Design and Fabrication of A Single Acting Hydraulic Crane

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***Abstract*— In this present work, the designed and fabrication of a single acting hydraulic crane was carried out. The hydraulic crane is made up of the following main components; the hydraulic actuator or actuating cylinder, the master cylinder, the fluid reservoir, pumps, seals, valves and conductor. The basic design elements and parameters considered in the design of the actuating cylinder are; the piston (diameter and cross-sectional area), and the barrel or cylinder (thickness, force and pressure developed). The fabricated machine was tested for performance using different loads. The time required for lifting each loads and retraction time were monitored and recorded. The results obtained reveal that the machine is capable of lifting loads up to 5000N at a time of 58.00sec. Also, it was observed that the performance of the machine was satisfactory and reliable since the correlation values were close to 1 for load plot against lifting time and retraction time. However, to improve more on its performance, it was recommended that motorized hydraulic systems should be incorporated into subsequent designs.**

Index Terms: **Design; Fabrication; Hydraulic Crane; Loads; Correlation Values; Performance.**

I.INTRODUCTION

The need to develop an efficient hydraulic machine is paramount for industries and designers. With the wide usage of hydraulically driven machines, specifically the hydraulic crane machines with large power, more research interest has been taken in energy-saving measures and strategies owing to energy cost, environmental legislation, etc. A crane is a machine equipped with a hoist, ropes or chain that can be used to lift and lower materials, and to move them horizontally. It is mainly used for lifting heavy materials and transporting them to required destination. It applies one or more simple machines to create the mechanical advantage needed to move the load beyond normal capability of man. It is defined as a machine used for moving heavy objects, typically by suspending them from a projecting arm or beam. Generally, cranes can be classified as; jib crane, overhead bridge crane, telescopic handler's crane, and the travelling gantry crane.

A hydraulic system is used for transmitting force or motion by applying pressure on a confined liquid. Hydraulic cranes are usually multi-degree-of-freedom (multi-DOF) mechanical booms. Their main function is to move and lift heavy load from a given position to another one using hydraulic drive. A hydraulic system consists of an assemblies of valves, cams, operating cylinder, etc., which have close fitting tolerance to obtain maximum efficiency from the system and protect intricate parts. I t is of utmost importance that the oil to be used must suit the system been developed. The hydraulic oil to be used must be able to perform two important functions which are.

1 It must be able to transmit the required power efficiently
2 It must be able to provide adequate lubrication

Hence, for the hydraulic oil to perform the above-mentioned functions, it must possess the following characteristics;

1 Film strength and lubrication, to provide adequate lubrication between closely fitted sliding parts
2 Resistance to emulsification, so as to separate quickly from any water which may have entered into the system
3 Resistance to corrosion and rusting so as to prevent damage to the closely fitted parts
4 Adequate viscosity to ensure a steady flow of oil at all times and to minimize leakage

At certain point in the system, mechanical devices must be used to control the fluid. A hydraulic system is a collection of mechanical parts linked together by connecting rods and in many cases by fluid levers. Pascal's law defines the basis of hydraulic system. Pascal's Law or principle of transmission of fluid pressure defines the basis of hydraulic systems. It states that the pressure exerted anywhere in a confined incompressible fluid is transmitted equally in all directions throughout the fluid such that the pressure ratio remains the same . Hydraulic systems make use of incompressible fluids. The pump moves the fluid in the system and the intake of the pump is connected to a fluid source called the reservoir. Atmospheric pressure acting on the fluid in the reservoir forces the fluid into the pump. When the pump operates, it forces the fluid from the tank into a discharge pipe at a suitable pressure. The flow of the pressurized fluid is categorized into three control functions which are;

1. Control of the fluid pressure
2. Control of the fluid flow rate
3. Control of fluid flow direction

A cylindrical tube fitted with a moveable piston called a hydraulic cylinder is often used when the pressurized fluid moves the piston, the piston rod impacts a force on the object through a desired distance. Restricting the movement of the piston in a hydraulic cylinder, as when the piston carries a load, creates a specific pressure relationship within the cylinder. The output force produced is the pressure of the pressurized fluid multiplied by the piston area, measured in Newton at the end of the piston rod. A seal is placed around the rod as it passes through the cylinder to prevent leakage of the fluid.

