KAUNAS UNIVERSITY OF TECHNOLOGY

FACULTY OF MECHANICAL ENGINEERING AND DESIGN

Abdallah Lagha

Design and Analysis of Car‘s Lifting Device

Final project for Master’s degree

Supervisor

Assoc. Prof. dr. Inga Skiedraite

KAUNAS, 2017

KAUNAS UNIVERSITY OF TECHNOLOGY
FACULTY OF MECHANICAL ENGINEERING AND DESIGN
MECHANICAL DEPARTMENT

Design and Analysis of Car‘s Lifting Device

Final project for Master’s degree

Title of program (code xxxxxx)

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"Design and Analysis of Car's Lifting Device"

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Kaunas

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MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT

Study program: MECHANICAL ENGINEER - 612H30001

Confirmed *2017 y. april m. 21 d. dekano įsakymu Nr. V 25-11-8*

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SUMMARY

The aim of this study is to create a system of mechanisms that is able to deal with various types of vehicles in different conditions and dimensions. It should be eco-friendly and with competitive price in the market.

A literature review is made on present types of vehicle lifters. It represents a description of different types of lifts and their respective advantages and disadvantages along with the specific mechanism to upgrade.

A scissor lift of specific properties is selected to be upgraded. A description of proposed prototype is carried out. A 3D model was made presenting its functionality and assembly. Assembly process is explained in detail.

A structural and ability analysis were applied on the proposed prototype on different levels. A comparison between the results of proposed prototype and standard mechanism. Specific materials were selected for the proposed model.

The results prove that the proposed structure is assured of its function. The proposed system eliminates the disadvantages along with it being eco-friendly.

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SANTRAUKA

(santraukos tekstas)

Contents

INTRODUCTION

Vehicle lifters are of modern mechanisms. If going through vehicle lifts' history, it is clear that this mechanism is aged around 50 to 60 years old. Before that, all mechanics used to lay underneath the vehicle for maintenance, this had the results of several injuries and non-accomplished jobs. One of the problems that faced the mechanics, is that the ground clearance for cars is too small which may cause an obstacle for removing some parts or close the way in front of some tools to fix the car.

The old mechanics had two ways to solve the mentioned problem: the first was an underground hole, and the second was a ramp, then it was upgraded to further modern types like two posts lifts and other mobile lifters. Each mechanism had a drawback and from there the idea of creating a mechanism preventing the old types down sides. The aim and tasks to do were as follow:

The aim: To create a system of mechanisms that is able to deal with various types of vehicles in different conditions and dimensions. It should be eco-friendly and with competitive prices in the market.

Tasks

The aim can be made by achieving the following tasks:

- Make a full literature review of existing lifting mechanism presenting advantages and disadvantages
- Choose a specific mechanism to upgrade
- Create a 3d model
- Eliminate the disadvantages
- Create a mechanism with variable dimension
- The use of the appropriate material to prevent wearing out in joints
- Create an eco-friendly mechanism
- Create a competitive product for the market

1. REVIEW OF EXISTING LIFT

The firstly existed types of vehicle lifters in the market was a ramp. A ramp is a sloping surface where car get over it to increase the clearance underneath the vehicle. This allows the mechanics to perform the job more easily. A drawback for the ramp is its inconvenience, since some vehicles don’t have the ability to move, as well sometimes the visibility underneath is restricted. With respect to the following, designers tended to create a new mechanism that have the ability to lift the vehicle while saving both the maximum clearance and space. Designers created several designs some of them are underground holes (Fig 1.) and above ground lifts (Fig 2.).

Fig 1. Underground hole [27]

Fig 2. Ramp [52]

1.1.Ground lifts

Ground lifts are known as a huge hydraulic cylinder in the ground. On the top of this cylinder, exist an H shaped beam which the bottom of the vehicle lay on, and later it gets lifted to a higher level (Fig. 3).

Fig 3. H ground lift [51]

Other models were released into market like using two hydraulic cylinders instead of one and telescopic arms on top of it. But it has a downside that it needs to dig a hole in the ground and in case of oil leakage the oil go under the ground which may harm the environment. Also, one more downside is in case of failure it is very hard to service.

1.2.Above ground lift

Due to the disadvantages and problems facing the ground system, an upgrade is applied and a new mechanism came to market which is above ground mechanism, for example: the various types of lifts can vary from movable scissor lift to fixed 2 poles and 4 poles car lifts and separated mobile poles.

And each one of these has its own assets and drawbacks.

1.2.1. Two Post Surface Mounted Car Lifts

The most important type of car lifts used nowadays is the 2 post surface mounted car (Fig 4.). Its structures consist of, two beams fixed to the ground on a strong concrete platform. Connecting the two vertical beams is a cross-beam, to insure the stability of the post. This cross-beam prevents the bending of the beams toward each other. On the beams, there is lifting arms which are synchronized hydraulically to raise up the load horizontally without any inclination.

Fig 4. 2 Post surface mounted car lift

Fig 5. Multi-post runway car lift [50]

1.2.2. Multi-Post Runway Car Lifts

Multi-post runway is often comprised of 4-post lift. In this type of lifts, the vehicle rides over a platform and then the whole platform is lifted, therefore the vehicle is lifted (fig 5.). An advantage of this type of lifts is its stability and having the ability of various types of vehicles. A withdraw, is its requirement for more empty space in the warehouse and its limited dimensions.

1.2.3. Scissor lift

Scissor lift is usually a complex mechanism friendly used usually used in small garages and it is used commonly in places to changes tires and peripheric job since it occupies a big area from the underneath of the vehicle. It has lots of downsides while operating, it has one fixed size and the other sliding on the ground (Fig. 6.)).

There are 2 types of scissor lifts mounts. The first type is can be mounted on the ground, the second type can be mounted in the ground. The withdraw of this type of lift is that it has very limited height compared to other post lifts.

Fig 6. Scissor lift [49]

Fig 7. Wheel Engaging Mobile Units [48]

1.2.4. Wheel Engaging Mobile Units

This type of lifts is multi movable post with minimum number post (fig 7.). What makes it more significant than other types, the posts are not connected mechanically. It can deal with wide range of vehicles, including long vehicles. Other difference than the other types, is it lifts the vehicle from the heels and not from the main body.

Every single system of the above has some advantages and disadvantages.

1.3. Advantages and disadvantages of each mechanism

Each mechanism presents some advantages and disadvantages starting from two post lift going to four post lift arriving to scissor lift. The advantages and disadvantages are presented in Table 1. And for four post lifts are presented in Table 2. For scissor lifts the advantages and disadvantages are presented in Table 3.

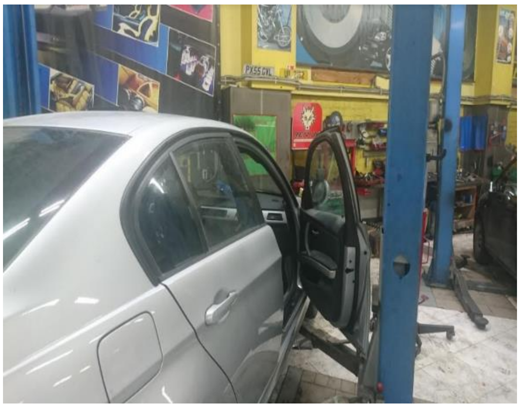


Fig 8. Problem opening the car door

Table 1. Advantages and disadvantages of two post lifters

Advantages	Disadvantages
• It is cheap – it does not cost like others it costs about 1000 USD. • It is good for work related to tires, brakes and suspension work, as these components hang free. • More undercar clearance.	• It loses stability very fast. • It loses its efficiency when changing from vehicle to other depending on the type and weight of vehicle. • It loses stability while changing engine or gearbox. • It cannot be moved. • It depends on the stability of underneath ground. • Door cannot be opened (fig 8.).

The two post lifters have common disadvantages the it limits the side clearance of the vehicle (Fig.8) it almost makes the access to the vehicle impossible.

Table 2. advantages and disadvantages of four post lifters

Advantages	Disadvantages
• 4-post is good for engine, transmission and exhausts work, and is generally more stable and less prone to failure due to improper installation or misuse. • A 4-post can approach the usefulness of a 2-post with the addition of rolling jacks. • 4-post is inherently more stable, relying more on simple gravity and mass. Disadvantages: • It is costly - almost double or triple the price of the 2-post lift. • It takes big area of the garage. • It cannot be moved. • Vehicle dimension is totally restricted.	• It is costly - almost double or triple the price of the 2-post lift. • It takes big area of the garage. • It cannot be moved. • Vehicle dimension is totally restricted.

Table 3. advantages and disadvantages of scissor lifters

Advantages	**Disadvantages**
• Depending on the work needs, the scissor lift can be found in two types, the first is movable the second is fixed. • It saves space, when the lift is not being used and compacted, the area consumed by this lift is minimal. • Its flat surface allows easier maneuverability • It is very stable.	• More expensive, especially for one to lift. • Its width is restricted, so it loses its efficiency from vehicle to another. • Some works in the vehicle are restricted, since the scissor take big place underneath the vehicle. • Wear out in joints (fig 9) • Lubricants and hydraulic ten to leak. • At certain height, it loses stability and fail down

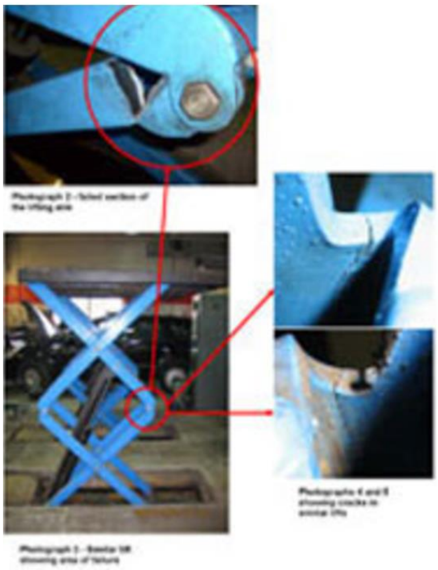


Fig 9. Wear and fracture in joints [47]

Fig 10. car in unstable position [27]

This scissor lift has a critical disadvantage (Fig.10) if the vehicle load is not distributed correctly it loose stability and tend to fall down to the side where the vehicle is heavier, that because the vehicle weight is not distributed evenly, the motor side is heavier than the rear of the vehicle. The vehicle lift when it is extended the distance between the lifting leg take the shape of X and the distance is so small between the end of legs, so if the vehicle is not positioned properly the lift loose stability and tend to fall down to the heavier side.

From what is previously shown, it is obvious that the need of universal modern vehicle lift is important especially with the growth of vehicles number worldwide.

1.4. Problem to be solved

From previous information, it is rare to find a universal lift without all the drawbacks marked above.

From what above it is clear the need for a universal mechanism with the least amount of downside in the market

Selected prototype

Scissor lift is the chosen mechanism to be upgraded for the following reasons:

- It can be a mobile system.
- It is stable with the variation of the ground (sand, concrete and asphalt …).
- It can deal with heavy loads.
- When it is extracted it take very small area so it can be stored in a pick up or commercial vehicle.

For these reasons, it is clear that this mechanism with some adjustments is capable to deal with the mission given to it, but it has many disadvantages to be eliminated.

2. MODEL PROPOSAL OF LIFTING MECHANISM

2.1. 3D model:

The 3D model presents the full mechanism beginning from motor and gearbox going to the driving gears, it is all connected mechanically and electronically to perform the needed operation whether lifting or lowering the vehicle. The model presents the full mechanism which can be divided to two sub frames, left and right frames. The left and right frame are similar and built from same component and they operate simultaneously controlled by height sensor. This mechanism is able to lift 4000kg with variable width and length that can be achieved by the rotating lifting arms and slider mechanism.

