OPTIMIZED DESIGN OF ELECTRICALLY OPERATED SCISSOR LIFT

A PROJECT REPORT

Submitted by

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SREEMAN VENKATACHALAM. G	**1010104046**

In partial fulfillment for the award of the degree of

BACHELOR OF ENGINEERING

IN

MECHATRONICS ENGINEERING

KUMARAGURU COLLEGE OF TECHNOLOGY,

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BONAFIDE CERTIFICATE

Certified that this project report on **OPTIMIZED DESIGN OF ELECTRICALLY OPERATED SCISSOR LIFT** is the bonafide work of **KARTHI. M, SAKTHI MANOKAR. D** and **SREEMAN VENKATACHALAM. G** who carried out the project work under my supervision.

Dr. S. A. PASUPATHY, PhD
Project Supervisor and HoD
The Department of **Mechatronics Engineering**
Kumaraguru College of Technology
Coimbatore

INTERNAL EXAMINER   **EXTERNAL EXAMINER**

ACKNOWLEDGEMENT

ABSTRACT

This project aims to develop a weight optimized mobile scissor lift for agricultural applications. The weight optimized model was numerically analyzed for stress distribution and buckling of links. The problems faced in the existing scissor lift system are heavy in weight and they are unstable when it is expanded to its maximum height. The main objective of this project is to reduce the weight and to increase the stability so as to provide maximum occupational safety. Since the weight is the major factor affecting the stability, two materials are compared (Aluminium alloy and Stainless Steel). For both of the materials, stress analysis, displacement, and impact/transient analysis and buckling analysis were done to predict the stress distribution. It was found that for SS is 59% heavier than the aluminium and the maximum stress in the aluminum is 54% higher than the steel. The design and analysis were done through Solid works, Ansys and the motion of the model was tested by using Altair Hyperworks Motion solver. A scaled down model with pneumatic power was built to verify the results obtained in motion solve. The circuit of power source was designed through Automation studio. The set up was having a free motion as in motion solve simulation.

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LIST OF ABBREVIATIONS:

2D	-	Two Dimension
3D	-	Three Dimension
TETRA	-	Tetrahedral
Quad	-	Quadrilateral
AC	-	Alternating Current
DC	-	Direct Current
N	-	Newton
GPa	-	Giga Pascal
gm	-	gram
Kg	-	Kilogram
lbs	-	Pounds
Ft	-	Feet
mm	-	Millimeter
N/m^2	-	Newton per meter square

CHAPTER 1

INTRODUCTION

The field of agriculture is being automated in every possible area where humans are exposed to risk of injury or death. The plucking of coconut from trees has always been a risky job where a person needs to climb trees of height ranging from 30 to 40 feet. Our project aim is to develop an **Optimized Design of Electrically Operated Scissor Lift** used for lifting a person to pluck the coconut and increase the productivity. The CAD model of scissor lift was designed using Solidworks software. The dimensions were formulated from the literatures studied. The designed CAD model was analyzed using Solidworks Simulation software and ANSYS software for stress distribution, strain developed in the system and the deformation occurred during load applied condition. Then the circuit for pneumatic system was designed and tested using Automation studio software. The scaled down model could not be fabricated using hydraulic system and hence we have used pneumatic system to operate the setup. The pneumatic system was designed and tested using Automation studio software. The dimensions of scaled down model was calculated based on MEMS scaling law. The scaled down model was fabricated using mild steel material and the pneumatic system were setup for the operation. The working of the scaled down model was tested several times in our Hydraulics and Pneumatics laboratory.

1.1 OBJECTIVE

This project aims to develop a weight optimized mobile scissor lift for agricultural applications. The weight optimization was carried out by changing the material and studying their mechanical properties. The scissor lift motion was solved numerically and it was verified with a scaled down pneumatic powered model.

CHAPTER 2

LITERATURE REVIEW

2.1 SCISSOR LIFT MECHANISM

In the year 1963, December 26th, patent number 333,454 filed on "Scissor-Lift Mechanism" by Charles L.Larson, Grants Pass, Oreg., assignor to Jeddeloh Bros. Sweed Mills Inc, Good Hill, Greg, a corporation of Oregon[1], states that the scissor lifts used in the automotive service lifts are mounted to the floor to lift the scissor ladder. Scissor lifts that are mounted on the floor has a greater possibility to collapse. Such ladders, when fully collapsed have a height of at least six inches above the floor. When the scissor lifts embodying is in the lower position it can be easily installed in a garage. They provide hydraulic support to the following components: Base, Platform with the hydraulic support for vertical movement with the base and First legs, second legs. The scissor lift mechanism is similar to the extensible lift mechanism for elevating high loads. It consists of a pair of scissor arms pivotally connected together. They are used in Material handling application. In most of the material handling processes, there are many instances where load must be shifted to different positions and a scissor lift provides a convenient method for performing this operation. Usually in a scissor lift, the scissor arms interconnect a base frame and the platform and they define a path of movement for the platform. This mechanism provides an improved scissor lift mechanism, by using ram in the mechanism,

whereby a relatively large amount of upward extension is possible with a relatively short ram.

2.2 HIGH LIFT TRAILER

Later on 1964 April 2nd, patent no. 356,878 filed on "High Lift Trailer" filed by Victor H. Carder, Pacific Grove, Calif., assignor to Cochran Equipment Company, Salinas, California, a corporation of California[2], the extension and retraction of the scissor lift is provided by twisting a torsion member and interconnecting the inner arms of the two scissors, at a point adjacent where these arms are pivoted. In extensible scissor lift mechanism which is extensible from a lower to a higher position, which includes a base frame and elevating work-supporting over frame. Base frame and supporting frame comprising of a relatively movable crossed scissor arms and pivot means interconnecting the ends of scissor arms for relative movement about the pivot axis.

2.3 DESIGN AND SIMULATION BASED ON PRO/E FOR A HYDRAULIC LIFT PLATFORM IN SCISSORS TYPE

Then in the year 2011, at International Workshop on Automobile, Power and Energy Engineering, a paper was published on, "Design and Simulation Based on Pro/E for a Hydraulic Lift Platform in Scissors Type" by Tian Hongyu, Zhang Ziyi[3], the paper explains the design of scissor lift platform to a height if 8m with platform dimension of 1800 mm x 900 mm using 3D software Pro/E. The three method of movement of bottom links are dragging, automatic running and force aiding. Each scissor mechanism has four

link pairs to meet the height requirement. The main parameters they have considered are: the carrying capacity was 500 kg, Maximum height extends upto 8m, Platform area was 1800 mm x 900 mm, Upward expansion velocity was 6 ~ 9 m/min and Downward retraction velocity of 6 m/min.

The design has two plans: two hydraulic cylinder driving type and one hydraulic cylinder driving type. The cylinders are put vertically in two hydraulic cylinder driving type, which can save labours, give the scissors equality force. The advantage of the one hydraulic cylinder driving type is when the platform is folded more space is saving.

2.4 AN INVESTIGATION ON THE DYNAMIC STABILITY OF SCISSOR LIFT

In the year 2012, in Open Journal of Safety Science and Technology, a paper was published on "An Investigation on the Dynamic Stability of Scissor Lift" by Ren G. Dong, Christopher S. Pan, Jared J. Hartsell, Daniel E. Welcome, Tim Lutz, Anne Brumfield, James R. Harris, John Z. Wu, Bryan Wimer, Victor Mucino, Kenneth Means[4] discuss about the stability of scissor lift and the major factors affecting the stability. A scissor lift model was analyzed in the paper for possibility of tip-over when the system is fully elevated. The unloaded weight of the lift is 1170 kg and can carry a load of 250 kg. The platform is equipped with a deck extension. Its maximum elevated height is 19 ft (measured from the ground to the floor of the platform). Two experiments are carried out on the fully elevated system. Curb impact and pothole depression are applied on the system and resulting frequency of bounce, pitch and rolling were found. Then another

experiment was performed to measure the center of gravity of scissor lift was found using a tilt table method. Then the tip-over threshold during curb impact is calculated. The impact speed determines the kinetic energy of the scissor lift. The kinetic energy is partially consumed due to the system damping and partially transferred into potential energy. In the standardized analysis, only the gravitational potential energy is considered in the calculation of the tip-over speed threshold.

RESULT FROM PREVIOUS PHASE OF THE PROJECT:

Table 1: Comparison of two materials used in scissor lift

CHARACTERISTICS		Aluminium Alloy (6061)	Stainless Steel
Mesh Dimension		3D	3D
Mesh Type		Mixed	Mixed
Element size		20	10
Element Type		RBE3	Rigids
No. of elements created		79,62,234	1,51,27,666
No. of nodes created		52,82,424	57,62,632
Weight of the System		620 Kg	1050 Kg
RADIOSS ANALYSIS	Displacement Analysis	Max = 2.808×10^{-1} mm Min = 0	Max = 7.67×10^{-2} mm Min = 6.72×10^{-2} mm
	Stress Analysis	Max = 5.184×10^{2} MPa Min = 6.305×10^{-2} MPa	Max = 2.81×10^{2} MPa Min = 1.01×10^{-2} MPa
OPTISTRUCT ANALYSIS	Buckling Analysis	12 iterations	20 iterations

RADIOSS analysis and buckling analysis are carried out using Hyperworks software to find the stress distribution and buckling for the scissor lift. The thickness was assumed as 25mm with minimum force of 2313 N applied on the base and maximum force of 6075 N is applied on the base of scissor lift. Stress analysis for two materials Aluminium alloy 6061 and stainless steel is carried out separately. From the result of impact load analysis by using Aluminium alloy, the max stress value was found to be 5.184 x 10^2 MPa and the bucking occurs after 12 iterations. From the result of impact load analysis by using stainless steel, the max stress value was found to be 2.81 x 10^2 MPa. The comparison is done based on the stability, and as a result the use of steel is recommended. To reduce the weight of steel topology optimization will be carried out in future and the stability of scissor lift will be increased in order to ensure the safety. The drawback of this system has been to found to be that when the platform is lifted to its maximum height, the scissor link supports only at one end of the platform making the platform to shake when the person on platform makes movement. This can be overcome by increasing the length of the link and also by increasing the number of the links in the system.

RADIOSS analysis is defined as the option in Altair Hyperworks software used to find stress distribution and displacement.

CHAPTER 3

METHODOLOGY OF PROJECT

Literature review

CAD model design using Solidworks

Analysis using Solidworks Simulation, ANSYS and Altair Hypermesh

Circuit Design using Automation Studio

Fabrication of Prototype
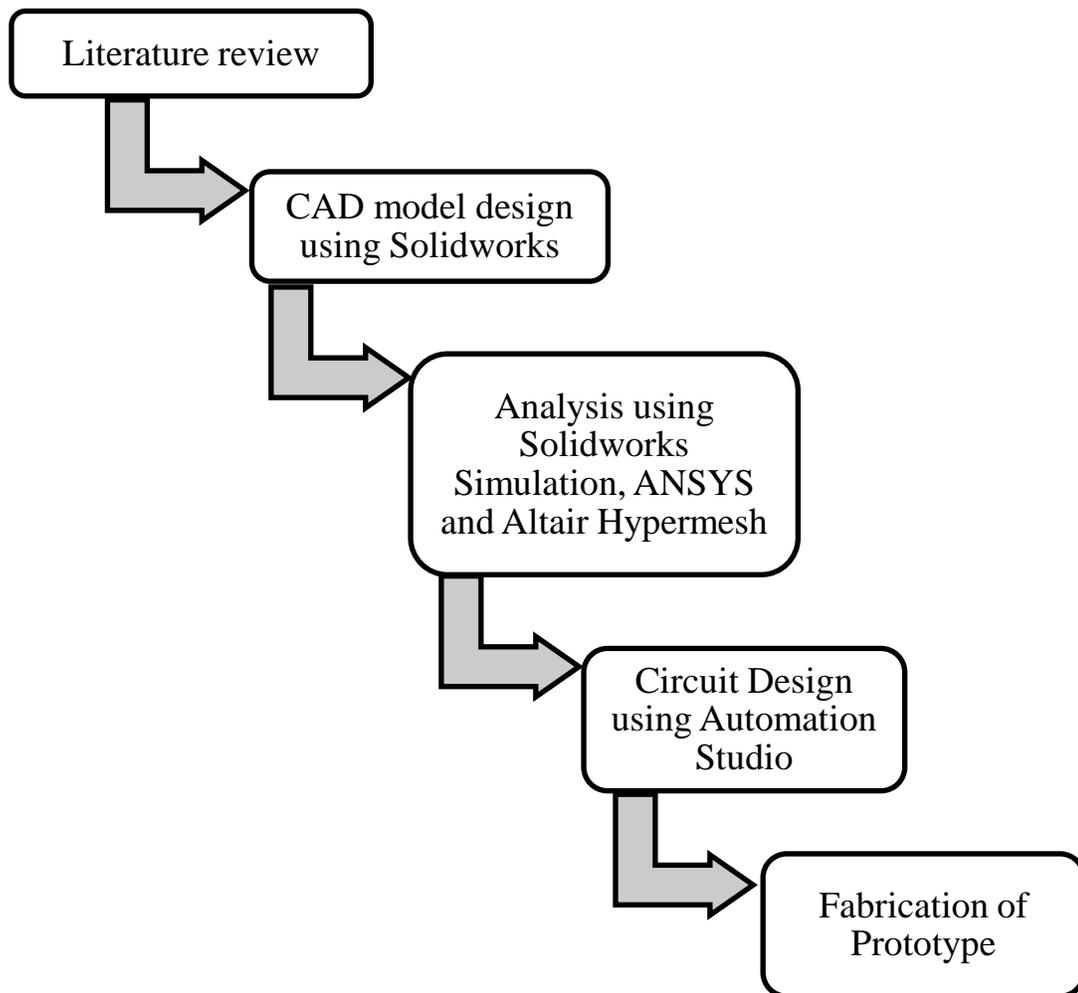
The methodology of our project starts with the literature review of journals and based on the journals studied, CAD model of scissor lift was designed in the Solidworks software. The designed model was first analyzed for stress, strain and displacement using Solidworks Simulation. Then the model was imported to ANSYS software to analyse the stress, strain and deformation of the system. The CAD model was solved for its motion. The pneumatic circuit for providing power was designed and simulated using Automation Studio software. The motion solved was validated with an in house developed scaled down model.

