Analysis & Optimization of Hydraulic Scissor Lift

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Abtract:
A hydraulic scissor lift is a mechanical device used for various applications for lifting of the loads to a height or level. A lift table is defined as a scissor lift used to stack, raise or lower, convey and/or transfer material between two or more elevations. The main objective of the devices used for lifting purposes is to make the table adjustable to a desired height. A scissor lift provides most economic dependable & versatile methods of lifting loads; it has few moving parts which may only require lubrication. This lift table raises load smoothly to any desired height. The scissor lift can be used in combination with any of applications such as pneumatic, hydraulic, mechanical, etc. Lift tables may incorporate rotating platforms (manual or powered); tilt platforms, etc, as a part of the design. Scissor lift design is used because of its ergonomics as compared to other heavy lifting devices available in the market. The frame is very sturdy & strong enough with increase in structural integrity. A multiple height scissor lift is made up of two or more leg sets. As per the discussion with the concern person of DS Engineering, Pune, It is found that they are facing some problems regarding hydraulic scissor lift like job to be lifted are heavier which causes more deformations in hydraulic lift frame checking deformations & stresses induced in it is a major objective of this project. It is also found that weight of the present lift is high weight optimization is also prime objective of this project. As loading & unloading is repeated there may be chances of fatigue failure, to check the life of lift. Design & Analysis of the Hydraulic lift that should with stand maximum load without failure in working conditions. To check vibration of hydraulic lift during working time by modal analysis.
Keywords: Analysis, Fatigue Analysis, Hydraulic Lift, Weight Optimization, etc.

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1. Introduction:

The most common industrial lift is the hydraulic scissor lift table. This may seem like a complicated piece of equipment, but in actuality hydraulic lift tables are really very simple in design.
Hydraulic scissor lift tables are comprised of five major components:
Platform – This is the top of the lift table where lifted product sits. It can be supplied in a variety of sizes.
Base – This is the bottom of the structure that rests on the floor. It contains the track the scissor legs travel in.
Scissor legs – These are the vertical members that allow the platform to change elevation.
Hydraulic cylinder – The most common industrial scissors lifts are actuated by one, two, or three single-acting hydraulic cylinders. These allow the lift table to lift and lower.
Motor or Power Source – Most hydraulic scissor lifts are powered by either an electric or air motor. These provide power to the hydraulic pump which actuates the lift table.

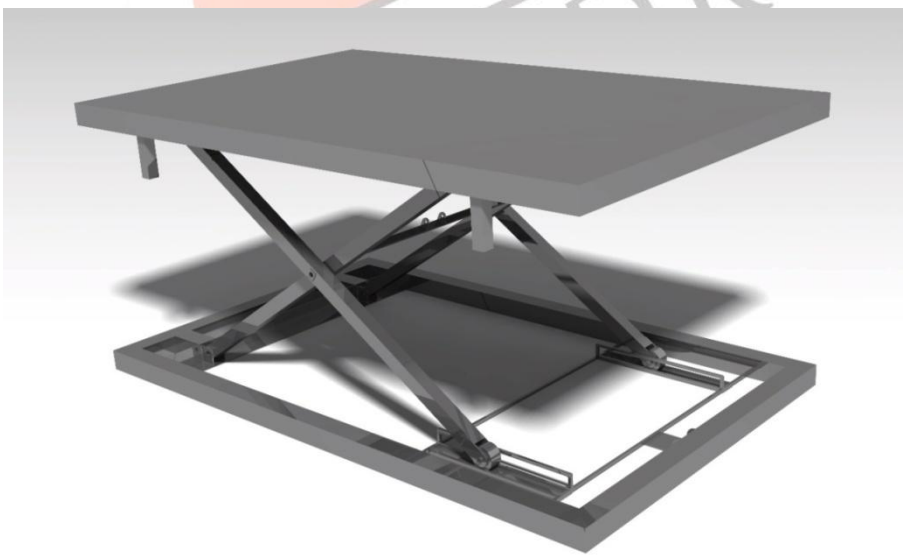


Fig. 1 Hydraulic Scissor Lift

1.2 Types of Hydraulic Lifts:

- Classification based on the type of energy used

(a) Hydraulic lifts

(b) Pneumatic lifts
(c) Mechanical lifts

- Classification based on their usage

(a) Scissor lifts
(b) Boom lifts
(c) Vehicle lifts

1.4 Applications of Hydraulic Scissor Lift

A scissor life table has many useful purposes. The applications of a scissor lift table include a variety of things, but the platform is ultimately designed to help lift and raise heavier objects. The industrial lift is most often seen in behind the scenes of retail establishments and warehouses, although manufacturing engineers are always redesigning the lift for various uses like lifting heavy loads.

1. The scissor lift table can raise a forklift so that maintenance to the underneath of the forklift can be performed.
2. By employing scissor lift tables in a warehouse, all heavy items can be lifted with ease. You can use it to stack boxes, pallets and other heavy materials.
3. Sheet metal is often stacked. The metal is usually too heavy for employees to try and lift for the stacking process. This is where a scissor lift table can help.
4. Distributaries often use scissor lift tables for the lifting of merchandise.
5. Scissor lift tables can be used to lift people and those in wheelchairs. By using a lesser capacity scissor lift, you can lift people for outdoor chores such as cleaning gutters and windows. Those who use wheelchairs can use the lift to reach higher levels with less constraint.
6. In major cities, you will often see scissor lift tables used as platforms for maintenance and construction.
7. Some scissor lift tables are used as weight platforms to weigh machinery and other mechanisms.
8. Use the lift as a deck extension during a major renovation or project. Scissor lift tables can help you in any renovation or remodel. It is useful for allowing people to reach higher areas of a building.
9. Scissor lift tables can be designed to operate in different ways, but they can all be lowered and raised, but their main purpose will always be to lift. Designers and engineers of new models have to keep this in mind, no matter how outside-the-box they're looking to be with their developments.

2. PROBLEM STATEMENT:

Fig: Fatigue Failure of Hydraulic Scissor lift

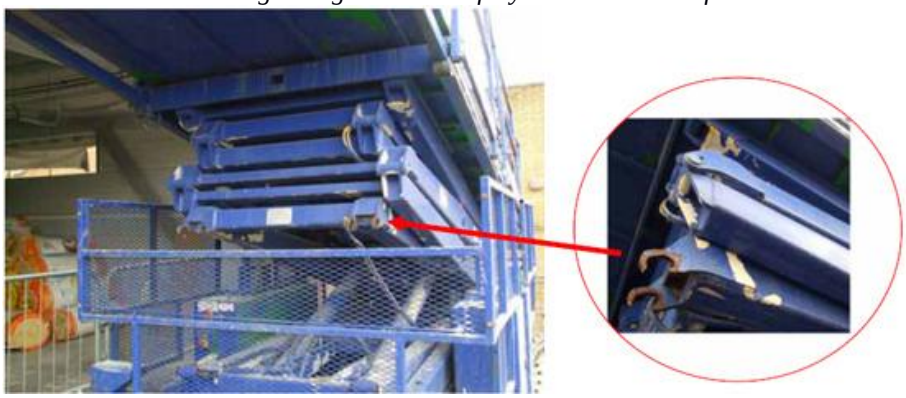


Fig: Failure of Hydraulic Scissor lift due to maximum deformations

As per the discussion with the concern person of DS Engineering, Pune, It is found that they are facing some problems regarding hydraulic scissor lift like job to be lifted are heavier which causes more deformations in hydraulic lift frame which may causes failure at loading points. As loading & unloading is repeated there may be chances of fatigue failure, it is also found that weight of the present lift is high. Vibrations produced by lift during working are also more. Above images shows the failure zones of lift which are taken at workshop.

3. LITERATURE REVIEW:

[1] "Design, Manufacturing & Analysis of Hydraulic Scissor Lift", Gaffar G Momin, et al

This Paper describes the design as well as analysis of a hydraulic scissor lift. Conventionally a scissor lift or jack is used for lifting a vehicle to change a tire, to gain access to go to the underside of the vehicle, to lift the body to appreciable height, and many other applications Also such lifts can be used for various purposes like maintenance and many material handling operations. It can be of mechanical, pneumatic or hydraulic type. The design described in the paper is developed keeping in mind that the lift can be operated by mechanical means by using pantograph so that the overall cost of the scissor lift is reduced. In our case our lift was needed to be designed a portable and also work without consuming any electric power so we decided to to use a hydraulic hand pump to power the cylinder Also such design can make the lift more compact and much suitable for medium scale work. Finally the analysis of the scissor lift was done in ansys and all responsible parameters were analyzed in order to check the compatibility of the design values

[2] "Design, Analysis and Development of Multiutility home equipment using Scissor Lift Mechanism", Divyesh Prafulla Ubale, et al.

The conventional method of using rope, ladder lift getting person to a height encounter a lot of limitation (time and energy consumption, comfortability, amount of load that can be carried etc.) also there may be a risk of falling down in case of ladders hence hydraulic scissors lift is designed to overcome all these difficulties. The main aim of this paper is design and analysis and to construct a multiutility home equipment for senior citizens so that they can carry their daily activities efficiently. Also the equipment should be compact and cost effective. Lifting height achieved by scissor mechanism is of 1 m from bottom level. Buckling and bending failure analysis of scissor is also done in this paper. With ceaseless development of science and technology, more and more new technologies are applied to lifting appliance design. This project aims at making equipment multifunctional, easy to use/operate, cost effective and portable so that it will be used conveniently at home and may be used in hospitals, hotels and other common places. Senior citizens face many problems to carry out their day to day activities, as this equipment is designed in such a way that (e.g. it is remote operated with battery) they can easily move in house and perform day to day activities. All safety considerations are taken into account while designing equipment. Scissor lifting mechanism is designed to lift person to desired height. A scissor lift mechanism is a device used to extend or retract a platform by hydraulic means. The Extension or displacement motion is achieved by the application of force by hydraulic cylinder to one or more supports. This force results in an elongation of the cross pattern. Retraction through hydraulic cylinder is also achieved when lowering of platform is desired.

