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An Improved Scissor Lift working on Lead Screw Mechanism

Aerial Scissor Lift and its Accessories

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Abstract — *Our Project relates to an Aerial Scissor Lift working on the Lead Screw Mechanism. An Aerial Scissor Lift is basically an Aerial Work Platform used for the Material Handling as well as Maintenance in Industries, Automobile Garages, Street Light Repairing etc. It is a lifting mechanism, operated by Hydraulic, Pneumatic as well as by Mechanical Means. Our Research relates to the accessories that should be included in the Design of an Aerial Scissor Lift, which will increase its Efficiency, Power, Safety and Ease of Working. This Aerial Scissor Lift consists of Linkages, arranged into criss-cross pattern, better known as a Pantograph. And the lift operates, because of the movement done by these linkages. The Accessories included consists of Saddle Plate for reducing thrust on the Lift, A Blocking Mechanism for holding the Lift in Elevated Position, Multiple Lift Sections for avoiding the issue of Collapsing of Lift, A Controller Mechanism for the Effective Movement of the Scissor Lift. We have also presented the brief study of Dynamic and Static Stability, as well as Brief Design Procedure of Scissor Lift.*

Keywords- *Aerial Work Platform, Scissor Lift, Pantograph, Stability of Scissor Lift, Lead Screw.*

I. INTRODUCTION

Considering the current Industrial Scenario, the Aerial Work Platforms employed into application are giving the appropriate performance with their apparatus. Industries at present, are using Hydraulic as well as Pneumatically Operated Scissor Lifts. These kind of lists are highly efficient and offer you with ease of application. But as far as Cost and Safety is concerned, the Hydraulic as well as Pneumatic Lifts lack in them. Thus, it becomes necessary to include some Accessories, Safety Measures as well as to think of an Alternate Mechanism to operate the Aerial Scissor Lifts. The Mechanically Operated Scissor Lifts, can be operated using two different Mechanisms, i.e. Rack & Pinion Method as well as Lead Screw Method. The Mechanical Methods gets Power from Electricity, basically an Electrical Motor which converts the Electrical Energy of the Motor into Kinetic Energy of the lift, which elevates the structure of the Aerial Work Platform in upward and downward position. The Accessories included in the present invention consists of a Saddle Plate, A Blocking Mechanism, A Self Locking Pair, Providing Multiple Sections for the Lifts as well as A Controller Mechanism. The present invention also demonstrates the Dynamic as well as Static Stability of the Scissor Lift and a Brief Design Procedure of the Mechanically Operated Scissor Lift working on the principle of Lead Screw. The present invention will increase the Safety Measures, Reliability, Efficiency as well as Performance of the Aerial Scissor Lifts to a certain extent.

II. ACCESSORIES OF SCISSOR LIFT

2.1 Static and Dynamic Stability of Aerial Scissor Lift

One of the main safety issue that these Aerial Work Platforms suffer is of Tip-Over due to wind. Tip Over generally causes the fall of the lift, which results into injuries as well as death of operators. **Ren G. Dong et al. [1]** in their research on **An Investigation on the Dynamic Stability of Scissor Lift** demonstrated a Lumped Parameter Model of an Aerial Work Platform. This invention led to preventive measures to be undertaken, during tip overs. The result as been stated by this experiment states the following conclusions, while working with an Aerial Scissor Lift:

1. The Natural Frequency of the Aerial Work Platform is around .3 to 2.08 Hertz.
2. The Tip Over potential increases, with the increase in Flexibility of the lift.
3. The Threshold of Tip Over also serves as a function of both Tilting Speed as well as Slope of Ground where the lift is working.
4. The lift is compatible to work only on flat surfaces, and shouldn’t be elevated on non-parallel, sloppy or deformable surface.
5. The operator should not continuously perform large periodic movement when the lift is in Elevated position, in order to avoid the tip-overs.
6. The Tilt Angle as well as the speed of Tilting should be monitored so as to avoid the issue of Tip Overs.

Similarly, as per the research undertaken by **Wei Zhang et al. [2]** in their topic of **A Study on the Static**

Stability of Scissor Lift, they studied the effect of Static Stability of Scissor Lift on 6 various parameters. First of all, the Static Stability of a Scissor Arm is determined with the help of Energy Method. For Modelling, they used the Nastran Software. The results stated that the value of modeling and simulation while using the Buckling Analysis is larger than the Energy Method Analysis, as the Eigenvalue is considered as the upper limit of the critical load. If we compare the Single Arm Scissor Lift with the Overall Scissor Lift because of it's boundary conditions. Whereas, the Overall Scissor Lift's condition is closer to the actual situation. However, the use of Single Arm Scissor Lift can be useful to determine the theoretical conditions of the Scissor Lift.

