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# Design, Analysis and Development of Hydraulic Scissor Lift

Material loading and unloading

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**Abstract —** *The following paper describes the design as well as analysis of hydraulic scissor lift. This paper resolves problem of material handling for cold storage industry. Goods were in cartoons which are likely to be perished if not loaded to cold room in stipulated time. The aim of this paper is design, analysis and to fabricate a hydraulic scissor lift which lifts maximum 2000kg load with minimum time. Lifting height achieved by scissor mechanism is of 2 m from bottom level. The aim of this paper is design, analysis and to fabricate a hydraulic scissor lift which operates efficiently and consistently and it should be compact and cost effective. Deformation analysis, beam 188 reaction forces, equivalent stress analysis of scissor were done by ANSYS design software and buckling and bending failure analysis were also done in this paper.*

***Keywords -*** *Scissor lift, Material handling, Hydraulic, Bending, Buckling, ANSYS, Platform, Mild Steel (MS), Beam 188.*

## I. INTRODUCTION

A scissor lift is type of platform that can move only vertically. With Today's development of science and technology, more and more new technologies were applied to material handling. This project aim was material handling and providing comfort to the operator. Scissor lift was easy to use/operate and it will be used conveniently at industries and other common places. [1]The mechanism incorporated to achieve this function was the use of linked, folding supports in a criss-cross 'X' pattern, known as a pantograph. All safety considerations were taken into account while designing equipment handling devices. Scissor lifting mechanism was design to lift person, materials, and loads smoothly to desired height. [2]A scissor lift provides most economic dependable & versatile methods of lifting loads; it had few moving parts which may only require lubrication. A scissor lift mechanism was a device used to extend or retract a platform by hydraulic, pneumatic, or mechanical means.

## II. MATERIAL SELECTION

As per the market study for material selection on the basis of Strength, Hardness, Weldability, Availability, Machinability and cost it was found out that the Mild Steel (MS) is suitable material for fabrication of Scissor lift. Also Brass material was used for making bush having low coefficient of friction.

## III. DESIGN

### 3.1 Design of Base Frame

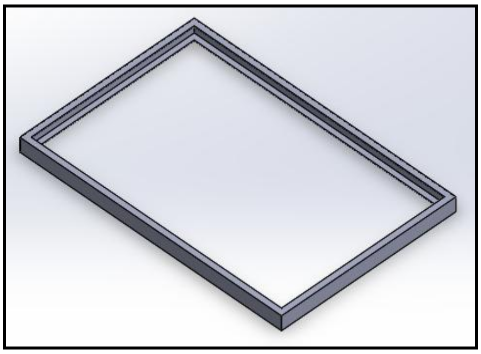

*Figure 3.1 Base Frame*

The base frame in a scissor lift only provides proper balance to the structure. Considering the size constraints, the dimensions of the base frame were taken as under. Also it had been found that not much of the stresses are developed in the base frame. The dimensions of base frame are 2000mm x 3000mm

### 3.2 Design of Middle Frame

The middle frame in a scissor lift was used to place the load and transfer it to the links. The designing of this frame was undertaken similar as the base frame.

 

### 3.3 Design of Link

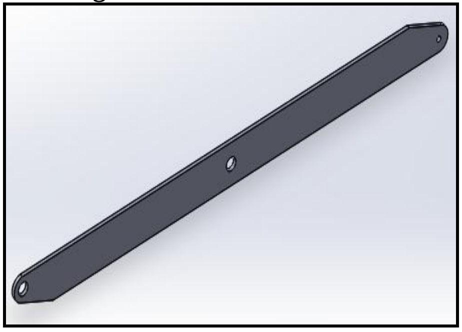

*Figure 3.2 Link*

Links in the scissor lifter were used to connect the upper frame with the bottom structure. This scissor links were subjected to buckling load and bending load tending to break or cause bending of the components. The suitable material for the link was mild steel.