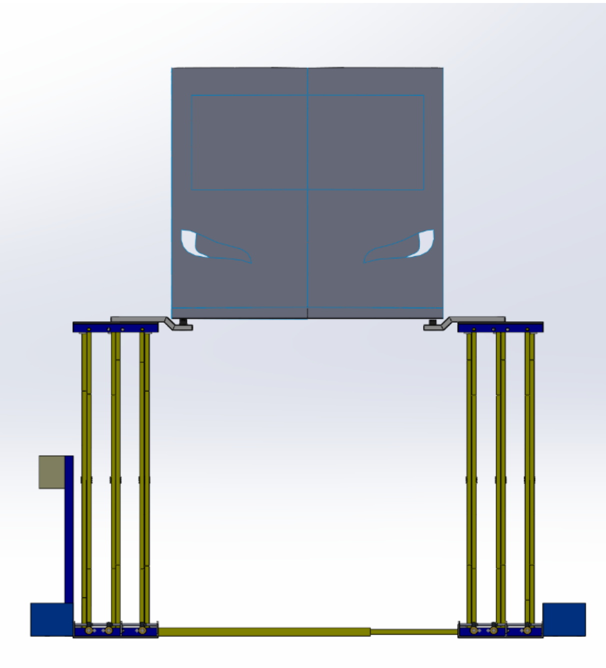


Fig 1. Mechanism front view

Loaded lift at highest position from the front view

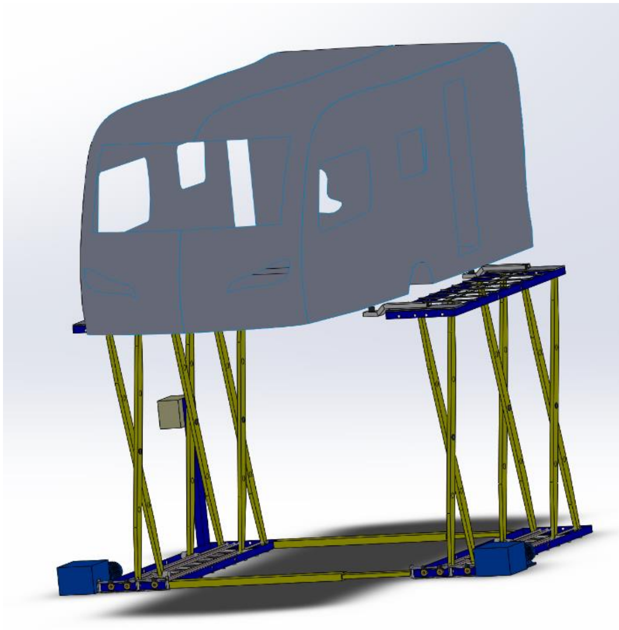
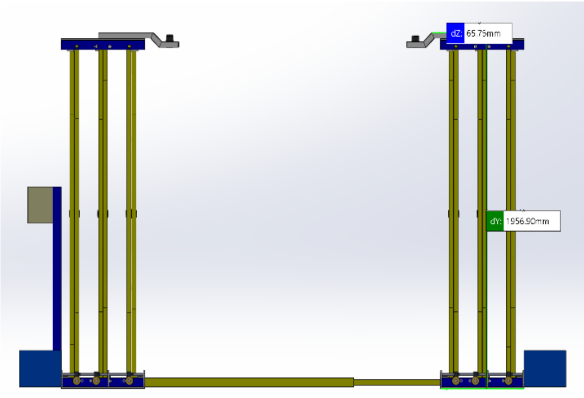


Fig 2. Isometric view in highest position

Isometric view of loaded lift in highest position

The Fig. 1 present the lift while it is loaded from the front view, it also presents the clearance underneath the vehicle is totally free and the worker can perform any action needed underneath the vehicle. Figure 2 present the isometric view of the loaded lift so it is clear that from all sides the clearance underneath the vehicle is empty and all types of operations can be done.



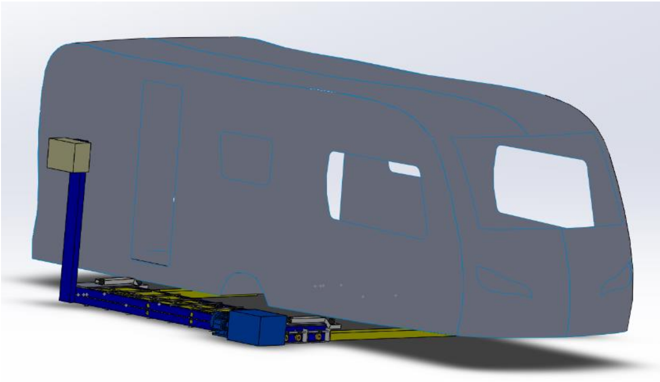


Fig 3. Maximum height

Figure presenting unloaded lift at maximum height of 1956mm

Fig 4. Side view in lowest position

Loaded lift at the lowest height

(Fig. 3) present the lift unloaded while it is fully extended.

(fig. 4) the loaded vehicle is at lowest point which mean fully retracted and the vehicle is over it and it shows that doesn't matter how low is the vehicle the lift is still operating normally.

the (Fig.5,6) present that when the system is fully retracted, it doesn't take a big area of the warehouse

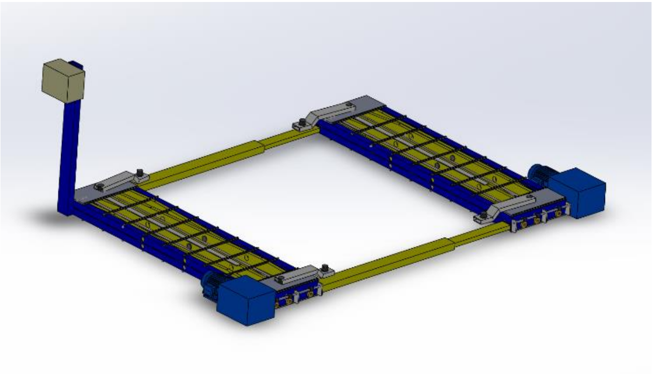


Fig 5. Retracted mechanism

Unloaded lift at lowest height

Fig 6. Extended mechanism

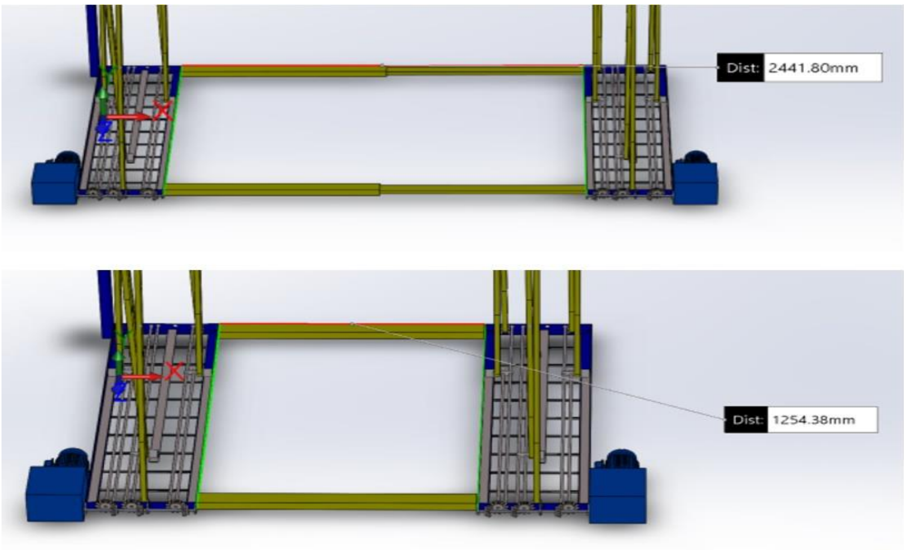


Fig 7. width difference

Figure presenting the width variation from 1254.38mm to 2441.80mm

The (Fig.7) present that this mechanism has variable width starting from 1254 mm to 2441mm depending on the need it can be changed regarding the width of the vehicle the operator is intend to work on.

Table 4. This model proposed consists of:

Part number	quantity	Part name	Description
I. Electrical component			
1	1	Distance sensor	Height detector
2	2	Switch	High level low level switch
3	6	Obstacle detector	Detect if any obstacle on the rail
4	1	Contactor	Contactor for three phase motor
5	1	Computer board	Brain of the system
6	2	Emergency button	A switch off button in case of emergency
7	1	Electrical motor	Motor powering the mechanism
8	1	LCD monitor	Monitoring the height
9	1	On off switch	On off switch
10	2	Up and down buttons	Up and down buttons
II. Mechanical components			
1	2	Feet	Supporting the mechanism
2	2	Wheels	To move the mechanism
3	2	Wheel hub	Fixing the wheels
4	20	Strength beam	Strengthening the frame
5	3 sets	Worm gear	Directing and ensuring the movement from motor to the mechanism
6	1	Shaft	Connecting the motor with the pinion of worm gears
7	2	Frame	The main frame
8	3	Scissor joints	Connecting the main arms
9	3	Guiding screw	Moving the scissor
10	6	Roller	Rolling on the rail
11	3	Guiding nut	Fixing the roller and moving through the guiding screw
12	6	Rail	When the roller move on

13	2	Arm support	Fixing the arm on the frame
14	2	Arm	Lifting car arm
15	2	Joints	Connecting arm with the arm support
16	6	Hinge	Hinge for arms

This system is moveable, can be used in different conditions and places. Telescopic arms are used depending on vehicle length. Hydraulic system is used to lift the vehicle. Control unit is responsible for the height to be achieved. The full mechanism works in combination to perform the action of lifting the vehicle without any complications. This whole mechanism lead to better performing as it leaves the bottom and border of the car without any borders to repair.

3. ANALYSIS OF PROTOTYPE

The new model will present some modern materials and features. Some of these features is using like using Teflon in joints to reduce friction and other functions, using electrical drive motors to operate this mechanism.

The previous headers will be discussed in detail.

How system works?

Operator give order to computer by control unit to lift the specific vehicle to a certain height, therefore, the sensor detects the width of the vehicle and adjusts its self-position depending on the vehicle dimensions. The electric motor receives its order and lifts the vehicle to the given height.

This operation can be achieved in the following process:

The operator after positioning the mechanism in place, he inserts the height tending to achieve by pressing the up and down button in the control unit and checking it on the screen located on the control unit, the control unit give order to the motor to operate and start lifting the vehicle, when the vehicle reach the defined height the distance sensor detect that and CPU give the order to the motor to stop.

The mechanical movement flow as follow: the motor rotates a shaft, on the shaft there are 3 worms of worm gears, those worm gears pinion in their order turn the main wormer gear which in their order turn three driving screws. The driving screws when it rotates in its place it moves a nut along the screw. The nut sliding forward and back ward on the screw and when it slides it moves with it the scissor arm and with this movement the lift raise up or down.

3.1. Structural and stability analysis

Force acting on the guiding screw in case of the standard lift and the proposed lift in case of standard lift in lifting mode (Fig. XXX).

The mechanism and system are in balance condition so $\sum F=0 \Rightarrow F_{load} = F_{motor}$.

Main parameters for calculations are: screw nominal diameter: d = 14 mm, screw core diameter d_c = 12 mm, pitch p = 2 mm, load w = 2000 kg, friction coefficient μ = 0.15, screw mean diameter d_m = 13 mm, screw helix angle α = 2.68°.

The needed tangential force at the circumference of the screw to raise the load[12], where $\mu = \tan \varnothing = 0.15$.

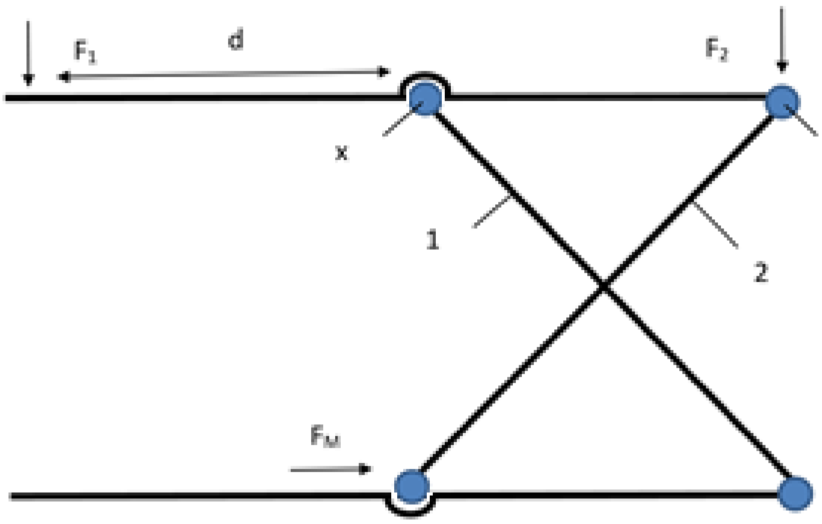


Fig 1. Standard mechanism free body diagram

$$P = w \times \frac{tan\,(\propto) + tan\,(\phi)}{1 - tan\,(\propto)\,.tan\,(\phi)} \approx 4000\ N \quad (1)$$

The needed torque to turn the screw

$$T = p \times \frac{d}{2} + \mu V_m \quad (2)$$

T = 4000 x 12/2 + (0.15 x 200 x 18) = 26540Nm = 26Nm.

T is 26 Nm, which is very high torque.

In case of proposed lift in system is in stable condition so ∑F=0. proposed mechanism has 3 sets of lifting legs.