This present work is expected to provide lifting capability required for lifting heavy objects especially in most mechanical workshops in Nigeria where servicing and repair of automobile engines are being done using primitive techniques such as using the hand to lift the engine out during overhauling. It will also be of great important in installation of machine tools, generators and so on. It is expected that the ease and comfort associated with the use of this machine in lifting and transporting loads, it will be helpful to industries, workshops in their day to day activities. This study is therefore undertaken to look for ways to improving on the local ways of lifting loads with aim of improving performance, safety and reliability of the device.

II. LITERATURE REVIEW

DESIGNWORK

The designing work was carried out using CATIA software. The required dimensions of the driver and the driven wheels were taken as per the design equations. CATIA is the most widely used design software's which helps in designing 2 as well as 3 dimensional models using simplified alphabetical and numerical commands. Both the driving and the driven wheels were drawn to the required dimensions using the circle command. A slot was cut on the Geneva wheel using the trim tool. It was then edited using polyline command and the remaining slots were constructed using the array tool. The crank pin and the driving wheel were drawn to the required dimensions

DESIGNCRITERIA

There are three major considerations in the design of cranes.
The crane must be able to lift the weight of theload;
The crane must not topple;
The crane must notrupture.

Lifting capacity

The lifting capacity of hydraulic crane mainly depends on following.

A.The lever

A balance crane contains a horizontal beam (the *lever*) pivoted about a point called the *fulcrum*. The principle of the lever allows a heavy load attached to the shorter end of the beam to be lifted by a smaller force applied in the opposite direction to the longer end of the beam. The ratio of the load's weight to the applied force is equal to the ratio of the lengths of the longer arm and the shorter arm, and is called the mechanicaladvantage.

B.The pulley

A jib crane contains a tilted strut (the *jib*) that supports a fixed pulley block. Cables are wrapped multiple times round the fixed block and round another block attached to the load. When the free end

of the cable is pulled by hand or by a winding machine, the pulley system delivers a force to the load that is equal to the applied force multiplied by the no of lengths of cable passing between the two blocks. This number is the mechanical advantage.

C. The hydraulic cylinder

This can be used directly to lift the load or indirectly to move the jib or beam that carries another lifting device. Cranes, like all machines, obey the principle of conservation of energy. This means that the energy delivered to the load cannot exceed the energy put into the machine. For example, if a pulley system multiplies the applied force by ten, then the load moves only one tenth as far as the applied force. Since energy is proportional to force multiplied by distance, the output energy is kept roughly equal to the input energy (in practice slightly less, because some energy is lost to friction and other in efficiencies).

The same principle can operate in reverse. In case of some problem, the combination of heavy load and great height can accelerate small objects to tremendous speed. Such projectiles can result in severe damage to nearby structures and people. Cranes can also get in chain reactions; the rupture of one crane may in turn take out nearby cranes. Cranes need to be watched carefully.

Research Methodology

The following processes were followed;

a. Critical study and analysis of the working principle of the machine
b. Detailed study and analysis of the machine component
c. Visit to places where similar machines are in use to know the similarities and differences in design and the problem associated with their uses

The hydraulic crane is made up of the following components;

a. The hydraulic actuator or actuating(slave) cylinder
b. The master cylinder
c. The fluid reservoir
d. Pumps
e. Seals, valves and conductor

Design Calculation

Hydraulic actuating cylinder is widely used in industrial hydraulic systems. It is one of the basic components of hydraulic crane. The actuating cylinder in this case is a linear actuator. An actuator is a device that converts fluid energy into a mechanical force or motion. The hydraulic cylinder consists of circular tube, sealed at both ends in which a piston and its rod move. The piston rod projects through either or both ends of the cylinder. Leakage of fluid out of the cylinder around the piston rod is controlled by a suitably designed seal usually containing packing. The basic design elements and parameters considered in the design of the actuating cylinder are;

a. The Piston (Diameter and Cross-sectional area)
b. The Barrel or Cylinder (Thickness, Force and Pressure developed).

The following data were used in the design of the actuating cylinder;

Diameter of the actuating cylinder piston, d1= 100mm Assuming a clearance between one side of the piston and one side of the wall as 0.25mm

Thus, clearance on each side = 2(0.25) mm= 0.5mm

Internal diameter of the actuating cylinder = Piston diameter (d1) + Clearance on each side = 100mm + 0.5mm= 100.5mm

Materials Selection

Material forPiston and Ram

The material used in constructing the piston and ram are mild steel and aluminium cast alloys. Mild steel was used because it possesses strength and toughness, readily available and possesses greater strength in tension, ductile and resists wear. The material is easy to polish in order to allow the piston have easy movement in the cylinder.

