



Development and Performance Evaluation of a Pedal Operated Hydraulic Jack

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Authors' contributions

This work was carried out in collaboration between all authors. Author OTO designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author MTI monitored the fabrication process and the final draft. Author OGA managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The paper developed an accessory that can be connected to the hydraulic jack to operate it by pedaling while standing upright at a convenient position. It is characterized by an adjustable rectangular frame that occupies less floor space, and wheels to facilitate easy positioning.

Study Design: Thorough design analysis of the member components were done to determine their actual dimensions and specifications required. The device has been designed for light weight automobile, car. Although the maximum weight of a car is not more than 2.5 tonnes, but the device was designed for a 3 tonne hydraulic jack, ensuring reasonable factor of safety.

Place and Duration of Study: Department of Mechanical Engineering, Federal University of Technology, Akure, Ondo State, Nigeria, between February 2014 and December 2014.

Methodology: An adjustable rectangular frame was incorporated. This occupied less floor space, and wheels to facilitate easy positioning. A low stiffness, 1.61 N/mm, tension spring was used to be

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the actuator of the hydraulic fluid pumping and thus enhances soft and easy pedaling for the user. The material used for the fabrication of the mechanism component was mild steel which was selected based on the design analysis result, availability and low cost for cost effectiveness.

Results: Performance evaluation of the fabrication, compared with that of hand operated hydraulic jack revealed similar characteristics for both jacks but greater efficiency for the designed pedal operated jack in terms of safety and ease of operation. The test results showed that this pedal operated hydraulic lifter for automobile workshops performed much more efficiently than the hand operated hydraulic lifter.

Conclusion: This design has really curbed the problems encountered by hydraulic jack users. It makes work easy for female users who cannot easily and conveniently bend or stoop down to jack up their vehicles for a purpose and old men who are too feeble to stoop low under their vehicle to jack it up.

Keywords: Design; efficiency; hydraulic jack; pedals; vehicles.

1. INTRODUCTION

A jack is a very common mechanical device to lift heavy weights or to apply great forces. While mechanical Jack uses screw thread, hydraulic jacks use hydraulic cylinder to apply very high liner forces. Their most well-known application is raising and supporting an automobile to facilitate the replacement of a flat tire. Auto Mechanics use jacks all the time to raise cars up and down when working on them. Even individuals who work on cars out of necessity use jacks for lifting cars up. The easier it is to use a particular jack the better. While ordinary car jacks use mechanical advantage to help lift a vehicle for maintenance, more powerful car jacks use hydraulic cylinder to provide capacity for lifting higher loads over a greater capacity [1]. These jacks are rated on the basis of maximum lifting capacity and generally mentioned in tons i.e. 1.5 tons, 3tons etc [2].

Some researchers have worked on hydraulic jack. Sainath et al. [3] developed a mechanical hydraulic jack. The existing bottle hydraulic jack is a very common device used in this part of the world by different categories of people - auto mechanics, vulcanizers, and individual motorists among others. One and most of its application is in the raising and supporting an automobile to facilitate the replacement of a flat tire. But the problems with this type of jack include- hand use which is laborious in operation, spine and arm aching etc. some other existing jacks of the type described here (floor jacks) have so far been made with a rigid frame and solid wheels, without compensation for flexing under load to transmit the effect to the floor. Ikechukwu et al. [4] developed a foot operated hydraulic lifter for automobile workshops. They designed a hydraulic jack that greatly reduced human efforts

from 2050.4 N to 136.7 N. They also incorporated compression springs which allows for flexing under load to transmit the effect of the load to the floor.

Therefore, there is urgent need to design a jack such that human effort will be reduced (although may be manually operated) to the barest minimum. The use of jack to lifting heavy objects, precisely an automobile in order to change a flat tire, is very helpful. It relieves the user out of the primitive method of using a lever for lifting which is more laborious and require greater effort [5]. The screw jack type, requires stressful and vigorous spinning of the screw while (the user) bending, curling or stooping down before lifting can be achieved. However, the better type of Jack with greater efficiency is the hydraulic jack [6]. But the common type in the market today is the cylindrical type with a lever or plunger that is used to pump the liquid that moves the piston. This requires the use of hand to operate. It is as well laborious, spine and arm aching. Therefore the design of a special mechanical mechanism to operate the hydraulic cylinder such that enables the user to operate by pedaling with foot, while standing upright at will, will reduce the rigors of operation to the barest minimum. This mechanism will also accelerate the pace of work, and will be users friendly [7,8].

