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Design and Analysis of Hydraulic System for Lifting Of Heavy Machinery

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Abstract - *The Compressors and Heat Exchangers required for applications in petroleum industry, fertilizer industry, for boilers, etc weigh upto 50 tonnes. The heavy machinery needs to be lifted so that the workers/technicians can work on the lower parts for maintenance. This lifting of heavy machinery and compressors in factories, necessary for maintenance and fitting, and assembly are still done using cranes. There is a considerable margin of risk and error in this process. Although this is currently the preferred way for lifting such heavy machines, there is need to opt for an easier lifting method. Our project focus is on designing a hydraulic system – forming a network of hydraulic actuators to effectively lift the desired load. This would include capacity of lifting of each actuator, position of the actuator and other such processes that would enable the system to lift the machine such that its level is maintained after lifting, to avoid any misalignment.*

Keywords: *Hydraulic Actuator, heavy machinery lifting, hydraulic circuit, leveling, flow equalizer circuit.*

Introduction

The compressors and heat exchangers are assembled at working stations. The problem faced by technicians and workers is that heavy machines need to be lifted to gain access to lower parts for assembly and maintenance.

Also, the conventional method for this process is completely manual and has a considerably margin of risk and error. This process causes various hazards to workers.

In the recent times, there has been a significant rise in the use of hydraulics in Indian Industries. Hence there is a great deal of urgency and importance to master the art of its application and maintenance. Hydraulic systems are being extensively used in machine tools, material handling devices, transport and automobiles, aviation systems, etc. At this moment there exists a big gap between the availability and requirement of trained manpower in this vital field of modern engineering in India.

The hydraulic system is a power transmission system using oil to carry power. The power maybe transmitted directly in the form of load or is transmitted in the form of control. The greater and finer the signal, the more positive, reliable, accurate and responsive is the control. The inputs and outputs of a power transmission and control systems is mostly mechanical. But the advantage of hydraulic system is that it can be initiated by electrical, chemical, manual, optical, electronic/digital or acoustic means. Hand levers, plungers, springs, rollers and strikers, solenoids and torque motors are common examples of control inputs, while the outputs maybe movement of a piston rod or the turning shaft. The project deals with the design of a hydraulic actuator and the entire hydraulic circuit for lifting machinery upto 50 tonnes.

1.1 Objective:

1. The machinery needs to be lifted by about 25-30 centimetres.
2. Another parameter is that these actuators need to be lifted to the same level irrespective of the inclination of the floor below.
3. Stress analysis of the actuator will also be executed on suitable software.
4. Simulation to demonstrate levelling will also be performed.

Literature Survey

Hydraulic cylinders are used extensively in industry to provide linear motion control. These cylinders are composed of cylindrically shaped metal case with a piston- rod assembly (A and B respectively in Figure.1) that moves back and forth within the case. The piston and rod assembly separates two different volumes inside the cylinder case. For a single rod cylinder, these two volumes are called: the rod end volume, where the rod end is the end of the cylinder from which the rod protrudes, and the cap end volume, where the cap end does not have a rod. As these volumes are pressurized, hydrostatic forces due to the pressurized fluid act on the surfaces of the vessel containing the fluid. Thus, the forces acting on the piston-rod assembly cause it to move, extending the rod out of the cylinder case or retracting the rod into the cylinder case. An external load can be attached to cylinder rod, and as the piston-rod assembly moves, a force is exerted on the load causing the load to move along a linear path. For a cylinder in retraction, the flow leaving the cap end exits through the cushioning cavity E before returning to the rest of the hydraulic circuit through the cylinder port I. The cylinder stops when the piston reaches the end of its stroke, or when the piston makes contact with the end cap, H. The components labelled F and G are the cylinder cushion spear and collar that decelerate the piston before it contacts the end cap in either retraction or extension, respectively.

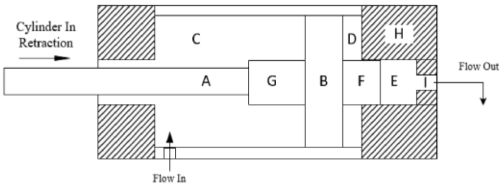

Fig 1. Hydraulic Actuator

Hydraulic cylinders provide high power density for moving heavy loads, but if the cylinders are allowed to reach end of stroke at full speed, sudden deceleration can cause excessive impact. Therefore, a cushioning mechanism was designed to decelerate the cylinder piston and reduce the speed at which impact occurs.

Cylinder cushions meter the flow leaving the cylinder case causing pressure to increase. When the area of the piston is exposed to this accumulating pressure, a force develops that opposes the motion of the piston-rod assembly causing deceleration. With the importance of accurately metering the fluid leaving the cylinder to create a resisting force, there is value in predicting the pressure response, i.e. the cushion pressure as a function of time, generated when the fluid is metered by the cushioning mechanism orifice.

In approaching the development of a mathematical model to describe the performance of a hydraulic cylinder and cylinder cushion, it was necessary to investigate how other researchers had treated similar systems. In their general approach to describing the system, other researchers seemed to choose one of two methods: an energy based model, or a model based on the principle dynamic equations. The earliest research efforts tended to lean towards the energy approach that required less complicated mathematics.

In more recent investigations, with the assistance of computer-based analysis, numerical simulation provided more insight into the response of the system. The details of how various researchers applied both of these methods, the energy approach and that based on principle equations.

