KAUNAS UNIVERSITY OF TECHNOLOGY

MECHANICAL ENGINEERING AND DESIGN FACULTY

Gnanabharathi Ganesan

STRENGTH ANALYSIS OF SCISSOR LIFT DEVELOPED FOR HOUSEHOLD APPLICATIONS

Master's Degree Final Project

Supervisor

Assoc. prof. dr. Audrius Jutas.

KAUNAS, 2017

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(Title and code of study programme, code)

"STRENGTH ANALYSIS OF SCISSOR LIFT DEVELOPED

FOR HOUSEHOLD APPLICATIONS"

DECLARATION OF ACADEMIC INTEGRITY

____ June 2017

Kaunas

I confirm that the final project of mine, **Gnanabharathi Ganesan**, on the subject "Strength analysis of scissor lift developed for household applications" is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarized from any printed, Internet-based or otherwise recorded sources. All direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by law) have been paid to anyone for any contribution to this thesis.

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KAUNAS UNIVERSITY OF TECHNOLOGY

FACULTY OF MECHANICAL ENGINEERING AND DESIGN

Approved:

Head of Mechanical Engineering Department	(Signature, date) Vytautas Grigas (Name, Surname)
Head of Study Programmes in the Field of Mechanical Engineering	(Signature, date) Kęstutis Pilkauskas (Name, Surname)

MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT
STUDY PROGRAMME MECHANICAL ENGINERING - 621H30001

Approved by the Dean's Order No. V25-11-8 of April 21, 2017 y

Assigned to the student **Gnanabharathi Ganesan**
____
(Name, Surname)

1. Title of the Project

Strength analysis of scissor lift developed for household applications.

2. Aim of the project

The aim of the project is to design and strength analysis of the scissor lift that is elevated by the mechanical drive (leadscrew and bevel gear) for household application.

3. Tasks of the project

- Operational modelling according to different conditions of expectation.
- Stress analysis of the structural elements consisting frame.
- To adopt mechanical drive for the scissor lift

4. Specific Requirements

The device is limited to a mean load of 300Kilograms.

5. This task assignment is an integral part of the final project

6. Project submission deadline: 2017 May 19th

Task Assignment received	Gnanabharathi Ganesan (Name, Surname of the Student)	______________________ (Signature, date)
Supervisor	Assoc. prof. dr. Audrius Jutas (Position, Name, Surname)	______________________ (Signature, date)

Gnanabharathi Ganesan. Strength analysis of scissor lift developed for household applications. Masters in Mechanical Engineering Supervisor Assoc. prof. dr. Audrius Jutas; Kaunas University of Technology, Mechanical Engineering faculty, Mechanical Engineering department.
Kaunas, 2017. 63 p.

Summary

In this research proposal, an attempt is made to strength evaluation according to stress analysis of scissor lift developed for household application. Conventionally a scissor lift or jack is used for lifting a person's, medium weight things to appreciable height and it will be used for numerous functions like maintenance and lots of material handling operations. We can find the scissor lift by mechanical, pneumatic or hydraulic kind. But in this project it's targeted to develop the scissor lift by exploitation of the mechanical drive (leadscrew, bevel gear) that is fitted upper plate of the lift to control the consumer throughout its exportation, when he is on the upper panel of the lift. But the design delineate within the paper is developed keeping in mind that the lift operated by mechanical drive with the above mentioned condition suggests that, so that the price of the lift is reduced. Also such design will build the lift's additional compact and a much more suitable for household application. To achieve this project objective, I followed the project design methodology from theoretical calculations, design had been done by exploitation SolidWorks 2014 package and analysis had been done by ANSYS R14.5 package.

KEY WORDS: scissor lift, mechanical drive, stress, simulation.

Gnanabharathi Ganesan. Namų ūkiams skirto žirklinio keltuvo stiprumo analizė.
Magistratūros studijų baigiamojo darbo vadovas doc. Audrius Jutas.
Kauno technologijos Universitetas, Mechanikos inžinerijos ir dizaino fakultetas,
Inžinerinės mechanikos katedra.
Kaunas, 2017. 63 p.

Santrauka

Šiame tyrime sprendžiami keltuvo, skirto namų ūkiams, stiprumo klausimai, pasitelkent įtempių analizę.
Šis keltuvas yra skirtas kelti žmones ar daiktus į pasirinktą aukštį bei suteikia galimybę atlikti tam tikrus ūkio darbus. Tarp dažniausiai naudojamų keltuvų yra mechaniniai, pneumatiniai ir hidrauliniai keltuvai. Šiuo darbu siekiama ištobulinti keltuvą su mechanine pavara (kūginiai krumpliaračiais), kuri yra sumontuota judančioje keltuvo platformoje ir gali būti valdoma naudotojo stovinčiam ant jos. Šio keltuvo dizainui būtina įtempių analizė, kuriais siekiama sukurti patrauklios kainos gaminį. Kita vertus, toks keltuvas turi būti kompaktiškas ir nesunkiai transportuojamas. Kad būtų įgyvendinti iškelti tikslai, keltuvo dizainas buvo kuriamas naudojantis programiniu paketu SolidWorks 2014, o įtempių analizei buvo naudojamasi analitinėmis įtempių būvio formulėmis ir programiniu paketu ANSYS R14.5.

RAKTINIAI ŽODŽIAI: *žirklinis keltuvas, mechaninė pavara, įtempiai, modeliavimas.*

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1. Introduction

Before the creation of weight lifting device like jack screw, pneumatic jack, hydraulic jack, crane, etc., people lift the 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 lifting stuffs.

Any machine part cannot be moved to a desired position with application of less amount of external force. For placing a component in required location, the motion of component follows commonly horizontal or vertical direction. Many machines such as aerial lift, boom lifts, scissor lift, man lift, tele handler, towable lift are used to move machinery and manpower in different directions based on the requirement. A scissor lift is a portable, easily extended and compressed, safe operating machine used for transportation of medium sized components to its expected position. A scissor lift is 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. The scissor lift mechanism is based on linked arms in a criss-cross 'X' pattern which can be folded and extended in exact direction similar to a pantograph. Usually upward motion is achieved by the application of pressure to the outside of the lowest set of supports, elongating the crossing pattern, and propelling the work platform vertically upwards.

This project aims at making a scissor lift, that is easy to use/operate, elevated height limit, cost effective and movable as well as reducing the maintenance cost. So that it'll be used conveniently used handily employed in day to day activities at home and may be used in garages, hotels and many further applications. For these application in this project a scissor lift, which is operated by a leadscrew mechanism, which is driven by the bevel gear is designed to lift material and consumer to the desired height. Lift capability is up to 300 kilograms and it can be elevated almost two-meter height that is suitable for the household application. The key inspiration of this design of the lift is mechanical drive (leadscrew, bevel gear and Ratchet Pawl) that is fitted in upper part of the lift.

1.1 Project Background

To pick and place stuffs, painting and to carrying light weight in a house or shop we are usually necessary to use the ladder or elevator. Accordingly, a variety of scissor lifts have been developed for lifting an object and consumer too. But for safety and cargo carrying purpose no one prefer the ladder in a house, ladder is only used for terribly small functions. Due to this normally individuals like the scissor lift rather than ladder for his or her safety and different functions. Furthermore, scissor lifts which is usually accessible within the market are generally massive, heavy, difficult to store, transport and expensive. In addition to the difficulties in repairing dispatch and assembly process and maintenance process. Probably for in operation these elevator, less physical effort is enough for the operator but user ought to be having knowledge and skills.

In light of such inherent disadvantages, commercial purpose user approaches unremarkably equipped scissor lift, wherein such system is raised and lowered via pneumatic, hydraulic or electrically-powered systems. However, because of the lift size, complex to operate, purchasing and maintaining these lifts people not prepared to get this system for the household application. So that during this project to avoiding these kind of difficulties and fulfil the expectation of the individuals wants and desires, a scissor lift that is operated by mechanical drive has been developed.

1.2 Project problem Statement

"Never attempt to solve all the matters at once- make them line up for one by one". According to the market basically today the lift machines provided victimization the hydraulic system and alternative advanced system as a result of for obtaining the precise movement and alternative functions. With the limitations encountered within the use of ropes, ladders, scaffold, hydraulic and other advanced lifts in obtaining to elevated height like the quantity of load to be carried, comfortable, time consumption, much etc. So what try to do this project proposal is an inspiration of attempt to develop carry machines that not use the advanced systems however mechanical drive scissors carry which can overcome the higher than declared limitations is employed.

1.3 Scope of the study

The design of the scissor lift is to elevate up to a height of about three meter and carrying capability of however 300 kilograms. For this requirements in this project I even ought to calculation for the applicable dimensions of the mechanical parts of the lift, how to design the scissor lift legs, upper plate, lower plate and the mechanical drive for the above same criteria and ultimately we've design this system using SolidWorks 2014 package and analysis by using ANSYS R14.5 package.

1.4 Project objective

- ➢ Operational modelling according to different conditions of expectation.
- ➢ Strength analysis of the structural elements consisting frame.
- ➢ The device is limited to a mean load of 300 kilograms.

We should additionally concern alternative criteria. Such as

- ➢ Expectation of selected materials
- ➢ Transportation and
- ➢ Safety related needs.

Targeted customers,

- Household consumer
- Warehouse consumer and
- Utility and Painting contractor

1.5 Project importance

To design associate degree an analyze, a scissor lift is to carry the consumer along with the belongings well and safely to a needed desired height. In this project, the mechanical drive fixed in upper plate of the lift to use the consumer throughout its exportation, when consumer on the upper plate of the lift. So that there's no have to be compelled to external help or help from a second party as a result of the beginning of the planning. And the scissor lift should be terribly easy, portable, strong, safety, very user friendly in handling method, environment friendly and less maintenance cost.

2. Analysis of existing approaches

A scissor lift is a kind of platform that can normally just move vertically. The instrument to accomplish this is the utilization of connected, collapsing underpins in a crosswise "X" design, known as a pantograph (or scissor system) [1]. Scissor lifts are a specific kind of airborne lift, intended to lift bigger loads and give more work space. Diesel or gas-fueled scissor lifts regularly called harsh territory scissor lifts are better for open air use, yet can't be utilized inside. Scissor lifts which is controlled by electric, pneumatic or mechanical drive, which settles on them a superior decision for use in distribution centers or other indoor work. The most fundamental thought while picking a scissor lift is weight carrying limit, the height we have to achieve, size and price of the lift.

2.1 Medium duty scissor lifts available in market

SL. No	**Name**	**Description**	**Specifications**				
			Platform size (length× width) mm	**Lifting height mm**	**Lowered height mm**	**Net Weight Kg**	**Lifting capacity Kg**
1	**Manually operated lift** [2] 	This is manually operated mobile scissor lift, which is operated by rotation of handle	950×600	1100	450	85	250

2	**Air bag lift** [2] 	This lift operated by using compressed air to give the linear motion to the system (Rise and lower operation)	1219×813	838.2	228.6	165	450
3	**Hydraulic scissor lift** [2] 	This lift is operated by using hydraulic power. Lift or lower the operation by simply handy foot pedal control	1010×520	1000	435	150	400

4	**Double scissor lift** [2] 	Double scissor lift basically operated by hydraulic power but it has been designed for increasing capable of increasing height limit.	1010×520	1500	450	180	500

On a comparative study of these various kinds of scissor lifts available in the market, we can infer that

- Incompact models, the highest height that they are able to lift is 1 meter.
- More the height required, the more the weight of the lift becomes.
- The price of the lifts increase as the capacity increases, which is more than affordable (or) expensive for household purposes. On the other hand, they might be feasible for commercial purposes.

2.2 Literature Review

Scissor lift design for use in the automotive industry [3]

Macaulay Oletu Stanley [3] discuss about what are lift available in the automotive industry. Now recent years, numerous platforms or devices with various means that of application have been made to be used within the automotive trade. He just said that how the automotive industry has additionally expertise the flow of numerous lifting platform which is operated by different power sources i.e. electrically operated lift, pneumatic operated lift and hydraulic powered lift. Recent research additionally shows the use of restraint for raising or lowering load (MichaelAdel, PE (2008): Scissors raise Deflection Understanding All these lifting devices have contributed impressively to the automotive industries. This report presents a scissors mechanism with a platform table that will be horizontal at each level. The proposed mechanism is a double scissors for stability.

Lift system to ascend/descend stairs [4]

This paper Leah McElhaney et.al [4] describes about design, manufacturing and analysis the carry for manual chair at some considering conditions. The main purpose of this automatic lift to ascend and descend front steps are going to be purposeful and sensible for the Giroux family. While coming up with this carry they are considering the important parts of this automatic lift. The client requests that the elevate be transferable thus that it will be utilized in many places and it can be easily portable and ready to operate into the family van. The lift can additionally be foldaway and ready to work into the family van. When folded, the lift can't exceed a breadth of 18" to confirm enough space for the consumer and his or her members of the family within the van while not threatening safety [4]. It is necessary that the lift even have tie downs at the bottom for the client's chair. Drawback of this carry can't be accessible to the shopper his or herself, and will solely be ready to begin and stop with help from a second party. In this project, wheel chair ramp designed to resist approximately a hundred and five pounds including client and wheel chair weigh. The ramp will conjointly be designed to carry additional weight to confirm that because the consumer grows client will be able to still use the wheelchair.

Design, development and analysis of z-axis translation for an earth sensor test facility [5]

Ghanashyam KG et.al [5] objective of the work is to design and auxiliary examination a z-pivot interpretation for an earth finder check office within the Earth research center, Laboratory for Electro-Optics System (LEOS), ISRO Bangalore. To develop a simple solution for the direction hub interpretation, considering the physical and material restrictions in addition in light of the fact that the administrator's safety and basic availability of the gadget. As of now there is an exist setup of direction hub interpreters that has been implemented on a limited extent for an equipment testing. This thesis the gadget established and exposes a comparatively new idea that's fitting space, safety and easy-access requirements of the take a look at facility in the earth laboratory.

An investigation on the dynamic stability of scissor lift [6]

Ren G. Dong et.al reveals [6] to learn about the tip-over of scissor lifts in operation has regularly brought about the serious wounds of faculty. The target of this paper is to upgrade the comprehension of its significant systems and elements affecting scissor lift stability of both exploratory and demonstrating methodologies were utilized. Two arrangement of examinations were performed under conceivable tip-over situations: check effect and pothole despondency. In view of the dynamic attributes distinguished from the test comes about, a lumped-parameter model of the scissor lift was produced. It was connected to research the impact of scissor structure adaptability on the tip-over capability of the lift, to comprehend tip-over instruments, and to investigate preventive systems.

United states patent 4534544 [7]

Heide et.al [7] research proposal had described, a lift comprises of a stage that the article to be lifted lays on and a scissors jack that is joined to the base of the stage and that can be spread up out of a developed position with rollers. One sets of the parallel scissoring legs of the jack is determinedly articulated with the platform and the left over pair of scissoring legs is appended to a pole that passages parallel to the base of the stage inside an aide mounted on it. Rollers are mounted on an unbending hub and the pivot is locked in by two chains that wrap around chain wheels inflexibly appended to the pole and which are associated with a transverse pillar. The front end of the transverse shaft is associated with a tensioning gadget that works parallel to the stage. Two freely turning rollers are mounted on the hub on every side of the jack, every roller leans against an assistant rail and mounted rail on each inside scissoring leg and the helper rails are inside the jack. One end of every secondary rail is mounted on the pole and the helper rails and guide rails are about half as long toward the free closures of the scissoring legs as the area of scissoring leg that stretches out from the central to the free end of the scissoring parts.

Design and kinematic analysis of gear powered scissor lift [8]

A.Roys Jeyangel et.al [8] their paper, scissor lifts controlled by rigging component has been presented. The parts of apparatus fueled scissor lift are spur gears, scissor arm platform and electric motor. The listed kinematic examination is performed on the instrument. For various length to sweep proportion, greatest translatory displacement is measured. For various pace of the engine, speed of the connection is concentrated on. Different lift statures can be accomplished by fluctuating the quantity of connections. The configuration scissor lift will have allowed their expected load with factor of safety and lifting to desired height. Finally, all these parts and its mechanism was simulated by using Automated Dynamic Analysis of Multi Body Dynamics Simulation Solution (ADAMS 2013) software package.

Design and optimization of scissor jack [9]

Chetan S et.al [9] the intention of this paper is about to design and optimization of scissor jack model for the automobile sector. Every engineering product consist of cost effective manufacturing and its flexibility maintaining as well as assign service life without failure. To considered those parameters this project focused on designing and analyzing the scissor jack model for actual loads at the same time to maintaining its strength and span time of the system for varying models of automobile (light motor vehicle) sectors. Basically automobile sectors are particularly focused at their productivity and customer satisfaction. In the wake of concentrating on disappointment models, done the scientific model scientifically and by utilizing programming's consequently made another adaptable scissor jack for this reason. At last demonstrating made by CATIA and scientific model finished by Graphic essential programming can be tried by ANSYS programming.

Design and calculation of the scissors-type Elevating Platforms [10]

Beqir Hamidi [10] main motive of his paper is to understand calculation and design of the scissor type lift. The scissors type hoisting platforms are made for elevated the load for vertical transport. They are of incredible use for the gathering works, the upkeep of developments or they can be utilized as parts of the internal material transportation framework. On the off chance that mounted on the right truck or vehicle they will get to be versatile, i.e. versatile to various purposes. The specificity in outlining and figuring of the structure of this kind of gadgets, originate from need that conveying structure needs to hold and transmit the heaps up to the right backings and in addition to guarantee the right kinematics of the mechanism. In addition, the conveying structure must be anticipated to accomplish required exhibitions (conveying limit, stage working surface, height of lifting and lifting time), and its general sizes must be as little as it be.

Design, development and analysis of electrically operated toggle jack using power of car battery [11]

Gaurav Shashikant Udgirkar et.al [11] motive is to breaks down the change of the present switch jack by joining an electric DC motor in the sink request to make load lifting simpler for emergency use with utilizing force of automobile battery (12 Volts). Gear proportion is utilized to build the lifting power. The signification and motivation behind this work is to change the current auto jack keeping in mind the end goal to make the operation simpler, more secure and more strength so as to extra individual interior strength and decrease safety chances particularly spinal pain issues connected with doing work in a twisted position for a drawn out stretch of time. The auto jack is produced utilizing CATIA V5R19 and broke down utilizing Finite Element Analysis to check safety variable and power acting. Creation work has been done utilizing with processing, boring, granulating, and welding machine. Finally, the created auto jack is tried on car. Execution of configuration will take care of issue connected with ergonomics.