The broad objective of this work is to design and fabricate an accessory that will be connected to a hydraulic Jack which will enhance the convenience of using the jack and requires minimum human effort for its operation, which will be made of locally available materials for cost effectiveness. Most of the commonly available jacks are hand operated and modifications of such designs to become foot operated are the main focus of this work. This work looks at the

possibility of controlling a hydraulic jack using a pedal operated linkage mechanism. This modification will greatly reduce stress and allow for comfort during usage and the effort required is also greatly reduced.

The greater efficiency for the designed pedal operated jack in terms of safety and ease of operation make this study new and is expected to curb problems encountered by hydraulic jack users by making available a well designed and fabricated pedal operated hydraulic jack, which will go a long way in making life easier for jack users.

This study only covers the design and fabrication of an accessory that can be connected to a 3 tonne hydraulic jack to operate it by pedaling while standing upright at a convenient position. Weights of hydraulic jack beyond 3 tonnes are not considered in this design.

2. MATERIALS AND METHODS

2.1 Materials

The major components of the pedal operated hydraulic jack are made of mild steel, medium carbon steel, carbon steel and non Flexible rubber tyre. The materials were selected because of their workability, accessibility, suitable strength, low cost, machinability, good toughness and ductility.

2.1.1 Material selection

The properties of engineering materials are of great significance for an engineering design. The machine elements were made of a material which has properties suitable for the conditions of operation. Thus, satisfactory performance of machine parts and systems depends greatly on the materials a designer selects. The choice of material for this design depends on many factors which include types and intensities of stress to which the component is subjected, corrosive action, whether is to be flexible or rigid, the type of manufacturing process required, the durability or expected service life, weight of the component, temperature effect, aesthetic value, cost of construction etc. Material property is the measured magnitude of its response to a standard test performed. The cost of producing the unit product is about \$135 (N27,000) which would be reduced affordably at mass production.

2.2 Methods

2.2.1 Analysis of forces

Maximum capacity of hydraulic cylinder selected = 3 tones = 3000 kg

From Fig. 1(b), according to Pascal's principle, pressure at the small cylinder is equal to the pressure at the larger cylinder [9].

Let d = plunger diameter = 10.5 mm

D = Ram diameter = 29.4 mm

It should be noted that only a fraction of the bottle jack capacity will be subjected on the ram as load.

Therefore, assuming $\frac{1}{4}$ of maximum capacity, Weight,

$$W = mg \quad (1)$$

where,

$$m = \text{mass (kg)} = \frac{1}{4} \times 3000$$

$$g = 9.81 \text{ m/s}^2$$

$$W = \frac{1}{4} \times 3000 \times 9.81 = 7357.5 \text{ N}$$

$$\text{Surface area of a cylinder} = \frac{\pi D^2}{4} \quad (2)$$

Therefore, the cross sectional area of the plunger

$$a = \frac{\pi d^2}{4} = \frac{\pi \times 10.5^2}{4} = 86.5 \text{ mm}^2$$

Cross sectional area of the Ram

$$A = \frac{\pi D^2}{4} = \frac{\pi \times 29.4^2}{4} = 678.9 \text{ mm}^2$$

2.2.2 Required maximum force on plunger

Required force on plunger

$$F = \frac{W a}{A} \quad (3) \quad [10]$$

$$F = \frac{7357.5 \times 86.5}{678.9} = 937.4 \text{ N}$$

i.e. The maximum force required on plunger to lift 7357.5 N load is 937 N

The jack mechanism is illustrated in Fig. 2. It shows the different parts and their dimensions