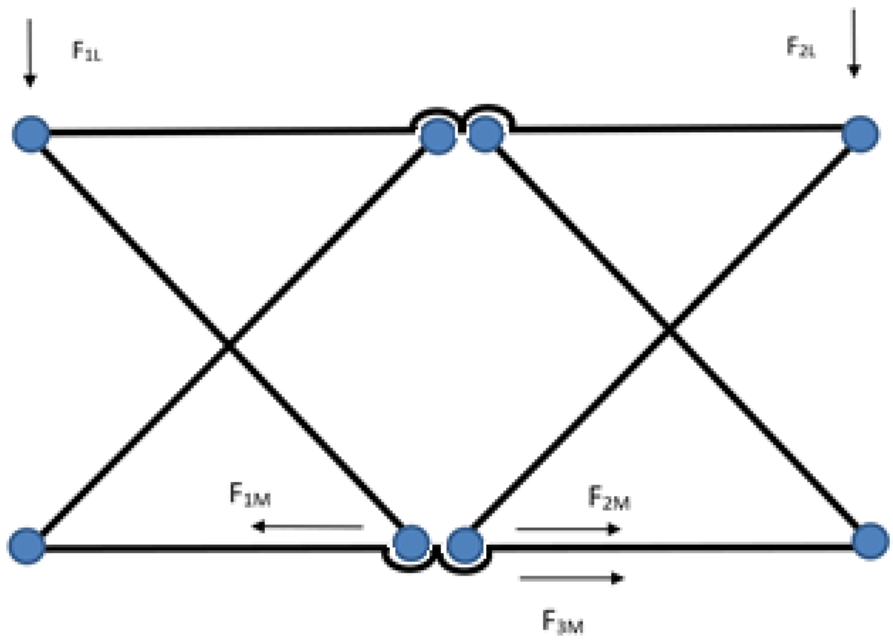


Fig 2. Proposed mechanism

$F_{load} - F_1 - F_2 - F_3 = 0$

$F_{load} = F_1 + F_2 + F_3$ $\quad$ $F_1=F_2=F_3$ *since of the symmetricity of the system*

$=> F_{load} = 3F_{motor}$

$F_{motor} = \frac{F_{Load}}{3}$

Concerning the same previous conditions as in standard lift.

The difference is that load is divided now to 3 screws, which mean $Load_1 = \frac{2000}{3} =$ 666.6kg

Tangential force required

$$P = w \times \frac{tan \propto + tan\ \phi}{1 - tan \propto .tan\ \phi} \approx 1400N \tag{1}$$

The needed torque to turn the screw:

$$p \times {}^{d}/_{2} + (\mu\ r\ m) \tag{2}$$

$9640Nmm = 9.6Nm$

The torque acting on the screw in the proposed mechanism is much smaller than in standard case. *9.6Nm<26Nm*

Load distribution in case of standard lift.

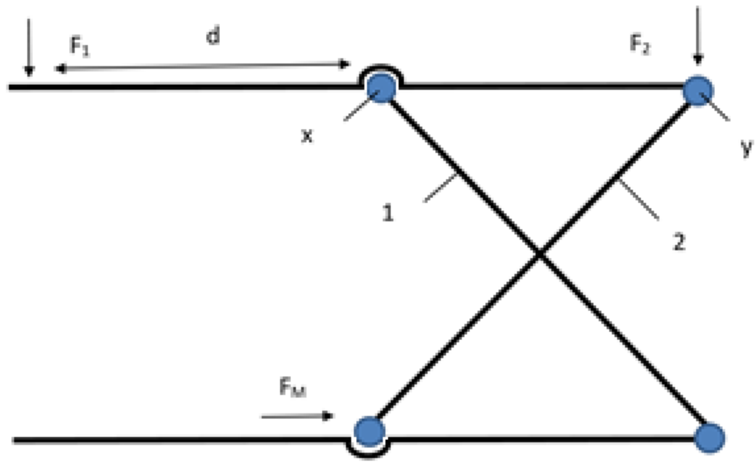


Fig 1. Standard mechanism free body diagram

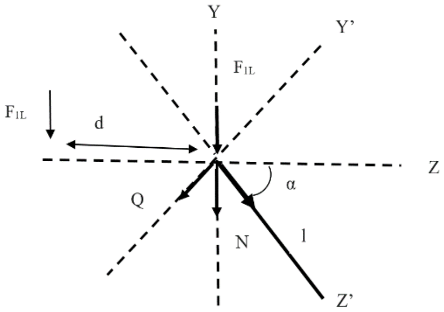
In this case while the lift is extended and it is loaded, it is important to understand the load distribution on the mechanism. The distance between x and y shown in the figure is changing. The highest point is the critical point, since points x and y are inversely proportional to distance d. When points x and y are at maximum therefore distance d is minimum and vice versa.

There is a moment acting on the frame $M = F.d$ (3)

$M = 9810 \times 1.48 = 14518.8Nm$

It is a big moment acting on the frame that leads to a bending and shear stress in the frame and joints.

That can be determined by applying a free body diagram analysis on leg "1"



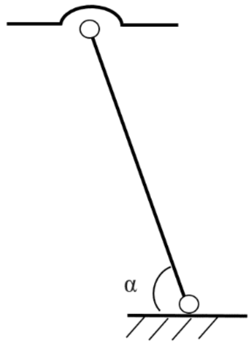


Fig 2. Free body diagram of the forces acting inside the link

Fig 3. Link under study

From the diagram

$$N = Fsin\propto = 9595.6N \quad (4)$$

$$Q = Fcos\propto = 2039.61N \quad (5)$$

$$M = Fcos\propto . l = 3875.2Nm \quad (6)$$

From the results above it is clear that huge stress is acting and system is not stable.

In case of proposed system

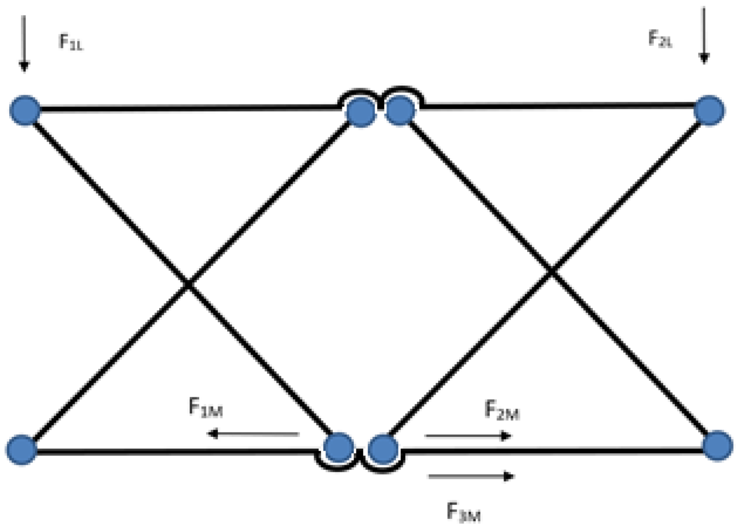


Fig 4. Proposed scissor lift

Structural analysis for proposal mechanism

First position $\propto = 78°$

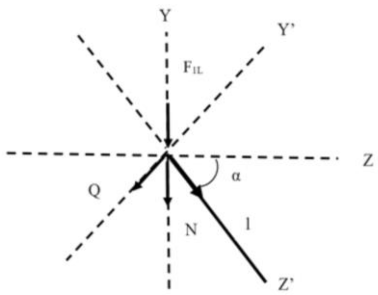


Fig 4. Free body diagram of the forces acting on the link in position one

The free body diagram shows that

$$N = Fsin \propto \quad (4)$$

$$Q = Fcos \propto \quad (5)$$

$$M = Fcos \propto . l \quad (6)$$

F: load acting on the leg. The total load is, *F = mg = 2000kg x 9.81 = 19620N*

F acting on each leg = *19620/3 = 6540N*

l is leg length = 1.9m

That means

$N = 6397N$

$Q = 1359.74N$

$M = 2583.5Nm$

At position two $\propto = 60°$

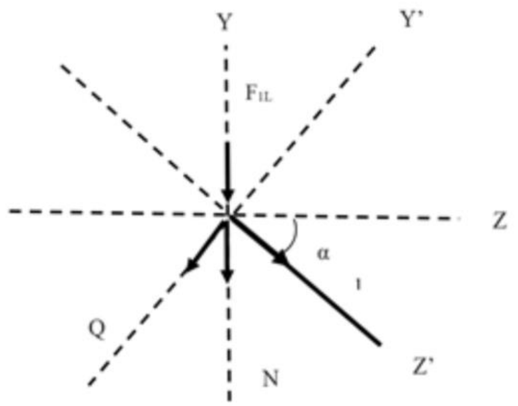


Fig 5. Free body diagram of the forces acting on the link in position two

The results of forces acting on the link are (Fig. XX): $N = 5663.8N$, $Q = 3270$N, $M = 6213Nm$

At position three ∝ = 45°

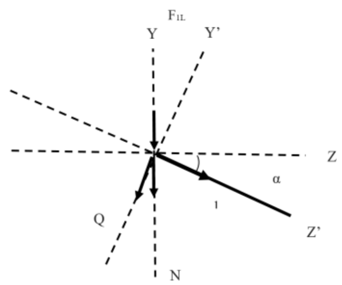


Fig 6. Free body diagram of the forces acting on the link in position three

The results of forces acting on the link are

$N = 4624.4N$

$Q = 4624.4N$

$M = 8786.5Nm$

At position four ∝ = 30°

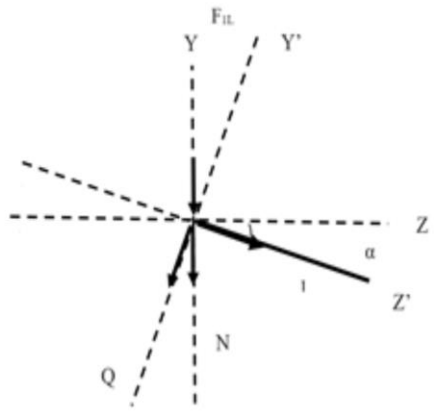


Fig 7. Free body diagram of the forces acting on the link in position four

The results of forces acting on the link are

$N = 3270N$

$Q = 5663.8N$

$M = 10761.2Nm$

At position five $\propto = 10°$

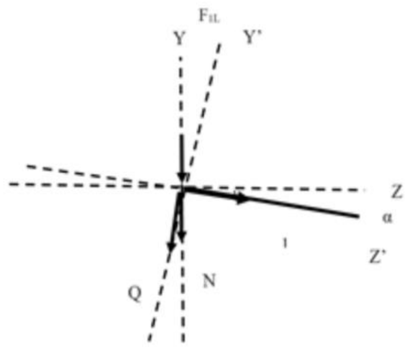


Fig 8. Free body diagram of the forces acting on the link in position five

The results are

$N = 1135.65N$

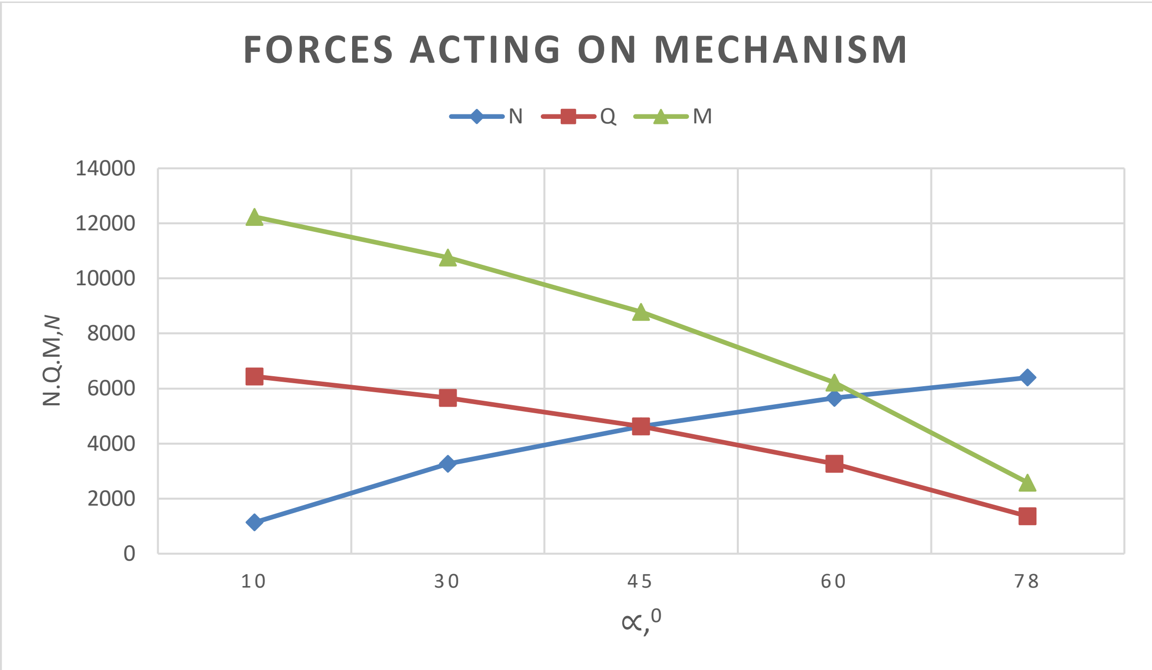
$Q = 6440.6N$

$M = 12237.2Nm$

Table 5. the shear forces and reaction and moment according to different angle

Position	1	2	3	4	5
∝	10	30	45	60	78
N	1135.65	3270	4624.4	5663.8	6397
Q	6440.6	5663.8	4624.4	3270	1359.4
M	12237.2	10761.2	8786.5	6213	2583.5

Table presenting the variance forces depending on different angles



This graph shows the variation of the moment (M) in accordance to the variable angles. The moment (M) is inversely proportional to the angle. As the angle is increasing, the moment is decreasing.

