DESIGN AND MANUFACTURE OF A HYDRAULIC WORKSHOP CRANE

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Work related musculoskeletal disorders are supposed to be casually linked to physical load lifting resulting from occupational activities. Disorders or injuries affecting muscles, tendons, joints, ligaments and bones are mainly by mechanical overload of the respective biological structures. Examples of occupational activities coinciding with high mechanical requirements are handling of objects as in transportation jobs or the application of pushing or pulling forces to tools and machines (Luttmann et al., 2003). Handling of heavy objects is a daily activity in most machine shops, welding and fabrication workshops and with the consistent maintenance need to mount heavy objects in machines, overhaul motor vehicle engines once in a while, handling of such heavy objects or engine has become a major problem in operational/automobile workshops, occasioning musculoskeletal injuries at most times where humans directly handle the carriage and installation of the vehicle engines and axles. That machining, welding and fabrication and auto mechanics work are laborious is a common saying born from the fact that most carriage and handling jobs in most workshops are purely manually executed. There are however few shops who have shop cranes. These shop cranes are imported at exorbitant cost and as such not within the reach of most operational/automobile workshops. In recognition of this need, this project intends to develop a made in Nigeria, affordable shop crane.

Keywords: Work, Crane, Workshop, Injury, Affordable

INTRODUCTION

The technological growth of Nigeria though slow have been fostered by the increase in welding and fabrication shop which arose from increased use of iron and steel, engineered in the 1970s through the establishment of Ajaokuta steel plant and other small steel plants in the country. The growth has been steady though slow. This relatively slow growth is followed with the geometrical increase in the importation of vehicles, making land transport the prime transport system in the country compared to water

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transportation and other modes of transportation. Continuous operation of these vehicles implies consistent repair and maintenance. It is noticed that there has been remarkable increase in the number of automobile workshop and spare parts dealers in order to meet the maintenance requirement of many vehicle plying the Nigeria roads. However the much drudgery experienced activities in both welding and fabrication works and automobiles repair job in the country continuously repels youths from taking up such careers. They therefore preferred to look for alternative means of livelihoods; hence the drift is to venture into commercial motorcycle riding. Much of these drudgery and job difficulties are either caused by improper handling of materials or handling materials that are too heavy, thereby exposing operators to health hazard as well as risking the damage of tools and fittings during assemble exercise.

As far back as the middle ages, crane structures were used to lift objects that were too heavy or cumbersome for hands on lifting. The development of cranes since then has gone hand in hand with the development of modern industry (Thompson Geoffrey, 2007). The welding and fabrication industry as well as the automobile repair workshop have grown tremendously in Nigeria, but without the matching indigenous development of equitable lifting contrivances like the movable shop crane, foldable shop crane and workshop overhead crane.

The high level of usage of vehicles for both private and commercial activities coupled with the inflow of second hand vehicles from abroad popularly called “Tokunbo Vehicle” brought about the need for very efficient and effective maintenance. Often times, the garages or workshops where the maintenance activities are carried out are of low capital base. A close look at the equipment being used reveals the level of poverty of the technicians (Fapetu and Akinola, 2008).

The development of engineering over the years has been the study of findings ever more efficient and convenient means of pushing and pulling, rotating, thrusting and controlling load, ranging from a few kilograms to thousands of tones. Cranes are widely used to achieve this. In hydraulic crane, the force generation, transmission and amplification are achieved using fluid under pressure. The liquid system exhibits the characteristics of a solid and provides a very positive and rigid medium of power transmission and amplification. In a simple amplification, a smaller position transfers fluid under high pressure to a cylinder having a larger position area, thus amplifying the force. There is easy transmissibility of large amount of energy with practically unlimited force amplification (Sumaila and Ibhadode, 2011).

A typical shop crane consist of a pump (small piston and handle which up and down motion actuate the small position’s up and down motion admitting oil from a reservoir on one stroke and expelling the oil at higher pressure into the larger position on the other stroke); a hydraulic cylinder, two one-way non-return valves, one release valve and piping. The hydraulic crane can therefore be designed and produced for any desired tonnage capacity. It is invaluable equipment in all workshops, laboratories and industries especially for lifting and transportation of heavy objects.

A look at the workshop in Nigeria reveals that all such machines are imported into the country (Sumaila and Ibhadode, 2011). It is therefore intended to design and manufacture a shop crane
which is low cost and hydraulically operated using locally sourced materials. This will not only help to recover monies lost in the form of foreign exchange but will enhance the level of our local technology in the exploration of hydraulic fluid power transmission.

