a spring, like weight or linear force. “Rate” describes how the load changes, as the spring deflects. Most springs are fairly constant in rate, but can vary in some conditions. Variable rate springs are sometimes used to allow a greater use variety of loading conditions. Spring rate defines the force of compression spring. Compression spring’s rate (k) is ratio of change in force to the change in length (Spring Engineers of Houston, Ltd. | http:/www.springhouston.com).

$$K = \frac{\Delta F}{\Delta L} \qquad 3.5$$

Force (F) exerted by the spring is:

$$\Delta F = K(L_f - L_s)$$

The amount of rate on a compression spring design based on physical dimensions calculated by equation 3.6 (https://www.thespringstore.com/compression-spring-designing-considerations. html):

$$k = \frac{Gdw^4}{8D^3N} \qquad 3.6$$

Where, G is Shear Modulus of Material (Stainless Steel = 73664x 10^6Pa = 7.3664*10^4MPa.

The spring rate calculated by equation 3.6

$$K = 73664\text{x } 10^6\text{Pa x}\frac{20^4}{8\text{x}90^3\text{x}10}$$

$$= 202.1N/mm$$

The maximum force compression spring with stand is calculated by equation 3.5 as:

$$F = K\text{x}\Delta L$$

$$= 202.1N/mm\text{x}40mm$$

$$= 8083.84N$$

The maximum force or load compression spring with stand is 8083.84N. Total weight loaded on wheel mechanism is the weight of vehicle, upper and lower parts of the lift, Weight of scissor arms and hydraulic cylinders

$$m_v + m_t + m_s + m_l + m_{cy} = 3{,}200 + 139.15 + 89.96 + 57.16 + 46 = 3532.27kg$$

$$= 3532.27\text{x}9.81\text{x}1.5 = 51{,}977.35N$$

The value of the safety factor, according to (Rupesh N. K. and K. R. Sontakke 2015), ranges from (1.3-2.25), and then take a factor of safety 1.5

So the total load of the mechanical and hydraulic parts of the mobile hydraulic scissor lift and vehicles (GVW) acting on the total wheel mechanism is 51.977kN. There are four wheel mechanisms attached under the base of the scissor lift. So the weight of one wheel mechanism is one-fourth of the total weight then.

$$W_w = \frac{W_T}{4} = \frac{51977.35N}{4} = 12.994kN$$

The pressure applied on the wheel mechanism head from the total weight is calculated as follow:

$$P = \frac{F}{A} = \frac{12994N}{0.02m^2} = \frac{649.717kN}{m^2} = 649.717kPa$$

3.5 Selection of Hydraulic System Components

The system has been incorporated with two hydraulic cylinders, pump and control valve for high load capacity as well as for safety reasons, hydraulic oil tanker and hoses.

3.5.1 The Hydraulic Actuating Force

Actuator force is the force required to raise or lower the load using hydraulic power of fluid. There are at least two methods of calculating the actuator forces require to raising the scissor lift. The first method is by using simultaneous equation. The second method is to use the principle of conservation of energy which states that energy can neither be created nor destroyed. This means that the total energy of the system at any location remains constant. In this method, friction forces are assuming zero, requiring that work in equals work out.

The equations used to derive actuator force in this thesis are deriving using principle of conservation of energy. The actuator force calculated by equation (3.7) (Saxena, 1989);

$$F = K\left(\frac{dh}{dl}\right) \qquad (3.7)$$

Let the force output of the actuator, as a function of time, be F, and length of actuator be l applying conservation of energy,

$Work\ done\ by\ actuator$ = $Work\ done\ to\ take\ lift\ to\ height\ h$

$$\int_{l1}^{l2} Fdl = \int_{h2}^{h1} L_E dh$$

Hence, the weight of the lift will be accounted by taking the effective load L_E, for a particular load L, force is $\frac{W}{2}$, which shows that the work done in keeping the weight of this arbitrary mass at height h_2, is the work done in bringing half its weight to height h_2. Such that:

$$L_E = L + \frac{W}{2}$$

$$\int_{l1}^{l2} F dl = \int_{h2}^{h1} (L + \frac{W}{2}) dh$$

Differentiating both sides with respect to actuator length l gives the required force equation:

$$F = \left(L + \frac{W}{2}\right) \frac{dh}{dl}$$

• Derivation of dh/dl assuming both actuator ends are pinned to a scissor member:

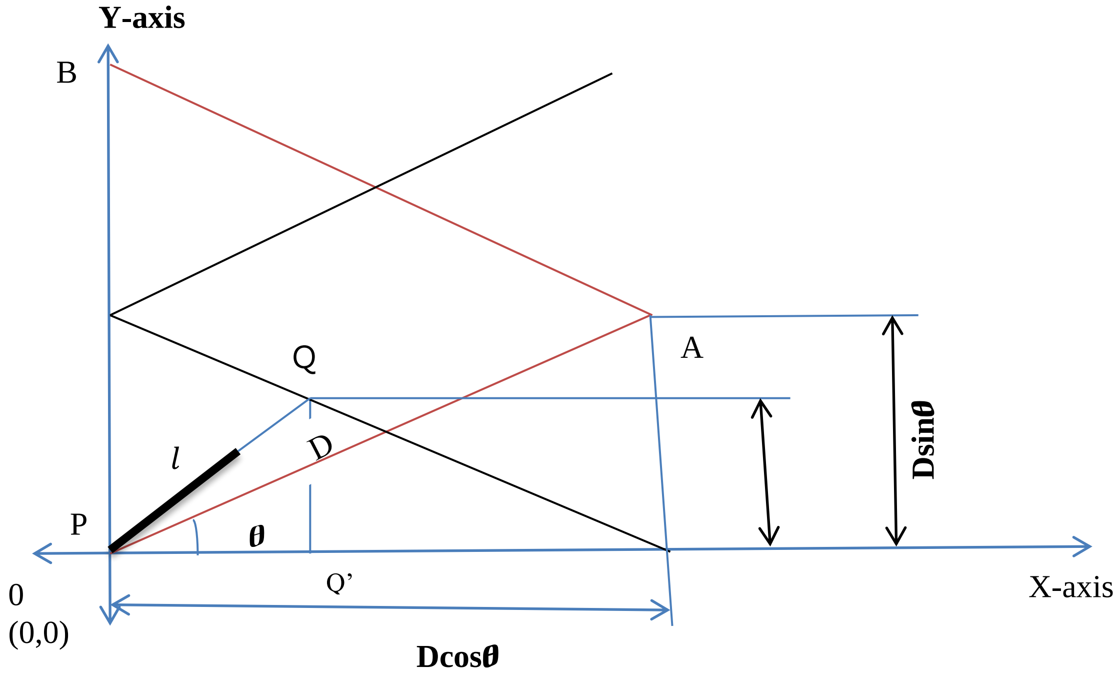


Figure 3.11 Two level lift loaded in the x and y directions

In figure 3.11 Q the point at which force is applied (i.e. the extending end of the actuator is attached). P the point at which the actuator is attached. Line PQ is hence the actuator length, l, ' the projection of point Q on the X-axis. O is the origin. θ is the angle between any of the sloping scissor arms and the X-axis. h is the height that the load has been lifted to, $h = nD\ sin\theta$. D is the length of the scissor arms. i is the number of complete scissor levels immediately below point Q. n be the number of levels of the scissor lift.

To consider the co-ordinates of point Q, relative to origin O, as (Q_x, Q_y)

$Q_x = (1 - a)\ cos\theta$

$Q_y = i + a\ D\ sin\theta$

Here, by substituting all value the final expression becomes:

$$F = n \text{ x } (L + \frac{B}{2}) \frac{\sqrt{Acos^2\theta - 2\text{B} \cos\theta + C}}{Btan\theta - A \sin\theta}$$

The force is applied directly at the hinge of the arm that the distance between the point of application of force and the hinge immediately below that point is zero i.e. $a = 0$

The static end of the actuator is fixed to the origin point itself. Hence the distance of that point from the origin is zero i.e. $b = 0$ and also one full scissor level immediately below the point of application of force i.e. $i = 1$

We must now obtain the three constants, B, C and D, given that:

$a = 0$, $b = 0$ and $i = 1$

The constants are given by:

$B = b\ (1 – a) = 0(1 – 1) = 0$

$C = b^2 + (i + a)^2 = 1$

$D = (2a + i) = 1(0 + 1) = 1$ and using the substitution $1 – cos^2\theta \equiv sin^2\theta$ and the values of the constants, the expression now becomes:

$$F = n(L + \frac{W}{2})$$

Let n be the number of levels of the scissor lift, two levels.

• Then the total load of GVW, 31392N and top platform and scissor arms weights, 1925N by above equation:

$$F = n\left(L + \frac{W}{2}\right) = 2\left(925 + \frac{31392}{2}\right)x1.5 = 49863N$$

Therefore the pushing force or actuating force of the hydraulic cylinder applied on the scissor lift is:

$$F_A = 49.863\text{kN} \cong 49.88\text{kN}$$

The capacity of hydraulic scissor lift at different Commercial Vehicle Sales and Service Companies is designed to operate at around 100 - 1500 bar and 160 bar (160MPa) is taken as the reference in the case of this thesis study. So according to the standard of hydraulic cylinder described in table 3.8, the pushing force (actuating force) is 49.88kN.

Table 3.9 Standard of hydraulic cylinder bore diameter with push force and operating pressure (source: http://ir.bdu.edu.et/handle/123456789/12811)

Piston or Bore (mm)	Piston Rod (mm)	Piston area, A_1, cm^2	Rod area, A_2, cm^2	Annuals area,A_3, cm^2	Force at 160bar		Flow at 0.1m/s^2	
					Pushing F_1,kN	Pulling F_2,kN	Out, Q_1 L/mm	In, Q_2 L/min
25	12	4.91	1.13	3.78	7.85	6.04	2.9	2.3
	18		2,54	2.37		3.78		1.4
32	14	8.04	1.54	6.50	12.87	10.40	4.8	3.9
	22		3.80	4.24		6.79		2.3
40	18	12.06	2.54	10.02	20.11	16.03	7.5	6.0
	22		3.80	6.77		14.02		5.3
	28		6.16	6.40		10.25		3.8
50	12	19.63	3.60	15.83	31.42	25.33	11.08	9.5
	28		6.16	13.48		21.59		8.1
	36		10.16	9.45		15.13		5.7
63	28	31.17	6.16	25.01	49.88	40.02	18.7	15.0
	36		10.18	20.99		33.59		12.6
	45		15.90	15.27		24.43		9.2
80	36	50.26	10.18	40.08	80.42	16.29	30.2	24.0
	45		15.90	34.36		20.45		20.6
	56		24.63	25.63		30.41		10.4
125	56	122.72	24.63	98.09	196.35	106.94	73.6	58.9
	70		38.48	84.23		134.77		50.50
	90		63.62	59.10		94.56		35.5

Inputs for selection of hydraulic system components

Table 3.10 Input Parameters for Hydraulic System Components (Source from table 3.9)

Parameters	Value
Pressure of the system	160 bar
Pushing/actuator Force	49880N
Piston or Bore diameter	63mm
Piston Rod diameter	28mm
Required Stroke Length	650 mm

By using the above input parameters of hydraulic system components we get standard hydraulic cylinder from Bosch Rexroth AG, RE 17341, and edition: 2022-07.

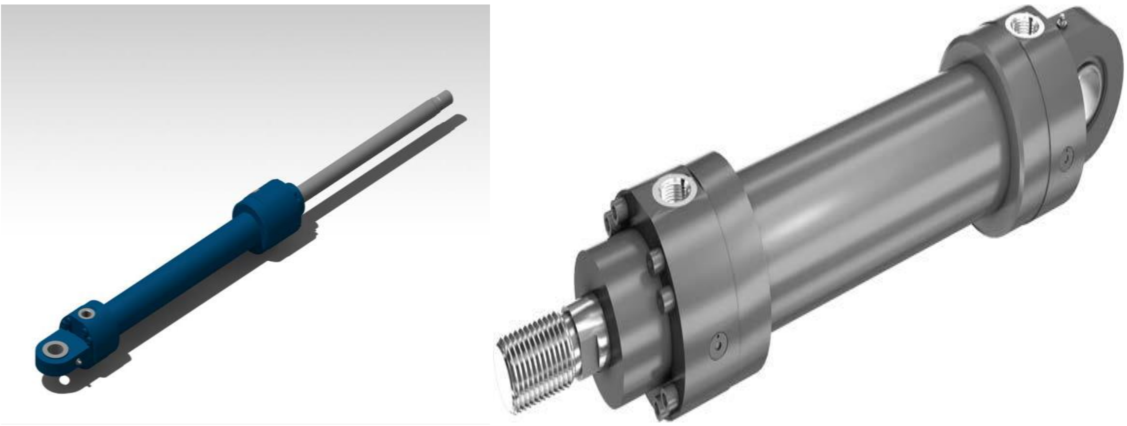


Figure 3.12 Bosch Rexroth Hydraulic Cylinders

The above hydraulic cylinder in figure 3.12 was chosen for the final design and is reliable as well as cost effective. Some of the technical specifications are given in the table 3.11.

Table 3.11 Technical specifications of Cylinder (Source: Bosch Rexroth AG, RE 17341, and edition: 2022-07)

Feature	Description
Model code	CDM1MP3/A3X
Mode of operation	Single rod cylinder, Double-Acting
Bore diameter	25…200 mm
Piston rod diameter	14…140 mm
Stroke length	up to 3000 mm
Mounting types	9 types of mounting
Design principle	Round flange at head and base
Installation dimensions	according to ISO 6020-1

All the parts shown above are assembled to form a complete structure of a mobile hydraulic scissor lift which is represented in the figure 3.13. The maximum extension length and closing length of the scissor lift can be observed to the value of rise up to 1608mm when it is opened. This scissor lift can be close up to 200mm when it is closed.

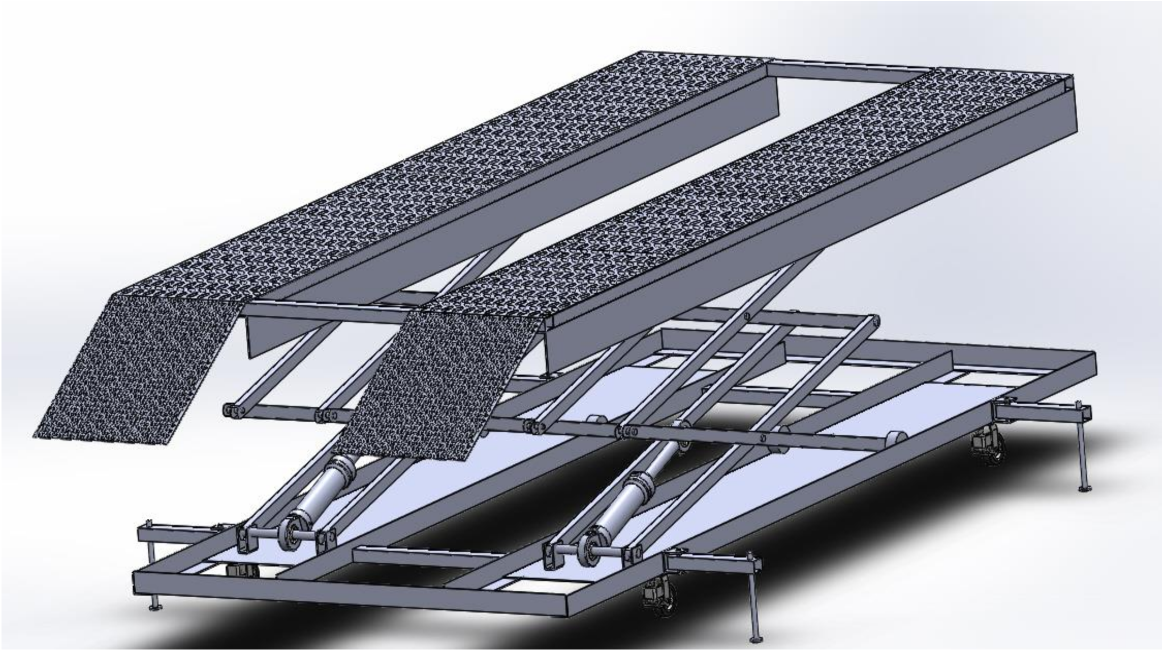


Figure 3.13 Assembly of mobile hydraulic scissor lift

3.5.2 Velocity and power required

Double acting cylinder uses hydraulic fluid to pour both the forward and return strokes. This makes them ideal for bushing and pulling within the same application. They are suitable for full stroke working only at slow speed which results in gentle contact at the ends of stroke.

The output force (F_1) and piston velocity (v) of double-acting cylinders are not the same for extension and retraction strokes. During the extension stroke, the fluid pressure acts on the entire piston area (A_1), while during the retraction stroke, the fluid pressure acts on the annular area ($A_1 – A_2$). This difference in area accounts for the difference in output forces during extension and retraction strokes. The extension force is greater than the retraction force for the same operating pressure. (Herbert E.et al.).

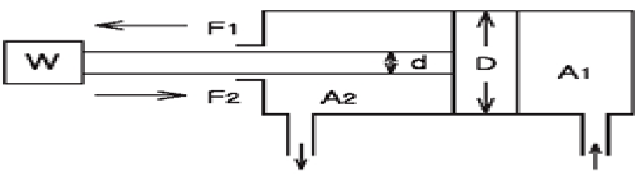


Figure 3.14 diameter of hydraulic cylinder

Since, pump speed N (2000 rpm) (from Table 3.11), the maximum actuator force (F) calculated 49.88KN and the pressure used to extend the whole system (P) is 160bar (from table 3.9). volumetric flow rate (Q) can be calculated by regarding stroke length of cylinder

(650mm), diameter of hydraulic cylinder (63mm), and the lifting time as given below (Dengiz et al., 2018b);

First, we calculate the volume as,

$$V = \frac{\pi D^2}{4} \text{x} L \qquad 3.17$$

$$= \frac{\pi (63)^2}{4} \text{x} 650$$

$$V = 0.002 m^3 = 2Lt$$

Then calculating the volumetric flow rate as,

$$Q = V \text{x} N \qquad 3.18$$

$$= 0.002 m^3 \text{x} 2000 rpm$$

$$= 4 m^3/min = 0.067 m^3/sec$$

When, Diameter of the cylinder, D = 63mm

Diameter of the rod, d = 28mm

Load during the extension, F = 49,880N

Velocity and pressure during extension and retraction stroke are calculated as follows:

a. Piston velocity during extension stroke,

$$V_E = \frac{Q}{A_1} = \frac{0.067}{\pi (0.063)^2} \text{x} 4 = 0.0215 m/sec$$

So lift it by 1.6m/1min

b. Piston velocity during retraction stroke,

$$V_R = \frac{Q}{A_1 - A_2} = \frac{0.067}{\pi (0.063 - 0.028)^2} \text{x} 4 = 0.069 m/sec$$

Retracted by 1.6m/0.50min

c. Cylinder pressure during extension stroke,

$$P_E = \frac{F}{A_P} = \frac{49880}{\pi (0.063)^2} \text{x} 4 = 160 bar$$

3.5.3 Selection of Hydraulic Pump and Motor

A Pump, which is the heart of a hydraulic system, converts mechanical energy into hydraulic energy. The mechanical energy is delivered to the pump via a prime mover such as an electric motor. Due to mechanical action, the pump creates a partial vacuum at its inlet. This permits atmospheric pressure to force the fluid through the inlet line and into the pump. The pump then pushes the fluid into the hydraulic cylinder (Anthony.et).

The selection of pump can be determined by a number of factors, which need to be considered during design such as maximum operating pressure, maximum delivery, type of control, pump drive speed and type of fluid (Peter J. et al 2003).

Various types of pump controls are available such as manual servo control, pressure compensated control, constant power control and constant flow control. From such type of control, we have selected manual servo control method (external gear), which is simple and not costly.

Table 3.12 Type of Hydraulic Pump

Pump Type	Maximum Pressure		Maximum delivery (L/min)		Speed(RPM)		Pulsation	Noise Level (dB)	Ƞ(%)
	From	To	From	To	From	To			
External gear	40	300	0.25	760	500	3000	High	90	70-90
Internal gear	100	210	0.6	740	3000	4000	Low	85	75-90
Vane	50	140	6	360	500	3000	Low	80	65-80
Balanced Vane	140	175	2	620	500	300	Low	85	70-90
Axial piston (swash plate)	200	350	1	1450	200	2000	High	90	80-90
Axial piston (bent-axis)	250	350	17	3500	200	2000	High	90	50-90

So selected manual servo control method (external gear) has an operating pressure range between 40-300 bars, a maximum delivery range of 0.25-760 L/min, a speed of 500 - 3000 rpm, and an efficiency of 70-90% (From table 3.12). Hence, the volumetric flow rate (Q) was determined as $0.067m^3/sec$, hydraulic cylinder stroke length (L=650mm), and diameter of hydraulic cylinder (D=63mm). So by considering hydraulic efficiency of motor (η = 0.75) and pump pressure (P=160bar), motor power (P_m) calculated by equation 3.22 (Dengiz et al., 2018b);

$$P_m = \frac{Q \times P}{3600\eta} ---------------- \quad 3.22$$

$$= \frac{0.06m^3/\sec x\ 160x10^6 N/m^2}{0.75x60} = 12.5kW$$

So it selected a phase (220/380v) induction motor that has a power output of 12.5kW (16.76hp) for the design of a mobile hydraulic scissor lift system.

