Investigation on design, analysis and topological optimization of hydraulic scissor lift

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Abstract: A pressure driven scissor lift is a mechanical gadget utilized for different purposes for hoisting of the heaps to a tallness or certain level. In this scissor lift there is a table that is used to mound, hoist, pass on and additionally move material in the middle at least two heights. The fundamental goal of the gadgets utilized for hoisting settle is to make the table movable to an ideal stature. In this venture we advanced the heaviness of the base and top of the scissor lift by utilizing I-outline structure and utilized regenerative technique to lessen weight in pole. Scissor lift gives most financial trustworthy and adaptable techniques for lifting loads. The edge is durable and sufficient with expansion in underlying respectability. A different stature scissor lift is comprised of at least two leg sets. It is dissected and advanced utilizing Autodesk Fusion 360° and FE investigation.

Keywords: Hydraulic scissor, design, scissor lift, load lift, optimized, modelling, pneumatic, regenerative method

1. Introduction

The regular larger part lift is the water driven scissor lift table since it is not difficult to plan and create. The principle reason for this paper is to raise the base stage for lifting the articles, to control the lift effectively, to decrease material weight and to give safe working conditions. Pressure driven scissor lift table comprises of five segments. They are Top stage, Base stage, Scissor legs, Hydraulic chamber and force source. Clarification of the above parts are i) Top platform, ii) Base platform, iii) Scissor Legs, iv) Hydraulic cylinder and v) Power source. Top platform is where the lifting item can keep. The lifting object doesn't have any size and weight. Base platform is the lower part of the table which is keep on the ground. It comprises of scissor legs to travel. It is kept in the upward position which is utilized to change the stature of the platform. It is the chamber where the cylinder will introduce. The chamber is loaded up with air through opening vent. Cylinder will move as indicated by the filled air. Hydraulic scissor lift is charged by an electric current or motor source. There are three types of Hydraulic lift like i) Hydraulic scissor lift ii) Pneumatic lift and iii) Mechanical lift. Pneumatic lift utilizes an effectively pliable gas, for example, air while water powered lift moderately smaller fluid media, for example, pressure driven or oil. Water driven have more noteworthy qualities
and lower working expense. So in this paper, Hydraulic lift is liked. The hydraulic scissor lift is as
given in Figure 1:

![Hydraulic scissor lift](image)

**Figure 1: Hydraulic scissor lift**

### 1.1 Working Principle of Hydraulic scissor lift

Pressure driven scissor lift deals with the rule of Pascal’s law. Water powered lift is a machine that utilizes a sections to lift move objects utilizing the power produced when pressing factor is utilized on fluid in a cylinder. At a point power produces lift and work. At the point when the force source is turned on and start the chamber also load up with water powered liquid or packed air. The air is squeezed starting with one region then onto the next. The chamber is constrained remotely and makes the legs send aside.

### 1.2 Advantages of Hydraulic scissor lift

It is effectively available and exact on the grounds that a framework can undoubtedly begin, stop, speed up and end the machine utilizing straightforward switches and press catches. Water driven frameworks are less difficult and simpler to keep up in light of the fact that these frameworks utilize less moving parts. It cost is very less in expensive compared to other type of lift type. Another advantages is that they settled less space in a structure, requiring practically 10% less region for the lift shaft. The water driven force gives incredible lifting strength.

### 1.3 Uses of Hydraulic Scissor lift

Water powered scissor lifts are utilized in a wide range of uses. They can be found in auto, dispatching, development, squander evacuation and mining as they are a successful methods for raising and bringing down products and supplies. The stage is very much evolved to help lift and set up bigger material. Polymer handling, metal expulsion, mass age, machine apparatus industry, paper enterprises, loaders, smashers, presses, and the material business are the employments of hydrodynamics. They are valuable in the development and building ventures where hydrodynamics are utilized as cranes, tractors, blackholes, and earth moving hardware. The car business is the biggest client of water power. Creation, fix, and interior segments on vehicles all utilization hydrodynamics. The three sorts of amphibian pressure driven frameworks are open, shut, and semi-shut. They are utilized for cranes, securing and anchor winches, stabilizers, guiding, engines, propellers, and stages. Force, controllability, unwavering quality, and workableness are necessities in mining due to the threats that are included. In contrast to other assembling, mining deals with an immense scope requiring gigantic gear. The limit given by power through pressure fits the conditions.