[3] "Design and Analysis of Hydraulic Pallet System in Chain Conveyor", Setu Dabhi, et al,

This paper describes the design and analysis of hydraulic pallet system in a chain conveyor used in automobile industries for loading and unloading of materials .The system, consisting of a hydraulic power pack, a chain conveyor, a pallet system is automatically controlled with the help of PLC. Our aim is to design a feasible and a cost effective mechanism to lift the given load using hydraulic actuation and listing merits of hydraulic actuations over pneumatic and servo actuation. The design module pallet along with mechanism used for balancing is design in CAD software CATIA and analyzed for variable loading in ANSYS .The design proposed is highly flexible with the manufactures requirement and its stability is analyzed under variable load. The result of the feasibility study showed a conspicuous shortening of working hours, and an alleviation of manual labor The manufacturer required a pallet system which is to be hydraulic actuated, rather than pneumatically or servo actuated. Comparing the three systems, we find pneumatic system rather advantageous over the other two. Merits of pneumatic system are listed below: Simplicity in design, Cost effective, Safety and reliability In spite of the above advantages, it was found that hydraulic system could handle more load as compared to the previous, and the back pressure so developed in hydraulic actuation could efficiently be handled as compared to pneumatic during movement of the pallet ,so as maintaining stability and reducing the amount of vibrations. Considering the involvement of the third system , where actuation of the pallet is via servo motors is out of question ,as its highly costly, requires frequent maintenance, and its load bearing capacity is also low as compared to others. The main advantage of using hydraulic system in our application over pneumatic other than the load bearing capacity is the fluid in hydraulic system is basically incompressible, hence it leads to minimum springing action. So even if the load on the pallet is non uniform, the actuators will balance the pallet in such a way so as to minimize the chances of over throwing the load. This sort of safety measure is difficult to achieve using pneumatic actuation, and even in case of uniform loading the vibration encountered is much more.

[4] "Finite Element analysis of Frame of Hydraulically Operated Beam Lifting Machine" S. B. Naik, et al

A special type of beam lifting device is designed for textile industries. The machine is hydraulically operated and is having two frames one horizontal and another vertical. Horizontal frame is mounted with two telescopic cylinders used for beam lifting to required height. The mobility for the structure is provided by using castor wheels. Finite element analysis of the frames is done by ANSYS software considering the need of the textile industries, a special purpose machine has been designed to lift the beams in textile industries. The finite element analysis of the frame of this machine is done to get the idea of the stresses & deformation of the structure in order to modify the same if needed.

[5] Design and analysis of an aerial scissor Lift, M. Abhinay, P.Sampath Rao

Aerial scissor lifts are generally used for temporary, flexible access purposes such as
maintenance and construction work or by fire-fighters for emergency access, etc which distinguishes them from permanent access equipment such as elevators. They are designed to lift limited weights usually less than a ton, although some have a higher safe working load (SWL). The increasing demand of Aerial Scissor Lifts in companies in order to improve their manufacturing flexibility and output by providing

variable height access to their work. This is especially true when the work being accessed is raised off the floor and outside an operator's normal ergonomic power zone. In either case, it is much more economical to bring the worker to the work rather than bringing the work to the worker. In this project, we have modeled a aerial scissor lift by using ANSYS software which is one of the software used for modeling components in most of the design based industries. While the modeling of the components the material selection is carried out simultaneously based on the design considerations related to loads, etc. Later the stress and strain concentration, deformation on the aerial scissor lift have been found by applying certain load on the lift's platform, using the Finite Element Analysis (FEA) by using ANSYS software that provides best output within few seconds. Finally the stress and strain concentration, deformation result.

[6] Design & Analysis of Hydraulic Scissor Lift" M. Kiran Kumar1, J. Chandrasheker2, Mahipal Manda3 , D.Vijay Kumar4.

This paper is mainly focused on force acting on the hydraulic scissor lift when it is extended and contracted. Generally, a hydraulic scissor lift is used for lifting and holding heavy weight components. Material selection plays a key role in designing a machine and also influence on several factor such as durability, reliability, strength, resistance which finally leads to increase the life of scissor lift. The design is performed by considering hydraulic scissor lift as a portable, compact and much suitable for medium type of load application. Drafting & drawing of hydraulic system scissor lift is done using solid works with suitable modeling and imported to Ansys work bench for meshing and analysis. Hence, the analysis of the scissor lift includes Total deformation load, Equivalent stress, was done in Ansys and all responsible parameters were analyzed in order to check the compatibility of the design value. The computational values of two different materials such as aluminum and mild steel are compared for best results.

4. OBJECTIVES:

- As job to be lifted are heavier which causes more deformations in hydraulic lift frame checking deformations & stresses induced in it is a major objective.
- Weight of the Present lift is high, Weight optimization by modifying existing design is also prime objective of this project
- As loading & unloading is repeated there may be chances of fatigue failure, to check the life of lift
- To check vibration of hydraulic lift during working time by modal analysis

5. METHODOLOGIES:

5.1 FEA ANALYSIS:

- **CAD MODEL:**

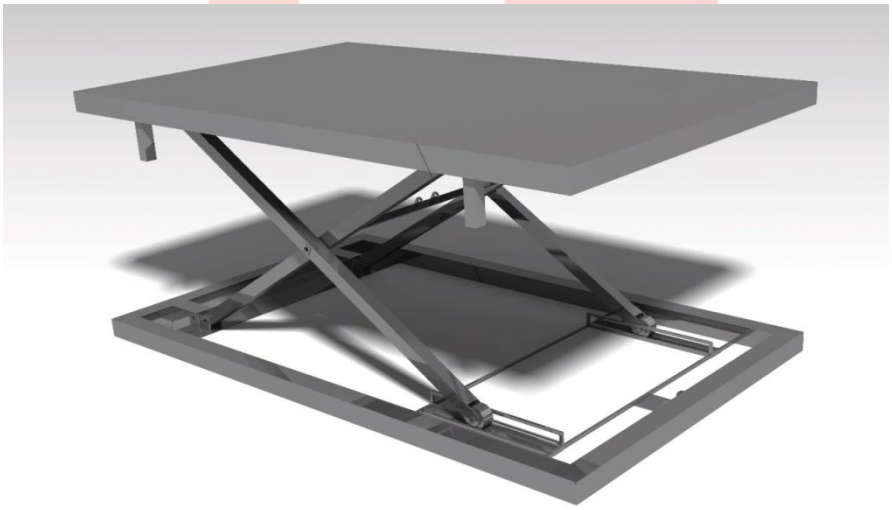
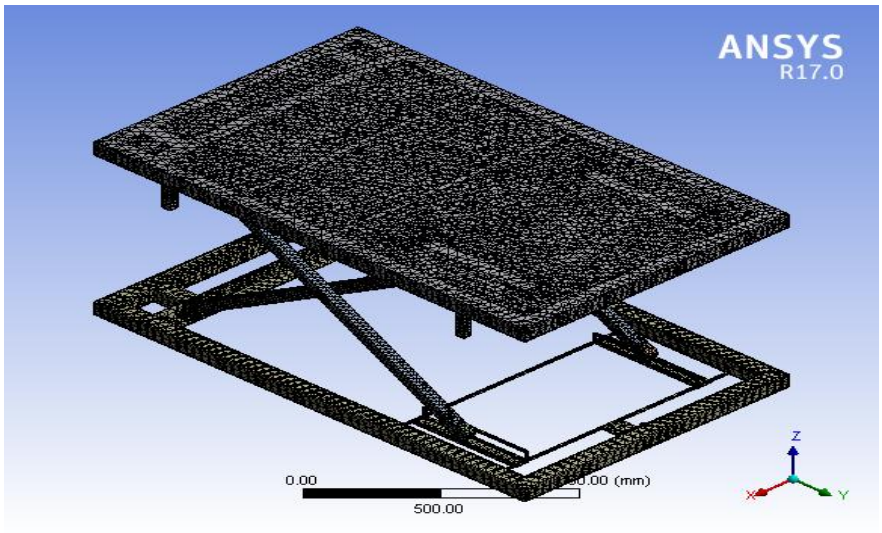


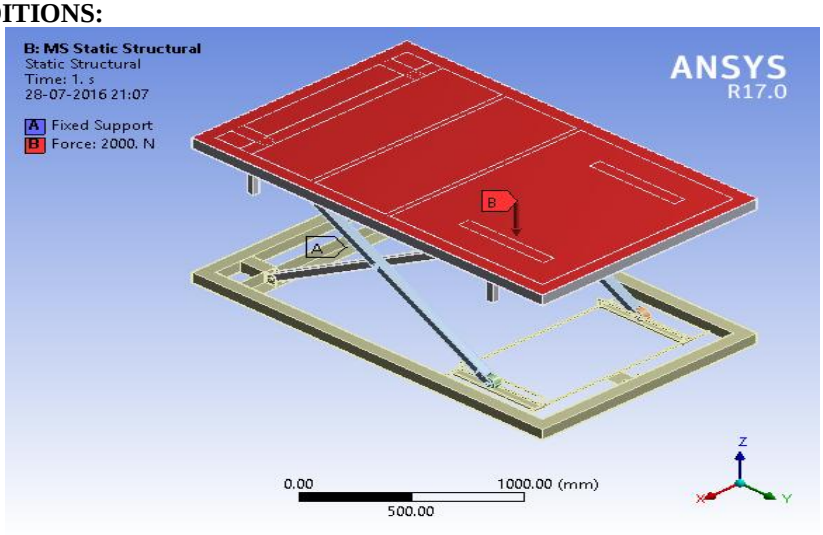
Fig: CAD model of Hydraulic Scissor lift

- **FEA MODEL**

No. of Nodes	158431
No. of Elements	78141



➢ **BOUNDARY CONDITIONS:**



5.2 ANALYSIS OF HYDRAULIC SCISSOR LIFT:

The analysis of lift has been carried out by using ANSYS 15 general purpose FEM software. The static analysis is done on the hydraulic lift

➢ **STATIC ANALYSIS OF HYDRAULIC LIFT:**

➢ **Procedure For Static Analysis in ANSYS:**

1. Build the FE model as explained in above chapter
2. Define the material properties such as young's modulus and density etc.,
3. Apply boundary condition and pressures.
4. Solve the problem using current LS command from the tool