STATEMENT OF THE PROBLEM

Nigeria’s aspiration to be among the world’s first twenty industrialized nation by the year 2020 may not be met unless adequate and endogenous workshop equipment are deployed to supplement imported ones in all its maintenance and production shops. Available data from the Nigeria Ports Authority shows that about 900,000 vehicles were imported into the country between 1992 and 2003. This figure has increased geometrically in the last ten years. According to the Nigeria Auto Industry Quarterly Update 2012, the country has an annual demand of 300,000 new vehicles (Business Monitor International, 2013). Repair and maintenance of these vehicles are regular and must take place for their continued operation. This informs the reason for the ever increasing number of such automobile repair shops in the country. Most shops however are grossly unequipped for proper handling and job execution in the shops.

Sound professional best practice aimed at workshops injury and accident prevention and reduction ensures the utilization of appropriate tools for any job. Motor vehicle repair and maintenance often require the lifting of the entire vehicle or sub-assembly part of it or the lifting up and down of its heavy components. Also in other industries and welding shops, there are items and repairs which need the employment of shop cranes. The lack of shop crane utilization in our industries and automobile repair shops not only leads to injury and accident but also to poor repair and maintenance occurrence.

The few crane and lift facilities currently employed in Nigeria production and maintenance shops are all imported at exorbitant costs. There is the need for the development of home initiated and home built shop cranes that are affordable with simplified technology which, could be proliferated to SMEs in order to ensure adequate usage of proper lifting tool in those sector. This project intends to address this issue from the angle of evolving the built of an affordable shop crane using mostly available materials.

OBJECTIVE

The broad objective of the work is to ease material handling in Small and Medium Scale Industrial workshops by the development and manufacture of various capacity hydraulic shop cranes in Nigeria. This will be value addition, as it would drastically reduce the drudgery and musculoskeletal injuries currently experienced in the operations of such industries. The specific objectives are:

• To design various hydraulic shop cranes within the range of 200 kg to 1 tonne.
• To manufacture their prototypes.
• To test-run the prototypes equipment and evaluate its performance and cost in comparison with imported ones.
• To disseminate the technology to SMEs for mass production.

METHODOLOGY

The research methodology is as follows:

• Review of existing work on Hydraulic Workshop Cranes and Cranes in general.
• Design of the equipment for various capacities.
• Selection of materials for the construction of the crane mainly from the local market.
• Fabrication of the prototype.
• Parametric studies of the prototype equipment in other to ascertain its performance and standardize it.
• Performance evaluation as economically in comparison with imported ones.

BACKGROUND HISTORY OF CRANE EVOLUTION

Crane use and evolution started with the needs in the erection of anvil and structural works. Travelling cranes of the hand operated type were in use in the 1880s. About this time complicated designs of powered motion were offered by English and American builders involving a driving shaft along the runway and multiple clutches for transferring the power of the driving shaft to the hoist, trolley or bridge motions. Successive crane development ran thus: 1880 saw the hand powered crane, 1900 the electrical driven crane with a motor for each motion; by 1920 definite standards had been established for cranes in general and for various types of services; 1940 brought the enclosed gear cases, roller bearings and standardized designs; and 1960 produced the changes in crane control which resulted in smoother operation, safer handling of load, remote operation and new safety features for protection of equipment and personnel (Greiner, 1967).

From the cranes used in building and structural engineering works, cranes have been developed for all cadre of material handling jobs in manufacturing and service industries. As a result, many different varieties of crane exist.

Broughton (1958) grouped all cranes into four main categories, which remain applicable today, as enunciated by Thompson Geoffrey (2007):

Overhead Travelling Crane: This consist of fixed rails lying on one or two elevated girders with the trolley or crane bridge (with hoisting apparatus) that can transverse the length of the rails.

The Jib Crane: This consists of an inclined member that can rotate about a central point and suspend the load from the outer end of the inclined member.

Gantry Crane: This is a girder or girders connected to vertical members which are either fixed or move along tracks at the base of the vertical member, the hoisting equipment can be usually traverse the bridge girder or girders.

Cantilever or Tower: This is a vertical mast with a horizontal cantilever that rotates horizontally around the vertical member. The trolley and hoisting equipment move along the horizontal cantilever. The hydraulic shop crane is a small cantilever crane operated manually and can be moved in all directions through the action of the steel or rubber tires installed at the base.

Current efforts in developed countries like Germany and the USA are geared towards the development of automated cranes; but Nigeria is yet to develop small cranes for small and medium scale material handling in industries. According to a document of control engineering practice, in the context of further automation of manufacturing processes, automated transportation of heavy weight using crane becomes more and more important. Applying the skills or Robots to crane automation, a wide market of new applications could be developed (Sawodny et al., 2002). A wide market of
applications exists awaiting the development of matching shop cranes in Nigeria.

**DESIGN**

Both the hydraulic plunger actuation and the crane operation are built on the simple lever principle. Characteristic parameters in hydraulic cylinder and actuating pump as well as the crane boom operations are given hereunder.

