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DESIGN AND ANALYSIS OF AN AERIAL SCISSOR LIFT

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ABSTRACT:

The following paper describes the design as well as analysis of a simple aerial scissor lift. 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, to lift the body to appreciable height, and many other applications Also such lifts can be used for various purposes like maintenance and many material handling operations. It can be of mechanical, pneumatic or hydraulic type. The design described 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 reduced. Also such design can make the lift more compact and much suitable for medium scale work. Finally the analysis is also carried out in order to check the compatibility of the design values.

KEY WORDS: *Aerial work platform, pantograph, lead screw, helix angle, Von Misses stress.*

1. Introduction

A scissor lift is a type of platform which moves in vertical direction. The mechanism incorporated to achieve this function is the use of linked, folding supports in a criss-cross 'X' pattern, known as a pantograph. The upward motion is achieved by the application of pressure to the outside of the lowest set of supports, elongating the crossing pattern, and propelling the work platform vertically upwards. The platform may also have an extending 'bridge' to allow closer access to the work area (because of the inherent limits of only vertical movement).

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 employed on the lift, it may require no power to enter 'descent' mode, but rather a simple release of hydraulic or pneumatic pressure. This is the main reason that these methods of powering the lifts are preferred, as it allows a fail-safe option of returning the platform to the ground by release of a manual valve.

Types of Aerial Scissor lift

The aerial 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

2. Design of Different Components of Aerial Scissor Lift

Aerial Scissor Lifts comprises of six components. There is no concrete design procedure available for designing these components. The main components of the lift are Base plate, Upper plate, lead screw, nut, links and pins. On the basis of certain assumptions the design procedure for each of the components has been described as follows:

Design of Base Plate

The base plate in a scissor lift only provides proper balance to the structure. Considering the size constraints, the dimensions of the base plate are taken as under. Also it has been found that not much of the stresses are developed in the base plate.

Length of the plate (L) = 450 mm and
Width of the plate (B) = 300 mm
Weight of the plate (W) = 250 N

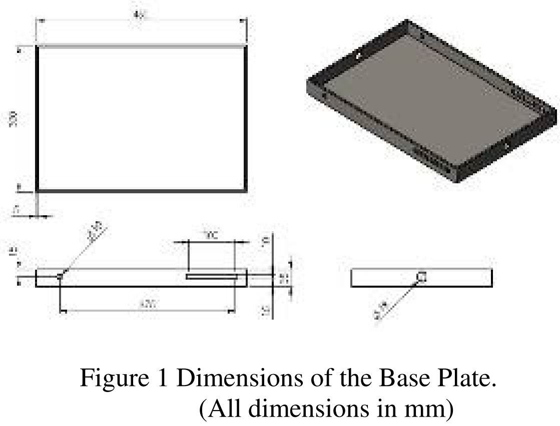

Figure 1 Dimensions of the Base Plate.
(All dimensions in mm)

Design of Upper Plate

The upper plate in a scissor lift is used to place the load and transfer it to the links. The designing of the upper plate is undertaken similar as the base plate. The upper plate has the similar requirements as the base plate. Also it has been found that not much of the stresses are developed in the upper plate as well.

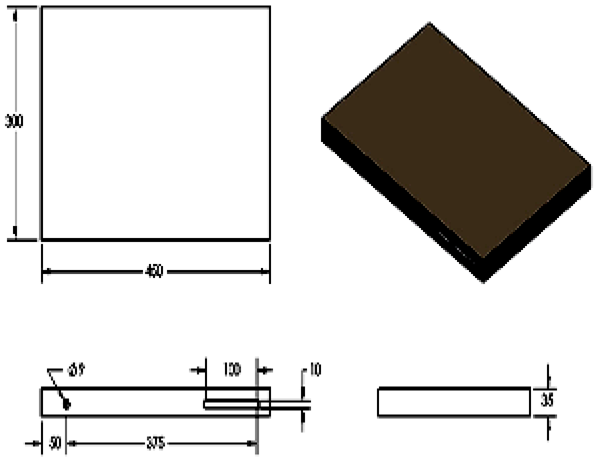

Figure 2 Dimensions of the Upper Plate.
(All dimensions in mm)

Design of Lead Screw

Lead screw is the ultimate component that takes up the load that is to be lifted or lowered by lift. It also delivers torque from the motor to the nut and also prevents falling of the lift due to its own weight. Link length is assumed to be 385 mm.

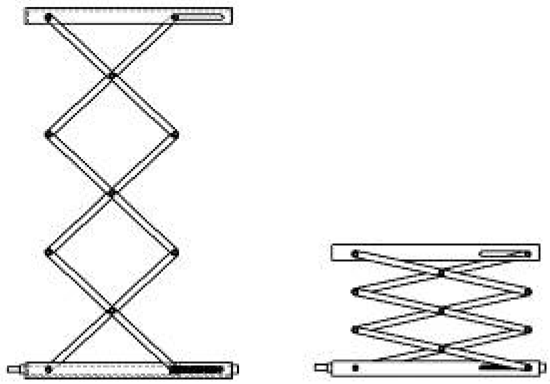

Figure 3 Scissor lift showing maximum and minimum positions.