Selection of Material for the Crane's Arm

The material used in constructing the arm which is of a hollow circular section is cold rolled steel. Cold rolled steel was used because like any other steel it has properties which make it suitable for this application. Some of these properties are; good weld ability, good ductility, and high strength in tension, easy formability, smooth and clean surface.

Material for Seals

For hydraulic crane to be able to perform well, the type of seal used plays an important role. Modern hydraulic equipment use variety of seals which are in large selection of different seal materials. In this research work, neoprene was used. Neoprene is a product of Elastomer, which are resilient and possess rubber like qualities.

Selection of material for the crane's column

The material used in constructing the column which is of a hollow circular section is galvanized iron. Galvanized iron was used because like any other construction material, it is cheap, readily available and has properties which make it suitable for this application.

Fabrication of the machine

The fabrication of the machine involves cutting operation, welding operation, drilling operation, machine operation, etc

Plate 1. Drilled Hole on one end of the crane's arm

Plate 2. Grinding of the ram rest on the arm

Plate 3. Welded hook holder

Plate 4. Fitting of the arm to the hydraulic crane assembly

Plate 5. Crane assembly with hydraulic jack fixed

Plate 6. Fabricated hydraulic crane

Project Layout

III. EXPERIMENT AND RESULT

After successful fabrication of the machine, it is imperative to test or evaluate the machines performance. Hence, the test was conducted as follows;

a. Selection of standard loads to be lifted (1000N, 2000N, 3000N, etc.)
b. Hook the selected load to the arm of the crane
c. Lock the control valve
d. Raise the load and take note of the maximum height and the time it takes to reach the height
e. Allow the loads to stay at different time interval
f. Then check if there is a drop in height

After various loads have been loaded on the crane, the correlation for the load versus time graph is gotten to be 0.9923. Also, a high correlation value close to 1 was obtained for the plot of load (N) against retraction time (s). This simply shows that the hydraulic crane is reliable and also in a very good working condition. Table 1 presents the time taken to raise each load, maximum height to which each load can be lifted to, and the retraction time.

ADVANTAGES

1. Most powerful means of lifting objects

It is one of the most powerful means of lifting objects is with the strength of a hydraulic crane. By harnessing the strength that liquid under pressure gives, and the ease with which it can be used, it is possible to transfer a relatively small amount of effort from one place to another, and hydraulic cranes are amongst the most efficient lifting systems available in the modern workplace

2. Extremely stable in use

Because the hydraulic cranes use a fixed system of pipes, constant pressure can be maintained once a part of the system has been moved into place, and this makes them extremely stable in use, and able to support relatively large weights.

3. Very easy to maintain

Hydraulic cranes are amongst the simplest systems that you can use within any industrial process, and are very easy to maintain. Provided that all the pumps and pistons are regularly checked for any leaks, and potential stress points where the levers are supported are inspected for damage, the crane will continue to operate completely reliably for long periods of time.

4. A very versatile tool

Most hydraulic cranes are comparatively light weight, and the ease with which they can be moved from one area to another within the factory or distribution center, makes them a very versatile tool with lots of uses on a day to day basis. From simple loading jobs in your loading bay area where the portable hydraulic cranes can be used to lift objects into a waiting truck to more complex jobs within the main factory, the lifts will come in very useful

5. Quite simple Design

A hydraulic system works with a system of pumps and pistons that are filled with a liquid, usually a light oil or water. By moving the liquid under pressure from the pumps, pistons can be extended or reduced, and when these pistons are connected to a system of levers, the pistons can be used to lift surprisingly heavy weight.

APPLICATIONS

Used for load lifting, carrying and shifting operations in small, medium and large industries like

1. Foundry
2. Welding workshops
3. Automobile workshops
4. Construction sites, etc.,

IV. CONCLUSIONS

In this research work, critical study and analysis of the working principle of a hydraulic crane was carried out with detailed analysis of the machine component. From the study, the design was based on ways of improving safety, weight, ergonomics, aesthetics, cost and durability. From the result obtained, it can be conclude that the hydraulic crane will do a lot of good to technicians and maintenance engineers at local automobile and plant repair workshops, because it would save the time and energy which might be expended on the crude way of lifting and moving heavy loads within the workshop. Circular irons were used to improve the strength of the crane and also add to its aesthetic values. The machine developed is capable of lifting loads up to 5000N at a time without fracture. The tyres used were of larger diameters and this ensured easy movement of the crane forward or side-ways when it is loaded or unloaded without stressing the user of the crane.

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