2.2 To load the lift in an Angular as well as Elevated Position

As per the research undertaken by **Bert J. Sikli [3][4]** in his Patent **Scissor Lifts.** This kind of lift keeps the Aerial Working Platform into Elevated Position for a long time. This makes the lift to collapse in compact position when not into application. The thrust is exerted in the direction of load. It also allows the full access to the linkages without their excessive movement. There is also a provision of Self Storing Maintenance Stand as shown by **Donald W. Blasdell et al.[5]** in their patent **Self Storing Maintenance Stand For A Scissor Lift Aerial Work Platform.** In which a pair of Scissor Lift arms which are freely pivoted in the middle portion of the Aerial Work Platform. For achieving this objective a Saddle Plate is provided on every end of arms for loading the arms of the Aerial Work Platform. It allows the arms to freely pivot when it is not into application. Finally there is also a provision of Controller Mechanism as explained by **Brian M. Boeckman et al.[6]** in his Patent **Scissor Lift Control and Apparatus Method.** Where with the help of Multiplexing Device for decreasing the number of Conductor lines. The Controller System consists of a Microprocessor which assures the safe operation of the Scissor Lift. With the help of this Mechanism, the movement of Scissor Lift can be employed with the help of Joystick.

III. DESIGN AND ANALYSIS OF AERIAL SCISSOR LIFT

There isn't any concrete Design Procedure available for the Designing and Analysis of Aerial Scissor Lift. So for getting the Aerial Scissor Lift properly designed, we have referred two research works undertaken by **Jaydeep M. Bhatt et al. [7]** and **M. Abhinay et al. [8]** entitled **DESIGN AND ANALYSIS OF AN AERIAL SCISSOR LIFT.**

3.1 Introduction

The current invention relates to the mechanically operated Aerial Scissor Lift working on the principle of Lead Screw. The whole mechanism is run by the linkages arranged into criss-cross patterns, betterly known as Pantograph. The whole mechanism is fed power with the help of Electricity. This is the most preferred method, as the overall cost as well as the number of parts of the Aerial Scissor Lift are reduced with the help of this method.

3.2 Base Plate and Upper Plate

The dimensions of the base plate were assumed depending upon the size constraints that we needed to follow in our model. Base Plate only provides proper balance to the structure. There aren't too much stresses on its parts.

Length of the Base Plate	=450 mm
Width of the Base Plate	=300 mm
Weight of the Base Plate	=250 N

The upper plate has similar requirements as the base plate. It just used to place the load and transfer to the links. It has been designed similar to the base plate.

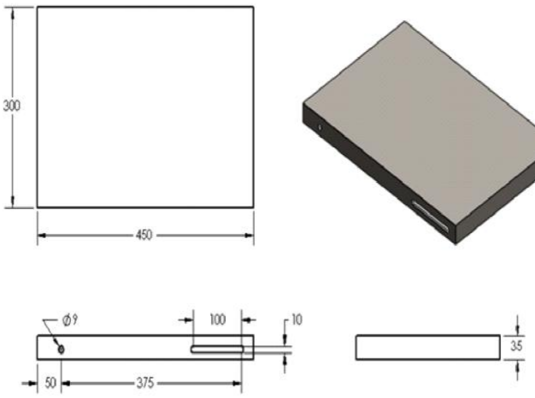

Fig. 1 Upper Plate

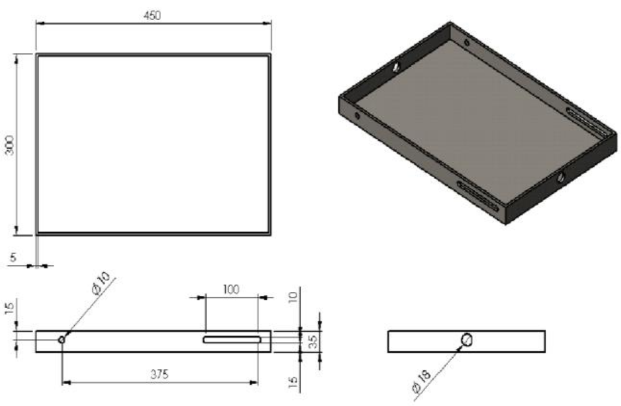

Fig. 2 Base Plate

3.3 Lead Screw

Power 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.

