Structural Analysis of Piston-Cylinder Assembly for Light Load Hydraulic Operations

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Abstract— The hydraulic system is mostly used when the power requirement is high. The system is comparatively too large for light load hydraulic operations. The paper represents the use of hydraulic piston-cylinder assembly for lifting the light load. The whole structure dimensions and design is considered as per the loading conditions. The structural and linear buckling analysis has been successfully completed for the structure design.

Key word: piston-cylinder assembly, light load hydraulic operations, hydraulic stand, hydraulic accumulator

I. INTRODUCTION

Hydraulics is the branch of engineering concerned mainly with moving liquids. The term is generally applied to the study of the mechanical properties of water, other liquids, and even gases when the effects of compressibility are small. The whole study can be divided into two parts 1) hydrostatics and 2) hydrokinetics. Hydrostatics, the consideration of liquids at rest, involves problems of buoyancy and flotation, pressure on dams and submerged devices, and hydraulic presses. The relative incompressibility of liquids is one of its basic principles. Hydrodynamics, the study of liquids in motion, is concerned with such matters as friction and turbulence generated in pipes by flowing liquids, the flow of water over weirs and through nozzles, and the use of hydraulic pressure in machinery.

A hydraulic accumulator is a device that stores the potential energy of an incompressible fluid held under pressure by an external source against some dynamic force. This dynamic force can come from different sources. The stored potential energy in the accumulator is a quick secondary source of fluid power capable of doing useful work. It is a simple hydraulic device which stores energy in the form of fluid pressure. This stored Pressure may be suddenly or intermittently released as per the requirement. In the case of a Hydraulic lift or hydraulic crane, a large amount of energy is required when the lift or crane is moving upward. This energy is supplied from the hydraulic accumulator. But when the lift is moving in the downward direction, it does not require a huge amount of energy. During this particular time, the oil or hydraulic fluid pumped from the pump is stored in the accumulator for Future use.

II. BACKGROUND

G. K. Gangwar, Madhulika Tiwari, Ravi Bhusan Singh and K. Dasgupta [1] presents a paper on Study of Different Type of Hydraulic Accumulators, Their Characteristics and Applications. The paper gives the outline of the accumulator. Charles R. Siegel and Chai Hong Yoo [2] present a paper on Column Loadings on Telescopic Power Cylinders. The paper predicts the critical column loadings on telescopic power cylinders based on finite element displacement formulations. Jae Gyu Lee and Ock Hyun Kim [3] present a paper on Development of new hydraulic servo cylinder with mechanical feedback. Conventional hydraulic servo systems require highly accurate servo valves, sensors and controllers, to construct feedback loops. Their costs are relatively high, which may impose restrictions on their general applications.I. Marczewska, T. Bednarek, A. Marczewski, W. Sosnowski, H. Jakubczak and J. Rojek [4] present a paper on practical fatigue analysis of hydraulic cylinders and some design recommendation. Gianni Nicoletto and Tito Martin [5] present a paper on failure of a heavy-duty hydraulic cylinder and its fatigue re-designs with combined use of fracture mechanics concepts and of the finite element method. The failure studied in this paper is premature failure the paper is organized as follows: initially the hydraulic cylinder under investigation is presented in terms of structure, function, geometry, material, service load, fabrication, and design details that are critical under fatigue loading.

From this research work we can say that, the hydraulic piston cylinder accumulator is used for energy storage and also for emergency power source. Very high power can be generated from hydraulic system. The hydraulic accumulator can lift the high load with ease. The power can be optimized by optimization of parameters of hydraulic accumulators. The material optimization can improve the strength of the structure. Controlling the various parameters can give the better output. The fatigue analysis is necessary for the cylinder due to load effects on it. The Uniaxial loads calculations give the more structural value. The calculation of stress can be helpful to predict the premature failure of the cylinder. The internal pressure controlling is necessary for better performance and convenient work. The pressure pulsation can be controlled with the help of hydraulic accumulators.

