Innovative Design and Structural Analysis of Hydraulic Lifting Systems

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Abstract- *Scissor-type lifting mechanisms are widely used in a variety of industrial applications, including repair, maintenance, and cleaning. This research examines the design and evaluation of the scissor lift systems with a 500kg load capacity and operating height of 2m. The SolidWorks programme was used to create a detailed solid model and system assembly. Structural study, including stress, deviation, and safety factor assessments, was performed with the same software to evaluate the system's reliability and effectiveness. The results of the evaluations show that the developed system is appropriate and safe to use in load/unload activities.*

Keywords— Hydraulic jack, Scissor lift, Design, Safety , Lifting System, Finite Elements etc.

I. INTRODUCTION

Platform that has evolved alongside scientific and technological breakthroughs. It is used for material handling and attempts to improve operator comfort during operations. It is widely used in a variety of industries and public settings. The scissor lift table holds, stacks, raises or lowers goods or weights, and transfers them between different heights. A scissor lift uses connected, folding arms organised in a crisscross 'X' pattern, called as a pantograph. This design makes lifts using scissor lifts economically reliable and adaptable for lifting high loads in the manufacturing sector, with few moving components that require merely oil. The platform is extended and retracted mechanically, hydraulically, or pneumatically.

Hydraulic jacks, which include scissor lifts, are used in a variety of uses, including pallet handling, truck loading, work placement, automated production lines, and shipping lines. Scissor lifts, also known as aerial job platforms, are frequently utilised for temporary access requirements such as maintenance and urgent access during building projects. They are particularly built to lift just a limited weight. The extension and retract movement of the scissor arms, which are commonly operated by hydraulic, pneumatic, and mechanical systems, helps to raise goods smoothly to any needed height.

In conclusion, scissor lifts are often regarded as the most cost-effective machines for lifting high objects, providing dependability and adaptability. With fewer components that move and efficient lubrication, they ensure years of trouble-free operation. Their popularity and effectiveness make them the favoured choice among the different types of scissors lifts employed in material handling operations.

II. PROBLEM STATEMENT

The current lift type can raise 1 tonne up to an elevation of 4.85m. With a body mass index of 851 kg, weight optimisation is the major goal. Furthermore, the process of loading and unloading situations may not be uniformly distributed, necessitating a Moment Loading analysis. The link connection, a key component of a scissor lift, provides significantly to the overall lift weight by supporting the cylinders. As a result, the emphasis is on developing a lighter link connector or altering the cylinder location to eliminate the requirement for link connectors altogether.

III. LITERATURE SURVEY

Gaffar G Momin et. al. The research focuses on the development and evaluation of a hydraulic scissors lift, which is often used for a variety of purposes such as lifting cars, easing maintenance activities, and handling commodities. Scissor lifts can function utilising mechanical, pneumatic systems, or hydraulic systems, with the design given in this article focussing on a low-cost hydraulic system. The elevator is mechanically driven using a pantograph, which reduces total expenditures. A hydraulic hand pump drives the lift's hydraulic cylinder, allowing it more portability and eliminating the requirement for an electric power source. This design decision provides compactness, providing the lift ideal for medium-sized enterprises. The scissor lift was then analysed using ANSYS, which evaluated important parameters to confirm the lift's design [1].

M. Kiran Kumar et. al. The testing found that a force is applied to the hydraulic scissor lift throughout both extension & contraction. Hydraulic scissor lifts are widely used to raise and support large components, highlighting the importance of material choice in design. Material selection influences a variety of aspects, including durability, dependability, strength, and resistance, all of which contribute to the lift's long life. The hydraulic lift is meant to be portable, small, and ideal for medium-load handling situations. SolidWorks software is used to draft and model the hydraulic system, which is then loaded into Ansys Workbench for meshing & analysis. The Ansys study comprises assessing the entire deformation load and corresponding stresses to ensure compliance with design values. A comparative investigation of two distinct materials, aluminium and mild steel, in this study to determine the optimal material for the lift's performance [2].

