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Optimisation in Design of Mechanical Scissor Lift

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ABSTRACT

This paper describes the design as well as analysis of a mechanical scissor lift which works on the principle of screw jack. Conventionally, a scissor lift or jack is used for lifting a vehicle to change a tire, to gain access to go to the underside of the vehicle for changing under body parts and for many material handling operations. The scissor lift can be of mechanical, pneumatic or hydraulic type. This type is separated according to the lifting mechanism used in construction of lift. The lift is selected such that calculation regarding the allowable maximum deflection must not be exceeded. To analyze, solid modeling and computer simulations were involved using CAE software. Several linear static FEA analyses have done to get accurate results. Also these results can be verified by using manual calculations simultaneously. The result shows that the designed component of scissor lift is still in the acceptable range. However, some manufacturers find the allowable maximum deflection is too excessive to improve factor of safety. Perhaps, advice on critical areas to the application must be given and other safety precautions must be taken to avoid failure during operating conditions.

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I. INTRODUCTION

A scissor lift is a type of platform which moves in vertical direction. Many tools in the automotive industry are designed to help technicians access difficult to reach places and improve workers comfort. When a technician is working on a vehicle at ground level they must lean over the vehicle or lie under the vehicle to complete the job or to service the vehicle. These positions can be awkward and strain the technician's muscles or joints, which decreases technician's efficiency. [5]A solution to this problem is lifting the vehicle to a comfortable working height allowing the technician to work in the fully upright position. There are two kinds of lifts that can accomplish this; the first type of lift doesn't lift the vehicle completely which is only provided for tire change or for some low duty applications. The second style of lift where the vehicle weight is supported by its tires while the vehicle is on the lift. [5]The mechanism incorporated to achieve this function is the use of linked, folding supports in two criss-cross 'X' patterns mounted over each other, known as a pantograph. The upward motion is achieved by the application of pressure to the intersection of two 'X' supports with the help of lead screw; the function of lift is performed by elongating the crossing pattern, and propelling the work platform vertically upwards. The platform may also have an extending 'bridge' patterns to allow closer access to the work area because of inability of scissor lift to move in the direction other than vertical. [1]The operation of the scissor action can be obtained by hydraulic, pneumatic or mechanical means (via a lead screw or rack and pinion system). Depending on the power system implemented on the lift it is categorized. it may require no electric power to raise the height, but hydraulic or pneumatic units can also be used for such applications of lifting with reduction in human efforts. There are different types of hydraulic or pneumatic cylinders are available in market which can be used according to application. [1]Nowadays these kinds of scissor lifts are used in commercial airline and airport industry, ground support equipments. During the hectic

hours of an airplane arrival, ground crews are then busy with the loading and unloading of baggage, catering supplies, water and also refueling the aircraft fuel tank in order to be prepared for the next flight departure. These routine activities must be carefully handled according to standard procedures and protocols of airport system using specific equipments and vehicles. Apart from this, safety concern is given first priority to the equipments and vehicles used and every design must follow certain standards. [6]
According to the different applications there are several types of scissor lifts:-

The scissor lifts can be classified as follows:-

1. Classification based on the type of energy used:
(a) Hydraulic lifts
(b) Pneumatic lifts
(c) Mechanical lifts

2. Classification based on their usage:
(a) Scissor lifts
(b) Boom lifts
(c) Vehicle lifts

Moreover sometimes as per the requirement these types of lifts may be observed in combination. e.g. mechanical scissor lift can be successively operated manually as well as with the help of pneumatic gun, further it is powered by the resources available at work station.

Pneumatics is a section of technology that deals with the study and application of pressurized gas to produce mechanical motion. Pneumatic systems that are used extensively in industry and factories are commonly plumbed with compressed air or compressed inert gases. This is because a centrally located and electrically powered compressor, that powers cylinders and other pneumatic devices through solenoid valves. Again these types of lifts has a problem of leakage and high cost of storage cylinders [3]

The only difference in hydraulic and pneumatic lift is that, hydraulic cylinder operates on fluid as a compressing medium where as pneumatic operates on air or gas [3]

So, each lifting mechanism has its own drawbacks and advantages. But, for making the car lift, portability and simplicity in design are also very important aspects that can't be neglected. So, for such constraints mechanical system is most suitable over other systems.