Shear force Q is inversely proportional with reaction depending on the angle.

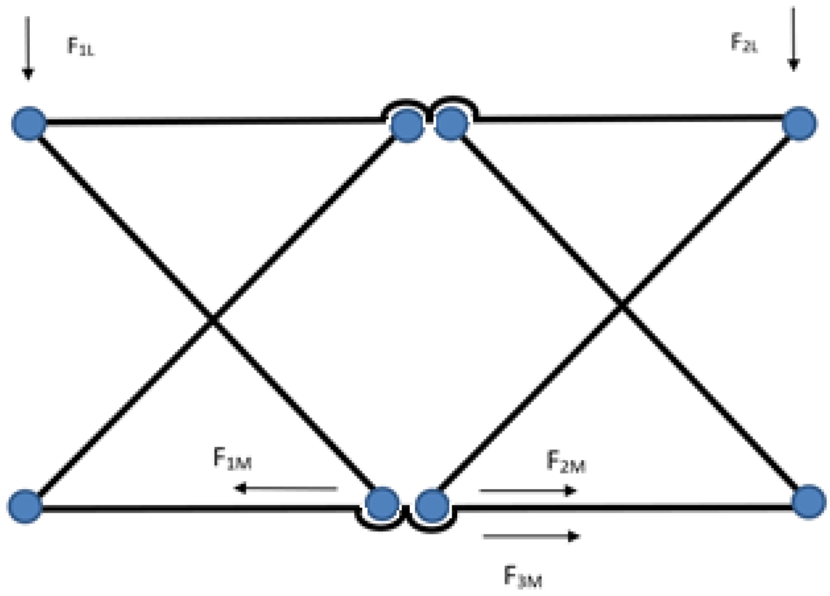


Fig 9. Proposed mechanism free body diagram

F1 and F2 are acting directly on the joint which mean d=0. Which leads to

$M = F \times d$

$M = F \times 0 = 0$

As a result, the system is not affected with load distribution.

Especially the vehicle weight distribution is not symmetrical, this means the weight on a side is more concentrated than other. Therefore, in case of standard lift it is important to take care of load distribution to not exceed the maximum shear stress to avoid fatal failure. While in the proposed system it is not obligatory.

Side way stability

Lift is consisted of two poles

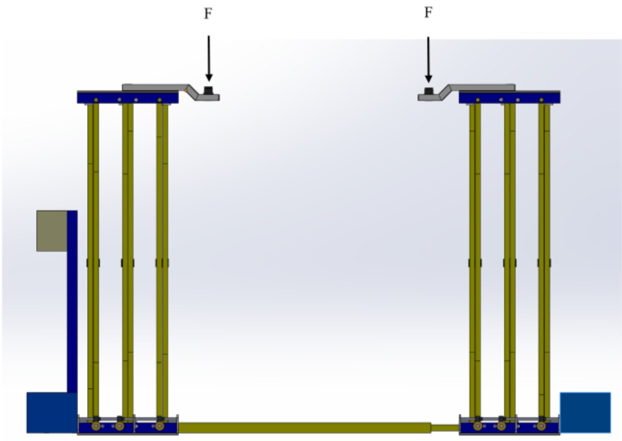


Fig 10. Forces acting on the mechanism

Drawing a simplified from body diagram of the front face of mechanism (Fig. 11) will be as follow

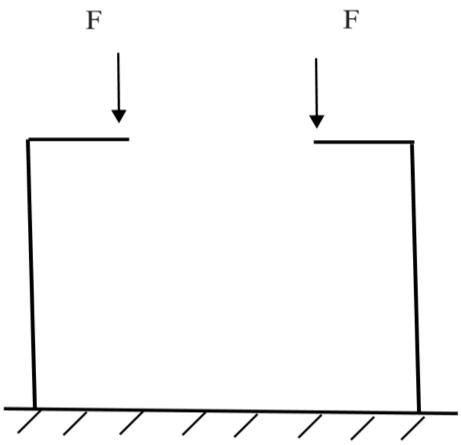


Fig 11. Simplified scheme of mechanism

Having one section from the mechanism (Fig. 12) give a clear view on what is happening in the structural view. Due to the moment resulted from the load: on the link 1 we have comparison and on link 2 we have tension.

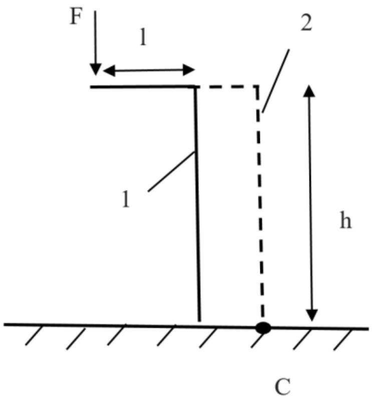


Fig 12. One section of the mechanism

M = F x l =1687.3Nm

Shows the moment acting on the legs and it presents that moment is not that big, while mean structure is safe. Note that “C” is a critical point.

3.2.Static deformation analysis of supporting mechanism

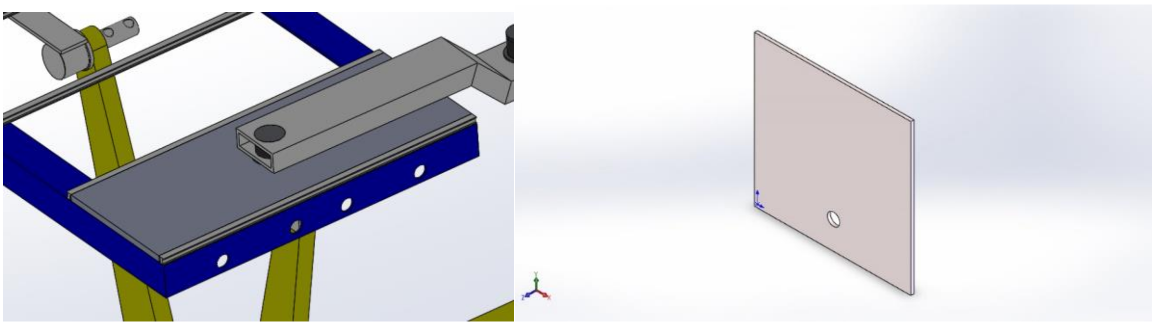


Fig 1. Arm support

A static analysis is performed on the plate supporting the arm and locating it in the mechanism. The mesh in use is automatically calculated by SolidWorks solid mesh (Fig.2)

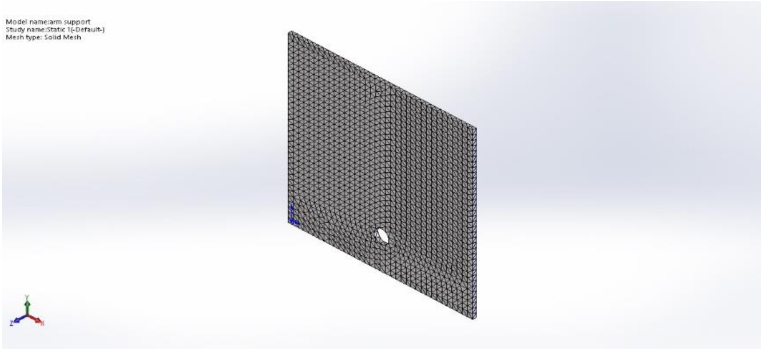


Fig 2. Mesh of arm support

Calculations presents under a load of 4 tons the von Mises stress at the minimum is 8.08834 N/m^2 and at the maximum was 103291 N/m^2 and it is presented in the following figure how the stress is distributed. (Fig. 3)

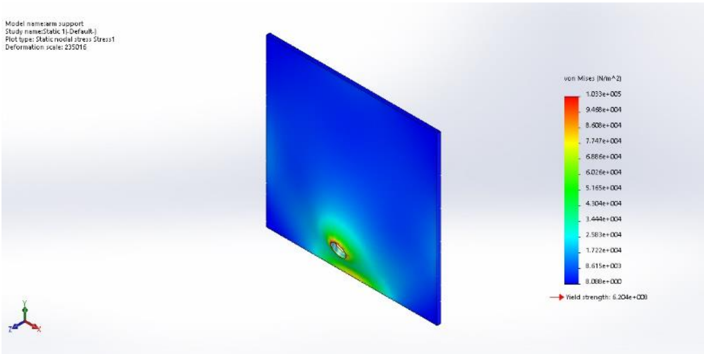


Fig 3. Stress result

Also from solid works calculations the resulted displacement is 0.00021 mm which is a very reasonable and safe number. (Fig.4)

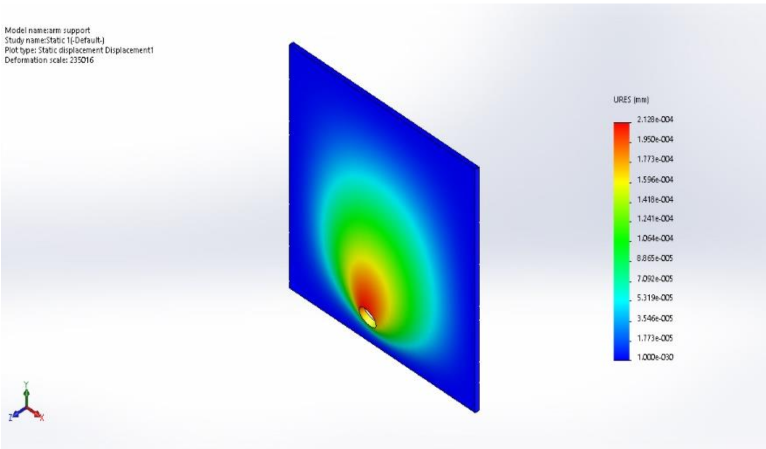


Fig 4. Displacement result

Strain results from SolidWorks present minimum strain as $1.95753x10^{-11}$and maximum strain is $2.63069x10^{-7}$ which is also reasonable number and it is presented as in the following figure. (Fig. 5)

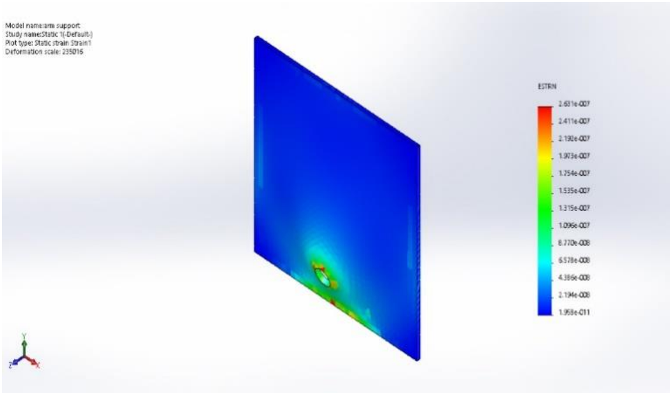


Fig 5. strain result

From the above it is clear that this part of mechanism falls in the safe region

Other static study was applied on the lifting arm and results were as follow:

Assume that vehicle weight is a ton and the vehicle is lifted by 4 arms so the load is divided to 4 which means 1 ton for each arm.