Design and fabrication of a novel three-wheel robot with a SLE based lifting mechanism and line tracking capability [12]

Shameek Ganguly et.al [12] manages the look and improvement of a standard three-wheel robot able to do self-governing exploring an organized surroundings by recommends that of taking after a sinusoidal line on the ground. Besides, it is outfitted with a deployable scissor lift with partner complete effector plate accordingly giving application measured quality to the robot. The primary application is imagined to work a programmed target-chasing vehicle in commercial ventures like car and development wherever esteem adequacy is a vital measure for computerization and quality might be an amazingly attractive usefulness. Mechanical design is completed using stress examination with the help of the finite part programming system package ANSYS and velocity reaction bends range unit created for the extremely non-linear movement of the scissor lift. At last algorithm is created for fast line following abuse light-transmitting diode and picture semiconductor device matches and comes about in terms of experimental data further as simulated.

2.3 Conclusion

From the analyzed literatures we can see that the various kinds of scissor lifts are contrasted from each other by the changes that are brought about in terms of their weights dimensions of the links, and working area, material used in the links. Whereas, when it comes to the mechanism by which the lifts are operated, most of them fall into the hydraulic system category which makes the lifts heavy. On analyzing these models, we can clearly notice that there is not much emphasis placed on the weight of the lifts, but there are only changes in layout of the hydraulic system which makes one model different from the other.

3. Design calculations for scissor lift components

Scissor lift be made up of base platform, upper platform, lead screw, bevel gear, ratchet & pawl, bolt, nut, links and pins. There is no outline strategy accessible for planning these parts. On the basis of specific assumptions, the design for each of the components has been described as follows.

In this section, execution of this outline taking into account the measurement different numerical relations are produced. Here I have calculated normal force, shear force, bending moment and buckling load for how scissor lift link responded for the applied load of 300kg. Then for getting accurate result of strength and stability values (deformation and von-mises stress) by utilizing Ansys software, which can helpful to understand whether our lift can carry required load limit or not.

3.1 Design of scissor legs (link)

In scissor lift these legs are the vertical individuals that permit the platform to change height. Legs are made by Structural steel with the same scissor join height. When operator gives the movement to the lift, Movable ends of the lift will elevate the table to the desired height, making an “X” design with the legs. so that it provides the necessary support for the base platform [13].

If length of the legs increases, the pantograph contracts, height decrease. similarly, if the length decreases while height increases. this is depending on the angle of the link [13].

$$\text{Cos}(\theta) = \frac{L}{1.7} \quad \text{and} \quad \text{Sin}(\theta) = \frac{h}{1.7}$$

Table 3. 1 Scissor lift link position

Angle (θ) Degree	**Length (L)** Meter	**Height (h)** Meter
5	1.6935	0.1481
10	1.6741	0.2952
15	1.6421	0.4399

20	1.5975	0.5814
25	1.5407	0.7184
30	1.4722	0.85
35	1.3925	0.9750
40	1.3022	1.0927
45	1.2021	1.2021
50	1.0927	1.3023
55	0.9750	1.3925
60	0.85	1.4722

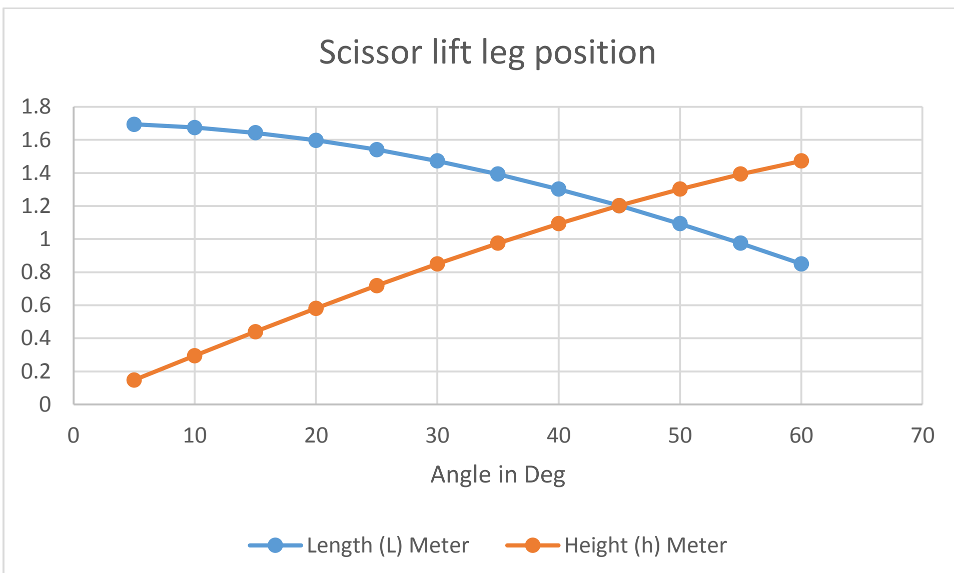


Figure 3. 1 scissor lift link position

For only one link it can reach 1.4722-meter height at 60^0, here in our design I have chosen double scissor lift link. So that we can capable to lift about 2.9-meter height.

3.1.1 Normal force, shear force and bending moment

Applied load (w) = 300Kg

Force (F) = 300×9.81= 2943N

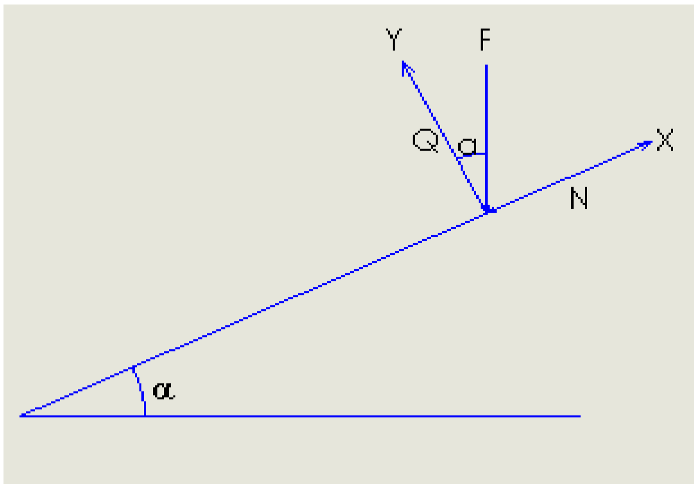


Figure 3.1. 1 Free body diagram

In scissor link due to applied force normal force takes place in longitudinal direction of the link and shear force is perpendicular to the normal force.

Table 3.1. 1 Normal Force, Shear Force and Bending moment

Angle (α) degree	$N = \frac{W}{4} \times \sin\alpha$ **N**	$Q = \frac{W}{4} \times \cos(\alpha)$ **N**	$M = \frac{W}{4} \times \frac{l}{2} \times \cos\alpha$ **Nm**
0	0	735.75	625.387
5	64.125	732.950	623.007
10	127.761	724.572	615.886
15	190.426	710.679	604.077
20	251.641	691.370	587.672

25	310.941	666.815	566.793
30	367.875	637.178	541.601
35	422.008	602.691	512.287
40	472.950	563.617	479.074
45	520.253	520.253	442.215
50	563.617	472.930	401.991
55	602.691	422.008	358.707
60	637.178	367.875	312.693

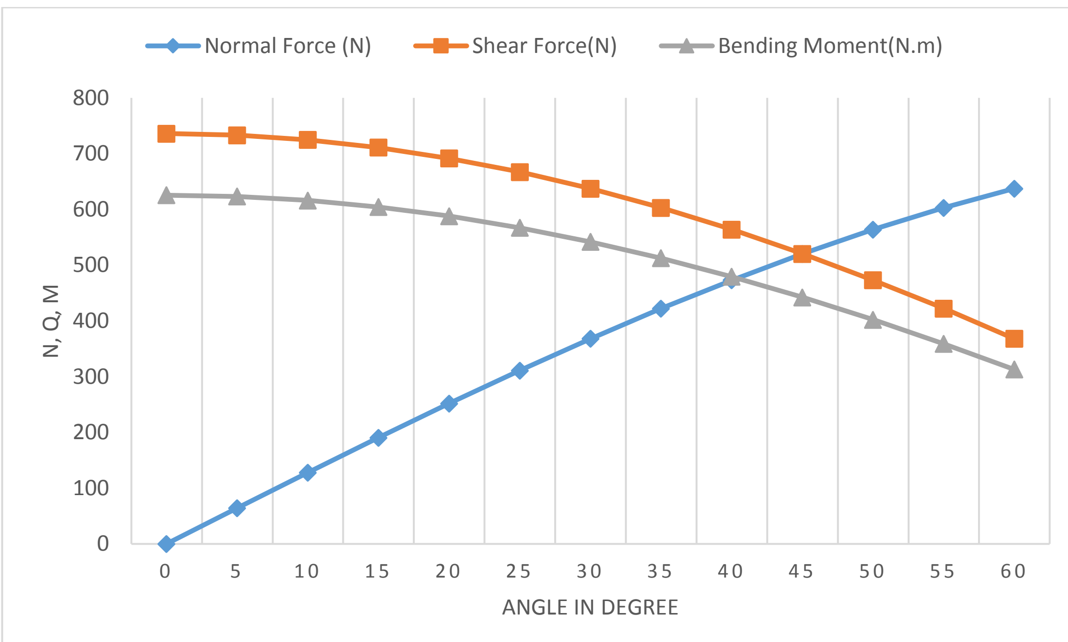


Figure 3.1. 2 Normal force, shear force & Bending moment

3.1.2 Normal stress due to normal force and bending

When we applied external load on the lift, shear force and bending moments are set up all the sections of the lift. Below I have calculated scissor lift link's normal stress values due to normal force and bending.

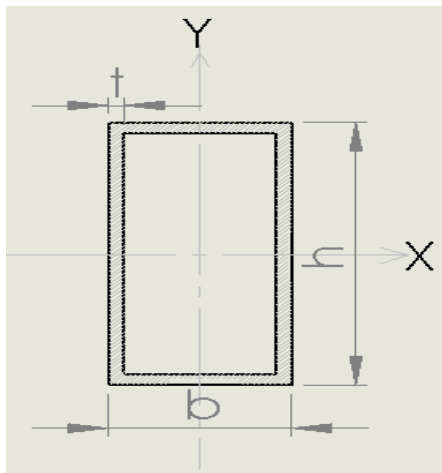


Figure 3.1. 3 Cross section of the link

Breath, b =30mm

Height, h= 60mm

Thickness, t= 2.5mm

where,

Normal stress due to normal force, $\boldsymbol{\sigma_N} = \frac{\boldsymbol{N(\alpha)}}{\boldsymbol{A}}$

Normal stress due to bending, $\boldsymbol{\sigma_M} = \frac{\boldsymbol{M(\alpha)}}{\boldsymbol{Wx}}$

Where,

$W_x = \frac{Ix}{|Ymax|}$ and $I_x = \frac{(b \times h^3) - ((b-2t) \times (h-2t)\text{^}3)}{12}$

Table 3.1. 2 Normal and Bending stress

Angle α	**σ(N)** MPa	**σ(M)** MPa	**Σϵx = σ(N)+ σ(M)** MPa
0	0	97.016752	97.01675195
5	0.1508824	96.6475739	96.79845628
10	0.3006141	95.5428495	95.84346361
15	0.4480612	93.7109863	94.15904747
20	0.5920965	91.1659259	91.75802238
25	0.7316259	87.9270378	88.65866366
30	0.8655882	84.0189718	84.88456002
35	0.99296	79.4714707	80.46443069
40	1.1128235	74.3191437	75.43196726
45	1.2241247	68.6012032	69.8253279
50	1.3261576	62.3611661	63.68732374
55	1.4180965	55.6465229	57.06461932
60	1.4992424	48.508376	50.00761833

Yield strength for structural steel is (250MPa)

σ_y = 250/1.5 = 166.66 MPa

σ Σx ≤ σ y (Condition is accepted, so our design is safe)

3.1.3 Bending Moment of the rectangular hollow section link

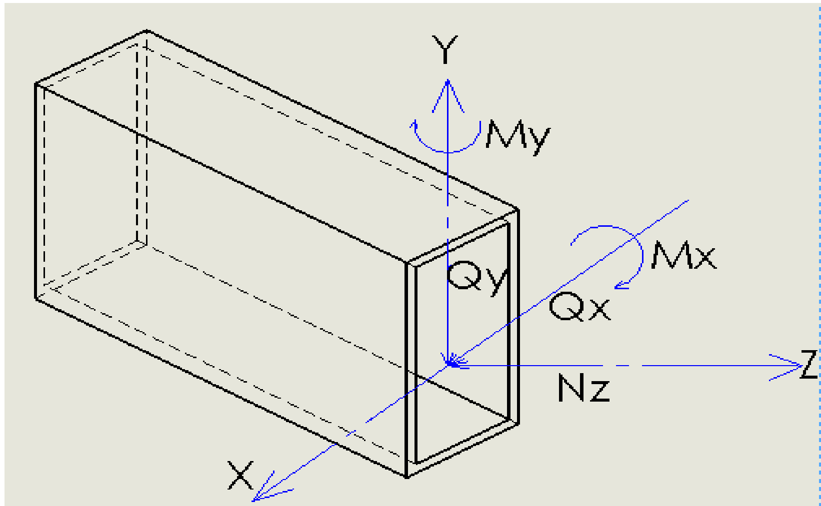


Figure 3.1. 4 General bending moment Diagram

Bending moment about Y axis,

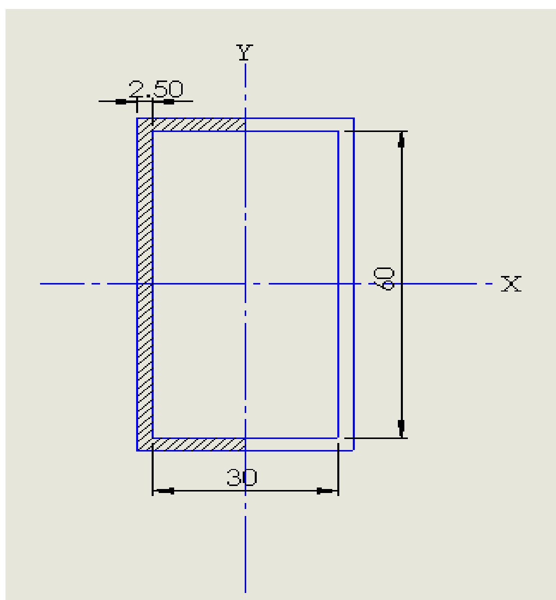


Figure 3.1. 5 Bending moment about Y axis

Input Values,

b1(m)	h1(m)	b2(m)	h2(m)	a1(m^2)	a2(m^2)	x1(m)	x2(m)	Iy(m^4)	$sy_{1/2}$(m^2)	QX
0.015	0.06	0.0125	0.055	0.0009	0.0006875	0.015	0.0125	7.92318 e-09	4.91 e-06	588.6

Where,

b1, h1, a1, x1- values for outer rectangular

b2, h2, a2, x2- values for outer rectangular

Formula,

$$\sigma_Y = \frac{\boldsymbol{My} \times (\boldsymbol{b}/\boldsymbol{2})}{\boldsymbol{Iy}}$$

where,

Moment of inertia, Iy $= \frac{\boldsymbol{b^3 h} - (\boldsymbol{b} - \boldsymbol{2t})^3 \times (\boldsymbol{h} - \boldsymbol{2t})}{\boldsymbol{12}}$

Assume that at M_{max}

$$M_y = \frac{1}{2}\, Mx = \frac{1}{2}\, Mx \cos 0$$

Then using equation

$$\mathbf{M_y}\ (\boldsymbol{\alpha}) = \frac{\boldsymbol{Mx}\ \boldsymbol{cos}(\boldsymbol{\alpha})}{\boldsymbol{2}}$$

Table 3.1. 3 Bending moment about Y axis

Angle (α)	**M_y in N.m**	**σ_y (MPa)**
0	312.6938	295.992769
5	311.5039	294.866427
10	307.9432	291.495974
15	302.039	285.90706
20	293.836	278.142221
25	283.3968	268.260552
30	270.8007	256.337257
35	256.1437	242.463082
40	239.5373	226.743616

45	221.1079	209.298494
50	200.9957	190.260485
55	179.3538	169.774478
60	156.3469	147.996385

$$\tau_{zx} = \frac{Qx \times Sy_{1/2}}{Iy \times h}$$

where,

$$Sy_{1/2} = (a1 \times x1) - (a2 \times x2)$$

Therefore,

$$\tau_{zx} = 6.07462284 \text{ MPa}$$

Bending moment about X axis,

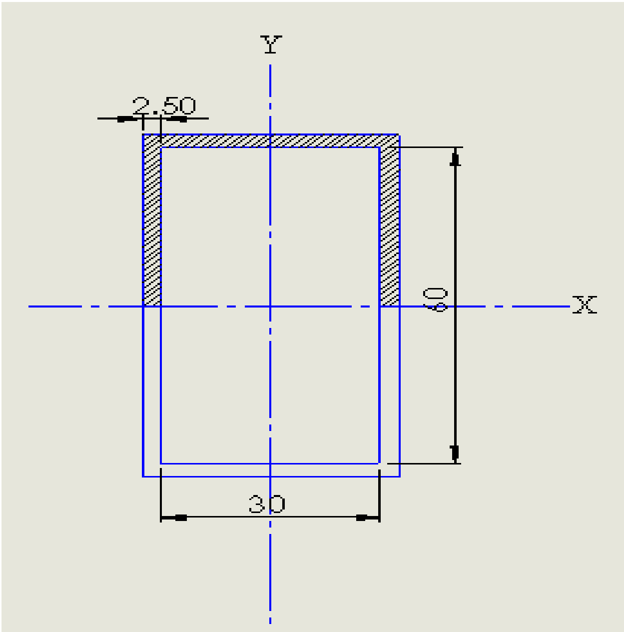


Figure 3.1. 6 Bending moment about X axis

Values,

b1(m)	h1(m)	b2(m)	h2(m)	a1(m^2)	a2(m^2)	y1(m)	y2(m)	Ix(m^4)	$sx_{1/2}$(m^2)	Qy
0.03	0.03	0.025	0.0275	0.0009	0.00069	0.03	0.025	2.41732 e-08	9.8125 e-06	588.6