A hydraulic oil tanker is an important part of a hydraulic power unit and represents the heart of the hydraulic system. The primary function of any tanker is the storage of substances or fluids. The tanker capacity is three or four times the flow rate of the hydraulic pump, equation 3.21(Lovrec, 2016).

$$C_t = 4Q\text{x}t \qquad 3.21$$

Where, Q - Volumetric Flow Rate Pump (0.067Lt/sec)

Ct - Capacity of Tanker,

The extension stroke takes 11 second for full extension then,

$$C_t = 4\text{x}0.067Lt/sec\text{x}11sec$$

$$= 2.95Lt$$

Then by considering the hoses the total fluid required to full the tanker is 6 liters.

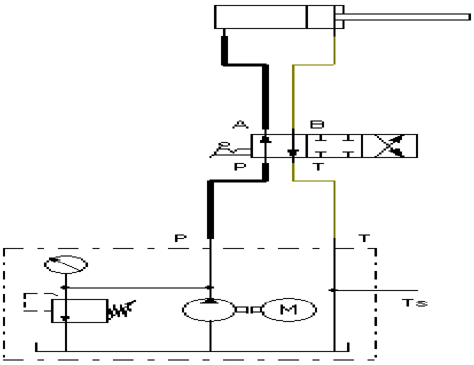
3.5.4 Selection of the Hydraulic Circuit and Control System

One of the most important considerations in any fluid power system is control. If control components are not properly selected, the entire system will not function as required. Fluid power is controlled primarily through the use of device called valves. To select the control valves, the following parameters are considered.

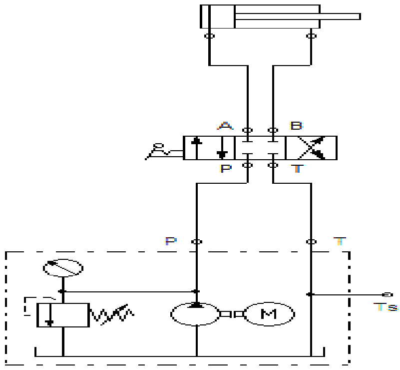
- Types of control valves,
- Size of the control device and,
- Actuating technique (Anthony.et.al.).

In our case of the hydraulic cylinder of double acting cylinder, the directional control valve is selected. The directional control valve is used to control the direction of flow in the hydraulic circuit. The control valve has four ports and three positions the fluid transverse with in a given circuit and then we can control the motion of the fluid.

The following figure 3.11 describes the four port three position valve which are designed by using Fluid Sim software during extension and retractions.



A) Extension Stroke



B) Retraction Stroke

Figure 3.15 Fluid flow of double acting cylinder (Source: Fluid- Simulation)

In the figure 3.15 A, the extension stroke position of the system during this time the fluid flow from high pressure side P to the port A that used to extend load to the required position. In figure 3.15 B, the retraction position of the hydraulic circuit, since the fluid flows from port A to tank or reservoir T.

3.6 Materials and Selection Processes

Material selection plays a very important role in machine design. The choice of the particular material for the machine depends on the particular purpose and the mode of operation of the machine components. Different parts of the mechanism take different loads and stress because they carry out different functions. The best material is one that serves the desired objective at the minimum cost. The following factors should be considered while selecting the material:

- Availability of the materials,
- Properties and Suitability of the materials for the working conditions in service and
- The cost of the materials,

The selection of the material is done according to the mechanical properties of the necessary components for the design of a mobile hydraulic scissor type lift machine that is strength, ductility, toughness, hardness, and stiffness.

The properties are:

Strength: is the ability of a material to resist the externally applied force without break down or yielding the internal resistance offered without break down or yielding the internally applied force is called stress.

Stiffness: it is the ability of a material to resist deformation under stress.

Ductility is the ability to undergo deformation with cracking.

Elasticity: it is the property of a material to regain its original shape after deformation when the external forces are removed.

Hardness: the resistance to indentation or abrasion

3.6.1 Structural steel

Structural steel is a category of steel used for making construction materials in a variety of shapes. Many structural steel shapes take the form of an elongated beam having a profile of a specific cross section. Structural steel is durable, strong, and versatile steel used in construction projects. It is most commonly used in buildings, bridges, and other large-scale structures. Structural steel has carbon content between 0.05- 0.25%. This is what makes it stand out among other types of steel

3.6.2 Stainless Steel

Stainless steel is a steel alloy with at least 10.5% chromium with or without other alloying elements and a maximum of 1.2% carbon by mass. Stainless steels, also known as inox steels or inox from French inoxydable (inoxidizable), are steel alloys, which are very well known for their corrosion resistance, which increases with increasing chromium content. Stainless steel can be rolled into sheets, plates, bars, wire, and tubing. This is steel with high rust and corrosion resistance to meet specific application requirements. Chromium is the alloying element in stainless steel and reacts with oxygen in the atmosphere to form a protective layer called chromium oxide. This layer provides considerable corrosion resistance.

3.6.3 Mild Steel

Mild steel is steel which contains only a small percentage of carbon and is strong and easily worked but not readily tempered or hardened. It’s made up of an iron (Fe) base with the addition of small amounts of carbon. Low carbon steel is typically defined as having less than 0.2% carbon by ASM international. It contains 0.05 to 0.3 percent carbons. The absence of alloying elements makes it more prone to corrosion (https://www.xometry.com > materials).

3.6.4 Aluminum Alloy Steel

Aluminum is a metal that can be combined with other elements including copper, magnesium, silicon, zinc, and manganese, to alter its mechanical and physical qualities. Aluminum is a soft, malleable metal known for its unique ability to resist corrosion due to the formation of an oxide layer when exposed to air and its light weight.

Table 3.13 Properties of steel materials (https://www.@Civilengineeringrealities.com and https://www.xometry.com > materials, eurocodeapplied.com).

Mechanical Properties	Stainless Steel	Structural steel	Mild steel	Aluminum Alloy
Density (Kg.m-3)	7750	7850	7850	2700
Compressive Yield Strength MPa	207	250	340	60
Tensile Yield Strength MPa	207	250	841	400
Tensile ultimate Strength MPa	586	460		600
Young's Modulus, MPa	$1.93e^{+5}$	$2e^{+5}$	$2e^{+5}$	$0.75\ e^{+5}$
Poisson's Ratio	0.31	0.30	0.303	0.303
Bulk Modulus MPa	$1.693e^{+5}$	1.6667e+5	215109	76
Shear Modulus MPa	73664	76920	11000	26000
Coefficient of linear thermal expansion,C-1	$1.7x10^{-05}$	1.2×10^{-05}	1.21×10^{-05}	2.32×10^{-05}

In general requirement, the properties of rust and corrosion resistance, strength, ductility, toughness, hardness, stiffness, and how the coefficient of friction were considered to meet all requirements and the choice of structural steel and stainless steel for the mobile hydraulic scissor lift components. Structural steel was used as the material of profiles in the scissor lifting system components like scissor arms, Frames, angle bars, and pins and stainless steel was preferred as top platform plates; a ramp extends and stands plate materials in the system. The mechanical properties of different materials are given in table 3.12.

3.7 Design Concept

The mobile hydraulic scissor lift has a table surface where the weight of the vehicles can be placed. The rising of a platform is carried out due to the work of a hydraulic cylinder. The management of the elevator is carried out by the control panel which has three buttons: the main switch, lowering, and rise. The physical appearance of the mobile hydraulic scissor lift machine should be compatible with all light duty vehicles. The total length of the machine is 5,000mm, with 2,500mm of width, and 2,000mm of overall height from the ground and carrying capacity of up to 3,200kg (3,200 kilograms).

The structure of the mobile hydraulic scissor lift machine as stated in the literature review stainless steel, and structural steel materials are strong and compatible with the design, Stainless steel is the material selected for designing the components of the hydraulic scissor lift as; the upper plate, ramp plate, spring and stand plate, structural steel material used for scissor arms, frames, angle bar, etc.

The mobile hydraulic scissor lift is designed for vehicle maintenance centers and different vehicle assembly industries that have leveled surface. In order to ensure the safe operation of the mobile hydraulic scissor lift, the mobile lift is generally equipped with four fixed outriggers to adjust the level to raise, which makes working on sloped or uneven ground more stable and secure.

3.8 Modeling of Mobile Hydraulic Scissor Lift

Modeling and numerical simulation are important parts of today's automotive sector. They are necessary to reduce the time-to-market for new products and the costs associated with experimental testing. Good modeling and simulation in design and analysis give many benefits such as minimizing product manufacturing time, material scrap, and material cost. In vehicle structure design, the automotive sector has been undertaking structural analyses (static, dynamic, safety, noise and vibration, handling, etc.) for many years. Gradually, the precision and accuracy of models increase in its quality, but until now except hydraulic jacks and a few electric lift do not involve. There are several types of electric lifts available now because car lift can be tricky to use. The evolution of these electric lifts has led to a progressive understanding of some of the issues they raise. Due to the torque needed to lift something as heavy as most automobiles, a severe mechanical advantage must be utilized. Hydraulic systems generally have long operating lives and require little maintenance.

3.8.1 3D modeling of the mobile hydraulic scissor lift

The 3D Modeling is a geometrical representation of a real object without losing information which the real objects have. 3D design software allows engineering teams to make smarter, faster decisions by reducing product development costs and improving workflows. Various mechanical design and manufacturing operations modeled using Solid work. This software allows the user to make changes very easily without having to go to back at the beginning and update all the drawings and assemblies. Generally solid work is easy to use and feature based parametric solid modeling software with many extended design and manufacturing applications. In this specific research, based on the dimension obtained from theoretical calculation and direct measuring data 3D modeling and 2D sketching of the mobile hydraulic scissors lift was created with the help of solid work 2022. Solid modeling software and analysis is done by using ANSYS 2022 R1 workbench for stress and deflection.

The complete system model of a mobile hydraulic scissor type lift for light duty vehicle is shown in figure 16.

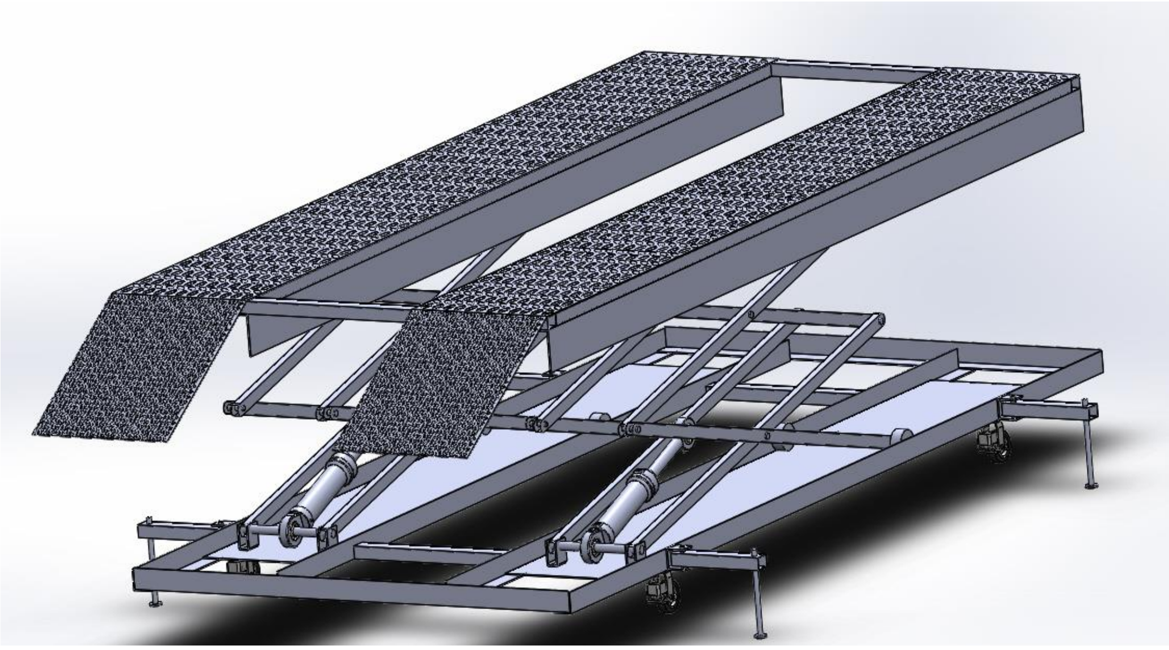


Figure 3.16 3D Modeling of Mobile Hydraulic Scissor Lift

3.9 Mathematical modeling of mobile hydraulic scissor lift components

A mobile hydraulic scissors lift is made up of a base platform, upper platform, scissor arms, hydraulic cylinder, hydraulic pump, control valve and wheel mechanism and etc. According to R.S. Khurmi and J.K. Gupta (2005) described in the textbook of machine design; the cross-section area, volume, moment of inertia about the neutral axis, applied pressure on the system, bending moment, and bending stress of lift components are calculated as given in the following equations.

3.9.1 Free Body Diagram of Mobile Hydraulic Scissor Type Lift

The maximum total weight of the light duty vehicle is can be expressed as the sum of the load of vehicle plus load of passenger/driver, m=3,200kg.

According to the value of factor of safety ranges = (1.3 – 2.25), then take factor of safety = 1.5

$$\text{Therefore, Total Weight (W)} = 3200\text{kg x } 9.81\ \text{m/s2 x}1.5 = 47{,}088\text{N}$$

So, total load apply on top platform, W = 47,088N

Since the mobile hydraulic scissor lift is two sections and the load are exerted on two sections equally.

Then the total weight on each section is:

$$W_t = \frac{47{,}088N}{2} = 23{,}544N$$

The pressure exerted on each section of top platform,

$$P = \frac{Load}{Area} = \frac{W}{A}$$

Area, $A_1 = A_2$ = L x W=5mx0.775m=3.875m^2

$$P = \frac{Load}{Area} = \frac{W}{A} = \frac{23544}{3.875} = 6075.87N/m^2 = 6075.87Pa$$

Weight of parts lifted by scissor arms is load of GVW 3,200kg = 31,392N

Load of top platform components, 139.15kg =1365.06N

Total load act on end joint is, 3539.15 = 3339.15x9.81x1.5 = 49,135.59N

Let W_v equal to the total vehicle applied load at the top of the lift, and let W_t equals W_v plus the weight of the lift in the negative y direction level i. Both levels have the same weight and this weight denoted W_i. Then $W_t = W_v + W_i$

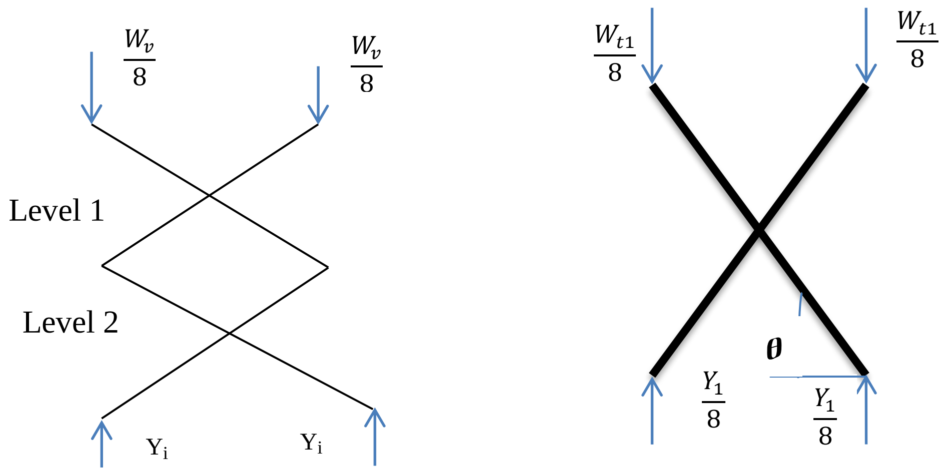


Figure 3.17 Free Body Diagrams for, A) total load applied, B) on level one

To find the reaction force Y_i at level one and two from the figure 3.17. Note that the equation of Y_i derived using the principles of static equilibrium as follow.

$$\Sigma Fy = 0 ------------------ 3.26$$

$$Y_i = \frac{W_v}{8} + \frac{W_i}{8}$$

$$Y_1 = \frac{W_v}{8} + \frac{W_1}{8} = \frac{47{,}088N}{8} + \frac{2047.59N}{8} = 6141.95N$$

$$Y_2 = \frac{W_v}{8} + \frac{W_2}{8} = \frac{47{,}088N}{8} + \frac{2468.145}{8} = 6194.52N$$

Weight of parts lifted by cylinders is:

$$m_v + m_t + m_s = 3{,}200 + 139.15 + 57.16 = 3396.31kg$$

$$3396.31\text{x}9.81\text{x}1.5 = 49976.70N$$

Force acting on the cylinder is based on the position of cylinder as in figure 3.18 and will be calculated considering the forces and reactions in two bars, whereas the hydraulic cylinder is connected (mounted) between two scissor legs of lower level.

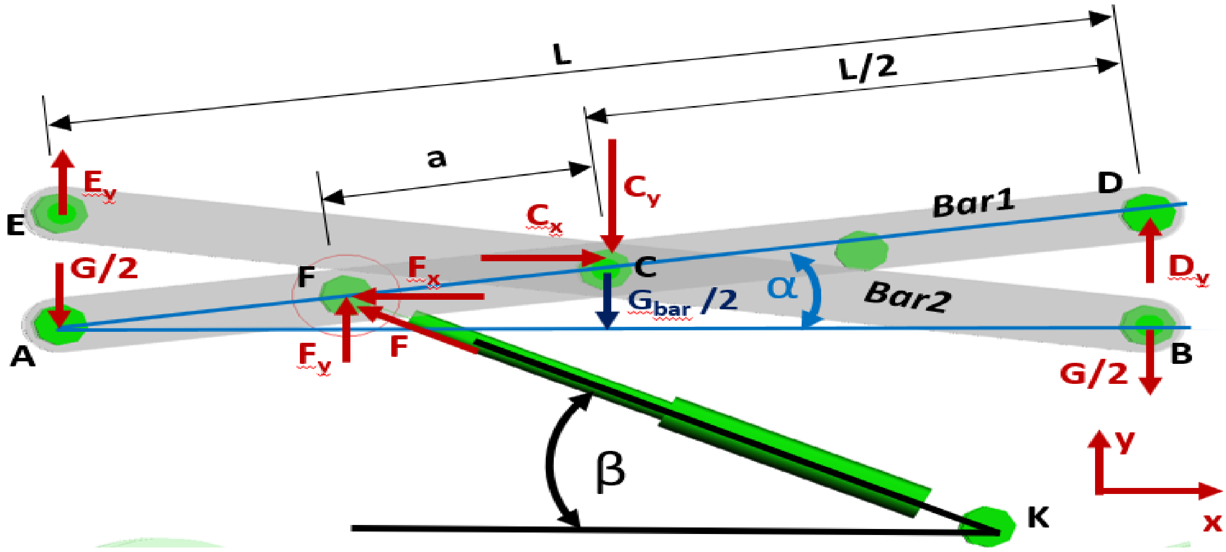


Figure 3.18 Parameters of force acting on cylinders

According to the diagram (Figure 3.18):

$$Dy = Ey = \frac{G + G_{bars}}{2} \qquad 1$$

$$G = m_v + m_t = 3{,}200 + 139.15 = 3539.15kg$$

$$G_{bars} = m_s = 57.16kg$$

$F_x = F \cdot \cos\beta$; $F_y = F \cdot \sin\beta$ - Force components in cylinder

α – Angle between the scissor bar and base,

β - Angle between the cylinder(s) and base.

C - Reaction force in the center of the bar’s connections,

G-Mass applied on cylinders

Equations of equilibrium in scissor leg/bar1: considering that other bars will undergo similar forces and stress.

- ✓ $\Sigma Xi = 0\,;\ Cx - Fx = 0 \rightarrow Cx = Fx = F \cdot \cos\beta$
- ✓ $\Sigma Yi = 0\,;\ -\frac{G}{2} + Fy - Cy - \frac{G_{bars}}{2} + Dy = 0$

$$-\frac{G}{2} + Fy - Cy - \frac{G_{bars}}{2} + \frac{G + G_{bars}}{2} = 0 \rightarrow Cy = Fy = F \cdot sin\beta$$

- ✓ ΣM_D=0 ;

$$\frac{G}{2}.Lcos\alpha + \frac{G_{bars}}{2}.\frac{L}{2}.cos\alpha - Fy.cos\alpha\left(\frac{L}{2} + a\right) + Cy.\frac{L}{2}.cos\alpha$$
$$+ Fx.sin\alpha.\left(\frac{L}{2} + a\right) - Cx.\frac{L}{2}.sin\alpha = 0$$

Using factorization and trigonometry identities,

$$\frac{G}{2} \cdot L \cdot cos\alpha + \frac{G_{bars}}{2} \cdot \left(\frac{L}{2}\right) \cdot cos\alpha - F \cdot sin\beta \cdot cos\alpha \cdot (\frac{L}{2} + a) + Cy \cdot \frac{L}{2} \cdot cos\alpha + F \cdot cos\beta$$
$$\cdot sin\alpha \cdot (\frac{L}{2} + a) - Cx \cdot \frac{L}{2} \cdot sin\alpha = 0$$

$$\rightarrow L \cdot cos\alpha \cdot \left(\frac{G}{2} + \frac{G_{bars}}{4}\right) - F \cdot sin\beta \cdot cos\alpha \cdot (\frac{L}{2} + a) + F \cdot sin\beta \cdot \frac{L}{2} \cdot cos\alpha + F \cdot cos\beta$$
$$\cdot sin\alpha \cdot (\frac{L}{2} + a) - F \cdot cos\beta \cdot \frac{L}{2} \cdot sin\alpha = 0$$

$$\rightarrow L \cdot cos\alpha \cdot (\frac{G}{2} + \frac{G_{bars}}{4}) + F \cdot [sin\beta \cdot cos\alpha \cdot (-\frac{L}{2} - a + \frac{L}{2}) + cos\beta \cdot sin\alpha \cdot (\frac{L}{2} + a - \frac{L}{2})]$$
$$= 0$$

$$\rightarrow L \cdot cos\alpha \cdot (\frac{G}{2} + \frac{G_{bars}}{4}) + F \cdot [-a \cdot sin\beta \cdot cos\alpha + a \cdot cos\beta \cdot sin\alpha] = 0$$

$$\rightarrow L \cdot cos\alpha \cdot (\frac{G}{2} + \frac{G_{bars}}{4}) - F \cdot a \cdot [sin\beta \cdot cos\alpha - sin\alpha \cdot cos\beta] = 0$$

$$\rightarrow L \cdot cos\alpha \cdot (\frac{G}{2} + \frac{G_{bars}}{4}) - F \cdot a \cdot sin(\beta - \alpha) = 0$$

$$F = Lcos\alpha.\frac{\frac{G}{4} + \frac{G_{bars}}{2}}{asin(\beta - \alpha)} = Lcos\alpha.\frac{\frac{w_v + w_t}{4} + \frac{w_s}{2}}{asin(\beta - \alpha)}$$

For our task, the parameters are:

L = 1.14m – Length between end of scissor leg to point of cylinder

a = 0.625m – Distance between the center of scissor bars joint (C) and restraint point of the cylinder in figure 3.18

n = 2–Number of cylinders. The power is distributed equally between two cylinders.