Uttam Panwar et. al. The research analyses the operating mechanism and investigates a hydraulic lift's study, which addresses material handling issues and improves operator comfort. It gives a thorough analysis and layout for the parts of a hydraulically scissor lift that are capable of raising a 300kg weight at a height of 3.5ft. The major goal is to explore and construct a moveable and portable pneumatic scissor lift with rollers or wheels enabling mobility within the lift's base. Due to the lack of electric authority, a pump with hydraulics is used to provide accurate and higher pressure. This hydraulic operation and design considerably improve the lift's effectiveness, making it ideal for industrial use. The research tries to optimize the employment of every element to get best outcomes [3].

Deepak Rote et. al. The study entails the creation and assessment of a screw jack-based mechanical lift with scissors. The three types of lifting mechanisms used by scissor lifts are hydraulic, pneumatic, and mechanical. In order to ensure that the maximum allowable deflection stays within the specified bound, the lift is chosen by computational methods. Validating the results involved linear static FEA research, solid modelling, and computer simulations using CAE software. It was found that the anticipated scissor lift components were within allowable bounds. To prevent failures throughout operations, it should be highlighted that some manufacturers may consider the allowable maximum deflection to be excessive. As a result, recommendations for crucial areas and extra safety precautions are necessary. This scissor lift's design aims to save manufacturing time and remove problems. A mechanical scissor lift, which functions on the basic principle of a screw jack, requires less energy compared to other types, allowing it to be portable and reach up to five feet in the air. The results of ANSYS demonstrate that the layout is safe for heavy loads that can lift up to 1000 kg of weight with little effort. The vehicle and manufacturing sectors make extensive use of this kind of lift, which offers potential for further improvement and investigation [4].

Doli Rani et. al. The scissor lift may be engineered to support heavy weights with the use of an appropriate high-capacity hydraulic cylinder. It is an effective option because of its ease of use and low maintenance needs, particularly when lifting larger weights. With its present specs, the scissor lift can raise a weight between 1.5 and 2 tonnes, with a 5-foot lift. The elevator has a low running cost despite its expensive starting cost. It is advised to heat treat the shearing tool in order to increase its strength. The device is quickly financially viable to purchase because to the cost savings realised from its use, especially in engineering sectors that deal with corroded and unusable metals. This adaptable gadget is attractive from a business standpoint since it can be modified in the future to increase operational efficiency. Because of this, scissor lifts are used in many different industries, including hydraulic pressure systems, automobile lifting in garages, huge machine maintenance, and stacking applications. As a result, adoption is highly advised [5].

N. Pandit et. al. The study concentrated on investigating the design, evaluation, and safety aspects regarding the scissor lift, a multipurpose material handling device that may run on mechanical, pneumatic, or hydraulic energy. During the design stage, forces were determined by determining the system's equilibrium in both closed as well as open positions. Furthermore, a range of attachments were investigated in order to improve worker safety while the machine was in use, including thorough instructions for operation [6].

Wubshet Yimer et. al. The design and construction of a portable working platforms lift that satisfies all design requirements and is raised by an individual hydraulic cylinder was concluded in this study. The double-type scissors lift is intended for typical load applications. It is powered by a foot pedal and raised by a single hydraulic cylinder. The hydraulic hydraulic scissor lift can carry larger loads and is easy to operate, needing little upkeep and repairs. The scissor lift is capable of raising a load up to 280 kg to an elevation of 1000mm with the specified parameters. It is therefore widely used in sectors, hydraulic pressure systems, car lifting in garages, heavy machine maintenance, and stacking applications [7].

Sandeep G. Thorat et. al. According to the study, the hydraulic cutter lift has a strong performance since it is designed for high load resistance. The scissor lift is easy to use and requires little upkeep on a regular basis. Because mild steel is more readily available, stronger, and more durable than other materials, it is used in the construction of scissor lifts. Based on the given measurements, the scissor lift can raise objects up to a height of 7 feet with loads between 3000 and 4000 kg. The lift's design provides great opportunity for upgrades aimed at further improving operational efficiency [8].