**Force of Hydraulic Cylinder**

The force of a hydraulic cylinder results from the pressure in the cylinder, \( p \), on the piston of the cylinder.

The formula:

\[
F(\text{kg}) = p(\text{bar}) \times A(\text{cm}^2) \tag{1}
\]

where

\( F = \) Force acting on the cylinder in kg

\( p = \) Operating pressure in bar

\( A = \) The cylinder effective area in \( \text{cm}^2 \) which is calculated from the piston diameter:

\[
A(\text{cm}^2) = \pi \times \frac{d^2}{4} \tag{2}
\]

**Actuating Pump Mathematics**

When a hydraulic cylinder is operated by a hand pump, the cylinder plunger moves a certain distance per pump actuation. This distance depends on the cylinders effective area and on the pump’s oil flow per stroke. When two-speed hand pumps are used, the low pressure oil flow VLP applies for cylinder movements without load and the high pressure oil flow VHP applies for cylinder movements with loads.

The formula:

\[
S(\text{mm}) = \left[ \frac{V(\text{cm}^3) \times 10}{A(\text{cm}^2)} \right] \tag{3}
\]

where

\( S = \) Cylinder’s shift in mm

\( V = \) Pump’s oil flow per stroke in \( \text{cm}^3 \)

\( A = \) Cylinder area in \( \text{cm}^2 \)
**The Crane Boom as a Lever**

Lever is a simple machine consisting of a rigid bar that rotates about a fixed point, called a fulcrum. Levers affect the effort, or force, needed to do a certain amount of work, and are used to lift heavy objects. To move an object with a lever, force is applied to one end of the lever, and the object to be moved (referred to as the resistance or load) is usually located at the other end of the lever, with the fulcrum somewhere between the two. By varying the distances between the force and the fulcrum and between the load and the fulcrum, the amount of effort needed to move the load can be decreased, making the job easier.

Physicists classify the lever as one of the four simple machines used to do work. There are three classes of levers: (a): Class 1 (b): Class 2 and (c): Class 3; depending on the arrangement of the force, the load, and the fulcrum along the lever bar. Each class of lever affects force in a different way, and each class has different applications.

The class 1 lever has the fulcrum between the force and the load. The class 2 lever has the fulcrum at one end, the force at the other end, and the load in the middle. A class 3 lever has the fulcrum at one end, the load at the other end, and the force in the middle. From Figure 3 it is seen that the crane boom is a class 3 lever. The load diagram is given in Figure 5. The crane intended capacity at highest load point is 5,000 kg. The specification of the hydraulic cylinder is put at 10,000 kg admitting a 50% factor of safety; but the computation for minimum load is executed with the 50,000 kg load capacity at maximum load point.

Hence taking moments,

\[
\text{Minimum Load} \times 152 \text{ cm} = 5,000 \text{ kg} \times 40 \text{ cm}
\]

\[
\text{Minimum Load} = \frac{5,000 \text{ kg} \times 40 \text{ cm}}{152 \text{ cm}} = 1,315 \text{ kg}
\]

Acceptable load at minimum load point = 1,000 kg.

From Equation (1), the operating pressure is evaluated and used to procure the requisite

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**Figure 4: Levers**

- **Class 1 Lever**: Load at one end, force at the other, fulcrum in the middle.
- **Class 2 Lever**: Force at one end, load at the other, fulcrum in the middle.
- **Class 3 Lever**: Load at one end, fulcrum at the other, force in the middle.

**Figure 5: Moment**

Minimum Load x 152 cm = 5,000 kg x 40 cm

\[
\text{Minimum Load} = \frac{5,000 \text{ kg} \times 40 \text{ cm}}{152 \text{ cm}} = 1,315 \text{ kg}
\]

Acceptable load at minimum load point = 1,000 kg.
hydraulic hoses for the system. Where the cylinder diameter is 46 cm;

\[ \text{Area} = \pi D^2/4 \]  

Hence,

\[ \text{Pressure} = \frac{\text{Load}}{\text{Area}} \]

\[ P = \frac{10,000}{(\pi \times 46^2)/4} \]

= 6 Bar

Similarly using Equation (1) and the number of strokes to achieve maximum extension of the cylinder, the quantity of hydraulic fluid for the actuating pump operation can be evaluated.

**CONCLUSION**

The equipment was fabricated and tested, and was observed to execute the lifting of highest rated load of 5,000 kg for one hour. Figure 6 is the picture of the Fabricated Shop Crane as it was displayed during the 2013 Abuja International Trade Fair tagged “ABUCCIMA 2013”. Arrangement is ongoing to cede the technology to SMEs who will erect production factories for the continuous of production of the product.

**REFERENCES**
