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Analysis and Optimization of Hydraulic Scissor Lift

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Abstract : *Scissor Lifts are widely used for lifting significant load at required height safely and efficiently. The area of application includes vehicle loading, pallet handling, work positioning, etc. Scissor Lifts come in varied form which can be built to facilitate specialized industrial activities and tasks. They can be driven by hydraulic cylinder, pneumatic sources and also push chains or hydraulic foot pump in case of light load. This paper deals with analysis and optimization of hydraulic scissor lift. Catia is used for modelling purpose, MSC Apex for meshing and SimXpert for analysis work i.e. to check stress, strain, displacement and deformation induced in the system. The main aim is to reduce lift weight by modifying parameters like the cylinder position and replacing supporting link of cylinder ultimately reducing the cost.*
Keywords - *Cylinder, Hydraulic, Scissor lift, SimXpert , Stress.*

I. Introduction

Any machine part in order to move to desired location requires a component which should move in horizontal or vertical direction to place it at desired position at required height. Thus for loading and unloading purpose scissor lift is used which is portable machine that can be easily extended or compressed for transportation of the component to its expected position. Scissor lift is a machine that has vertical with criss-cross ‘X’ pattern scissor arms .Among its classified types are hydraulic, pneumatic and mechanical scissor lift. Hydraulic scissor lifts are used very popularly due to their ability to bear heavy load operations. The main components of scissor lift are bottom and top frame, scissor arm, link connector and cylinder.Hydraulic scissor lift is a vertical transportation cab which can be raised or lowered by using hydraulic actuator. The concept of hydraulic scissor lift comes from Pascal’s Law applied to the hydraulic ram which states that “The pressure exerted by incompressible fluid anywhere is transmitted equally in all directions throughout the fluid such that its pressure ratio remains the same”.

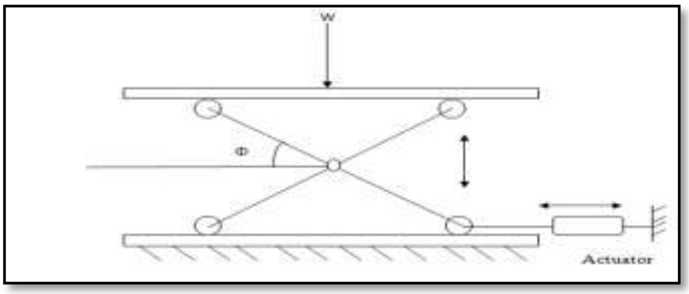

Fig 1.1: Principle of operation

The scissor lift consist of a special lifting platform is driven by the simple metallic structure having links which look like number of scissors connected with each other to form a long chain. This scissor like structure formed by the links is comprises of two well-known mechanisms which is four bar mechanism and slider crank mechanism.

II. Literature Review

GhangalePrashaletal., described the design and analysis of hydraulic scissor lift. Lift was needed to be designed portable and also work without consuming any electric power therefore cylinder was actuated by using hydraulic hand pump. Also such design can make much suitable for medium scale work[3].SabdeAbhijitManoharraoetal., investigated the problem at DS Engineers regarding hydraulic scissor lift. It was found that job to be lifted is heavier which causes more deformations in hydraulic lift frame hence, checking deformations &stress induced in it was the major objective of this project. Also weight of the lift was high so weight optimization was prime objective of this project. As loading & unloading is repeated there were chances of fatigue failure so life of lift was checked. Thus Design& Analysis of the Hydraulic lift that should with stand maximum load without failure in working conditions and checking vibration of hydraulic lift during working time by modal analysis was carried out[4].Gaffar G. Mominetal., in the paper" Design manufacturing and analysis of hydraulic scissor lift" Has described the design and analysis of hydraulic scissor lift. In this paper they have provided the brief description of different parts of hydraulic scissor lift and the material used for that part as per the mechanical properties of that material like ductility, strength, toughness, hardness etc. Also they have discussed all the design concepts for the different parts of the lift. Then the analysis were carried out by using Ansys software in which parameters like Deformation , Von misses stress , Shear stress were analysed. Thus they have done the design and fabrication of hydraulic scissor lift including Ergonomics, Material handling as well as comfort [8]. P S K Narasimha Murthy etal., has done modelling and analysis (Linear Static) of a scissor lift which is carried out using Solid Works. Whenever a load is applied on the top of the platform, every post leg of the lift is subjected to displacement, stress, and strain. In this project result of the displacement, stress and strain values, and their behaviour are tabulated [9].