Table 3.1. 4 Bending moment about X axis

Angle (α)	Mx in N.m	σx (MPa)
0	625.388	388.067008
5	623.008	386.590296
10	615.886	382.171398
15	604.078	374.843945
20	587.672	364.663704
25	566.794	351.708151
30	541.601	336.075887
35	512.287	317.885883
40	479.075	297.276575
45	442.216	274.404813
50	401.991	249.444664
55	358.708	222.586091
60	312.694	194.033504

For X axis formula are similar but it should be respect with x axis

$$\tau_{zy} = 7.96425 \text{ MPa}$$

When scissor lift reaches its maximum height (60^0), normal stress reaches maximum and shear stress should be the same i.e. Mx = My

3.1.4 Stresses in a link bidirectional

This calculation will understand how column or beam will maintain its straight structure (bending state) with respect to the applied load, but not a matter how long it will maintain its stability. Basically eccentric load (Bending, Mx=Load(P)×Eccentricity distance(e_x)) acting particular distance from the center of body [14, p. 808], but in our case the load is acting exactly center point of the link. So,

$$Mx = Qy \times \frac{l}{2}$$

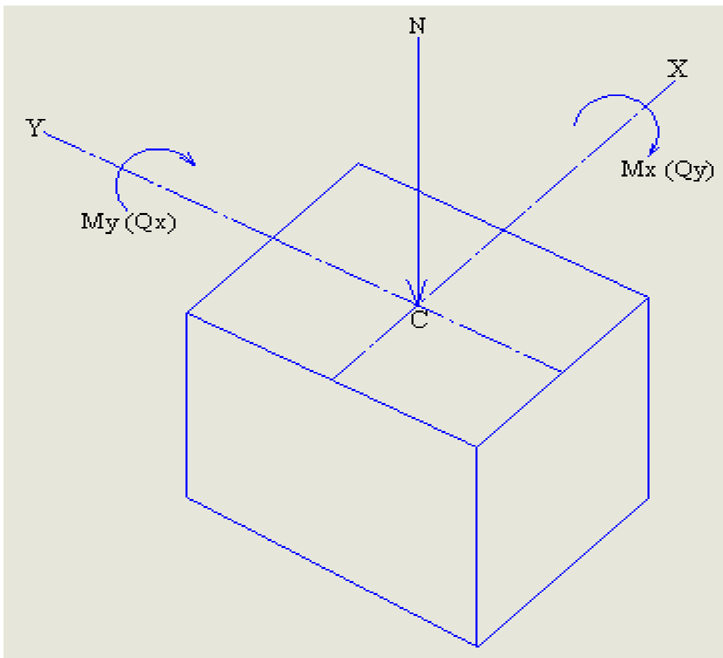


Figure 3.1. 7 stresses in bidirectional

Values,

Weight (N)	**Length (m)**	**Base 1 (m)**	**Height 1 (m)**	**Thickness (m)**	**Base 2 (m)**	**Height 2 (m)**	**Area (m^2)**	**Ix(m^4)**	**Iy(m^4)**
2943	1.7	0.03	0.06	0.0025	0.025	0.055	0.000425	1.93385 e-07	6.33854 e-08

Formula,

$$\sigma z_{(N,Mx)} = \frac{Nz}{A} + \frac{Mx \times (h/2)}{Ix}$$

$$\sigma z_{(N,My)} = \frac{Nz}{A} + \frac{Mx \times (b/2)}{Iy}$$

Table 3.1. 5 Bending about X & Y axis

Angle (α)	**Normal Force N**	**Mx N.m**	**$\sigma z_{(N,Mx)}$ N/m²**	**$\sigma z_{(N,My)}$ N/m²**
0	0	625.3875	103.9414578	154.9210904
5	64.125	623.0075	103.572247	154.3578694
10	127.761	615.8862	102.4675153	152.6726316
15	190.426	604.07715	100.63557	149.8780495
20	251.641	587.6645	98.08946538	145.994037
25	310.941	566.79275	94.85161781	141.0547897
30	367.875	541.6013	90.9436525	135.0932962
35	422.008	512.28735	86.3961612	128.1562234
40	472.950	479.07445	81.24382336	120.2964738
45	520.253	442.21505	75.52580171	111.5737892
50	563.617	401.9905	69.28574224	102.0547503
55	602.691	358.7068	62.57111493	91.81177112
60	637.178	312.69375	55.43308186	80.92289816

Interaction Method,

For X axis

$$\frac{\frac{F}{A}+\frac{Mx\times(h/2)}{Ix}}{\sigma all} \leq 1$$

Where,

σ all = σ y/ FOS [Structural steel Yield strength value]

Therefore 0.623649 ≤ 1

Similarly,

For Y axis

$$\frac{\frac{F}{A}+\frac{My\times(b/2)}{Iy}}{\sigma all} \leq 1$$

Therefore 0.9252 ≤ 1

The above condition is satisfied for our dimension of the link, so design will be safe.

3.1.5 Euler Equation

This equation is used to find out Euler's critical load i.e. longitudinal compression load on the scissor lift link. Therefore, we can understand the lift link will remain maintain their state straight or bending for the applied load on the link. Suppose if the link will starts deflect which cause the link to bend and broke by buckling load. So that load should lower than the critical load for avoiding unstable equilibrium.

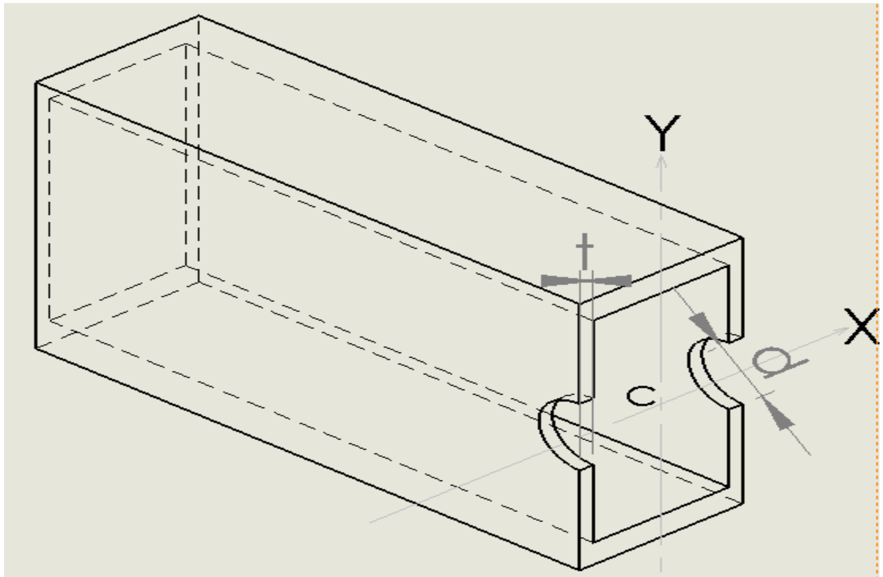


Figure 3.1. 8 critical load

Formula,

$$\mathbf{F_{cr}} = \frac{n^2\pi^2 I_{min} E}{{L_{ef1}}^2} \qquad [15, p. 808]$$

$$\sigma_{cr} = \frac{Fcr}{A}$$

σall = critical load/factor of safety

where,

P_{cr} = Euler's critical load,

E = modulus of elasticity of column material,

I = minimum area moment of inertia of the cross section of the column,

L = length of the link

K = column effective length factor

Note:

- $Lef_{1} = \mu_1 \times L$, about X axis $\mu_1 = 1$
- $Lef_{12=} \mu_2 \times L$, about X axis $\mu_2 = 0.5$

μ depends on the support related co-efficient

Values,

b1 (m)	**h1 (m)**	**b2 (m)**	**h2 (m)**	**t (m)**	**d (m)**	**L_{ef-1}**	**L_{ef-2}**	**n**	**π**	**E (GPa)**
0.03	0.06	0.025	0.055	0.0025	0.0175	1.7	0.85	2	3.14	69

a1 (m^2)	**a2 (m^2)**	**a3 (m^2)**	**Ix (m^4)**	**Iy (m^4)**	**Xc**	**A (m^2)**
0.0018	0.001375	0.00004375	1.91152 e^{-7}	7.4353 e^{-7}	0.01375	0.00038

Therefore,

About X axis $F_{cr} = 522662.1531 N/m^2$

$\sigma_{cr} = 162.380$ MPa

$\sigma_{all} = 81.190$ MPa

Therefore,

About Y axis $F_{cr} = 8132104.02 N/m^2$

$\sigma_{cr} = 252.647$ MPa

$\sigma_{all} = 126.323$ MPa

3.1.6 Stress analysis due to complex loading

In the case of multi-axial deformation, the complex loading conditions takes place. The most failure criteria generally stress based. For the evaluation of stress and for the assessments of safety, this work should overcome more comprehensive explanation of states carrying out on the several area of the elements. Commonly, we can find how stresses distributed in each and every point of the material because of external load, by the way of doing tensile testing and using analysis software. In analytical method by using formulae we can calculated these values. In general calculations are done by tensile loading condition.

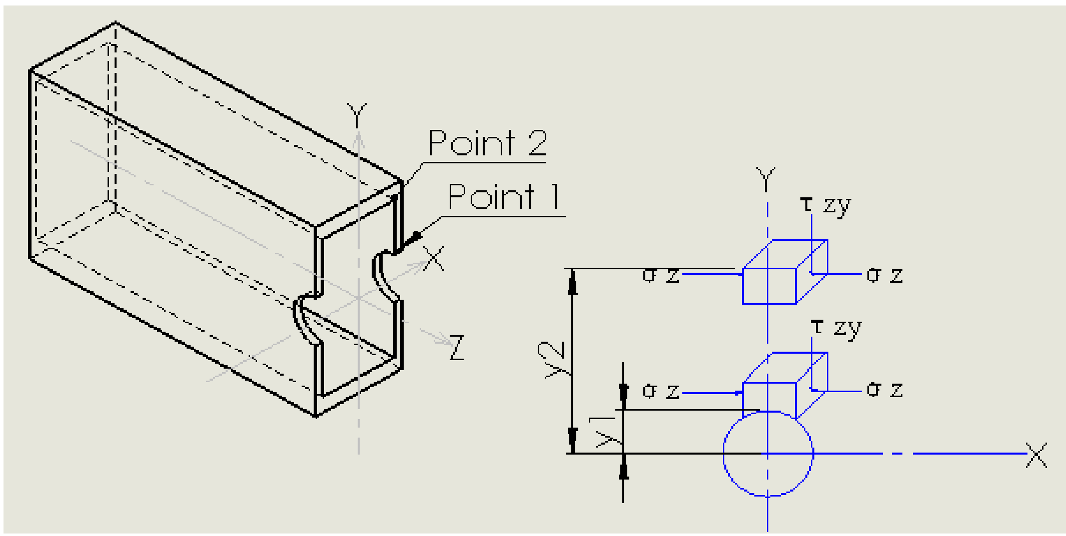


Figure 3.1. 9 complex load acting section

In our scissor lift according to the load, x axis will be more dangerous. so maximum stress affecting area is close to the cylindrical zone.

From figure 3.1.9 for point 1 Principle stress state that,

- Normal stresses (σ_x, σ_y and σ_z) values in negative sign because of compression force.
- Shear stress (τ_{zy}), takes place in z direction and opposite side.

From figure 3.1.9 point 2 principal stress states that,

- Due to pending there is no shear stress influenced here, in this case von-mises will be similar to the axial σ zx,

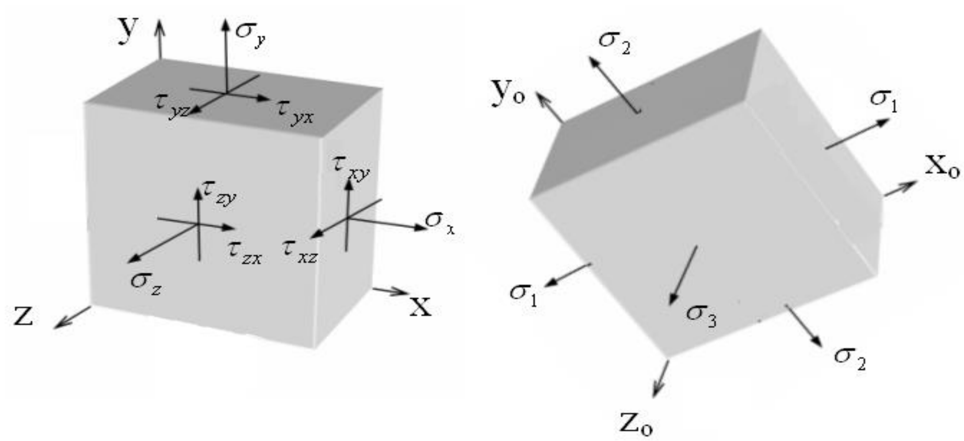


Figure 3.1. 10 stress elements

Therefore,

$$\sigma = \begin{pmatrix} \sigma 3 & 0 & 0 \\ 0 & \sigma 2 & 0 \\ 0 & 0 & \sigma 1 \end{pmatrix}$$

This state is presented by cubic equation

$$\sigma^3 - I_1\sigma^2 + I_2\sigma - I_3 = 0$$

where,

σ- principle stress

I - Stress invariants

$$I_1 = \sigma_x + \sigma_y + \sigma_z$$

$$I_2 = \begin{vmatrix} \sigma_y & \tau_{yz} \\ \tau_{yz} & \sigma_z \end{vmatrix} + \begin{vmatrix} \sigma_z & \tau_{zx} \\ \tau_{zx} & \sigma_x \end{vmatrix} + \begin{vmatrix} \sigma_x & \tau_{xy} \\ \tau_{xy} & \sigma_y \end{vmatrix} = \sigma_x\sigma_y + \sigma_y\sigma_z + \sigma_z\sigma_x - \tau_{yz}^2 - \tau_{zx}^2 - \tau_{xy}^2$$

$$I_3 = \begin{vmatrix} \sigma_x & \tau_{yx} & \tau_{zx} \\ \tau_{xy} & \sigma_y & \tau_{zy} \\ \tau_{xz} & \tau_{yz} & \sigma_z \end{vmatrix} = \sigma_x\sigma_y\sigma_z + 2\tau_{xy}\tau_{yz}\tau_{zx} - \sigma_x\tau_{yz}^2 - \sigma_y\tau_{zx}^2 - \sigma_z\tau_{xy}^2$$

Principal stresses,

$$\sigma_1 = \frac{I_1}{3} + c\cos\theta; \quad \sigma_2 = \frac{I_1}{3} + c\cos\left(\theta - \frac{2\pi}{3}\right); \quad \sigma_3 = \frac{I_1}{3} + c\cos\left(\theta + \frac{2\pi}{3}\right),$$

Where,

$$a = \frac{I_1^2}{3} - I_2; \; b = -2\left(\frac{I_1}{3}\right)^3 - \frac{I_1 I_2}{3} - I_3; \; c = 2\sqrt{\frac{a}{3}}; \;\; \theta = \frac{1}{3}\arccos\left(-\frac{3b}{ac}\right).$$

By using this above formula, we can find the principle stress and shear stress values for any point of the material.

Von- mises stress,

Due to the complex loading acting on the material, at particular time it tends to start yielding. So that von mises used to determine yielding of the material. This maximum stress value can be calculated from the Cauchy stress tensor. In generally von-mises stress equation is

$$\sigma v = \sqrt{\frac{1}{2}\left[(\sigma x - \sigma y)^2 + (\sigma y - \sigma z)^2 + (\sigma z - \sigma x)^2 + 6(\tau^2 xy + \tau^2 yz + \tau^2 zx)\right]} \quad [16]$$

For 2 dimensional stress state, σz = 0.

Principal stress,

$$\sigma v = \sqrt{\frac{1}{2}\left[(\sigma 1 - \sigma 2)^2 + (\sigma 2 - \sigma 3)^2 + (\sigma 3 - \sigma 1)^2\right]} \quad [17]$$

So by using stress tensor and von mises equations for the complex loading conditions, we can predict the values of maximum stress acting on the section.

I have find this von-mises stress values by the help of ansys package. It will give very accurate values of von mises stress and we can clearly understand where it will occur minimum and maximum in the element.

3.2 Design of base plate

Usually, in scissor lift the base plate is mounted to the floor. it is constructed using structural steel. It gives the proper balance to the structure additionally it should be rigidly supported from underneath to support the point loading created by the two scissor leg roller and the two scissor leg hinges. The base plate has attached by four wheel.

Length (l) = 1800 mm

Breadth (b) = 900 mm

Thickness (t) = 6 mm

3.3 Design of upper plate

The upper plate in a scissor lift is utilized to put the load and exchange it to the lift legs. The outlining of the upper plate is attempted comparative as the base plate. It is likewise comprised of structural steel material. Additional setup of this upper plate gives operator comfortable and security.

Length (l) = 1800 mm

Breadth (b) = 900 mm

Thickness (t) = 6 mm

It is required to design a platform which should serve under heavy load application and withstand high stresses. Structural steel has high compressive and tensile strength, good stability and reliability. Furthermore, it is widely used in industries for manufacturing structural shape steel members, such as c- beam, I- beam, hollow structural section (Rectangular, square and pipe). So that the above mentioned and many other purpose this material should be suitable for our scissor lift [18].

Table 3.3. 1 Platform calculations

Input	**Formula**	**Output**
Breadth b1=1.8m Height h1=0.9m Thickness t=0.006m	b2=b1-t h2=h1-t A1=b1×h1 A2=b2×h2 A_0 = A1-A2	b2=1.794m h2=0.894m A1=1.62m^2 A2=1.6038m^2 A_0=0.0161m^2
$N_{(60)}$ = 637.178N	Normal Stress $(\sigma_N) = \frac{N_\alpha}{A}$ [19]	σ_N = 39576.27N/m^2
$M\alpha$ = 573.460 N	Bending Stress $\sigma_M = \frac{M(\alpha)}{W_x}$ [19] $W_x = \frac{I_x}{y_{max}}$ Moment of Inertia $I_x = \frac{b_1h_1^3 - b_2h_2^3}{12}$	I_x = 2.5297 × 10^{-3} m^4 W_x = 2.810 ×10-^{3} m^3 σ_M = 2.04 ×10^5 N/m^2
For Structural steel σ_y=250MPa Factor of Safety =1.5	$\sigma_{Z=}\sigma_{N+}\ \sigma_M$	σ_Z=2.435 ×10^5 N/m^2 $\sigma_Z \leq \sigma_y$ So that our design is safe.