In minimum position,

Therefore, $\cos\theta = \frac{375}{385}$ ⇒ $\theta = 13.09°$

Fig. 3 Pull on Lead Screw in Minimum Position

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

Considering force diagram, $\frac{W}{2} = P \times \sin\theta$

⇒ $P = \frac{W}{2 \times \sin\theta}$

$= \frac{250}{2 \times \sin(13.09°)}$

≈ 552 N

⇒ $H = P \times \cos\theta P \times \cos\theta$

$= 552 \times \cos(13.09°) 552 \times \cos(13.09°)$

≈ 538 N

∴ Magnitude of pull on square –threaded screw, F = 538 N

Let d_c = Core diameter of the screw,

∴ $538 = \frac{\pi}{4} \times (d_c)^2 \times \sigma_t \frac{\pi}{4} \times (d_c)^2 \times \sigma_t$

⇒d_c = 2.62 mm

But this diameter is too small to be achieved. That is why a standard diameter can be taken which is greater than the above value.

Assume d_c = 12 mm

Nominal Outer Diameter, $d_o = d_c + p = 12 + 2 = 14$ mm

Mean Diameter, $d = d_o - \frac{p}{2} = 14 - \frac{2}{2} = 13$ mm

Let α = Helix angle

∴ $\tan\alpha = \frac{p}{\pi \times d} = \frac{2}{\pi \times 13} = 0.0489$

Assume $\mu = \tan\emptyset = 0.20$

WKT effort required to rotate the screw while increasing height,

$$P = W \times \tan(\alpha + \emptyset)$$

$$= W \times \left(\frac{\tan\alpha + \tan\emptyset}{1 - \tan\alpha \times \tan\emptyset}\right)$$

$$= 538 \times \left(\frac{0.0489 + 0.20}{1 - 0.0489 \times 0.20}\right)$$

$$= 538 \times 0.2514$$

$$= 135.23\ \text{N}$$

Similarly effort required to lower the load,

$$P' = W \times \tan(\emptyset - \alpha)$$

$$= 80.5\ \text{N}$$

Torque required in rotating the screw,

$$T = P \times \frac{d}{2} = 135.23 \times \frac{13}{2} = 878.9\ \mathrm{N-mm}$$

Torsional Shear Stress,

$$\tau = \frac{16 \times T}{\pi \times (d_c)^3} = \frac{16 \times 878.9}{\pi \times (12)^3} = 10.36\ \frac{N}{mm^2}$$

Direct Tensile Stress,

$$\sigma_t = \frac{W}{\frac{\pi}{4} \times (d_c)^2} = \frac{538}{\frac{\pi}{4} \times (12)^2} = 4.76\ \frac{N}{mm^2}$$

Maximum Principal Stress,

$$\sigma_{t(max)} = \frac{\sigma_t}{2} + \frac{1}{2} \times \sqrt{(\sigma_t)^2 + 4 \times \tau^2}$$
$$= \frac{4.76}{2} + \frac{1}{2} \times \sqrt{(4.76)^2 + 4 \times 10.36^2}$$
$$= 13\ \frac{N}{mm^2}$$

Maximum Shear Stress,

$$\tau_{max} = \frac{1}{2} \times \sqrt{(\sigma_t)^2 + 4 \times \tau^2}$$
$$= \frac{1}{2} \times \sqrt{4.76^2 + 4 \times 3.72^2}$$
$$= 10.63\ \frac{N}{mm^2}$$

Since the maximum stresses are in permissible limits, all the dimensions are correct.
All the dimensions of the power screw are shown in the figure.

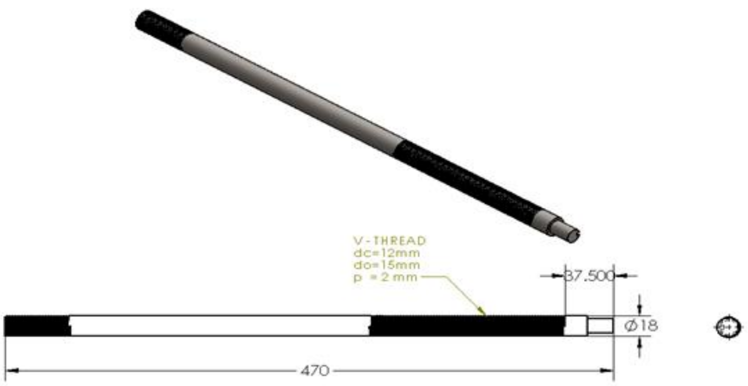

Fig. 4 Lead screw

3.4 Nut

Bearing Pressure for Mild Steel, $P_b = 20\ \frac{N}{mm^2}$

Let n = number of threads in contact with screw

Assuming that the load W is distributed uniformly over the cross-sectional area of the nut, therefore bearing pressure between the threads,

$$P_b = \frac{W}{\frac{\pi}{4} \times [(d_o)^2 - (d_c)^2] \times n}$$
$$\therefore 20 = \frac{538}{\frac{\pi}{4} \times [18^2 - 12^2] \times n}$$
$$\Rightarrow n = 0.1903$$