Problem Statement

The existing lift has lifting capacity of 1 ton up to height of 4.85m. The weight of lift is 851 kg which is high so weight optimization is the prime objective. Also loading and unloading may not be uniformly distributed so lift is to be analyzed for Moment Loading. Link connector, one of the components of scissor lift constitutes large weight of total lift weight. They serve the purpose of supporting cylinders. Thus we have to find an alternative for link connector which has less weight or modify cylinder position such that the link connectors are replaced.

III. Methodology

4.1Material of the Lift

The materials used for different components of the scissor lift are as follows:

1.Scissor Arm: They are subjected to buckling and bending load which cause breaking of lift. The desired material properties are strength, stiffness, plasticity and hardness and thus Mild Steel is used.

2.Top Platform: It is subjected to weight of workman and equipment so it should possess strength. Thus Mild Steel is used.

3.Base Platform: It is subjected to weight of Top platform along with the weight of scissor arm. It is responsible for overall stability of the system. It should have great strength and stiffness. Thus Mild Steel is used.

4.Hydraulic Cylinder: It is considered as strut with both ends pinned. The compressive stress acting on it imposes bending stress which causes buckling. Also it is subjected to compressive pressure which exerts stress around wall. Mild Steel is used as required material properties are ductility, toughness and hardness[3].

4.2Design calculations

I = Moment of inertia, kg-mm^2 σ = Allowable bending stress, MP
W = Force acting on the link, Nθ = Angle made by link with horizontal, degrees
E = Modulus of elasticity, N/mm^2 L_e = Effective Length, mm
FOS = Factor of safety P = Total force applied on pin, N
l = Length of link, m P_{cr} = Critical load, N
d= diameter of pin,mmτ_{all} = Allowable shear stress, N/mm^2
σ_e = Critical stress, N/mm^2

4.2.1 Design of Base Frame

It only provides proper balance to the structure. In this part not much stresses are developed.
The dimensions considered are 1700x1500 mm

4.2.2 Design of Link

It connects upper frame to bottom structure and is subjected to buckling load and bending load.

$$\sigma_{all} = \frac{Syt}{FOS} = \frac{250}{1.5}$$

$$= 166.67\ MPa$$

On the basis of platform size, the link dimensions is: 20 x 40 x 1570

For buckling,By Euler's Formula

$$P_{cr} = \frac{\pi^2 EI}{L_e^2}$$

I= Moment of Inertia
E = Modulus of elasticity

For both ends hinged

L_e= L

$$P_{cr} = \frac{\pi^2 \times 210 \times 10^3 \times 106666.66}{1570^2}$$

$$\sigma_{cr} = \frac{P_{cr}}{A} = 112.113 Mpa$$

4.2.3 Design of Pin

Pins are used for joining links with top and bottom frame. They undergo shear stress.

$$\tau_{all} = \frac{0.5 Syt}{FOS} = \frac{0.5 \times 250}{2} = 62.5 Mpa$$

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

$$62.5 = \frac{4 \times 4905}{2 \times \pi \times d^2}$$

$$\therefore d = 10 mm$$

4.2.4 Design of cylinder

As the pay load is given as,

W = 1 ton

FOS = 1.5

Total load on lift = 1 x 1.5

Considering FOS the total load is,

$$W_{fs} = 1.5 ton$$

$$\text{Sin}\,\theta = \frac{W_{fs}}{R}$$

$$\therefore R = \frac{W_{fs}}{\text{Sin}\,\theta} = \frac{1.5}{\text{Sin}\,10} = 8.638 ton$$

At closed condition ɵ = 10˚, the reaction force is,

R/cylinder = R/4 = 2.1595 ton

= 21185.076N

The maximum pressure is consider as 80 bar,

8 x Area = 21185.076

Area = 2648.1345mm^2

$$\sigma_p = 250 \times FOS = 250 \times 1.5 = 375$$

For rod: $375 = \frac{\pi}{4} d^2$

$$d = 21.85 mm$$

For cylinder :

$$2648.4315 = \frac{\pi}{4}(D^2 - d^2)$$

D= 62.04 mm [1]