3.4 Design of leadscrew

Lead screw is an important part in a scissor lift, that takes up the operator or considerable load to be lifted or brought down by lift. A lead screw is a component that converts rotational movement to straight(linear) movement [20]. The most widely recognized frame comprises of a cylindrical shaped shaft with helical grooves or edges called threads around the outside. The fasten goes through a gap another object or medium, with threads within the gap that mesh with the screw's threads. At the point. When the shaft of the screw is turned with respect to the stationary threads, the screw moves along its pivot in respect to the medium encompassing it.

Lead screw can enhance constrain; a little rotational compel (torque) on the [14]pole can apply a substantial hub drive on a heap. The littler the pitch, the separation between the screws' strings, the more noteworthy the mechanical preferred standpoint, the proportion of yield to info constrain.

There is a large contact range among male and female threads in lead screws and this outcomes vast frictional loss amid the operation. Because of these frictional misfortunes, lead screws are not exceptionally proficient but generally self-locking. In self-locking lead screws, the load can't bring down itself without an outside exertion. Because of this feature it is generally used to hold loads. so that in our scissor lift subsequent to lifting required stature assume in the event that we discharge the hand from handle our framework effectively won't permit to move downwards.

Outer diameter of screw rod, d_0 = 60mm

Root diameter of screw rod, d_1 = 50 mm

Length between supports, L = 2000 mm

Lead or pitch of screw rod, p = 10 mm

Mean diameter (d) = $d_0 - \frac{p}{2}$ = 55mm

Coefficient of friction (μ) = tan ϕ = 0.15

$$\tan \alpha = \frac{p}{\pi d}$$

$$=0.05787$$

Frictional force

$F = \mu \times P$

$= 0.15 \times 2943$

$F = 1611.24$ N

- Force required to rising the load $P = W\times \tan(\alpha + \phi) = w\left[\frac{\tan\propto + \tan\phi)}{1 - \tan\alpha \tan\phi}\right]$ [20, p. 634]

  $= 617.12$N

- Force required to lower the load $P = W\times \tan(\alpha - \phi) = w\left[\frac{\tan\propto - \tan\phi)}{1 + \tan\alpha \tan\phi}\right]$ [20, p. 634]

  $= 268.80$N

3.5 Design of Bevel gear

Gears are rotating machine part having cut teeth or pinion, which meshed with another toothed part to transmit the power. Gears can change the speed and torque through their gear ratio furthermore it is used to change the direction of input power source. Gears are classified according to the orientation of axis such as Parallel axis (Spur Gear, Helical Gear, Gear Rack and Internal Gear), Intersecting axis (Miter Gear, Straight Bevel Gear, Spiral Bevel Gear) and Non-Intersecting axis (Screw Gear, Worm, Worm Gear).

Bevel gears are gears, axes of the two shafts intersect and the tooth-bearing faces of the gears themselves are conically shaped. bevel gears are frequently mounted on shafts that are 90 degrees apart, however can be intended to work at different angles too. The pitch surface of the bevel gear is a cone [20, p. 1080]. In this project I have selected straight bevel gear for giving rotational motion to the lead screw. Here in this design we used two bevel gear, one is attached in handle and another one is attached in leadscrew. Both are having same number of teeth.

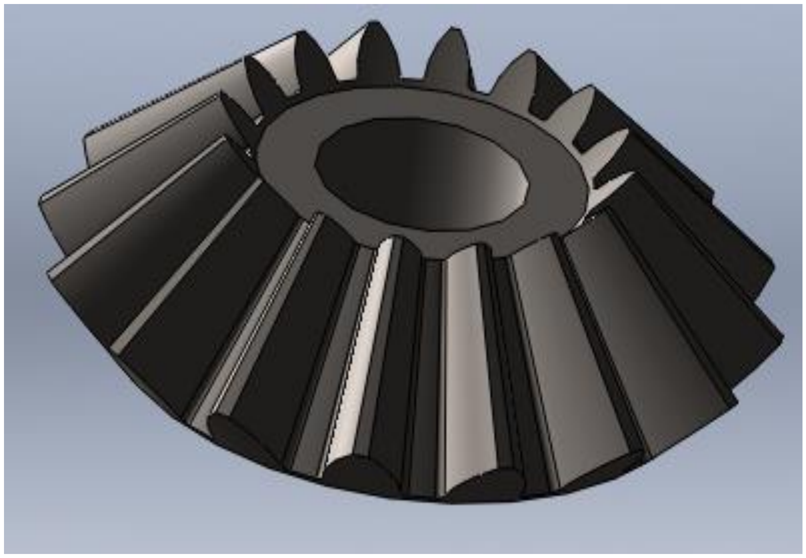


Figure 3.5. 1Bevel gear

Number of teeth (N) = 16 – 2 Nos.

Large diameter = (N + 2) / D.P [20]

= 18 / 11

= 1.636” = 41.56 mm

Pitch angle = 45^{0}

Pitch cone radius = (PCD)/ (2 SIN Φ) [20]

Where,

Sin Φ -Pitch angle

∴PCD = N / DP [20]

= 16 / 11

= 1.4545” = 36.945 mm

Therefore,

Pitch cone radius = 36.945 / 2 Sin45

= 26.124mm

Dedendum Angle = Tan^{-1} {(Dedendum / Pitch cone Radius)} [20]

Where,

Dedendum = 1.157 / DP

= 1.157 / 11

= 2.672 mm

∴Dedendum Angle = Tan^{-1} {2.672 / 26.124) [20]

= 5^0 50”

Cutting Angle = Pitch angle – Dedendum angle

= 45^0 - $5^0$50” = 39^0 30”

3.6 Design of Ball Bearing

A course is a machine component that constrains relative movement to only the desired movement, and decreases friction between moving parts. Here, in this lift ball bearing is utilized for giving rotational movement to the bevel gear. A ball bearing that utilizes balls to keep up the friction between the bearing races. It accomplishes this by utilizing no less than two races to contain the balls and transmit the loads through the balls [21]. In many applications, one race is stationary and the other is connected to the pivoting get together. As one of the bearing races pivots it makes the balls turn also. Since the balls are moving they have a much lower coefficient of friction than if two level surfaces were sliding against each other.

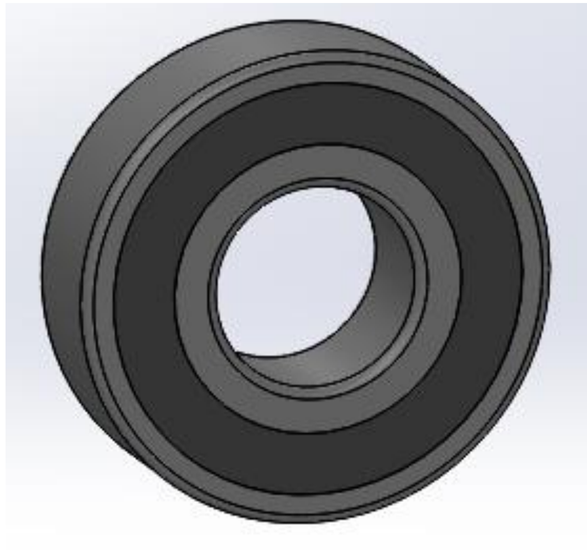


Figure 3.6. 1Ball bearing

Outer Diameter of Bearing (D)	=	37 mm
Thickness of Bearing (B)	=	12 mm
Inner Diameter of the Bearing (d)	=	15 mm
r_1	=	Corner radii on shaft and housing
r_1	=	1 [22]
Mean Diameter (dm)	=	(D + d) / 2
	=	(35 + 15) / 2
	=	25 mm

Whal Stress Factor,

Ks = $\frac{4C-1}{4C-4} + \frac{0.65}{C}$ [22]

Where, [C= (D/d= 2.33)]

Therefore, Ks = 1.85

3.7 Bolt & Nut calculation

Bolt and Nuts are used to connect one end of the link to another end of the scissor lift link.

Basic diameter, D = 40 mm

Screw thread pitch, p = 6 mm

Length of thread engagement, l = 60 mm

Pitch circle diameter, d_p = (D - 0.64952. p) [22]

= 36 mm

Stress area formula:

Tensile stress area of the (male) screw

$A_t = \frac{\pi}{4}(D - 0.938194.p)^2$ [23]

= 1197.77 mm^2

3.8 Ratchet and Pawl

Ratchet is a mechanical device that permits consistent straight or turning movement in just a single direction. A ratchet is made out of three primary parts: round gear, pawl and a base or mount [24].

Ratchet:

Ratchets created from gears are regularly round and are made out of uniform but asymmetric teeth intended to confine movement to a single direction. The edges on one side of the gear's teeth have moderate or gradual slope (frequently almost perpendicular to the tangent of the gear's circumference) while alternate edges of the gear's teeth have a much steeper slope [24].

Pawl:

The pawl is a hinged or pivoted device that adapted to engage with the teeth of the ratchet wheel or linear link. At the point when the gear is rotated in one direction, the pawl will gently slide over the teeth without confining the normal movement of the device. At the point when the direction of movement is turned around the pawl will come into contact with the steep slope on the ratchet tooth and will block movement in that direction [24].

Mount:

Gears or Linear Racks and Pawls are normally mounted in a fixed relationship to each other on a mount [24].

Backlash:

Even the ratchet wheel prevents backward motion at tooth boundaries, ratchet allow a limited amount of backward motion, which is permitted to maximum distance equal to the spacing between the teeth is called backlash.

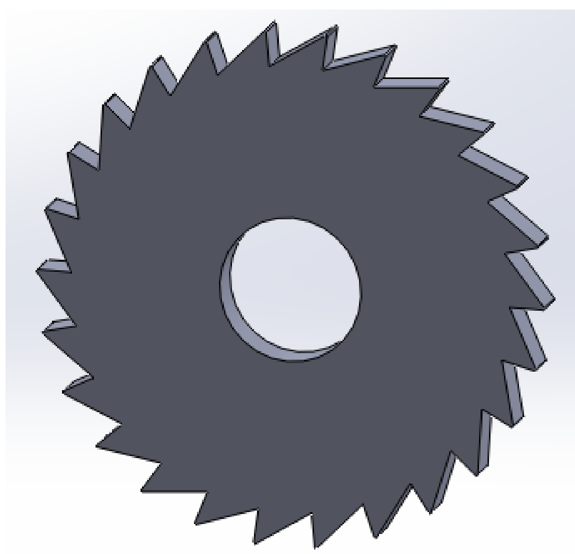


Figure 3.8. 1Ratchet

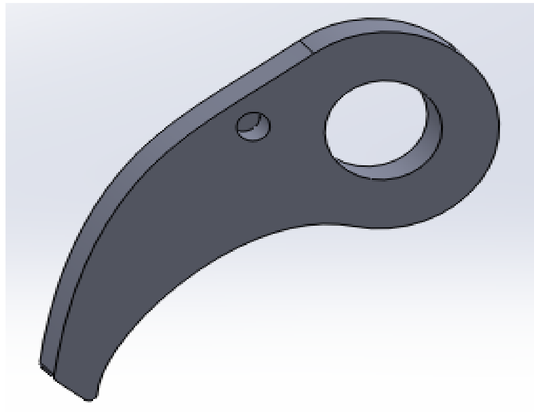


Figure 3.8. 2 Pawl

3.9 Castor Wheel

Caster wheel is a gadget which is mounted under the base plate of the scissor lift. It gives the rolling motion of the framework, so we can utilization this lift exceptionally convenient way. Caster wheel contains locking device to keep the wheel from the rolling motion or the swivel assembly from turning, with the goal that we can keep up and hold the lift stable while working the scissor lift.

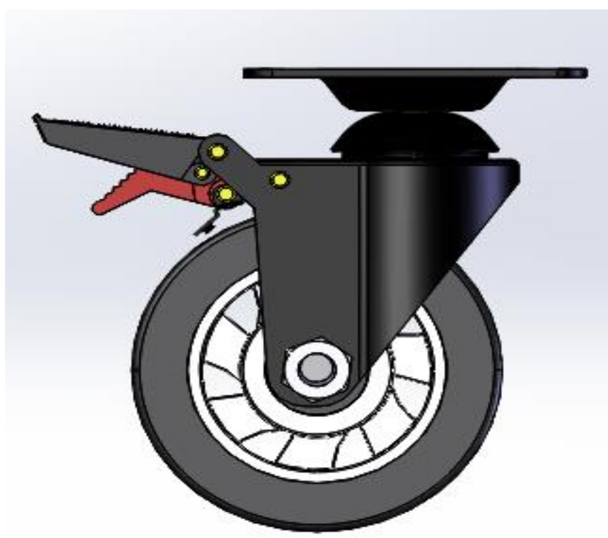


Figure 3.9. 1 Caster Wheel

3.10 Final Design of the scissor lift

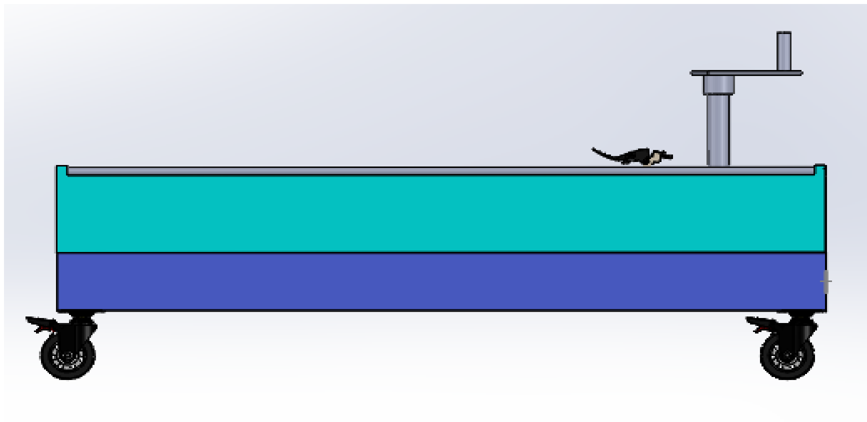


Figure 3.10. 1scissor lift at initial position

Figure 3.10. 2 Scissor lift at final position

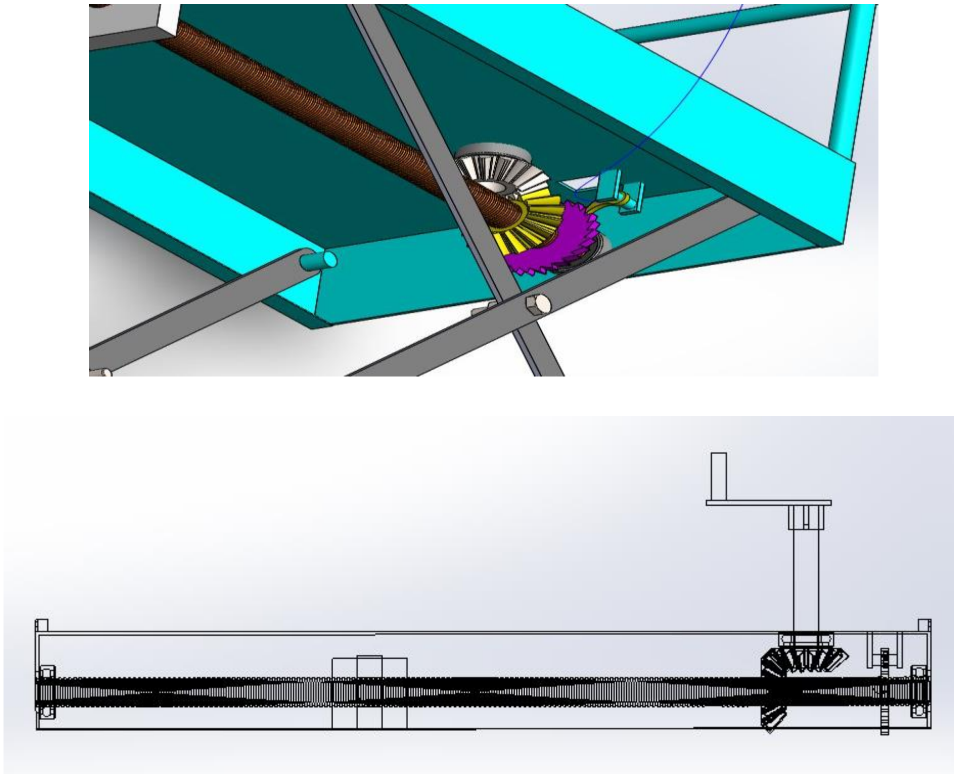


Figure 3.10. 3 Mechanical drive setup in top plate bottom side

3.11 Working Principle

When the operator rotates the handle in clock wise direction (hand lever is attached with bevel gear and another bevel gear is attached perpendicularly in screw rod) bevel gear will drive the leadscrew. Then leadscrew converts the rotary movement into linear movement to the lift, as a result lift moves upwards. After reaching the required distance or in any case if we leave the handle all of sudden the lift wouldn’t move due to presence of the Ratchet and pawl, it prevents one direction (downward movement) of the lift movement. For provided that downward movement, it is necessary to separate the pawl from ratchet by means of hand brake system, then if we rotate the handle in anti-clockwise direction the lift will moves towards down. Due to this mechanism scissor lift gives more reliable safety to the consumer.

4. Simulation Procedure

After the scissor lift model was developed by solid works software, it is directly imported to Ansys workbench. These process will lead us to assigning the material for the model, generate meshing and then strength analysis of the lift for the concern mean load of 300kg. In order to check the compatibility of the lift, we should know the values of Total deformation, Equivalent elastic stress and Equivalent elastic strain. Results are influenced by our concern material and loading condition.