Finally, force in the cylinder(s) is calculated by the formula:

$$F_{cyl} = Lcos\alpha.\frac{\frac{G}{4} + \frac{G_{bars}}{2}}{na.sin(\beta - \alpha)} = Lcos\alpha.\frac{\frac{w_v + w_t}{4} + \frac{w_s}{2}}{2a.sin(\beta - \alpha)}$$

Hydraulic cylinder forces are calculated by dividing lifting height in three positions:

Position 1 – Lowest position of the platform. Height is H_1 = 0.22 m. Parameters, as in figure 3.18, are: α= 5°, β = 14°, a = 0.625m, L=1.14m.

Value of the force in the cylinders is:

$$F_{cyl} = Lcos\alpha . \frac{\frac{w_v + w_t}{4} + \frac{w_s}{2}}{2asin(\beta - \alpha)} = 49{,}199.15N$$

Position 2 - Middle height of the platform. Height is H_2 = 0.85m. Parameters are as in figure 3.18, α= 25°, β = 37°, a = 0.625m, L=1.14m. Value of the force in the cylinders is:

$$F_{cyl} = Lcos\alpha \text{ x} \frac{\frac{w_v + w_t}{4} + \frac{w_s}{2}}{2asin(\beta - \alpha)} = 32{,}589.43N$$

Position 3 - Highest position of the platform. Height is H_3 = 1.608m. Maximum opening angle of the scissor arm is calculated as:

$$sin\theta = \frac{2\text{h}}{\text{l}} = \frac{2\text{x}804}{2500} = 0.6432$$

$$\theta = 40^0$$

So α= 40°, β = 60°, a = 0.625m, L = 1.14m.

Value of the force in the cylinders is:

$$F_{cyl} = Lcos\alpha . \frac{\frac{w_v + w_t}{4} + \frac{w_s}{2}}{2asin(\beta - \alpha)} = 17{,}300.63N$$

3.9.2 Forces and pressure acting on Wheel Mechanisms

Wheel mechanisms of the lift are connected with the lower base of the lift and enable to travel of the lift by caster wheel. Weight of parts loaded on wheel mechanism is weight of upper and lower parts of the lift, weight of scissor arms and hydraulic cylinders

$$m_v + m_t + m_s + m_l + m_{cy} = 3{,}400 + 139.15 + 89.96 + 57.16 + 46kg$$

$$= 3686.27kg$$

The value of the safety factor, according to (Rupesh N. K. and K. R. Sontakke 2015), ranges from (1.3-2.25), and then take a factor of safety 1.5

$$WT = 3686.27 \text{ x } 9.81 \text{ x } 1.5 = 54{,}243.46N$$

So the total load of the mechanical and hydraulic parts of the mobile hydraulic scissor lift and vehicles (GVW) acting on wheel mechanism is 54.24kN. There are four wheel mechanisms attached under the base of the hydraulic scissor lift. So the weight of one wheel mechanism is one-fourth of the total weight then.

$$W_w = \frac{W_T}{4} = \frac{54{,}243.46N}{4}$$

$$= 13{,}561N$$

3.9.3 Bending Moment and Stress

In the strength of material application of load, force and stress cause the deflection in the structural member. This deflection is can be positive or negative. Generally, it is called bending and the effect generated by the applied force is known as the bending moment. Bending moment also depends on the direction of the application of stress.

Bending moment value may occur due to the pressing of load. Can be calculated with the following formula:

$$\frac{Mb}{I} = \frac{\sigma b}{yc} = \frac{E}{R} - - - - - - - - - - - - 3.6$$

Where:

M_b=bending moment

σb =bending stress

y_c=distance of from C.G

E=modulus of elasticity

R=radius of curvature

I= moment of inertia, I=$(bh^3)/12$

- ☞ The maximum bending moment is calculated by equation:

$$M_b = W \text{ x } y - - - - - - - - - - - - - - 3.7$$

$$= 16677N \text{ x } 0.804m = 13.408kNm$$

Where, y is the perpendicular distance to the neutral axis, 0.804m

Bending stress is the internal resistance generated within component when an external bending moment or force is applied.

Then bending stress, calculated by equation 3.6

$$\sigma b = \frac{M_b \text{ x } yc}{I}$$

$$I = \frac{bh^3}{12} = (2.5 \text{ x } (5^3))/12 = 26.042m^4$$

$$= 26.042m^4$$

$$\frac{13408.3 \text{ x } 2.5}{26.042} = 1287.18MPa$$

When apply a force onto a solid object, the type of stress the objects feels depends on the direction of the applied force. There are four types of stresses that we should consider:

When the force applied to our object causes the object to elongate along some axis, the type of stress applied to the object is known tensile stress. It occurs when an object is stretched or lengthened, compressive stress is essentially the opposite of tensile stress as the object actually compresses rather than elongates. Compression stress occurs when an object is squeezed or shortened, and shear stress, the force applied onto the object has to run parallel to the cross sectional area of the object that we are considering. Note that for both compressive and tensile stresses, the force needs to act perpendicular to the cross sectional area that we are considering. It occurs when an object is twisted or experiences forces that cause different parts of it to move in different directions or at different speed Compressive stress can be calculated with the following formula:

$$\sigma c = \frac{F_N}{A_t} - - - - - - - - - - - - - - - - - 3.8$$

Where, F_N value is perpendicular force that occurs at the point of the lift. Can be calculated with the following formula: $F_N = F_C \sin\theta$

'FC' is the actual force value each scissor leg after distributed to the number of scissor legs used or cylinder force.

$$F_C = \frac{F}{No} = \frac{50031N}{8} = 6253.875N$$

$$F_N = F_C sin\theta = 6253.875 sin40 = 4019.91N$$

$$\sigma c = \frac{F_N}{A_t} = \frac{4019.91}{3.875} = 1037.39N/m^2$$

Shear stress is the parallel force that occurs in lift package. Can be calculated with the following formula:

$$\tau = \frac{F_N}{A}$$

$$= \frac{6233.51N}{3.875m^2} = 7124.01kN/m^2$$

Where: F_N is normal force parallel to the cross sectional area of the object

The deflection is calculated to determine the curvature that occurs on the scissor arm after getting the load. The smaller the deflection value, the better the assumptions are used. Can be calculated using the following formula:

$$\delta = \frac{WL^3}{3EI} - - - - - - - - - - - - 3.9$$

$$\delta = \frac{33354N \text{ x } 2.5^3}{3\ x\ 2\ x\ 10^{11} N/\text{m}^2\ x\ 1.2x10^{-5}\text{m4}} = 0.0724m$$

The maximum allowable platform edge deflection calculation using the ANSI Standard MH29.1-2003 "Safety Requirements for Industrial Scissors Lifts" (Revision on ANSI MH29.1-1994) is using Equation 3.27:

$$D = \frac{n(L+W)}{200} ------------- 3.27$$

Where: D - Maximum allowable platform edge deflection,

n - Number of levels,

L - Platform length,

W - Platform width,

Then calculated by substitute the value of each parameter as;

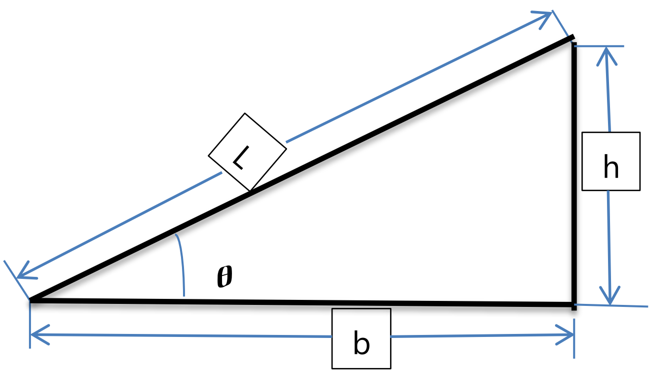
$$D = \frac{n(L+W)}{200} = \frac{2(5000+2500)}{200} = 75mm$$

This implies that the total level can deflect up to 75mm, but if the deflection is greater than 75mm the total system is unstable.

3.9.4 Comparison of height with scissor leg and angle

In mobile hydraulic scissor lifts, scissor legs are the vertical individuals that permit the platform to change height. Legs are made of structural steel with the same scissor join height. When the operator gives the movement to the lift, the movable ends of the lift will elevate the table to the desired height, so that it provides the necessary support for the top platform.

The lifting height of a mobile hydraulic scissor lift depends on the length of the scissor arm and angle between base and scissor arms. Scissor arm length is constant, but at angle increase height also increases. This is depending on the angle of the link or arm.



Therefore height is calculated by using trigonometry formula as follows:

$$\sin\theta = \frac{op}{hy} = \frac{h}{l}, \qquad \mathrm{h} = \sin\theta * l$$

Table 3.14 Angles and Height Measurement

Angle (θ), degree	Length (l) Meter	Height (h) Meter
5	0.90	0.078
10	0.95	0.165
15	1.00	0.259
20	1.05	0.359
25	1.1	0.465
30	1.15	0.575
35	1.2	0.688
40	1.25	0.804

So the system was positioned at an angle of 5° in a fully closed position and fully opened position at an angle of 40°. During a fully opened position, at an angle of 40^o, the lifting height of the hydraulic scissor lift reaches 1.608m, which is what it capable to lifting height.

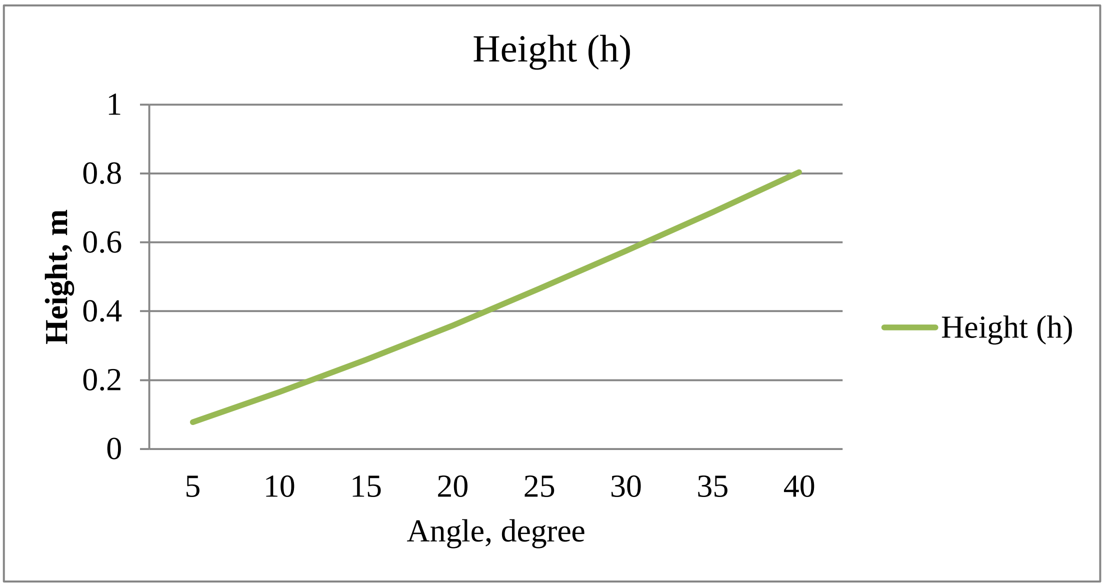


Figure 3.19 Proportionality of height and angle

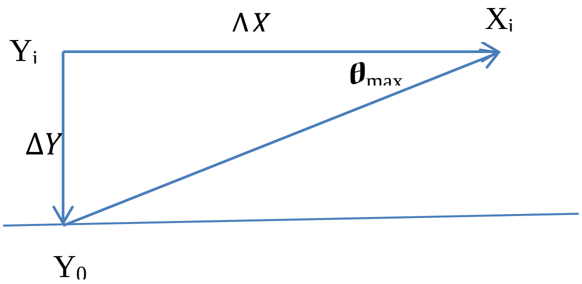
Figure 3.19 shows the relation between the opening angle and height of each level. When the opening angle was increased at the same time the height also increased.

3.10 Effect of Surface Level on Design of Mobile Hydraulic Scissor Lift

The road elevation is modeled as a sinusoidal disturbance signal affecting the mobility of a hydraulic scissor lift that refers to the vertical and horizontal dimensions of the road surface. It considers how the road profile is represented with a set of elevations of a continuous elevation Y as a function of distance X, the distance values of Yi, where i is the number of elevations in a data set. The slope between these two points is calculated as equation 3.29.

$$Slope = \frac{\Delta Y}{\Delta X} = \frac{Y_i - Y_0}{X_i - X_0} \qquad 3.29$$

To design a mobile hydraulic scissor type lift machine that is compatible with surface level takes into consideration when ΔY is height of the stand plate from the ground and ΔX is the length of stand plate.



Where:

ΔX is length of stand plate, 215mm from table 3.7

ΔY is height of stand plate from the ground

$\boldsymbol{\theta}_{max}$ = maximum slope angle between base of stand plate and ground.

The slope of the road used for mobility of a hydraulic scissor lift is calculated in two ways: During the vehicle is loaded on the machine, the free length of the spring is compressed to a solid height and the spring should take a permanent set and push the wheel to rise from the ground. When the wheel leaves the ground, the lift machine stands by a stand plate as described in figure 3.24.

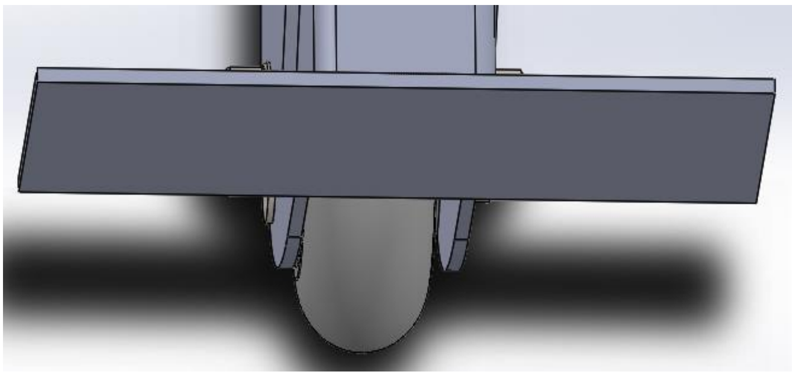


Figure 3.20 stand plate of wheel mechanism

At this time, $Y_0 = 0$, $Y_i = 0$, $X_0 = 0$ and $X_i = 215mm$

$$Slope = \frac{0}{215} = 0$$

At zero slopes there is no angle between the stand plate and an imaginary horizontal line of the ground. This implies that when a vehicle is loaded on a lift machine at uneven ground, the machine cannot maintain its balance and comes to fall.

During unloading the vehicle, the lift machine stands by the wheel, $Y_0 = 0$, $Y_i = 120mm$, $X_0 = 0$ and $X_i = 215mm$

$$Slope = \frac{120}{215} = 0.56$$

The maximum slope angle between the stand plate and an imaginary horizontal line of the ground is 56% or 34^0. This implies that during lift machine unloading the maximum road surface slope is up to 34^0.

Therefore, the mobile hydraulic scissor lift is designed for vehicle maintenance centers and different vehicle assembly industries that have been used on a level surface during loading or working and up to 34^0 during unloading. When the loaded machine moves on sloped or uneven ground during loading, the machine is affected by the ground surface and it cracks. So in order to safe operation and durability of the mobile hydraulic scissor lift, it is designed to be used at the surface level during loading.

3.11 Analysis of Mobile Hydraulic Scissors Lift Using Finite Element Method

Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behavior of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations. ANSYS is general-purpose finite element analysis (FEA) software package. It is a computational tool for breaking down a complex structure into tiny parts known as components. Designers use ANSYS in a wide range of industries, including aerospace, automobile, construction, nuclear, communications, biomedical, and many others, and simulation tools to monitor design performance on their desktops. As a consequence, it facilitates rapid, dependable, and cost-effective product development from concept to validation. The ANSYS designers in resolving issues such as structural deformation, heat transfer, fluid flow, electromagnetic effects, and a mixture of these phenomena working together, and so on, which helps to speed up and streamline the product development process (Wing Kam Li et al. 2022).

3.11.1 Static Structure Analysis

A static structural analysis determines the displacements, stresses, strains, fatigue analysis, Strength analysis, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly concerning time. A static structural load can be performed using the ANSYS software solver. The types of loading that can be applied in a static structure analysis include:

- Externally applied forces and pressures
- Steady-state inertial forces (such as gravity or rotational velocity)
- Imposed (nonzero) displacements
- Temperatures (for thermal strain)

We analysis under this topic deformation analysis, shear stress analysis by mesh influences the accuracy. There are various steps that are to be followed in analyzing a component structurally. They are:-

- Mesh generation
- Fixed supports
- Application of loads
- Evaluating result

3.11.2 Static structure of mobile hydraulic scissor lift model analysis

A mobile hydraulic scissor lift was subjected to the 31.392kN weight of the vehicle. The static structure of the mobile hydraulic scissor lift component is analyzed by following these steps:

3.11.3 Engineering Data

The specific material property of the steel materials used was stated in the table 3.15 and 16.

Table 3.15 Engineering data of Stainless steel

Item No.	Stainless steel Properties	Value
1	Density(kg/m^3)	7750
2	Young's Modulus(MPa)	$1.93e^{+05}$

3	Poisson’s ratio	0.31
4	Bulk modulus (MPa)	$1.693e^{+05}$
5	Shear modulus (MPa)	$7.3664e^{+04}$
6	Tensile yield strength (MPa)	207
7	compressive yield strength (MPa)	207
8	Tensile ultimate strength (MPa)	586
9	compressive ultimate strength (MPa)	0
10	stainless steel coefficient of thermal expansion (1/°C)	$1.7e^{-05}$

Table 3.16 Engineering data of structural steel

Item No.	Structural steel Properties	Value
1	Density(kg/m^3)	7850
2	Young’s Modulus(MPa)	$2e^{+05}$
3	Poisson’s ratio	0.3
4	Bulk modulus (MPa)	$1.6667e^{+05}$
5	Shear modulus (MPa)	$7.6923e^{+05}$
6	Tensile yield strength (MPa)	250
7	compressive yield strength (MPa)	250
8	Tensile ultimate strength (MPa)	460
9	compressive ultimate strength (MPa)	0
10	Structural steel coefficient of thermal expansion (1/°C)	$1.2e^{-05}$

3.11.4 Geometry of mobile hydraulic scissor lifts structure

Geometry of mobile hydraulic scissor lift is shown in figure 3.21.

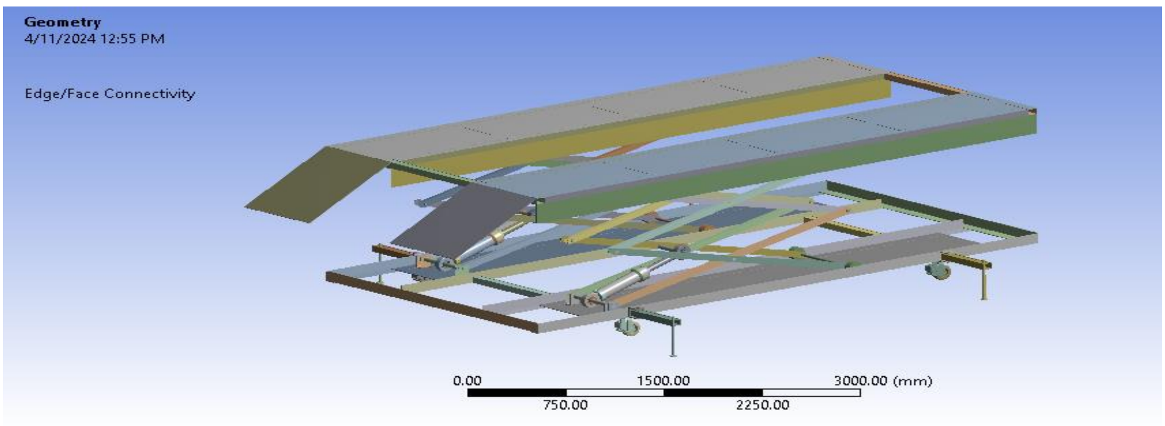


Figure 3.21 Imported 3D model of mobile hydraulic scissor lift

3.11.5 Meshing of mobile hydraulic scissor lift

Applying mesh allows for the smooth distribution of contact stresses by providing an appropriate mesh density on contact surfaces. Similarly, offers a mesh density sufficient for resolving stresses; areas of interest for stresses or strains require a comparatively fine mesh compared to those required for displacement or nonlinearity resolution. Figure 3.22 shows a meshed mobile hydraulic scissor lift.