Then load is calculated through this formula

F = M x g ;

F: force (N)

M: weight (kg)

g: gravity $(\frac{m}{s^2})$

F= 1000 x 9.81 = 9810 N

Then pressure $P= \frac{F}{A}$ *[39]*

P= pressure

F= force

A= area

$P= \frac{9810}{1256.64} = 7.8\ N/mm^2 \approx 10\ N/mm^2$

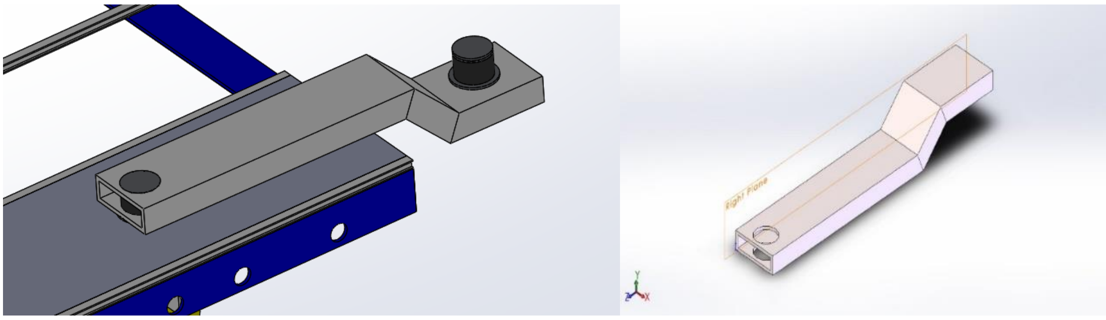


Fig 6. Lifting arm

The calculation applied on this arm is performed using solid work simulation static study under the load calculated above, the mesh was initially made SolidWorks and the type of mesh is Solid Mesh (Fig. 7)

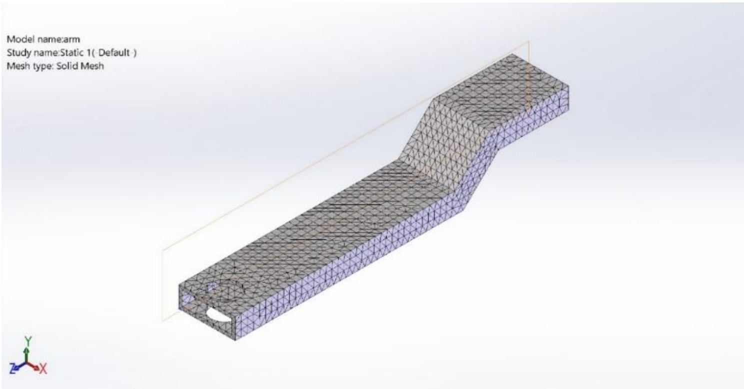


Fig 7. Mesh of lifting arm

And the results came as follow:

For stress "Von Mises Stress" the results were $7.89044x10^6$N/m^2 for minimum and for maximum $5.05883x10^9$N/m^2 those values are very reasonable for such load on one arm and the stress distribution is presented in the following figure. (Fig. 8)

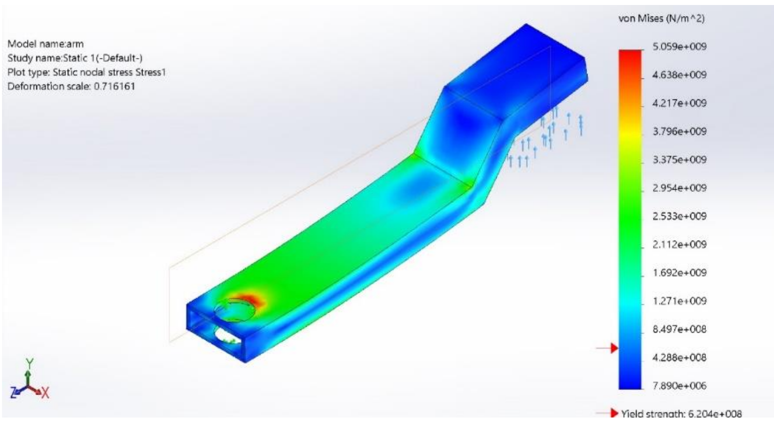


Fig 8. Stress result

Displacement result were not very optimistic but it still falls in the safe region as 67.23mm and it is presented as follow: (Fig. 9)

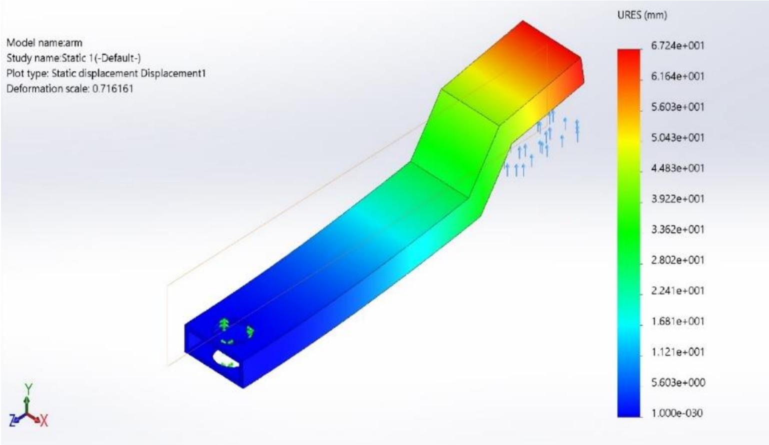


Fig 9. Displacement result

The strain results from equivalent shows it in its maximum as 0.0177 which fall in the safe region.

It is distributed as follow: (Fig. 10)

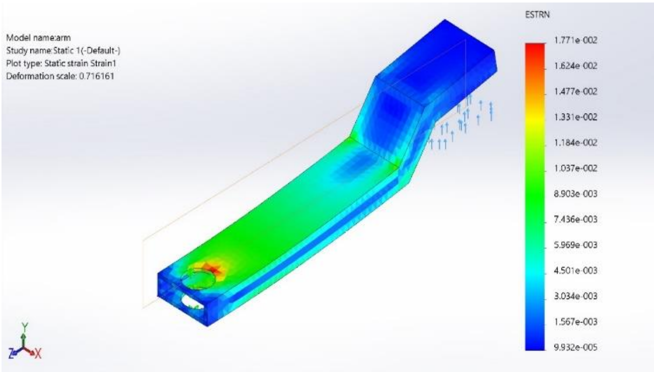


Fig 10. Strain results

The following part in study is a critical part which is the joint in scissor this part work at hinge it connects two parts together under the previous described load

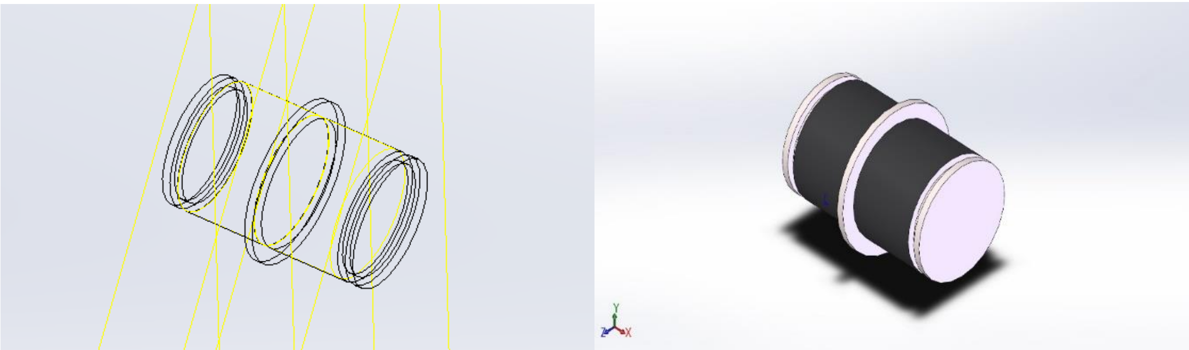


Fig 11. Joint for scissor

As it was assumed before the weight of the vehicle is four tons divided on two mechanism the load on each mechanism is two tons the force from this load is calculated as follow:

F=Mxg = 2000x98.1= 19620N

This force is divided on three joints the F/3= 6540N

So, the torque applied on the joint is calculated as follow:

$$torque = \tau = rFsin\theta$$

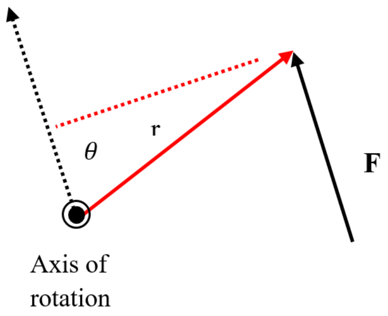


Fig 12. Torque formula

In the (Fig. 12), the angle between r and F is smaller than 180’ when they are drawn from the same point. According the right-hand rule the direction of torque is given, it gives a vector out toward the reader. [40]

An efficient way to calculate the magnitude of the torque is to first determine the lever arm and then multiply it times the applied force. The lever arm is the perpendicular distance from the axis of rotation to the line of action of the force. [28]

If a force of magnitude F = 6540 N is applied at a distance r = 0.02 m from the axis of rotation in an orientation where r makes the angle θ = 90 degrees with respect to the line of action of the force, then the lever arm = 0.02 m and the magnitude of the torque is τ = 135 Nm.

A solid mesh was applied on the part for more accurate calculation (Fig. 13)

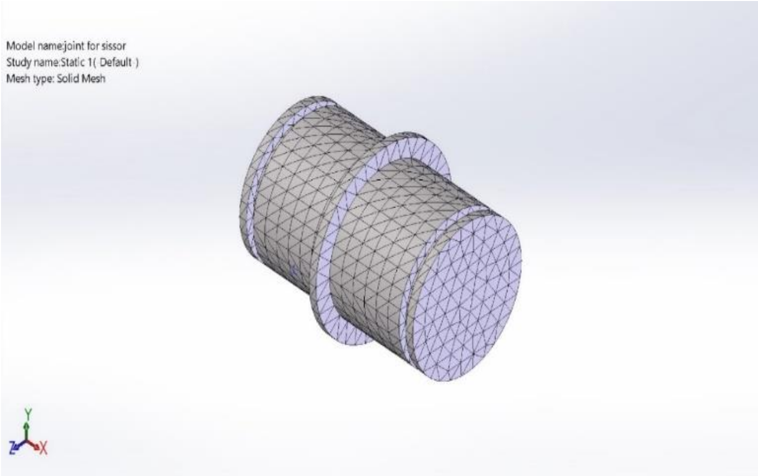


Fig 13. Mesh of scissor joint

The static results show:

In stress, the minimum is equal to 27.0014 N/m^2 and maximum as $2.33412x10^7$N/m^2 which is not bad number and it present the location where is the maximum stress. (Fig. 14)

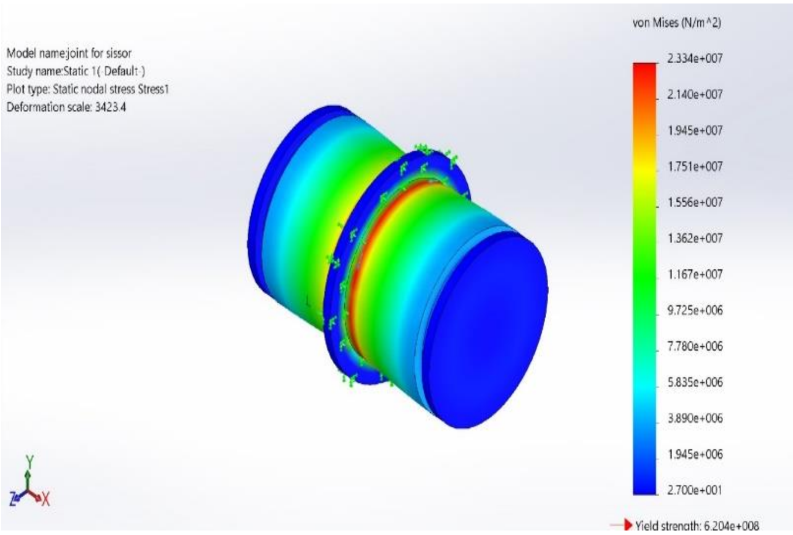


Fig 14. Stress results

Displacements results shows that the maximum displacement is 0.00186mm which is very small number. (Fig. 15)

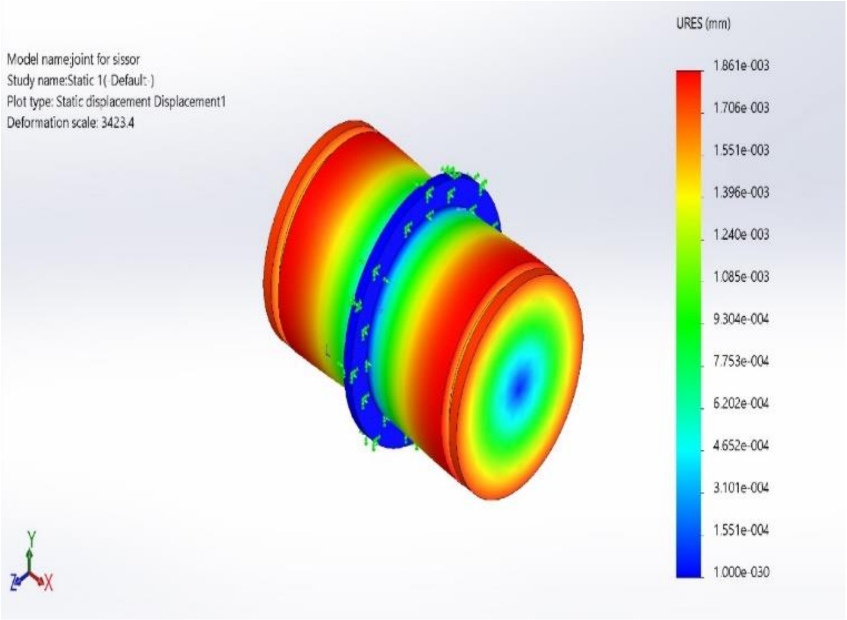


Fig 15. Displacement results

And for strain the minimum is $1.26045x10^{-8}$ and for maximum $9.19185x10^{-5}$ and distributed as follow. (Fig. 16)