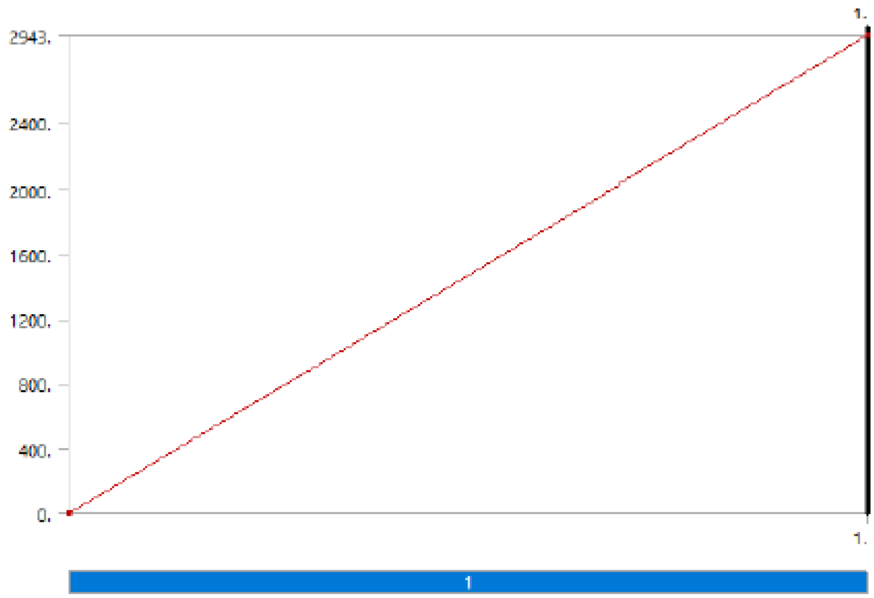
4.1 Analysis details

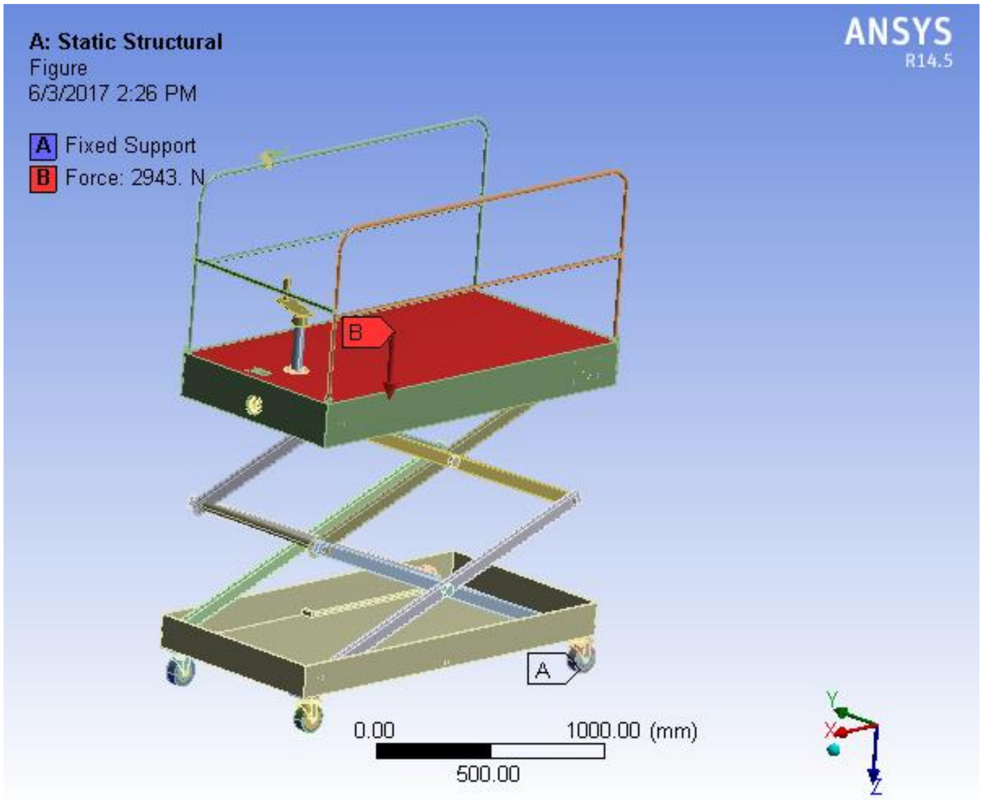
Object Name	*Static Structural (A5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	22. °C
Generate Input Only	No

4.2 Loading condition

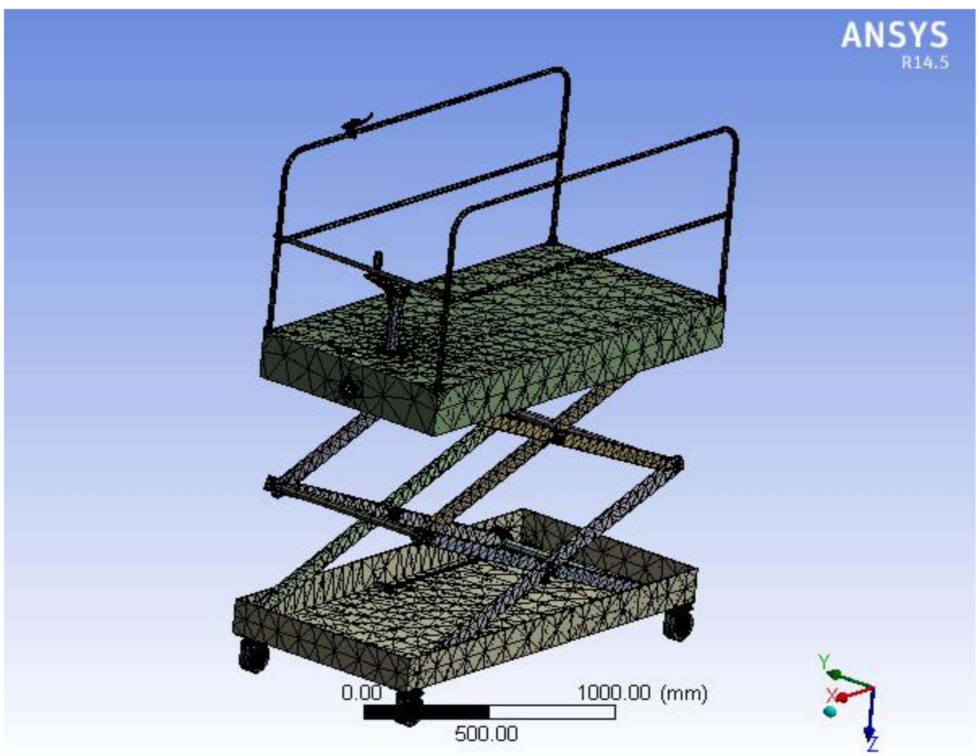
Object Name	*Fixed Support*	*Force*
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	
Geometry	4 Faces	1 Face
Definition		
Type	Fixed Support	Force
Suppressed	No	
Define By		Vector
Magnitude		2943. N (ramped)
Direction		Defined

Ansys generated graph for force acting on the static structural,





4.3 Mesh formation



4.3.1 Meshing Details

Object Name	*Mesh*
State	Solved
Defaults	
Physics Preference	Mechanical
Relevance	0
Sizing	
Use Advanced Size Function	Off
Relevance Center	Coarse
Element Size	Default
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	1.016e-004 mm
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No

Patch Conforming Options	
Triangle Surface Mesher	Program Controlled
Advanced	
Shape Checking	Standard Mechanical
Element Midside Nodes	Program Controlled
Straight Sided Elements	No
Number of Retries	Default (4)
Extra Retries For Assembly	Yes
Rigid Body Behavior	Dimensionally Reduced
Mesh Morphing	Disabled
Defeaturing	
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Automatic Mesh Based Defeaturing	On
Defeaturing Tolerance	Default
Statistics	
Nodes	591290
Elements	319586
Mesh Metric	None

4.4 Properties of the Materials

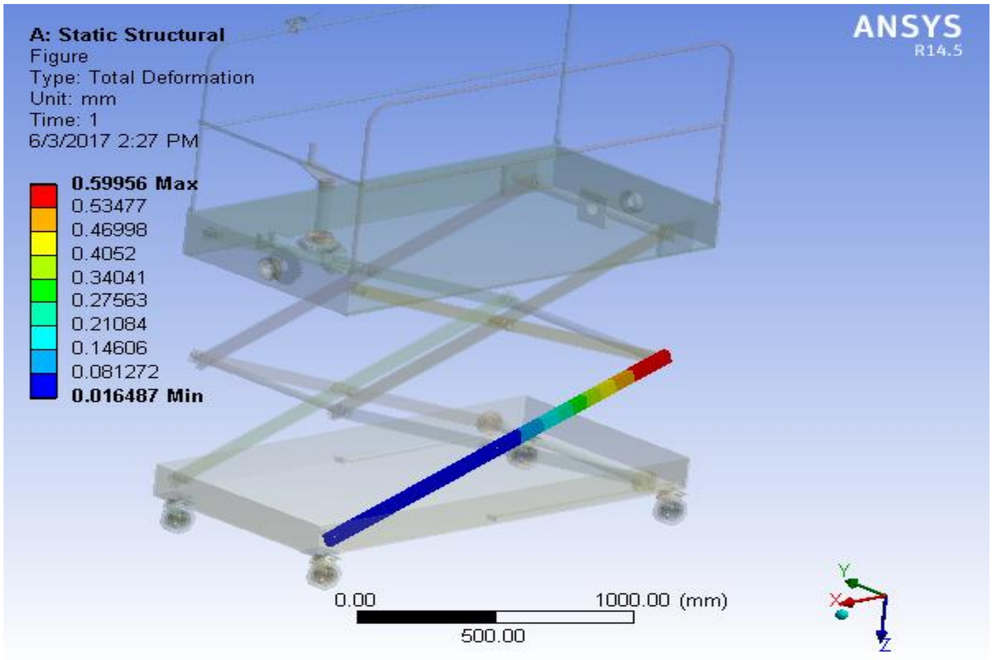
Table 4. 1 Material Properties

Material	Stainless Steel	Gray Cast Iron	Structural steel	Polypropylene
Density ($Kg.mm^{-3}$)	7.75 e^{-006}	7.2e^{-006}	7.85e^{-006}	1.5e^{-006}
Compressive Ultimate Strength	0	820	0	-
Compressive Yield Strength MPa	207	0	250	-
Tensile Yield Strength MPa	207	0	250	-
Tensile Ultimate Strength MPa	586	240	460	20
Young's Modulus MPa	1.93e^{+005}	1.1e^{+005}	2.e^{+006}	2000
Poisson's Ratio	0.31	0.28	0.3	0.45
Bulk Modulus MPa	1.693e^{+005}	83333	1.6667e^{+005}	6666.7
Shear Modulus MPa	73664	42969	76923	689.66