➢ **STATIC ANALYSIS OF MS LIFT:**

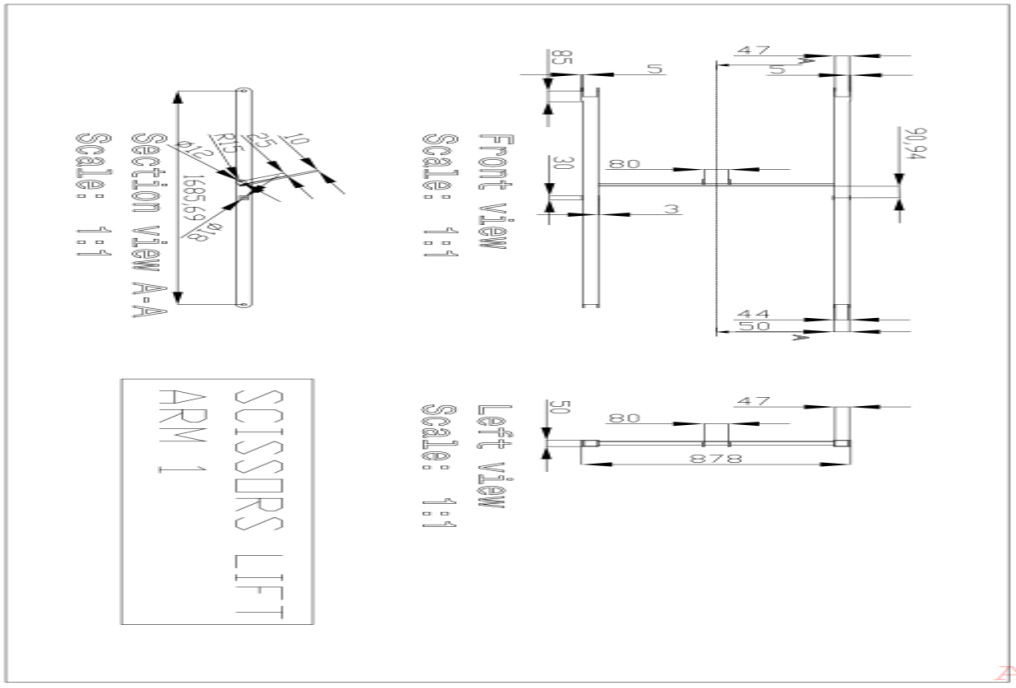
➢ **Properties of MS Lift:**

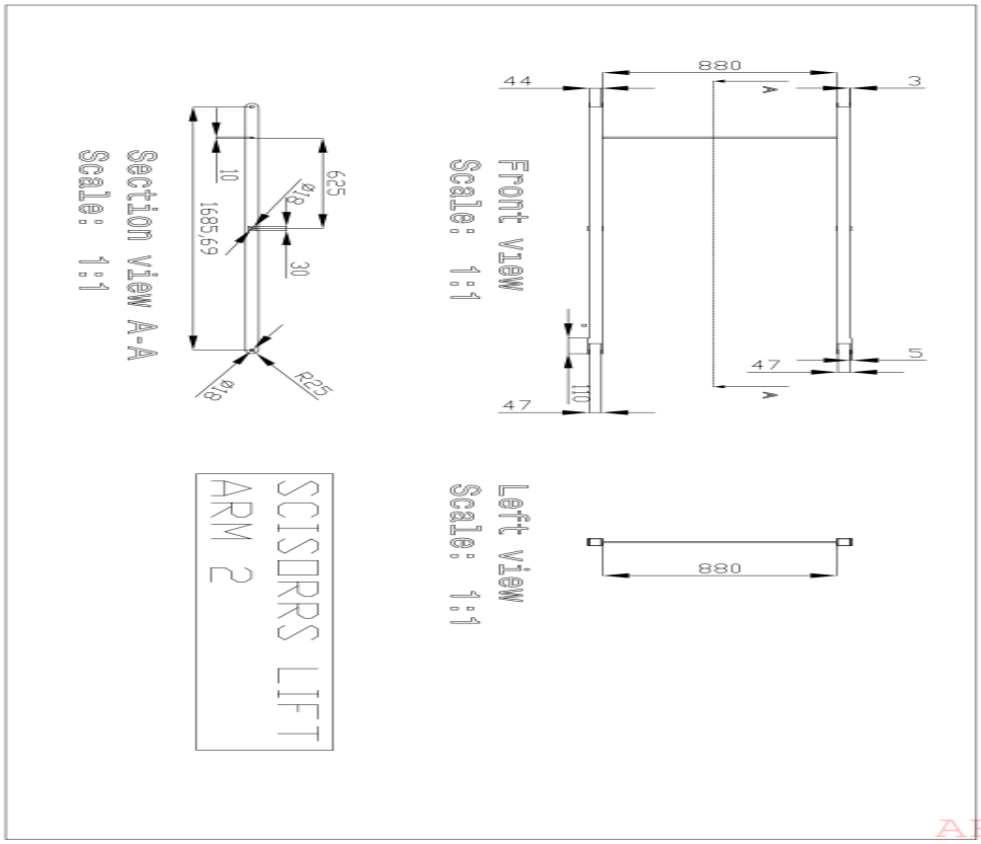
1. Young's modulus E= 210 MPa
2. Poisson's ratio NUXY=0.303
3. Mass density =7860 kg/m3
4. Damping co-efficient =0.008

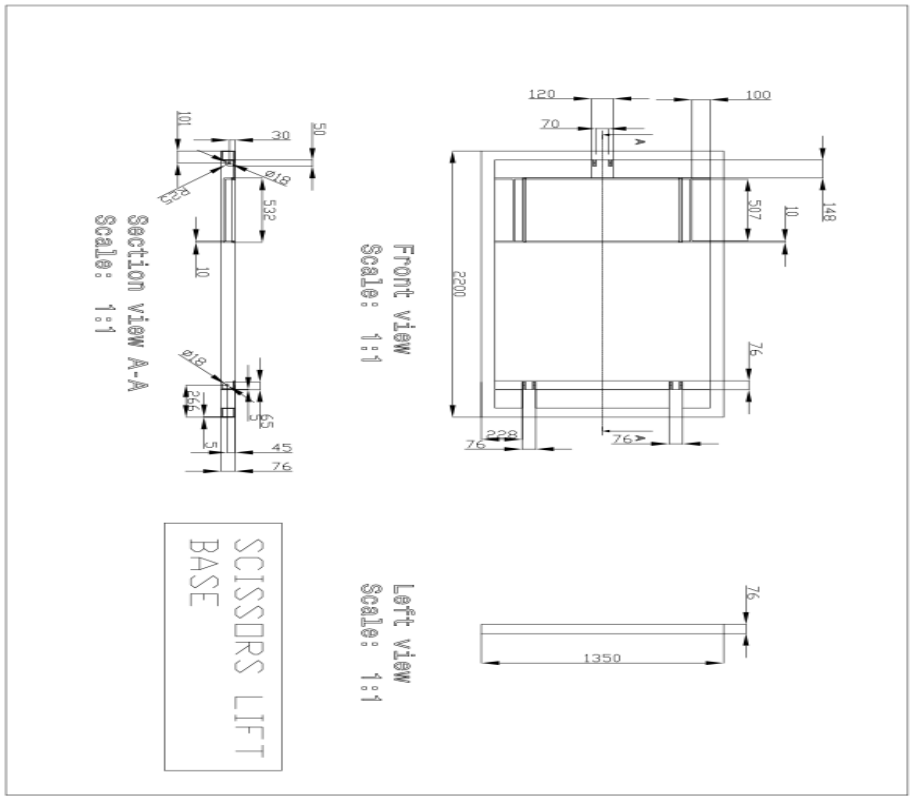
5.3 OPTIMIZATION OF LIFT BY MODIFYIG EXISTING DESIGN

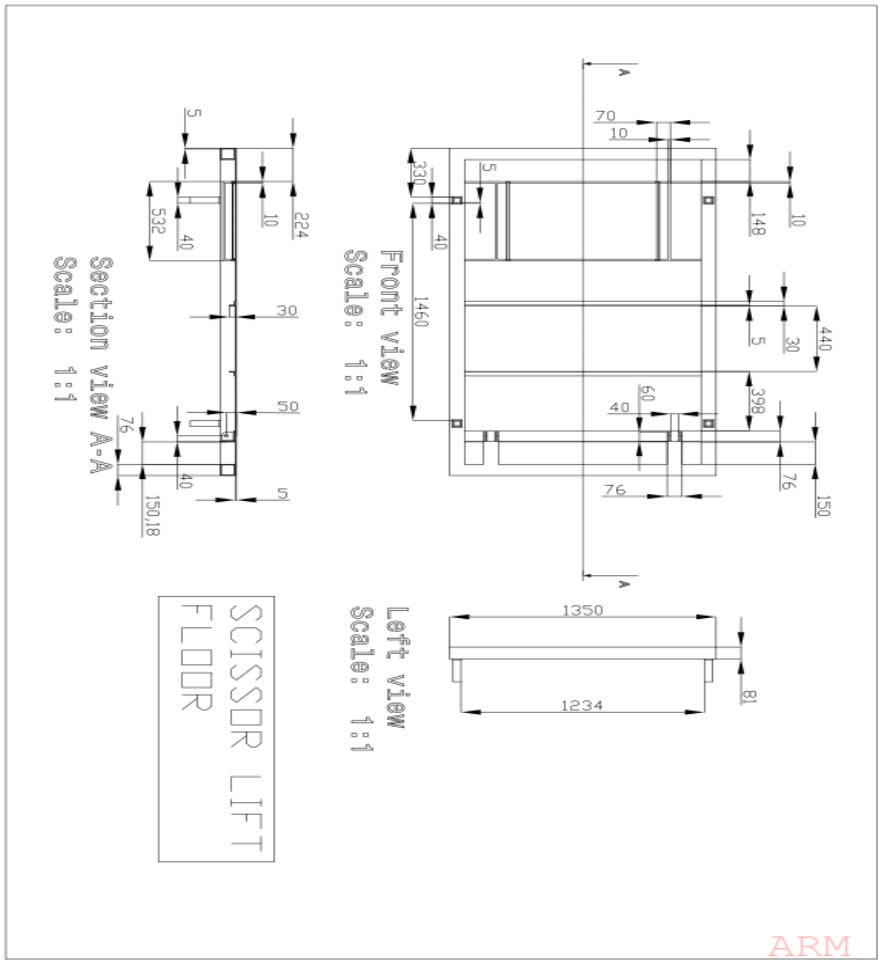
5.3.1 SCISSOR LIFT BEFORE MODIFYING DESIGN:

- Drafting:



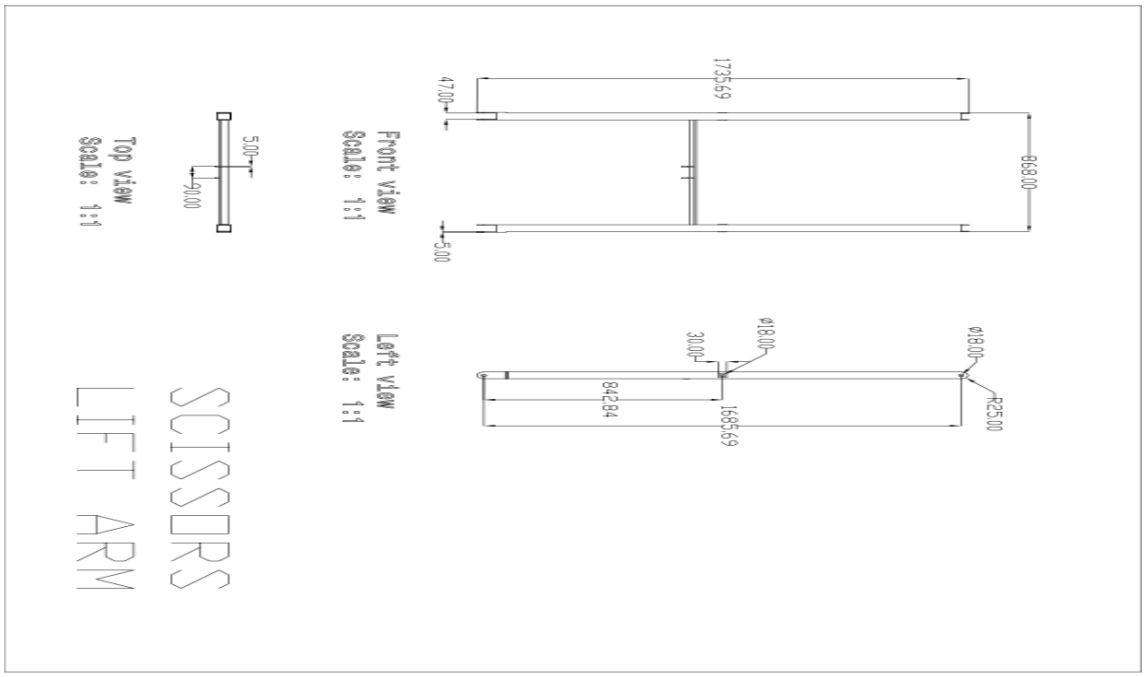


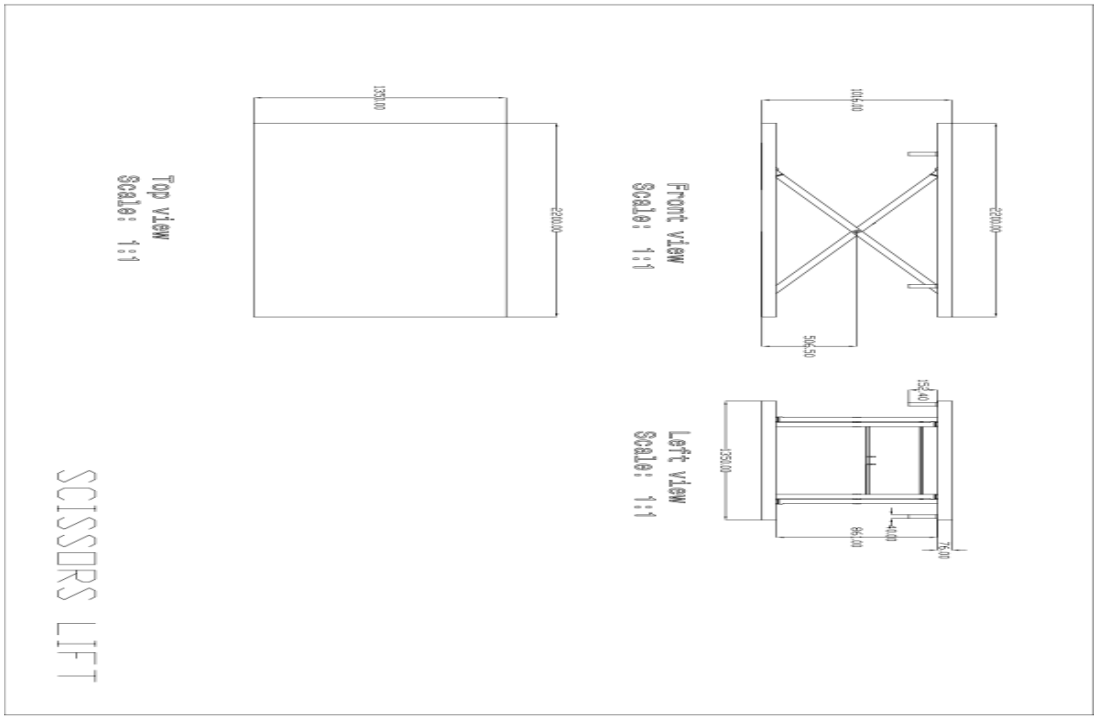

SCISSORS LIFT
BASE
Section view A-A
Scale: 1:1
Front view
Scale: 1:1
Left view
Scale: 1:1
120
100
70
148
507
10
2200
76
1350

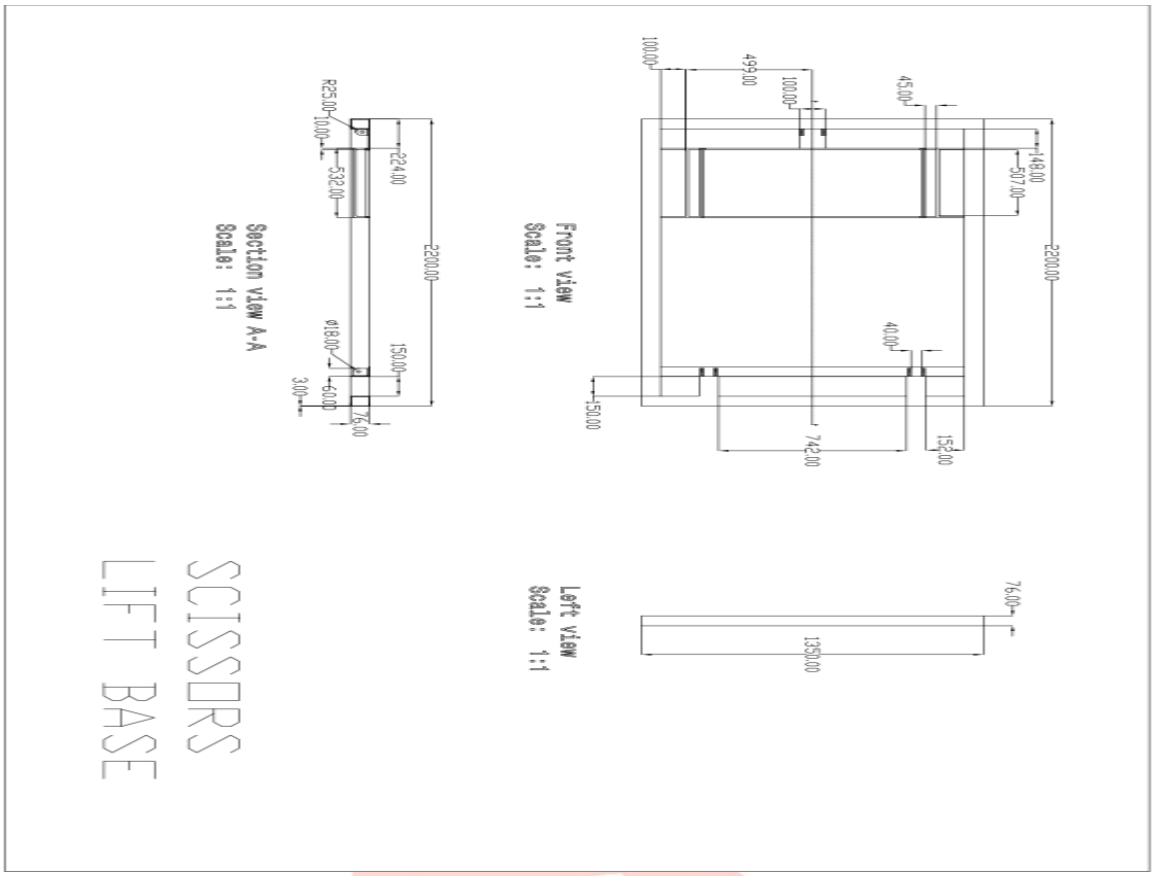

SCISSOR LIFT
FLOOR
Section view A-A
Scale: 1:1
Front view
Scale: 1:1
Left view
Scale: 1:1
70
10
148
440
398
1460
1350
1234
81
150

6.2 SCISSOR LIFT AFTER MODIFYING DESIGN:

6 Drafting:






SCISSORS
LIFT BASE
Section view A-A
Scale: 1:1
Front view
Scale: 1:1
Left view
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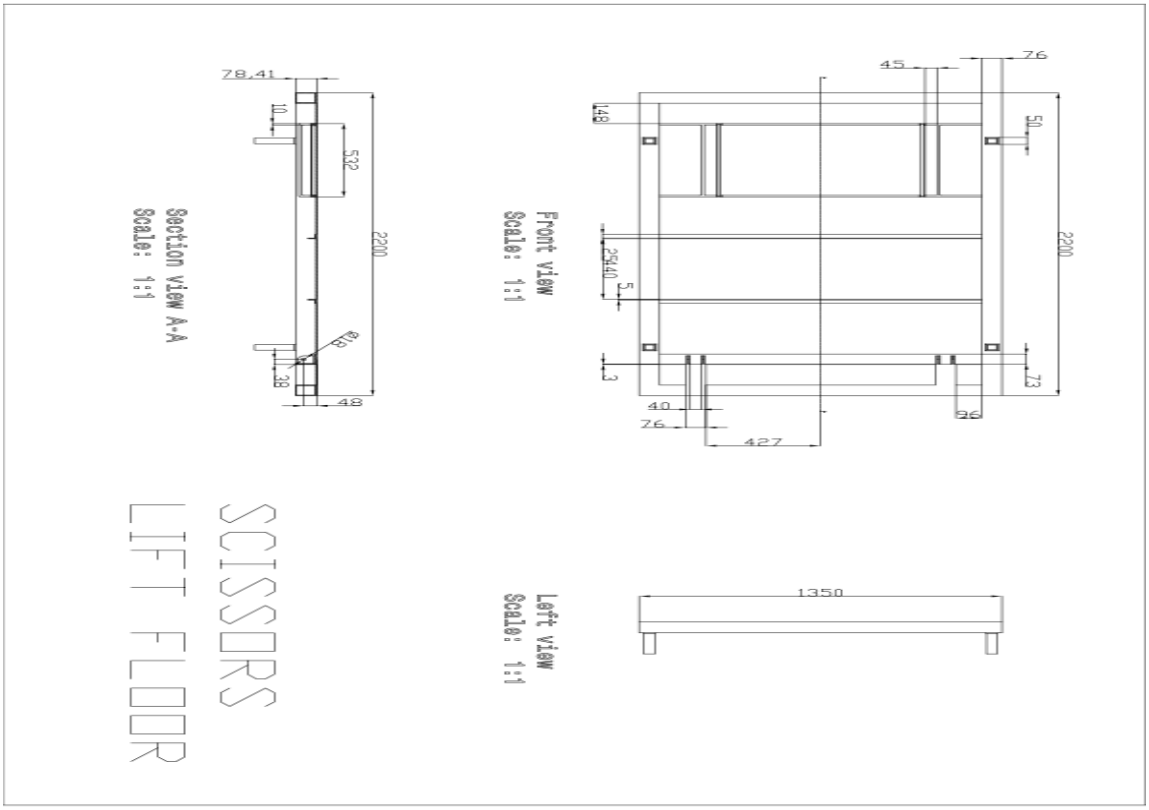
SCISSORS
LIFT FLOOR
Section view A-A
Scale: 1:1
Front view
Scale: 1:1
Left view
Scale: 1:1
78.41
10
532
2200
38
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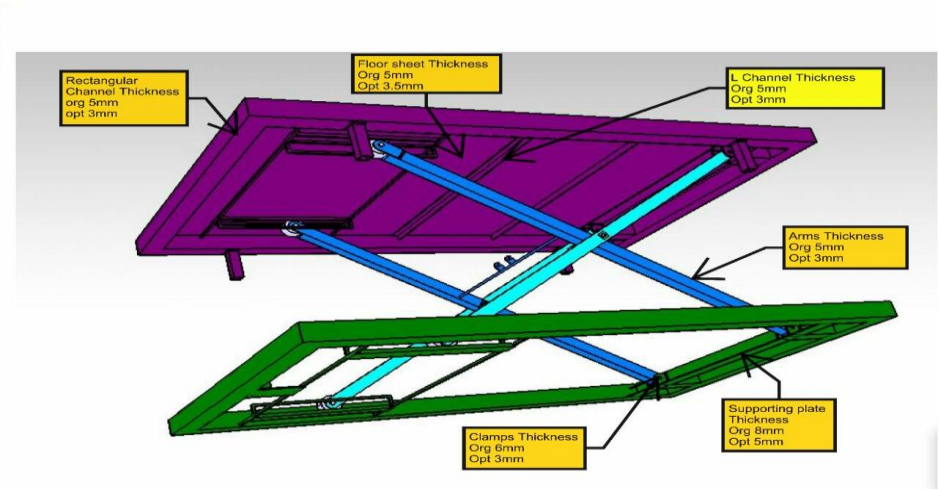
50
2540
5
3
73
40
76
427
1350