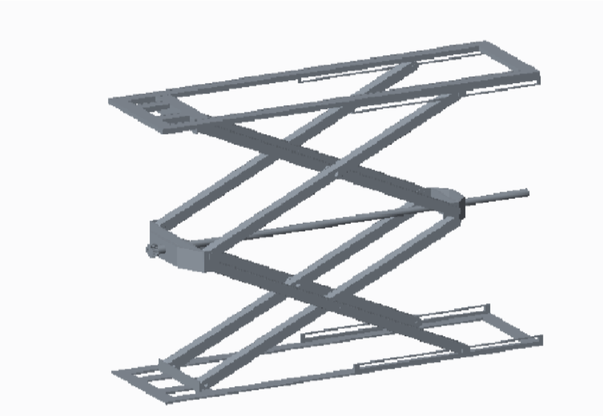
Many of the organizations around the world have been using all kinds of scissor lifts. But, many of these lifts are failed with portability constraint. For heavy duty applications hydraulic and pneumatic is preferred. Also, there are some mechanical alternatives are also available which can improve portability, simplicity and by providing proper gearing, input energy is reduced along with the cost. Therefore, advantages of mechanical system over other mechanism are explained below:-

Simple in construction.
Portable over other mechanism.
Cost of manufacturing is low.
Lift heavy loads with help of proper gearings.
Easy to find faults. (Diagnose)
Don't consume electric sources for operation. (Operate manually)
No external storage required. (Hydraulic and pneumatic requires tank for fluid and air)

Mechanical lift is another type of scissor lift which works on the principle of screw jack. Because of simple design aspects and simplicity in construction, mechanical lift has wider range of applications over other types of lift mechanisms.

Screw jack is an example of mechanical lift. Screw jack is made by using lead screw of square thread. as per the today's scenario of cost reduction, we need to find the cost effective solution for long term benefits. So, in the production system it is necessary to redesign the various products for reducing the cost of the product over the same product. For that purpose we have chosen such exercise with the scissor lift. By implementing same principle with using two 'X' patterns, even better results can be achieved. The figure shown below shows same mechanism as explained above. [4]

The figures given below are taken from already designed CAD modeling in CREO 2.0.:-



Mechanical Scissor lift designed in CAD software

II. COMPONENT DETAILS

The lift shown above consists of several components. Those are as given below:-

- Upper Base
- Lower Base
- Links
- Lead Screw
- Nut
- Roller Support
- Connecting pins etc.

Hence, to design these components some calculations must be performed. Dimensions of upper base and lower base is designed in such a way that it should move inside the car easily. So, that the manufactured model can perform its function for which it is designed.

Design of Upper Base:

The upper base is made of mild steel material and its rectangular cross section is of 20 mm X 40 mm. The length of the upper base is 1400mm and the breadth is 400mm.

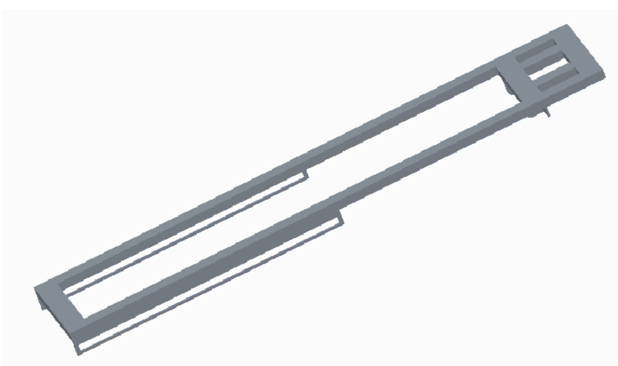


Figure of upper base

Whereas, the base plate has two rigid supports. These supports are provided for connecting base plate to links.

Design Of Lower Base:

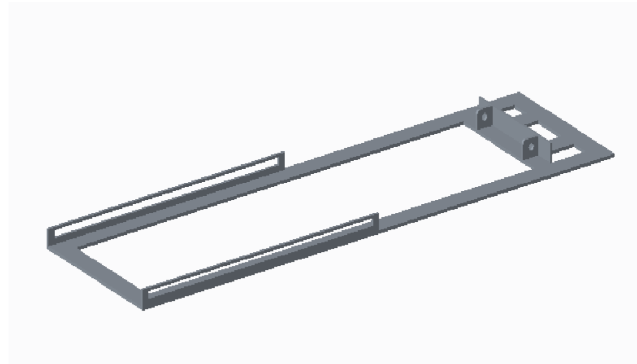
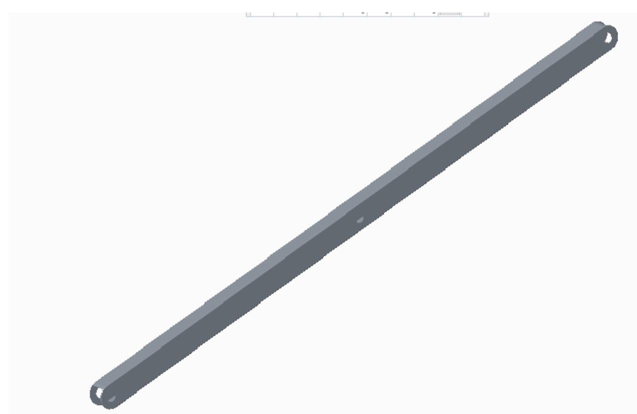


Figure of lower base

The lower base plate is of mild steel material and has a thickness of 7mm. The upper and lower base is connected by links via fixed supports. While the other parameters are same as upper base.

Design of Links:

Thickness of link = 1.6 mm.
Cross section of link = 40X40
Load acting on one link = F / 2 = 6000N
The link is designed for buckling load, assuming factor of safety (FOS) = 5
Thus critical buckling load = 6000 x 5 = 30000 N



Design of link

Since for buckling of the link in the vertical plane, the ends are considered as hinged, therefore equivalent length of the link is, L = 1100 mm.

Design Of Lead Screw:

While designing the lead screw the EN24T material is selected. This Material has a yield strength of 650 N/mm2

and the ultimate strength is of 850 N/mm2. For further design of lead screw factor of safety is taken as 5.
Design of lead screw of material EN24T:
Yield strength (Syt) = 650N/mm2
Factor of safety (N) = 5
Permissible tensile stress (σ) = Syt/N = 80N/mm2
Stress is given by force to the cross section area of lead screw
So, From σ=W/A
We get the core diameter of the screw = 14mm
Diameter of screw,
D = dc + p = 18mm.
Torque required to overcome thread friction is
$T = (W*dm/2)*(\tan(ø + \lambda))$
But, $\tan \lambda = (l/\pi*dm) = 2.603$.
Also, $\tan ø = \mu$.
Taking μ=0.15,
ø = 8.53.
As ø> λ, there is self locking.
Hence, torque required to overcome thread friction,
T = 33.060 Nm.
To check whether the design is safe, torsion formula is used:
$G\theta/L = T/J = \tau/r$.
Hence, shear stress τ = 21.35 N/mm2 in loading condition.
Permissible shear stress = (0.5*Syt)/N = 40 N/mm2.
Hence, as 40>21.35, the design is safe.

Roller Support:

The material used for manufacturing of roller is MS. Roller support is provided to avoid friction between base and links.

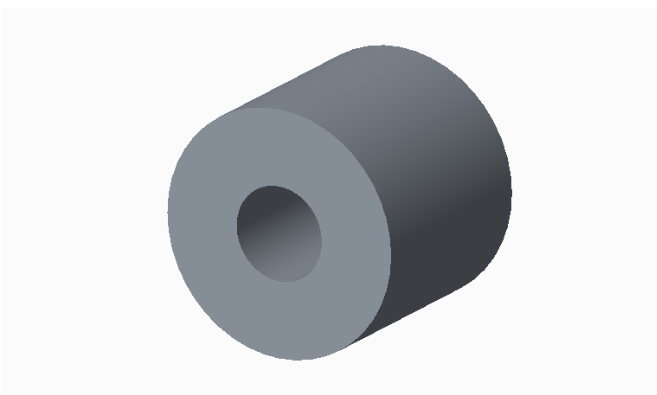


Figure of roller

The material used for manufacturing of roller is mild steel. This solid cylinder like shaped roller has diameter of 44 mm and the width is 25mm. also one well centered hole of 16 mm is provided for other assembly.