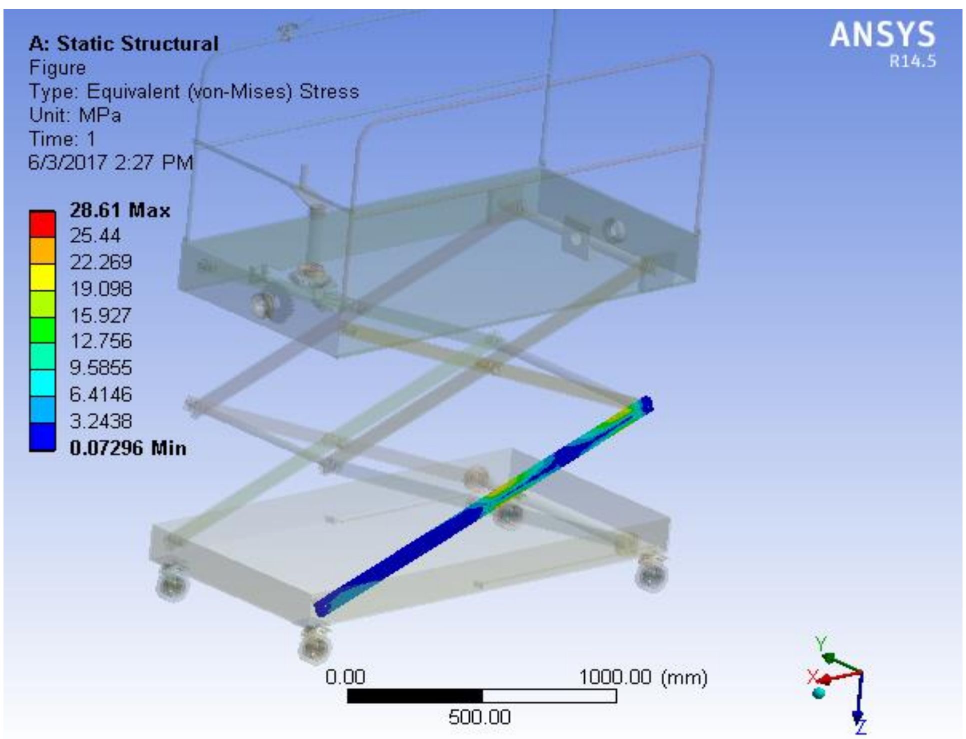
4.5 Results

4.5.1 Analysis of link Total Deformation

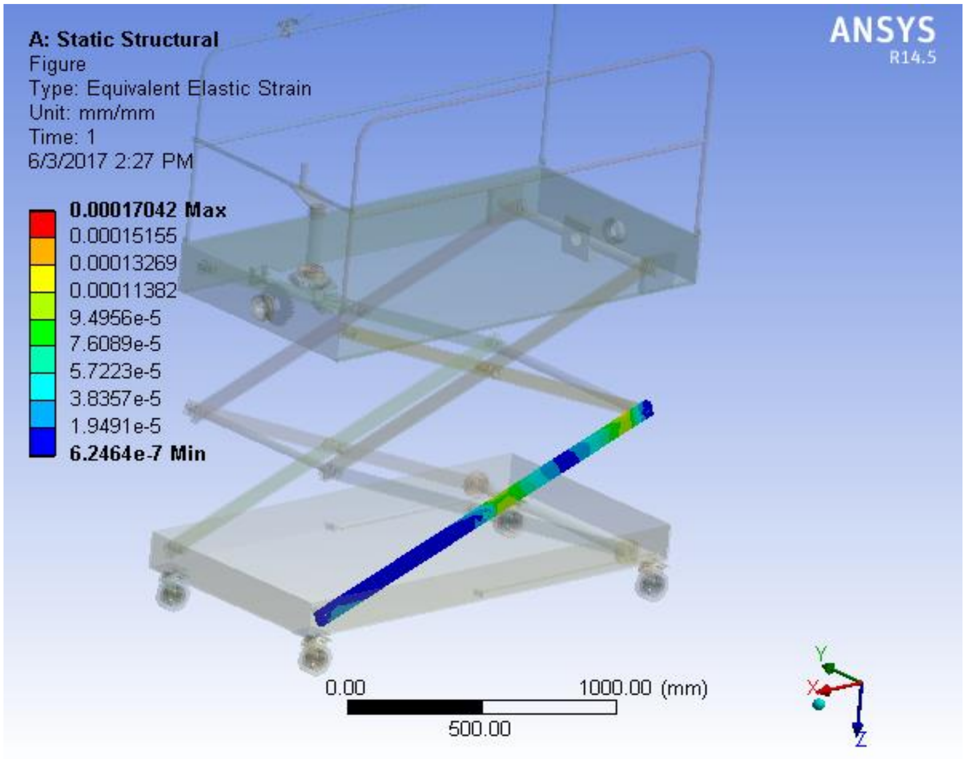
Material – Structural Steel



4.5.2 Equivalent von-mises Stress



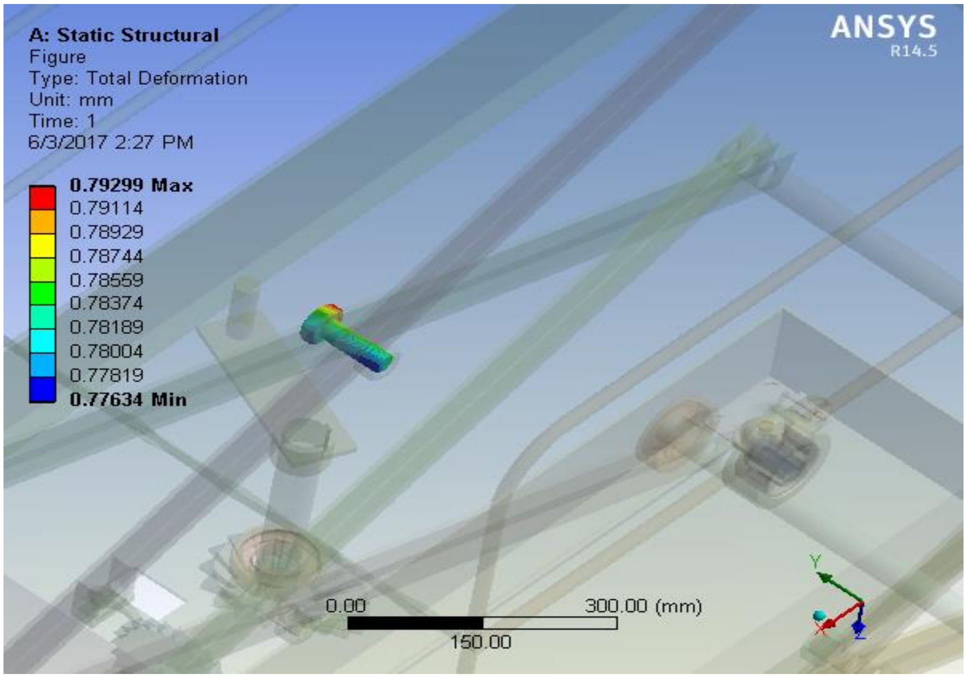
4.5.3 Equivalent Elastic Strain



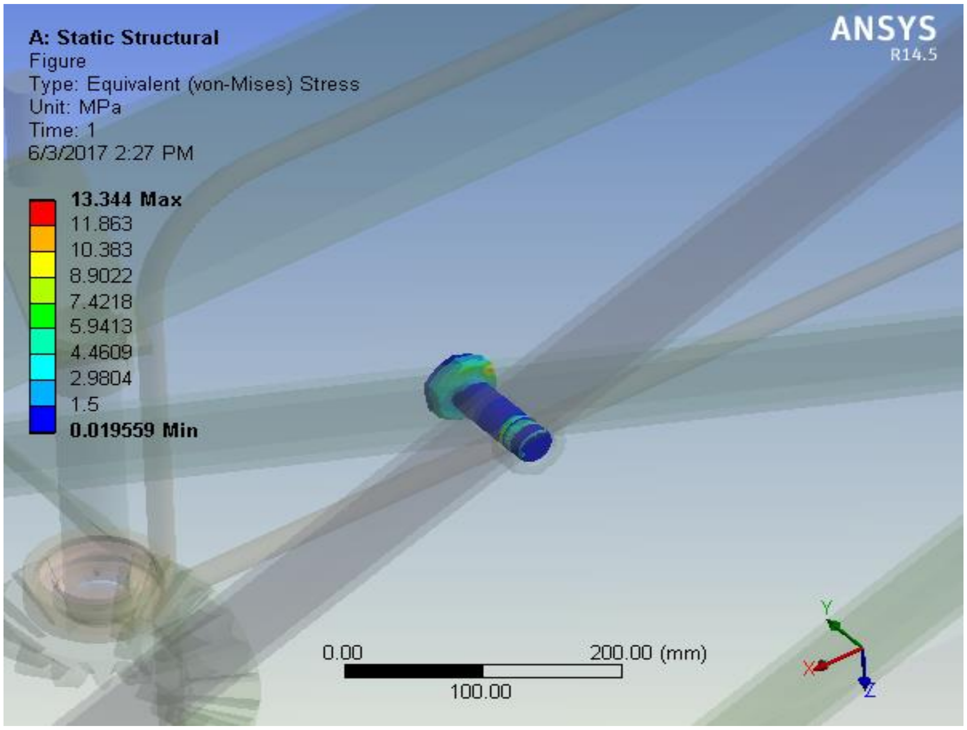
4.6 Analysis of Bolt

Material – Stainless steel

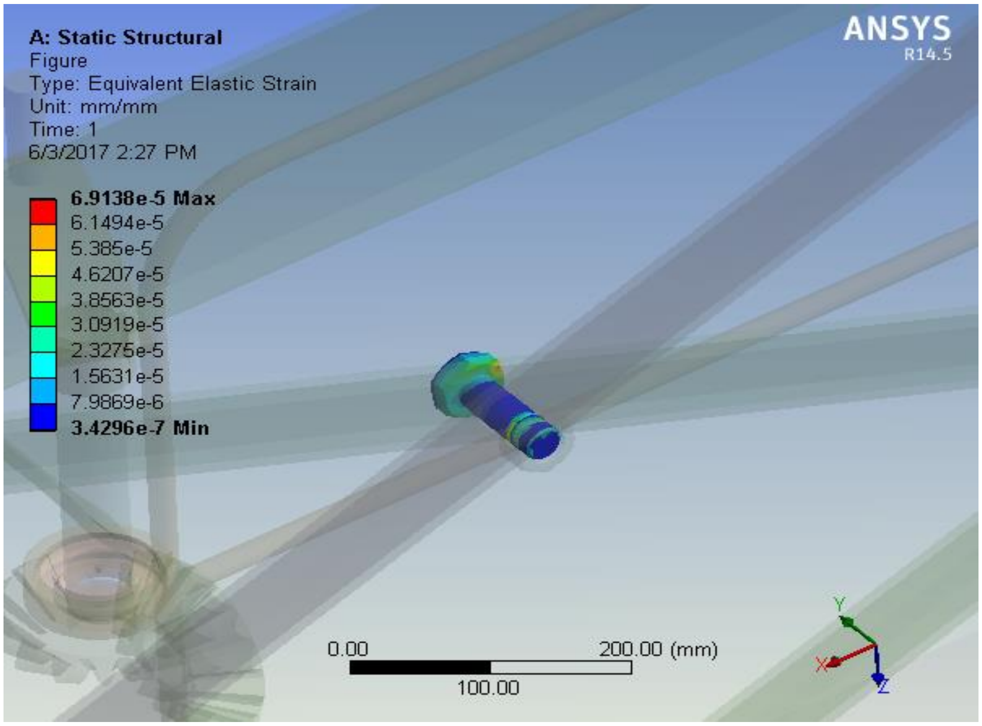
4.6.1 Total Deformation



4.6.2 Equivalent Elastic Stress



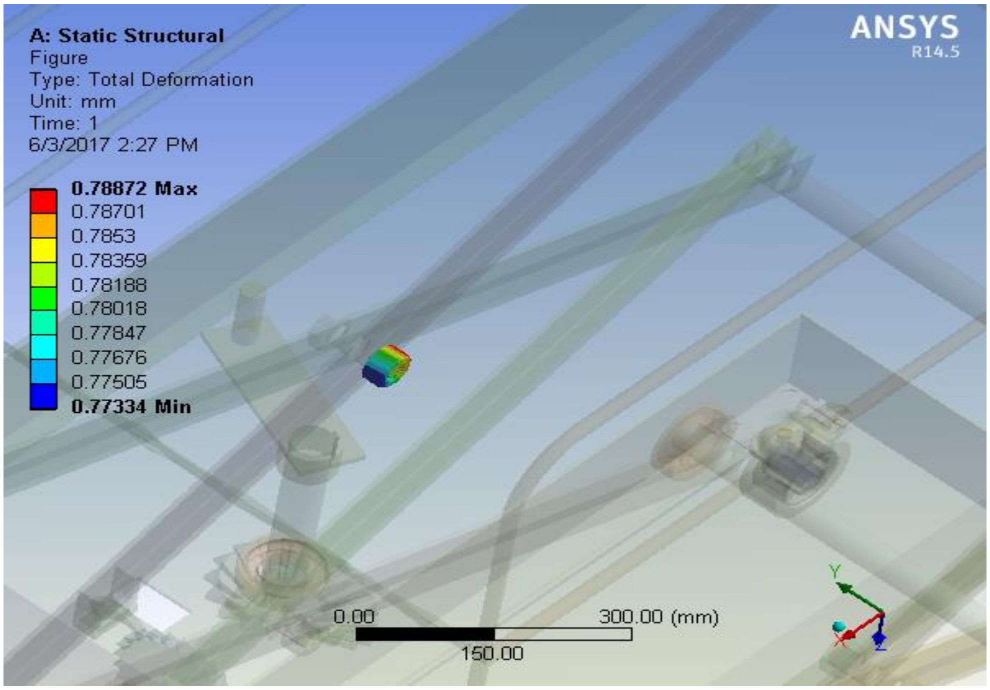
4.6.3 Equivalent Elastic Strain



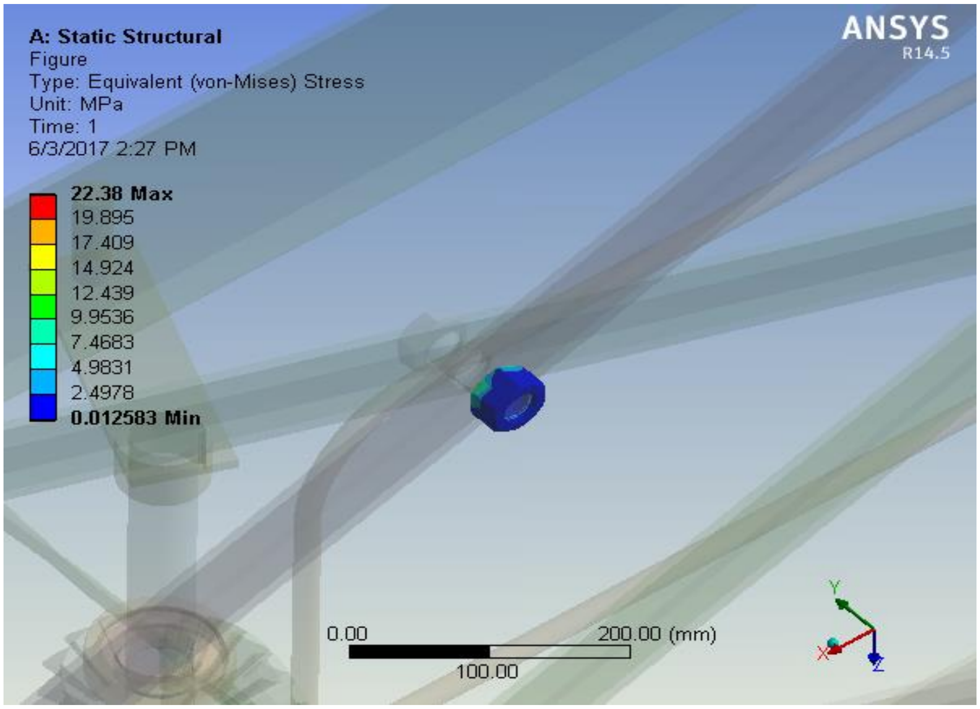
4.7 Analysis of Nut

Material – stainless steel

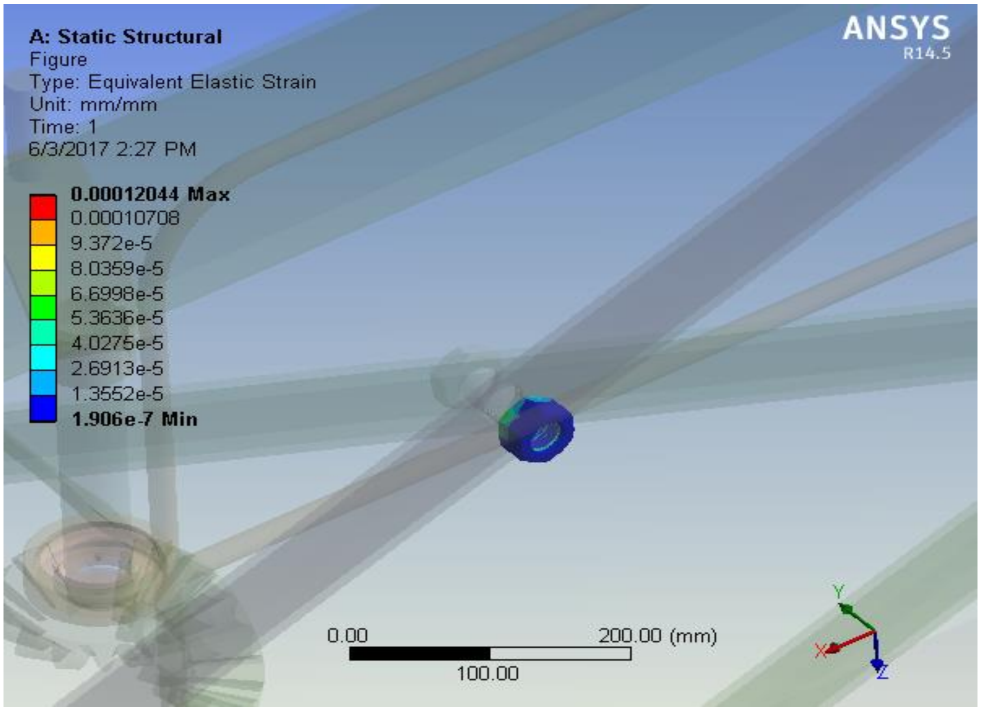
4.7.1 Total deformation



4.7.2 Equivalent Elastic Stress



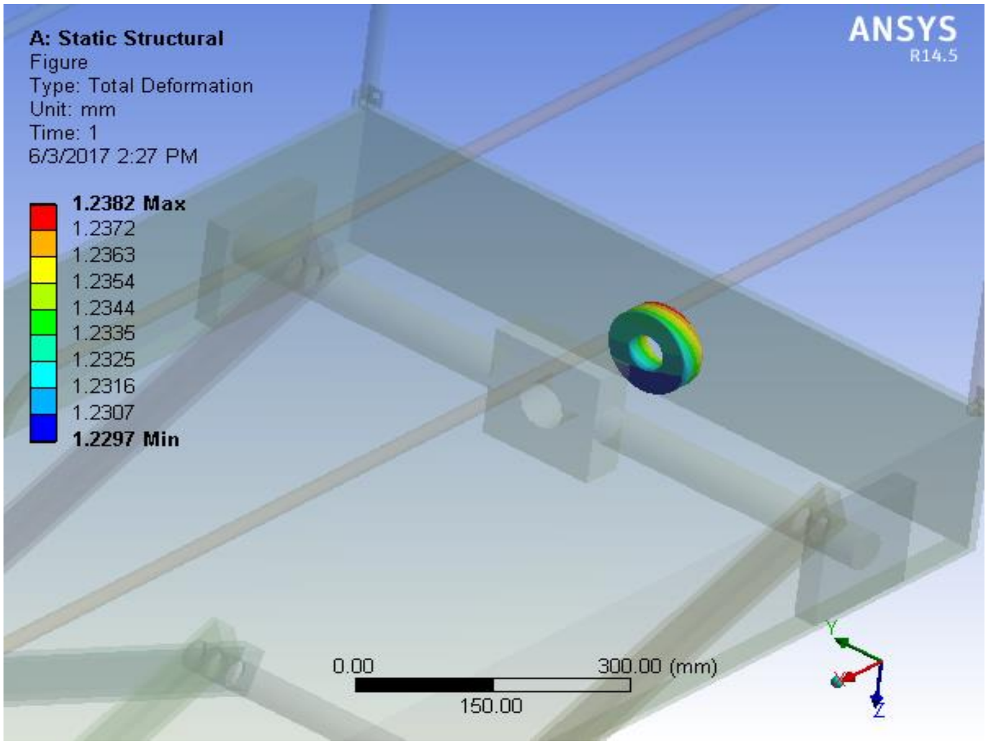
4.7.3 Equivalent Elastic Strain



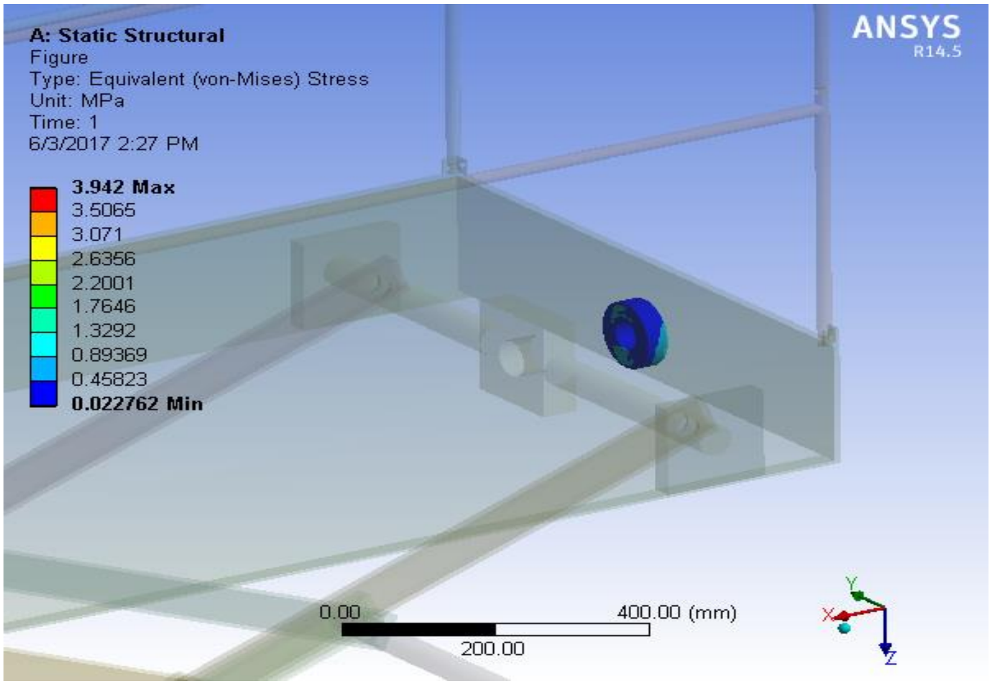
4.8 Analysis of Bearing

Material - stainless steel

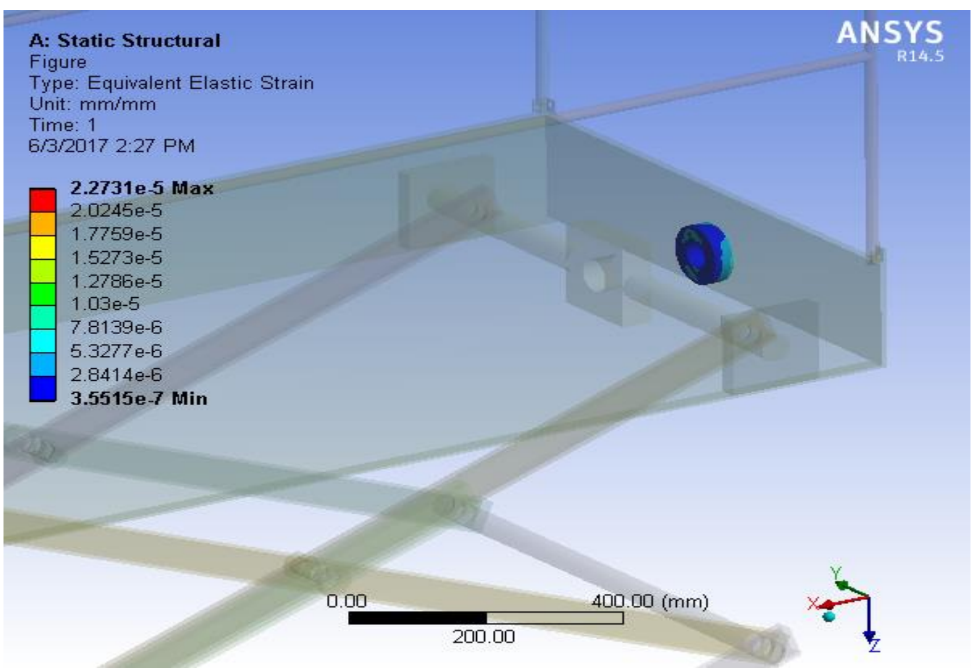
4.8.1 Total Deformation



4.8.2 Equivalent Elastic Stress



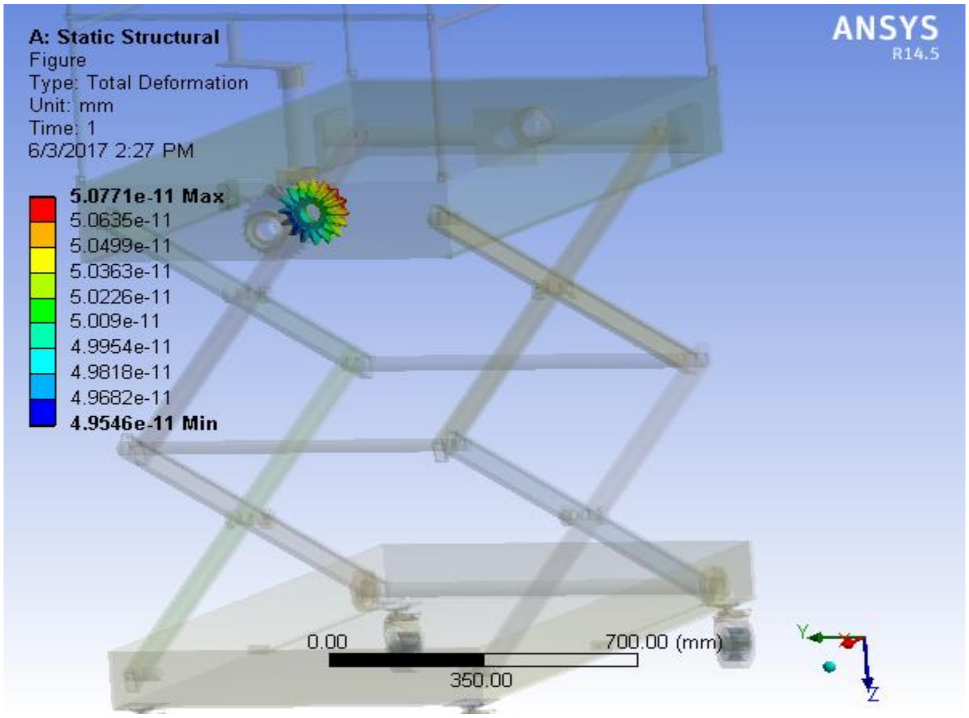
4.8.3 Equivalent Elastic Strain



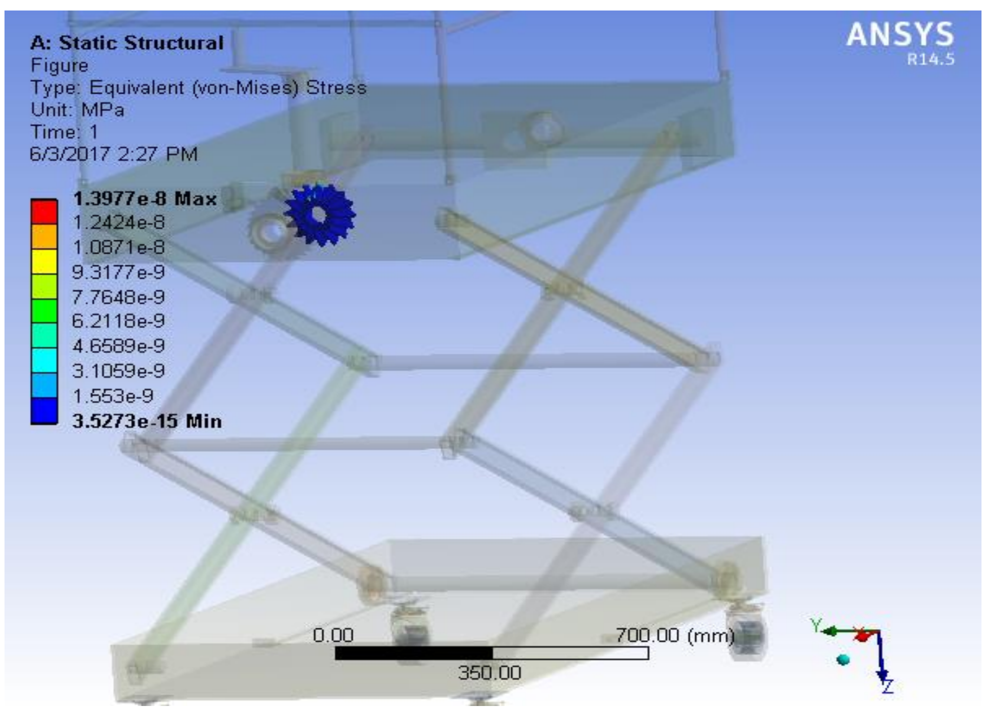
4.9 Bevel Gear

Material – Gray Cast Iron

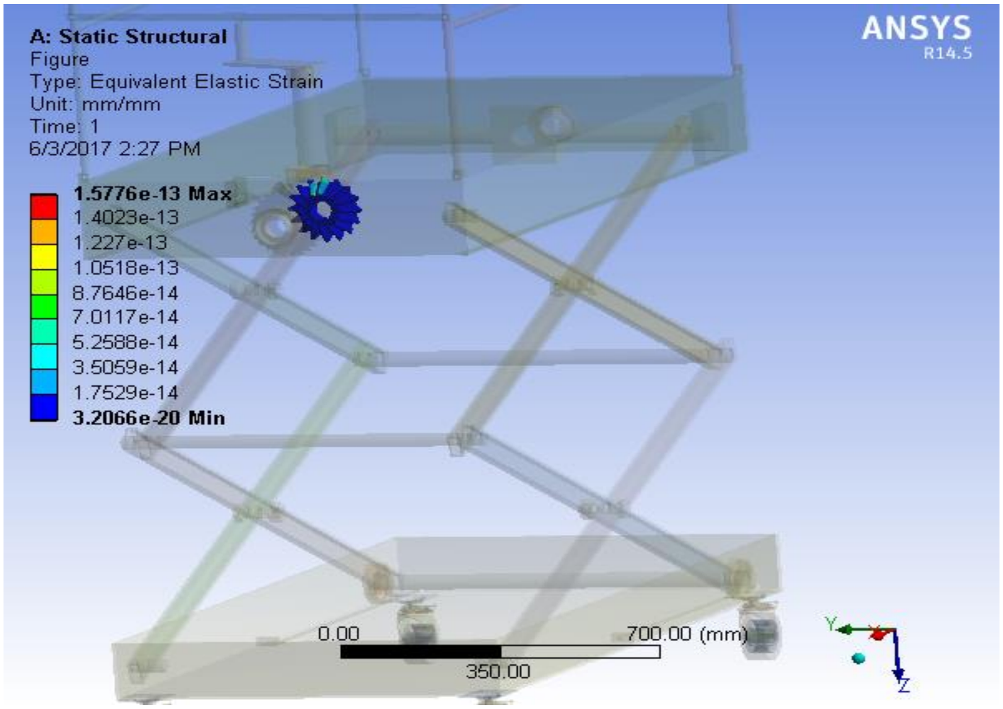
4.9.1 Total Deformation



4.9.2 Equivalent Elastic Stress



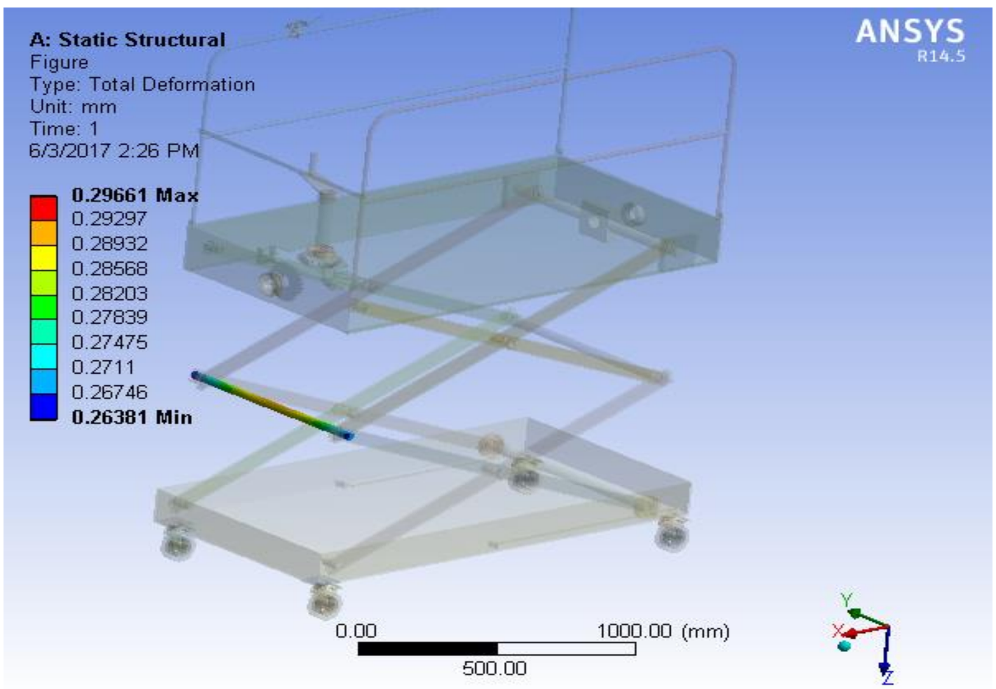
4.9.3 Equivalent Elastic Strain



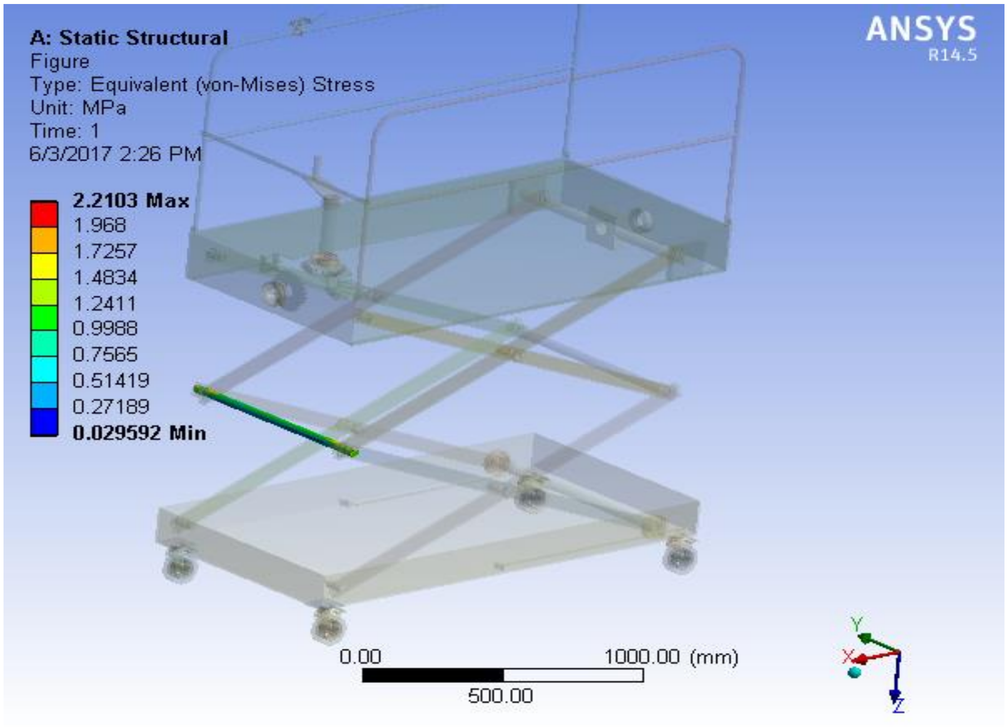
4.10 Analysis of Connecting Link

Material – Stainless steel

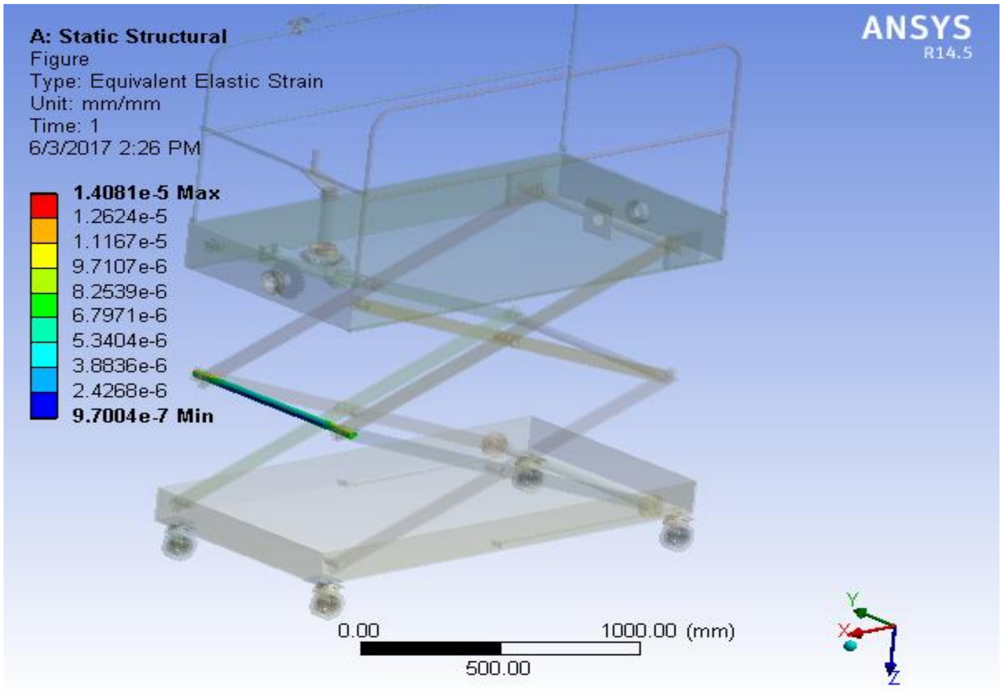
4.10.1 Total Deformation



4.10.2 Equivalent Elastic Stress



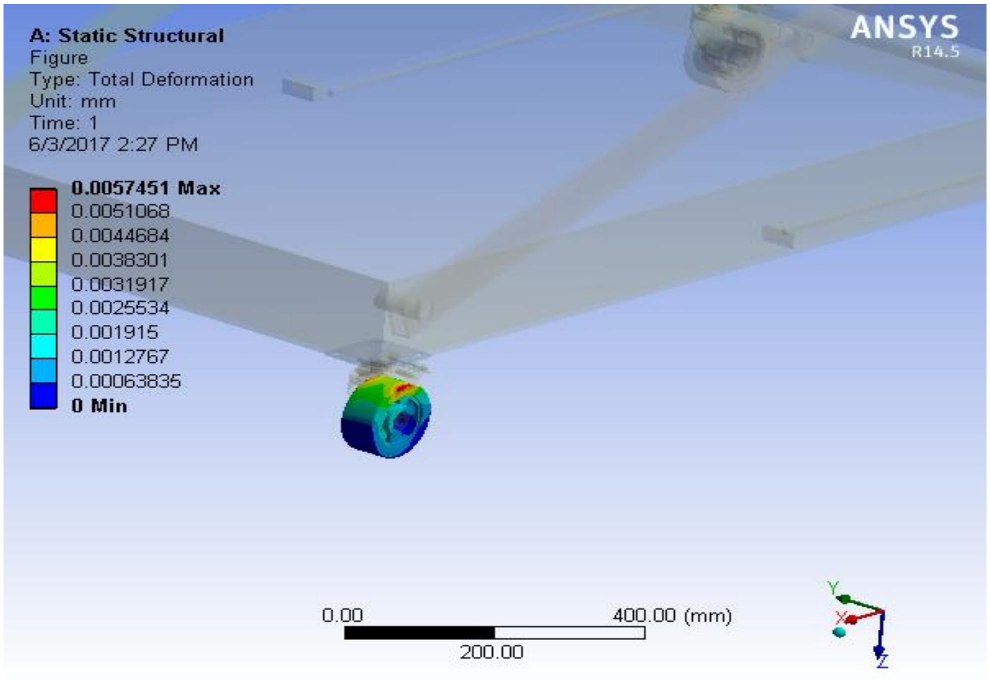
4.10.3 Equivalent Elastic Strain



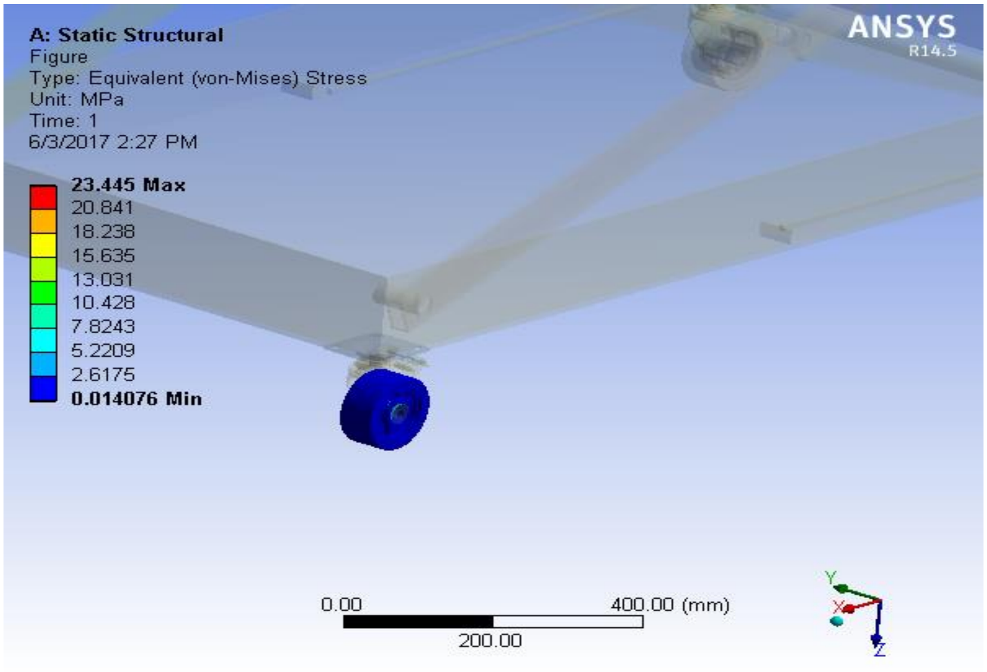
4.11 Analysis of Caster Wheel

Material – Poly Propylene

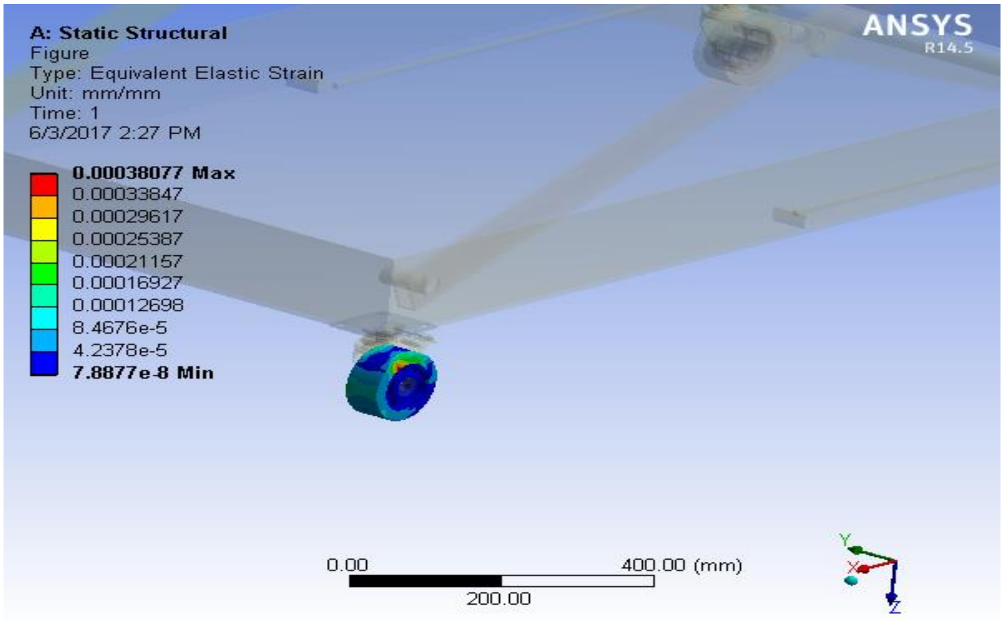
4.11.1 Total Deformation



4.11.2 Equivalent Elastic Stress



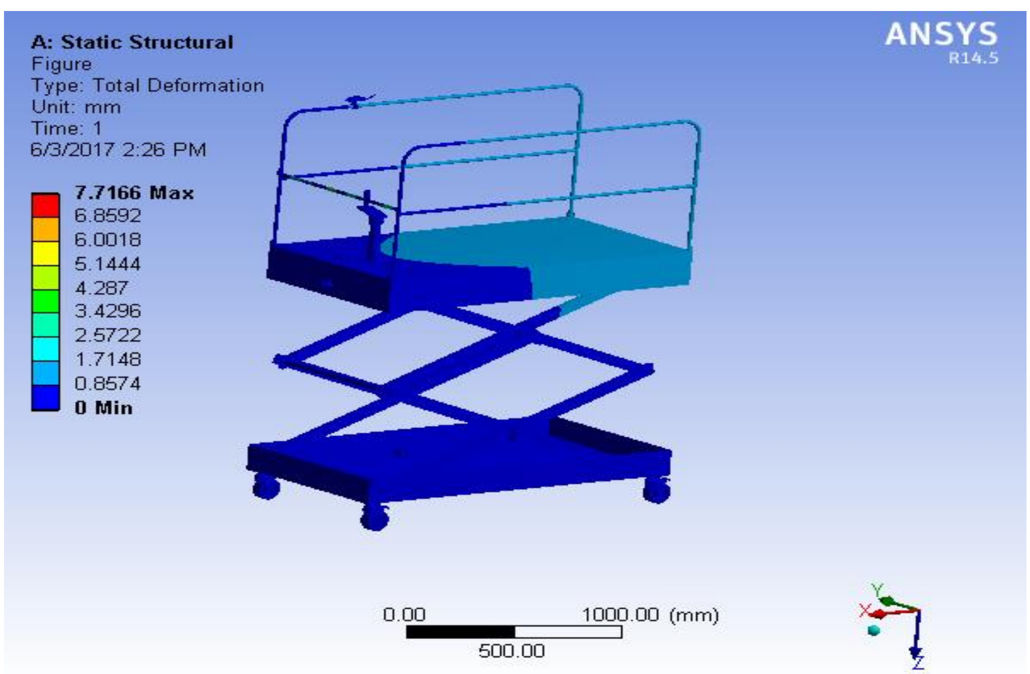
4.11.3 Equivalent Elastic Strain



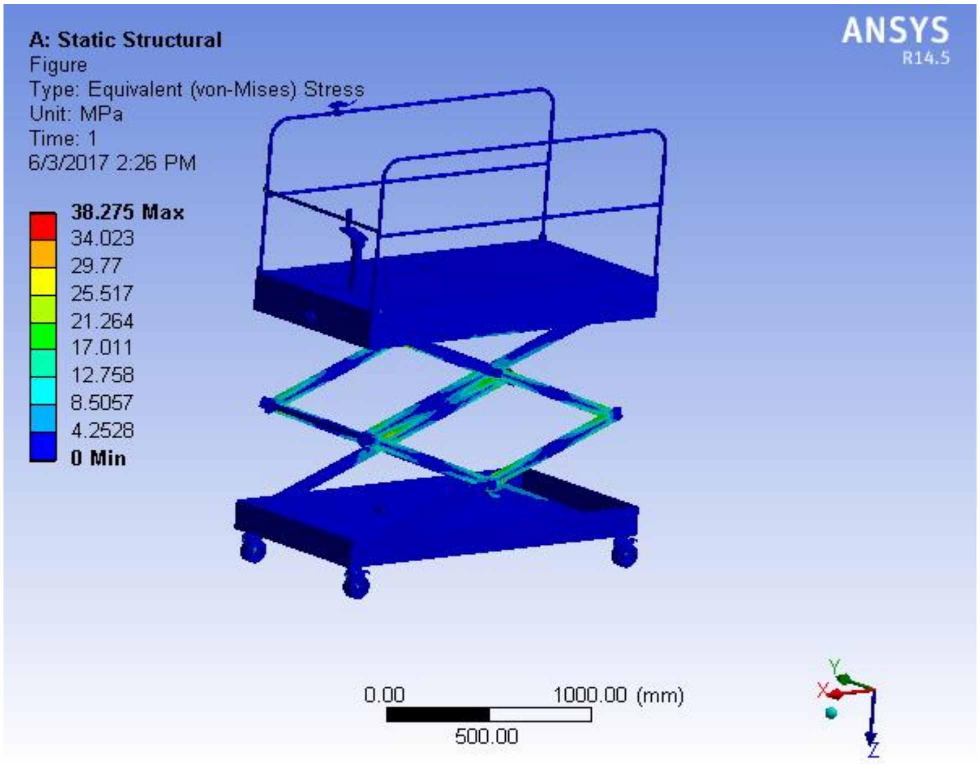
4.12 Analysis the structure of scissor lift model

Here we can see how the forces acting on the scissor lift and how it executes under the mean load 300Kg.

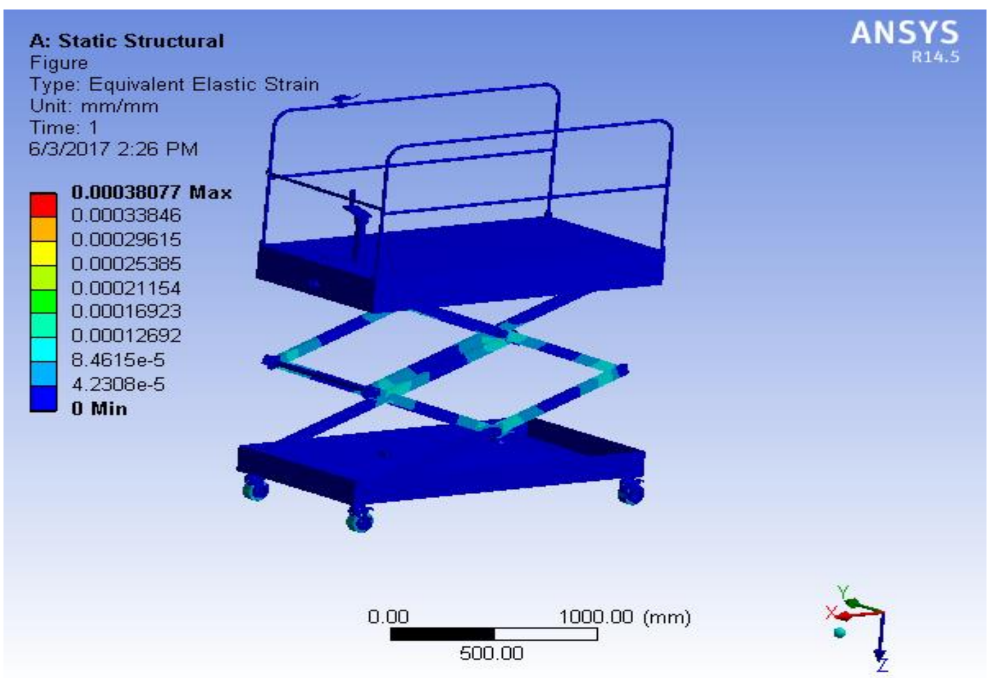
4.12.1 Total Deformation



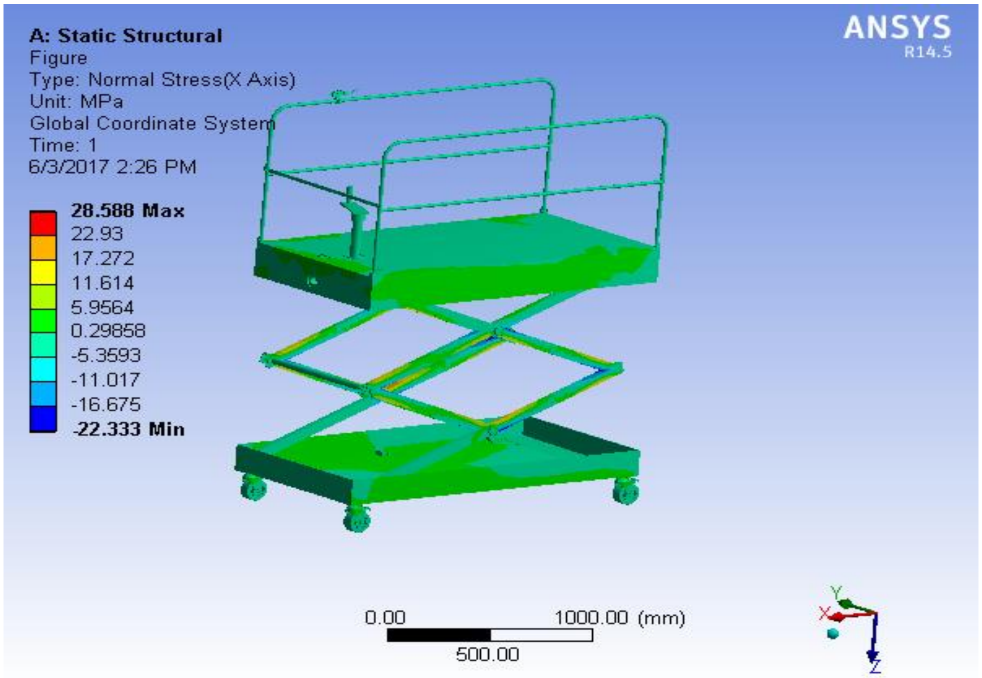
4.12.2 Equivalent Elastic Stress



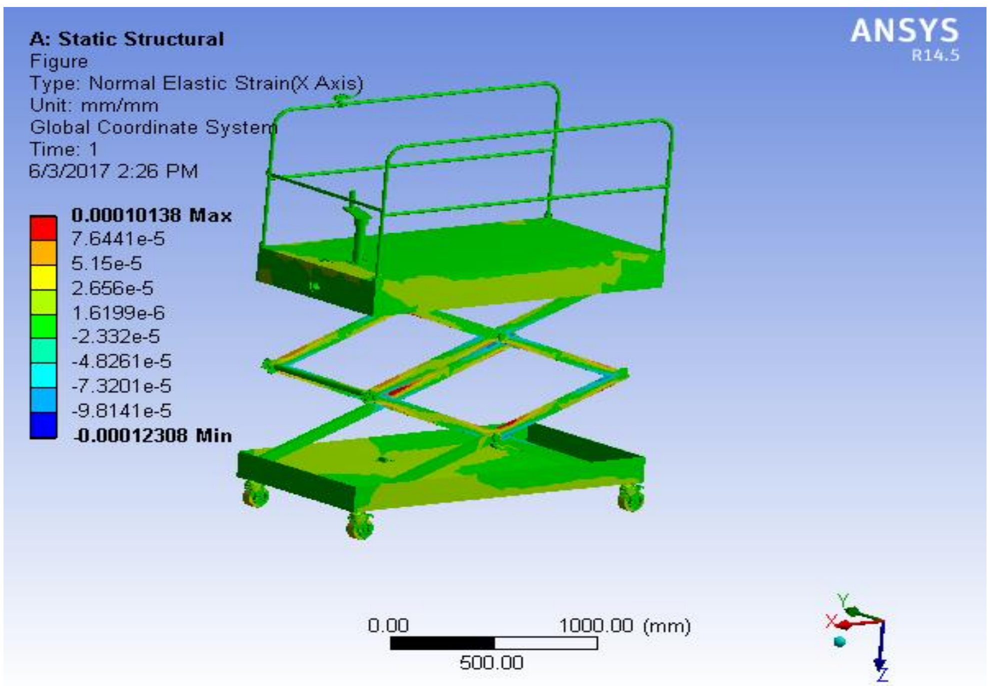
4.12.3 Equivalent Elastic Strain



4.12.4 Normal Stress



4.12.5 Normal Elastic Strain



4.13 Discussion

Table 4. 2 Analysis Results

Analysis Part	Total Deformation (mm)		Equivalent (Von-Mises) Elastic Stress (MPa)		Equivalent Elastic Strain (mm)	
	Minimum	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**
Link	0.016487	0.59956	0.07296	28.61	6.2464 e^{-7}	0.00017042