III. DESIGN AND ANALYSIS

The hydraulic piston-cylinder assembly is to be used for lifting the load. Load to be lifted given by the industry named i-CUBE engineering solution is 150 kg.

We are calling this hydraulic piston-cylinder assembly system as HYDRAULIC STAND. A hydraulic stand stores the potential energy of an incompressible fluid held under pressure by an external source against some dynamic force. This dynamic force can come from different sources like pump. The stored potential energy in the piston cylinder assembly will be capable of doing useful work. It is a simple hydraulic device which stores energy in the form of fluid pressure. This stored Pressure may be suddenly or intermittently released as per the requirement. Thus the load is lifted with this arrangement.

The load predetermined for this work is 1500 N as per given by the i-CUBE Engineering Solutions. The following data is given by the industry for the required work.

Dimensions of the main components are as follows:

1) DIMENSIONS OF PISTON
 – Length 35 mm
 – Diameter 50 mm
2) DIMENSIONS OF CYLINDER
 – Height 250 mm
 – Internal diameter 50 mm
 – Thickness 3 mm
3) DIMENSIONS OF CONNECTING ROD
 – Length 300 mm
 – Diameter 20 mm

The design of assembly made in PTC CREO 2.0 is as below.

Fig. 1: design of the Piston-cylinder Assembly

The stroke length is taken as 150 mm. The load to be lifted is taken as 1500 N for the piston cylinder assembly. So the work done from the above calculation is 225 Nm. Hence for the time period of 4 seconds the power required will be 0.0754 hp. So the pump of 0.1 HP capacities will be used.

The design based on the dimensions is used in the CREO. Components are designed as parts. Cylinder, piston, end plates, connecting rods, mid-span, supporting rods etc are the parts designed. All the parts are assembled and the hydraulic piston-cylinder assembly is generated.

The further work is done in the ANSYS software. After the assembly designing work the first step to be done is generating the mesh and defining in the structure.

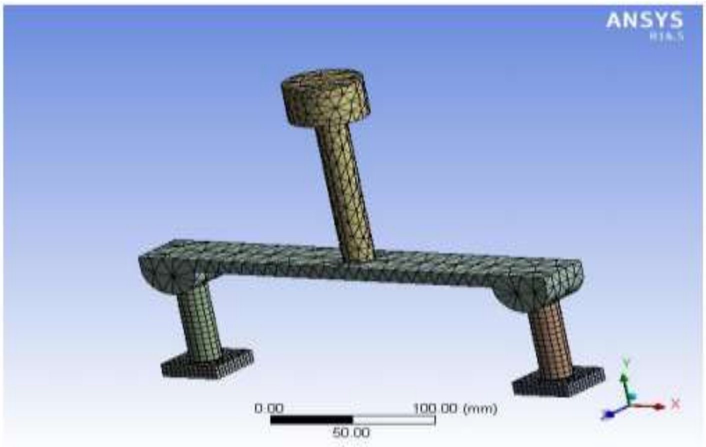

Fig. 2: Mesh Generation

The above figure shows the mesh generation in the structure done in ANSYS software. As per the ANSYS statistics there are 13099 nodes and 3640 elements in the mesh.

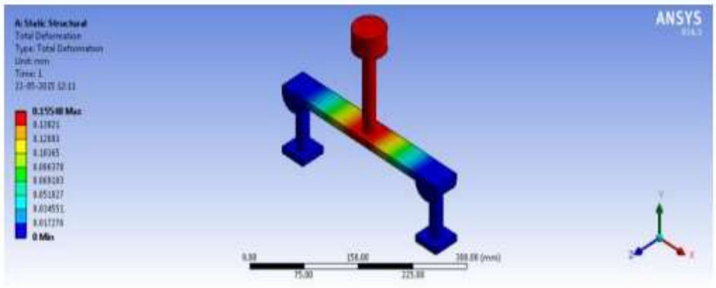

Fig. 3: structural analysis (total deformation)

The above figure represents the structural analysis with total deformation and the below figure represents structural analysis with equivalent stress.