### 1.4 Selection of material

Material is vital for each item. In this venture we favored material called gentle steel. Since steel have high elasticity, low weight, solidness and moldable properties. Underlying steel is quite possibly
the most usually utilized materials in business and modern structure development. Steel comprises of amalgam of iron, carbon and some component of Mn. Steel can be stiff, acute, erosion safe and the unadulterated iron is generally delicate metal that rust effectively.

Table 1. Mechanical properties and its values for mild steel

| Mechanical Properties                      | Values   |
|-------------------------------------------|----------|
| Durability, flex                          | 370MPa   |
| Elongation at Break (In 50 mm)            | 15.0 %   |
| Reduction of Area                         | 40.0 %   |
| $\lambda$ (Typical for steel)             | 205GPa   |

The table 1 shows the mechanical properties upsides of gentle steel. Medium and high carbon steel have higher carbon content than gentle steel.0.25% of carbon content in delicate steel anyway a couple of perspectives consider carbon steel as gentle steel up to a carbon substance of 0.45%.

The low carbon content makes this steel a significantly machine capable metal. It might be cut, machined, outlined into diverse shapes without adding relative tensions to the workpiece. It furthermore energizes better weldability. A huge gathering of alloying segments improves the compound properties. These segments will impact the physical/manufactured properties well and make the possible result sensible for the application. The segments that may be added join Cr, Co, P, S, Mn, among others.

For example, Cr gives the property of disintegration resistance and additions delicate steel's hardness. In its unadulterated design, delicate steel will erode adequately as a result of oxidation. As opposed to squeeze oxide, chromium metal on receptiveness to the environment shapes a thick layer of chromium oxide that doesn't tumble off, and ultimately safeguards the metal under from extra disintegration attacks. Cu in confined sums moreover works like CrO$_2$. Delicate steel lines have better affirmation from the climate. Various parts such as added to better erode hindrance, outrageous unbending nature, and warmth resistance.

The objective of this work is to rises (or) lower platforms for lifting the devices, to control the lift easily, to reduce material weight, to make scissor lift as a portable product, to provide Safe Working Condition. Bekir Cirak [1] has studied the model of lifting platform comprising of scissors and hydraulic cylinder is designed. Static state equivalences have been used for the mathematical model of the mechanism. The weights and mass inertia moments of the platform followers and the higher table have been ignored. Varun Jaiswal [2] has studied about the projects of “Source up Industries Pvt Ltd.” In this work procedure they design and analysis of hydraulic scissor lift which is used as an elective or alternative of regular car jack just because of this jack is only used for change the tires. The project described [3] is developed observance in mind that the lift can be functioned by mechanical means by using pantograph so that the complete cost of the scissor lift is reduced. Kiran kumar et al. [4] mostly concentrated on force acting on the hydraulic scissor lift when it is stretched and contracted. Commonly, a hydraulic scissor lift is used for lifting and holding heavy weight machineries.

Wankhed [5] dealt the analysis and optimization of hydraulic scissor lift. The exhibiting purpose can be used via Catia, MSC Apex for engaging and SimXpert for 8. In [6] a hydraulic pallet lift is a mechanical method used for different presentations for lifting of the loads to a height or equal. A lift table is distinct as a scissor lift used to stack, hoist or below, convey and/or transfer material. In the study by Sandeep G. Thorat [7], a hydraulic scissor lift is a mechanical method used for lifting of the loads to a height or level. In this paper the design presented in the similar is targeted to explain the problem faced by the industry. The work by Uttam Panwar [8] explains material handling and provide relief to the operator. They have showed the study in addition to design of hydraulic scissor lift
components. The problem of material handling for cold storage industry has been described in [9]. Goods were in cartoons which are probable to be perished if not loaded to cold room in required time. The author explains the design, analysis and to fabricate a hydraulic scissor lift which lifts maximum 2000kg load with least time.