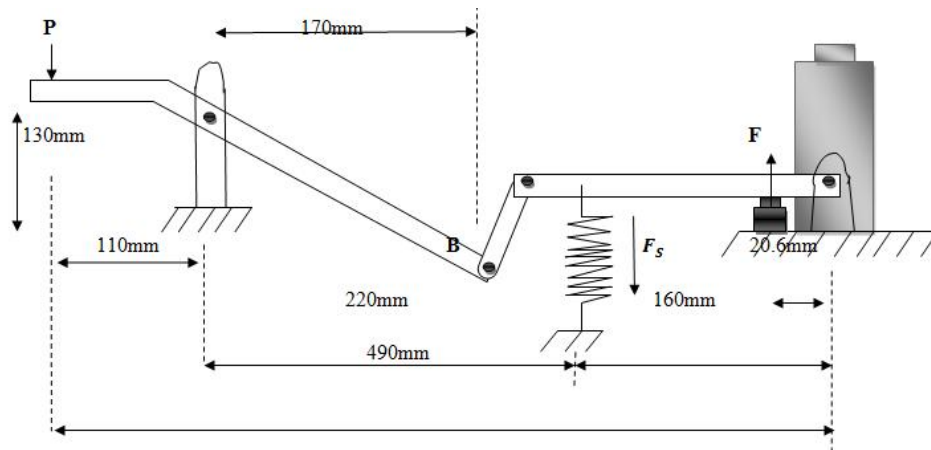
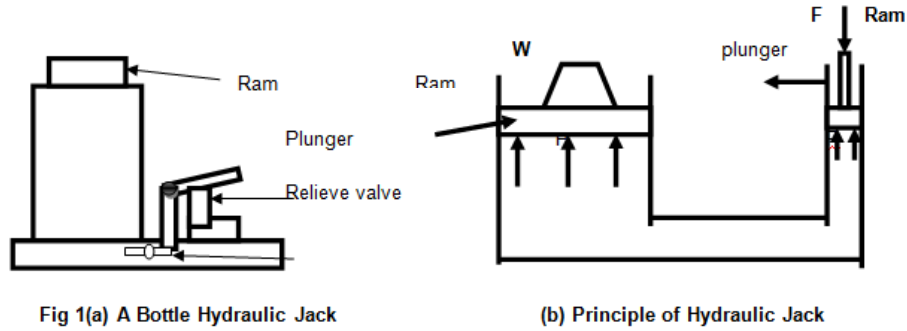


Fig. 2. Jack mechanism

3. RESULTS AND DISCUSSION

The assembly of the various parts of the jack include coupling the wheels to the wheel axle, affixing the hub washers and compression springs on the axle assembly, coupling the axle assembling to the hub on the frame, affixing the hydraulic jack on the frame, affixing the foot pedal and link bar together, connecting the link to the hydraulic jack plunger and pivoting the pedal with the pivot pin and affixing the return (tension) spring.

3.1 Performance Evaluation

The component was tested using different kinds of automobiles, this was carried out to determine the effectiveness of the component and to determine its longevity being a new component.

For effective evaluation, the following were ensured to be in place:

- (1) The vehicle selected was properly packed and well chocked.

- (2) The release valve of the jack was securely locked into position in the clockwise direction.
- (3) The right place under the vehicle was located in order to place the jack.
- (4) The jack was rolled under with the aid of the tyres and placed in the proper place.
- (5) In case of cars with higher height, the ram of the jack was unscrewed from the piston up to the point of carriage.
- (6) The pedal was used to actuate the pump to raise the main piston and to establish a firm grip with the vehicle.
- (7) After these, the pedaling was continued, noting the number of strokes and also timing it, till it lifts the tyre of the ground.

Table 1 represents the performance evaluation of pedal operated hydraulic jack while Table 2 represents the performance test of hand operated hydraulic jack. Weight of each car was considered, the time to lift the tyre off ground was also considered together with the number of strokes. The pedal operated hydraulic jack was

compared with the hand operated hydraulic jack without the accessory as represented below. It takes lesser time to lift the vehicle off ground using the pedal operated hydraulic jack compared to the hand operated hydraulic jack.

that will facilitate the ease of jack use, the safety of use and the friendliness/convenience of operation of the equipment which has been achieved.