3.1 PROBLEMS IDENTIFIED:

The drawbacks and problems identified from the literatures are:

- The worker on the lift should avoid continuous movement when lift will be fully elevated, as it may tip-over the system.

- The total weight of the scissor lift system for 33 feet extension is 4500 Kg.

- The solid links have possibility of bending due to overweight.

- The cost of 33 feet mechanically operated scissor lift costs Rs 9.5 Lakhs.

- Motion of the links connected with roller should not move more than three-fourth of the distance between two ends of scissor lift.

CHAPTER 4

DESIGN OF SCISSOR LIFT

Based on the study of existing scissor ladders and scissor lift from literature, we have proposed a design as follows. The components of our scissor lift are:

- Base

- Platform

- Link

- Roller Wheel

- Shaft

- Rivet Joints

- Hydraulic Cylinder

The design of parts was done using SolidWorks software. The design of each part has been described in the upcoming chapter with dimensions.

4.1 DESIGN OF BASE

The base of the scissor lift was made with Cast Alloy Steel. The total weight of the base is 695 Kg. The dimension on the base is 2360mm x 1200mm with a thickness of 30mm.
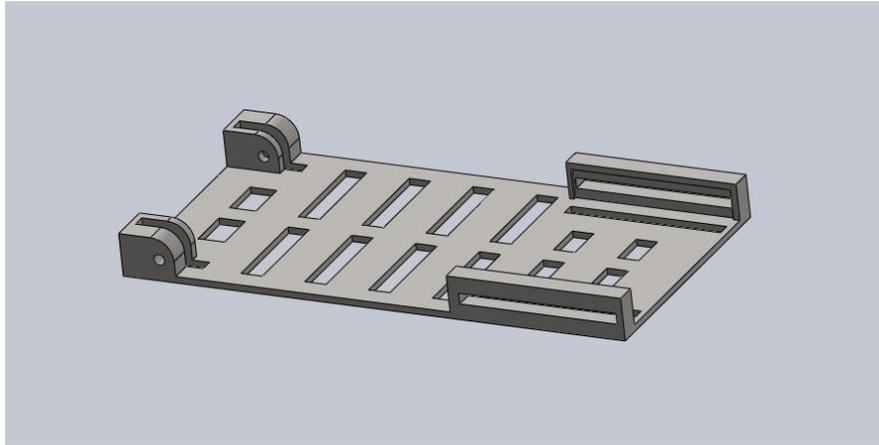
Figure 1: Isometric view of Base

4.2 DESIGN OF LINK

The links were made up of Cast Alloy Steel. Each Link weighs 26 Kg. Totally 24 links are used in the scissor lift for a lift of 30 feet. The dimension of the link is 2200mm x 120mm. The links are hollow in shape with a wall thickness of 5mm. The width of the link is 60mm.
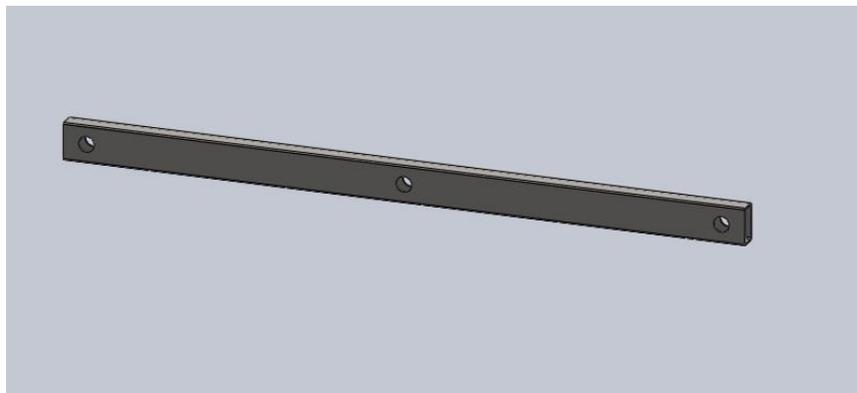
Figure 2: Isometric view of Link

4.3 DESIGN OF PLATFORM

The platform was made up of Aluminium alloy of 6061. The dimensions of the platform are 2360mm x 1200mm and thickness of 20mm. The weight of platform is 224 Kg.
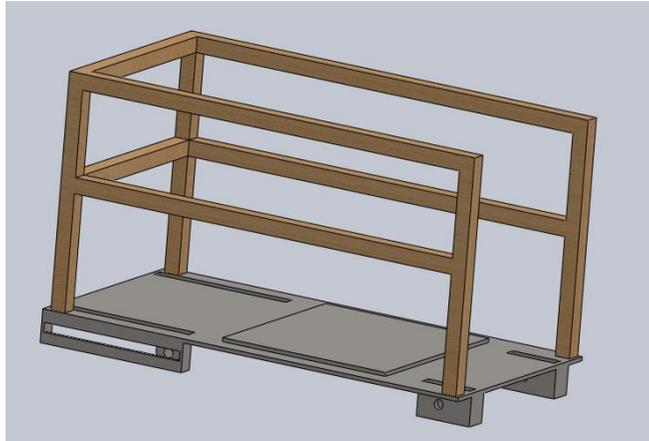
Figure 3: Isometric view of Platform

4.4 DESIGN OF ROLLER WHEEL

The roller wheel has been used for free movement of the link on one side of the base and platform. The material of wheel is Steel. Totally 4 wheels are used. Each wheel weighs 2 Kg and the total weight of wheels used in system is 8 Kg. The diameter of the wheel is 140mm and thickness is 80mm.
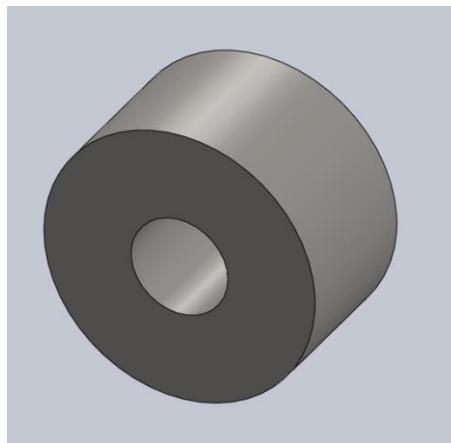
Figure 4: Isometric view of roller wheel

4.5 DESIGN OF SHAFT

Shafts are used to connect the pair of links on opposite sides at the base and platform. Totally four shafts are used in the scissor lift. They are made up of Steel weighing 18 Kg. The radius of shaft is 25mm and the length is 1240mm.
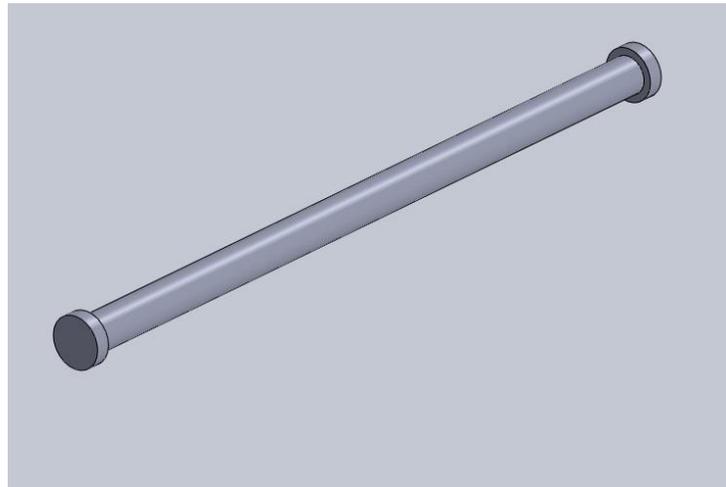
Figure 5: Isometric view of shaft

4.6 DESIGN OF RIVET JOINTS

The rivet joints are used to connect two links together in the scissor lift setup for free movement. The rivet joints are of diameter 50mm and length 150mm.
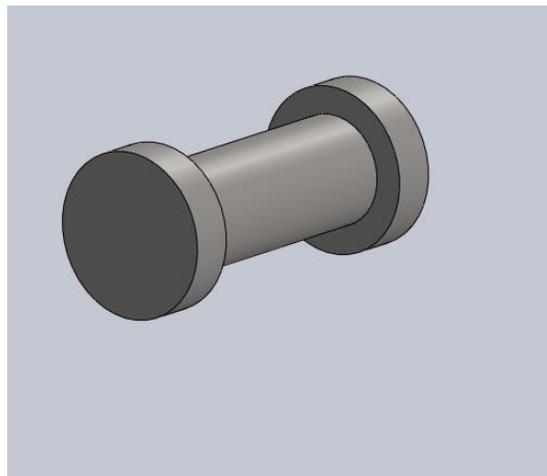
Figure 6: Isometric view of rivet joint

4.7 ASSEMBLY OF SCISSOR LIFT

The assembly of scissor lift was done using SolidWorks Assembly by selecting the option File >> New >> Assembly. The base has been first imported into assembly and the links are imported followed by it. Totally 24 links are imported, pair of 6 links on opposite sides for the lift of 30 feet. Then rivet joints are imported for locking the links in pair. Then the shafts are imported for fixing one side of link to base and platform. The other side is fixed with roller for free movement across the surface of base and platform. The complete weight of the system is measured 1020 Kg. The height of scissor lift when fully compressed is 1362.03mm (4.6 feet) and when fully raised is 9297.21mm (30 feet).
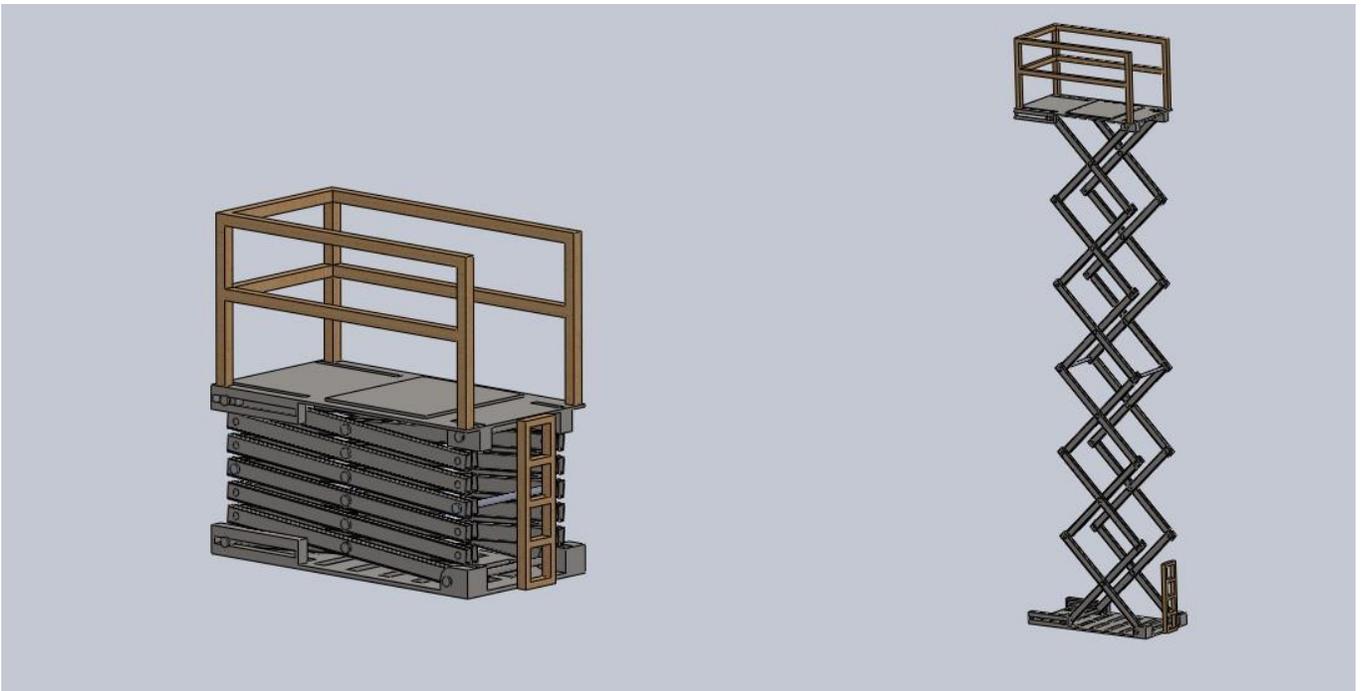
Figure 7: Scissor lift at lowered state   **Figure 8: Scissor lift at fully raised state**

CHAPTER 5

ANALYSIS OF SCISSOR LIFT

5.1 ANALYSIS USING HYPERWORKS:

5.1.1 PROBLEM DEFINITIONS AND INPUT

- Material Assumption

- Material Properties

- Meshing Process:

  - Geometry Clean up
  - 2D Meshing
  - 3D Meshing
  - Thickness assignment
  - Quality Checks
  - Motionview:
    - Joints
    - Motion

5.1.2 MESHING USING HYPERWORKS

- The designed model was imported to Hyperworks and visualisation option was clicked to view the free edges.