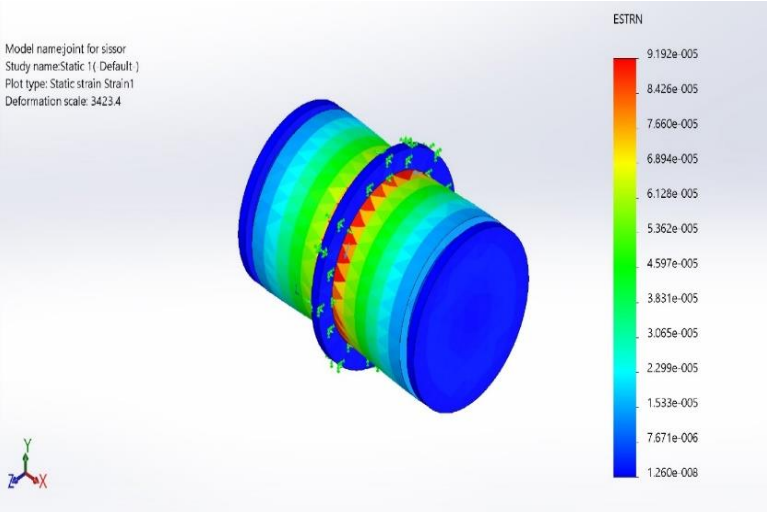


Fig 16. Strain results

All results show that the mechanism fall in the safe region. And it is ready to be manufactured

4. Production process of lifting mechanism

For all operations like cutting, drilling, threading and welding, the technical needed parameters are present in the drawings of the parts. The dimensions fit all the requirements of the machinery process in order to have a simple manufacturing.

Standard measuring tools are used to measure all the dimensions. Standard cutting tools are used in the manufacturing of surfaces. Technological process and part's construction does not require special operations nor the usage of non-standard tools.

The process was done using the following machines:

- CO_2 laser ByAutonom 3015 6.0 kW
- CNC milling machine OKUMA MCR-A5C
- CNC three axial auto welding WT-NVA

For CO_2 laser ByAutonom 3015 6.0 kW: [33]

- Sheet cutting range: 3048x524 mm (two changeable tables)
- Maximum sheet thickness: 25mm (steel), 25mm stainless steel), 15mm (aluminum)
- Positioning speed simultaneous: 169m/min
- Acceleration: 30m/s^2
- Positioning accuracy: +/- 0,1 mm/m
- Repeatability: +/- 0,05 mm
- Edge detection accuracy: +/- 0,5 mm [33]
- Feed 0,83 cm/s of 12 mm thickness

Cutting tool: laser beam

Control tool: vernier calipers

For CNC milling machine OKUMA MCR-A5C: [33]

- Effective distance between columns -3050mm [33]
- Table size (X x Y) -6300 x 2500mm [33]
- Maximum table load -30000kg
- Spindle speed -4000 rotations per minute
- Axis travel (X/Y/Z) – 6500/3500/650 mm [33]

For CNC three axial auto welding WT-NVA:

Types: two-axial planar type

Three-axial curved-surface type

Features:

- Servomotor driven, with CNC control
- Teaching program allows easy presetting
- With approximately 100 memory sets
- Prevents high-frequency interference
- Works with TIG (tungsten inert gas) [34]

Part is rigid and has characteristics of an equilateral. There will be any problems of basing this part and the basing will be reliable.

This system is composed of the following material:

- Part’s blank material L beam, it is used in frame manufacturing
- Square metal sheet, it is used to make the arm support and guiding rail
- Aluminum I beam, it is used in order to make frame support
- Legs were made by casting
- Rectangular beam is used to make stability strength and sliding mechanism

4.1.Selecting and designing worn gears:

Worn gears are selected for this mechanism due to the following characteristics:

Mechanical characteristics:

- High corrosion resistance
- High mechanical strength:
    - Tensile strength R_m: 560 N/mm^2
    - Strain limit $R_{P0,2}$: 290 N/mm^2
    - Strain at failure A_5: 15%
    - Hardness HB2,5/62,5: 140-170
    - Shearing strength: 470 N/mm^2
    - Alternating stress: 170 N/mm^2 ($20x10^6$ cycles)
- Good gliding characteristics
- High wear resistance
- Allow movement in a single direction (self-brake)

Gears in use are standard from FramoMorat gears A35U35.

$F_{motor} = \frac{F_{Load}}{3}$

Concerning the load acting on the worm gear.

The difference is that load is divided now to 3 screws, which mean $Load_1 = \frac{2000}{3} =$ 666.6kg on each screw which mean each worm gear

Tangential force required

$$P = w \times \frac{\tan\propto + \tan\phi}{1 - \tan\propto . \tan\phi} \approx 1400N \qquad (1)$$

The needed torque to turn the screw:

$$p \times {}^{d}/_{2} + (\mu\, r\, m) \qquad (2)$$

9640Nmm = 9.6Nm

i=gear ratio

$\propto_m$=lead angle

M= module

z_1= number of threads

d_{m1}= pitch diameter (worm)

d_{a1}= tip diameter (worm)

z_2= No. of teeth

d_{m2}= pitch diameter (worm gear)

d_A= max. diameter (worm gear)

T_2= output torque

MG= mineral grease

MO= mineral oil/synthetic grease

SO= synthetic oil

Table 6. the selected worm gear specifications

Catalog	I	$\propto_m$	m	**Worm**			**Wormgear**			T_2[Nm] No. Bronze		
				Z_1	d_{m1}	d_{a1}	z_2	d_{m2}	d_A	MG	MO	SO
A35U35	35:1	$35^{\circ}51'$	1.4	1	20.85	23.65	35	49.15	53	17.1	20.5	25.6

4.2.Control unit

The control unit is divided to two section the controller and the control panel. It is consisted of a set of switches and sensors and CPU. Those sensors and switches are connected together to form a full electric circuit and it is presented as follow:

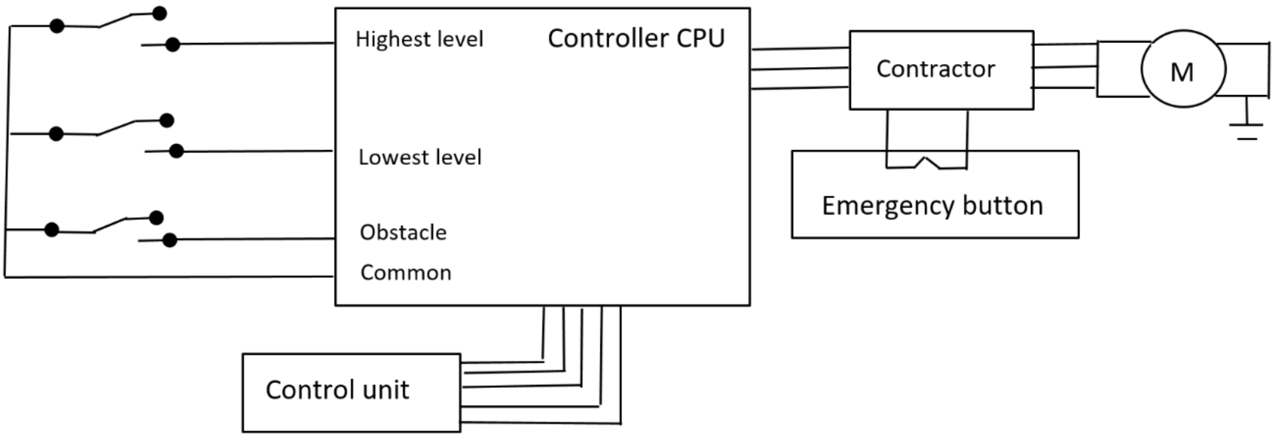


Fig 5. Electrical diagram

The control panel in this mechanism can be displayed as follow:

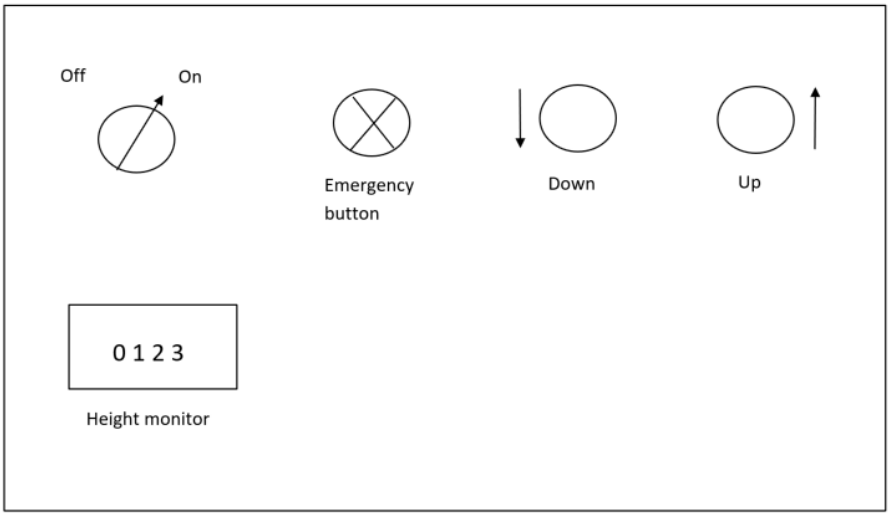
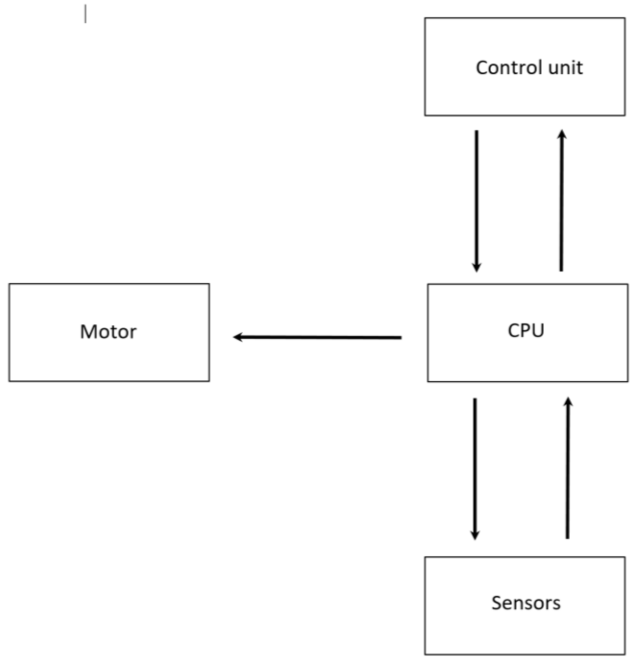


Fig 6. Control unit

Flowchart of the data flow



Flowchart presenting the movement of information

The flowchart present the flow of data in the system, it present how the control unit give order to the CPU, which in it is order give feedback to the screen on the control unit of present and selected height, also it gives order to the motor to lift the mechanism to the desired height, this action will be done only after having feedback from the sensors like if there are any obstacle or the desired height was reached.

4.3.Motor selection:

To select the correct electric motor, there are 5 important steps should be in consideration and they are as follow:

Step 1: *Characteristics of the load*

The main characteristic of loads in line-operated motors, can be sectioned into three different categories. The torque represents the load acting on the motor. These categories are: torque that suddenly changes, continuously changing torque overtime, and constant torque. Examples of line-operated motors which run at relatively steady levels of torque are conveyors in general, extruders, pumps, and compressors.

Once the horsepower (or torque) is known for a certain application, defining the correct motor for the correct application, it is a simple and easy. Load demands by elevators, compactors, punch presses, saws, and batch conveyors change abruptly from low to high, does not require time, usually in a part of a second. [41]

A motor whose speed-torque curve exceeds the load torque curve [41], is the most critical consideration according to these cases for motor selection.

Depending on the use of the motor, loads from some equipment are variables, for example, in some machines load start at maximum in the startup and decrease with time, while others start at minimum and increase with time. Examples are as fans, blowers, lifters.

Step 2: *Clarify the horsepower*

To have a clear view of the horsepower, its necessary to avoid the appeal of oversizing or under sizing but use the needed horsepower only. From that, the needed horsepower can be calculated as follow:

Horsepower = Torque x Speed / 5250 =118 x 176/5250 =4Hp

Where torque is in lbf-ft (later it is converted to Nm) rpm is the unit used for speed.