### 3.3.1 Design of link for bending:

$$\frac{M}{I} = \frac{\sigma}{Y}$$

Where, M= Maximum Bending moment on the link considered as beam.
I= Moment of inertia
Y= Distance of neutral axis from the ends

$$= \frac{h}{2}$$

σ = Allowable bending stress

$$\sigma = \frac{Syt}{Fos} = \frac{250}{1.5} = 166.67\text{Mpa}$$

For a link design it had been considered that, the entire load was acting on half of link length. Length of entire link = 2850 mm

Length of link was consider as the beam for calculation purpose= 1425mm

Load pattern on link was uniformly varying load (U.V.L.) due to inclination with the horizontal. The calculation was done for the link in shut height position, i.e. when the angle made by the links with horizontal was 10˚.

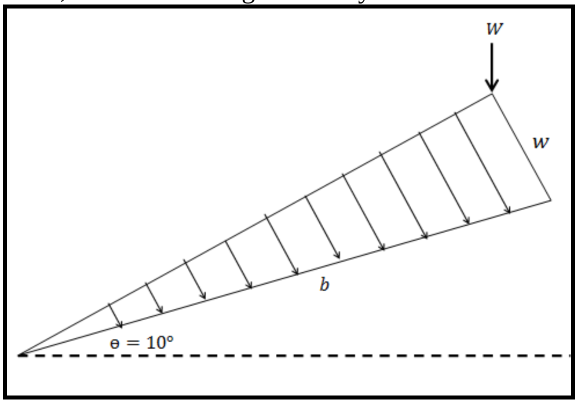


*Figure 3.3 U.V.L. on link*

Where, W= force per unit length of the beam can be evaluated as follows,
As the load pattern of U.V.L. was a triangle, we can say,

W (total force perpendicular to the link)

$$= \frac{1}{2} \text{x b x w}$$

Load on 1 link

$$\frac{37500}{4} = 9375 \text{ N}$$

Actual load on one link,

$$9375\cos 10^0 = 9232.57 \text{ N}$$

Now,

$$9232.57 = \frac{1}{2} \text{x} \, 1425 \text{ x W}$$

So, W= 13.95N/mm

 

Maximum bending moment,

$$= \frac{Wl^2}{9\sqrt{3}}$$

$$= 13.95 \text{ x } \frac{1425^2}{9\sqrt{3}} = 1687968.97 \text{ Nmm}$$

Assume, Y= and b = 10h

$$I = \frac{bh^3}{12} = \frac{20 \times 200^3}{12} = 13333333.33\text{mm}^4$$

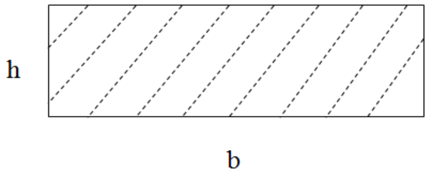


***Figure 3.4 Cross section of link***

Substituting in

$$\frac{M}{I} = \frac{\sigma}{Y}$$

We get,
h= 18.24≈ 20mm
b= 200mm
Therefore, the link dimension was 20 x 200 x 2850 mm.

**3.3.2 Design of link for buckling:**
According to Euler's Formula Method,

$$\text{Critical Load } = P_{cr} = \frac{\pi^2 EI}{l_e^{\,2}}$$

Where,

$l_e =$ Equivalent length of link
I = Moment of inertia
E = Modulus of Elasticity

We know that, in our condition one end was fixed and other end was free. Therefore, by standard consideration
Equivalent length of link = 2 x Length of the link
Length of link = 2850mm
Also, Modulus of Elasticity (E) = 210 GPa =210 x $10^3$ N/mm$^2$
Therefore,

$$P_{cr} = \frac{\pi^2 \text{x } 210 \text{ x } 10^3 \text{ x } 13333333.33}{(2 \text{ x } 2850)^2} = 850566.09 \text{ N}$$

We know that,

$$A = bh = 20 \text{ x } 200 = 4000 \text{ mm}^2$$

$$\text{Critical stress } (\sigma_e) = \frac{(P_{cr})}{(A)} = \frac{850566.09}{4000} = 212.64 \text{ N/mm}^2$$

Here, calculated critical stress was less than the standard value of mild steel (300 N/mm$^2$) Therefore, design will be safe.