Connecting Pins:

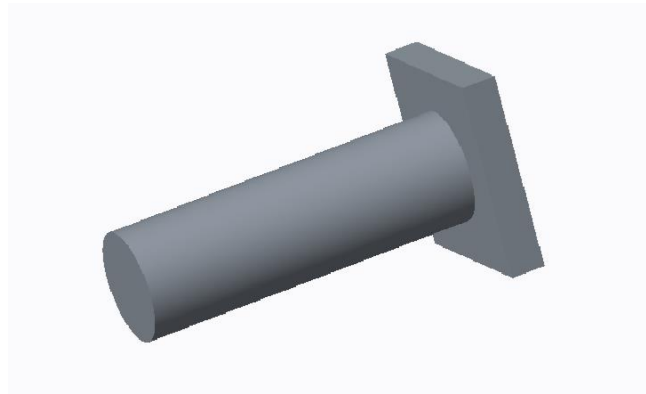


figure of connecting pin

Links, base and other components are connected to each other by using pin connections where, these pins are made of hard steel material which is having cylindrical cross section of diameter of 16 mm.

By taking the reference of above shown calculations, CAD model of the scissors lift is generated using Solid Works/Pro-e/Creo software. The purpose of doing so is to predict that how the model will look after complete manufacturing process. Then the same CAD file is converted to STP/STL format. This format is then imported in ANSYS for further simulation process. Load, stress and deformation test is carried out and results are obtained by this software. These results are used for further modification.The design process explained in the paper is developed keeping in mind that the lift can be operated by mechanical means so that the overall cost of the scissor lift is minimized. Also such design makes the lift more compact and much suitable for medium scale work as well as heavy load duties. Finally the analysis is also carried out in order to check the compatibility of the design values.

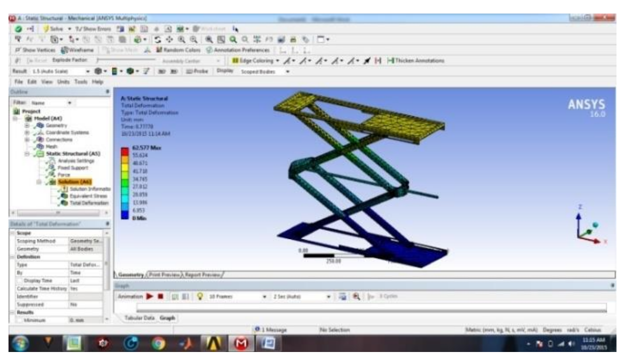


Figure of analyzed model

It can be seen that the weight of the complete system is restricted to 40 kg by using mild steel material. From the above results can be observed that, the upper base is displaced downward after applying load. The distribution of weight for complete manufactured model in mild steel is as shown in table given below:

Sr. No.	Component Name	Approximate Weight (kg)	Total
1	Upper base	3.4	3.4
2	Lower base	7.6	7.6
3	Link	2.1*8	16.8
4	Roller	0.2*4	0.8
5	Lead screw and nut assembly	6.75+1.56	8.31
6	Connecting pins	0.1*20	2
7	Total		38.91

The results shown in the above table come us to a conclusion that the complete manufactured model has a approximate weight of 38-39 kg. So, that can be observed that, this much weight cannot be lifted by a single person. For the solution if the same designed model if manufactured in aluminum alloy of scale 7050 then the weight can be reduced drastically. Because, this alloy has nearly same properties like mild steel and having very low density.So, the table given below describes the weight distribution for the design with Al7050 alloy.Aluminum Estimate of weight comparison with mild steel even having nearly double thickness:-

Sr. No.	Component name	Weight (MS 1.6 mm thickness)	Weight (Al) (4mm thickness)
1	Upper base	3.4	2
2	Lower base	7.6	2.6
3	Link	16.8	9.23
4	Roller	0.8	0.5
5	Lead screw and nut assembly	8.31	8.31
6	Connecting pins	2	1.5
7	Total	38.91	24.14

III. CONCLUSION AND FUTURE SCOPE

With such a design of a scissor lift, the complexities in the design can be reduced. With design process explained above, the manufacturing time of a scissor lift can be reduced. Mechanical scissor lift operates o very simple principle of screw jack. This consumes less energy as compare to other types of scissor lifts. Also, it makes the lift portable. Height of five feet can easily be achieved. Also, the analysis on ANSYS shows that this design is safe for high loads. i.e. this lift is capable of lifting the weight up to 1000 kg with minimum efforts. Such a design can be widely used in automobile industries and for production in other industries. Also further modifications can be implemented for optimizing the design and further analysis can also be carried out for better optimization related to scissor lifts.

Secondly, same system if designed in aluminum alloy then, the weight can be reduced by nearly 15 kg because this alloy has very low density as compare to mild steel.

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