- Geometry clean-up is done using "Edit Element → Quick Edit"
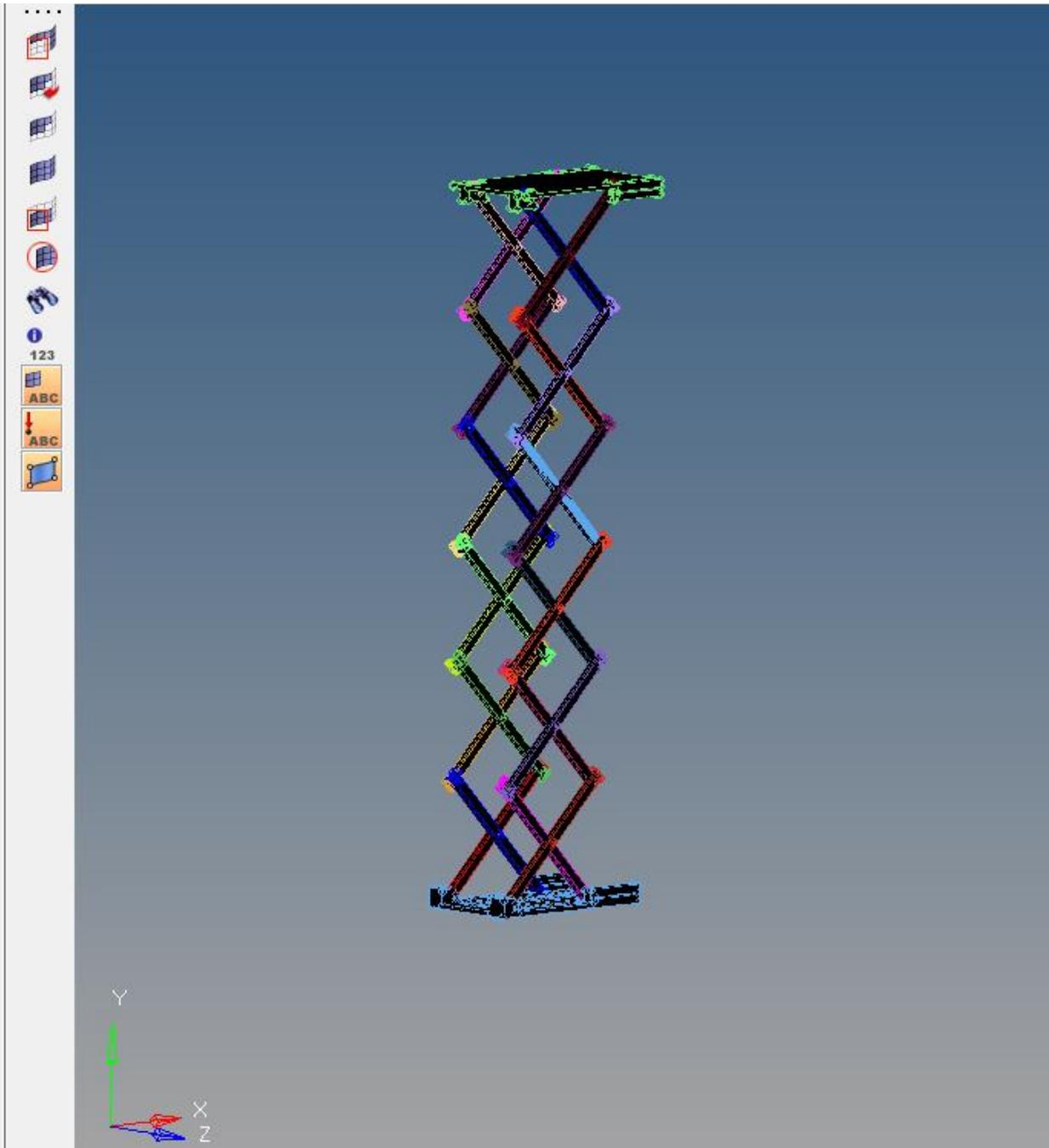
Figure 9: Scissor Lift after Geometry cleanup

5.1.3 MATERIAL ASSUMPTION
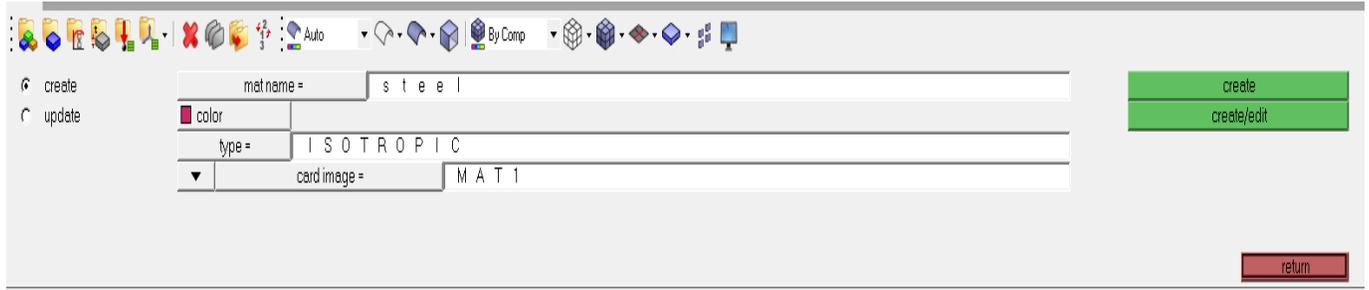
Figure 10: Material Assumption

5.1.4 MATERIAL PROPERTIES
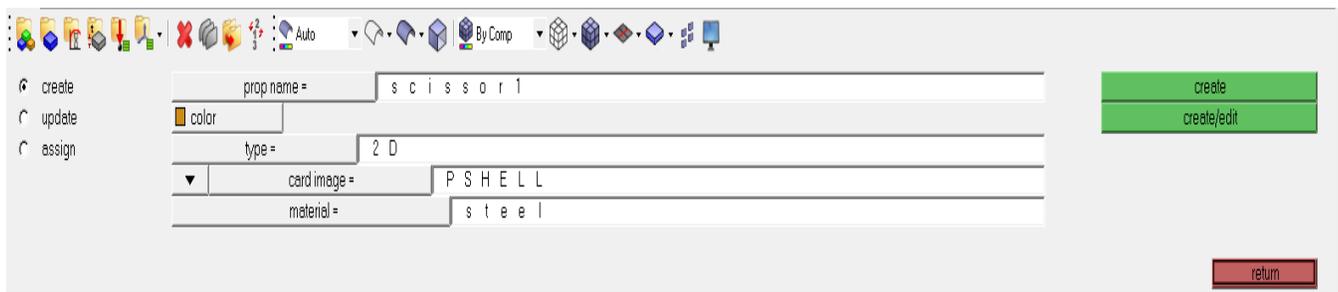
Figure 11: Properties of links in 2D
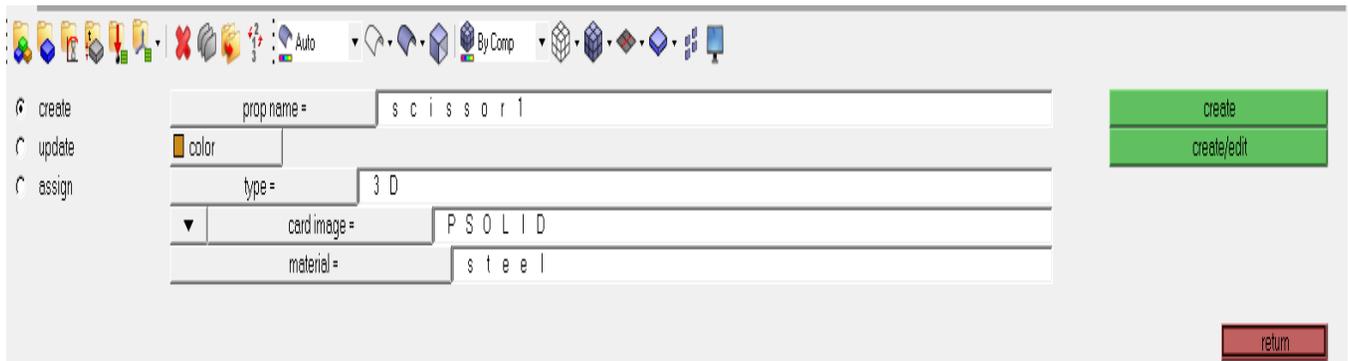
Figure 12: Properties of Platform and Base

5.1.5 MIDSURFACE

The Midsurface has been created for the model and geometry clean-up has been carried out to remove all the free edges in the model.

5.1.6 2D MESHING FOR LINKS

- The links property was updated with the properties of steel and separate 2D mesh has been carried out.

- Mesh Type: Quad

- Mesh Density: 20

- Total number of elements created:596635

5.1.7 3D MESHING FOR PLATFORM AND BASE

- The link and base property has been updated with the properties of aluminium and separate 3D mesh has been carried out.

- Mesh Type: Tetrahedral

- Type : Tris

- Mesh Density: 20

5.1.8 3D MESHING

- Mesh Type: Tetrahedral

- Type : Mixed

- Density: 20
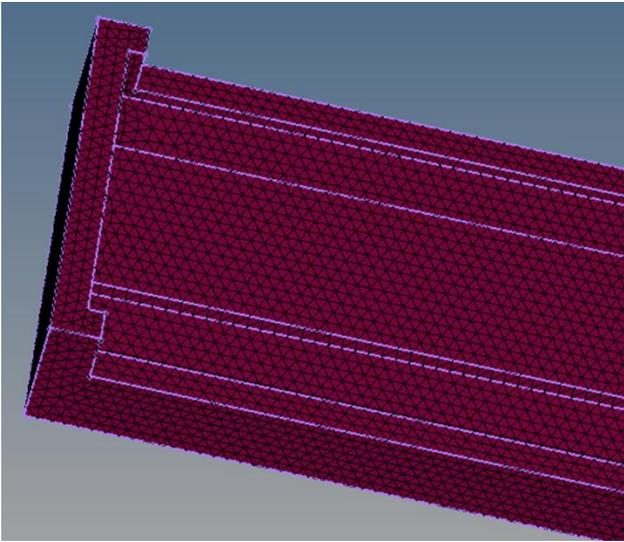
Figure 13: 3D Meshing of Base

5.1.9 QUALITY CHECKS

Warpage

This is the amount by which an element (or in the case of solid elements, an element face) deviates from being planar. Since three points define a plane, this check only applies to quads. The quad is divided into two tria's along its diagonal, and the angle between the tria's normal is measured. Warpage of up to five degrees is generally acceptable.

Ideal Value = 0 (Acceptable < 10)

Aspect Ratio

This is the ratio of the longest edge of an element to either its shortest edge or the shortest distance from a corner node to the opposing edge. For 3-D elements, each face of the element is treated as a 2-D element and its aspect ratio determined. The largest aspect ratio among these faces is returned as the 3-D element's aspect ratio. Aspect ratios should rarely exceed 5:1.