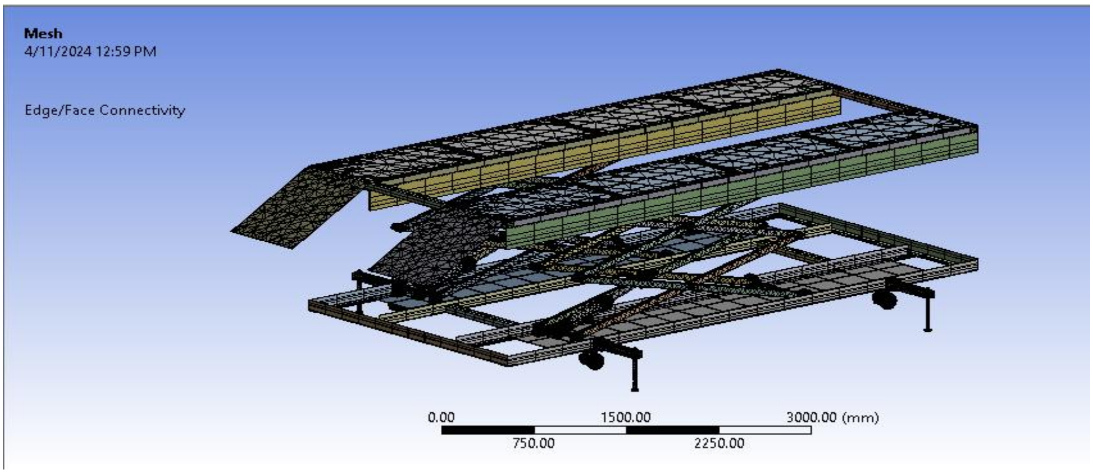


Figure 3.22 Meshed model of mobile hydraulic scissor lift

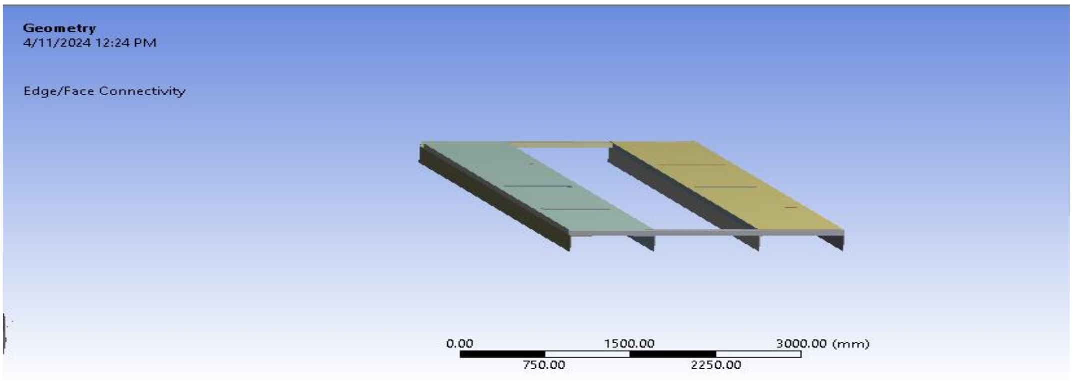


Figure 3.23 Imported 3D model Top platform

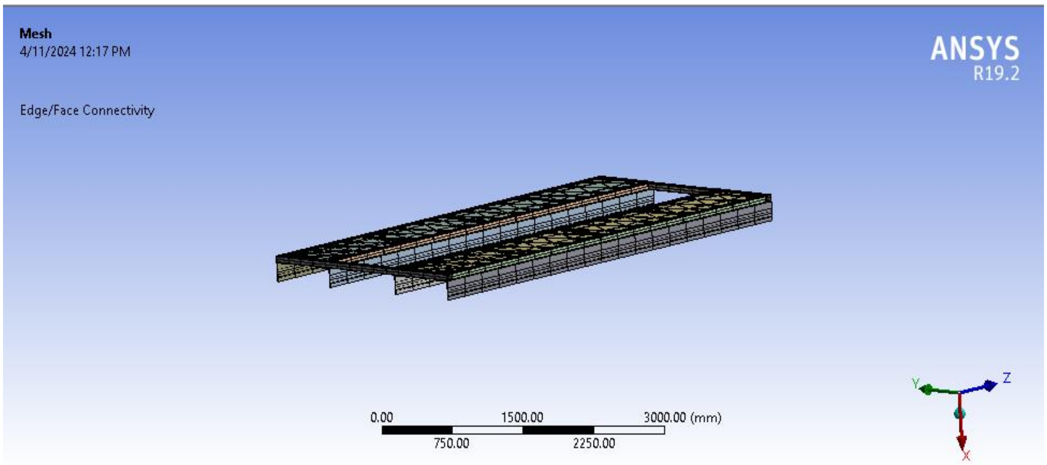


Figure 3.24 Meshed Top Platforms

3.11.6 Geometry of scissor arms

Scissor arms will be subjected to the weight of the vehicle and top platform components of the system. The upper tip of the scissor arm is connected to the base of the top platform and the lower part is connected to the base of the lift by a connecting link. The total force applied at the top scissor arm is 52,078.59N. In the system, there are eight scissor arm links, and then the total load is divided into eight, 6509.82N force applied to each scissor arm. The geometry of the scissor arms is shown in the figure 3.25.

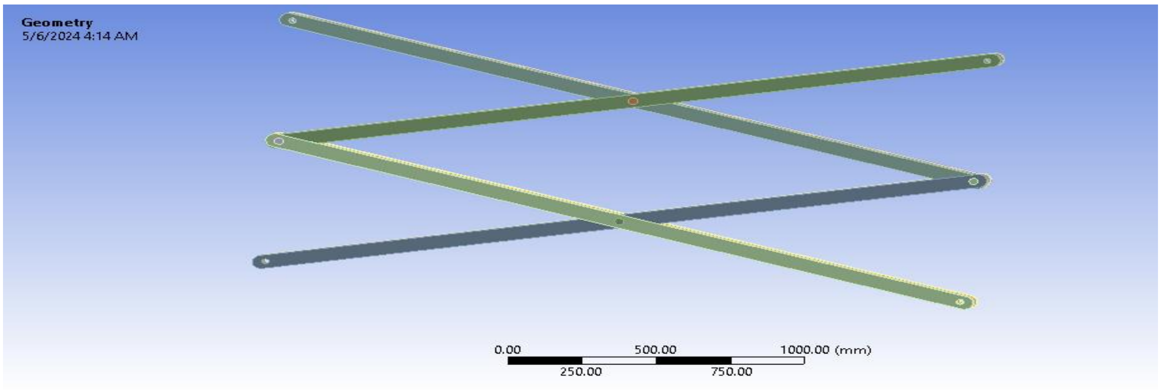


Figure 3.25 Imported 3D model scissor arms

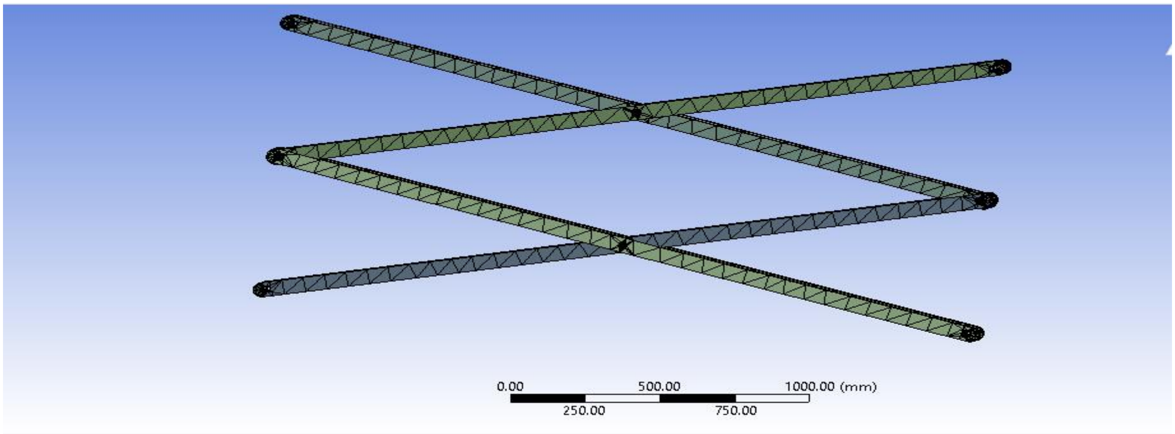


Figure 3.26 Scissor Arms Solid Model Meshed

The total number of nodes and the number of total element are determined as 96700 and 50625, respectively.

3.11.7 Geometry of Wheel Mechanism

The wheel Mechanism will be subjected to the weight of the vehicle and all components of the system except the weight of the wheel mechanism. The face of the wheel mechanism is connected to the lower base of the lift and enables travel of the lift. The total force applied at the top wheel mechanism is 54,243.46N. In the system four wheel mechanisms, then the total load is divided into four wheels and 13560.87N force is applied to each wheel mechanism. The components of the wheel mechanism are wheels, two springs, two u-shapes, supporting plates, and stand plates. The geometry of the wheel mechanism is shown in figure 3.27

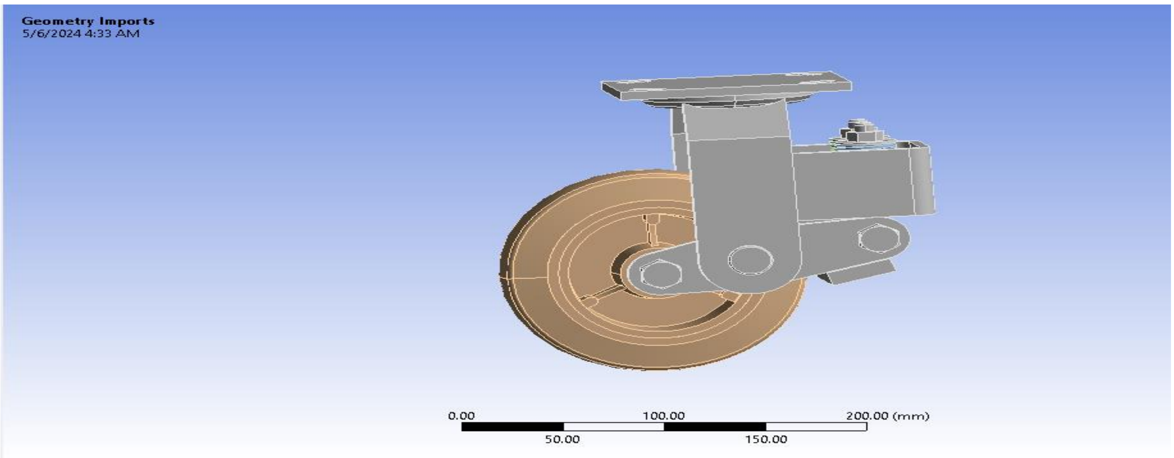


Figure 3.27 Imported 3D model wheel mechanism

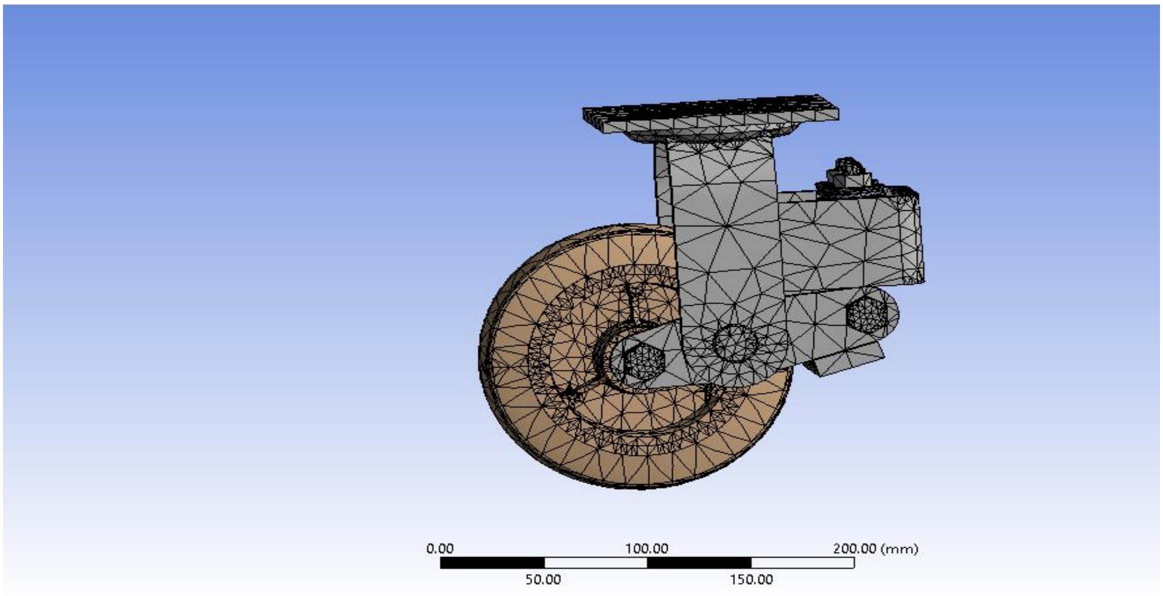


Figure 3.28 Meshed model of wheel mechanism

3.12 Dynamic analysis of mobile hydraulic scissor type lift

The modal analysis calculates natural frequencies and mode shapes of the structure. In addition, participation factors and effective mass provide information about the most prominent modes in certain directions that will be excited by the forces in those directions, and whether enough modes have been extracted for further analysis such as harmonic, response spectrum, or random vibration. In dynamic analysis the process is similar to static analysis but the difference is instead of static structural we use the modal analysis, different types of modal shape of natural frequency and harmonic response.

Modal analysis helps us to identify various modes of vibration as well as the frequency at which those modes are created and to calculate natural frequency of system so we know which frequency can be destructive and dangerous for system that causes resonance. A modal analysis is typically used to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed. Modal analyses, while being one of the most basic dynamic analysis types available in ANSYS, can also be more computationally time consuming than a typical static analysis. A reduced solver, utilizing automatically or manually selected master degrees of freedom is used to drastically reduce the problem size and solution time.

Frequency (harmonic response) analysis calculates the response of an object when load is applied. It is steady-state response of a linear structure exited at a single frequency. In frequency response analysis each frequency is solved independently for applied force. It can be used for structure which operates continuously at a single speed or those which change speed slowly enough so that steady state is maintained.

The natural frequency of mobile hydraulic scissor lift components are calculated by Euler-Bernoulli Beam theories. The Euler-Bernoulli beam theory is a method for determining the load-carrying and deflection characteristics of beams. It is a simplification of the linear theory of elasticity. It covers the case for small deflections of a beam that are subjected to lateral loads only. The Euler's equation for natural frequency is given as

$$\omega_n = \frac{n^2\pi^2}{L^2}\sqrt{\frac{EI}{\rho}}\ ;\ f_n = \frac{\omega_n}{2\pi} ---------------- 3.10$$

$$f_n = \frac{1}{2\pi}[n\pi/L]^2\sqrt{\frac{EI}{\rho}}, \qquad n = 1,2,3\ldots\ldots\ldots.. --------- 3.11$$

i) The dynamic frequency of the scissor arms/leg calculated by applying different deformation forces on it and analyzing the results.

Where, n = Mode Shape, n = 1, 2, 3…,

f_n = natural frequency, ω_n = angular speed

I = Moment of inertia of a system, 1.2×10^6 $mm^4 = 1.2x10^{-5}m4$

ρ = Density of material, structural steel 7850 kg/m^3,

A = Area of scissor arm cross-section, $804mm^2 = 8.04x\ 10^{-4}m^2$

L = Length of scissor arm, 2.5m,

E = Modulus of Elasticity for structural steel, $2x10^5$ $N/mm^2 = 2x10^{11}$ N/m^2

Mode natural frequency of the scissor arm calculated by equation 3.11:

$$f_n = \frac{1}{2\pi}\left[\frac{n\pi}{L}\right]^2 \sqrt{\frac{EI}{\rho}}, \qquad n = 1,2,3$$

$$f_1 = \frac{1}{2 \times 3.14} \times \left[\frac{1 \times 3.14}{2.5}\right]^2 \times \sqrt{\frac{2 \text{ x } 10^{11}\ N/m^2 \times 1.2 \times 10^{-5} m^4}{7850 kg/m^3}}$$

$f_1 = 0.159x1.579x17.48 = 4.39Hz,\ f_2 = 17.55Hz, f_3 = 39.50Hz, ...$

ii) The dynamic frequency of a wheel mechanism is calculated by applying different deformation forces to it and analyzing the results.

Where, L = Length of wheel mechanism spring, 0.20m

I = Moment of inertia of a system, 1.2 $\times 10^6$ mm^4 $= 1.2x10^{-5}$m4

$$I = \frac{1}{3} m r^2 = \frac{8083.84}{3 * 9.81} * (0.035)^2 = 0.336 m^4$$

ρ = Density of material, stainless steel 7750 kg/m^3,

E = Modulus of Elasticity For stainless steel, $1.93*10^5\ N/mm^2 = 1.93*10^{11}\ N/m^2$

$$f_1 = \frac{1}{2 \times 3.14} \times \left[\frac{1 \times 3.14}{1.608}\right]^2 \times \sqrt{\frac{1.93 * 10^{11} \frac{N}{m^2} \times 1.2x10^{-5} m^4}{\frac{7750kg}{m^3}}} = 10.598Hz$$

Table 3.17 Dynamic analysis of scissor arm and wheel mechanism

It.No	Frequency (Hz)	1	2	3	4	5	6
1	Scissor arm	4.39	17.55	39.50	70.22	109.72	158.0
2	Wheel mechanism	10.598	42.392	95.382	169.569	264.951	381.529

CHAPTER FOUR

RESULT AND DISCUSSION

The static and dynamic structural evaluations performed on the mobile hydraulic scissor lift components are reported in this chapter. The findings concentrate on mobile hydraulic scissor lift of total deformation, equivalent (Von-Misses) stress, and equivalent elastic strains. The finite element analysis technique is vital in finding the maximum and minimum total deformation, equivalent (Von-Misses) stress, and equivalent elastic strains on the structural model; therefore it is critical to understand the considerable data output appropriately. The static and dynamic structural analysis results were determined by following the ANSYS 2022 R1 workbench's standard static structural and modal analysis system step by step.

4.1 Result

4.1.1 Static structural results

The static analysis is concerned with the determination of the response of the mobile hydraulic scissor type lift to steady state loads. The corresponding stresses and strains are obtained using strain-displacement and strain-stress (constitutive) relations. The FEA equivalent (Von-Misses) stress, total deformation, and maximum primary elastic strain values of the mobile hydraulic scissor lift components are described below.

The equivalent (von-mises) stress values of the scissor arm and wheel mechanism using FEA respectively are shown in figures 4.1 and 4.2.

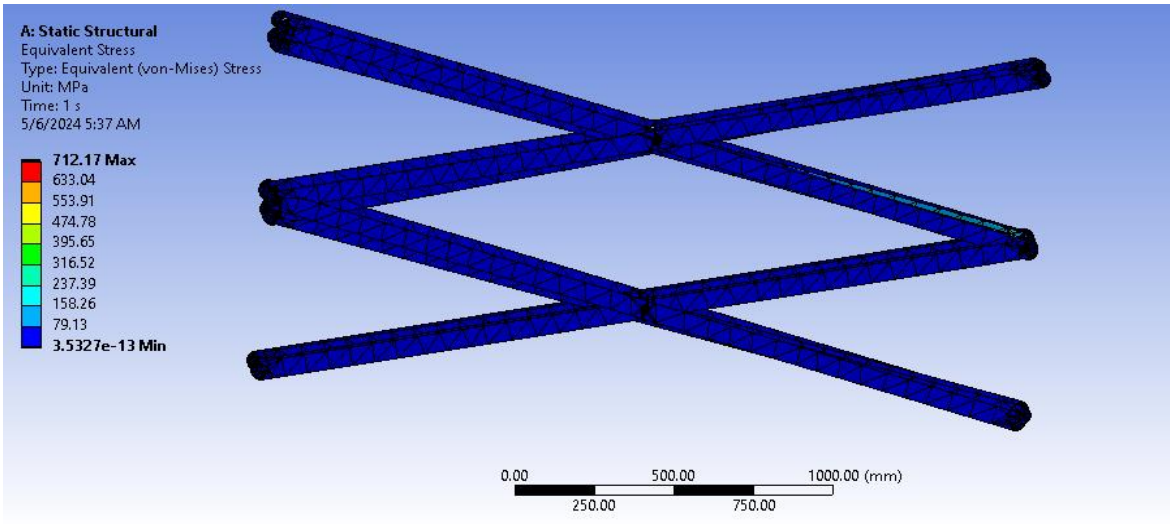


Figure 4.1 Equivalent (von-misses) stresses of scissor arms

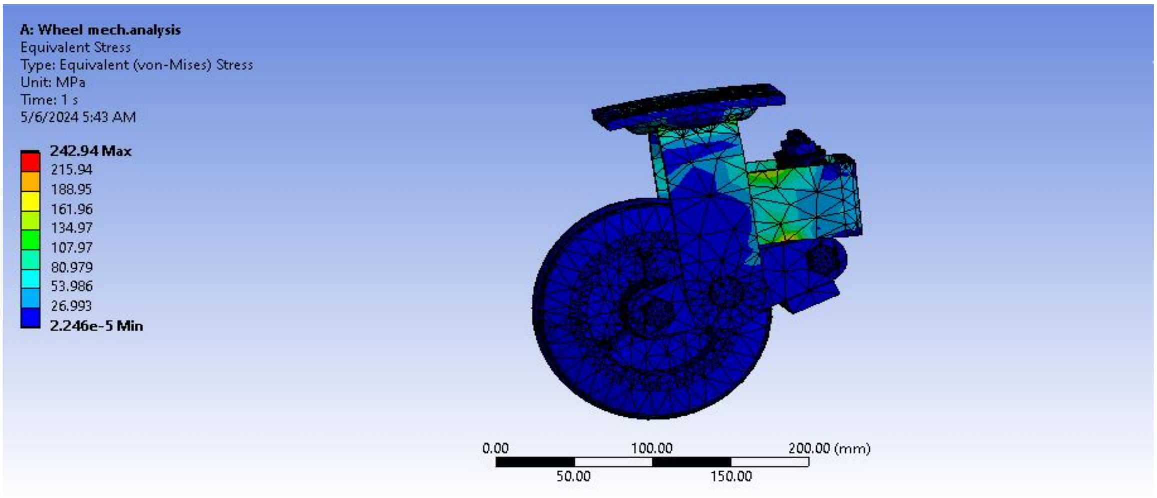


Figure 4.2 Equivalent (von-misses) stress of wheel mechanism

The total deformation values of the scissor arms and wheel mechanism using FEA are shown in figures 4.3 and 4.4 respectively.

