Design and Analysis of Screw Operated Lifting Equipment

Bhavin H Mehta[1] Mehul G.Joshi[2] Utsav M.Dholakiya[3]
[1]PG Scholar [2,3]Assistant Professor
[1,2,3]Department of Mechanical Engineering
[1]Noble Groups of Institutions, Junagadh [2,3]Dr.Subhash Technical Campus, Junagadh

Abstract— The project relates to the lifting equipment or more particularly to a scissor jack for lifting a body to appreciable height that can be used for a various purpose like maintenance and many material handling operations. The mode of operation can be a mechanical, pneumatic or hydraulic. Mechanical mode of operation is suitable for the medium scale work, and precise range of application, where elevation for extended period of time is required, precisely without drifting. So the project is aimed with an objective to design the Screw Operated Lifting Equipment, for the maintenance purpose of the building with ceiling height of 1.625 m along with four workmen each weighting 80 kg along with their equipments. So this lifting equipment is designed for load carrying capacity of 500 kg keeping F.O.S – 1.4(with the reference of research paper), which overcomes the limitations of the hydraulic scissor lift in Repeatable positioning in the millimeter range even at high speed, maintaining the position with no drift at specified elevation for extended period of time, completely smooth motion and uniform speed, constant force and lifting speed, low vibration and noise, etc.

Key words: Scissor Lift, Screw Operated Lifting Equipment

I. Introduction

A. Introduction

A scissor lift or mechanism is a device used to extend or position a platform by mechanical means. The term “scissor” comes from the mechanic which has folding supports in criss cross “X” pattern, which is known as Pantograph.

The force applied to extend the scissors mechanism may by hydraulic, pneumatic or mechanical (via a lead screw or rack and pinion mechanism).The need for the use of lift is very paramount and it runs across: Labs, Workshops, Factories, Residential/Commercial buildings to repair street lights, Fixing of bill boards, electric bulbs etc.

B. Scope of the Study

The design and construction of the Screw scissors lift is to lift up to a height of 1.6m and carrying capacity 500kg. So this screw scissor lift can be used for the respective applications as:

- Repeatable positioning in the millimeter range even at high speed
- Maintaining the position with no drift at specified elevation for extended period of time
- Completely smooth motion and uniform speed
- Constant force and lifting speed
- Low vibration and noise

II. Problem definition

A. Problem Definition

It is difficult for a scissor lift operating with hydraulic mode to position at a precise range with high speed, with no drifting at a specified elevation for an extended period of time.

B. Objective

This project is aimed with an objective to ascent and descent the scissor lift table operating by lead screw at a precise range of applications with high speed, at specified elevation for extended period of time.

III. Methodology

A. Design Procedure

Aerial Scissors Lift comprises of six components. There is no concrete design procedure available for designing these components. So the design procedure is followed by the research paper for designing the screw scissor lift. But, the dimensions of the screw scissor lift components are taken from the Indian standards.

B. Assumptions & Consideration

This lift is designed to lift the workman along with their equipments for the maintenance purpose in multi-story building with the ceiling height of 2.5 meter. Since the project is focused to lift four workmen with their equipment so, the load carrying capacity of 500 kg is taken assuming the weight of one workmen along with his equipment equals to 80 kg, but for the safe design 500 kg is taken(FOS = 1.4). Plat-form size of, L × W = 2060 × 900 has been taken based on the consideration of four workmen. Elevated height of 1625 mm is taken, since the height of the ceiling is 2.5 meter as per the assumption. Since the scissor lift is designated by its load carrying capacity, so the other design parameters are selected based on load carrying capacity from the Indian Standards. So,

If W = 500 kg then, let Platform size (L × W) = 2060 × 900; Closed height H1 = 325 ; Elevated height H2 = 1625 Lift H = 1300

C. Material Selection

Material selection plays a very important role in machine design. It is necessary to evaluate the particular type of forces imposed on components with a view to determine the exact mechanical properties and necessary material for each equipment. A very brief analysis of each component follows thus:

- Base plate form – Mild Steel (MS)
- Top plate form – Mild Steel (MS)
- Lead Screw – Medium Carbon Steel (30C8)
- Nut – Medium Carbon Steel (30C8)
- Link – Stainless steel