Georgy Olenin et. al. The study looked at a scissor lifting platform's analysis and design from both the top and bottom locations. The study explores the many types of scissor lifts and their operating mechanism. It also discusses potential problems that might occur when operating a scissor lift and offers solutions to get rid of them so that production can increase. Standard formulae and the idea of body diagrams that are free are used in design calculations. The article contains several examples of cylinder mountings, which depend on the cylinder's angle of inclination and the force it applies to the arms. Shear force diagrams or bending moment diagrams are used in the study [9].

IV. WORKING OF HYDRAULIC SCISSOR LIFT

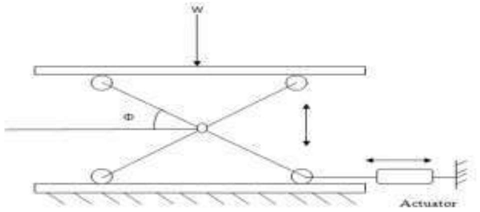

Fig 1. Principle of operation

The scissor lift consists of a customized lifting platform powered by a basic steel framework with links that resemble a number of scissors joined together to create a long chain. This scissor-like structure generated by the links consists of two well-known mechanisms: the four-bar mechanism and the slider crank mechanism.

Lowered Positioning: In its stationary or lowered condition, the scissor lift has completely contracted scissor arms and the platform is at its lowest point, usually resting on the floor or a base frame.

Activating the Lift: The operator activates the hydraulic pump, which pressurizes the hydraulic fluid. Control valves deliver pressurized fluid to the hydraulic cylinders. The fluid fills the cylinders and exerts an upward push on the pistons, forcing the serrated arms to extend.

Platform Elevation: By extending the chopping arms, the raised platform rises naturally and controllably. The control system enables the operator to modify the ascent rate, resulting in safe and accurate placement.

Attaining required Height: The operator controls the system of hydraulics until the platform achieves the required height. The lift may be stopped and held at any place throughout its working range.

Lowering Process: When lowering the lift, the user initiates the control system, which releases the hydraulic pressure into the cylinders. The drop in pressure, along with both the weight of the scaffolding and the load, causes the cutting arms to progressively retract, lowering the platform.

Safety Features: Hydraulic scissor lifts have emergency stop controls protection from overload, and safety rails. These characteristics assure the safety for both operators and end users.

In summary, a hydraulic a shaft lift uses hydraulic pressure to raise and lower scissor arms, allowing for the controlled lifting and lowering of an object or cargo. This mechanism is stable, precise, and versatile, making it ideal for a variety of lifting and entry applications.

V. COMPONENTS OF SCISSOR LIFT

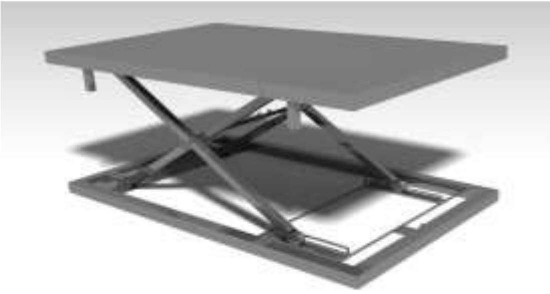

Fig 1.CAD Model

1. Scissor System: At the core of hydraulic scissor lifting tables is the scissor mechanism, which consists of linked folding arms. These arms, often made of steel, make a crisscross pattern like extended scissors.
2. Hydraulic Cylinders: Hydraulic cylinders are connected to a single set of scissor arms and contain a hydraulic fluid plus a moving piston. The exertion of hydraulic pressure causes the piston to extend or retract, pushing or pulling the attached scissor arms.
3. Platform: The lift's platforms or deck is attached to the upper pair of scissor arms. This component acts as the region where loads or workers are placed during lifting operations.
4. Hydraulic Pump then Fluid Reservoir: The hydraulic pump pressurizes hydraulic fluid kept in a reservoir and, when triggered, distributes pressurized fluid to the linked cylinders.