2. Methodologies

Any machine part can't be moved to an ideal circumstance with utilization of less proportion of outside power. For setting a fragment around there, the development of portion follows conventionally even or vertical course. Various machines like flying lift, impact lifts, scissor lift, man lift, tele administrator, towable lift are used to move contraption and work in different manners subject to the need. A scissor lift is a flexible, conveniently widened and compacted, secure working machine used for transportation of medium assessed portions to its typical position. A machine which travels upstanding way by using transversely 'X' plan scissor arms. The essential stature of the lift is refined ward on the amount of befuddle 'X' plan scissor arms annexed. The part relies upon associated arms in a confuse 'X' plan which can be fallen and loosened up exact way like a pantograph. The vertical development is refined by the utilization of strain to the outside of minimal course of action of supports, expanding the convergence plan, and moving the work stage upward upwards. The stage may similarly have a growing 'join' to allow closer permission to the work zone.

The lifts is such a phase and it will move just upward. With today's progression of science and development, a consistently expanding number of new advances were applied to material dealing with. The essential mark of the scissor lift was material managing and offering solace to the director while playing out the movement. The scissor lift was useful to work and it will be used intermittently in ventures and other ordinary spots. A scissor lift table is used to stay, hoist or downward, pass on or move materials or weights between at any rate two height. The segment used in a scissor lift to achieve this limit was just the utilization of associated, imploding arms during a confuse 'X' plan, instilled as a pantograph. A scissor lift gives the most monetarily reliable and adaptable strategies for lifting considerable weights in the business; it had relatively few moving parts which can simply require oil.

The lift is used to enlarge a phase by pneumatic, pressure driven, or accurately. There are a couple of employments of pressing factor driven jack are bed managing, vehicle stacking, and work arranging, modified creation lines, dissemination lines, and so on (Aerial work stages when everything is said in
done) are generally used for transient methodology expectation like upkeep and for improvement work for emergency access, which remembers them from enduring access equipment like lifts. They're planned to lift limited burdens. The extension and withdrawal action of the scissor arms are generally done by water controlled, pneumatic, or definitely. A Scissors lifts are the most traditionalist contraption to hoist the pile. It is furthermore a reliable and versatile procedure for lifting profound weights. It has less portable items; they are throughout lubed up and give various years without giving difficulty. It hoist the stacks effectively to any vital stature and may be conveniently organized to satisfy the important speed, cut off, and impression essential of any water driven hoisting purposes. Additionally, it is helpful for all type of managing purposes.

In this segment, all plan created are examined and dependent on assessment models and interaction created, and a last here changed to additional upgrade the usefulness of the plan. Contemplations made during the plan and manufacture of a solitary acting chamber is as per the following:

(a) Utility of the design
(b) Assembly
(c) Profitability

The general expense of material and creation procedures utilized Hydraulic chamber: The water-driven chamber is mounted in a slanted position. The all-out load following up on the chamber comprises of:

\[
\text{LOAD} = W = 200\text{kg} ; d = 789\text{mm}; L_2 = 1543\text{mm} ;a = 140\text{mm} ;L = 1684\text{mm} ;\alpha = 33^\circ;\beta = 28.5^\circ
\]
2.1 To find reaction force

Taking moment at point C

\[ \Sigma M_C = 0 \]
\[ W.d - D_y.AB = 0 \]
\[ D_y = \frac{W.d}{AB} \]
\[ = \frac{W}{789/1543} = 0.511W = D_y \]
\[ \Sigma F O Y = 0 \]
\[ D_y + C_y - W = 0 \]
\[ C_y = W - D_y \]
\[ C_y = W - 0.511W \]
\[ C_y = 0.489W \]
\[ \Sigma F O X = 0 \]
\[ P_x - F_x = 0 \]
\[ Taking \ moment \ about \ C \]

\[ \Sigma M_C = 0 \]
\[ D_y.L . \cos\alpha - P_y(L/2 + a) \cos\alpha + F_y.L/2 \cos\alpha - P_x.(L/2 + a) \sin\alpha + F.L/2 \sin\alpha = a \]
\[ 0.511W.L . \cos\alpha - P \sin\beta(L/2 + a) \cos\alpha + P \sin\beta \ L/2. \ Cos\alpha -0.022W.L/2.\cos\alpha - P \cos\beta(L/2 + a). \ sin\alpha + P.\cos\beta \ L/2. \ sin\alpha =0 \]
\[ 0.489W.L.\cos\alpha - P.a(\sin\beta \ \cos\alpha + \cos\beta \ \sin\alpha) = 0 \]

\[ F_x = P.\cos\beta \]
\[ \Sigma F O Y = 0 \]
\[ -D_y + P_y - F_y + C_y = 0 \]
\[ F_y = P_y + C_y - D_y \]
\[ F_y = P_y + 0.489W - 0.511W \]
\[ F_y = P.\sin\beta - 0.022W \]