– Pin – Medium Carbon Steel (30C8)

D. Base Platform/Upper Platform

Since the project is focused to lift four workmen with their equipment so total weight is 360 kg on the lift, but the load carrying capacity of 500 kg is taken considering, FOS = 1.4 (FOS of 1.5 is taken – Design of automated triggers for self propelled Hydraulic Scissor Lift – IJERT, May 2014)

Since the scissor lift is designated by its load carrying capacity, so the other design parameters are selected based on load carrying capacity from the Indian Standards. So, the Plat-form size taken is, L × W = 2060 × 900 considering four workmen. The dimensions of upper plate form follows as per the dimensions of base plate form.

E. 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. The maximum load on the screw is when the jack is in the bottom most position.

So considering lift table at minimum position

$\cos\Theta = 100 - 15/110 = 39.4^\circ$

Magnitude of pull in the square threaded screw,

$F = W/2\,(\tan\Theta) = 3510$ N

For the screw to be safe in tension,

$$dc = (P1 \times 4)/(\pi \times \sigma t)$$

So, dc = 16.24

But this diameter is small to be achieved. That is why a standard diameter can be taken which is greater than the above value. Therefore assuming dc = 20 mm and so according to IS 4694-1968 (Basic dimensions for screw thread) p = 5 for d = 20, 22, 24. Therefore,

Nominal Outer Diameter, do = dc + p = 20 + 5 = 25 mm

Mean Diameter, d = do – p/2 = 25 – 5/2 = 22.5 mm

Helix angle, tan = p/πd = 2/π(13) = 0.01415

Angle of friction = tan−1 μ = 0.20

Effort required to rotate the screw, P = W× tan (α + $\emptyset$) = 1720 N

Torque, T = P × dm/2 = 19350 N/mm2

Torsional shear stress in screw, =16$T/\pi dc^3$ = 12.32 N/mm2

Direct tensile stress in screw, σt = W × π/4 × (dc^2) = 15.60 N/mm2

Maximum principal stress in screw = 22.38, which should be less than 200 MPa, hence safe.

Maximum shear stress = 14.58, which should be less than 85 MPa, hence safe.

F. Nut

Bearing Pressure for Phosphorous Bronze, $P_b = 17\ \frac{N}{mm^2}$

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

$$P_b = \frac{W}{\frac{\pi}{4} \times [(d_o)^2 - (d_c)^2] \times n} \Rightarrow n = 1.32$$

In order to have good stability and also to prevent rocking of the screw in the nut, we shall provide n = 6 threads in the nut.

Thickness of nut, $t = n \times p = 6 \times 5 = 30$ mm

Width of the nut, $b = 1.5 \times d_o = 1.5 \times 25 = 37.5$ mm

G. Link

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

Load on each link = F/2

Assuming, b1 = 3t1

For buckling of links in the vertical plane, the ends are considered hinged.

Therefore, using Rankine-Gordon formula, for critical load, $Pcr = (Syc \times A)/[1+a\,(le/K)^2]$

$$\therefore 15825 = \frac{\sigma_c \times A}{1 + a \times \left(\frac{L}{k}\right)^2} \quad \therefore t_1 \approx 15 \text{ mm}$$

$$\therefore b_1 = 3 \times 3 = 45 \text{ mm}$$

For buckling of links in the vertical plane, the ends are considered fixed. Therefore, using Rankine-Gordon formula, for critical load, $Pcr = (Syc \times A)/[1+a\,(le/K)^2]$ = 8775 N

So, t1 = 15 mm and b1 = 45 mm

For design load, Pcr = F.O.S × F = 8775 < 15825

Critical load is more than design load so design is safe

H. Pin

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

$$\therefore 3510 = 2 \times \frac{\pi}{4} \times (d_1)^2 \times \tau = 78.54 (d_1)^2 \therefore d_1 = 40 \text{ mm}$$

But to account for dimensions of other components let us take d_1= 15 mm

IV. Modeling and Analysis

A. Modeling using Creo 2.0

Before analysis we have to make 3-D Model of Screw Operated Lifting Equipment. There are few software's available which enables 3-D modeling i.e. CATIA, SOLIDWORKS, AUTOCAD, etc.