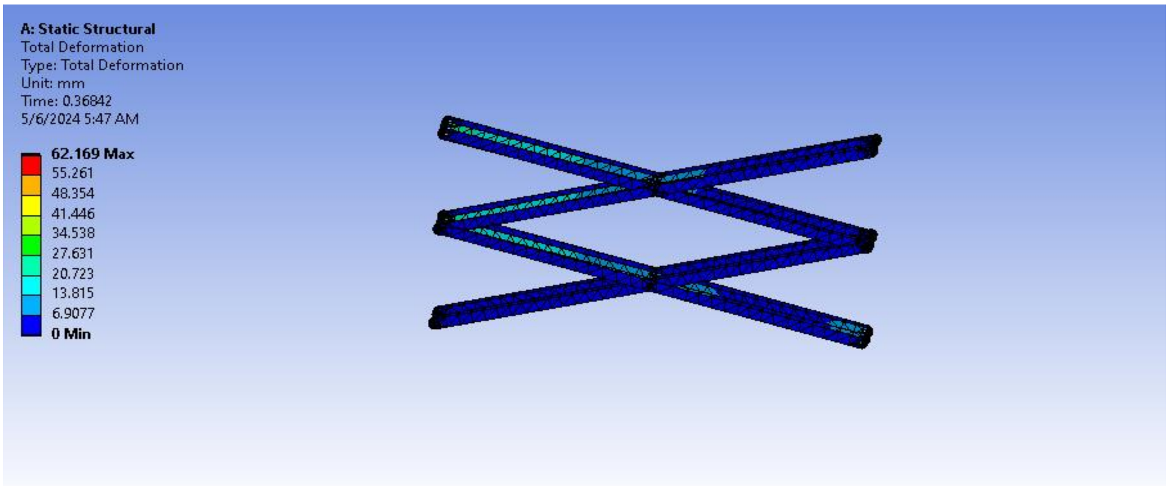


Figure 4.3 Total deformations of scissor arms

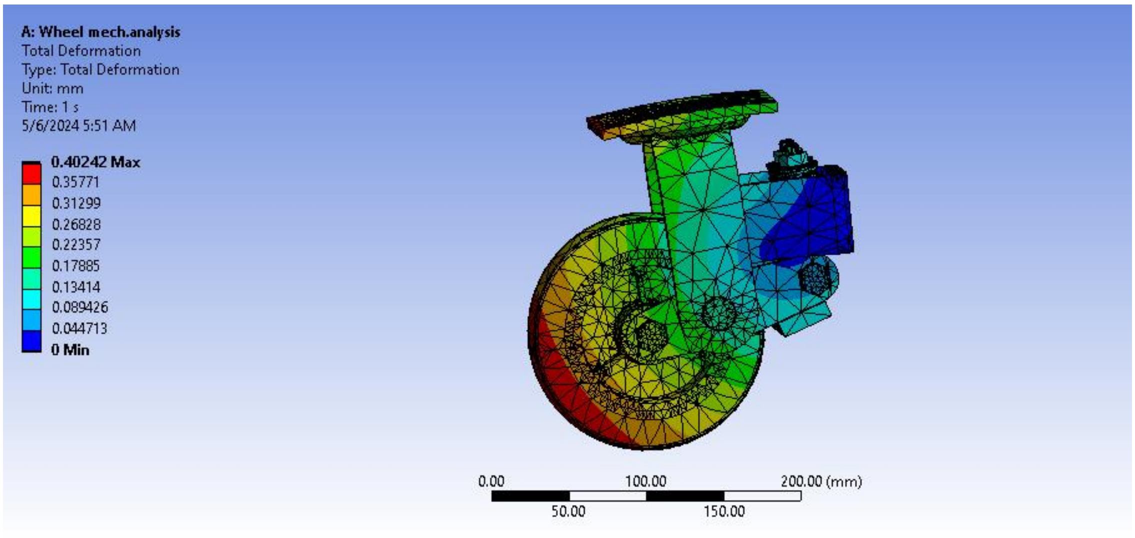


Figure 4.4 Total deformation of wheel mechanism

The maximum principal elastic strain values of the scissor arms and wheel mechanism using FEA are shown in figures 4.5 and 4.6 respectively.

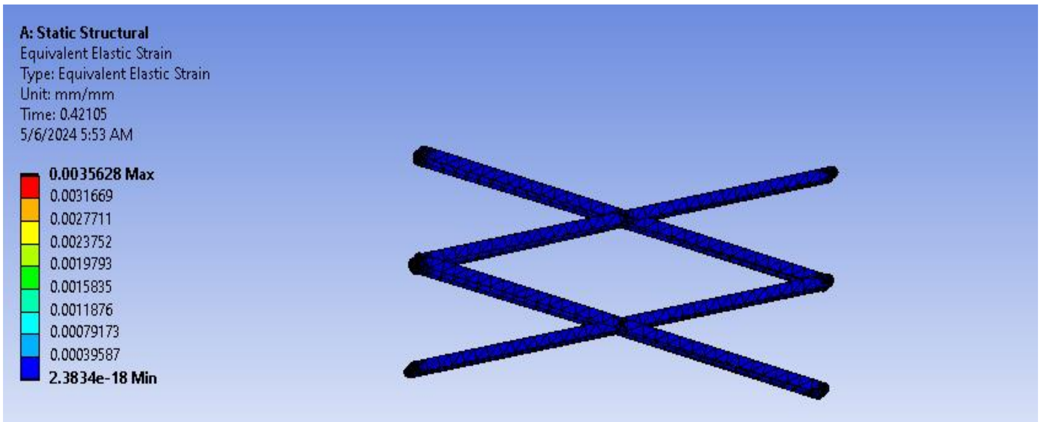


Figure 4.5 Maximum Principal Elastic Strain of scissor arms

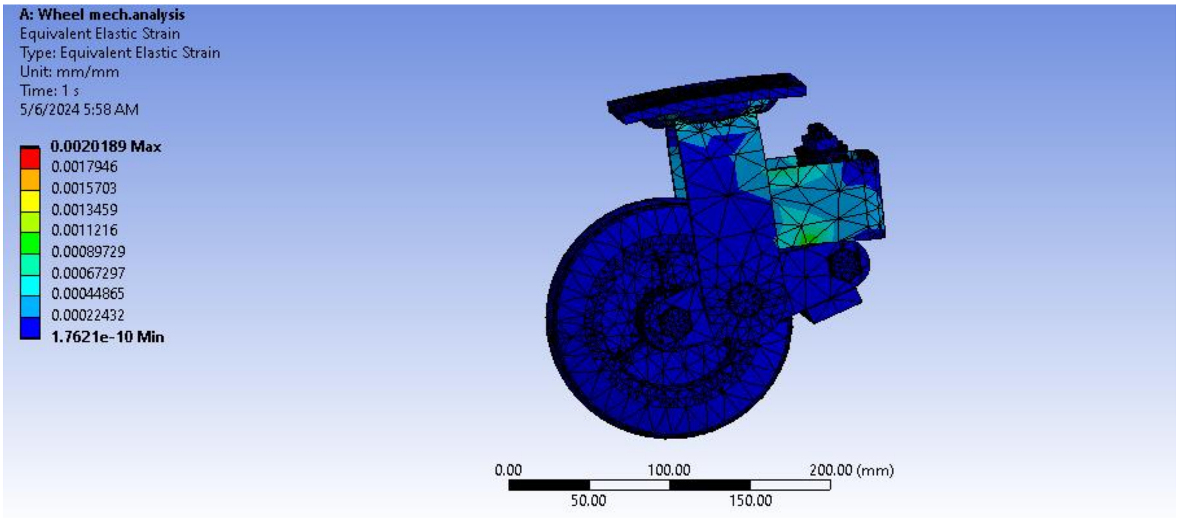


Figure 4.6 Maximum Principal Elastic Strain of wheel mechanism

The von-mises stress equation is derived from principles of mechanics, allowing engineers to determine if materials have enough capacity to withstand loads they'll be exposed to during their lifetime. The von-mises theory predicts that failure by yielding will occur when the yield strength of the material equals the von-mises or effective stress equals the material. It is the most widely used predictor of ductile material failure.

From the above workbench analysis, the input parameters are 47088N force loaded on the lift. The model is designed with solid work and meshed. The maximum equivalent (von-mises) stress scissor arm is 712.17MPa and minimum 3.5327e^{-13}MPa. The analytically calculated result of the scissor arm bending stress is 1287.18MPa. Since critical stress is less than the yield strength of structural steel (1287.18MPa). Hence, the material is safe. The equivalent von-misses strain is negligible and cannot affect the system. The maximum total deformation on the scissor arm is 62.169mm less which is an acceptable value. Also the maximum principal von-misses stress of the wheel mechanism is 242.94MPa and minimum von-misses stress 2.246e^{-5}MPa and the maximum deformation is 0.40242mm. The principal von-misses stress result shows that it can resist or can carry without failures. The maximum deformation show that the deformation is at optimum range which is the value is in the acceptable range of value. Generally, in both analysis methods, the result shows that the scissor arm and wheel mechanism materials can resist the applied load safely.

4.1.2 Modal analysis results

A modal analysis is determines the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component. It can also serve as a starting point for another, more detailed, dynamic is, such as random vibration, transient dynamic analysis, a harmonic response analysis. The natural frequencies and mode shapes are important parameters in the design of a structure for dynamic loading conditions.

The measurement of dynamic parameters of the mobile hydraulic scissor lift in the frequency domain at six distinct deformation analyses is known as the modal analysis of the scissor arms and wheel mechanism. Figures 4.7 - 4.18 consecutively list the dynamic analysis of scissor arms and wheel mechanisms at different six frequency ranges.