**3.4 Design of Pin**

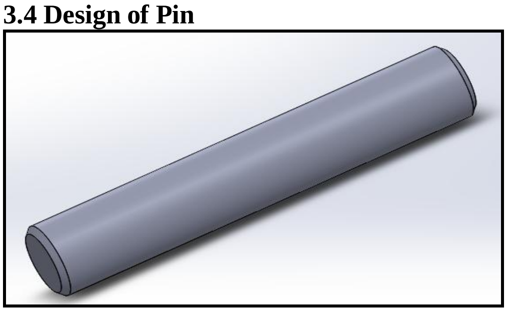

***Figure 3.5 Pin***

Pin is the major factor in scissor lifter. It played an important role in joining the links with the top and bottom frame. We know that in scissor lifter, pin goes under shear stress. Shear stress defined as force per unit cross section area.

$$\tau_{all} = \frac{0.5 \text{ x Yieldstress}}{\text{Fos}} = \frac{0.5 \text{ x } 250}{4} = 31.25 \text{ N/mm}^2$$

 

$$\tau_{all} = \frac{P}{2A}$$

Where, $\tau_{all}$= Allowable shear stress in pin ($N/mm^2$)
P = Total force applied on pin (N)
A = Cross section are under in shear ($mm^2$)

$$31.25 = \frac{4 \times P}{2 \times \pi D^2}$$

Therefore, D= 19.54 ≈ 25mm

**3.5 Design of Cylinder**

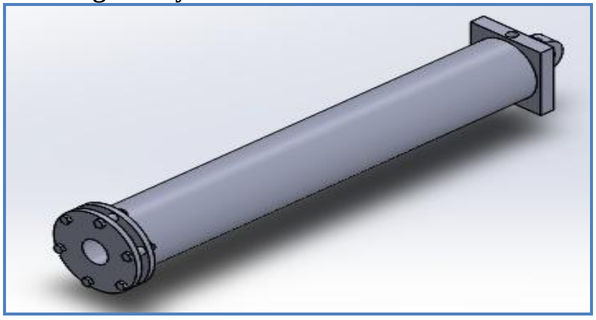

*Fig 3.6 Cylinder*

Considerations made during the design and fabrication of a single acting cylinder was as follows:
a. Functionality of the design
b. Manufacturability

The hydraulic cylinder was mounted in inclined position. The total load acting on the cylinder consists of:

- Mass to be put on lift= 2000 kg
  Taking FOS = 1.5 for mass in pallet
  2000 x 1.5 = 3000 kg
- Dead weight of lift =800kg

Total Mass= 3000+800= 3800kg
Total load = 3800 x 9.81 = 37278N≈ 37500N
This load was acting on two cylinders.

Now the maximum force will act on the cylinder, when the cylinder was in shut down position i.e. when the scissor links were closed. For calculations we will consider angle 10˚
Load acting on 1 cylinder (with considering dead weight and factor of safety).
37500/2=18750N
Actual load on 1 cylinder,
$18750\cos 10^0 = 18465N \approx 18500N$
For cylinder design we use pressure was 30 bar i.e. 3 $N/mm^2$

Therefore,

$$\frac{\pi}{4} D^2 = \frac{18500}{3}$$

Therefore,

$$D = \sqrt[2]{\frac{4 \times 18500}{3\pi}}$$

=88.7 ≈ 100 mm

Therefore we selected 100 mm diametric cylinder.

## IV. FINITE ELEMENT ANALYSIS OF MACHINE ON ANSYS

**4.1 Material Props & Assumption:**
Material: Mild steel

- Material Properties-
  i. Material Yield Strength = 250 MPa
  ii. Torsional Stiffness = 379125 Nmm/degree

 

- Assumptions:
  i. 2 ton load was uniformly distributed over scissor top.
  ii. Revolute joints were considered rigid to reduce computational time.