In order to have good stability and also to prevent rocking of the screw in the nut, we shall provide n = 4 threads in the nut.

$\therefore$ Thickness of nut, $t = n \times p = 4 \times 6 = 24\ \mathrm{mm}$

$\therefore$ Width of the nut, $b = 1.5 \times d_o = 1.5 \times 18 = 27\ \mathrm{mm}$

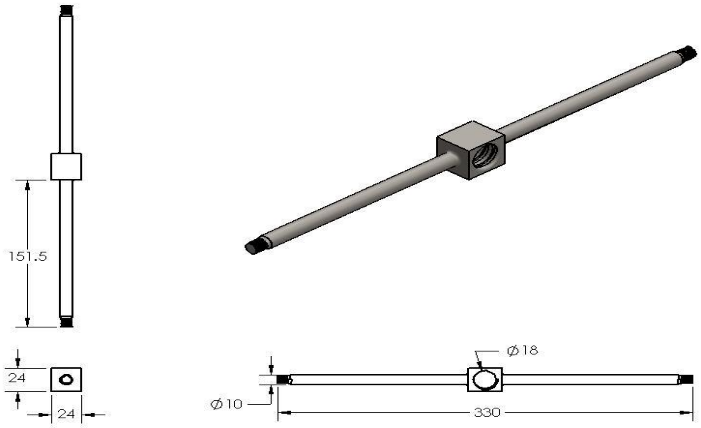

Fig. 5 Nut

3.5 Link

Load on one link $= \frac{F}{2} = \frac{538}{2} = 269$

Assuming FOS=5, the links may be designed for a buckling load of

$$W_{cr} = 269 \times 5 = 1345 \text{ N}$$

Let, t_1= Thickness of the link

b_1= Width of the link

Assume $b_1 = 3 \times t_1 b_1 = 3 \times t_1$

Cross-Sectional Area of link $= 3 \times {t_1}^2$

Moment of Inertia, $I = \frac{1}{12} \times t_1 \times (b_1)^3 = \frac{1}{12} \times t_1 \times (3 \times t_1)^3 = 2.25 \times {t_1}^4$

Radius of gyration, $k = \sqrt{\frac{I}{A}} = \sqrt{\frac{2.25 \times {t_1}^4}{3 \times {t_1}^2}} = 0.866 t_1$

Since for buckling of the link in the vertical plane, the ends are considered as hinged, therefore equivalent length of the link,

$$L = l = 385 \text{ mm}$$

And Rankine's constant, $a = \frac{1}{7500}$

According to Rankin's formula, buckling load (W_{cr}),

$$\therefore 1345 = \frac{\sigma_c \times A}{1 + a \times \left(\frac{L}{k}\right)^2} = \frac{100 \times 3 \times {t_1}^2}{1 + \frac{1}{7500} \times \left(\frac{385}{0.866 t_1}\right)^2} = \frac{300 {t_1}^2}{1 + \frac{26.35}{{t_1}^2}}$$

$$\therefore 4.483 = \frac{{t_1}^4}{{t_1}^2 + 26.35}$$

$$\therefore {t_1}^4 - 4.483 {t_1}^2 - 118.127 = 0$$

$$\therefore {t_1}^2 = 13.339$$

$$\therefore t_1 \approx 3 \text{ mm}$$

$$\therefore b_1 = 3 \times 3 = 9 \text{ mm} \approx 10 \text{ mm}$$

Now let us consider buckling of the link in a plane perpendicular to the vertical plane.