Fig. 3 gives the representations of the time in which the tyre leaves the ground against the weight of the vehicle while Fig. 4 represents the number of the strokes to lift up the tyre off the ground against the weight of the vehicle. Looking at both graphs, it was realized that normal jack is a little bit faster than the Pedal operated jack, this is due to the loss caused by the link when jacking and also the stiffness of spring used. But the major aim of this design is to add an accessory

3.2 Detail Drawing and Assembly of the whole Machine

The assembly of the pedal operated hydraulic jack is shown Fig. 5. The assembly contains rear pipe, T-nut, bolt, compression spring frame, metallic wheel, compression spring, hydraulic jack handle, hydraulic jack, return spring, connecting bar, foot pedal frame, foot pedal guide, foot pedal bar, foot pedal support and foot pedal.

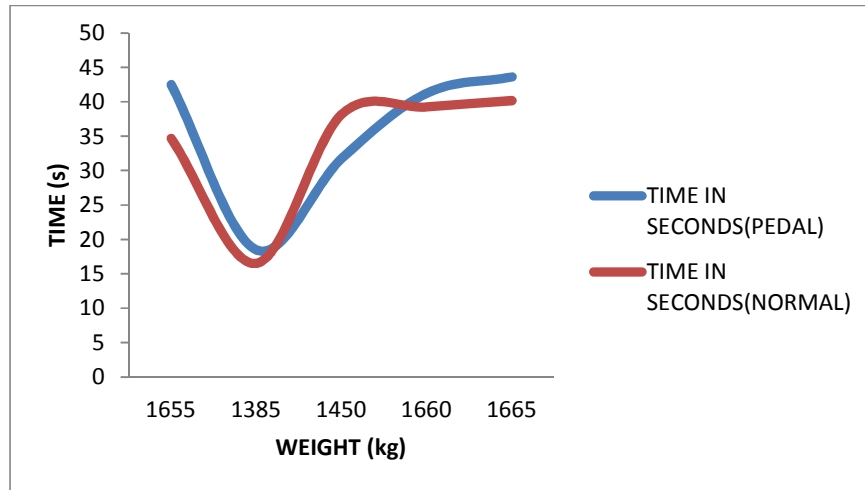


Fig. 3. Graph of times (seconds) against weight (Kg)

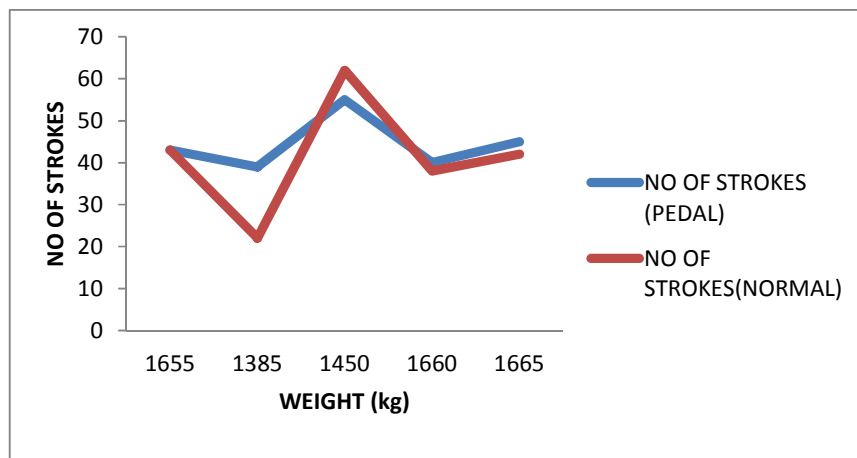


Fig. 4. Graph of number of strokes against weight (Kg)