Valves and Controls: Valve controls play a critical function in managing the distribution of hydraulic fluid into the cylindrical objects, ensuring accurate oversight over the lift's motion. Operators use a variety of controls, including levers, buttons, and a control panel, to perform lifting, lowering, or stopping movements as needed.

VI. CALCULATION

Load = W = 200 kg
d = 834 mm
L2 = 1405 mm
a = 130 mm
L = 1684 mm
$\alpha = 33o$
$\beta = 28.5o$

To find Reaction forces

Taking moment at point C

$\Sigma Mc = 0$
$W.d - Dy.AB = 0$
$Dy = W.d/AB = W*834/1405 = 0.594 W$
$\Sigma Foy = 0$
$Dy + Cy - W = 0$
$Cy = W - Dy$
$Cy = W - 0.594W$
$Cy = 0.406W$
$\Sigma Fox = 0$
$Px - Fx = 0$
$Px = Fx$
$Fx = P.\cos\beta$
$\Sigma Foy = 0$
$-Dy + Py - Fy + Cy = 0$
$Fy = Py + Cy - Dy$
$Fy = Py + 0.406W - 0.594 W$
$Fy = P.\sin\beta - 0.188W$

Taking moment about C

$\Sigma Mc = 0$

$Dy.L.\cos\alpha - Py.(L/2 + a)\cos\alpha + Fy.L/2.\cos\alpha - Px.(L/2+a).\sin\alpha + Fx.L/2.\sin\alpha = 0$

$Dy.L.\cos\alpha - P.\sin\beta.(L/2 + a)\cos\alpha + Fy.L/2.\cos\alpha - P.\cos\beta.(L/2+a).\sin\alpha + Fx.L/2.\sin\alpha = 0$

$0.594W.L.\cos\alpha - P.\sin\beta.(L/2 + a)\cos\alpha + P.\sin\beta.L/2.\cos\alpha - 0.188W.L/2.\cos\alpha - P.\cos\beta.(L/2+a).\sin\alpha + P.\cos\beta.L/2.\sin\alpha = 0$

$0.594W.L.\cos\alpha - 0.188W.L/2.\cos\alpha - P.\sin\beta.(L/2 + a)\cos\alpha + P.\sin\beta.L/2.\cos\alpha P.\cos\beta.(L/2+a).\sin\alpha + P.\cos\beta.L/2.\sin\alpha = 0$

$0.5W.L.\cos\alpha - P.a(\sin\beta.\cos\alpha + \cos\beta.\sin\alpha) = 0$

By rule of geometry ,

$(\sin\beta.\cos\alpha + \cos\beta.\sin\alpha) = \sin(\alpha + \beta)$

$$P = \frac{0.5W.L.\cos\alpha}{a.\sin(\alpha + \beta)}$$

The highest stress will be at point where piston-cylinder is mounted to the arms i.e at point 'E'. Hence we are finding stress at point 'E'. For that we are going to consider arm 'AC' only for calculation.

At highest position of lift, the angle.

$\alpha = 33o$
$\beta = 28.5o$

Find force by piston cylinder at highest position.