It can be seen from the above figure 3 that maximum pull on the power screw occurs when lift is in lowermost position.

In minimum position,
The core diameter of the screw is taken as dc = 12 mm
And the pitch of the screw is taken as p = 2 mm
Therefore outer diameter do = 14 mm.
And the average diameter, d = 13 mm
Let α be the helix angle
Now $\tan \alpha = p / (\pi.d) = 2 / (\pi.13) = 0.0489$
Assume $\mu = \tan \Phi$. Thus we get $\Phi = 0.20$

Effort required to rotate the screw while increasing the height, $P = W \times \tan(\alpha + \Phi) = 135.23$ N
Similarly effort required to reduce the height,
$P = W \times \tan(\alpha - \Phi) = 80.5$ N
Torque required in rotating the screw, $T = P \times (d/2) = 878.9$ N.mm
Torsional shear stress (calculated) = 10.36 N/mm^2
Direct tensile stress (calculated) = 4.76 N/mm^2
Maximum principle stress (calculated) = 13 N/mm^2
Maximum shear stress (calculated) = 10.63 N/mm^2
It has been found that all the above calculated values are within the permissible limits. Therefore all dimensions considered are correct.

Design of Nut

The material of the nut is assumed to be mild steel. And therefore the bearing pressure of mild steel = 20 N/mm^2.
Assumed that the load W is uniformly distributed over the cross sectional area of the nut, therefore the bearing pressure between the threads is given by
$P_b = W / (\pi/4) \times [(do^2) - (dc^2)] \times n$
Thus we get n = 0.1903 (n is the number of threads in contact with screw)
In order to have good stability and also to prevent the undesirable movement of screw in the nut, take n = 4
Now thickness of nut (t) = n x p = 24 mm and width of nut (b) = 1.5 do = 27 mm

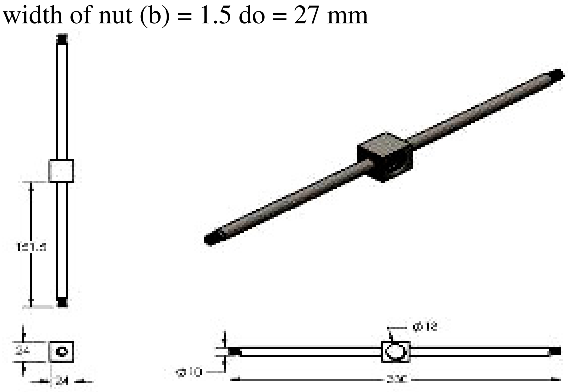

Figure 4 Dimensions of Nut
(All dimensions in mm)

Design of Link

Load acting on one link = F / 2 = 269 N
The link is designed for buckling load, assuming factor of safety (FOS) = 5
Thus critical buckling load = 269 x 5 = 1345 N
Assume width of link = 3 x thickness of link and c/s area of link = 3 x $thickness^2$
Moment of Inertia = 2.25 x $thickness^4$
Radius of gyration = 0.866 x thickness
Since for buckling of the link in the vertical plane, the ends are considered as hinged, therefore equivalent length of the link is, L = 385 mm.
Considering the Rankine's Formula, we find Thickness of link = 5 mm and Width of link = 15 mm

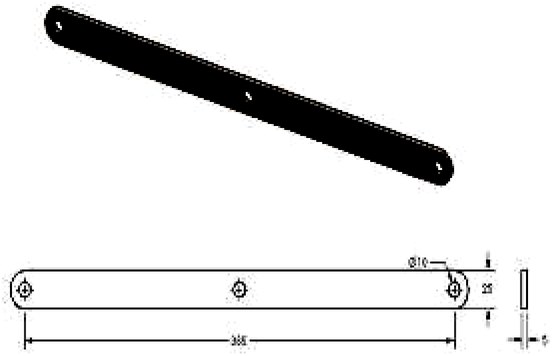

Figure 5 Dimensions of Link (All dimensions in mm)

Design of Pin

The pins will be in double shear conditions. Thus the diameter of pin is calculated as 10 mm

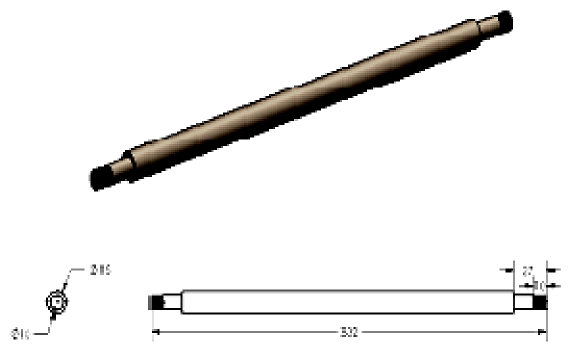

Figure 6 Dimensions of Pin (All dimensions in mm)

3. Design Analysis of Aerial Scissor Lift

The analysis of the designed Aerial Scissor Lift is carried in ANSYS. The different analysis carried out on the assembly are as under –