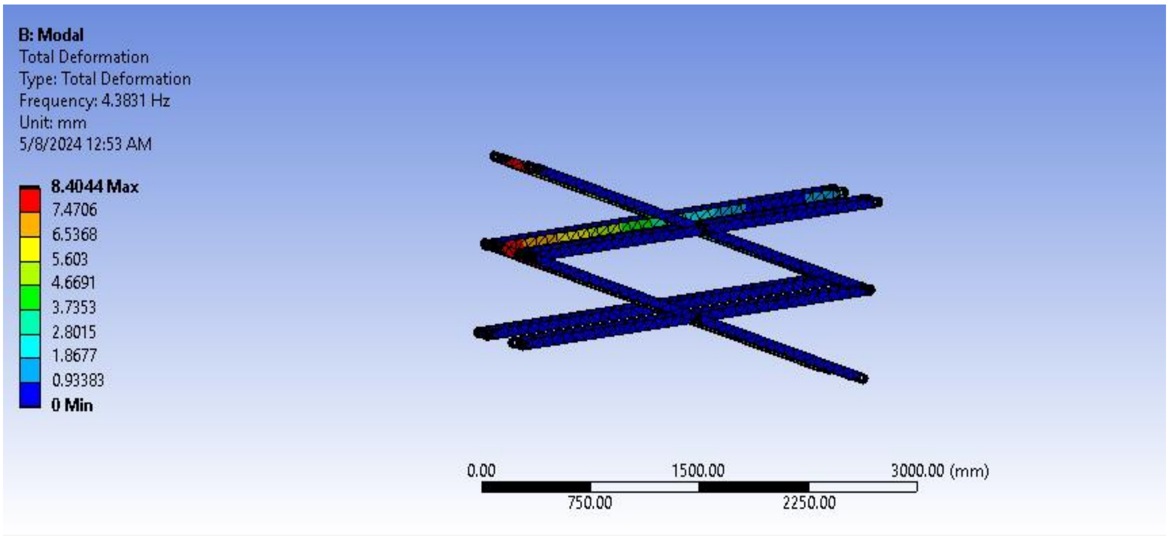


Figure 4.7 Total deformation of the scissor arm at frequency 4.3831 Hz

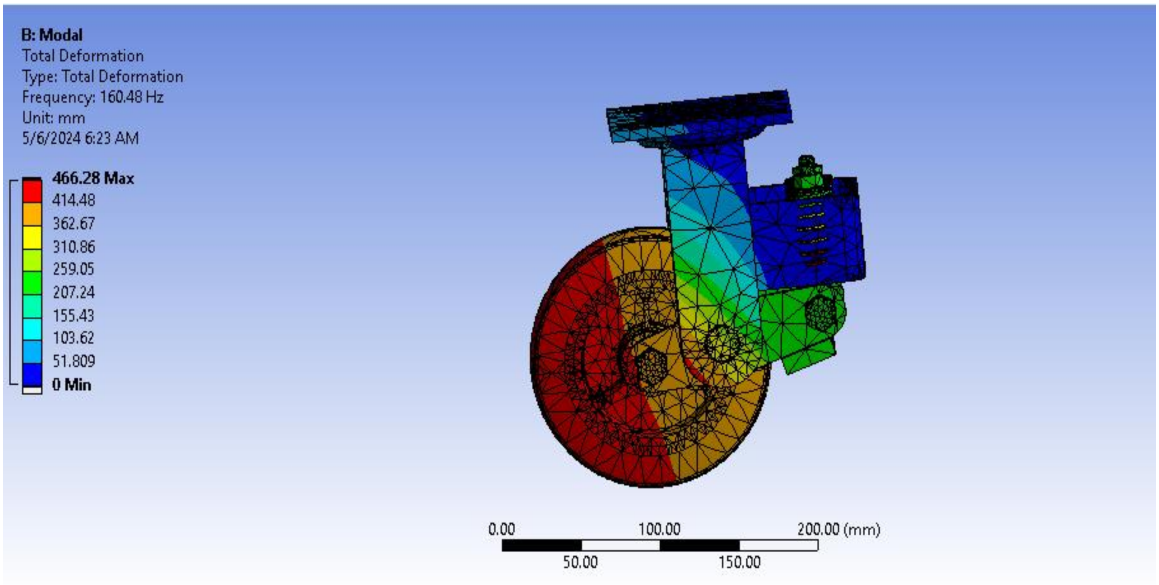


Figure 4.8 Total deformation of the wheel mechanism at frequency 160.48 Hz

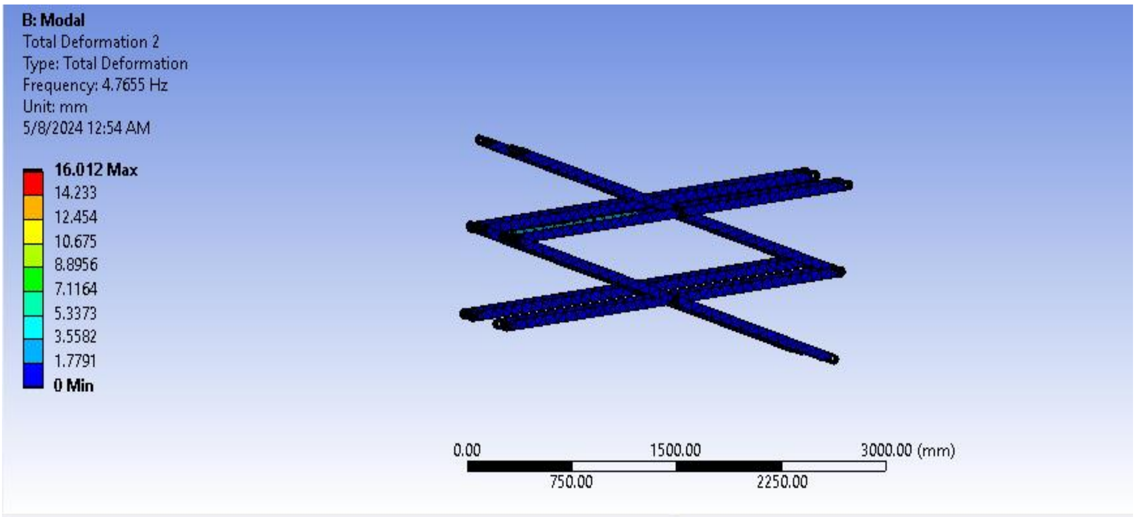


Figure 4.9 Total deformation of the scissor arm at frequency 4.7655 Hz

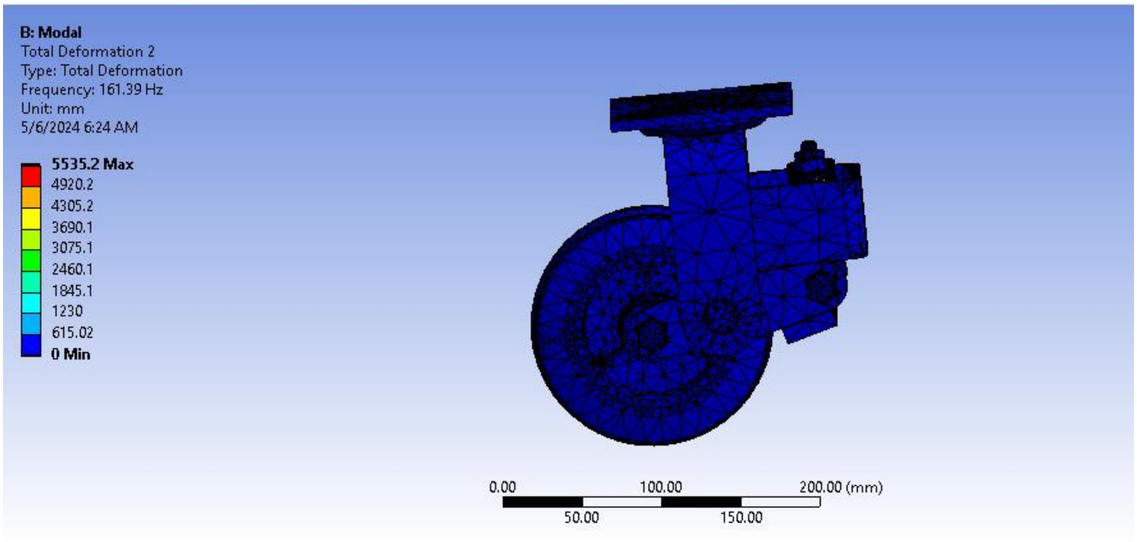


Figure 4.10 Total deformation of the wheel mechanism at frequency 161.39 Hz

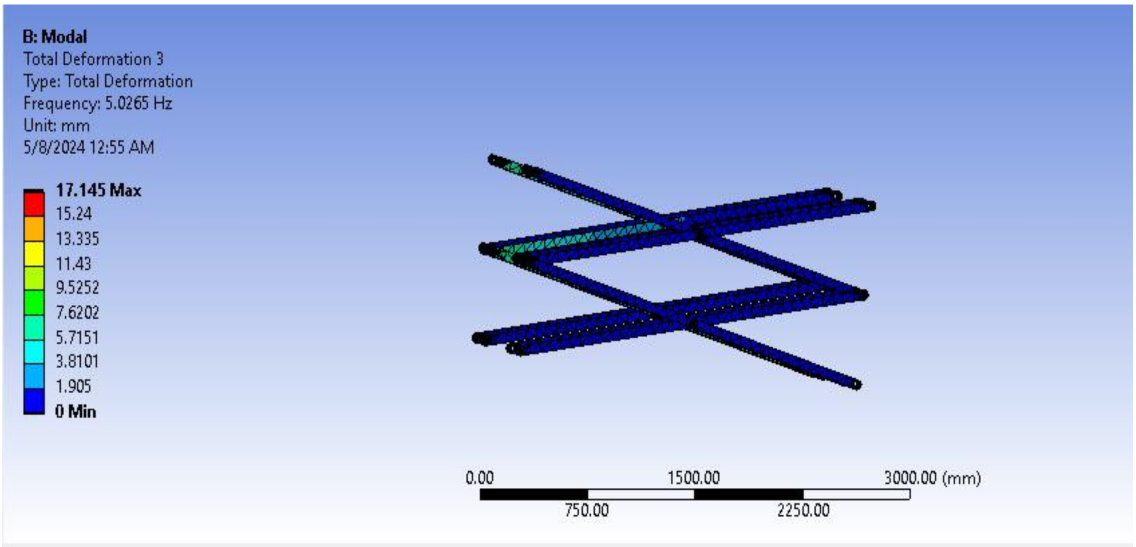


Figure 4.11 Total deformation of the scissor arm at frequency 5.0265 Hz

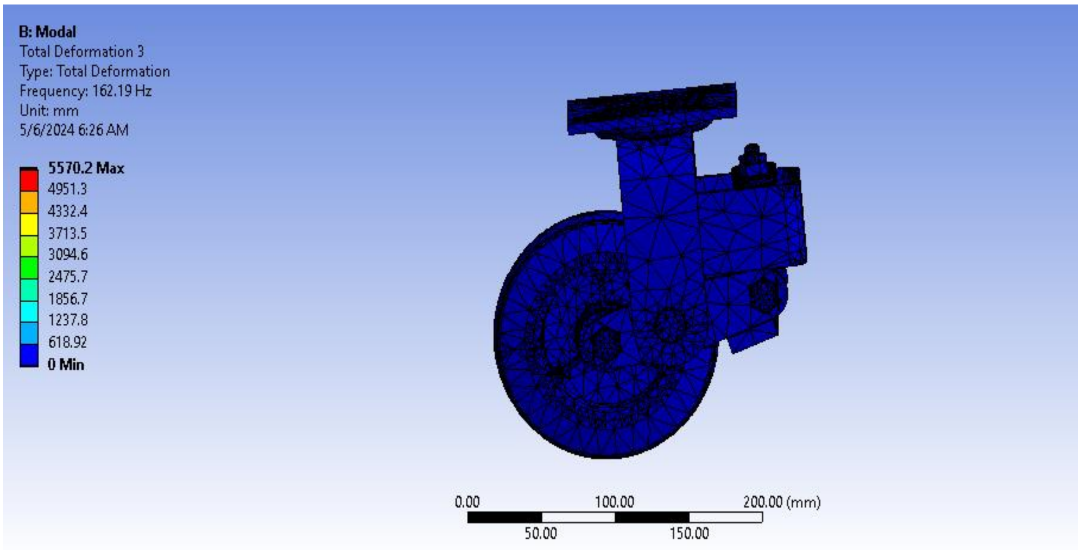


Figure 4.12 Total deformation of the wheel mechanism at frequency 162.19 Hz

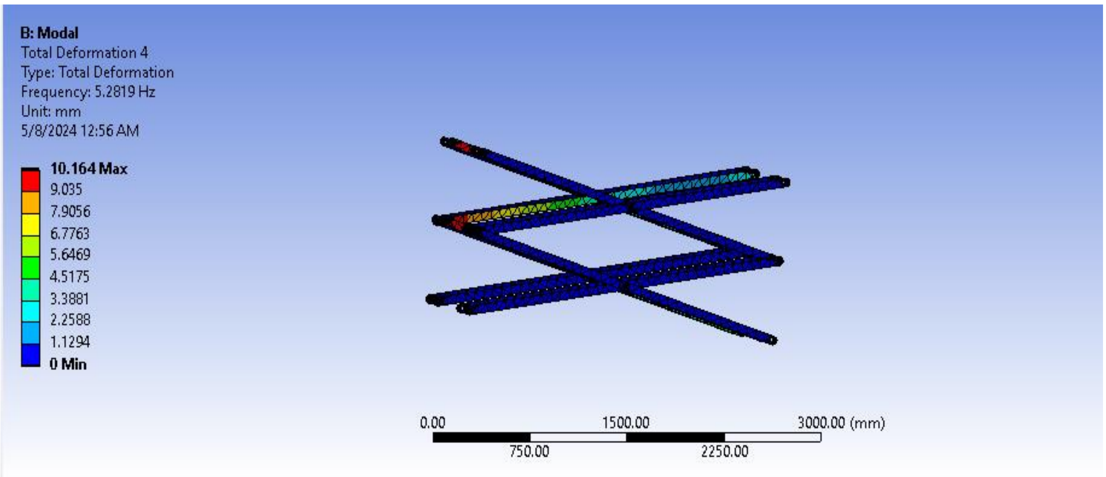


Figure 4.13 Total deformation of the scissor arm at frequency 5.2819 Hz

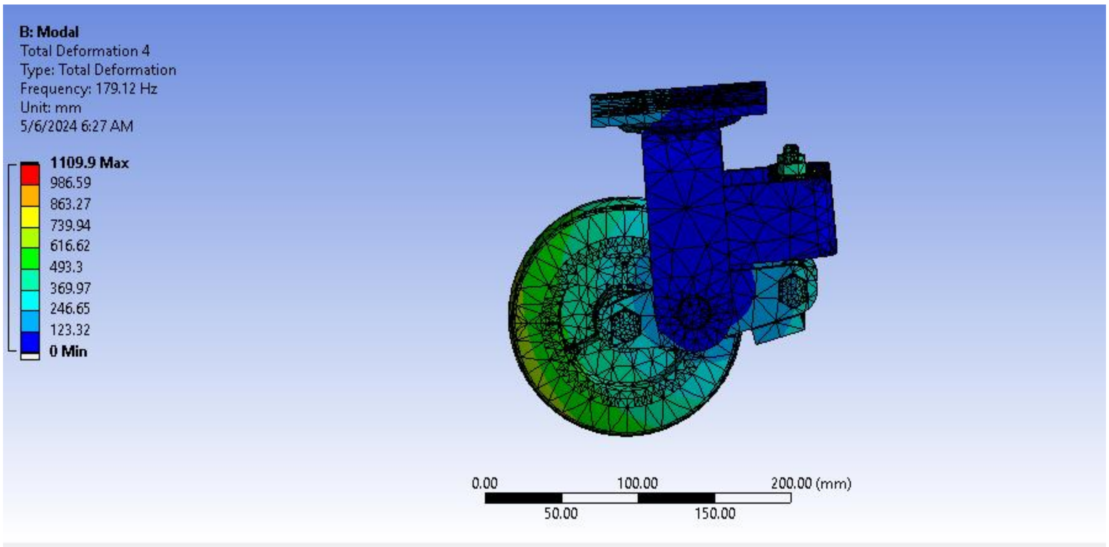


Figure 4.14 Total deformation of the wheel mechanism at frequency 179.12 Hz

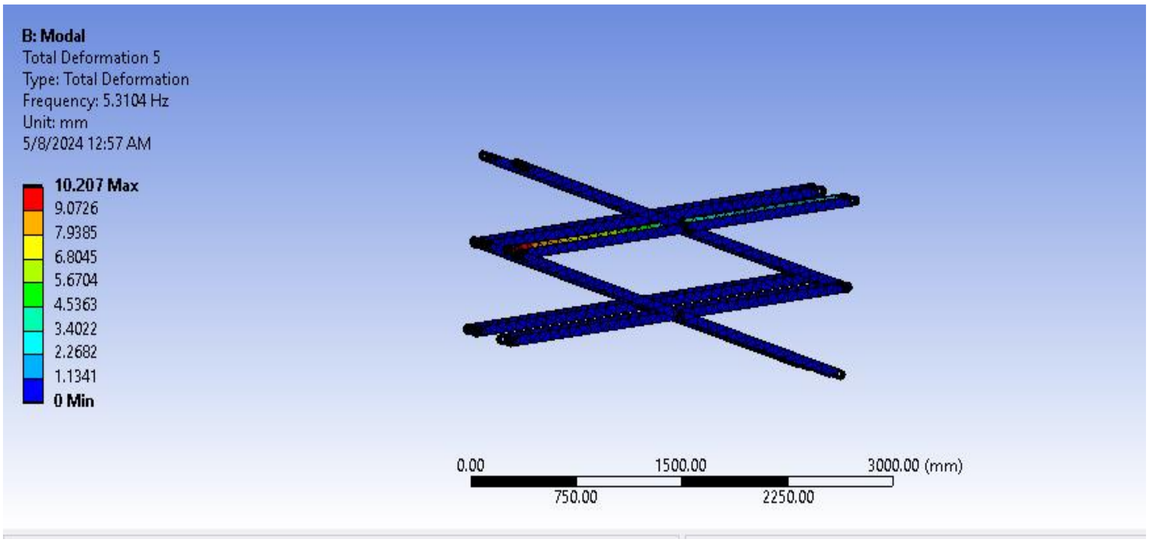


Figure 4.15 Total deformation of the scissor arm at frequency 5.3104 Hz

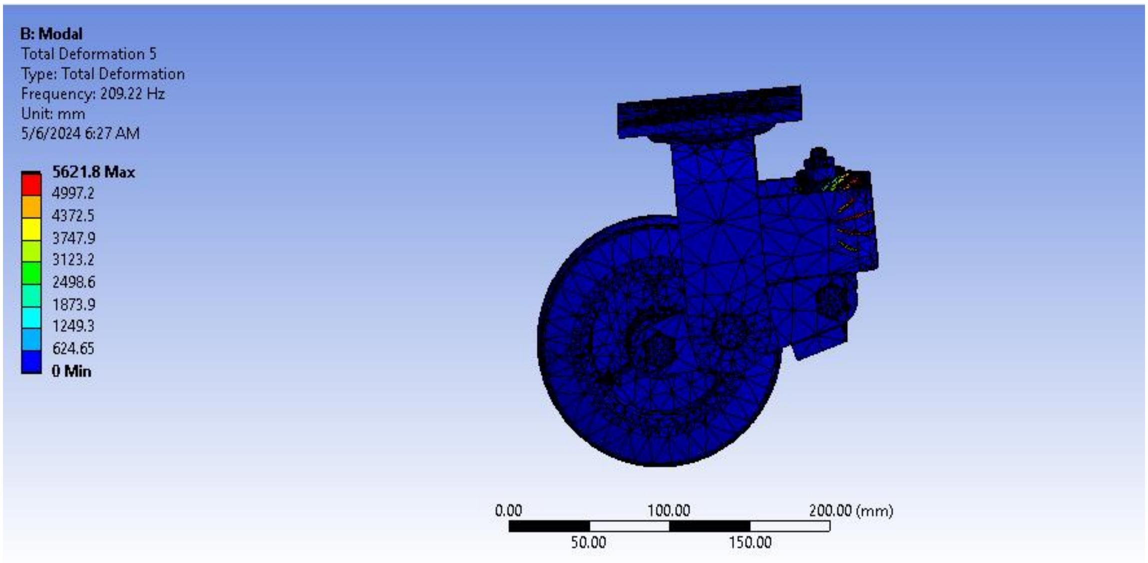


Figure 4.16 Total deformation of the wheel mechanism at frequency 209.22 Hz

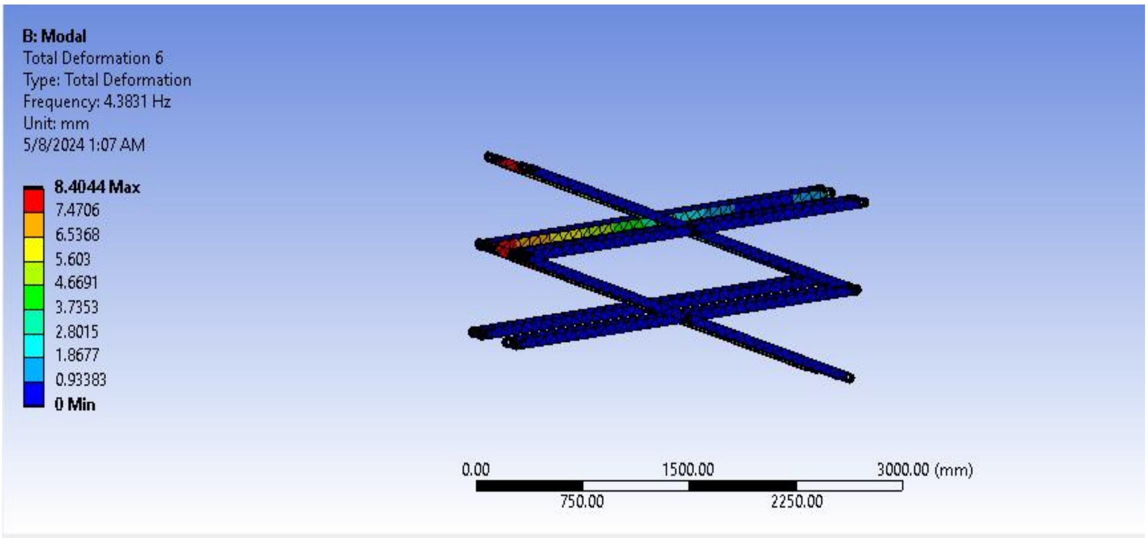


Figure 4.17 Total deformation of the scissor arm at frequency 4.3831 Hz

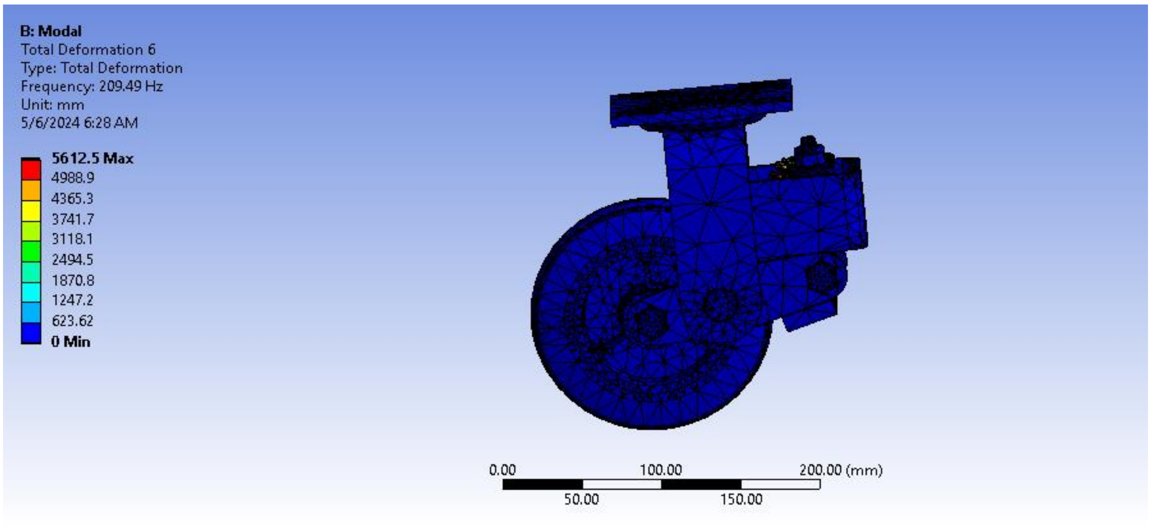


Figure 4.18 Total deformation of the wheel mechanism at frequency 209.49 Hz

When to generalized from the above figure frequency, the harmonic frequencies listed in figures 4.9, 4.11 and 4.14 are low vibration frequencies, figures 4.10, and 4.12 are medium vibration frequencies and figures 4.7, 4.8, 4.13, 4.15, 4.16, 4.17, and 4.18 are high vibration frequencies determined from six different frequencies of the scissor arm/leg and wheel mechanism to determine dynamic analysis. The harmonic frequencies shown in figures 4.7, 4.8, 4.13, 4.15, 4.16, 4.17, and 4.18 are not safe to design with, whereas the harmonic frequencies shown in figures 4.9, 4.10, 4-11, 4.12, and 4.14 are smoothly adjusted up and down. As a result, these five harmonic frequencies are optimal for the construction of mobile hydraulic scissor type lift components.

4.2 Discussion

A static load of 47,088N is applied to a mobile hydraulic scissor type lift from a light duty vehicle in the static and dynamic structural analyses. When the unit power switch is on, the hydraulic fluid is pushed under pressure through a hydraulic pump, hoses, and hydraulic motor, the hydraulic fluid is pushed through the cylinder to elevate vehicle loads. If the valve is closed, the fluid will get back to the tank. Figure 4.19 depicts the assembly of a mobile hydraulic scissor type light duty vehicle lift when fully lift.

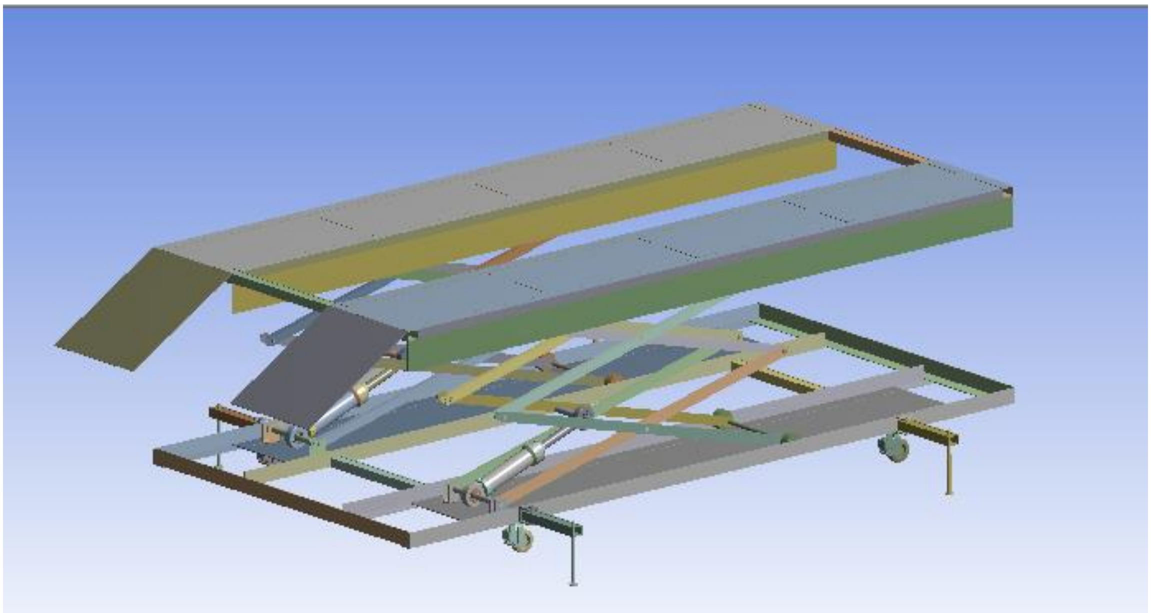


Figure 4.19 3D modeling of mobile hydraulic scissor type light duty vehicle lift

The static and dynamic structural analysis of mobile hydraulic scissor lift components like scissor arms and wheel mechanism prepared from steel material was achieved for applying a static load of 47088N.

4.2.1 Mesh (Moderate Mesh)

Meshing is the process used to fill the solid model with nodes and elements to create a finite element analysis (FEA) model. Applying mesh allows for the smooth distribution of contact stresses by providing an appropriate mesh density on contact surfaces. This was automatically created by the system at the high density and the high quality. The total number of nodes and the number of total elements are determined as 1851808 and 1004338, respectively. Only the scissor arm nodes and the number of elements are 94352 and 40152 and the wheel mechanism nodes and number of elements is 60672 and 31332 respectively. A mesh structure of the analyzed mobile hydraulic scissor lifting system after loading is shown in figure 4.20.

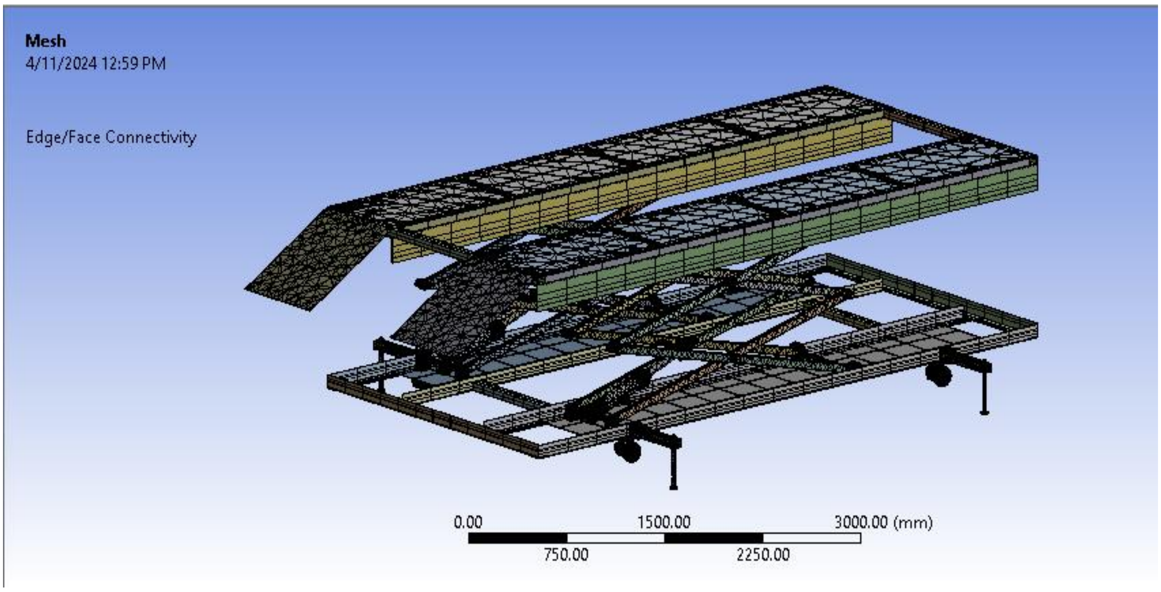


Figure 4.20 meshed mobile hydraulic scissor lift

4.2.2 Simulation Results

The analysis was made to get the maximum and minimum of total deformation, equivalent (von-mises) stress, and equivalent (von-mises) strain.

4.2.3. Equivalent (Von-mises) stress

Equivalent (Von-mises) stress is a value used to determine if a given material will yield or fracture. It is mostly used for ductile materials, such as metals, and composite materials. It is computed from an equation based on distortion energy failure theory, this criterion is particularly effective in the prediction of failure for ductile materials and widely used by designers to check whether their design will withstand a given load condition.

By using the ANSYS 2022 R1 Workbench software, the maximum and the minimum equivalent (Von-mises) stress values of steel material used for the scissor arm and wheel mechanism were presented in table 4.1 The results of this static structural analysis show the calculated numerical value of the equivalent (Von-misses) stress result of bending stress, 1287.18MPa greater than the analytical result. The principal von-misses stress result shows that when loaded with a light vehicle, it can resist or carry without failures. The equivalent von-misses strain is negligible and cannot affect the system. Generally, in both analysis methods, the result shows that the structural steel and stainless steel material selected for the scissor arm and wheel mechanism of the mobile hydraulic scissor lift can resist the applied load safely without failures.