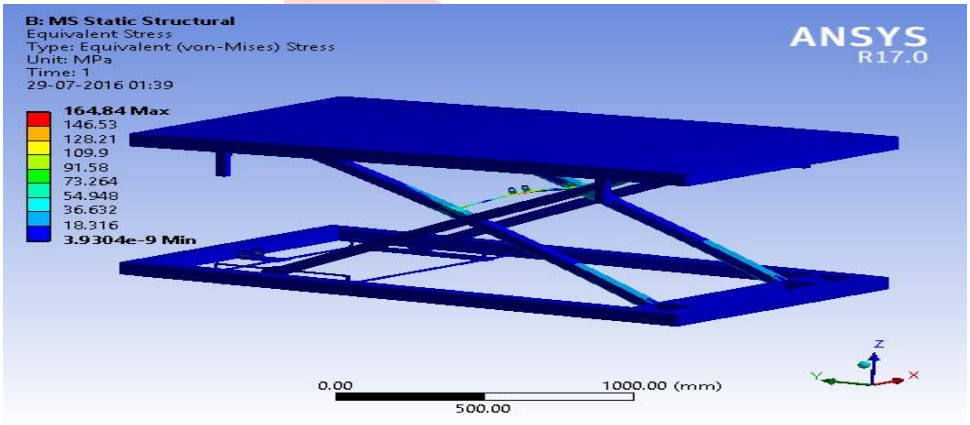
6.3 SUMMARY FOR OPTIMIZATION OF DESIGN:



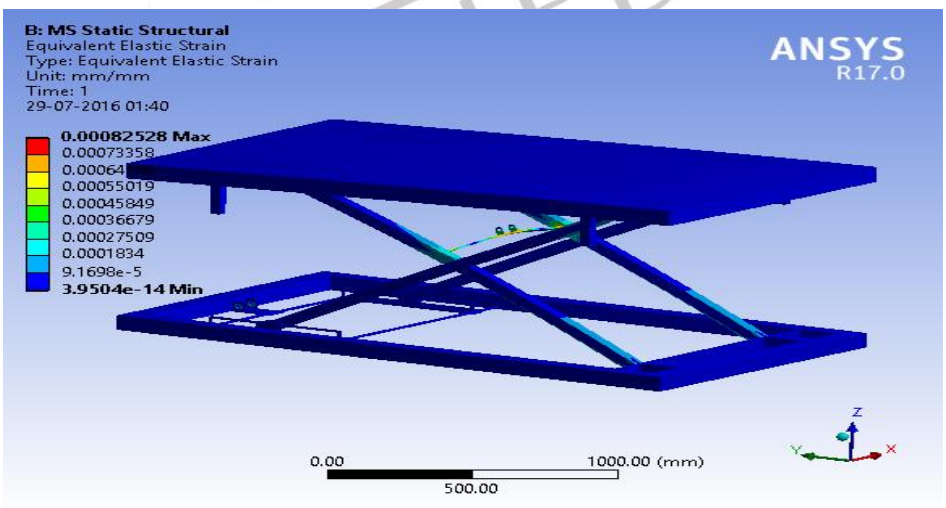
6. ANALYSIS OF LIFT AFTER MODIFYING DESIGN:

6.2 STATIC ANALYSIS: Material: MS

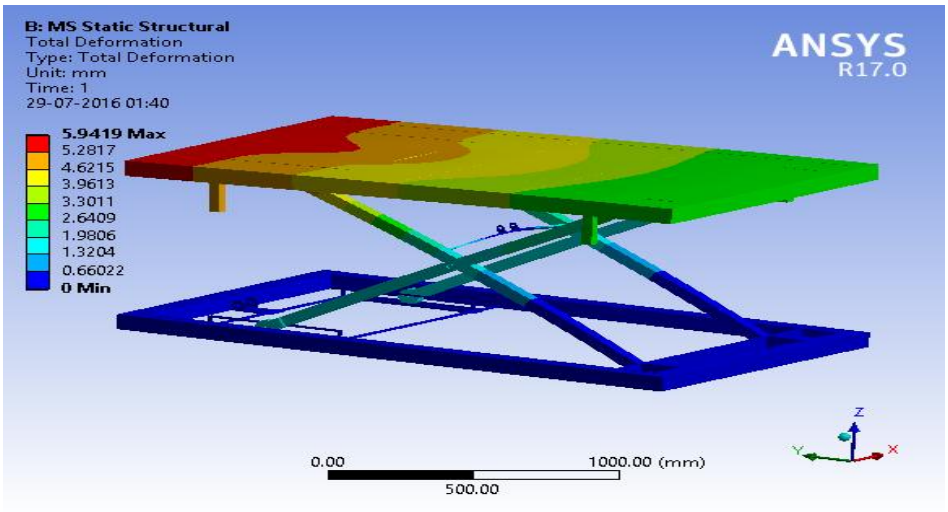
- **VON-MISES STRESS:**



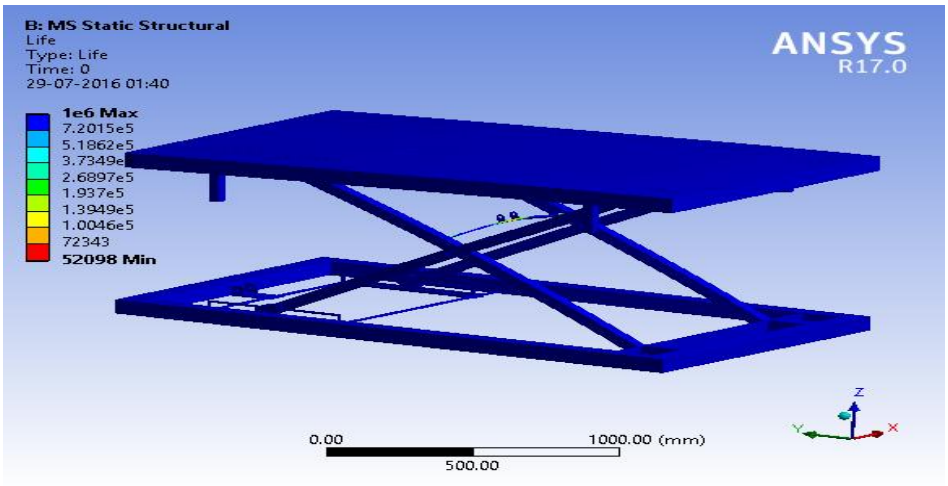
- **VON-MISES STRAIN**



- **TOTAL DEFORMATION**

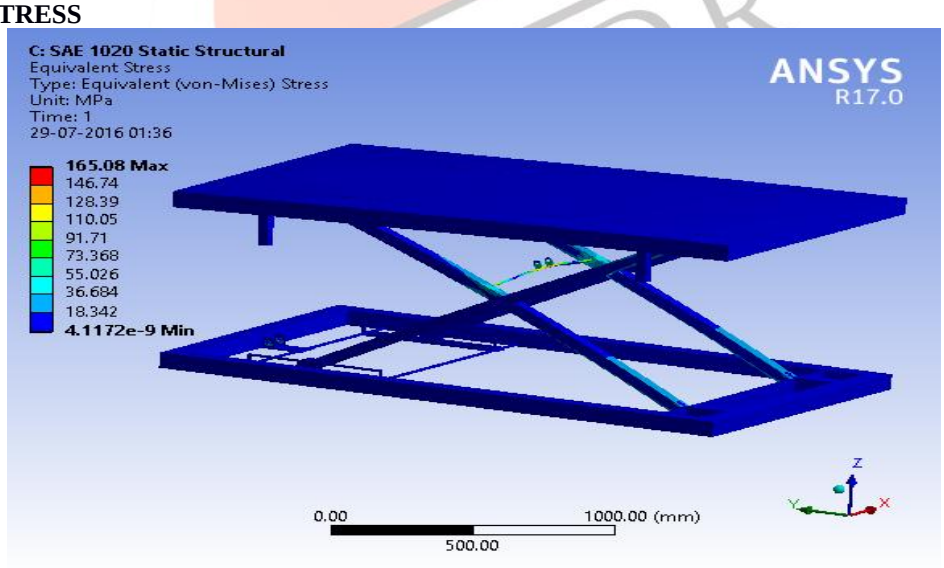


6.3 FATIGUE ANALYSIS

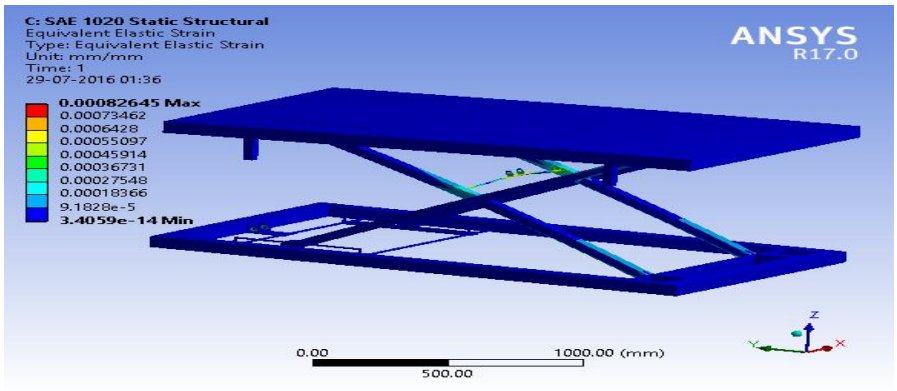


6.4 STATIC ANALYSIS OF SAE 1020 LIFT:

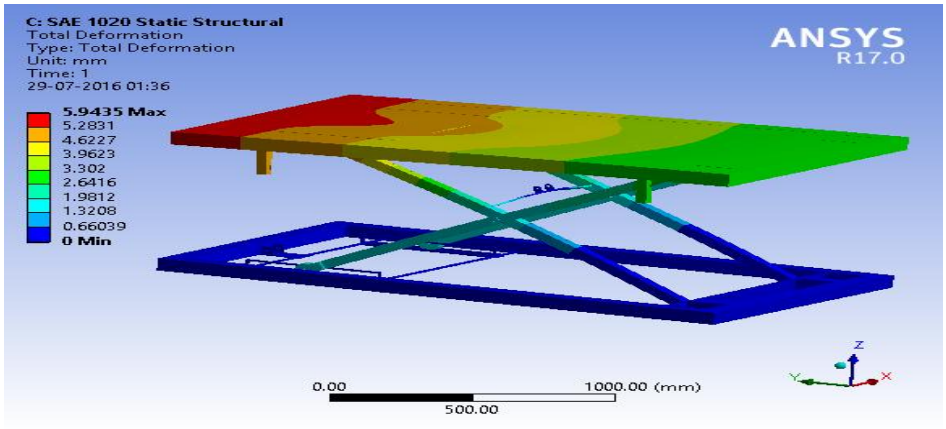
- **VON-MISES STRESS**



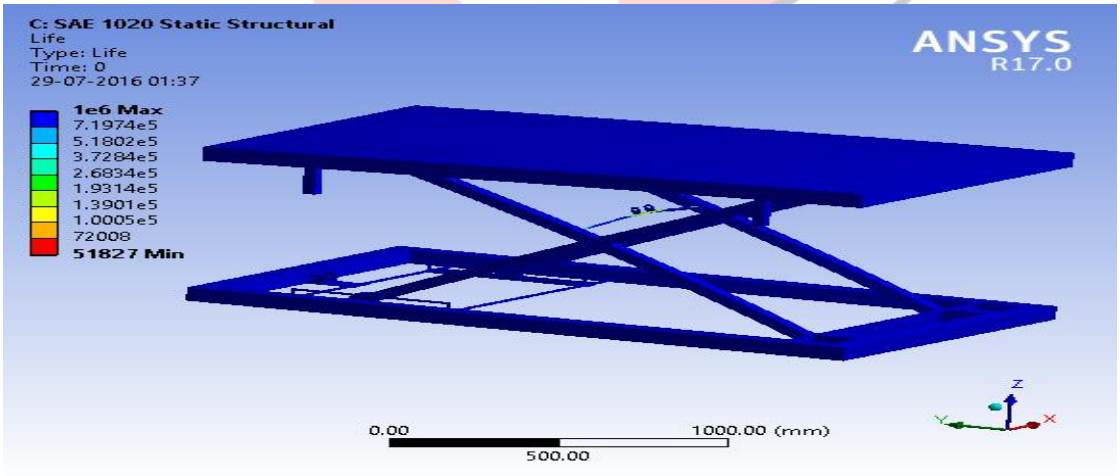
- **VON-MISES STRAIN:**



- **TOTAL DEFORMATION**

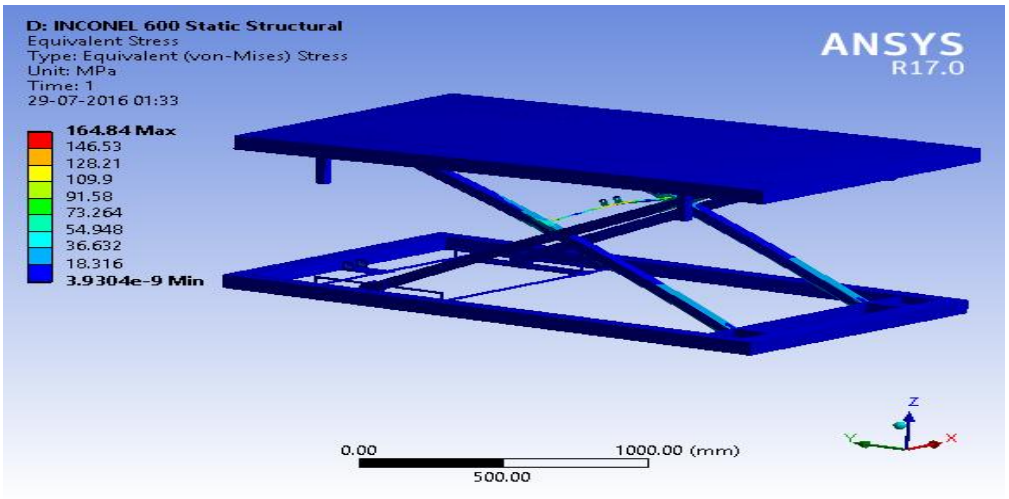


6.5 FATIGUE ANALYSIS

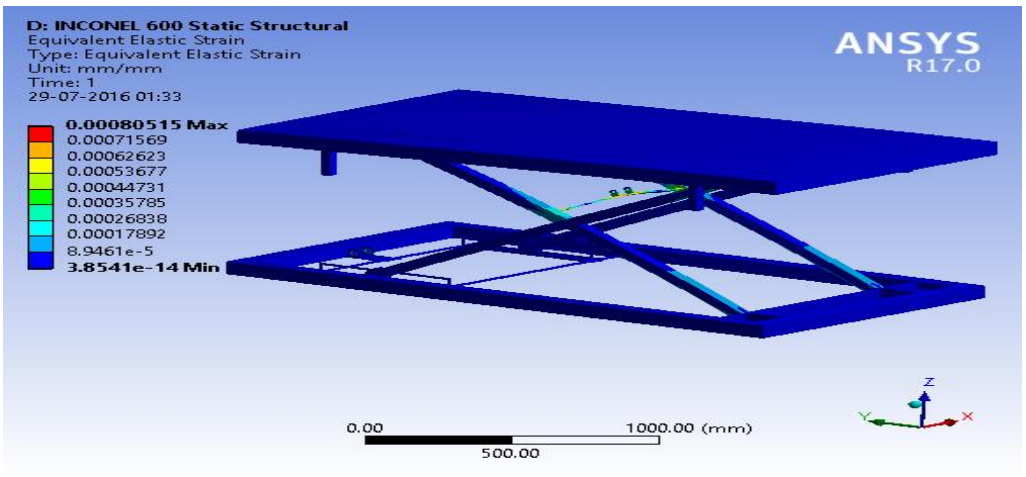


6.6 STATIC ANALYSIS OF INCONEL 625 LIFT:

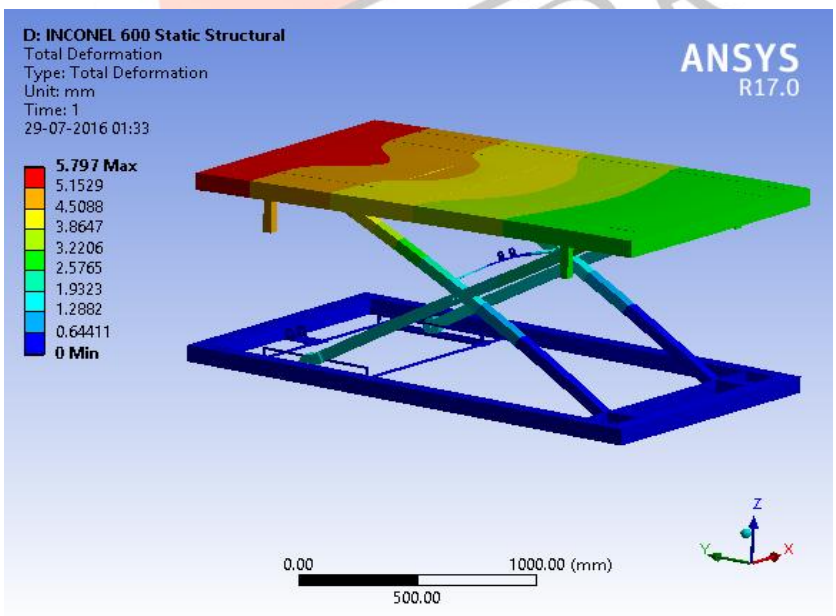
- **VON-MISES STRESS**



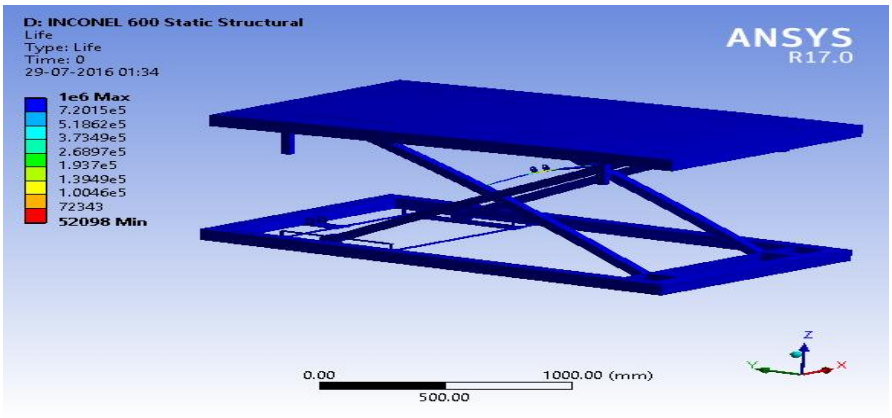
- **VON-MISES STRAIN**



- **TOTAL DEFORMATION**



6.7 FATIGUE ANALYSIS



6.8 RESULT TABLE:

MATERIAL ⟶	MS	SAE1020	INCONEL 625
STRESS (MPa)	164.84	165.08	164.84
STRAIN	8.25E-04	8.26E-04	8.05E-04
DEFORMATION (mm)	5.94E+00	5.94E+00	5.80E+00
WEIGHT (kg)	291.97	292.57	298.16
MINIMUM FATIGUE LIFE (CYCLES)	52098	51827	52098

The maximum deformations induced in MS hydraulic lift is 5.96mm, which is in safe limits (1% of total span). Hence based on rigidity the design is safe, but if we compare deformations induced in SAE1020 (5.94), it is same as MS. If we compare corresponding deformations in Inconel it is 5.80 mm which has less deformation. The equivalent stress induced for three materials is almost same i.e. 28.924 Mpa, 29.003 Mpa, 28.924 Mpa which is less than the allowable stress (380Mpa).Hence the design is safe based on strength. Corresponding weight of each lift are shown in above table. By modifying design weight of the MS lift is optimized compare to other lift. Fatigue life of MS lift (52098 Cycles-7.5 yrs) also increased by modifying design of lift. Failure of lift at localized area as discussed in problem statement improved by modifying the design of lift as shown in above figures. On optimization it is clear that MS lift shows good results as compared to other two lift, hence MS lift is suggested for manufacturing to said industry.