2.2 Rules of geometry

\[ (\sin\beta \ \cos\alpha + \cos\beta \ \sin\alpha) = \sin(\alpha + \beta) \]
\[ P = 0.489W.L.\cos\alpha/a. \sin(\alpha + \beta) \]

At height position of Lift

The angle,
\[ \alpha = 33^\circ \]
\[ \beta = 28.5^\circ \]
\[ P = 0.489 \times 2000 \times 1684 \times \cos33/ 140 \times \sin(33 + 28.5) \]
\[ P = 11226.54 \text{ N} \]

This force is by piston cylinder.
Figure 5: Free body diagram

The Figure 5 shows the free body diagram.

\[ Ay = Dy & Cy = By \]

but opposite in direction

\[ Cyx = Cy \cos 57 \]
\[ = 0.489 \times 2000 \text{N} \]
\[ = 532.67 \text{N} \]

\[ Ayx = Ay \cos 57 \]
\[ = 0.511 \times 2000 \text{N} \]
\[ = 556.62 \text{N} \]

\[ Cyy = Cy \sin 57 \]
\[ = 0.489 \times 2000 \text{N} \]
\[ = 820.22 \text{N} \]

\[ Ayy = Dy \sin 57 \]
\[ = 0.511 \times 2000 \text{N} \]
\[ = 857.12 \text{N} \]

\[ P_{x'} = P \cos 61.5^\circ \]
\[ = 11226.54 \times 0.485 \]
\[ = 5356.84 \text{N} \]

\[ P_{y'} = P \sin 61.5^\circ \]
\[ = 11226.54 \times 0.615 \]
\[ = 9866.10 \text{N} \]

\[ F_{x'} = -Ayx + P_{x'} + C_{yn} \]
\[ = -556.62 + 5356.84 + 532.67 \text{N} \]
\[ F_{x'} = 5332.89 \text{N} \]
\[ F_y' = -A_{yy} + P_y' + C_{yy} \]
\[ = -857.12 + 9866.10 + 532.67 \]
\[ F_y' = 9541.65 \text{N} \]

\[ F' = \sqrt{(F_x')^2 + (F_y')^2} \]
\[ = \sqrt{(5332.89)^2 + (9541.65)^2} \]
\[ F' = 10930.82 \text{N} \]

2.3 Design Calculation

Shape = Hollow square section
Material = Mild steel
Outside = 76mm = 0
Inside = 56mm = I
Thickness = 10mm

2.3.1 Cross-Section area

\[ A = 0^2 - I^2 \]
\[ A = 76^2 - 56^2 \]
\[ = 2640 \text{mm}^2 \]

2.3.2 Tensile Stress

\[ \Sigma_n = \frac{F}{A} = A_{yy} - \frac{P_y'}{A} \]
\[ = 857.12 - \frac{9866.10}{2640} \]
\[ = -3.41 \]

2.3.3 Equivalent Stress

\[ \sigma' = \sqrt{(\Sigma_n)^2 + \tau'^2} \]
\[ = \sqrt{(1.82)^2 + (3.41)^2} \]
\[ = 3.865 \text{MPa} \]

According to Hooke’s Law,

\[ E = \frac{\sigma}{\rho} \]
\[ E = \frac{\sigma}{(dL/L)} \]

For Base/Top

\[ dl = \frac{\sigma \times L}{E} \]
\[ dl = 3.865 \times 2200/(2 \times 10^5) \]
\[ dl = 0.043 \text{mm} \]

For Rod

\[ dl = \frac{\sigma \times L}{E} \]
\[ dl = 3.865 \times 1684/(2 \times 10^5) \]
\[ dl = 0.0325 \text{mm} \]
2.3.4 Compressive Stress

\[ \sigma = \frac{F}{A} = \frac{Ay}{x} - \frac{Px'}{A} \]
\[ = 556.62 - \frac{5356.84}{2640} \]
\[ = -1.82 \text{MPa} \]

3. Procedure for designing hydraulic lift

3.1 Platform
Platform lifted hefty work pieces, and they located in the top of the lift table. It very well may be accessible in an assortment of sizes. This part is exposed to the heaviness of the work piece and its hardware, consequently, strengthen is required.