Bolt	0.77634	0.79299	0.019559	13.344	3.4296 e^{-7}	6.9138e^{-5}
Nut	0.77334	0.78872	0.01258	22.38	1.906 e^{-7}	0.00012044
Bearing	1.2297	1.2382	0.022762	3.942	3.5515 e^{-7}	2.2731 e^{-5}
Bevel Gear	4.954 e^{-11}	5.0771 e^{-11}	3.5273 e^{-15}	1.3977 e^{-8}	3.2066 e^{-20}	1.5776 e^{-13}
Connecting Link	0.26381	0.29661	0.029592	2.2103	9.7004 e^{-7}	1.4081 e^{-5}
Wheel	0	0.0057451	0.014076	23.445	7.8877 e^{-8}	0.00038077
Scissor lift model	0	7.7166	0	38.275	0	0.00038077

Based on the analysis, particularly in our scissor lift, Lift's leg and wheel have higher von-mises stress value as compared to other components. For the reason that when we operate the lift (up and down movement), link is the crucial part to carry the impact load and wheel sustain the overall weight of the lift. Then nut, bolt and bearing these components have higher von-mises stress, but in generally as compared to yield strength all the structural elements of scissor lift have lower Equivalent stress values. Furthermore, each and every parts do not beyond their yield stress values of the material. As a result, design of the scissor lift components is safe. Final design of the scissor lift assembly analysis results shows that, it is considered safe to use targeted weight carrying (300 Kilograms) purpose.

5. Expected cost of the scissor lift

Table 5. 1 Product cost

Sl. No.	PARTS	Material	Qty.	Amount (Euros)
1	Top platform	Structural steel	1	30
2	Bottom platform	Structural Steel	1	30
3	Bevel gear	Gray Cast Iron	2	15
4	Lead Screw	Stainless steel	1	20
5	Cross link	Structural Steel	8	40
6	Racket Pawl	Gray cast iron	1	10
7	Connecting link	Stainless steel	3	20
8	Fasteners (Bolt and Nut)	Stainless Steel	4	5
9	Bearing	Stainless steel	3	15
10	Castor wheel setup	Polypropylene	4	30
11	**Total**		29	**215**

- Machining Cost (Drilling, Welding, Grinding,

  Gas Cutting Cost, Punching etc.,) = 15 Euros
- Labour cost = 30 Euros

If we purchase lift machineries (required specification) from the wholesale market then doing assembly process, price will come about **245 Euro**s. While assembly process supposed to machining process involved, it will take some additional amount for this process. So total cost is,

Total Cost

Total cost = Material Cost + Machining Cost+ Labour cost

= **260 Euros** (roughly)

Today simple hydraulic, pneumatic and electrical lifts, which are available in the market has higher price and also bulkier as compared to our scissor lift. I focused to Let's make product simple and useful, in this project I have designed and analysis the scissor lift developed for household application.

5.1 Recommendations