$$P = \frac{0.5*2000*1684*\cos 33}{130*\sin(33 + 28.5)}$$

P = 12362 N

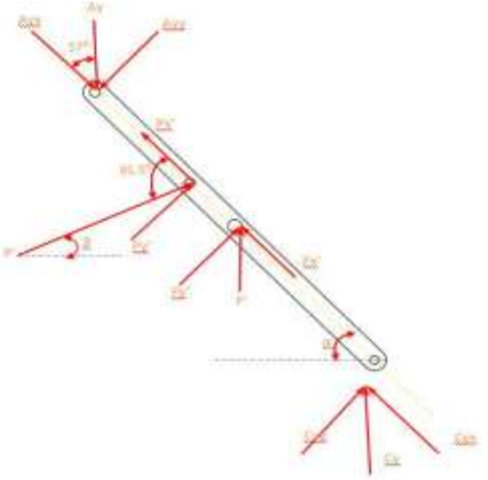

Fig 2.Free Body Diagram of Arm

As we can see in free body diagram Ay = Dy and Cy = By but opposite in direction

From free body diagram

Cyx = Cy.cos57 = 0.406W.cos57 = 442.25 N

Cyy = Cy.sin57 = 0.406W.sin57 = 681 N

Ayx = Ay.cos57 = Dy.cos57 = 0.594W.cos57 = 647.03 N

Ayy = Ay.sin57 = Dy.sin57 = 0.594W.sin57 = 996.34 N

Px' = P.cos61.5 = 12362*cos61.5 = 5898.64 N

Py' = P.sin61.5 = 12362*sin62.5 = 10863.94 N

Fx' = - Ayx +Px'+Cyx

Fx' = -647.03+5898.64+442.25

Fx' = 5690.86 N

Fy' = - Ayy + Py' + Cyy

Fy' = - 996.34+10863.94+681

Fy' = 10548.6 N

$$F = \sqrt{[(Fx')2 + (Fy')2]}$$

$$F' = \sqrt{5690.86^2 + 10548.6^2}$$

F' = 11985.78 N

Finding maximum stress and deformation

1. For Original lift model

Shape = Hollow Square Channel

Material = Mild Steel

Outer side = O =50mm

Inner side = I = 40mm

Thickness =5 mm

Cross Section Area

A = O2 – I2

A = 502 – 402

A = 900 mm2

Compressive Stress

$$\sigma_n = \frac{F}{A} = \frac{Ayx - Px'}{A} = \frac{647.03 - 5898.64}{900} = -5.84$$

Negative sign shows stress is compressive

$$\tau = \frac{F}{A} = \frac{Ayy - Py'}{A} = \frac{996.34 - 10863.94}{900} = -10.964 \text{ MPa}$$

Equivalent stress

$$\sigma_{eq} = \sqrt{(\sigma_n)^2 + \tau^2}$$

$$\sigma_{eq} = \sqrt{(5.84)^2 + 10.964^2}$$

σeq= 12.42 MPa

Maximum deformation

According to Hook's Law

$$E = \frac{\sigma \ Stress}{\rho \ Strain}$$

$$E = \frac{\sigma}{dl/L}$$

Where, dl is deformation,

$$dl = \frac{\sigma * L}{E}$$

$$dl = \frac{12.42 * 1684}{2 * 10^5}$$

dl = 0.1045 mm.

For Optimized lift model

Shape = Hollow Square Channel

Material = Mild Steel

Outer side = O =50mm

Inner side = I = 44mm

Thickness =3 mm

Cross Section Area

A = O2 – I2

A = 502 – 442

A = 564 mm2

Compressive Stress

$$\sigma_n = \frac{F}{A} = \frac{Ayx - Px'}{A} = \frac{647.03 - 5898.64}{564} = -9.30 \text{ MPa}$$

Negative sign shows stress is compressive ,

$$T = \frac{F}{A} = \frac{Ayy - Py'}{A} = \frac{996.34 - 10863.94}{564} = -17.495 \text{ MPa}$$

Equivalent stress

$$\sigma_{eq} = \sqrt{(\sigma_n)^2 + \tau^2}$$

$$\sigma_{eq} = \sqrt{(9.30)^2 + (17.495)^2}$$

σeq= 19.82 MPa

Maximum deformation

According to Hook's Law

$$E = \frac{\sigma \ Stress}{\rho \ Strain}$$

Where, dl is deformation,

$$dl = \frac{\sigma * L}{E}$$

$$dl = \frac{19.82 * 1684}{2 * 10^5}$$

dl = 0.1688 mm .