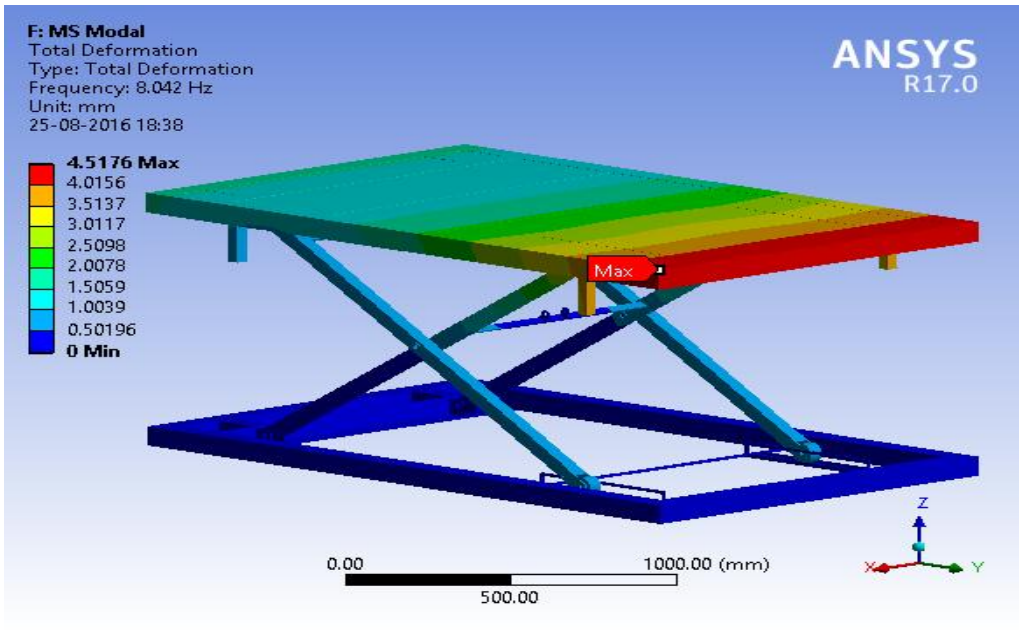
7 MODAL ANALYSIS OF LIFT AFTER MODIFYING THE DESIGN:

- **Procedure For Modal Analysis In ANSYS:**

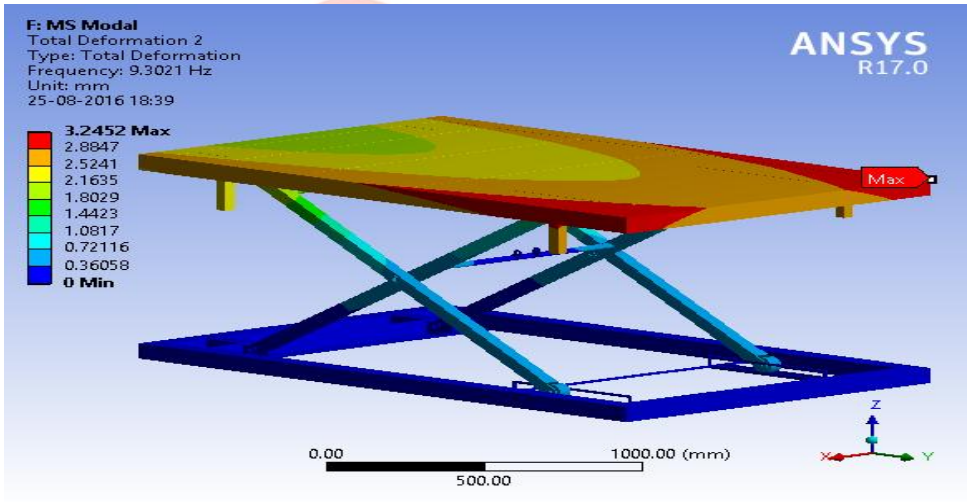
1. Build the FE model explained in chapter 5
2. Define the material properties such as young's modulus and density etc
3. Apply boundary conditions
4. Enter the ANSYS solution processor in which analysis type is taken as modal analysis, and 'by taking mode extraction method, by defining number of modes to be extracted. Solution method is chosen as Block lanczos method.
5. Solve the problem using current LS command from the tool bar.

- **MATERIAL: MILD STEEL (MS)**

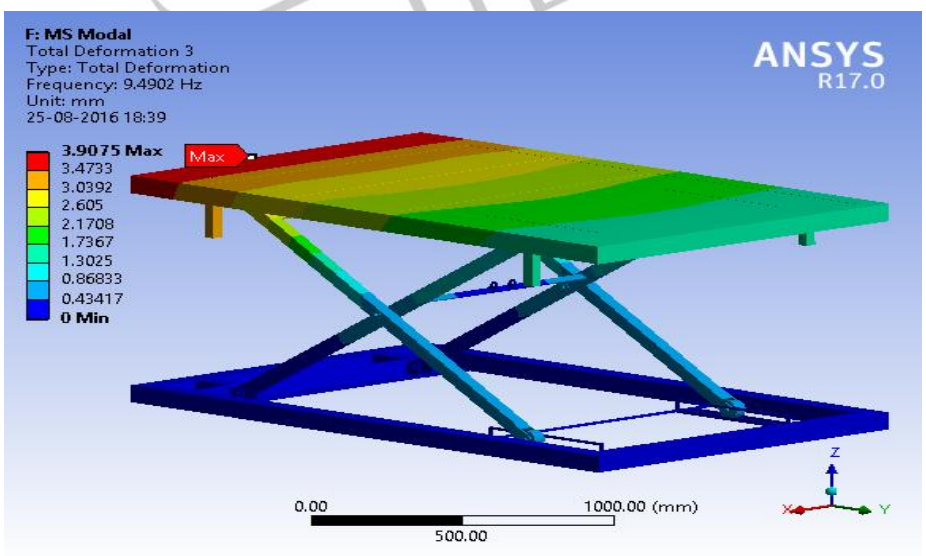
1ST Mode:



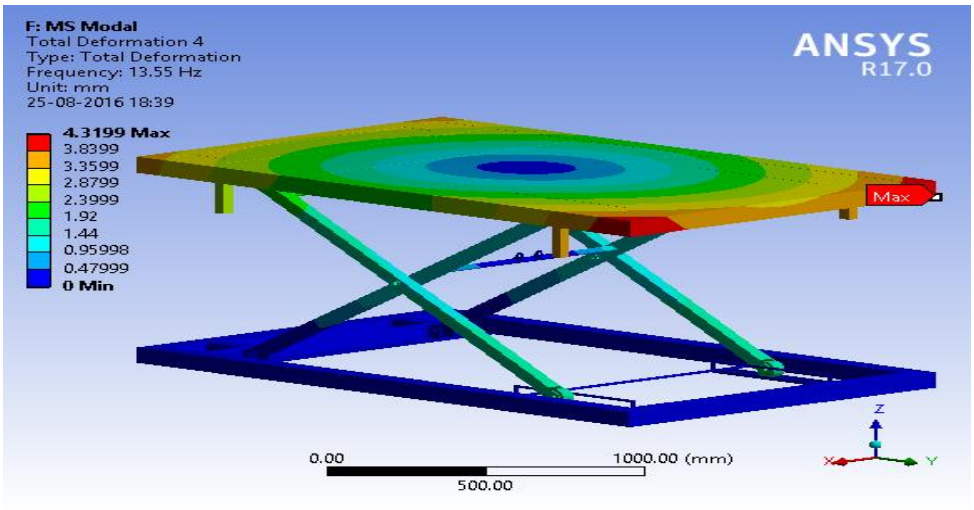
2nd Mode:



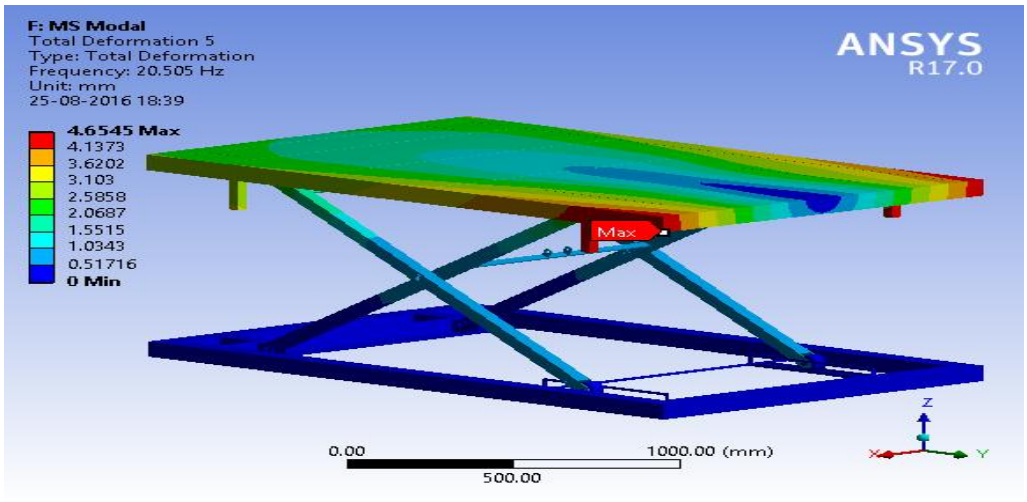
3rd Mode:



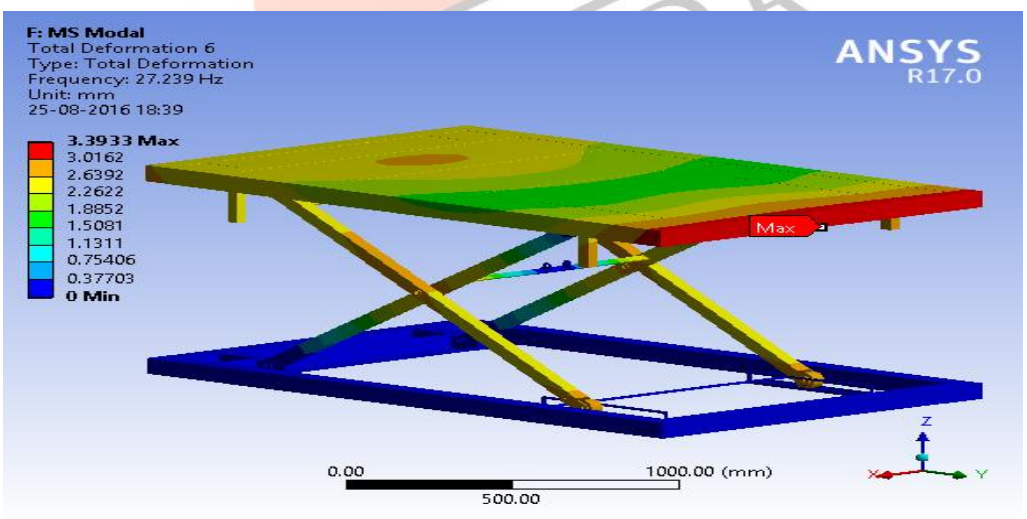
4th Mode:



5th Mode:

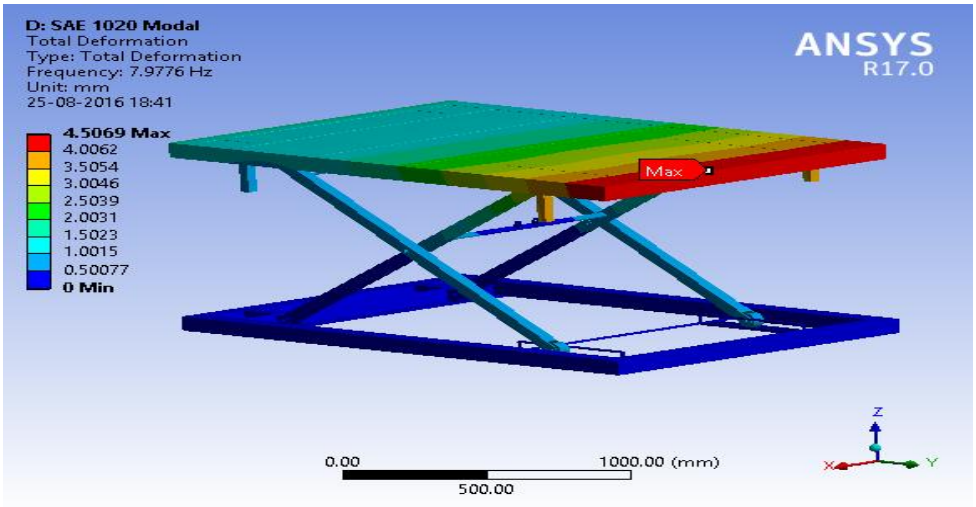


6th Mode:

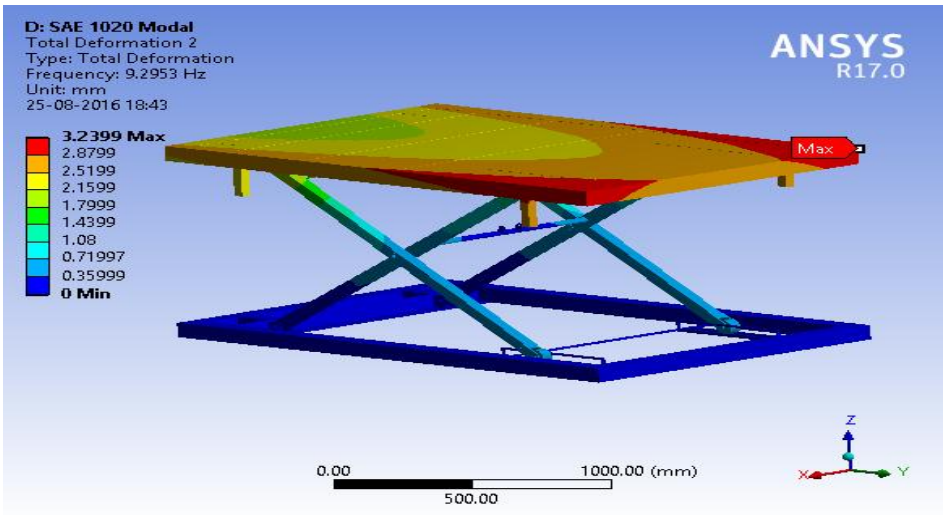


- **MATERIAL: SAE 1020**

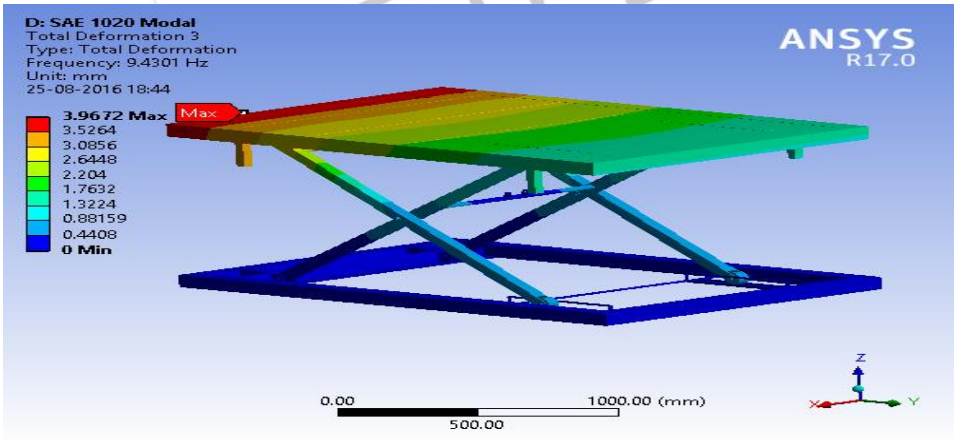
1ST Mode:



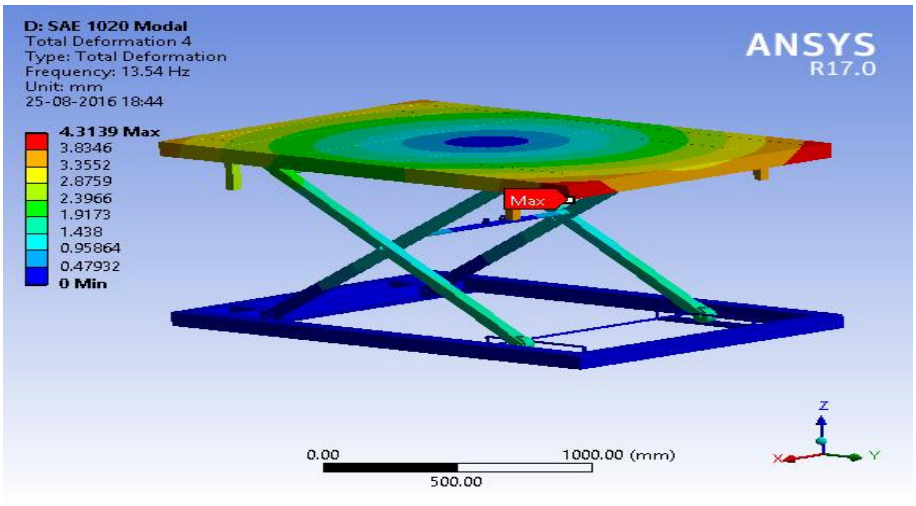
2nd Mode:



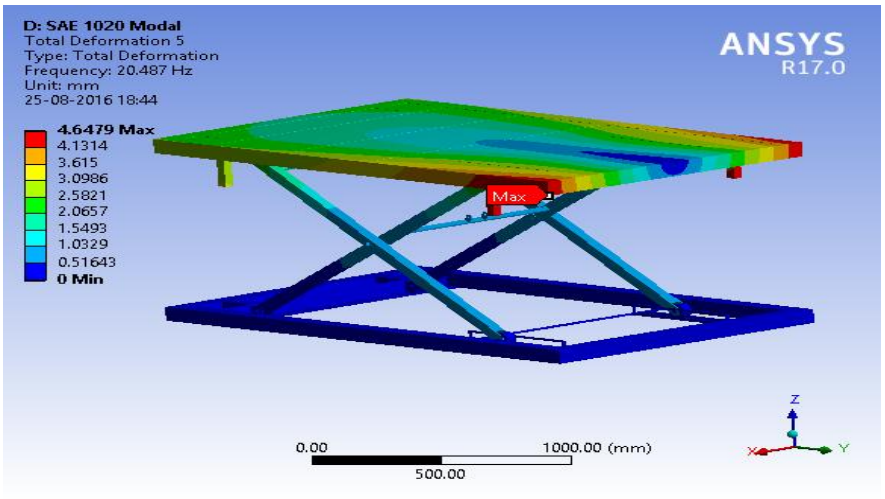
3rd Mode:



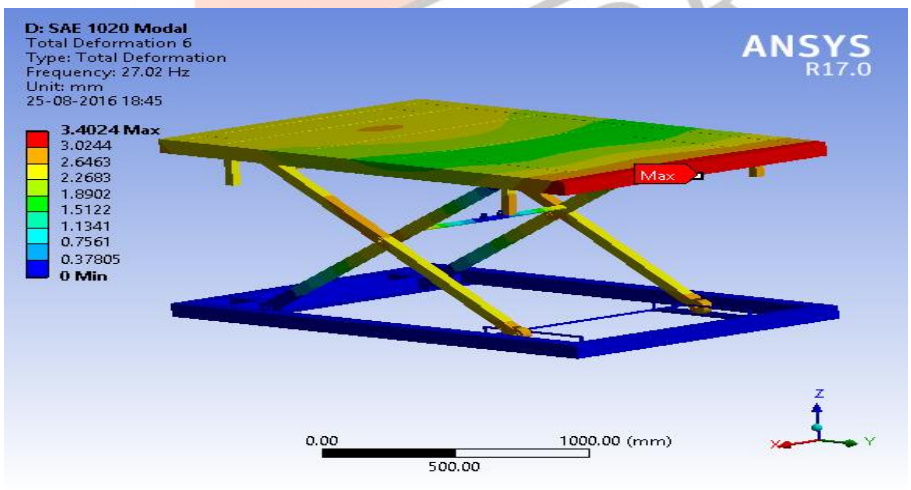
4th Mode:



5th Mode:



6th Mode:



7.1 RESULT TABLE:

No. of Modes	Natural frequencies of MS Lift in Hz	Natural frequencies of SAE 1020 Lift in Hz
1	8.042	7.9776
2	9.3021	9.2953
3	9.4902	9.4301
4	13.55	13.54
5	20.505	20.487
6	27.239	27.02

The natural frequency of MS Lift does not match with frequency of external excitation, which causes resonance. But natural frequencies of SAE 1020 match with frequency of external excitation; hence there will be resonance which will causes severe vibrations. The detail modal analysis which has been done in ANSYS 16 with its sequential mode shapes are as shown in above figures. If we compare corresponding deformations of each mode shape MS lift has less deformation so less chance of failure of lift parts.

8. CONCLUSIONS:

1. Weight of the hydraulic scissor lift optimized on modifying existing design.
2. As loading and unloading is repeated fatigue failure is checked and hence life of the hydraulic scissor lifts.
3. Deformations induced in MS lift are less as compared to SAE 1020 lift and Inconel 625 hence failure of lift minimizes
4. On modifying the design of lift i.e. reducing thickness of ribs, plates, and adding proper channels for the support as described in chapter 6.2, strength and weight of the lift optimized.
5. As natural frequency of modified lift does not match with external excitation frequency hence no vibrations.
6. After modification of lift failure at surface as shown in problem statement get minimized.
7. SAE 1020 material also gives good results; this material is also suitable for fabrication of scissor lift.

9. REFERENCES:

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