Ideal Value = 1 (Acceptable < 5)

Skew

Skew of triangular elements is calculated by finding the minimum angle between the vector from each node to the opposing mid-side, and the vector between the two adjacent mid-sides at each node of the element. The minimum angle found is subtracted from ninety degrees and reported as the element's skew.

Ideal value = 0 (Acceptable < 45 degree)

Length (min.)

Minimum element lengths are calculated using one of two methods. This method is used for non-tetrahedral 3-D elements. The shortest distance from a corner node to its opposing edge (or face, in the case of tetra elements); referred to as "minimal normalized height".

Jacobian

This measures the deviation of an element from its ideal or "perfect" shape, such as a triangle's deviation from equilateral. The Jacobian value ranges from 0.0 to 1.0, where 1.0 represents a perfectly shaped element. The determinant of the Jacobian relates the local stretching of the parametric space which is required to fit it onto the global coordinate space. HyperMesh evaluates the determinant of the Jacobian matrix at each of the element's integration points (also called Gauss points) or at the element's corner nodes, and reports the ratio between the smallest and the largest. In the case of Jacobian evaluation at the Gauss points, values of 0.7 and above are generally acceptable.

Trias: min angle

The minimum allowable interior angle for a tria element. Any element for which any interior angle falls below the specified value is highlighted and remains highlighted until you exit the Check Elems panel or you select another check

Trias: max angle

The maximum allowable interior angle for a tria element. Any element for which any interior angle is greater than the specified value is highlighted and remains highlighted until you exit the Check Elems panel or you select another check

Tria: Ideal Value = 600 (Acceptable = 200 < θ < 1200)

Quality check is done in order to increase the accuracy of mesh.

Table 2: Quality check

○ 1-d							tria faces:	
○ 2-d	warpage >	5.000	length <	7.500			min angle <	20.000
⦿ 3-d	aspect >	5.000	length >	20.000			max angle >	120.000
○ time	skew >	60.000	jacobian <	0.700			quad faces:	
○ user	tet collapse <	0.500	equia skew >	0.600			min angle <	45.000
○ group	cell squish >	0.500	vol skew >	0.600			max angle >	135.000
			vol AR >	5.000				

5.1.10 MOTION ANALYSIS USING MOTIONVIEW:

Motionview is an option used in Hyperworks to check for proper motion of the multibody components. It imports the graphic files of the design and deals only with the 3D graphics.

Joints option used in Motionview:

Links are connected using revolute joints.
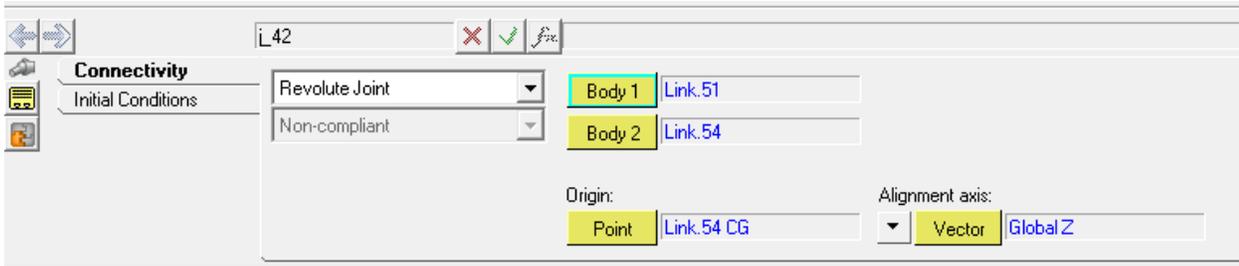
Figure 14: Connectivity option in Revolute joint
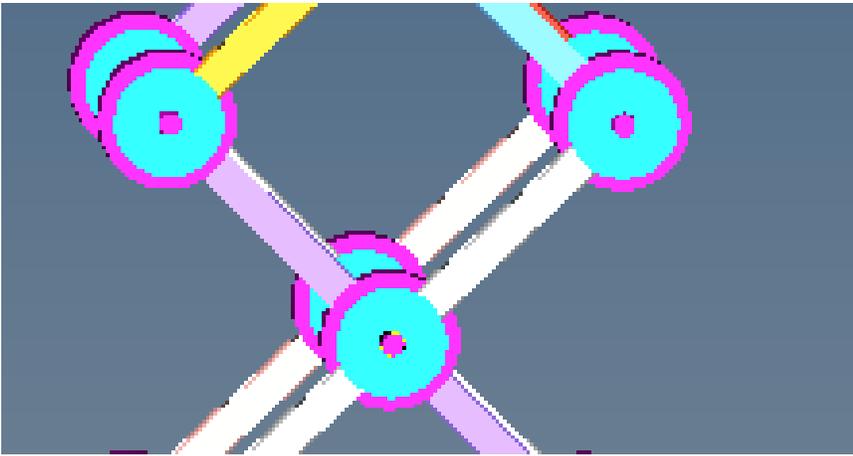
Figure 15: Links connected using revolute joints

The rollers in the link and the base are connected using translational joints.
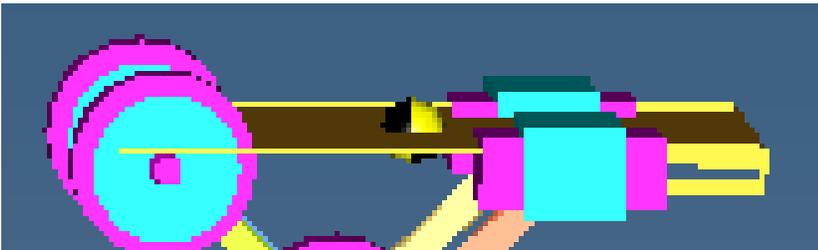
Figure 16: Translational joint given between link and platform

Totally 38 revolute joints and 2 translational joints are created.
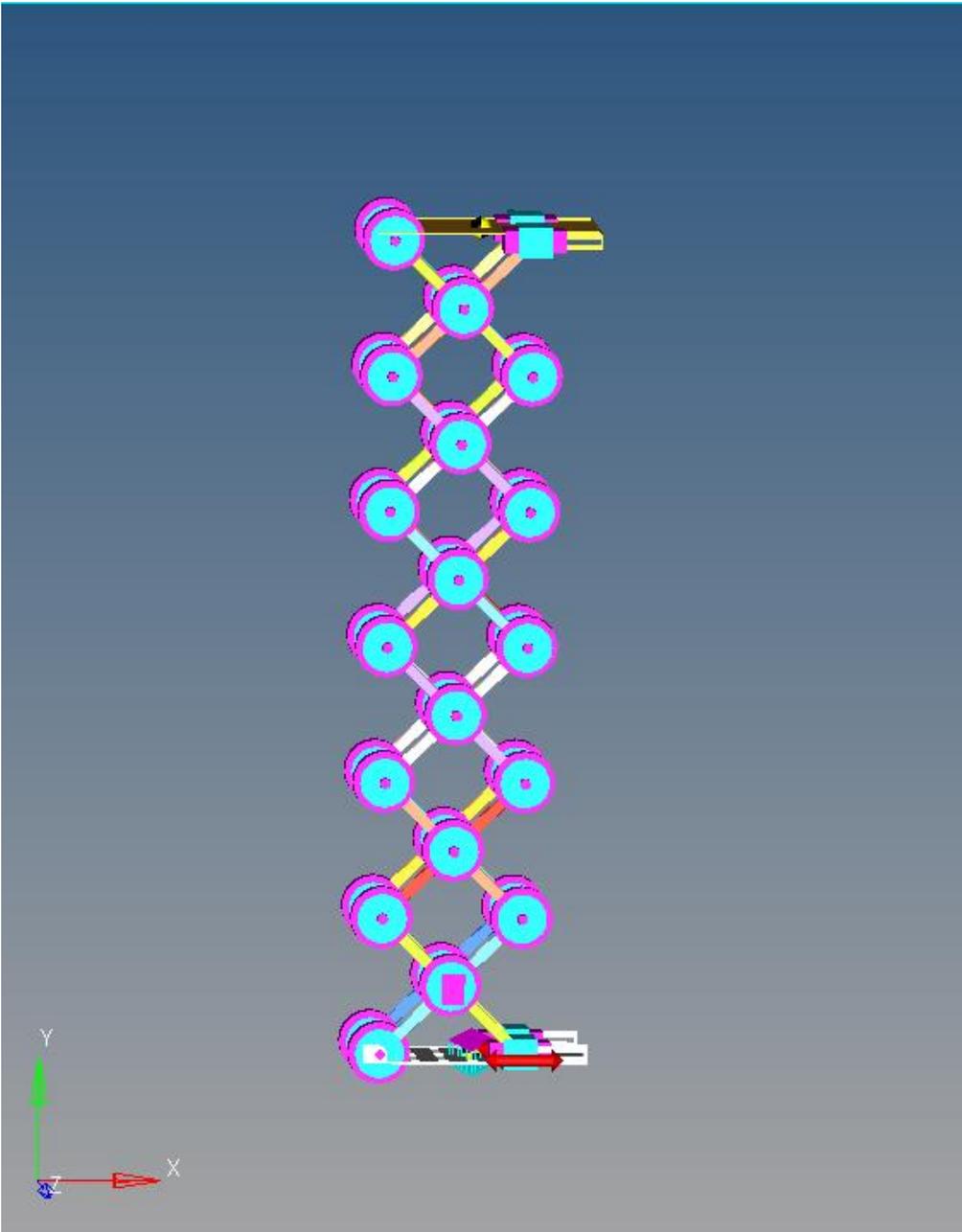
Figure 17: Final image after giving joints.

Creating Transational Motion:

Translational motion is an option used to give motion to the joints. In this model, motion is given to 38th and 39th translational joints which allow translational motion of the links.
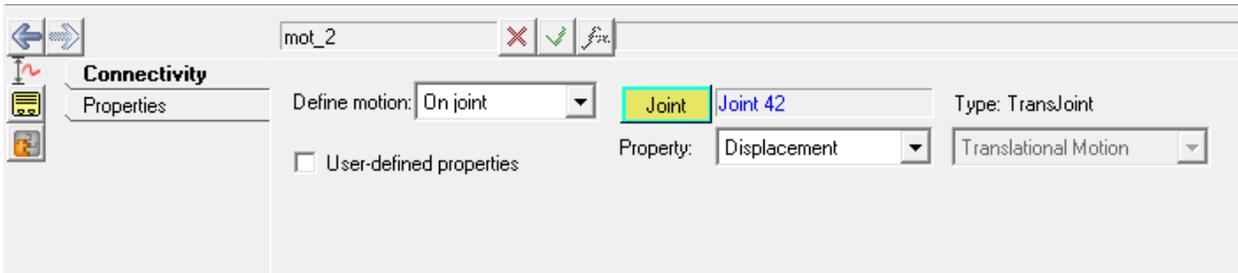
Figure 18: Connectivity option for translational motion

In properties option, expression is given STEP(time,0,0,5,-10000d)

Figure 19: Property assigned for giving translational motion
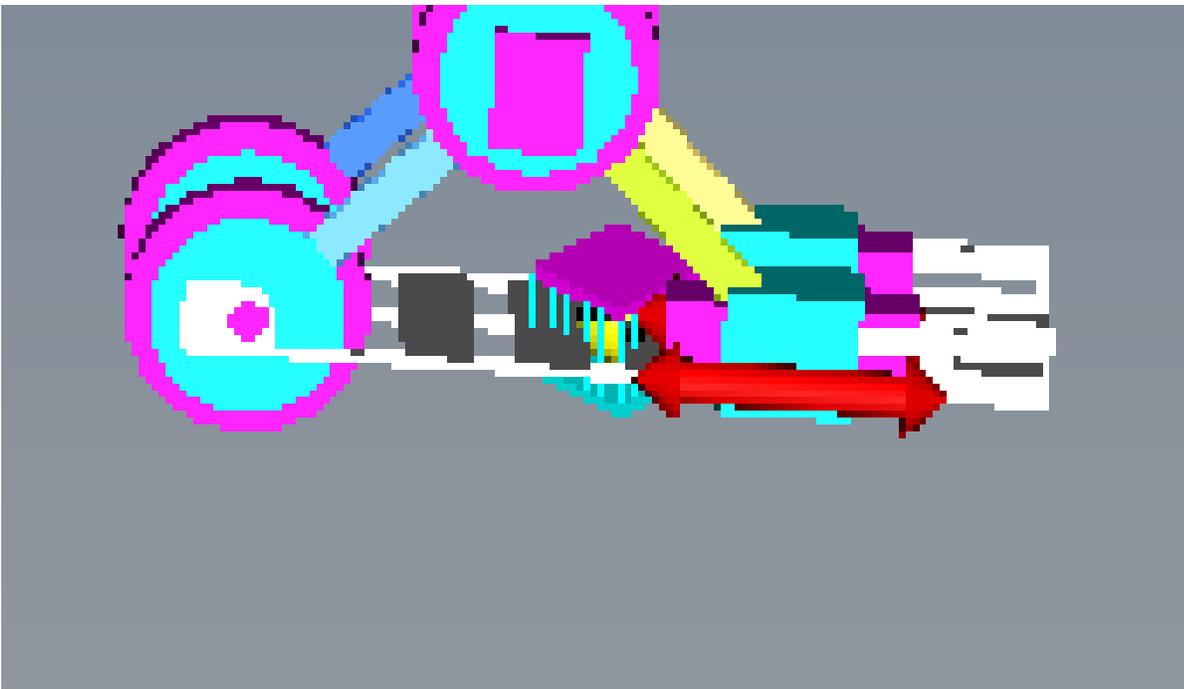
Figure 20: Translational motion given to the joint in between link and base