Moment of inertia, $I = \frac{1}{12} \times b_1 \times (t_1)^3 = 0.25 (t_1)^4$

Radius of Gyration, $k = \sqrt{\frac{I}{A}} = \sqrt{\frac{0.25 \times {t_1}^4}{3 \times {t_1}^2}} = 0.289 t_1$

Since for buckling of the link in a plane perpendicular to the vertical plane, the ends are considered fixed, therefore Equivalent length of the link,

$$L = \frac{l}{2} = \frac{385}{2} = 192.5 \text{ mm}$$

Again according to the Rankin's formula,

$$W_{cr} = \frac{A}{1 + a \times \left(\frac{L}{k}\right)^2} = \frac{100 \times 3 \times t_1^{\ 2}}{1 + \frac{1}{7500} \times \left(\frac{192.5}{0.289 t_1}\right)^2} = \frac{300 t_1^{\ 2}}{1 + \frac{59.16}{t_1^{\ 2}}}$$

Substituting the value of $t_1 = 3$ mm$t_1 = 3$ mm, we have

$$W_{cr} = \frac{300 \times 3^2}{1 + \frac{59.16}{3^2}} = 356.5 \text{ N}$$

Since the buckling load is less than the calculated value, therefore link is not safe for buckling in a plane perpendicular to the vertical plane.

∴ We may take $t_1 = 5$ mm and $b_1 = 15$ mm

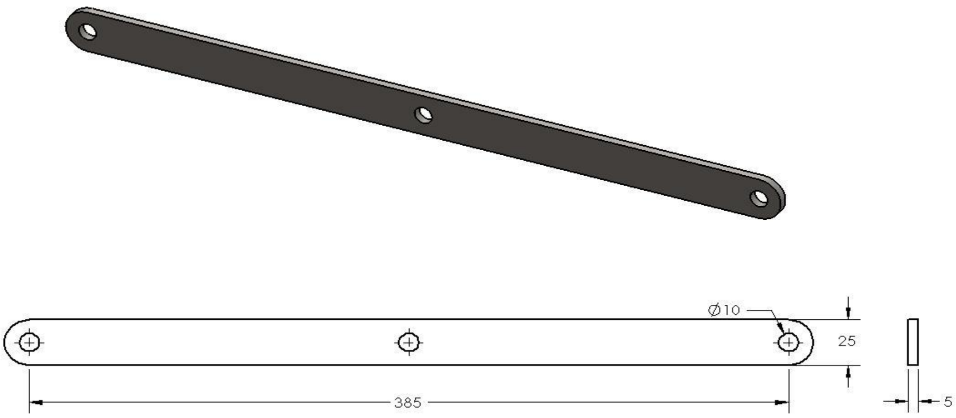

Fig. 6 Link

3.6 Pin

Let d_1= Diameter of pins

Since the pins are in double shear, therefore load on the pins,

$$\therefore 538 = 2 \times \frac{\pi}{4} \times (d_1)^2 \times \tau = 78.54 (d_1)^2$$

$$\therefore d_1 = 2.62 \text{ mm}$$

But to account for dimensions of other components let us take d_1= 10 mm

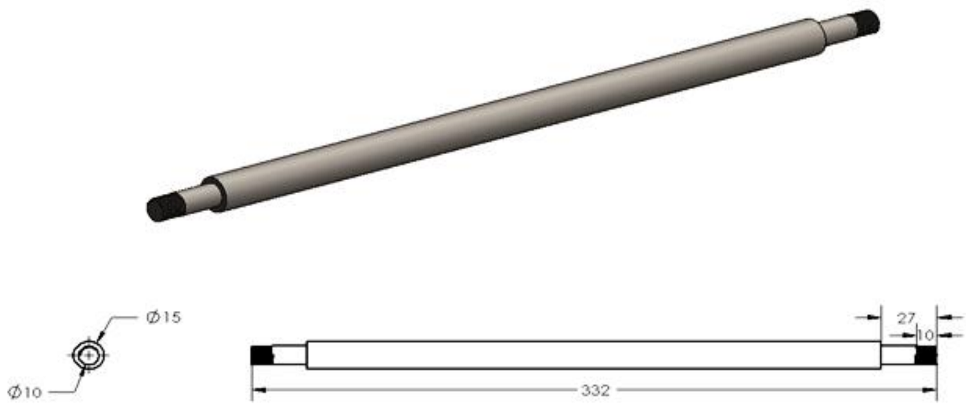

Fig. 7 Pin

IV. CONCLUSION

With the help of current research, we briefed out the basic Design Procedure of the Mechanically Operated Scissor Lift working on the principle of Leadscrew. Moreover, we also explained the importance of some useful accessories such as Self Storing Maintenance Stand, Blocking Mechanism, Self Locking Pair, Loading by Saddle Plate, Stability Conditions as well as Controller Mechanism.

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