4.3 Analysis of Existing Lift

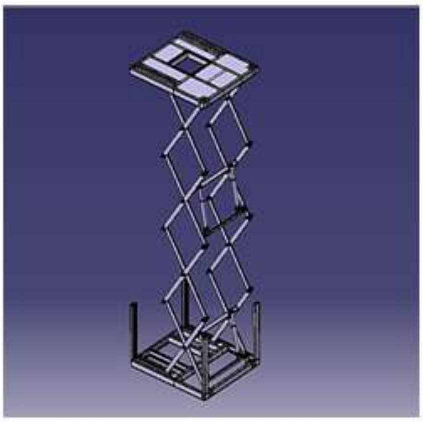

Fig.4.3.1.CAD model of Existing Lift

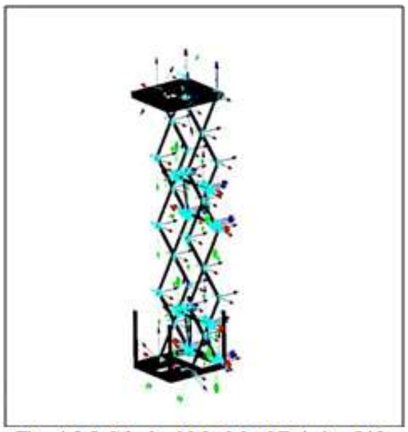

Fig. 4.3.2. Meshed Model of Existing Lift

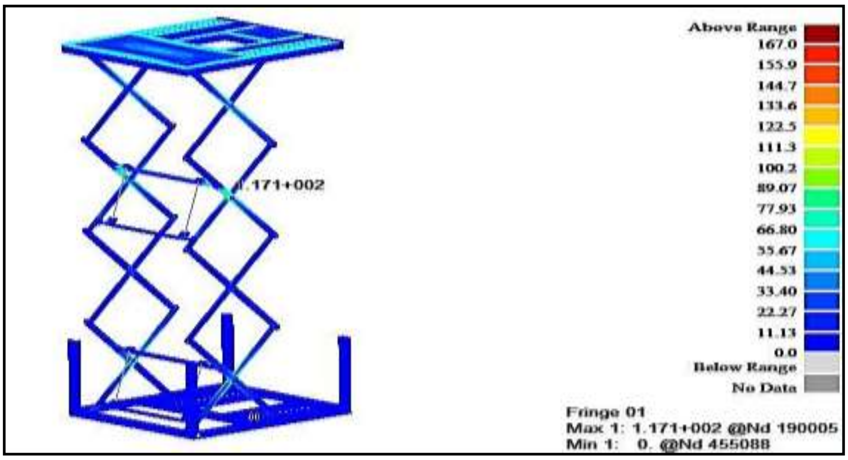

Fig.4.3.3. Stress Analysisof Existing Lift

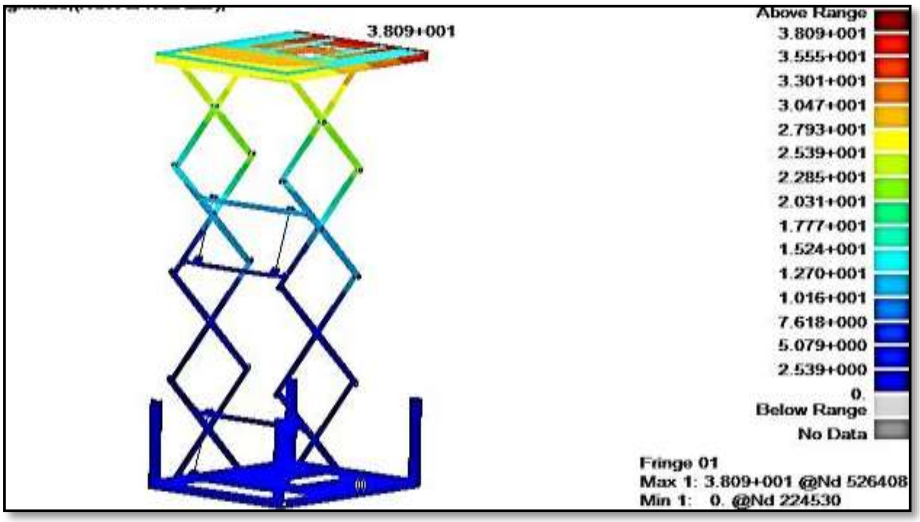

Fig.4.3.4. Displacement Analysis of Existing Lift

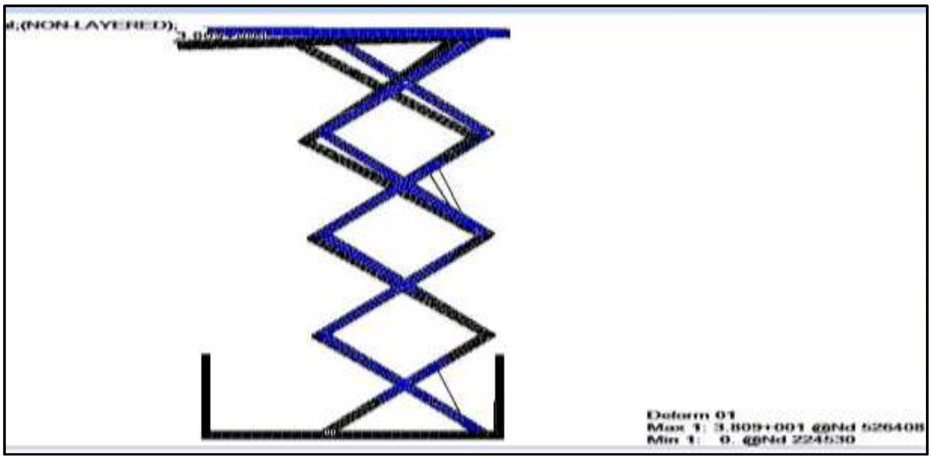

Fig.4.3.5. Deformation Analysis of Existing Lift

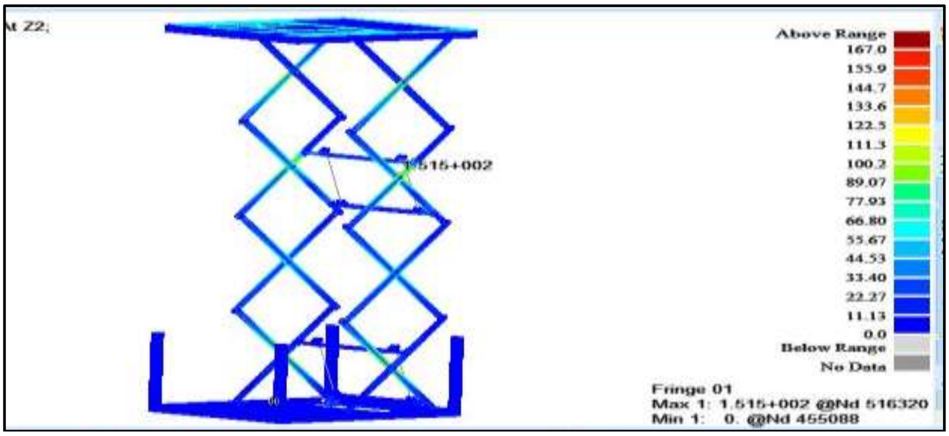

Fig.4.3.6. . Stress Analysis of Existing Lift for moment loading

It has been found that link connectors individually constitute large weight of total lift weight. Hence change in cylinder position has been suggested. The cylinders are connected on the link itself with the help of pin arrangement by removing link connectors. As the connectors are being removed, links may not be stable. For the stability of the lift rod has been connected on the links supporting cylinder.