5.1.11 MOTION ANALYSIS:

Run option is selected to check for errors and the result is viewed in hyperview panel.
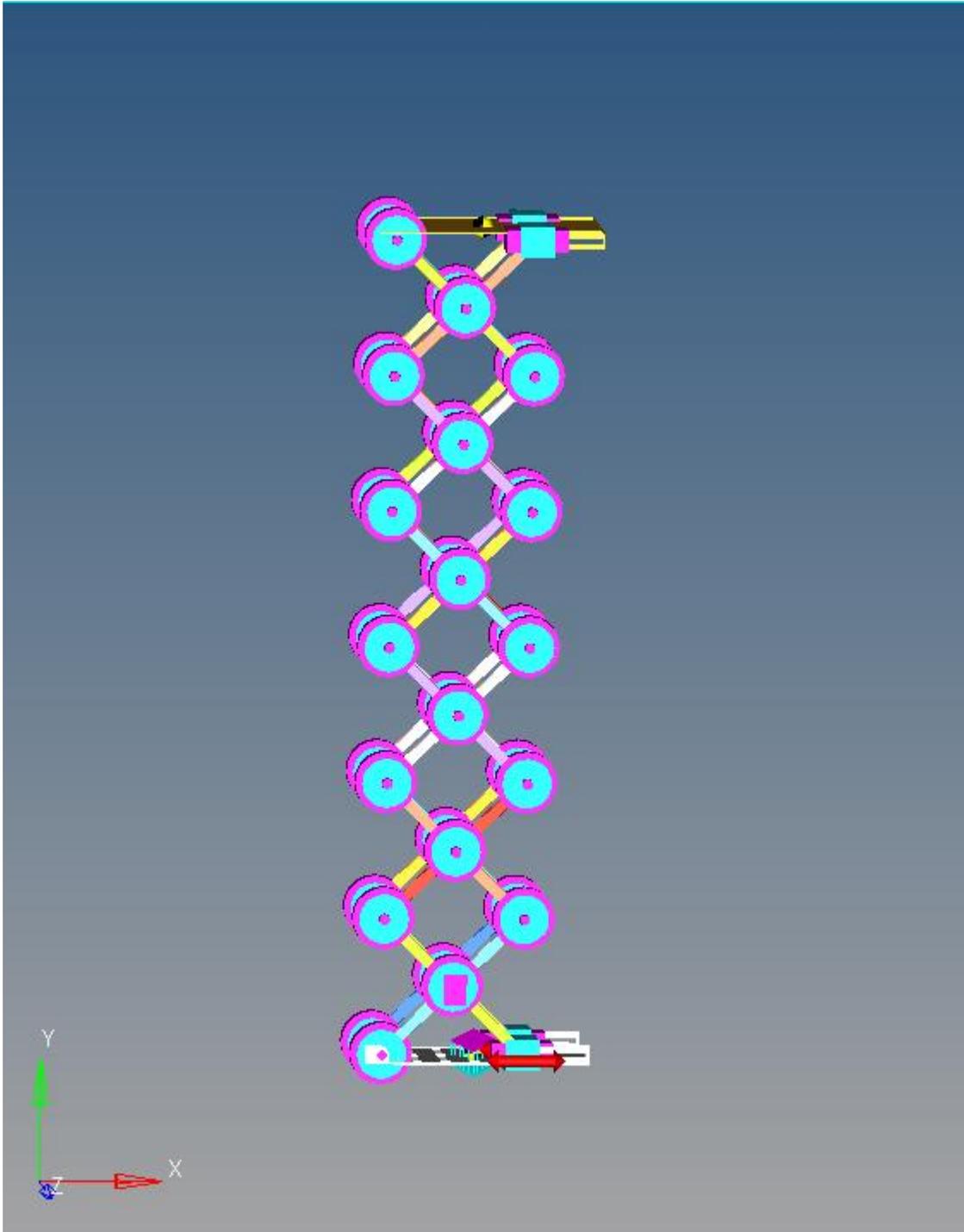
Figure 21: Final image after giving joints and motions

5.2 ANALYSIS USING SOLIDWORKS SIMULATION:

- The analysis was carried of using Solidworks Simulation 2012 software.

- The base of the model was given FIXED constrain and load was applied on the platform.

Table 3: Analysis information

Analysis type	Static
Mesh type	Solid Mesh
Compute Free body forces	On
Friction	Off
Unit system	SI (MKS)
Length	mm
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

5.2.1 MATERIAL PROPERTIES:

- Model type: Linear Elastic Isotropic
- Material used: Cast Alloy Steel
- Yield Strength: $2.41 \times 10^8 \, \text{N/m}^2$
- Tensile Strength: $4.48 \times 10^8 \, \text{N/m}^2$
- Elastic modulus: $1.90 \times 10^{11} \, \text{N/m}^2$
- Poisson's ratio: 0.26
- Mass Density: $7300 \, \text{kg/m}^3$
- Shear Modulus: $7.80 \times 10^{10} \, \text{N/m}^2$

5.2.2 MESH INFORMATION
Table 4: Mesh Information

Mesh type	Solid Mesh
Mesh Used	Curvature based mesh
Jacobian points	4 Points
Maximum element size	567.75 mm
Minimum element size	113.55 mm
Mesh Quality	High
Total Nodes	108146
Total Elements	59241
Maximum Aspect Ratio	306.62
% of distorted elements (Jacobian)	0

5.2.3 RESULTANT FORCES:

Reaction Forces:

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	4.83675	244.433	0.00270804	244.481

Reaction Moments:

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N-m	0	0	0	0

5.2.4 STRESS ANALYSIS RESULT:

Name	Type	Min	Max
Stress1	VON: von Mises Stress	41.6545 N/m^2 Node: 1847	533477 N/m^2 Node: 22190

Model name: SL
Study name: Static Test
Plot type: Static nodal stress Stress1

von Mises (N/m^2)

533,477.1

489,024.2

444,571.2

400,118.3

355,665.3

311,212.3

266,759.4

222,306.4

177,853.5

133,400.5

88,947.6

44,494.6

41.7

→ Yield strength: 241,275
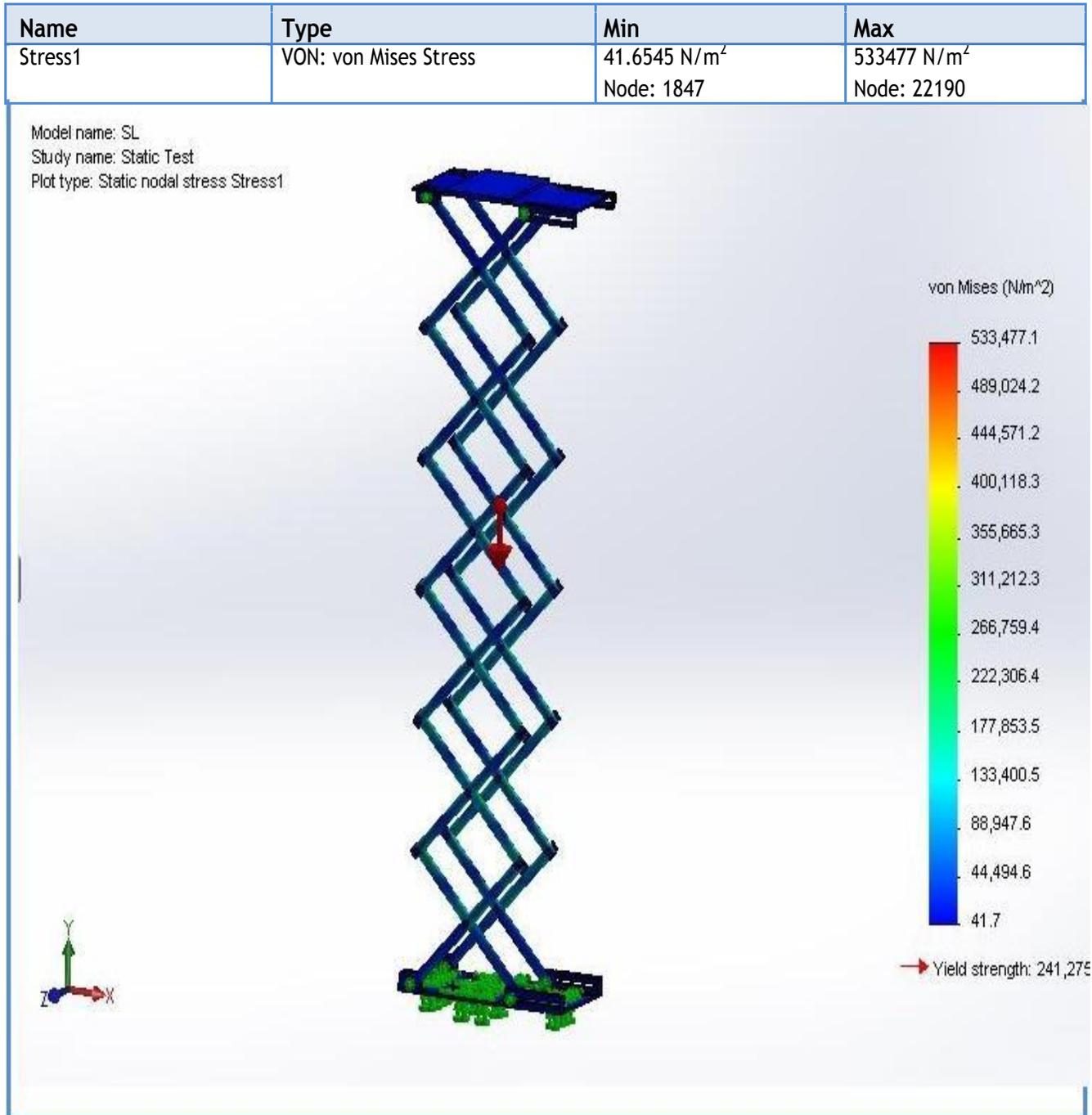
Figure 22: Result of Stress Analysis by Solidworks Simulation