Additionally, one detail that is often not clear in the published research is the mathematical model used to describe the flow through the annular clearance created by the spear entering the cushioning cavity. The orifice equation appears to be the most utilized model, but there is also a pressure drop as fluid flows through an annular pipe.

3. Proposed Design

The various parameters and considerations that were taken while designing are as follows:

- Space Constraint
- Height Constraint
- Ease of Handling

Initially the layout having frame structure was considered and it was rejected as it would be constrained for single machinery. Thus, a individual block design was adopted which satisfied all the constraints.

3.1 Actuator Design and Selection

For the design and selection of the actuator, two methods were adopted.

A] In the first approach,

The load of the machine is distributed over multiple actuators interconnected to each other, but only one single actuator which experiences the maximum force, is designed

The maximum weight and the corresponding maximum force at a point are found out.

The resistive and frictional forces at that point are calculated.

The total forces including the maximum force and the resistive force are added and calculated.

Considering a factor of safety of 5, the final force at the point is calculated, which will be used for calculating the bore and piston diameter of the actuator.

With the equation $F_{p} = P \times \frac{\pi}{4} D^2$ and assuming a certain value of the diameter, a pump pressure is selected based on the system requirements and as per available pumps.

For the most feasible pump pressure, the piston and rod diameters are selected.

B] In the second approach,

Assuming that the entire load of the heavy machine is acting on a single actuator, the total weight of the machine and the corresponding force is calculated.

Considering a factor of safety of 5, the total force is calculated.

Using the same equation as above and assuming a suitable pressure based on the pump, the area of one actuator is calculated. This area gives the equivalent diameter of the single actuator which lifts the entire machine.

As 6 actuators are going to be used, the total area is divided by 6 to get the areas of each actuator.

Using this area, the diameter of the individual 6 actuators is calculated.

The diameters obtained from both the above approaches match each other and therefore propose the most feasible diameter for piston and piston rod are selected.

3.2 Hydraulic Circuit Design

Since our application requires us to lift all the actuators connected in the circuit and at time and to the same level, we must be able to use a device which allows us to do so irrespective of the resistance that is offered at each actuator. For this, a flow divider circuit is used.

For dividing a single hydraulic line into more than two identical paths, a tee joint or several tee joints should be used. However, the flow will vary to a great extent if the resistance to flow is not the same in all the branches.The flow can be equalized to change resistance with the use of tee outlets, but the work resistance changes as the machine operates, work resistance changes often require constant flow modifications. A*flow divider*is a device whichsplits flow and compensates for pressure differences in most cases. A flow divider is capable of splitting flow equally, unequally, and into more than two paths.

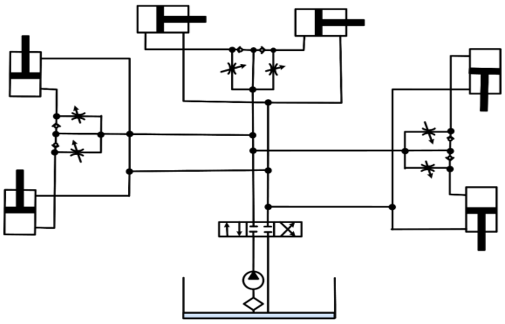

Fig 2. Proposed Hydraulic Circuit

A hydraulic circuit with Flow Dividers is designed and analysed on Automation Studio 6.0. The circuit works for the designed purpose giving the simultaneous extensions and retractions.

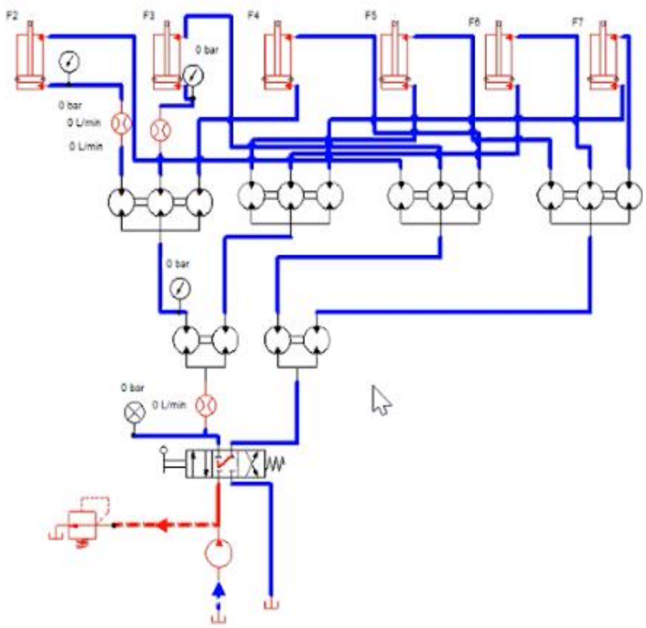

Fig 3. Actual Circuit on Automation Studio 6.0

3.3 Hydraulic System Components

The various components which are selected after the design of circuit are:

- Hydraulic Oil
- Hydraulic Pump
- Hydraulic Actuator
- Flow Control Valves
- Rotary Flow Dividers
- Direction Control Valve
- Pressure Relief Valve
- Hydraulic Pipes and Hoses
- Hydraulic Oil Sump

Discussion

In this paper, the methods for design and selection of the actuators are finalized. The most suitable actuator based on the various design and load constraints is selected.

The final circuit diagram for the application is designed on Automation Studio 6.0 software.The circuit is designed using flow dividers which are mostly suitable in applications where simultaneous lifting of two or more actuators is required.

The different components of the hydraulic system are selected based on all the design constraints.

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