**4.2 FEA Mesh Model:**

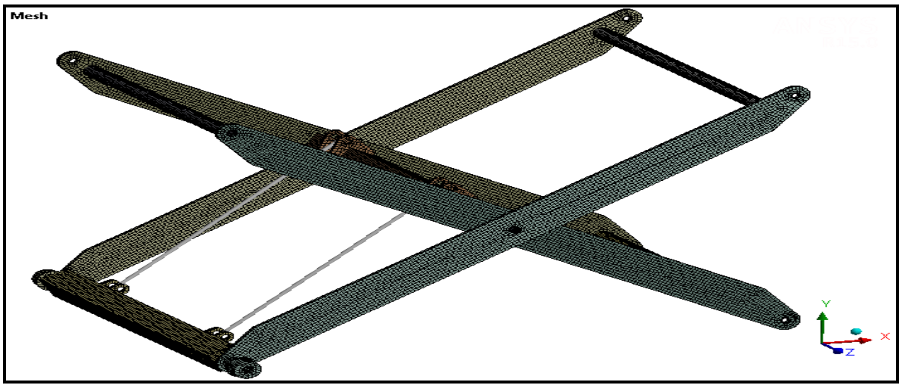


***Figure 4.1 FEA mesh model***

Meshing was a common term used for preprocessing phase of Finite Element Analysis (FEA). In meshing the minimum elements across the thickness are 5 to achieve desired accuracy or to get precise results.

**4.3 Mesh Metrics:**

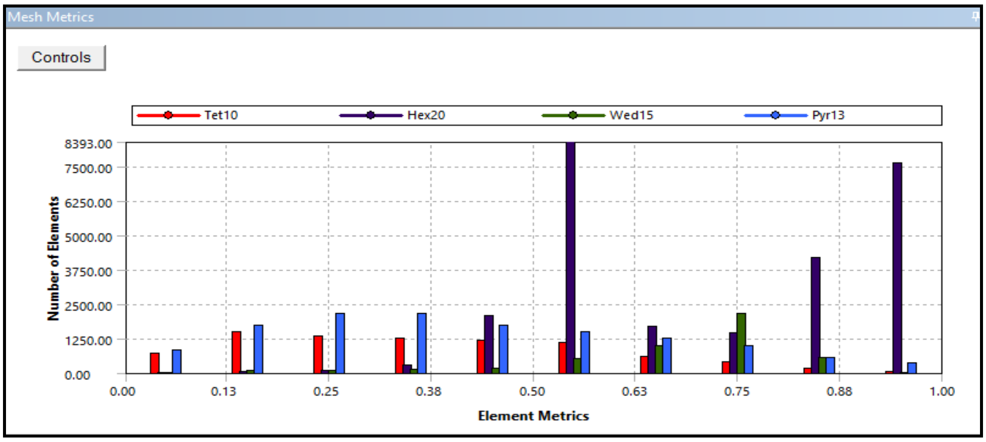


***Figure 4.3 Mesh metrics***

Three dimensional meshes created for finite element analysis (FEA) are needed to consist of tetrahedral, pyramids, prisms or hexahedra.

The Aspect ratio is defined as relationship between width and its height. For more accurate result and fine meshing aspect ratio is maintain below 5. The above plot shows number of elements present in the structure. From the above plot we selected hexahedral meshing which give precise results.