5.2.5 STRAIN ANALYSIS RESULT:

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	1.15153×10^{-10} Element: 1009	1.94333×10^{-6} Element: 10724
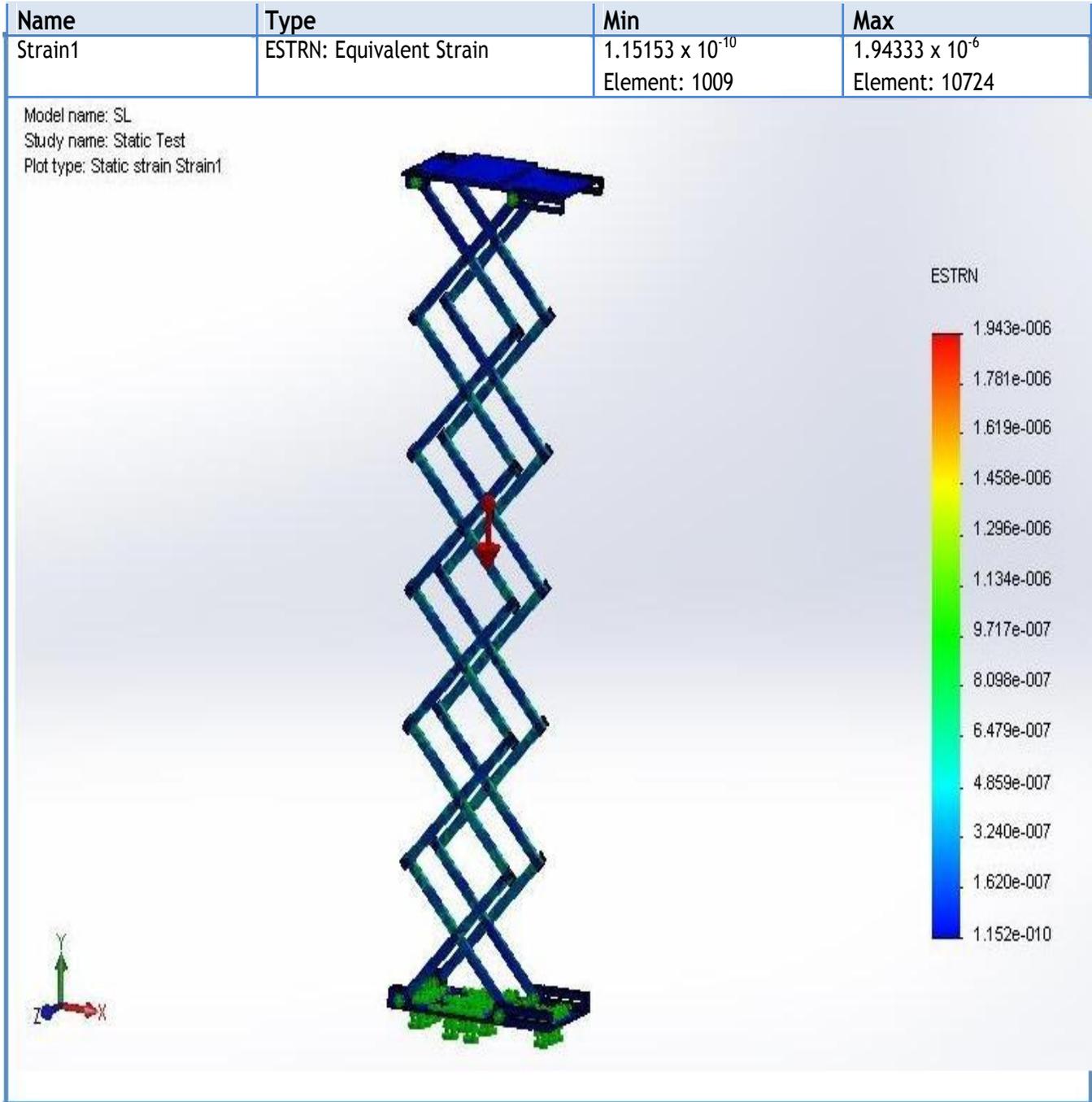
Figure 23: Result of Strain Analysis by Solidworks Simulation

5.2.6 DSIPLACEMENT ANALYSIS RESULT:

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 57	0.0367844 mm Node: 82366

Model name: SL
Study name: Static Test
Plot type: Static displacement Displacement1

URES (mm)

3.678e-002
3.372e-002
3.065e-002
2.759e-002
2.452e-002
2.146e-002
1.839e-002
1.533e-002
1.226e-002
9.196e-003
6.131e-003
3.065e-003
1.000e-030
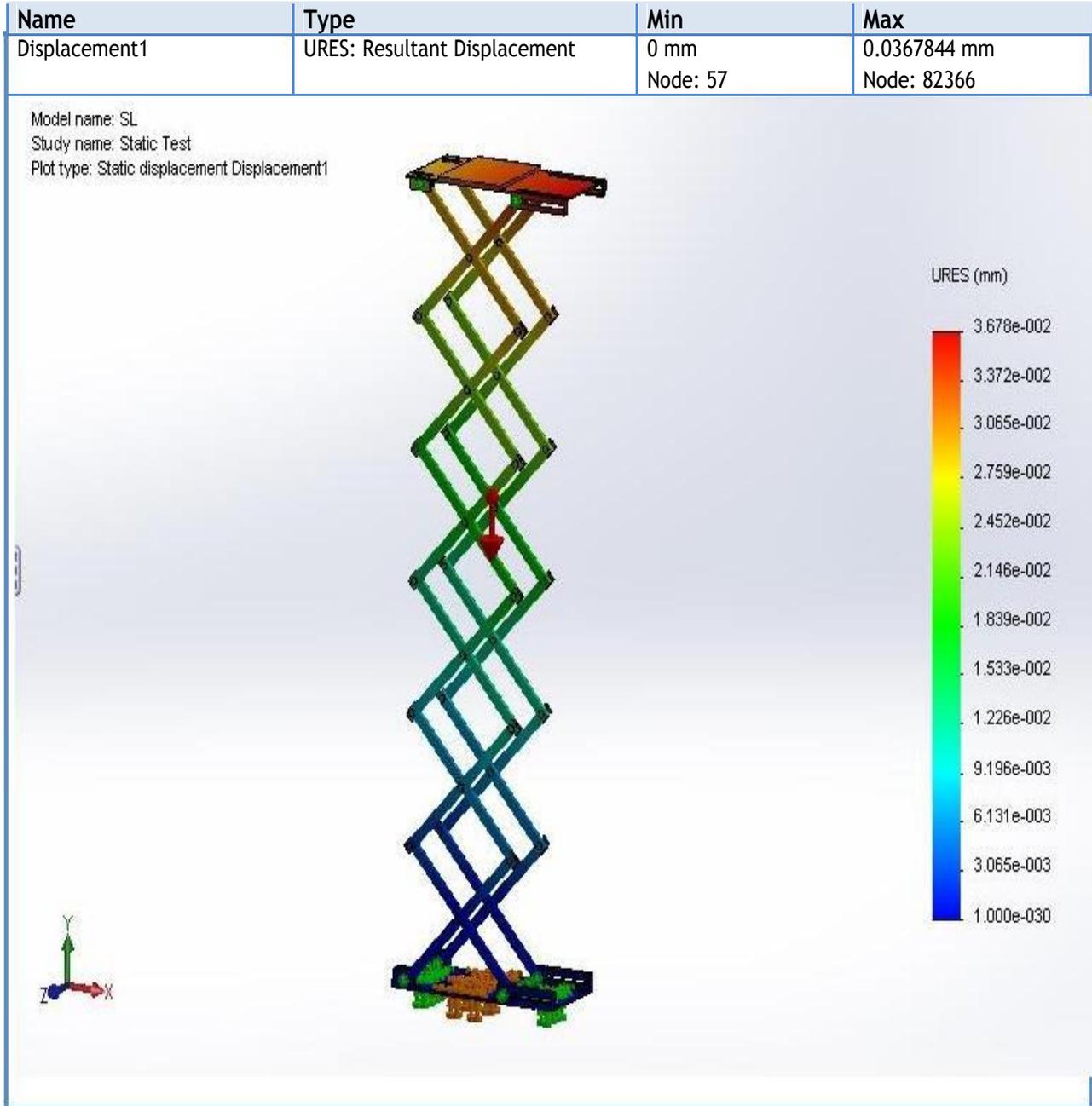
Figure 24: Result of Displacement Analysis by Solidworks Simulation

Thus from the above results from Solidworks Simulation shows that the design is safe and can there is no deformation occurs in the scissor lift.

5.3 ANALYSIS USING ANSYS:

5.3.1 MAXIMUM PRINCIPAL STRESS:
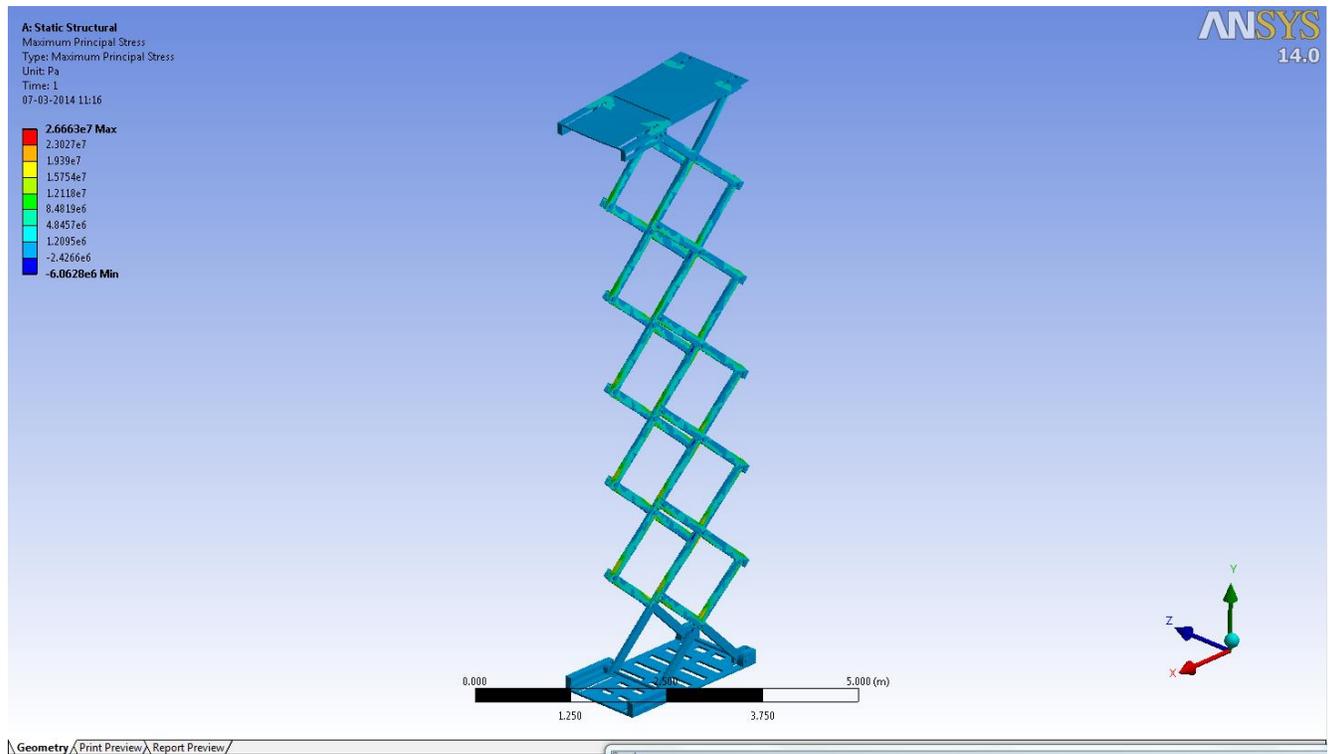
Figure 25: Result of maximum principal stress from ANSYS

Table 5: Details of Maximum principal stress

Details of "Maximum Principal Stress"	
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Maximum Principal Stress
By	Time
Display Time	Last
Calculate Time History	Yes
Identifier	
Suppressed	No
Integration Point Results	
Display Option	Averaged
Results	
Minimum	-6.0628e+006 Pa
Maximum	2.6663e+007 Pa
Minimum Occurs On	Part 63
Maximum Occurs On	Part 52
Information	
Time	1. s
Load Step	1
Substep	1

5.3.2 EQUIVALENT ELASTIC STRAIN:
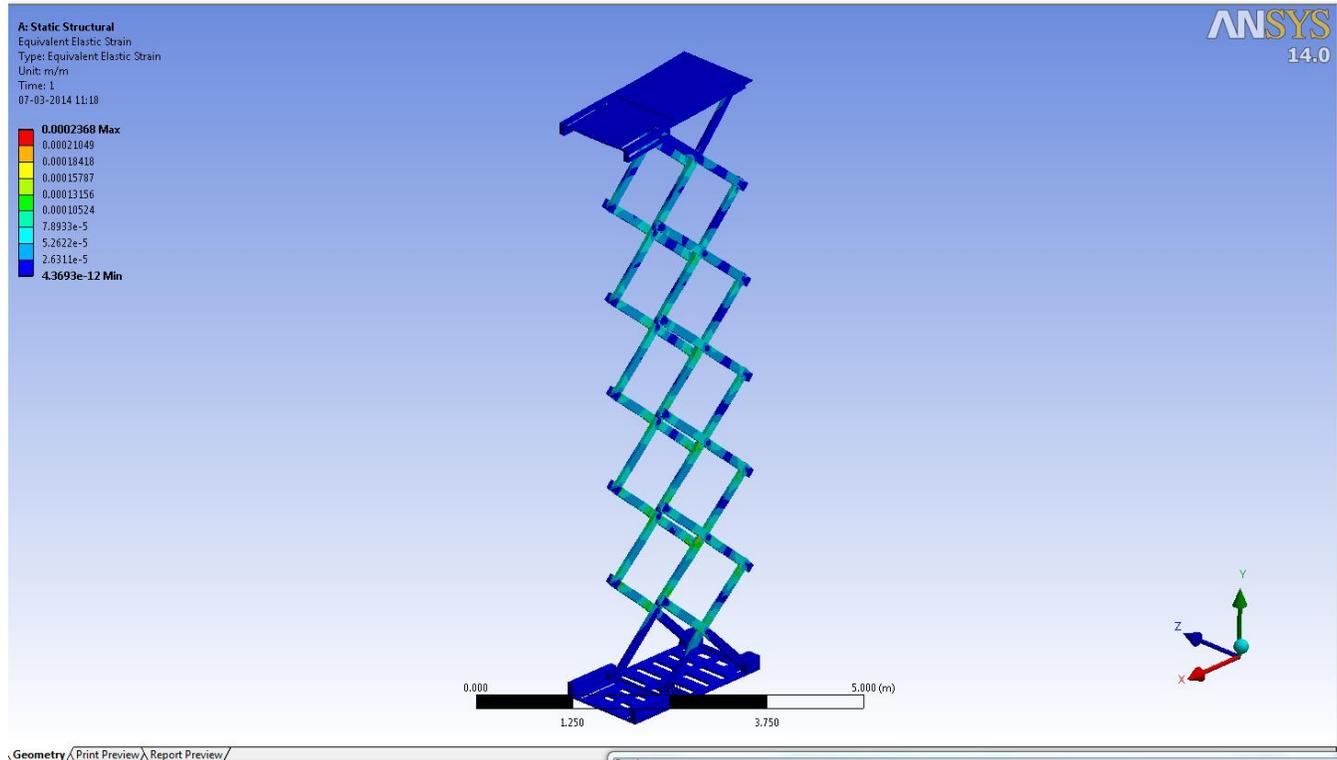
Figure 26: Result of equivalent elastic strain from ANSYS

