# DESIGN AND BUCKLING ANALYSIS OF MULTISTAGE HYDRAULIC LIFTER

**Sachin Wangikar[1], Ashish Patil [2], Sangam Patil[3]**

*[1] Assistant Professor, Department of Mechanical Engineering, Shaikh College of Engineering and Technology, Belgaum, Karnataka, India*
*[2] Assistant Professor, Department of Mechanical Engineering, Shaikh College of Engineering and Technology, Belgaum, Karnataka, India*
*[3] Assistant Professor, Department of Mechanical Engineering, Shaikh College of Engineering and Technology, Belgaum, Karnataka, India*

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**Abstract -** ***Design & Buckling analysis of multistage hydraulic lifter is very complex phenomenon that involves various interactions between the two stages. Depending upon different configurations of the cylinder, one of the failure modes of the hydraulic lifter is buckling. The cylinders tend to buckle which are generally large in length, and cause lateral deflections. In this work, buckling loads on the cylinder under axial loading condition is investigated using analysis and theoretical approaches. Multistage cylinders require careful design as they are subjected to large side forces especially at full extension. Initially the stresses are computed which are acting on both the stages of the lifter, as well as the buckling load is calculated theoretically. The stiffness effect on the lifter is determined and it was found that on applying the load of 60KN, the oil in the lifter gets compressed by 35.6mm. The stresses obtained from the theoretical calculations were found to be within the safe limits.***

***Key Words:*** *Two stage hydraulic lifter, buckling, Oil, Stress, deflection, loads, and supports.*

## 1. INTRODUCTION

Structural efficiency is the primary concern in most of the industries of the hydraulic lifter. This brings about the need for strong and light weight materials. Due to their high specific strength they do find wide applications. The advantage of multi stage cylinders is that they extend to an overall length that is longer than their retracted length.
This enables them to provide a very long output stroke from a very short retracted length in one combined actuator. A multistage hydraulic lifter shown in Fig-1 below comprises mainly of three parts which are barrel, hollow cylinder and solid piston rod. The oil gets filled into barrel and the hollow cylinder and keeps on exerting the pressure to carry out the extraction stroke. Single acting multistage cylinders are the simplest and have most common design. As with a single acting rod style cylinder, the single acting multistage cylinder is extended using hydraulic pressure but retracts using external forces when the fluid medium is removed and relieved to the reservoir.

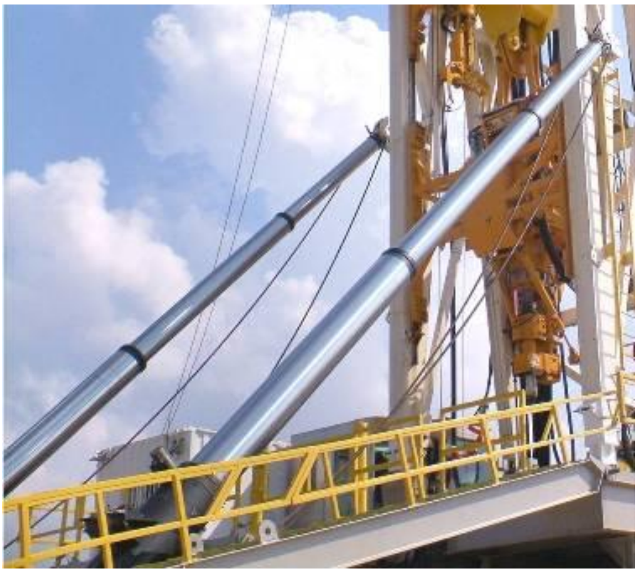

**Fig -1**: Multistage hydraulic lifter

The maximum available force output of any multistage cylinder is limited to the effective area of its smallest stage. Because of their long length when fully extended multistage cylinders must be very carefully designed. A poorly designed multistage actuator will wear out quickly in the field and cause a machine failure. It may even buckle and collapse causing a dangerous catastrophic failure of the machinery. A single acting two stage hydraulic cylinder employs hydraulic force in only one direction, usually to extend the cylinder.