3.2 Base Platform
Base platform lays on the ground, and they located in the lower part of the design. It hold the track the scissor legs carry in his segment is exposed to the heap of the top stage and the scissors arms. It is likewise at risk for the solidness of the entire get-together, accordingly power. Stiffnessness and solidness are esssential goods for the scissor lift.

3.3 Scissor legs
It varries elevation and they are in vertical member to allow the platform and it causes breaking or bending of the components. The desired material is stainless steel is due to power, firmness, flexibility and hardness requirement. Scissor legs control its bending, under heavy load and its too longer. The leg strength increased through the leg material height also improves deflection to resistance. Hydraulic cylinder: Modern hydraulic scissors lifts are for the most part worked by one, two, or three single-acting water-driven chambers. So the lift table rises and lower the heap to the necessary stature. This segment is known as a swagger with the two closures stuck. So they are exposed to coordinate compressive power which would aim bowing pressure which can end clasping of the segment. It is exposed to an inside compressive pressing factor which produces boundary burdens and meridian anxieties throughout the divider extent. Subsequently, the essential material property should incorporate strength, pliability, durability, and hardness.

3.4 Power Source
For the most part, hydraulic scissor lifts are fueled by an voltaic engine or air engine. These give the capacity to the water-powered siphon which impels the lift table to move uphill or descending. Pascal’s Law took away the hydraulic scissor lift chips. The guideline of transmit of liquid pressing factor or Pascal Law is the standard in liquid mechanics that clarify that the pressing factor applied anyplace in a limited incompressible liquid is sent similarly every which way all through the liquid to such an extent that the pressing factor varieties stay consistent.

The basic rationale behind each pressure-driven system is straightforward is Force that is applied at one point is communicated to other point utilizing an incompressible liquid. The power is quite often duplicated in a cycle. A typical pressure-driven system comprises two cylinders and an oil-filled line interfacing with them. Because of the state of the first gadget, a pantograph is additionally alluded to as such a design that will withdraw or broaden like an agreeing, shaping a trademark rhomboidal scissor lifts, and vary scissor components viz the pantograph is used in electrical trains and prepares.

4. Topology Optimization
During the twentieth century, organizers and creators have used innovative and novel procedures to make ideal sorts of developments and figures. While the techniques used by these pioneers made capable and in vogue structures, they shared an average cutoff showing up at the ideal plan. Though the justification applying geology smoothing out has never been a standard technique, progressions
in finding ideal development structures let the researchers and originators be allowed to foster better plans.

Figure 6: Optimization in Base platform design based on design calculations

Figure 7: Optimization in Top design based on design calculations

Topography smoothing out offers a determined arrangement for lighter and stiffer developments. It helps with showing up at useful and polished plans inside an unobtrusive range. The benefits are:

(a) Building weight-saving and complete plans.

(b) Decrease required opportunity to present and test item.

(c) By the assistance of FEM programming, you can check your plan.

It has shown its power and adequacy in the arrangement of plans by the development in progress on computational speed and power. Changes in PC hardware and programming advancement have moreover changed the best approach to manage geology improvement of plans. Nowadays, you could use appealing programming outlining different topographies like it is a standard task, along these lines, you can adjust old plans and produce new elective plans in a virtual environment. Originators and engineers are fulfilled to have a stunning resource in their work.
4.1 FEA Analysis after Optimization For Top

We have done the study using FEA analysis. For each part we have analysed separately. The resultant stress values and summary table are given below:

**Table 2. Stress Values after optimization for top**

| Parameter                      | Maximum          | Minimum          |
|--------------------------------|------------------|------------------|
| Factor of safety (Per body)    | 15               | 15               |
| Von Mises                      | 1.09E-08 M Pa    | 1.279 M Pa       |
| Displacement                   | 0 mm             | 0.3527 mm        |
| Reaction force                 | 0 N              | 189.4N           |
| Strain                         | 6.377E-12        | 6.211E-05        |