Step 3: *Torque cycle*

Depending on the usage of the machine, the torque work cycle changes. For example, in lifters, gearboxes, presses, crushes that drive large rolls, these machines perform high torque on the motor at the startup.

The correct motor of appropriate size selected according to the correct horsepower should offer enough torque to turn the machine from a dead stop, which is called (locked-rotor torque). It should be able to reach the operating speed which is known as (pull-up torque), and then preserve the operating speed. [41]

Special specifications should be available for the motor for these applications. Some of the particular specifications are as the temperature. The temperature should always be in operating conditions and preventing any overheating with respect to a certain limit. According to their ability to tolerate the heat resulted from the startup and pulling up, these motors are considered as one of the design types.

Step 4: *Duty cycle*

It is important to clarify the duty cycle, which can be defined as the torque that the motor should handle it while it is operating which mean startup torque, maintaining torque and stoping torque. There are several types as the continuous duty and intermittent duty.

Continuous duty:

Continuous duty till now is the most simple and functional purpose. The temperature in a motor of continuous duty has a chance to stabilize, therefore the selected motor will be operating at the rated capacity. The duty cycle starts by the motor startup, then in a constant operation both motor and heat are in a steady situation.

Intermittent duty:

Intermittent duty is more complicated than continuous duty. Each motor has its life time. The life time of the motor is determined by the number of startups it triggers. [41] As similar as buttons, has the life according to the numbers of clicks. Since the flow of high current at startup, the heat in the motor increase rapidly. Therefore, frequent starts shorten life. Referring to this criterion, motors' lifetime is limited by the number of its starts and stops in an hour.

Step 5: *Motor hypoxia*

At altitude, the low density of the air prevents it from cooling down the motor. A motor will be unable to operate at its full level service factor in a case, therefore, the selected motor should fall within the safe limits of temperature rise and it should be derated on sliding scale depending on the operated area altitude from sea level. [41]

The selected motor is Siemens self-ventilated motors Cast-iron series 1LE1521/1LE1621 Basic/Performance Line [42] connected to a gearbox with input 10 rpm and output 1 rpm

With the following specifications:

Table 7. electric motor specifications

kW	hp	FS	rpm	Nm	kg
3	4	100 L	1760	16	30

4-pole: 1500 rpm at 50 Hz

- Cooling: self-ventilated (IC 411) or with order code F90 forced-air cooled without external fan and fan cover (IC 416) [42]
- Efficiency: NEMA Premium Efficient, UL, CSA and service factor (SF) 1.15 – for operation in the USA, Canada and Mexico [42]
- Insulation: thermal class 155 (temperature class F), IP55 degree of protection, utilization in accordance with thermal class 130 (temperature class B) [42]

Fig 1. Siemens 1LE1023[42]

The electrical component in use are as follow:

The height sensor in use is:

Table 8. height sensor specifications

Technical Specifications
Electrical parameters: JSN-SR04T [43] Operating voltage: DC 5V [43] Quiescent current: 5mA [43] Total current work: 30mA [43] Acoustic emission frequency [44]: 40khz Farthest distance: 4.5m [44] Blind: 25cm [44] Module size: 41mm * 28.5mm [44] Resolution: about 0.5cm [44] Angle: less than 50 degrees [44] Working temperature: -10 ~ 70 ℃ [44] Storage temperature: -20 ~ 80 ℃ [44]

Fig 1. Height sensor [44]

The switches in use in case of maximum height and lowest height are:

Fig 2. Level switch [45]

The industry-defining name in snap-action switches, Honeywell MICRO SWITCH™ premium subminiature switches are designed for repeatability and enhanced product life. [45]

Useful both in high precision, presence/absence detection or simple on/off application needs, Honeywell's MICRO SWITCH™ SM and SX Series premium basic switches feature a broad range of ratings, operating actions, and terminations. Their very wide temperature range allows for years of reliable performance in extremely harsh conditions. [46]

- Best suited for high cost-of-failure applications
- Small size and lightweight
- Covered case construction with molded-in terminals
- MIL-PFR-8805 qualified listings available
- UL/CSA, CE, ENEC approvals [46]

Table 9. Switch features

FEATURES: [46]
- Long operating life - Elongated mounting hole for easier, more accurate mounting - Choice of actuation (plunger, as well as a variety of integral and auxiliary actuators) - Choice of electrical termination (solder, quick connect, PCB) - Choice of operating characteristics - Optional series constructions available (gold contacts for low energy switching, bifurcated gold contacts for maximum reliability, power load switching capability to 11A) [46]

The switch in use to detect anything on the rail is the following switch it will roll on the rail in front and behind the scissor roller it is a switch from **Omron corporation** with the serial number D4MC-2000 it works on 250V AC

Fig 3. Roller switch [24]

An electric contactor is applied for the motor is from ABB 3phase 50Amp A30-30-10-81

Fig 4. ABB contactor [29]

4.4.Materials in use

This assembly is consisted of several parts so it is clear that several materials are in use, for example aluminum 2024 is used for frame strengthening, frame is made of alloy steel and joints are coated with Teflon and so on, for many reasons and it is explained in detail later.

4.4.1. Teflon

Teflon coating method is used to coat the joints. Teflon is the appropriate material to be used in joints for its specific characteristics by which it reduces the process of wearing out.

Teflon is used in joints and bearing for the following characteristics:

Very Low Friction Constant

The friction constant is lower than for any other solid material. Since the static and dynamic sliding coefficient are very close, no so-called stick-slip effect occurs.

For the sake of simplicity, the following friction constants may be assumed under optimum installation conditions: [7]

PTFE friction bearing, unlubricated about f = 0.1

PTFE friction bearing, lubricated about f = 0.04

Corrosion Resistance

The PTFE glide plates are absolutely corrosion resistant, resistant against chemicals and aging. The steel parts of the bearings are by standard sandblasted and provided with a zincphosphate coating. [7]

Temperature Resistance

The range of application of our bearings is limited to those temperature ranges which are secured by official friction tests under load. [7]

Table 10. PTFE temperature at glide plate

Temperature at glide plate	
up to 80° C	glide plate PTFE-TLLQ 3071
up to 150° C	glide plate PTFE-TLFG 3124
up to 180° C	glide plate PTFE-TLFG 3124 with reduced face pressure
up to 550° C	glide plate PTFE-TLFG 3124 high temperature bearing with integrated insulation

- Use at temperatures of -60°C is ensured by tests.
- Use at temperatures of over 180°C requires custom constructions / high temperature bearings. [7]

Maintenance-Free

PTFE friction bearings are totally maintenance-free, this also applies to lubricated PTFE bearings; no subsequent lubrication is required. [7]

Low Form Factor

Compared with other bearing types, PTFE friction bearings require only very low form factors. [7]

To work the PTFE polymer coats the material sliding against it. Once the mating material is coated with PTFE film, you have PTFE molecules sliding over PTFE molecules and the wear slows significantly and will accelerate only if something erodes the film or PTFE bearing substrate which creates a need to refresh the film accelerating the wear. [8] (Furthermore, details are explained in appendix 1).

4.4.2. Aluminum alloy 2024

2024 is fatigue resistant and of high strength. It is a heat-treatable aluminum alloy with copper as the primary alloying element [36]. It is widely used in aircraft structures; fuselage skins, wing skins and engine areas where elevated temperatures to 250°F (121°C) are often encountered [38]. Also, in applications requiring high strength to weight ratio, and good fatigue resistance. Are used -in fuselage structural, wing tension members, shear webs and ribs and structural areas [12].

4.4.3. Uses of Alloys steel

One of the most widely used alloys is alloy steel. **Stainless steel** alloys are also immensely used in many industries. Alloy steel is also commonly used in mechanical structure and offer high strength and durability with economically efficient [11].

4.5.Eco-friendly

This mechanism is eco-friendly due to many reason and it can be displayed as follow:

- It is lubricant free due to the usage of Teflon in joints;
- It can be made from recycled materials, it can be recycled later;
- It doesn’t need to make any base in the ground;
- Can be moved from place to other depending on the need;
- all environmental requirements are satisfied, electric isolation, no lubricants to leak;
- easy installation and use;

4.6.Elimination of scissor lift disadvantages

The disadvantages of scissor lift can be eliminated by dividing it to two separated mechanisms. Which means having two separated mechanism, and in this way the width of the vehicle is not a problem anymore and the working area underneath the vehicle is not restricted anymore and clear to work. Those to mechanism are synchronized by the controlling model.

In addition to that, using two separated electric motors increases the lifting power of the lift. The use of two motors reduce the need of one powerful motor, since the torque from lifting is divided on two motors.

Usually existing lift scissors has a problem with limited length since doesn’t have lifting arms, and the vehicle lay on the top of the lift, by installing telescopic arms on the top of the lift so it can be extended to reach far points from vehicle and as a result the length of vehicle can change with no major effect on the lift.

Using two separate scissor has the efficiency to increase stability and can occupy wide range of vehicles without eliminating the clearance underneath of vehicle and without limiting the doors area.

Using Teflon in term to eliminate the wear out in joints and making the mechanism as fluid free.

Further information will be explained and presented by the 3D model.

5. ASSEMBLY PROCESS OF LIFTING MECHANISM

The (fig. 8) present how the assembly is connected. The control unit (12) is fixed on the control panel support (11), which in its order fixed on the base frame (10). The electric motor (9) is connected to gearbox (7) which is fixed on the base frame (10). Both base frame (10) are connected through sliding and stability mechanism (8). Lifting legs (4,6) are connected through legs joint (6) and fixed on the base frame (10) and upper frame (13). Lifting arm (1) is fixed on the arm support (3) which is located on the upper frame (13)

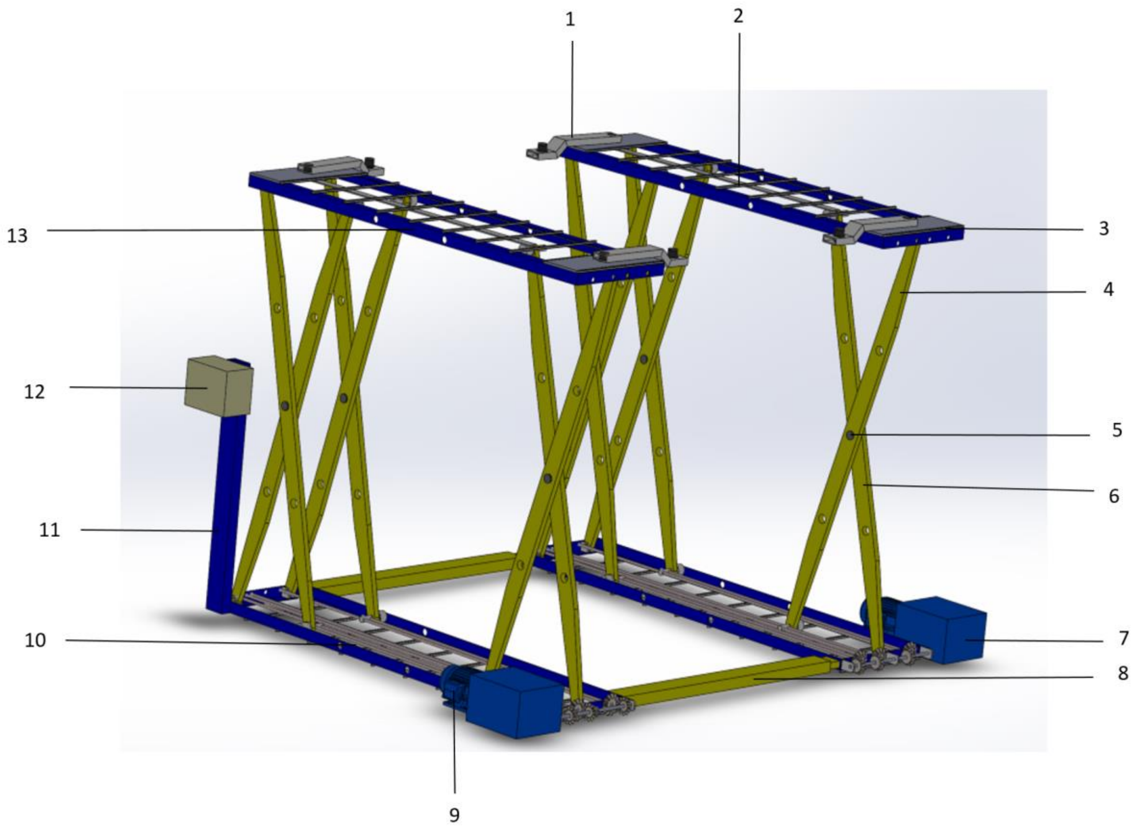


Fig 8. Assembly

Table 11. assembly consisting parts

Part number	Part name
1	Lifting arm
2	Base support
3	Arm support
4	Inner lifting leg
5	Legs joint

6	Outer lifting leg
7	Reducer gear box
8	Sliding and stability mechanism
9	Electrical motor
10	Base frame
11	Control panel support
12	Control unit
13	Upper frame

All are welded together forming the main frame of the assembly. Then the legs (4a,6a) are located on the frame on hinges using screw and nut. Each 2 legs (4a,6a) are connected by a screw joint (5a). Shaft hinge (8a) is welded to the frame and gear base (10b) and motor (11b) are connected to the shaft (7a). Therefore, one side of the leg is fixed on the hinge and the other is rolling on the rail (4b) by roller (3b). The roller is moved by guiding screw (2b) in accordance to the guiding slide (1b). the gears (8b,9b) are fixed on the guiding screw and shaft to transmit action from gear box to roller. Sliding and stability mechanism (8a) is fixed between two base frames by welding.