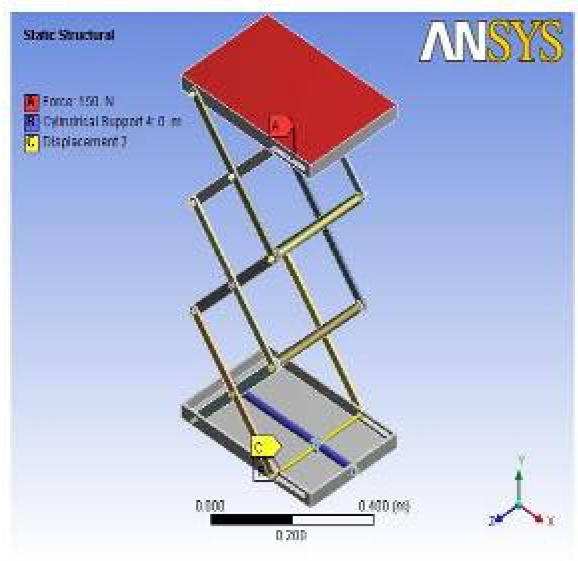

Figure 7 Force analysis

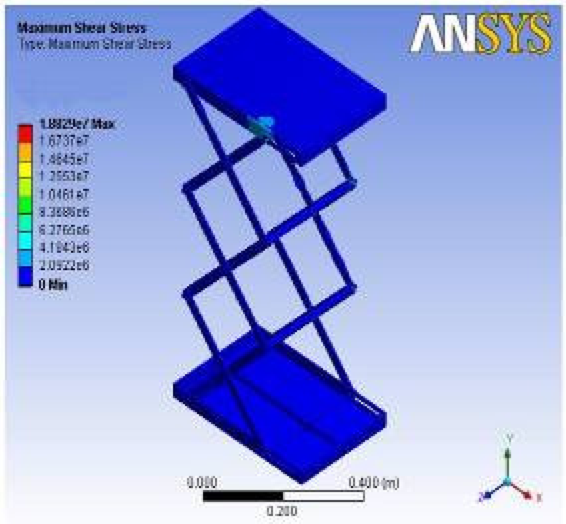

Figure 8 Stress analysis

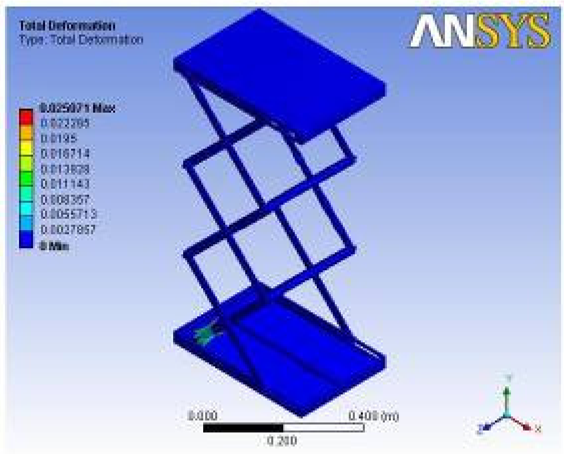

Figure 9 Deformation analysis

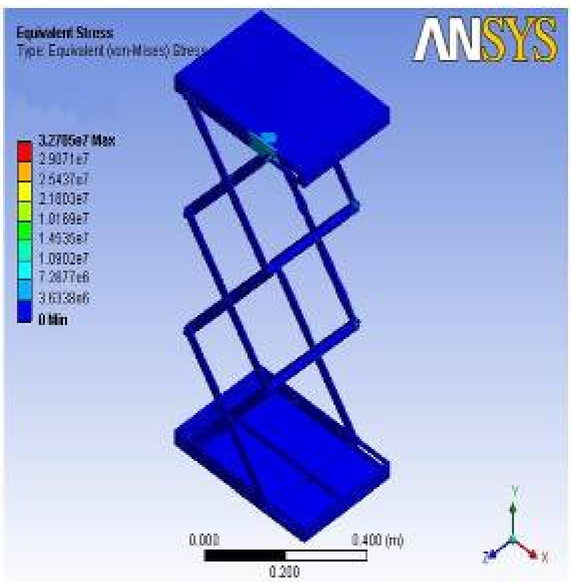

Figure 10 Shear Stress analysis

4. Results of Analysis

The result analysis for nut is as under

Name	Type	Min	Max
Stress	Von Mises Stress	1.67013e-010 N/mm^2 Node: 3854	396.258 N/mm^2 Node: 901

The result analysis for link is as under

Name	Type	Min	Max
Stress	Von Mises Stress	0.501183 N/mm^2 Node: 28024	119.853 N/mm^2 Node: 34482

5. CONCLUSION

With such a design of an aerial scissor lift, the complexities in the design can be reduced. Also with such design parameters, the manufacturing time of an aerial scissor lift can be reduced. So such a design can be used for production in industries. The analysis on ANSYS has also shown that the design is safe under certain accepted parameters. Also further modifications can be implemented for optimizing the design and further analysis can also be carried out by finding other important parameters related to aerial scissor lifts.

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