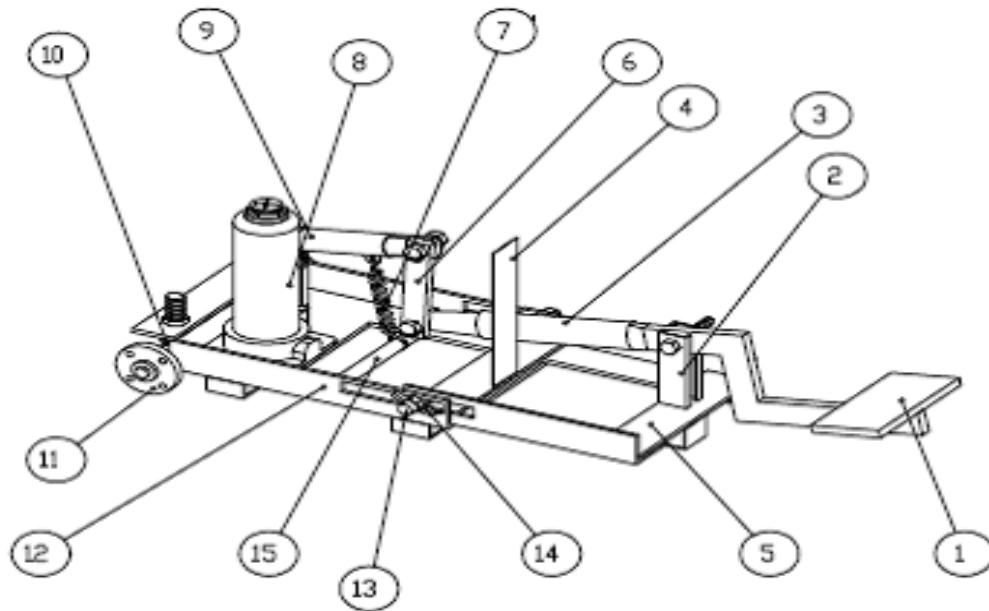


Fig. 5. Assembly of the pedal operated hydraulic jack [4]

PART LISTS

S/N	Name	Quantity	Material
15	Rear Pipe	1	Medium Carbon Steel
14	T-Nut	1	Mild Steel
13	Bolt	2	Mild Steel
12	Compression Spring	2	Carbon Steel
	Frame		
11	Metallic Wheel	2	Mild Steel
10	Compression Spring	2	Mild Steel
09	Hydraulic Jack Handle	2	Mild Steel
08	Hydraulic Jack	1	Medium Carbon Steel
07	Return Spring	1	Carbon Steel
06	Connecting Bar	1	Carbon Steel
05	Foot Pedal Frame	1	Mild Steel
04	Foot Pedal Guide	1	Mild Steel
03	Foot Pedal Bar	1	Mild Steel
02	Foot Pedal Support	1	Mild Steel
01	Foot Pedal	1	Mild Steel

Table 1. Performance evaluation of pedal operated hydraulic jack

Time for assembling: 35:38Secs

S/N	Car type(Salon, SUV, Bus)	Car name	Maximum weight Kg	Time to lift the vehicle off ground (Secs)	Number of strokes
1	Salon car	Toyota Carina E	1,655	34.65	43
2	Salon car	Toyota Corolla	1385	16.52	39
3	Salon car	Mazda	1450	31.75	55
4	Salon car	Honda Accord	1660	39.22	40
5	Salon car	Peugeot505	1665	40.14	45

Performance evaluation of pedal operated hydraulic jack*Table 2. Performance evaluation of hand operated hydraulic jack**

Time for assembly: 0 Secs

S/N	Car type(Salon, SUV, Bus)	Car name	Maximum weight Kg	Time to lift the vehicle off ground (Secs)	Number of strokes
1	Salon car	Toyota Carina E	1,655	42.50	43
2	Salon car	Toyota Corolla	1385	18.48	22
3	Salon car	Mazda	1450	38.14	62
4	Salon car	Honda Accord	1660	41.25	38
5	Salon car	Peugeot505	1665	43.62	42

**Performance evaluation of normal hydraulic jack*

4. CONCLUSIONS

This work looked at the possibility of controlling a hydraulic jack using a pedal operated linkage mechanism. This modification greatly reduced stress and allows for comfort during usage in an automobile workshop, and the effort required is also very minimal. The test results showed that this pedal operated hydraulic lifter for automobile workshops performed much more efficiently than the hand operated hydraulic lifter. The designs made are in terms of lifting effectiveness, usage, occupied space, easy transportation, easy maintenance, and method of operation by foot pedal. This is more convenient than hand use. In terms of cost, it is affordable to the common users of hydraulic jacks.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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