I have used Creo 2.0 as modeling tool. First we made 3-D models of all the parts i.e. upper plate, base plate, links, pin, screw, same nuts as per the designed dimensions. After completing the part modeling we assembled all the parts together to transform them into an Screw operated lifting equipment 3-D model.

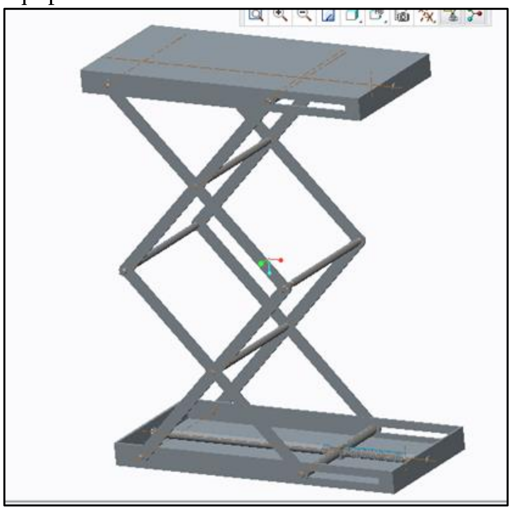

Fig. 1: Geometric modeling in CREO-2.0]

B. Analysis using ANSYS 16.0

I have used ANSYS 16.0 as an analysis tool.

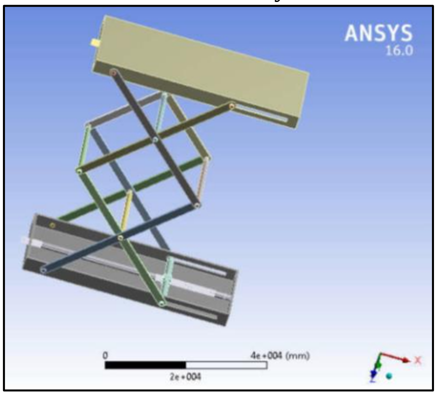

Fig. 2: Analysis in ANSYS

Here, first I took 3-D model on ANSYS then I applied some conditions like,

- Put weight at 500 kg on the upper plate
- Kept base plate fixed
- Curve motion constraints to pins which are connected to links only i.e. rotational motion w.r.t. Z-direction.
- Curve motion constraints to the pin which are connected to link and adjusted in the slots at upper and base plate i.e. rotational motion w.r.t. z-direction and displacement along X-direction.

After setting basic conditions, finally I simulated the movement of Screw Operated Lifting Equipment i.e. upward and downward movement of upper plate.

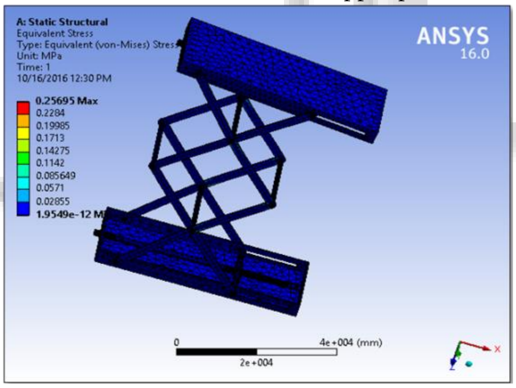

Fig. 3: Stress analysis on assembly

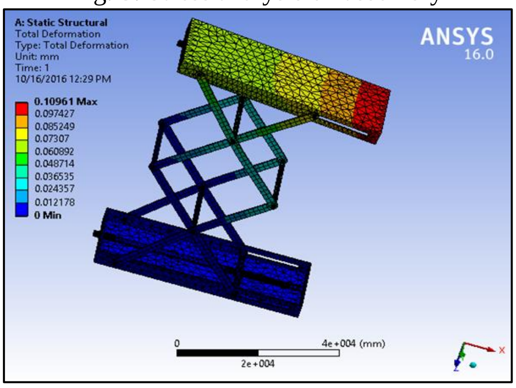

Fig. 4: Deformation analysis on assembly

V. CONCLUSIONS

With increasing employee and industry pressures to implement ergonomics solution for labor intensive tasks that are prone to elevate at precise range with high speed, without drifting at specified height for extended period of time, the Screw Operated Liftting Equipment operating by a Lead Screw at precise range with high speed, at speified elevation for extended period of time is good alternative.

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