## 2. DESIGN CONSIDERATIONS

Hydraulic cylinders must be used in a way that avoids side loads from pushing on the actuator. Side loads will cause excessive wear and a decreased service life. In extreme cases, a catastrophic failure could occur such as when the cylinder buckles in service. This is even more critical in the use of multistage cylinders. The long extended body length of a multistage cylinder makes them very susceptible to side forces .For this reason, a multistage actuator must only be used as a force generating device and never as a stabilizing structural component. Features taken into consideration while designing a two stage hydraulic lifter are as follows

- The lifter is operated for 30MPa non-shock pressure.
- The hydraulic lifter is designed for easy maintenance.
- All stages have hard chrome on the outer surface to resist corrosion.
- The tube of each stage is re-enforced by the gland and piston, making the stages considerably stronger.
- A multistage lifter should be designed to use the fewest number of stages, for economy and strength.

## 2.1 Objective

Buckling plays an important role in failure of cylinders. Cylinders are subjected to various types of stresses and transient loads. Failure results into performance degradation of the cylinders and sometimes leads to complete failure causing huge loss to the company in terms of money and time. The buckling load and stresses need to be identified during performance of lifter. The result obtained from finite element analysis has to be validated with the results of theoretical calculations.

## 2.2 Scope of Work

Determination of resultant stresses and deflection gives information about the failure regions of hydraulic system, and this information helps in controlling failure by designing the lifter in correct way to minimize stresses developed in lifter. The study of stresses and deflection gives the effect of load on the object being applied. It also gives the indication of the load at which the lifter is supposed to buckle.

## 3. THEORETICAL CALCULATIONS

The two stage hydraulic lifter is considered to be fixed at one end and free at the other end as that of the cantilever beam. We have to determine the maximum stresses, deflection and the buckling load for the lifter. Initially we need to find out the pressure and hoop stress acting on the lifter. As we know that the weight to be lifted by the two stage hydraulic lifter is 60KN. Also the dimensions are been given by the customer for both the stages, considering these dimensions the calculations are carried out. The theoretical calculation was carried out for two stage hydraulic lifter which is shown in Fig-2.

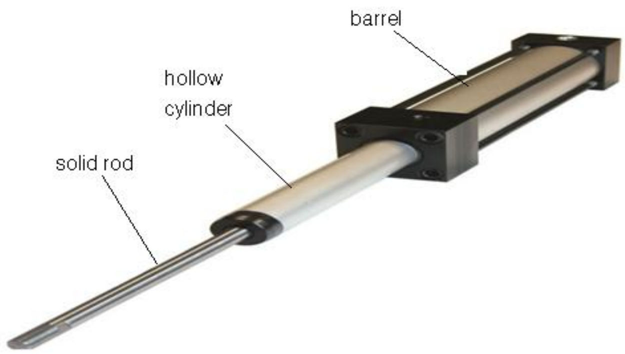


**Fig -2**: Two stage lifter

From theoretical calculation the results found are shown in the Table-1.

**Table -1:** Theoretical results of two stage hydraulic lifter

| STAGES | Pt's | BENDING STRESS In MPa | COMP STRESS in MPa | SHEAR STRESS in MPa | HOOP STRESS in MPa | VON MISES in MPa |
|---|---|---|---|---|---|---|
| STAGE -2 (Solid rod) | A | 480 | -30.55 | 0 | 0 | 449.5 |
| | B | 0 | -30.55 | 5.388 | 0 | -25.12 |
| | C | -480 | -30.55 | 0 | 0 | -510.5 |
| STAGE-1 (OUTER FIBER) | $A_{o1}$ | 475.4 | 0 | 0 | 84.12 | 439.4 |
| | $B_{o1}$ | 0 | 0 | 24.66 | 84.12 | 72.46 |
| | $C_{o1}$ | -475.4 | 0 | 0 | 84.12 | 522.1 |
| (INNER FIBER) | $A_{i1}$ | 363.18 | 0 | 0 | 114.12 | 344.5 |
| | $B_{i1}$ | 0 | 0 | -24.66 | 114.12 | 138.4 |
| | $C_{i1}$ | -363.18 | 0 | 0 | 114.12 | 449 |
| BARREL (OUTER FIBER) | $A_{o2}$ | 411.4 | 0 | 0 | 136.4 | 363.0 |
| | $B_{o2}$ | 0 | 0 | 19.033 | 136.4 | 140.2 |
| | $C_{o2}$ | -411.4 | 0 | 0 | 136.4 | 493.9 |
| INNER FIBER | $A_{i2}$ | 342.9 | 0 | 0 | 166.33 | 323.0 |
| | $B_{i2}$ | | 0 | -19.033 | 166.33 | 186.1 |
| | $C_{i2}$ | -342.9 | 0 | | 166.33 | 444.8 |