4.2.4 Validation of the von-mises stress

From the previous research done on the Design & Analysis of Hydraulic Scissor Lift (M. Kiran Kumar et al. 2016) is observed at 2943N load on mild steel and aluminum material and in this research project at 47088N load on structural steel and stainless steel, the maximum von-mises stress and deformation is shown in the table 4.1. Based on the analysis, particularly in mobile hydraulic scissor lift, scissor leg, and wheel mechanism components von-mises stress value is less. For this reason, when operating the lift (up and down movement), the link is the crucial part to carry the impact load and sustain the overall weight of the hydraulic scissor lift. Then in general as compared to yield strength all the structural elements of scissor lift have lower equivalent stress values. Furthermore, each and every part does not beyond the yield stress values of the material. As a result, the design of the mobile hydraulic scissor lift components is safe and has a better performance. The final design of the mobile hydraulic scissor lift assembly analysis results show that, it is considered safe to use targeted weight carrying (3200kg) purpose. For the validation, the finite element analysis of the von-mises stresses is compared to the analytical as shown in the figure 4.21

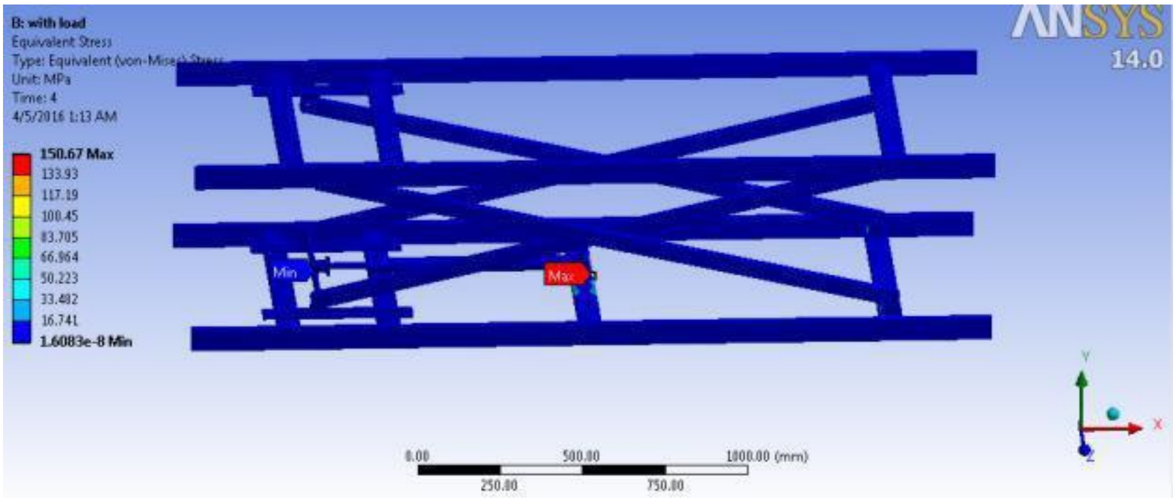


Figure 4.21 Equivalent Stress (M. Kiran Kumar et.2016)

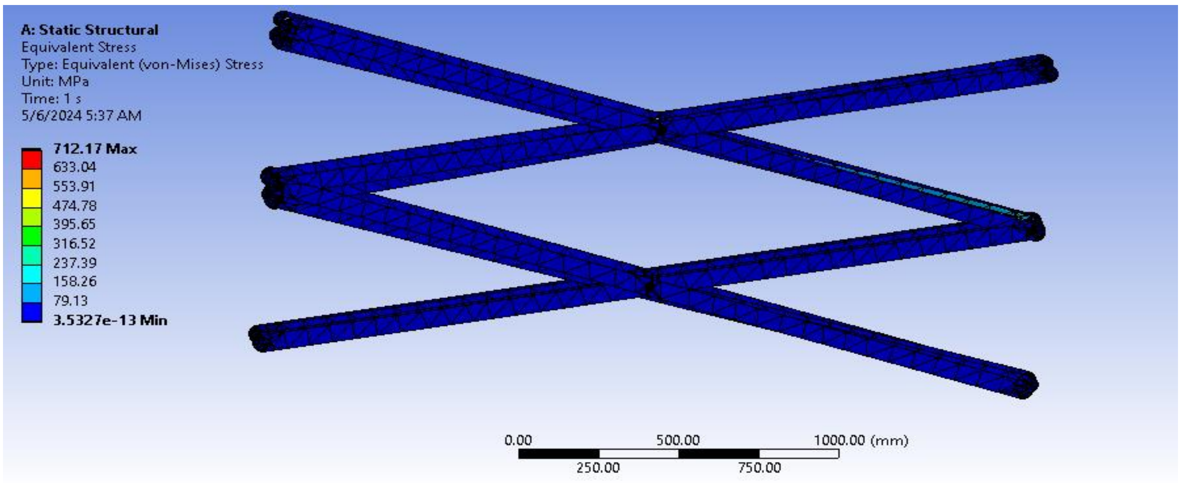


Figure 4.22 Equivalent (von-Mises) stresses of scissor arm

4.2.5 Total Deformation

As observed from the analytical and the simulation results of ASYSIS 2022 R1 software, the values of total deformation at the center of the structural steel and stainless steel of scissor arms and wheel mechanism of mobile hydraulic scissor lift were obtained in table 4.1 show that the maximum deformation is at optimum range which the value is in the acceptable range of value.

4.2.6 Summary of the static structure results of mobile hydraulic scissor lift

Table 4.1 Maximum equivalent (Von-Misses) stress values and the stress reduction

Component materials	Max. equivalent stress (MPa)	Minimum equivalent stress (MPa)	Maximum Total deformation (mm)	Minimum Total deformation (mm)
Aluminum Alloy of scissor arm	1014.7	$7.5197e^{-14}$	61.156	0
Structural steel of scissor arm	712.17	$3.5327e^{-13}$	62.169	0
Structural steel of Wheel mechanism	242.94	$2.246e^{-5}$	0.40242	0
stainless steel of Wheel mechanism	274.11	$6.4756e^{-5}$	0.54419	0

The graph plotted below would show the FEA values obtained due to an applied load of 6509.82N on each scissor arms.

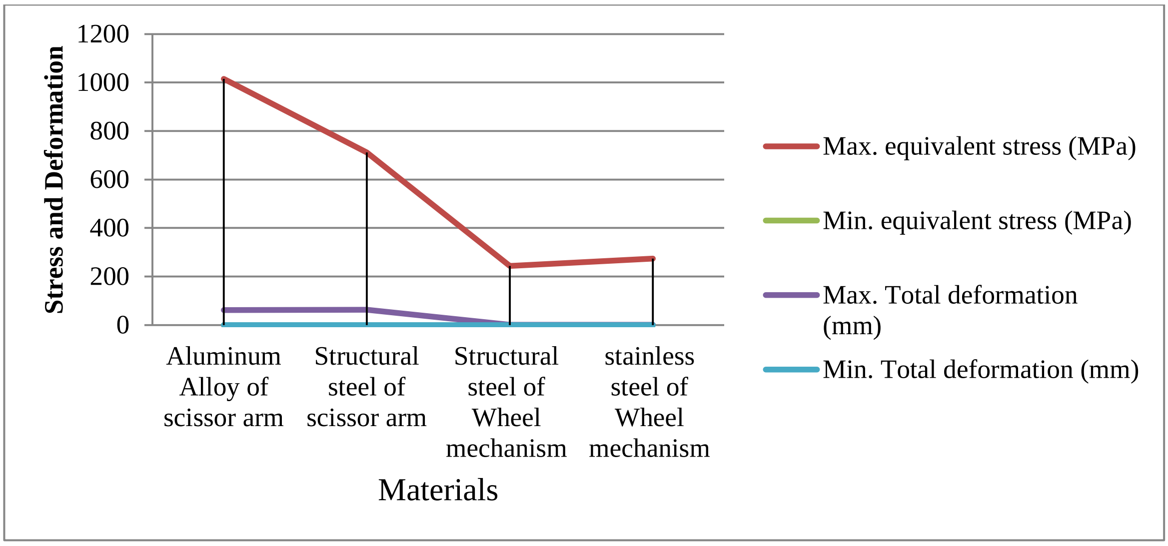


Figure 4.23 Natural frequencies (Hz) of different materials

As described in the above graph the maximum equivalent stress induced in structure steel is 242.94MPa, Aluminum alloy is 1014.7MPa and stainless steel is 274.11MPa. If compared corresponding equivalent stress structure steel is 242.94MPa which has less than equivalent (von-mises) stress. Almost all structures and stainless steel are the same which is less than the allowable stress (1287.18MPa). Hence the design is safe based on strength and rigidity. The deformation induced for three materials is structure steel is 0.40242mm, Aluminum alloy is 61.156mm and stainless steel is 0.54419mm.

Generally, the computational values of three different materials such as structural steel, aluminum alloy, and stainless steel were compared for the results. All structural steel, aluminum alloy, and stainless steel are good at their different aspects. Structural steel has greater durability and strength and it is also easily available and stainless steel has high corrosion resistance. Depending on their properties, in designing the mobile hydraulic scissor lift structural steel and stainless steel were selected as of greater importance.

4.2.7 Modal analysis table

Table 4.2 Natural frequencies (Hz) of six modal deformations

Natural frequency	Scissor arm Structural steel Frequency	Scissor arm Structural steel Max. deformation	Scissor arm Aluminum alloy Frequency	Scissor arm Aluminum alloy Max. deformation	wheel mechanism Structural steel Frequency	Wheel mechanism Structural steel Max. deformation	wheel mechanism stainless steel Frequency	Wheel mechanism stainless steel Max. deformation
Modal 1	4.3831	8.4044	4.3909	8.2809	160.48	466.28	162.59	178.02
Modal 2	4.7655	16.012	4.7457	15.374	161.39	5535.20	163.04	178.15
Modal 3	5.0265	17.145	5.060	16.987	162.19	5570.2	168.14	20.477
Modal 4	5.2819	10.164	5.3052	10.143	179.12	1109.9	203.28	84.956
Modal 5	5.3104	10.207	5.399	10.200	209.22	5621.8	209.42	155.2
Modal 6	5.7584	10.435	5.6816	10.923	209.40	5612.5	211.19	133.13

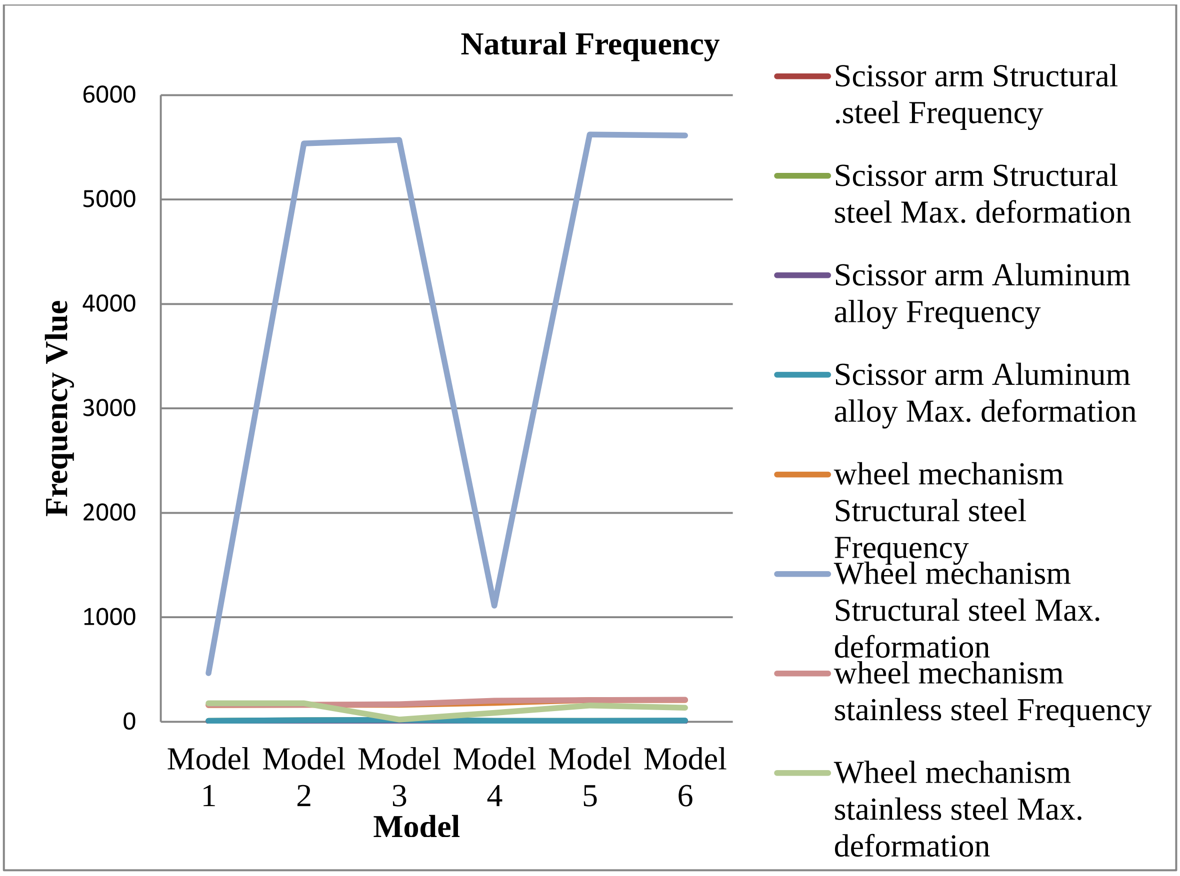


Figure 4.24 Natural frequencies (Hz) of six modal deformations

In dynamic analysis as observed from the analytical and the simulation result of ASYSIS 2022 R1 version software, the values of total deformation at the scissor arm of mobile hydraulic scissor lift materials of structure steel and stainless steel had almost uniform size throughout its length, so small variation of maximum deformation occurs in figure 4.24.

Table 4.3 Natural frequencies (Hz) of Scissor arm components

Natural frequencies	Scissor arm Structure steel Max. deformation	Scissor arm Aluminum alloy Max. deformation
Modal 1	8.4044	8.2809
Modal 2	16.012	15.374
Modal 3	17.145	16.987
Modal 4	10.164	10.143
Modal 5	10.207	10.2
Modal 6	10.435	10.923

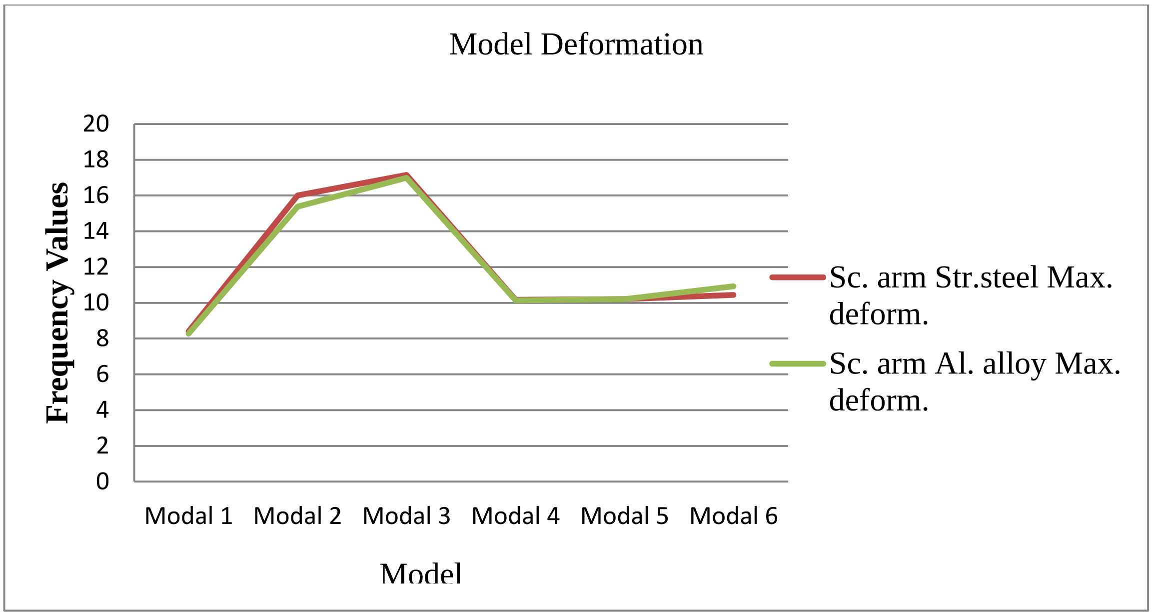


Figure 4.25 Natural frequencies (Hz) of Scissor arm component

When comparing structural steel material with what reviewed in the literature review, the natural frequencies of MS and SAE 1020 materials of the Analysis & Optimization of Hydraulic Scissor Lift research done by (Sabde. et al 2016) are described in the table 4.4.

Table 4.4 Natural frequencies (Hz) of six modal deformations of different materials

No. of Modes	Natural frequencies of MS Lift in Hz	Natural frequencies of SAE 1020 Lift in Hz	Natural frequencies of structure steel Lift in Hz
1	8.042	7.9776	8.4044
2	9.3021	9.2953	16.012
3	9.4902	9.4301	17.145
4	13.55	13.54	10.164
5	20.505	20.487	10.207
6	27.239	27.02	10.435

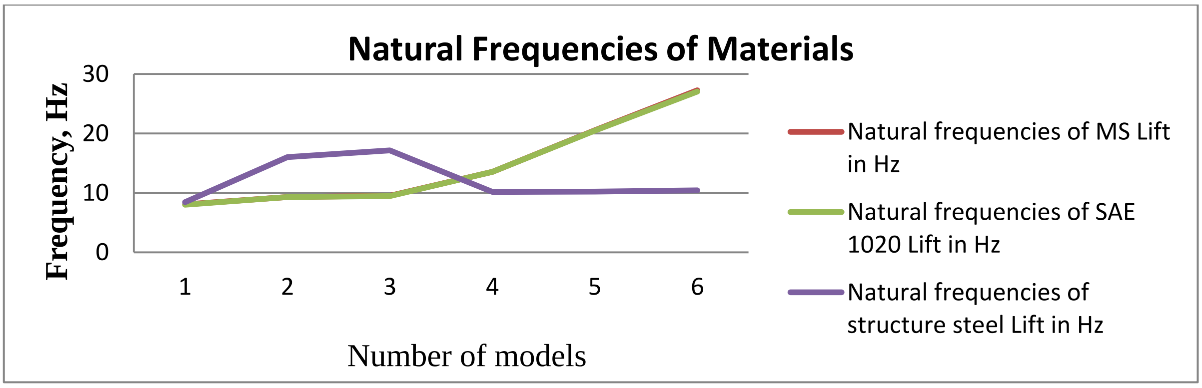


Figure 4.26 Model analyses of different materials

The natural frequency of MS and SAE 1020 lift does not match with frequency of external excitation, which causes resonance. But natural frequencies match with the frequency of external excitation; hence there will be resonance which will cause severe vibrations. The detailed modal analysis that has been done in ANSYS 2022 R1 with its sequential mode shapes is shown in the above figures. If we compare corresponding deformations of each mode shape MS lift and SAE 1020 with structure steel, structure steel has almost similar and less deformation so less chance of failure of lift parts.

As research studied on “Design and Analysis of an Aerial Scissor Lift” (Soma Raghavendra. et al 2017) using different steel materials and structural steel material used in this thesis, the analyzed results shown in table 4.5 and 4.6.