**4.4 Loading & Boundary Conditions:**

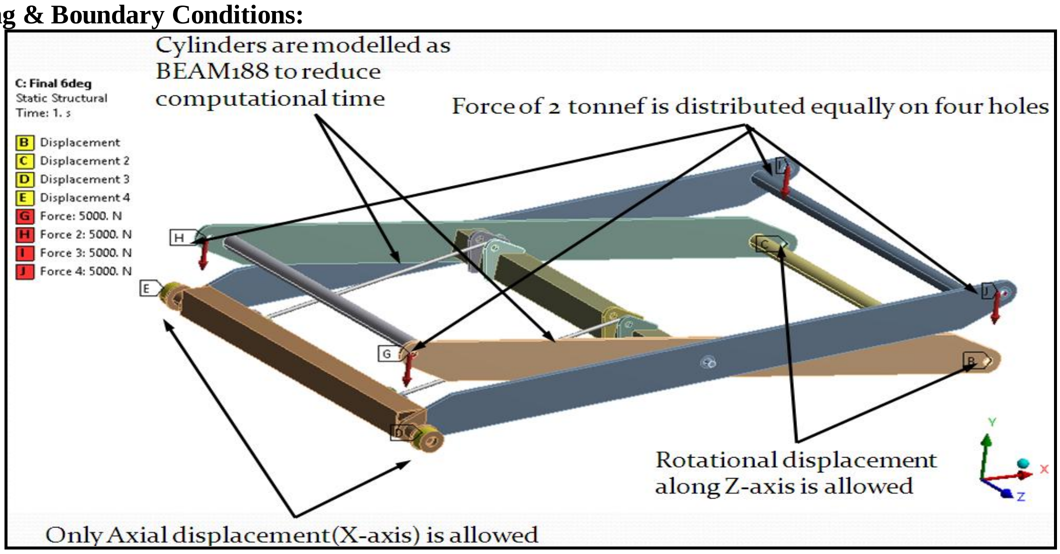


***Figure 4.3 Loading and boundary conditions***

To convert actual scenario into engineering prospect loading and boundary were defined as follows-

1. From the above plot ends C and D of the links we allowed rotational displacement along Z-axis.
2. At the ends E and D of links where roller are attached at the link we allowed only axial displacement along (X-axis).
3. We were distributed load equally on four links.

### 4.5 Total deformation:

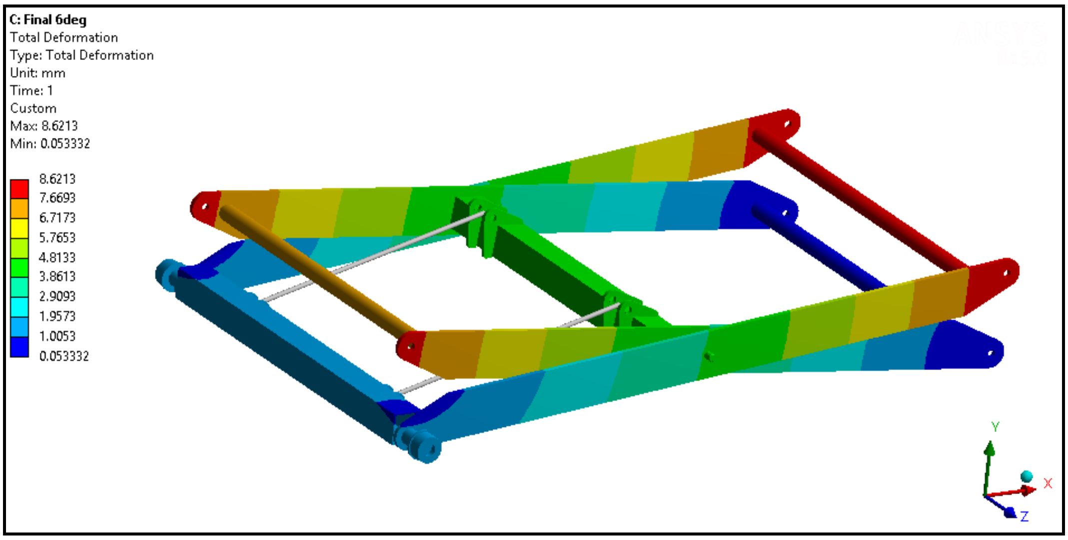


*Figure 4.4 Deformation of scissor lift*

The deformation analysis figure shows the deformation at the ends E, D, C, B of links was very small. The deformation at the ends G, H, I, J of links was approximate 9 mm and which was negligible so design was safe.