**Table 3. Result summary for FEA Analysis after optimization for top platform**

| Parameter                              | Maximum          | Minimum          |
|----------------------------------------|------------------|------------------|
| Average Element Size (% of model size) | Parabolic        | Parabolic        |
| Average Element Size (absolute value)  | 10               | 10               |
| Element Order                          | Parabolic        | Parabolic        |
| Create Curved Mesh Elements            | Yes              | Yes              |
| Max. Turn Angle on Curves (Deg.)       | 60               | 60               |
| Max. Adjacent Mesh Size Ratio          | 1.5              | 1.5              |
| Max. Aspect Ratio                      | 10               | 10               |
| Minimum Element Size (% of average size) | 20              | 20               |

4.2 FEA Analysis after Optimization for base platform

**Table 4. Stress values after optimization for base platform**

| Parameter                              | Maximum          | Minimum          |
|----------------------------------------|------------------|------------------|
| Average Element Size (% of model size) | 10               | 10               |
| Average Element Size (absolute value)  | 10               | 10               |
| Element Order                          | Parabolic        | Parabolic        |
| Create Curved Mesh Elements            | Yes              | Yes              |
| Max. Turn Angle on Curves (Deg.)       | 60               | 60               |
| Max. Adjacent Mesh Size Ratio          | 1.5              | 1.5              |
| Max. Aspect Ratio                      | 10               | 10               |
| Minimum Element Size (% of average size) | 20              | 20               |
Table 5. Result Summary after optimization for base platform

| Parameter                  | Maximum     | Minimum |
|----------------------------|-------------|---------|
| Factor of safety (Per body)| 7.028       | 15      |
| Stress, Von Mises          | 1.982E-005MPa | 29.45MPa |
| Displacement               | 0 mm        | 0.009001mm |
| Reaction force, Total      | 0 N         | 27.9N   |
| Strain, Equivalent         | 1.332E-10   | 2.412E-04 |

4.3 FEA Analysis after optimization for Scissor rod

Table 6. Stress values after optimization for scissor rod

| Parameter                  | Maximum     | Minimum |
|----------------------------|-------------|---------|
| Average Element Size       | 10          |         |
| Average Element Size (absolute value) |            | 10 |
| Element Order              | Parabolic   |         |
| Create Curved Mesh Elements| Yes         |         |
| Max. Turn Angle on Curves (Deg.) | 60     | |
| Max. Adjacent Mesh Size Ratio | 1.5  | |
| Max. Aspect Ratio          | 10          |         |
| Minimum Element Size (% of average size) | 20 | |

Table 7. Result Summary after optimization for Scissor rod

| Parameter                  | Maximum     | Minimum |
|----------------------------|-------------|---------|
| Factor of safety (Per body)| 1.116       | 15      |
| Stress, Von Mises          | 7.283-04MPa | 185.4MPa |
| Displacement,Total         | 0mm         | 0.9036mm |
| Reaction force, Total      | 0N          | 3404N   |
| Strain, Equivalent         | 3.788E-09   | 0.001461 |
5. Conclusion

The water powered scissor lift was fundamental being utilized. Material managing and offering comfort to the chairman was our essential creative mind driving the improvement of this lift. An arrangement of scissor lift, the problem in an arrangement and assembling time were diminished. However, control of this Hydraulic lift is the elevated early on amplify. The examination and recreation on AUTODESK FUSION 360° programming has furthermore shown that the arrangement was ensured underneath certain recognized limits. In this paper, we did an unequivocal investigation of scissor part joins went against bowing and catching dissatisfaction and moreover middle around various arrangement perspectives. In this, the lift was simply fit for lifting the heap up to 200kg with the least effort.

In this paper, we have examined the primary concerns for advancing the plan and investigating the Hydraulic Scissor Lift execution in different format. From the recreation results, unmistakably utilizing generative plan and geography enhancement strategy has been diminished by the kerb load of the scissor lift. As, force is one of the significant measure in the hustling and cruiser bicycles, as weight gets diminished the motor vehicle will carry quicker, henceforth generative plan and geography improvement are useful to diminish mass up to 38% of the Hydraulic Scissor Lift.

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