## 4. FINITE ELEMENT METHOD

First geometric model of two stage hydraulic lifter was prepared in CATIA V5 then meshing and boundary conditions where applied using Ansys and finally static analysis was carried out on the FEA model.

## 4.1 Geometric Modeling

The lifter is shown in fully extended position, and is used to lift heavy loads. The following Fig-3, illustrates the

CATIA assembly model of the two stage hydraulic lifter established by using the individual CATIA part models. The assembly model of lifter shows both the stages, including barrel, loading bracket as well as the base plate connected with each other and held in proper positions.

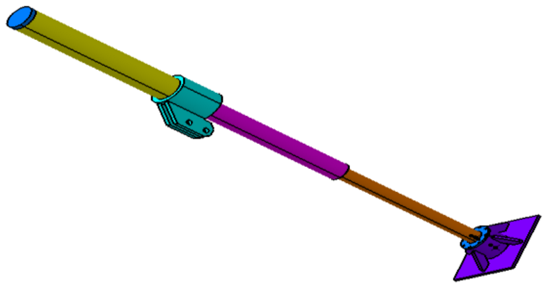

**Fig -3**: Isometric view of two stage hydraulic lifter

### 4.2 Meshing and Boundary Conditions

Meshing is carried out on the entire lifter, considering each part. The fine mesh is carried out on the loading bracket using tetrahedron element for meshing, as it has 4 holes on it, where the area suddenly reduces and there more chances that the component may fail in this region. The rest part of the lifter is provided with coarse mesh, using the same tetrahedron element. The entire lifter assembly is meshed in order to obtain the results to greater accuracy. The Fig-4 shows meshed model of two stage hydraulic lifter assembly.

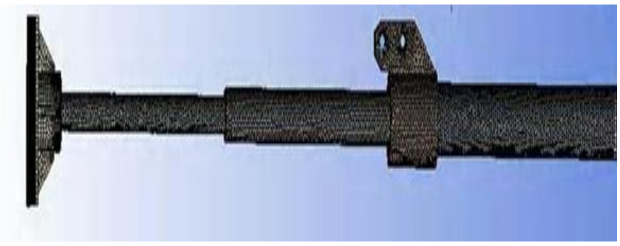

**Fig -4**: Meshed model of two stage hydraulic lifter

Multistage hydraulic lifter is analyzed with the boundary conditions applicable for cantilever structure. The barrel has the loading bracket on it where the lifter is considered to be pinned by two pins or fixed at that point. The violet color indicated on the loading bracket in the image below shows that it is constrained at that particular region. The load is to be applied on the base plate of the lifter, in order to carry out the analysis. The complete area of the base plate is selected in order to apply the axial load of 60KN. The Fig-5 below shows the boundary conditions applied.

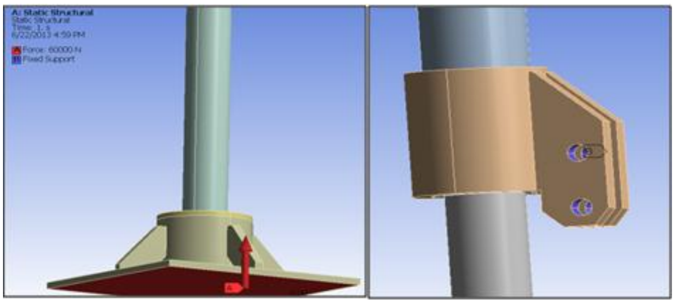

**Fig -5**: Boundary conditions

### 5. RESULTS AND DISCUSSIONS

Model analysis is carried out to determine the stress and the buckling behavior characteristics of a structure or a machine component while it is being designed. The structure is considered to be fixed at one end and free at the other, as that of cantilever beam. The von mises stresses, deflection and the buckling results are shown for the particular parts.