Table 6: Details of equivalent elastic strain

Details of "Equivalent Elastic Strain"

Scope		
	Scoping Method	Geometry Selection
	Geometry	All Bodies
Definition		
	Type	Equivalent Elastic Strain
	By	Time
	Display Time	Last
	Calculate Time History	Yes
	Identifier	
	Suppressed	No
Integration Point Results		
	Display Option	Averaged
Results		
	Minimum	4.3693e-012 m/m
	Maximum	2.368e-004 m/m
	Minimum Occurs On	Part 66
	Maximum Occurs On	Part 51
Information		
	Time	1. s
	Load Step	1
	Substep	1

5.3.3 DIRECTIONAL DEFORMATION:
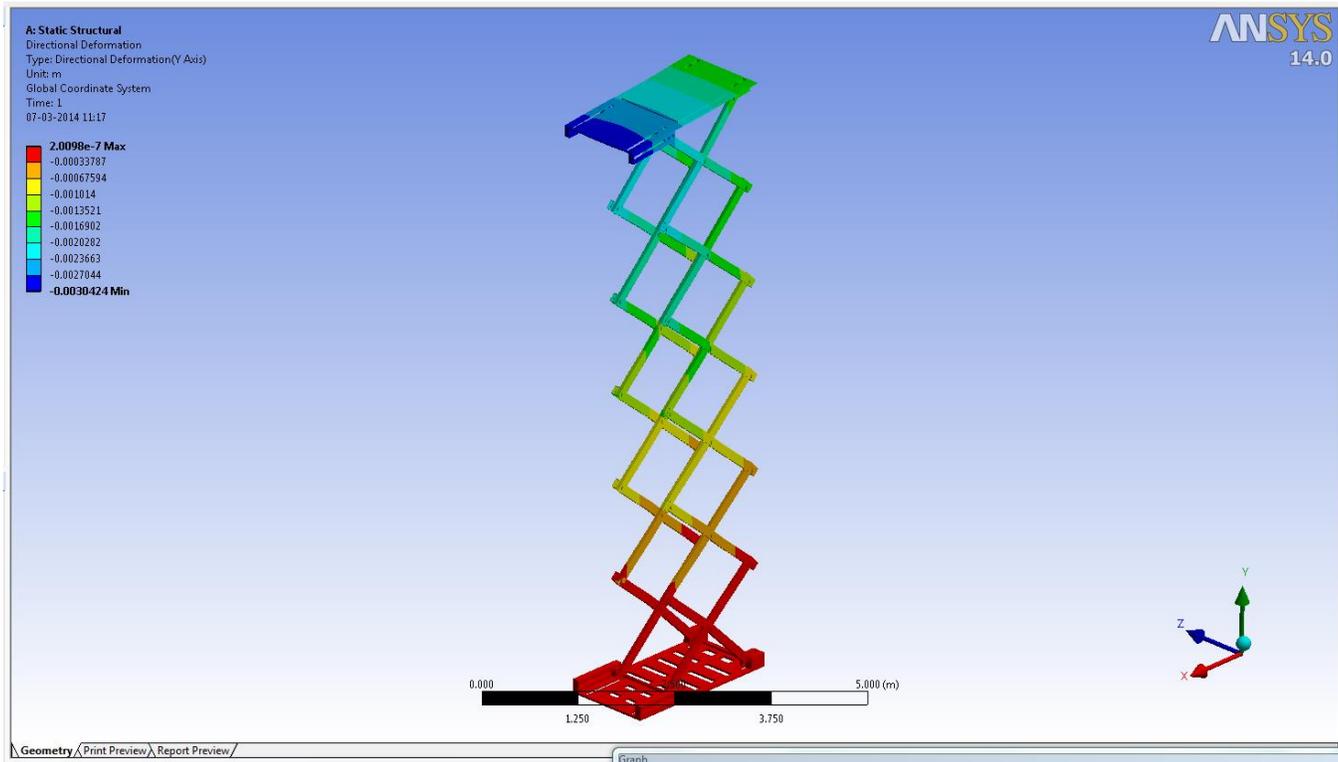
Figure 27: Result of directional deformation from ANSYS

Table 7: Details of directional deformation

Details of "Directional Deformation"

Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Directional Deformation
Orientation	Y Axis
By	Time
Display Time	Last
Coordinate System	Global Coordinate System
Calculate Time History	Yes
Identifier	
Suppressed	No
Results	
Minimum	-3.0424e-003 m
Maximum	2.0098e-007 m
Minimum Occurs On	Part 34
Maximum Occurs On	Part 41
Information	
Time	1. s
Load Step	1
Substep	1

33

5.3.4 TOTAL DEFORMATION:
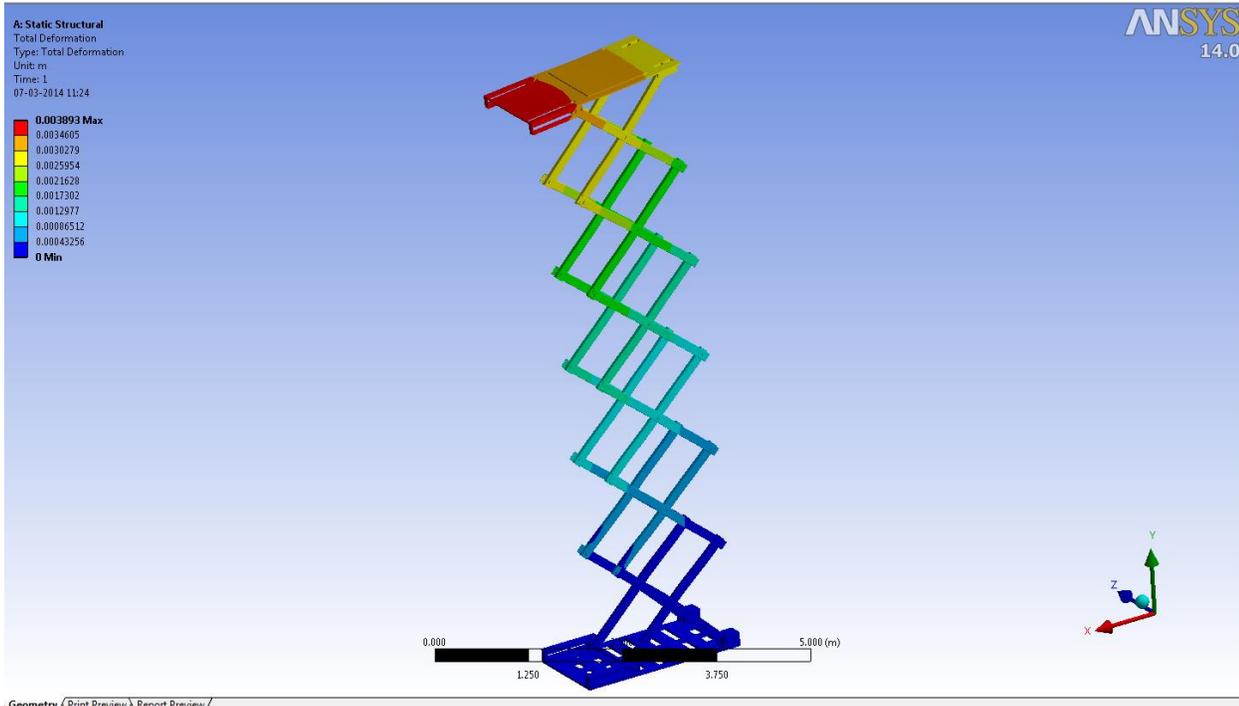
Figure 28: Result is total deformation from ANSYS

Table 8: Details of Total deformation

Details of "Total Deformation"	
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Total Deformation
By	Time
Display Time	Last
Calculate Time History	Yes
Identifier	
Suppressed	No
Results	
Minimum	0. m
Maximum	3.893e-003 m
Minimum Occurs On	Part 66
Maximum Occurs On	Part 34
Information	
Time	1. s
Load Step	1
Substep	1
Iteration Number	1

CHAPTER 6

HARDWARE DESIGN OF PNEUMATIC SYSTEM

6.1 CIRCUITS COMPONENTS:

- Compressor
- FRL unit
- Push button
- 5/3 solenoid operating with spring return valve
- Flow control valve
- Double acting cylinder

6.2 COMPRESSOR:

The compressor is act as a power source for the pneumatics controlled system. It is a mechanical device that reduces the volume and increase the pressure of fluid. These compressors are many types like reciprocating, rotary screw, scroll compressors, etc…Out of these compressors we have used the reciprocating compressor in our project. **Reciprocating compressors** use pistons driven by a crankshaft. They can be either stationary or portable, can be single or multi-staged, and can be driven by electric motors or internal combustion engines. Small reciprocating compressors from 5 to 30 horsepower (HP) are commonly seen in automotive applications and are typically for intermittent duty. Larger reciprocating compressors well over 1,000 HP (750 kW) are commonly found in large industrial and petroleum applications. Household, home workshop, and smaller job site compressors are typically reciprocating compressors 1½ HP or less with an attached receiver tank.

Figure 29: Compressor

6.3 FRL UNIT:

The FRLunit mainly consist of three components they are

- Filter
- Regulator
- Lubricator

6.4 FILTER:

The filter is used to filter the dust particles and sent the purest form of fluid to next unit. Compressed air enters the inlet port and passes over a needle valve orifice attached to a pick-up tube. This tube - often equipped with a sintered bronze filter - is submerged into a reservoir bowl filled with light machine oil. And it also contains thick paper with small pores in it to filter the dust particles.

Figure 30: Filter

6.5 REGULATOR:

The regulator is used to regulate the fluid supply according to require application .These regulated fluid can get adjusted with the help of pressure guage with adjustable knob.Ater the the fluid which gets regulated by regulator has sent to lubricator unit.

Figure 31: Regulator

6.6 LUBRICATOR:

A lubricator should always be the last element in an FRL (Filter-Regulator-Lubricator) unit. If an FRL is connected "backwards" with incoming air connected to the lubricator, oil-laden air interferes with pressure regulator operation, oil is separated from the air stream and drained by the filter, and very little or none is delivered to connected equipment. It's used to supply the fluid to the cylinders and it gives the free motion without resistance to move.

Figure 32: Lubricator

6.7 OVER-ALL ASSEMBLY OF FRL UNIT:

Figure 33: FRL unit

6.8 PUSH BUTTON:

The push button is act as the source for solenoid which is connected to the actuating valve. There are many types like **SPST, SPDT, DPDT**, etc…. Here we have used **SPST SWITCH** and also it's in normally open condition. When we externally press that switch the circuit get closed and the electrical current will flow to solenoid valve and it gets actuated. And there are two push buttons are used in this project one is for **FORWARD** motion and another is for **BACKWARD** motion.