For reducing the friction between the mechanical parts, it is recommended that we have to lubricated frequently. Lubricants also reduces wear rate movable parts of the scissor lift. Spindle, nut and some parts of the lift maybe susceptible to corrosion, in that way reducing its strength and toughness. So it is furthermore suggested that to use drying agents and moisture barrier products.

5.1.1 User safety precautions

- Before working a lift operator have to know with the surface whether it is even or not. Assume in the event that it is slope, uneven or delicate operator don't raise the lift in this conditions.
- While raising the scissor lift user must keep up least security separation from the electrical connections.
- Check work region for clearances overhead while lifting the scissor lift.
- During operation, keep all body parts inside the platform railing.
- After achieved the desired height user ought to lock the handle of the system generally because of the bevel gear lift naturally begins to move downwards.
- User should convey load inside the scissor lift weigh up limit.

6. Conclusion

Strength conditions of structural elements of the model have been analyzed and the optimal results have been achieved. The prime goal being analysis of strength of conditions of structural elements, we have 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 the hydraulic lifts we use in our daily basis, our model consists of a mechanical drive. It paves the way for many advantages:

- Ease of use - Just one person will be required for operation. So, the person who is using the lift can operate it by himself, whereas in traditional models, we require an additional person for operation.
- Weight - Absence of the hydraulic cylinder resulted in reduction of the weight of the model. Our model can carry a net weight of 300 Kgs of load and can go upto a height of 2.9 meters which are comparatively better results than the existing models.
- Storage Space - Requires very less space for storage and wage because our model is foldable and its dimensions are very user friendly for a home purpose usage.
- Price factor – Our lift will be available for a price of around 250 euros, whereas the existing lifts in the market are priced from a range of 350 to 600 euros
- Maintenance – The operational costs and maintenance costs are very less compared to the other lifts in the market

We are able to produce lifts at a less cost because it doesn’t involve any hydraulic (or) electrical systems in it. Only mechanical technology benefits a lot in when it comes to the production costs.

To conclude, I strongly believe that apart from the design being successful, our scissor lift is also a new approach to the market.

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