4.4 Analysis of Optimized Lift

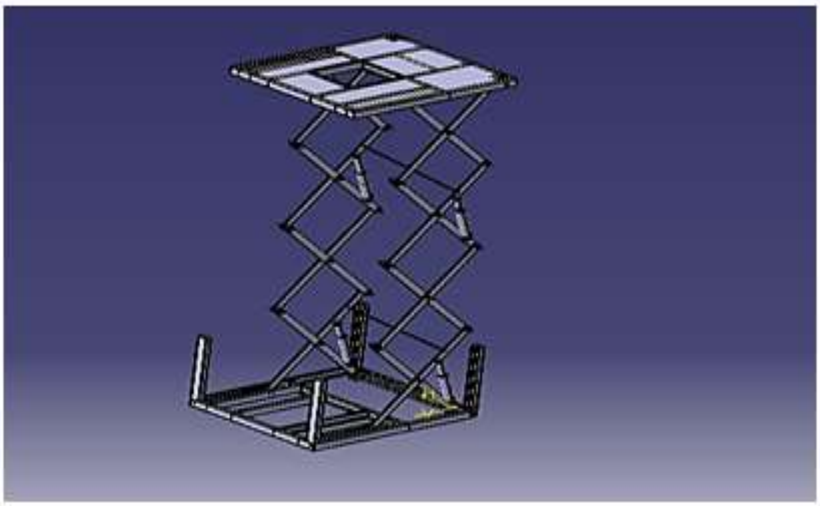

Fig. 4.4.1 CAD Model of Optimized Lift

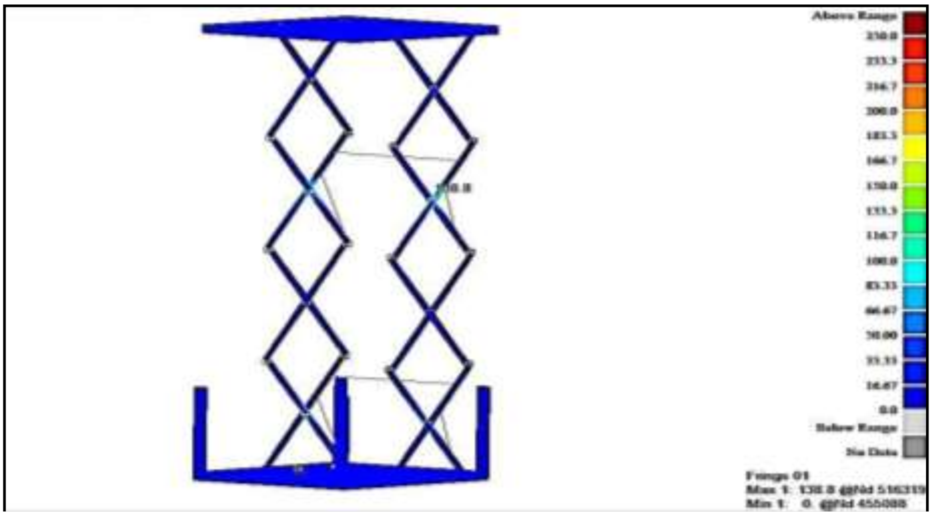

Fig.4.4.2. Stress Analysis of Optimized Lift

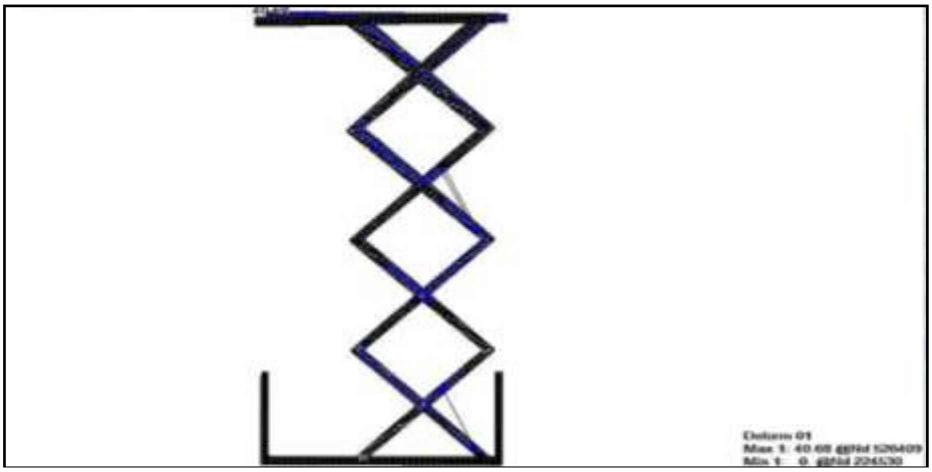

Fig.4.4.3. .Deformation Analysis of OptimizedLift

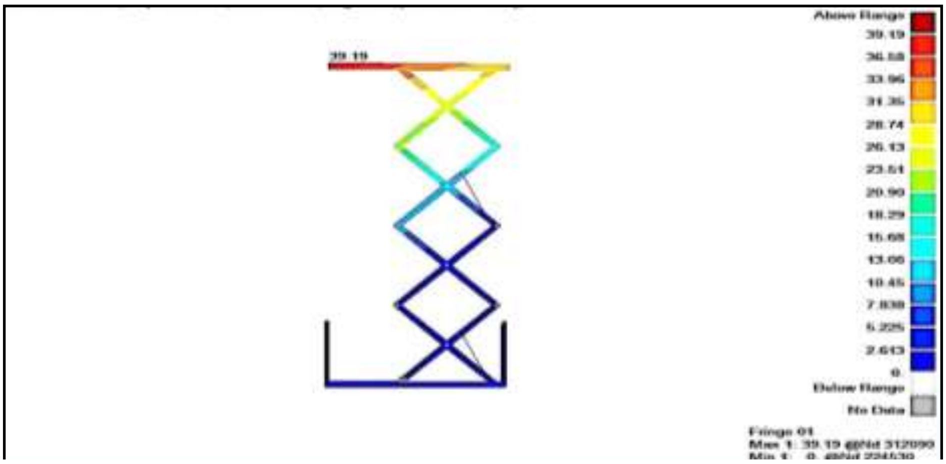

Fig.4.4.4. .Displacement Analysis of Optimized Lift

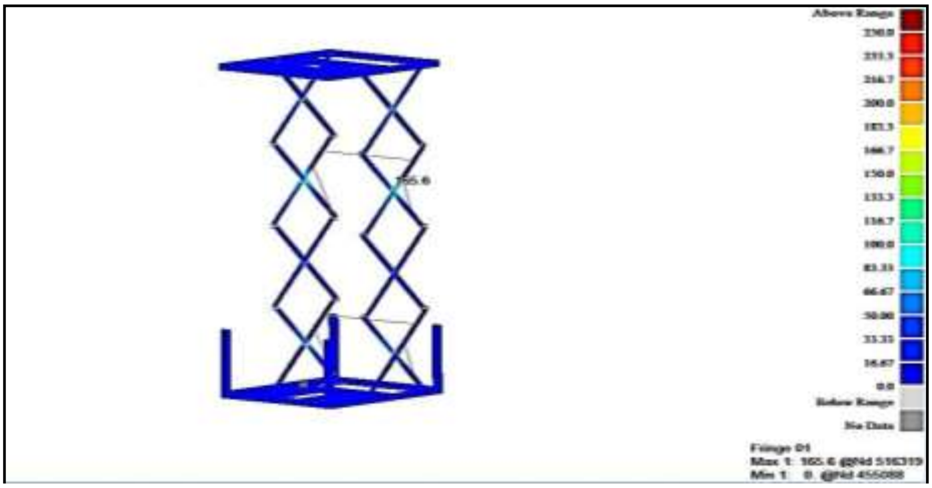

Fig.4.4.5. Stress Analysis for Moment Loading of Optimized Lift

IV. Result and Discussion

Table no 1: Uniformly Distributed load

	STRESS (Mpa)	**DISPLACEMENT**(mm)	**DEFORMATION**(mm)	**WEIGHT**(Kg)
EXISTING LIFT	**117**	**38.09**	**38.09**	**851**
OPTIMIZED LIFT	**138.8**	**39.19**	**40.69**	**749**

Table no 2: Eccentric load

	STRESS (Mpa)
EXISTING LIFT	**151.5**
OPTIMIZED LIFT	**165.6**

The equivalent stress induced in existing lift is 117 Mpa and that for optimized lift is 138.8 Mpa which is less than allowable stress 167 Mpa, hence the design is safe based on strength. Weights of existing and modified lift are as shown in table 1.
Weight of existing lift = 851 kg
Weight of Optimized lift = 749 kg
Percentage Reduction of weight = 11.9 %
By modifying design, weight of existing lift has been reduced.
There may be possibility that load may not be uniformly placed so analysis for eccentric loading (moment loading) has been carried out. The stress values obtained are within allowable range as shown in table 2. Thus, the design is safe in case of eccentric loading also.The displacement for existing and optimized is almost comparable. Hence the change in cylinder position in the existing lift is suggested to the said industry for weight reduction purpose.

V. Conclusion

The weight of the Scissor Lift has been reduced from 851 kg to 749 kg which resulted in 11.9% weight reduction.The stability of lift is not affected even though link connectors were removed as rods were introduced as support between two links and the displacement values obtained for both the lifts are same.The moment loading check has been done for Existing as well as Optimized Lift and we can infer that the stress values are within allowable limit. So we can say that the lift is safe in case of eccentric loading.

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