### 4.6 Beam188 Reaction Forces:

- Beam forces are compressive
- Beam Axial force = -8.036kN

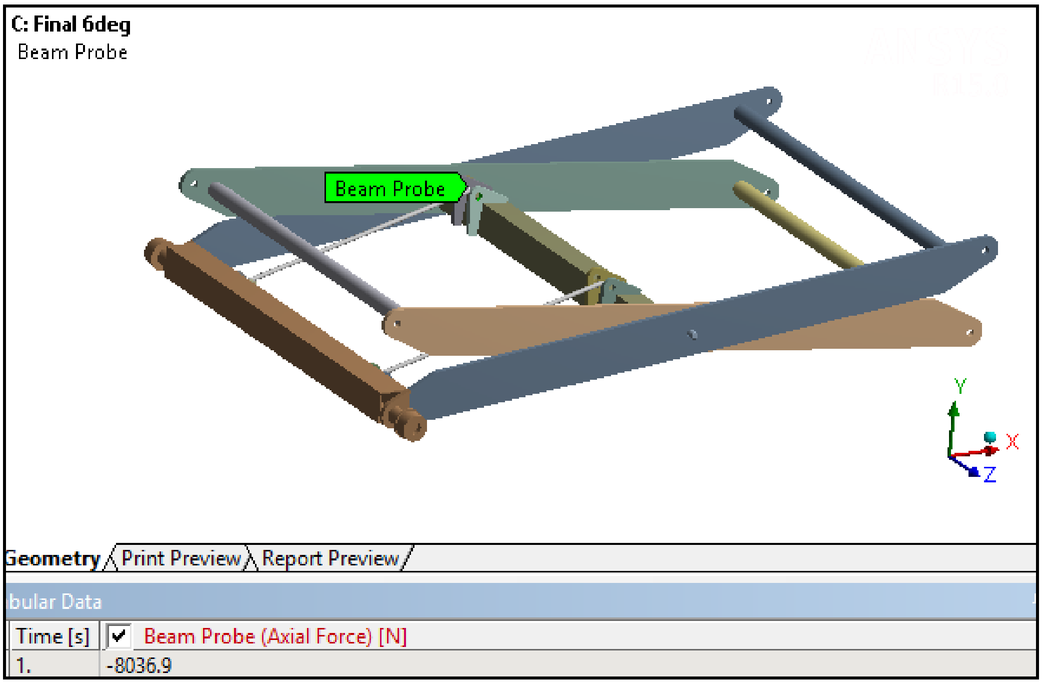


*Figure 4.5 Beam 188 reaction forces*

Beam elements are line elements used to create a one dimensional idealization of a three dimensional structure. They are computationally more efficient than solids and shell and are mostly used in several industries. ANSYS has many other beam elements, but BEAM188 is generally recommended because,

1. Applicable to most beam structures
2. Reduce computational time of ANSYS
3. Easy to use

 

4. Support linear as well as nonlinear analyses

### 4.7 Equivalent Stress:

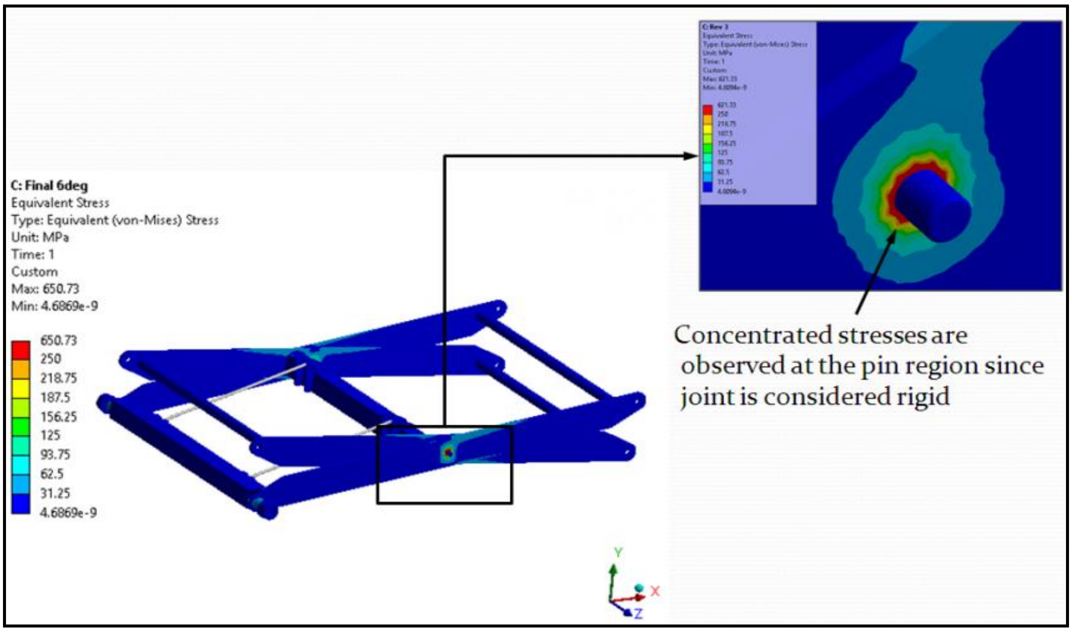


*Figure 4.6 Equivalent stresses on lift*

Equivalent stress i.e. Von mises stress gives average value of stresses. Von mises stress is widely used by designer to check whether their design will withstand a given load conditions.