Table.4.5 Maximum and minimum Equivalent stress and deformation

Material	Equivalent stress		Total Deformation	
	Min	Max	Min	Max
Aluminum alloy	0	41.407	0	17.254
Magnesium alloy	0	40.949	0	27.288
Stainless steel	0	42.042	0	6.0984

Table.4.6 Analysis of different material modal of six deformations

Material	Aluminum alloy	Magnesium alloy	Stainless steel	Structure steel
Mode 1	5.0365	5.0351	2.9754	8.4044
Mode 2	4.4864	4.9799	2.6525	16.012
Mode 3	1.2897	5.3649	2.6049	17.145
Mode 4	4.6839	5.9013	3.1404	10.164
Mode 5	5.3044	6.3762	2.9588	10.207
Mode 6	4.2924	5.6374	2.608	10.435

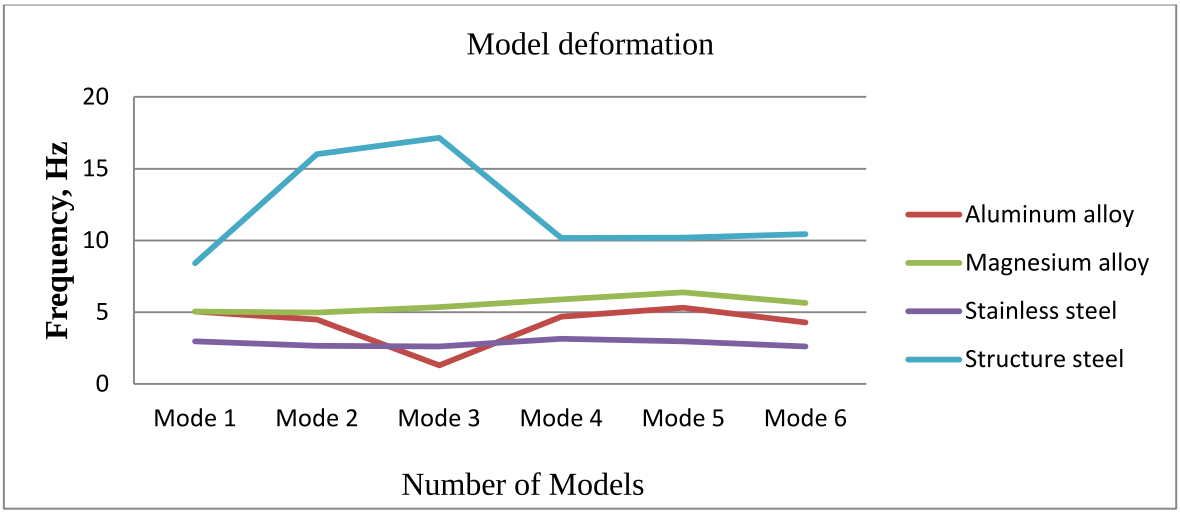
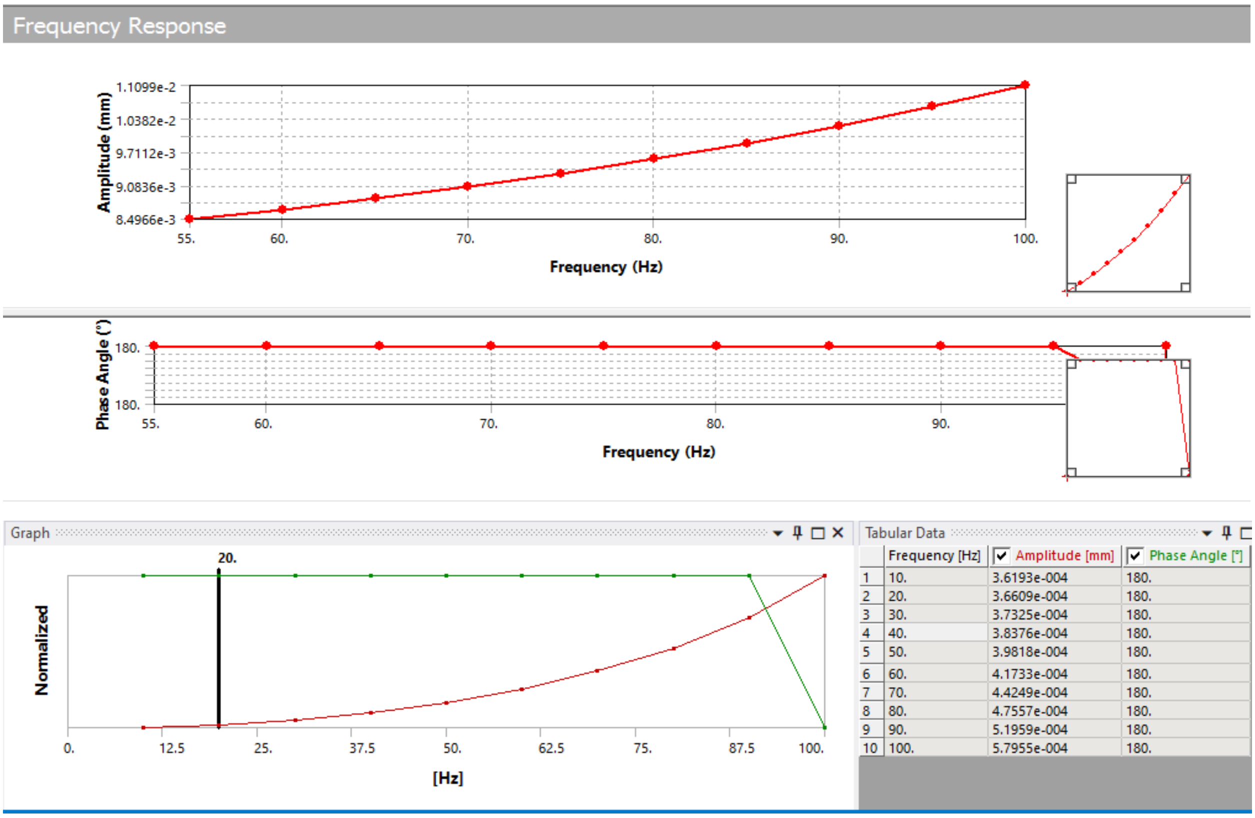


Figure 4.27 Model analyses of different materials

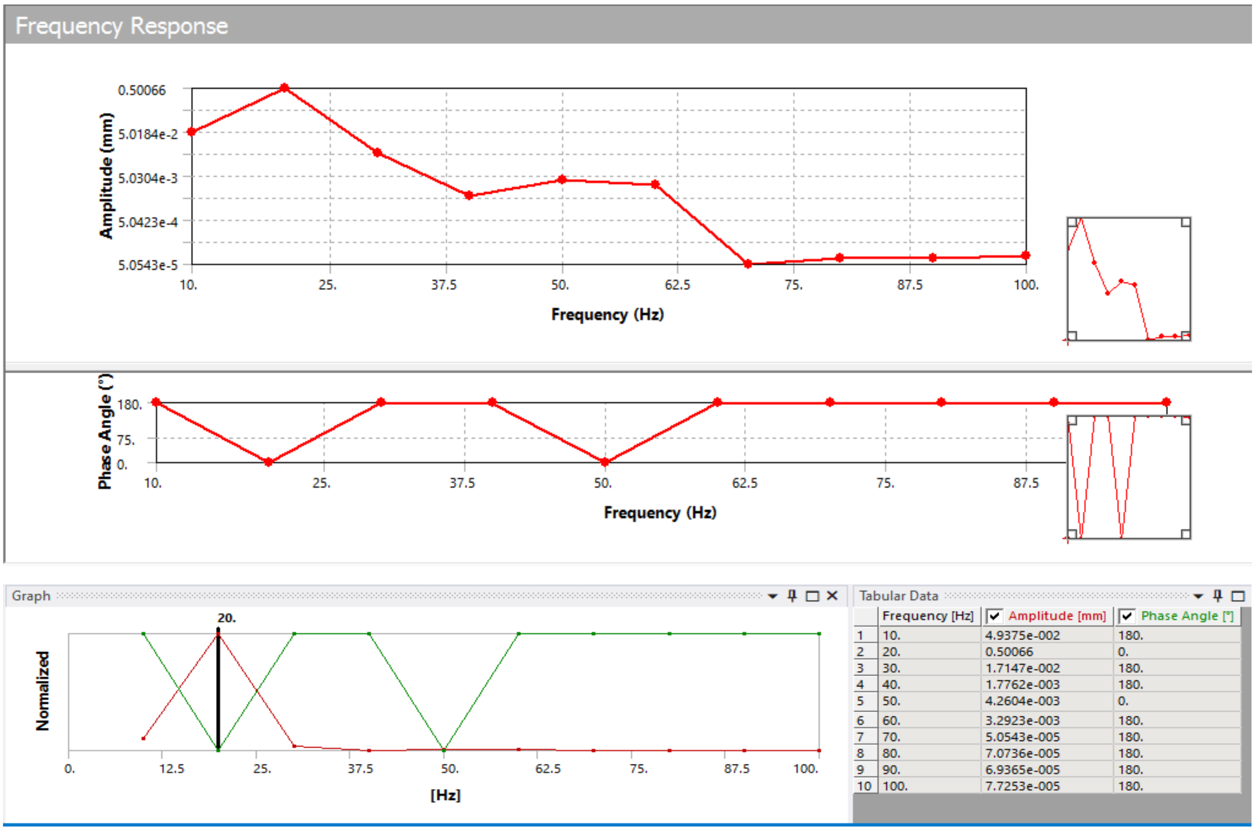
4.3 Frequency Response of Harmonic Analysis

The harmonic response analysis determines the steady state response of a structure that is subjected to loads that vary sinusoidal over time. This analysis enables us to verify whether the designs will successfully handle resonance, fatigue, and other harmful effects of forced vibrations. Harmonic response analysis is used to simulate how the structure will respond to sinusoidal repeating dynamic loading. Amplitude is the distance between the waves's resting position and its maximum displacement. Frequency is the number of waves that pass by a specific point per second. The step of harmonic analysis of mobile hydraulic scissor lift components was first it has been solved for modal analysis of natural frequency. The harmonic response was dragged and put into a modal solution setting, in the harmonic response of the analysis setting it has been seen what the frequency spacing from the modal analysis is. The range harmonic response from the minimum and maximum natural frequency has been taken after 47088N load was applied to harmonic response which was done for a frequency range of 0Hz to 100Hz. The analysis consists of a plot of the amplitude of spring which is nothing but the deflection and equivalent stress of spring plotted against the defined frequency range. Modal analysis for the scissor arm and wheel mechanism was done and frequency responses are plotted as shown in the figure 4.28.

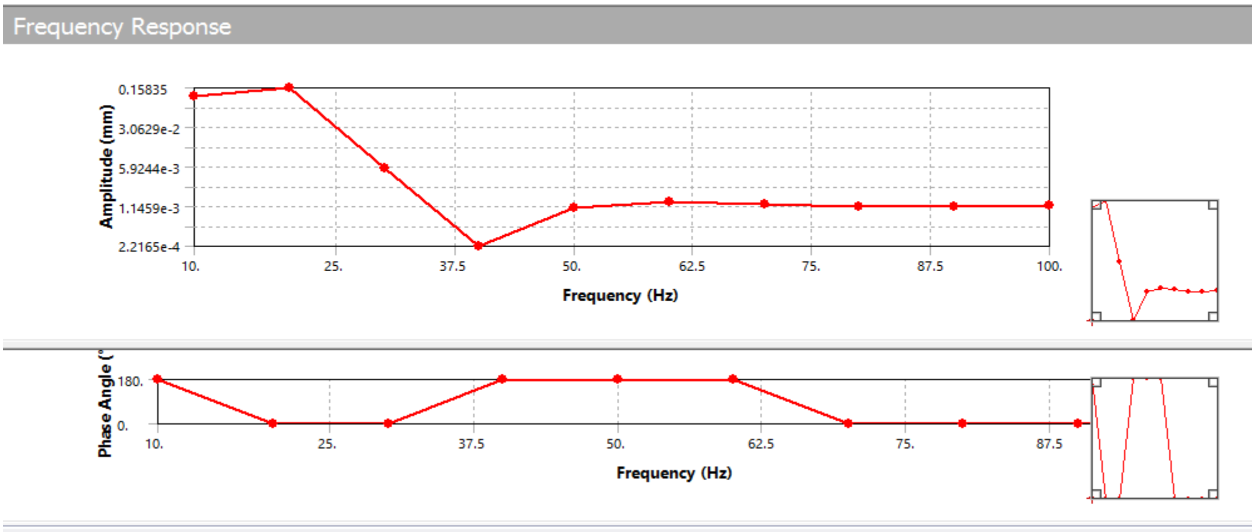


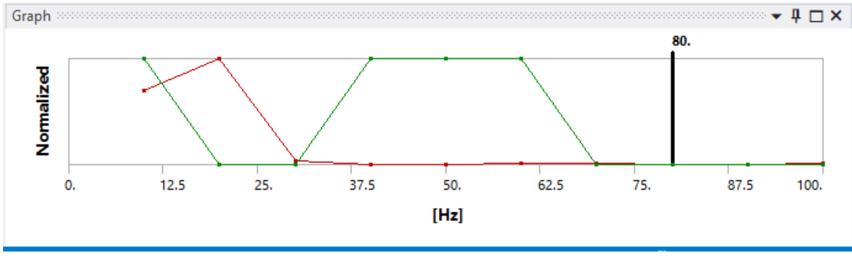
	Frequency [Hz]	Amplitude [mm]	Phase Angle [°]
1	10.	3.6193e-004	180.
2	20.	3.6609e-004	180.
3	30.	3.7325e-004	180.
4	40.	3.8376e-004	180.
5	50.	3.9818e-004	180.
6	60.	4.1733e-004	180.
7	70.	4.4249e-004	180.
8	80.	4.7557e-004	180.
9	90.	5.1959e-004	180.
10	100.	5.7955e-004	180.

Figure 4.28 Deformation of wheel mechanism frequency response



	Frequency [Hz]	Amplitude [mm]	Phase Angle [°]
1	10.	4.9375e-002	180.
2	20.	0.50066	0.
3	30.	1.7147e-002	180.
4	40.	1.7762e-003	180.
5	50.	4.2604e-003	0.
6	60.	3.2923e-003	180.
7	70.	5.0543e-005	180.
8	80.	7.0736e-005	180.
9	90.	6.9365e-005	180.
10	100.	7.7253e-005	180.





Tabular Data

	Frequency [Hz]	Amplitude [mm]	Phase Angle [°]
1	10.	0.11125	180.
2	20.	0.15835	0.
3	30.	5.7651e-003	0.
4	40.	2.2165e-004	180.
5	50.	1.1086e-003	180.
6	60.	1.3789e-003	180.
7	70.	1.2835e-003	0.
8	80.	1.1298e-003	0.
9	90.	1.125e-003	0.
10	100.	1.1913e-003	0.

Figure 4.29 Deformation of scissor arm frequency response of stainless and structure steel

The above graph shows the frequency response (resonance curve) for the same node and load case. We can recognize see that the structure has high resonant at frequencies around 10Hz, and 20Hz. At frequencies 30Hz, 40Hz, 50Hz, and 60Hz medium resonant, and higher frequencies above 60Hz smaller resonances. When we compare the deformation of scissor arm frequency response of stainless steel and structure steel materials from the above two graphs, structure steel resonant is almost the same and smaller at frequencies increases. From the above graphs, it can be realized that for certain frequency values, the maximum deflection gets. This frequency is not the natural frequency of that material but the frequency near the natural frequency for which we get maximum deflection.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

The mobile hydraulic scissor lift is extremely beneficial for workers in the automotive industries, vehicle maintenance workshops, or service stations. The results obtained from the study performed were summarized as follows:

The mobile hydraulic scissor lift studs is made of mechanical, hydraulic and electrical parts which have a 1.875m2 area of each two sections, hollow between two sections that used to be visible under the side of the vehicle and working height of 2m from the ground, 5m length, and 2.5m width, under the base of the system four wheel mechanisms were attached and the total maximum load applied on the system is 47,088N.

A mobile hydraulic scissor lift has a double-acting hydraulic cylinder with a 650mm stroke and 63mm cylinder diameter to extend and contract the system safely. Also, the maximum working pressure of the pump was determined as 160 bar. In this case decided to use electric power as a source of power and implement an electrical motor that operated the hydraulic pump applying pressure on hydraulic cylinders, which reciprocate by lifting the scissor arms and the load. According to the calculation of motor power, the electric motor selected for this system is 12.5kW. To carry the load safely, the scissor arms and all frames are designed from structural steel material as it has greater durability, strength, etc. stainless steel is selected for the construction of the top platform plate, stand plate, and extend ramp plate as it has greater corrosion resistance.

The mobile hydraulic scissor lift is simple to use and does not require routine maintenance. The main constraint of this device is sturdy, flexible, and durable, can lift heavy objects, it's a less initial cost, maintenance cost, and is easy to use.

The design and analysis of the mobile hydraulic scissor lifting system were performed with a finite element method program that is the system is modeled with the Solid Work 2022 software and the analysis was done with ANSYS 2022 R1 workbench. The analyses are processed in static and dynamic structural conditions. We analyzed the maximum von-misses stress after applying a pressure of 16.677kPa on each section. The results showed that the maximum equivalent stress induced in structure steel is 242.94MPa, Aluminum alloy is 1014.7MPa and stainless steel is 274.11MPa. When compared to the corresponding equivalent stress structure steel 242.94MPa, it has less equivalent (von-mises) stress. Then the design is safe and easily sustains the load. The maximum deformation that occurred at the scissor arm was determined as 62.169mm and the maximum deformation at the optimum range value is in the acceptable range of value.

During working it is found that the natural frequency of the lift should not be equal to the external excitation frequency hence vibration in the lift is low. The hydraulic circuit of the system was created with the Fluid-Sim program. In case of any pressure loss (power failure, etc.), the hydraulic accumulator in the system began to start ensuring the operation of the system safely.

So what conclusion from the result, structural steel has greater durability and strength and it is also easily available and stainless steel has high corrosion resistance. These properties play an important role in designing a mobile hydraulic scissor lift. So in designing the mobile hydraulic scissor lift structural steel used to design scissor arms, frame, angle bar, etc. and stainless steel used for top plate, ramp extension plate and stand plates were selected as of greater importance.

5.2 Recommendations and Future Work

In this study there are still some shortcomings and possibilities to do further research, among others:

- Researchers will be able to conduct research on mobile hydraulic scissor type light duty vehicle loading/unloading lift technology that can generate energy to move it easily from one place to another for use everywhere.
- Researchers will be able to design a winch mechanism used to pull unfunctional vehicles to load/unload.
- Researchers may do a design by increasing the carrying capacity of the wheel mechanism spring that stands with vehicle weight to move unfunctional vehicles from one place to another.

The hydraulic scissor lift has always been an integral part of any operation related to servicing the vehicle; it can be used for light duty vehicle loading/unloading while improving the balancing of the machine. Different factors affect the balancing of the mobile hydraulic scissor lift system such as the effect of the land topography and wind. In this work, the balancing mechanism is not detail studied. So needs further investigation to study on balancing of the mobile hydraulic scissor lift structures and some adjustments to the stand plate may also be necessary to accommodate the mobile hydraulic scissor lift.

REFERANCES

Abdalla, M.O. and Nagarajan, T. (2015) A Computational Study of the Actuation Speed of the Hydraulic Cylinder under Different Ports Sizes And Configurations', 10(2), pp. 160–173.

Anthony E. and Pr. Emeritus. Department of manufacturing engineering Miami University Fluid Power with Applications 4th Ed.TJ843.E86.

Bosch Rexroth AG, RE 17341, edition: 2022-07.

Cengiz D., Mahmut et al (2018). Design and Analysis of Scissor Lifting System by Using Finite Elements Method.

Dengiz, C. G. et al. (2018a) 'Design and Analysis of Scissor Lifting System by Using Finite Elements Method', (March). doi: 10.13189/ujms.2018.060202.

Dengiz, C. G. et al. (2018b) 'Design and Analysis of Scissor Lifting System by Using

Dhanawade, S. B. et al. (2017) Design, Analysis and Development of Hydraulic Scissor Lift Material loading and unloading', International Journal of Advance Engineering and Research, pp. 214–221.

Dishant G. and Yogesh D. (2018). Design and Development of Scissor Type Car Lifter. Asian Review of Mechanical Engineering ISSN: 2249- 6289 Vol.7 No.2

Divyesh P., Alan F. et al (2015). Design, Analysis and Development of Multiutility home equipment using Scissor Lift Mechanism. IJSRM ||Volume||3||Issue||3|| 2405-2408 ISSN (e): 2321-3418.

Gaffar G, Momin, et al (2015). Design, Manufacturing & Analysis of Hydraulic Scissor Lift. International Journal of Engineering Research and General Science Volume 3, Issue 2, Part 2, ISSN 2091-2730.

Gnanabharathi G. (2017). Strength analysis of scissor lift developed for household applications, Unpublished.'' Thesis submitted to Kaunas University of Technology.

Herbert E. and Merritt J. W. Hydraulic Control Systems. New York.lendon.

He, S. et al. (2019) 'Mechanical simulation and installation position optimization of a lifting cylinder of a scissors aerial work platform', pp. 74–78. doi: 10.1049/joe.2018.8961.

Hibbeler, R. C (2016)."Engineering mechanics statics and dynamics" 14th edition Finite Elements Method', 6(2), pp. 58–63. doi: 10.13189/ujms.2018.060202.

http://ir.bdu.edu.et/handle/123456789/12811.

https://www.industrialmanlifts.com.

https://www.thespringstore.com/compression-spring-designing-considerations. html

https://www.abilitylifts.co.uk

https://www.toyota-gib.com/eng/models/dual-purpose-type/hilux/hilux-lhd-30l-diesel-5-seater-LAN125L-DNMSEN.html,https://www.edmunds.com.

https://www.@Civilengineeringrealities.com

https://www.xometry.com>materials, eurocodeapplied.com.

http://www.internationaljournalssrg.org/.

Liu, T. and Sun, J. (2009) Simulative Calculation and Optimal Design of Scissor Lifting Mechanism, pp.

Lovrec, D. (2016) Design of Modern Hydraulic Tank doi: 10.2507/IJSIMM11(2)2.202.

M. Kiran, J. Chandrasheker et al (June-2016). Design & Analysis of Hydraulic Scissor Lift. IRJET e-ISSN: 2395 -0056 Volume: 03 Issue: 06.

M.Pranita B. et al, (December 2016). Design and Fabrication of Mechanical Lift for Transportation. GRD Journal for Engineering | Volume 2 | Issue 1 | ISSN: 2455-5703.

Miss.Pranita B.D., Verushali et al Design and Fabrication of Mechanical Lift for Transportation, vol. 2, 90 no. 1, pp. 30–34, 2016.

Peter J.Chapple, (2003) Principles of Hydraulic System Design circuite, Brtish Fluid Power assocation, First Edition, ISBN 1901892158, Cocusion Mur Puplishing Company.

R.Panchamoorthy, Velappan et al. (June/ 2020). Design and fabrication of hydraulic scissor lift. Journal of Engineering Science Volume 11, Issue 6, ISSN No: 0377-9254

Sabde A. and Prof. Jamgekar R.S., (2016). Analysis & Optimization of Hydraulic Scissor Lift. IJEDR | Volume 4, Issue 4 | ISSN: 2321-9939.

Saxena, A. (1989) 'Deriving a Generalized, Actuator Position-Independent Expression for the Force Output of a Scissor Lift', pp. 1–18.

Spring Engineers of Houston, Ltd. | http:/www.springhouston.com/www.steelexpress.co.uk

Wubshet Y. and Yanshuang W. (2019) Design, Analysis and Manufacturing of double Scissors Lift Elevated by One Hydraulic Cylinder. IJERT ISSN: 2278-0181, Vol. 8 Issue 11,