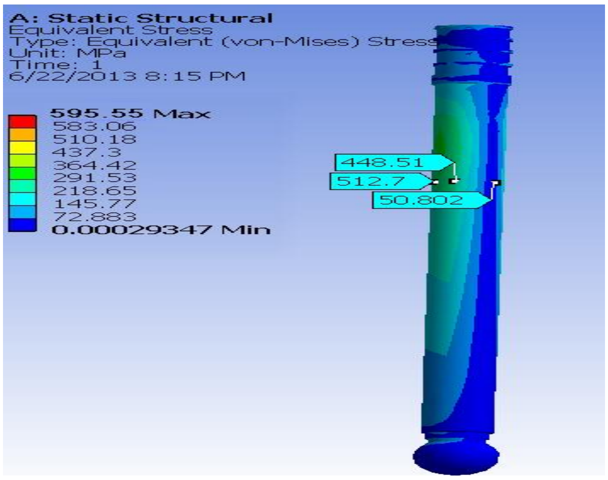


**Fig -6**: Von mises stress on the solid rod

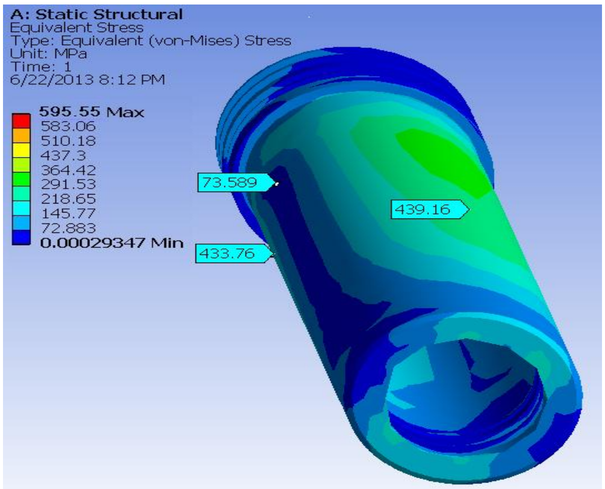


**Fig -7**: Von mises stress on the hollow cylinder

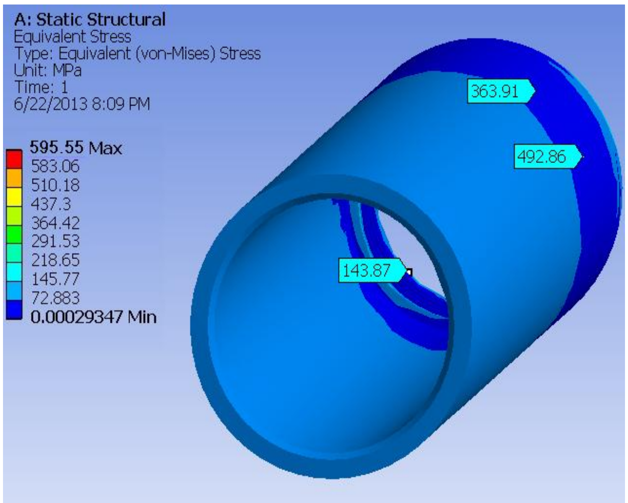


**Fig -8**: Von mises stress on the barrel

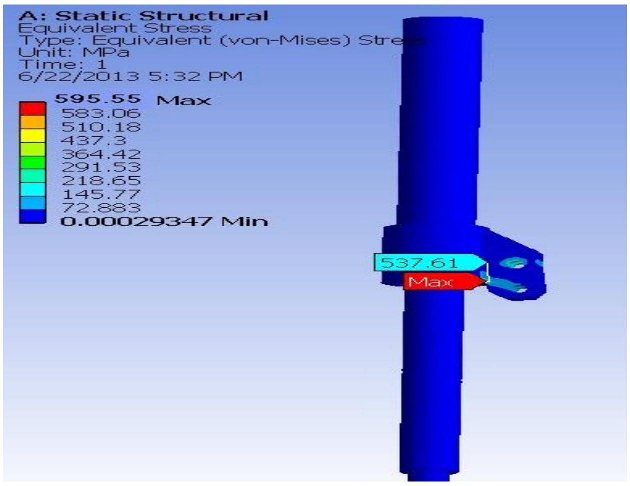


**Fig -9**: Von mises stress on the loading bracket

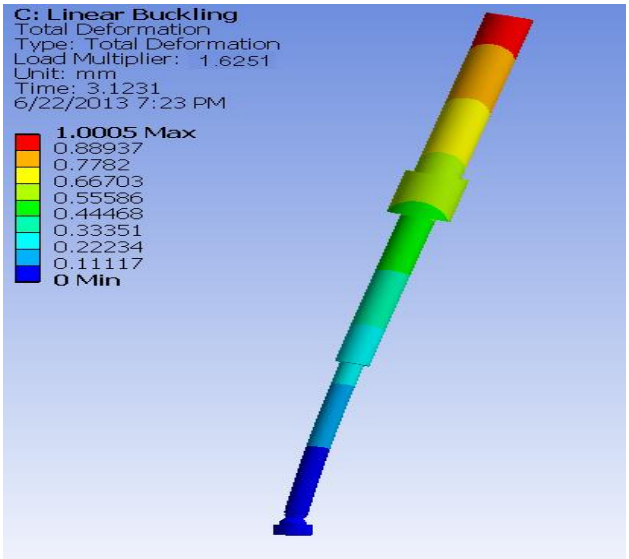


**Fig -10**: Linear Buckling Analysis

The results of various parts of a two stage hydraulic lifter shown in Fig- 6, 7, 8, 9 are mentioned in the Table-2.

**Table -2:** Von-mises stresses

| SI.NO | Parts | Von-mises stress (Mpa) |
|---|---|---|
| 1 | Solid Rod | 512.7 |
| 2 | Hollow Cylinder | 439.16 |
| 3 | Barrel | 492.36 |
| 4 | Loading Bracket | 537.61 |

The buckling analysis is carried out on the two stage hydraulic lifter. The lifter is supposed to buckle at a load of 1.6251 times more than that of load applied on it as indicated from the figure below. Therefore as we are applying the load of 60KN, it will buckle at a load of 97.5KN. Therefore the design of the lifter is safe.

According to rigidity criterion the maximum deflection should not exceed the specified value .Excess of deflections in the cylinders may result in cracks .Deflection in lifter should be limited to very small