Sr. no.	Equivalent Stress	Deformation
Original Lift	12.42 MPa	0.1045 mm
Optimized Lift	19.82 MPa	0.1688 mm

VII. FEA ANALYSIS

Fig 3.CAD Model of Hydraulic Scissor lift

MESHING

FEA MODEL

No. of Nodes	158431
No. of Elements	78141

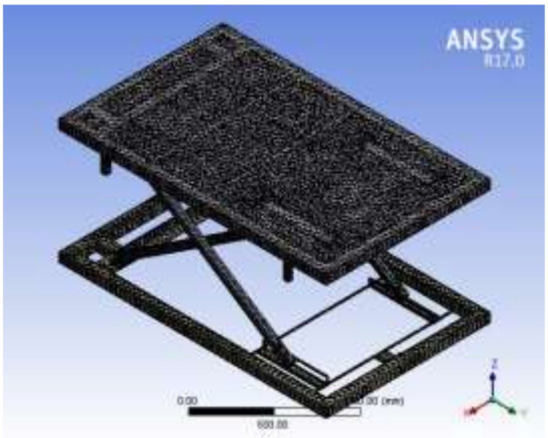

Fig .4. FEA Model of Hydraulic Scissor Lift With Meshing

BOUNDARY CONDITIONS

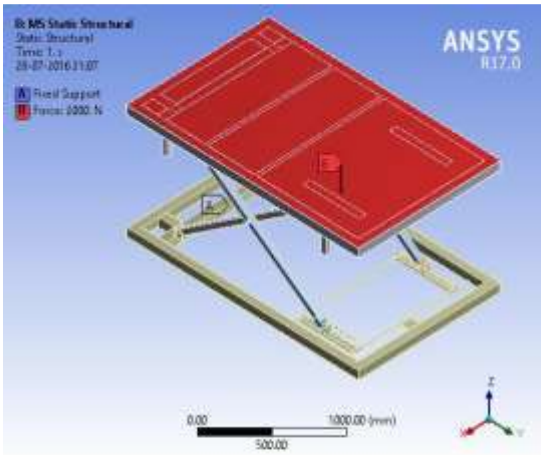

Fig 5.FEA Model of Hydraulic Scissor Lift With Boundary Condition

VIII. RESULT

Material ⇒	MS
STRESS(Mpa)	28.924
STRAIN	1.47E-04
DEFORMATION(mm)	1.26E+00
WEIGHT (kg)	354.53
MINIMUM FATIGUE LIFE (CYCLES)	1.00E+06

The maximum deformations induced in MS hydraulic lift is 1.26mm, which is in safe limits (1% of total span). Hence based on rigidity the design is safe.

IX. APPLICATION

- Domestic purpose.
- Hospitals.
- Computer centers.
- Auditoriums.
- Cultural centers.
- Schools.
- Colleges.
- Large scale industries.
- Medium scale industries.
- Theatres.
- Educational institutions.

X. CONCLUSION

It is imperative that operators feel more comfortable on the company's premises, and a hydraulic cylinder drives a movable work platform in this direction. A hand pump makes the operation easier and guarantees the operator's comfort while using the equipment.

It is imperative that the lift's natural frequency and the external stimulation frequency differ in order to prevent vibrations in the lift.

High load resistance is the main design goal of a hydraulic scissor lift for a portable work platform.

One notable feature of the hydraulic scissor lift is how little regular maintenance it requires and how easy it is to use.

The design process has been simplified with the introduction of a scissor lift, resulting in a decrease in complexity and manufacturing time.

Although the scissor lift concept has improved efficiency and comfort, it is important to recognize that there is an initial cost constraint.

A scissor lift's motor-driven hydraulic cylinder powers its moveable work platform, which guarantees efficient operation.

A appropriate high-capacity hydraulic cylinder can be used in the design of a scissor lift to achieve high-load capacity.

The scissor lift's cheap running cost and capacity to carry larger weights make it appealing even with its expensive original cost.

ACKNOWLEDGMENT

I would like to use this opportunity to show our sincere appreciation and respect to our project guide at the KDK College of Engineering in Nagpur, who gave us direction and space to complete this assignment.

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