Equivalent stress analysis shows stresses at the pin area. These stresses were not through thickness. The figure equivalent stress analysis shows there maximum stress values. For that we were doing a stress linearization to check whether our design was safe for this stresses or not.

### 4.8 Stress Linearization:

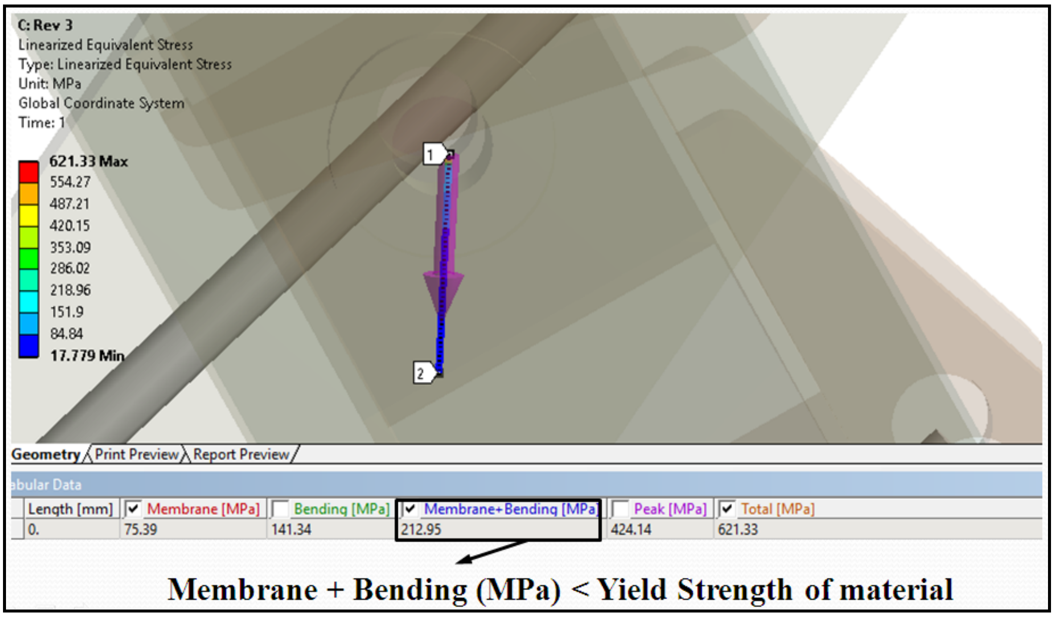


*Figure 4.7 Stress Linearization*

Stress linearization is always done in the direction of crack propagation. In this case we were not aware about crack propagation direction so number of linearized path we were considered and maximum out of these was reported in given figure.

The above fig shows the summation of membrane (axial) stress and bending stress and it is less than yield stress so our design was safe according to API 17L2.

**Remarks:**

- Axial force of around 8kN (without considering dead weight and factor of safety) was required at each cylinder to hold hydraulic scissor against 2 ton load.

 

- As shown in the last figure, stresses observed at the highlighted region were peak stresses. So as per API 17L2, design was safe for working.

## IV. CONCLUSION

The hydraulic scissor lift was simple in use. It can also lift heavier loads. Material handling and providing comfort to the operator was our main motivation behind the developing this lift. With such design of scissor lift, the complexities in a design and fabrication time was reduced. But the limitation of this lift is high initial cost. The analysis on ANSYS has also shown that the design was safe under certain accepted parameters. In this paper we carried out detailed analysis of scissor mechanism links against bending and buckling failure and also focused on various design aspects. In this, lift was only capable of lifting the weight up to 2000kg at elevation 2m with minimum effort.

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