values; otherwise it may lead to catastrophic failures. The lifter undergoes deflection due to bending moment and shear force. From the below Fig-11 we get to know that maximum deflection of 37.111 occurs at end of the solid rod.

This deflection result is less than the allowable deflection for the lifter length as per structural standards.

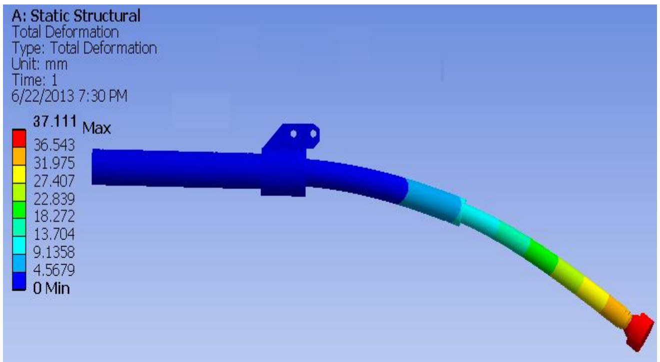


**Fig -11**: Deflection due to side force

## 6. CONCLUSION

The results obtained from the theoretical calculations and the analysis for the two stage hydraulic lifter is found to be within the safe limits.

- The maximum stress of 537.6MPa is developed on the loading bracket. This is the component which is bearing the higher stress because the entire load of the lifter gets transferred to the loading bracket, as it is fixed at that point.

- The maximum deflection of 37.111 mm occurs at the end of the solid rod. This deflection occurs due to the side load coming on the lifter.
- The buckling load developed is 1.6251 times more than the load applied. As we are applying the load of 60KN on the lifter and it is supposed to buckle at 97.5KN.
- All the factors obtained are found to be within the desired limit; therefore the design of two stage hydraulic lifter is safe.

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