Figure 34: Push button and SPST switch

6.9 5/3 SOLENOID VALVE:

This valve has named as these because it has five port and three positions. And it has two solenoids on both sides. One is for forward and another is for backward. These sides gets connected with the help of push button and through power supply .It also has two types 5/3 solenoid with spring return and without spring return solenoid valve. The simple solenoid valve is used for continuous movement and spring return valve is used for discontinuous motion. When the forward button is pressed first port will get supply and the cylinder will move in forward direction. Similarly it is the vice-versa for reverse direction. When we release the button it will get changed to neutral position. It makes the main difference between two types of valves.
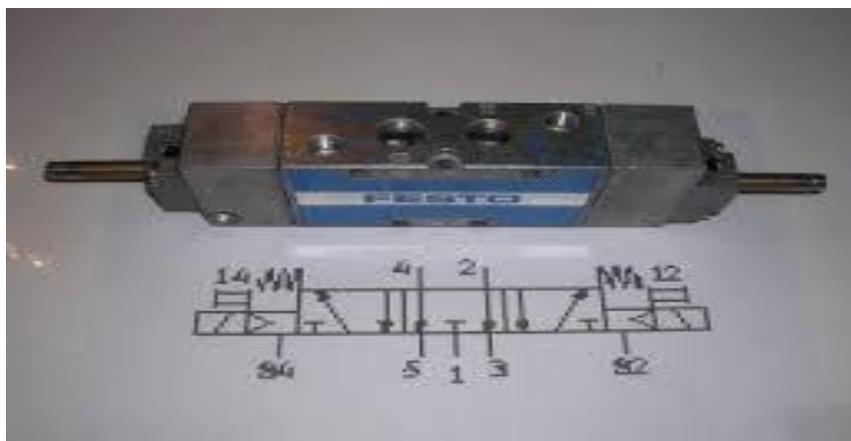
Figure 35: 5/3 solenoid operated with spring return valve

6.10 VARIABLE CHECK VALVE:

The check valve is also called as one way valve or non-return valve. It normally allows the fluid flow in one direction. It is of two types, non-variable and variable check valve. In non-variable type the amount of fluid flow in to the cylinder cannot adjusted but in variable we will adjust the amount of fluid flow into the cylinder. By having the variable controlled valve the speed of output can get adjusted according to user requirement.so in this we have used variable controlled valve because it the ladder should get raised slowly and retracted slowly otherwise it gets collapsed.

Figure 36: Variable Check Valve

6.11 **CYLINDER:**

The cylinder is the out device for all hydraulics and pneumatics product. Based on cylinder connection the output get modulated and varied. These cylinders are of many types. They are:

- SINGLE ACTING

    - WITHSPRING RETURN

    - WITHOUT SPRING RETURN

- DOUBLE ACTING

    - WITH SPRING RETURN

    - WITHOUT SPRING RETURN

- TANDEM CYLINDER

- TELESCOPIC CYLINDER

- RODLESS CYLINDER

In our project we are using double acting cylinder because it consist of two ports. When the fluid enters into first port the cylinder will move forward and when it enters into second port the cylinder gets move backward. And the input is get from 5/3 solenoid with spring return valve through variable check valve.

Figure 37: Double acting pneumatic cylinder

6.12 CIRCUIT DIAGRAM BY USING SOFTWARE:
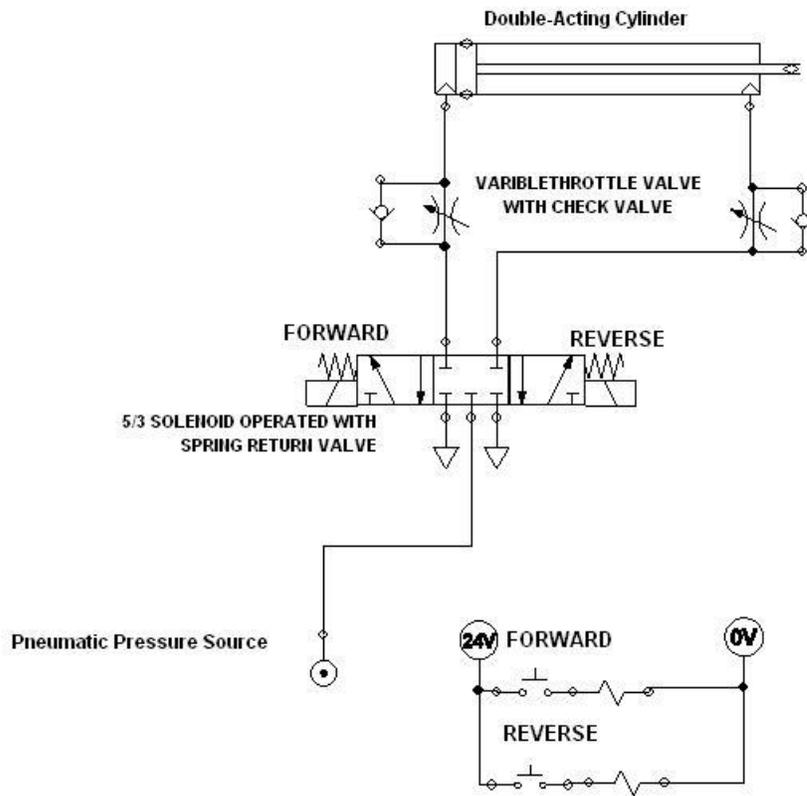
Figure 38: Circuit diagram of Pneumatic control of Scissor Lift.

The about circuit has designed by using the software AUTOMATION STUDIO 5.6.The circuit has operated with the help 24V power supply. When the push button has pressed the solenoid gets supply then it actuates the cylinder in forward motion. Likewise when another push button has pressed the cylinder gets actuated in backward. In this the main component is 5/3 solenoid with spring return valve. The advantage is behind is when the user operates the forward button when he needs to stop at half of the stroke length of piston it can get stopped. Because when the button gets released the valve gets transferred into neutral position so the cylinder cannot move forward and backward.

Figure 39: Hardware assembly of pneumatic circuit

6.13 CALCULATION FOR CLYINDER AND PUMP DESIGN:

For 200 kg:

6.13.1 For Cylinder [6]:

Diameter of piston=50 mm

Length of piston stroke=12.9 cm

Diameter of piston rod=35 mm

Volume of cylinder=289.2 cm^3

6.13.2 For pump [7]:

Pump displacement=148.5×10^{-7} m^3/rev

Q in=0.5 lts/sec

Q out=0.10 lts/sec

Capacity of tank=2.2 lts

Power=357.7 W

CHAPTER 7

FABRICATION OF PROTOTYPE OF SCISSOR LIFT

The scissor lift's prototype model was fabricated with dimensions being scaled down by using MEMS scaling law [5]. According to the MEMS scaling method, on scaling down to a 1:10 ratio, the volume is scaled down to 1000 times smaller.

If we let

L = linear dimension of a solid, we will have:

The volume: $V \propto L^3$

The surface: $S \propto L^2$

$S/V = L^{-1}$

A 10 times reduction in length: $10^3 = 1000$ time reduction in volume.

But $10^2 = 100$ time reduction in surface area

From the original dimensions, after using MEMS scaling law,

7.1 THE DIMENSIONS OF PROTOTYPE:

DIMENSION OF BASE:	250mm x 120mm,	thickness = 2 mm
DIMENSION OF PLATFORM:	250mm x 120mm,	thickness = 2 mm
DIMENSION OF LINK:	240mm x 22mm,	thickness = 1mm
DIMENSION OF RIVET:	diameter = 5mm,	length = 5mm
DIMENSION OF ROLLER:	diameter = 30mm,	thickness = 20mm
DIMENSION OF SHAFT:	diameter = 5mm,	length = 140mm

Figure 40: Scissor lift in compressed position

Figure 41: Scissor lift in expanded position
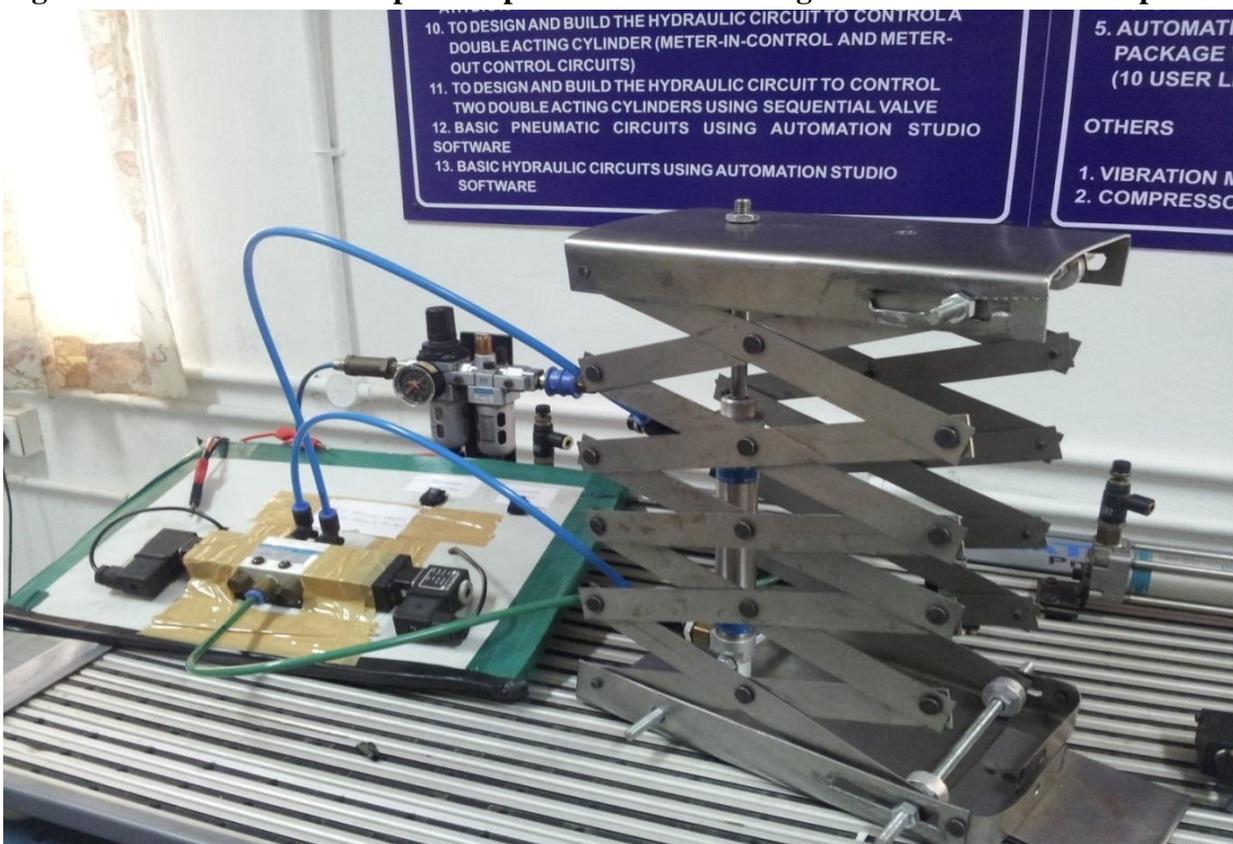
Figure 42: The completed prototype of scissor lift model with electrical control.

7.2 PROJECT COST FOR FABRICATING PROTOTYPE OF SCISSOR LIFT:

Sheet metal MS thickness 1mm   = Rs 270

Sheet metal MS thickness 2mm   = Rs 190

Aluminium Rod (6061)   = Rs 340

MS rod   = Rs 30

Fully threaded stud   = Rs 65

Rivets   = Rs 25

Nut   = Rs 105

Cutting, Bending, Grinding, Drilling   = Rs 650

Turning, Facing, Soldering

TOTAL COST   = Rs 1675

CHAPTER 8

RESULT

Table 9: Result of the analysis for Stainless Steel material carried out using software

CHARACTERISTICS	Solidworks Simulation	ANSYS
Mesh Dimension	3D	3D
Mesh Type	Solid Mesh	Mixed
Element size	20	10
No. of elements created	59,241	1,51,27,666
No. of nodes created	1,08,146	57,62,632
Displacement Analysis	Maximum = 0.036 mm Minimum = 0	Maximum = 0.038 mm Minimum = 0
Stress Analysis	Minimum = 45.6545 N/m^2 Maximum = 5,33,477 N/m^2	Minimum = 6.06 N/m^2 Maximum = 2,66,300 N/m^2
Strain Analysis	Minimum = 1.15 x 10^{-10} Maximum = 1.94 x 10^{-6}	Minimum = 4.36 x 10^{-12} Maximum = 2.36 x 10^{-4}

CONCLUSION

Thus the project was finished with successful CAD model design. The designed CAD model was analyzed using Solidworks Simulation software and ANSYS software for stress distribution, strain developed in the system and the deformation occurred during load applied condition. Then the circuit for pneumatic system was designed and tested using Automation studio software. The scaled down model could not be fabricated using hydraulic system and hence we have used pneumatic system to operate the setup. The pneumatic system was designed and tested using Automation studio software. The dimensions of scaled down model was calculated based on MEMS scaling law. The scaled down model was fabricated using mild steel material and the pneumatic system were setup for the operation. The working of the scaled down model was tested several times in our Hydraulics and Pneumatics laboratory.

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[5] Wautelet, Michel. "Scaling laws in the macro-, micro-and nanoworlds."*European Journal of Physics* 22.6 (2001): 601.

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[7] "Oil Hydraulics systems and their Principles and Maintanence" by SR.Majmuder