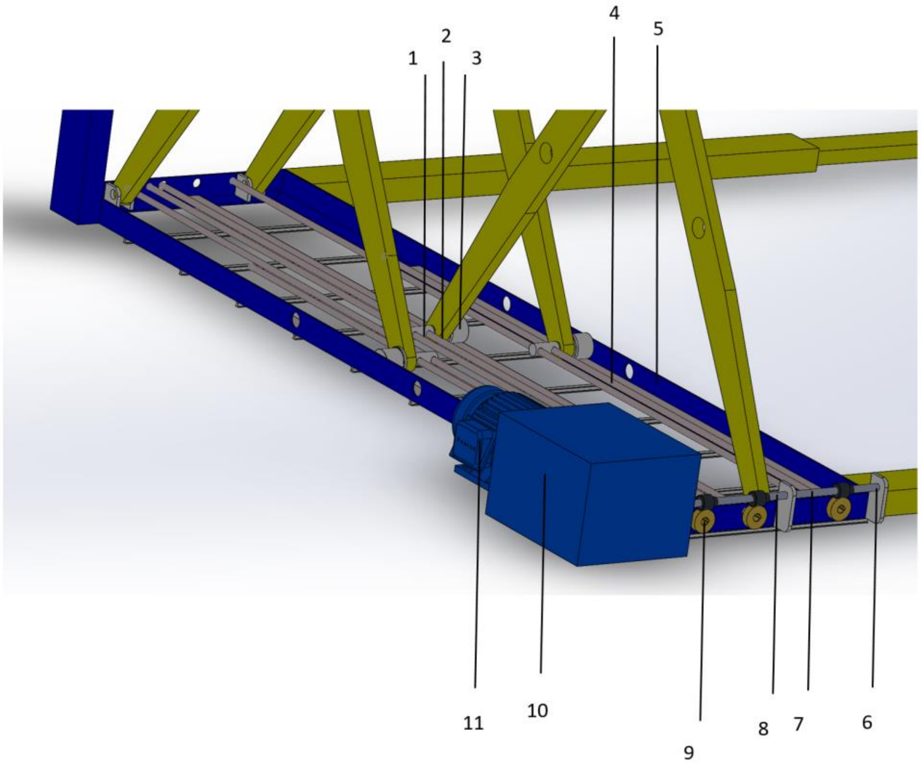


Fig 9. Assembly close look

Part number	Part name
1	Guiding slide
2	Guiding screw
3	Roller
4	Rail guide
5	Base frame
6	Shaft hinge
7	Shaft
8	Worm gear
9	wormer
10	Gear box
11	Electrical motor

The frame (10a,13a) assembly process, each is composed of:

- Two short L Beam “500mm” (5b)
- Two long L Beam “2000mm”
- Eleven I Beam “500mm” (2a)
- Three hinges
- Three guiding rail (4b)

5.1.Technical specifications of the prototype:

Operation	Electrical
Capacity	4000 kg
Weight	420 kg
Lift height	1950mm
Motor	3KW;4HP;230V;50Hz;3Phase
Dimension (length; width “each frame”)	2000mm;500mm
Lifting speed(seconds)	90s

6. COST OF THE MECHANISM ELEMENTS

Since each mechanism is made from standard elements, the parts can be found in the market with different prices, the price of each element is presented in Table 1. And the total cost of the mechanism is the sum of the parts prices. Note that the prices presented in the table 1. Are individual customer prices, for sure for a whole seller or manufacture the prices are much cheaper.

Table 1. elements costs

Part number	quantity	Part name	Cost(euro)
I. Electrical component			
1	2	Distance sensor	30
2	4	Switch	10
3	12	Obstacle detector	48
4	2	Contactor	20
5	1	Computer board	5
6	2	Emergency button	8
7	2	Electrical motor	400
8	1	LCD monitor	10
9	1	On off switch	3
10	2	Up and down buttons	5
11	1	Electrical enclosure	15
12		Wires	30
II. Mechanical components			
1	4	Feet	10
2	4	Wheels	15
3	4	Wheel hub	10
4	40	Strength beam	1m=14 mechanism need 20 m =280
5	6 sets	Worm gear	30
6	2	Shaft	3
7	4	Frame	1 m=3 eur system need 20m=60eur
8	6	Scissor joints	30
9	6	Guiding screw	20
10	12	Roller	60
11	6	Guiding nut	36

12	12	Rail	2 by 1 meter square sheet cost 20
13	4	Arm support	1 by 1 meter square sheet cost 20
14	4	Arm	1 meter of the beam cost 6-euro system need 2 meter which mean 12 euros
15	4	Joints	20
16	12	Hinge	25
Total cost			1235

From the table above, the cost to make the full lift cost around 1235euro which is almost the price of 2 pole lifts.

Note that, these prices presented in the table are the prices as individual buyer and not as a wholesaler. Also, the labor work is not included.

This cost of 1235 euro is a competitive price in the market.

7. REQUIREMENTS FOR SAFETY AND HEALTH AT WORK

According to the producer law, and for safer work. All the mechanisms especially those, which are dealing with heavy loads, must have work safety instructions. There is no exception for vehicle lifting mechanism:

- The mechanism should be controlled only through the control unit;
- The lift should be installed on a flat surface;
- In case of over load the mechanism can't be helped with hand;
- During the operation mode while lifting or going down the area underneath of the vehicle should be clear;
- After lifting the vehicle, the worker should insure that the mechanism is locked;
- before lifting the vehicle, worker should make sure that the arms are located in its place underneath the vehicle;
- before starting the operation, worker must check that there is electricity in the system and connected properly;
- The load must not exceed 4000 kg

CONCLUSION:

All the tasks were achieved as follow:

- ✓ Literature review was made in detail presenting all advantages and disadvantages of all existing lifting mechanism.
- ✓ The scissor lift was selected as lifting mechanism to redesign and upgrade.
- ✓ A 3D model of the mechanism was made.
- ✓ The disadvantages of the mechanism to upgrade were eliminated.
- ✓ The proposed mechanism consists of two separated lifts so it has a variable dimension.
- ✓ Teflon is used as prevention method of the wear out in joints.
- ✓ The mechanism is eco-friendly
- ✓ The proposed mechanism value is competitive in the market

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Appendix 1:

Teflon coating method is used to coat the joints. Teflon is the appropriate material to be used in joints for its specific characteristics by which it reduces the process of wearing out.

What is Teflon?

Teflon® is the trade name for a polymer called polytetrafluoroethylene or PTFE. **Polytetrafluoroethylene** (**PTFE**) is a synthetic fluoropolymer (a fluorocarbon solid) of tetrafluoroethylene [35]. PTFE is a high-molecular-weight compound consisting of carbon and fluorine. PTFE is hydrophobic: neither water nor water-containing substances wet PTFE. As well, fluorocarbons demonstrate mitigated London dispersion forces due to the high electronegativity of fluorine. [36]

In general; PTFE is used as a lubricant, corresponding to the fact that it reduces friction, wear and energy consumption of machinery.

How Teflon Is Used In Building Construction

Bearing Pads — Teflon can be used as a bearing pad for light loads, while Teflon Bearing made with Fluorogold can be used for heavier loads.

Advantages of PTFE Friction Bearings

Very Low Friction Constant

The friction constant is lower than for any other solid material. Since the static and dynamic sliding coefficient are very close, no so-called stick-slip effect occurs. [7]

Differentiation is made between dry running bearings and lubricated bearings.

For lubricated bearings, pan-shaped recesses are pressed in the PTFE sliding plate and provided with depot lubrication (silicone grease 300 medium, bridge bearing quality). [7]

The friction constant of PTFE deteriorates in case of low temperatures, while it remains largely constant for high temperatures. The values stated by us therefore refer to the most unfavorable values of -35°C, which occur in the approval procedures. [7]

For the sake of simplicity, the following friction constants may be assumed under optimum installation conditions:

PTFE friction bearing, unlubricated about f = 0.1

PTFE friction bearing, lubricated about f = 0.04

Corrosion Resistance

The PTFE glide plates are absolutely corrosion resistant, resistant against chemicals and aging. The steel parts of the bearings are by standard sandblasted and provided with a zincphosphate coating.

Upon request, all usual corrosion protection processes are offered, including hot galvanizing. Versions made of special steel alloys or stainless steel are also possible. [7]

Temperature Resistance [7]

The range of application of our bearings is limited to those temperature ranges which are secured by official friction tests under load.

Temperature at glide plate	
up to 80° C	glide plate PTFE-TLLQ 3071
up to 150° C	glide plate PTFE-TLFG 3124
up to 180° C	glide plate PTFE-TLFG 3124 with reduced face pressure
up to 550° C	glide plate PTFE-TLFG 3124 high temperature bearing with integrated insulation

- Use at temperatures of -60°C is ensured by tests.
- Use at temperatures of over 180°C requires custom constructions / high temperature bearings. [7]

Maintenance-Free

PTFE friction bearings are totally maintenance-free, this also applies to lubricated PTFE bearings; no subsequent lubrication is required. [7]

Low Form Factor

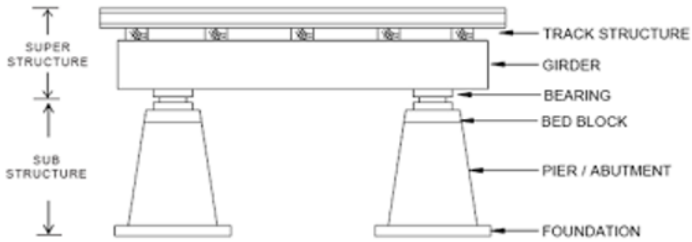
Compared with other bearing types, PTFE friction bearings require only very low form factors. [7]

To work the PTFE polymer coats the material sliding against it. Once the mating material is coated with PTFE film, you have PTFE molecules sliding over PTFE molecules and the wear slows significantly and will accelerate only if something erodes the film or PTFE bearing substrate which creates a need to refresh the film accelerating the wear. [8]

Bridges typically consist of two components: the superstructure and the substructure. The superstructure is subject to various dimensional deformations due to the nature of loads placed upon it. These deformations could include: [37]

- Thermal expansion/contraction
- Elastic deformation under live load
- Seismic forces
- Creep and shrinkage of concrete
- Settlement of supports
- Longitudinal forces - tractive/ breaking
- Wind loads[37]

The nature of these forces makes it necessary to have a device in between the substructure (base) and the superstructure which allows for the required movement, while also giving stability and having the capacity to bear the loads placed on the bridge. The device most popularly used, is a *bridge bearing* which assumes the functionality of a bridge by allowing translation and rotation to occur while supporting the vertical loads. [37]



Thus, a bridge bearing is an element of the superstructure which provides a vital interface between the superstructure and substructure.

PTFE in Structural Bearings

The use of PTFE in such bearings has been steadily increasing, although its application does not extend to all variants of bridge and structural bearings. PTFE has an exceptionally low coefficient of friction and high self-lubricating characteristics, resistance to attack by almost any chemical, and an ability to operate under a wide temperature range. [37]

Furthermore, while unmodified PTFE can be used to a PV value of only 1,000, PTFE filled with glass fiber, graphite, or other inert materials, can be used at PV values up to 10,000 or more. In general, higher PV values can be used with PTFE bearings at low speeds where its coefficient of friction may be as low as 0.05 to 0.1.

The low coefficient of friction exhibited by PTFE is unique for two primary reasons:

PTFE against stainless steel exhibits an even lower coefficient of friction that PTFE against PTFE. In fact, the coefficients of PTFE against steel have been found to be the lowest between any two solid materials

1. PTFE against stainless steel exhibits an even lower coefficient of friction that PTFE against PTFE. In fact, the coefficients of PTFE against steel have been found to be the lowest between any two solid materials
2. The coefficient reduces with increased pressure - allowing for coefficients as low as 0.03[37]