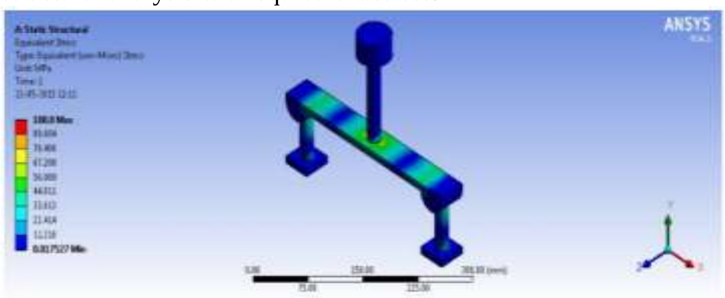

Fig. 4: structural analysis (equivalent stress)

The minimum stress is generated at end plates and maximum at piston and mid span for total deformation and equivalent stress respectively.

The next figure represents the linear buckling analysis. Minimum occurs on end plates and maximum occurs on piston.

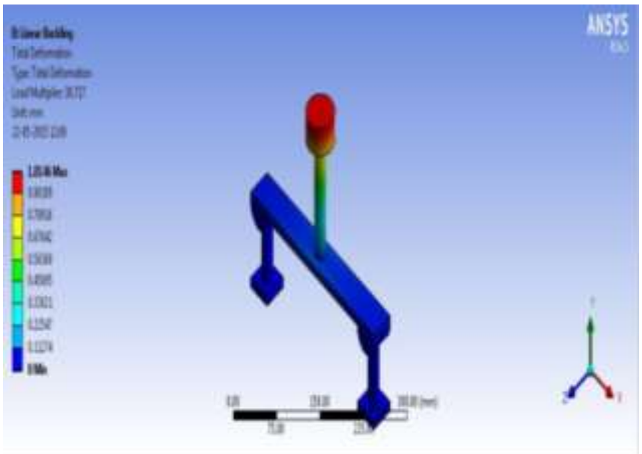

Fig. 5: Linear buckling analysis

The hydraulic stand designed here has to lift the load of 150 kg, which is the very light load application for hydraulic operation. The piston-cylinder motion lifts the load. The structure is very basic and compact. The material used for the analysis purpose is the structured steel. The software used for the design is CREO by PTC and for the analysis ANSYS is used.

IV. Results and Discussion

The design of piston-cylinder assembly structure is analyzed in ANSYS software. The structural and linear buckling analysis is represented through the images. The first table shows the result of static structural analysis of both total deformation and equivalent (von-Mises) type and the second one show the results of linear buckling analysis.

Results of Structural analysis		
Type	**Total Deformation**	**Equivalent (von-Mises) stress**
Minimum	0. mm	1.7527e-002 MPa
Maximum	0.15548 mm	100.8 MPa
Minimum Occurs On	END_PLATES	
Maximum Occurs On	PISTON_2	MID_SPAN

Results of Linear buckling	
Type	**Total deformation**
Load Multiplier	38.717
Minimum	0. mm
Maximum	1.0146 mm
Minimum Occurs On	END_PLATES
Maximum Occurs On	PISTON_2

The maximum and minimum stress values achieved in ANSYS software are under the permissible limits, hence the design is proved as safe.

The minimum stress is generated at end plates and maximum at piston and mid span for total deformation and equivalent stress respectively in structural analysis and in linear buckling analysis minimum occurs on end plates and maximum occurs on piston.

V. Conclusion

With the above design and analysis, we can say that the design of the structure is safe. Hydraulic piston-cylinder assembly can be used as a light load lifting machine. The stress result shows that the maximum stress generated by the loading conditions is under the maximum and minimum limits. Hence the design is safe. And with further modification, it can be used in future and the applications will be spread.

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