Uluslararası Mühendislik Araştırma ve Geliştirme Dergisi
International Journal of Engineering Research and Development

UMAGD, (2019) 11(1), 124-134.

10.29137/umagd.440893

Cilt/Volume:11 Sayı/Issue:1 Ocak/January 2019

Araştırma Makalesi / Research Article

Design of Remotely Controlled Hydraulic Bottle Jack for Automobile Applications

Ikpe Aniekan E.[*1], **Owunna Ikechukwu B.**[1]

[1] *Department of Mechanical Engineering, University of Benin, Benin City, P.M.B. 1154, NIGERIA*

***Başvuru/Received**: 07/06/2018* ***Kabul/Accepted**: 27/08/2018* ***Son Versiyon / Final Version:** 31/01/2019*

Abstract

Remotely controlled hydraulic bottle jack was designed in this study to alleviate the difficulties encountered during auto servicing that requires certain choice of elevation. Major components of the hydraulic jack were housed in a metal casing of 220mmx220mmx180mm with 2mm thickness. Curb weight (weight of the car with all fluids and components but without the driver, passengers, and cargo) of several cars ranging from 1086kg-1970kg were determined using a scale at nearby automobile shop. Considering the weight of individual cars that the designed hydraulic jack elevated, the time required to attain upward stroke of the piston and specific height of elevation was recoded accordingly. The time varied between 1.2 minutes with specific height of 150 mm and 1.44 minutes with specific height of 112 mm. Half weight of 1970 kg (985 kg) was used as the load case in Finite Element Analysis (FEA) to check the stress deformations, displacement and equivalent strain. Maximum von-mises stress of 8.465x106 N/mm^2 was obtained which is below the yield strength of the jack piston material. Maximum displacement of 2.999x10-1 mm and maximum equivalent strain of 3.56x10-3. Factor of safety was chosen on a scale of 1-10, and the colour chart in the analysis indicated blue colour in the range of 7-10 throughout the jack assembly. This was an indication that the jack is safe to operate under the aforementioned applied load. Therefore, adoption of remotely controlled hydraulic bottle jack can save time and energy required to elevate vehicles to working height.

Key Words

"Hydraulic jack, Automobile, Design, Remotely controlled, Electric motor.

***Corresponding Author:** ikpeaniekan@gmail.com*

1. INTRODUCTION

Vehicles are lifted for various purposes like for downside inspection or repair, replacement of tyres etc. Till date, the application of manually operated devices also known as lifting gears such as block and tackles, hoists, rotating screws, gantries, wedges etc. in lifting and lowering of heavy equipment is still common in some developing countries with low technological expertise. However, the practice of lifting and lowering is as old as the existence of man, and continuous development of effective and suitable medium for lifting and lowering heavy equipment has evolved through these era. This study is focused on the design of remotely controlled hydraulic jack for lifting or jacking up of vehicles for basic maintenance and servicing. The application of a jack in automobile is generally for raising up vehicles so that auto mechanics/technicians can have more work space or easy access to perform various tasks underneath the vehicle. Jacks are commonly applicable to cars but are also used in several mechanical applications including industrial machineries (Patel et al. 2016). They can be short, tall, fat, or thin depending on the amount of pressure they are subjected to and the space they are required to fit into. In other words, Car jack is a mechanical device that allows drivers and mechanics to have easy access underneath a car, usually to replace tyres, oil or some car parts like the brakes. The need for the car jack is often necessitated by flat tyres that require repairs or replacement. Other cases where the use of car jack comes into play may include tasks that require going underneath the vehicle or cases where the mechanic has limited work space to access vehicle parts located at narrow areas. The type of car jack used will determine the amount of physical labour needed to raise the car up to the required height which sometimes may result in much exertion from the operator and could be time and energy consuming (Agu and Igwe, 2016). There are two major types of jacks namely, hydraulic jack and mechanical jack. In a typical hydraulic jack which usually consist of a cylinder and piston mechanism, the upward or downward movement of the piston rod is mainly used to raise or lower the load, whereas, Mechanical jacks can either be hand operated or power driven (Kamalakkannan et al. 2016). According to Singh & Mishra (2015), mechanical jacks are devices used for lifting and lowering heavy equipment. The most common types include a car jack, floor jack or garage jack which lifts vehicles so that maintenance can be carried out. Car jacks usually use mechanical advantage to simplify the act of raising up a vehicle and this in turn offsets the workforce and man power that could have been exhausted in the process. More powerful jacks use hydraulic power to provide more lift over greater distances. Mechanical jacks are usually rated for maximum lifting capacity. However, hydraulic jacks are typically used for shop work, rather than as an emergency jack to be kept in the trunk of a vehicle. Use of jacks not designed for a specific vehicle requires more than the usual care in selecting ground conditions, the jacking point on the vehicle, and to ensure stability when the jack is extended. Hydraulic jacks are often used to lift elevators in low and medium and high-rise buildings. In principle, hydraulic jack uses an incompressible fluid that is forced into a cylinder by a pump plunger (this depends on the pressure generated by the pump), and oil is generally used because of its lubricating effects on the moving parts (Singh & Mishra, 2015). When the plunger is pushed backward, it draws oil out of the oil sump through a suction check valve into the pump chamber. When the plunger is moved forward, it pushes the oil through a discharge check valve into the cylinder. The suction valve ball is within the chamber and opens with each draw of the plunger. The discharge valve is located outside the chamber and opens when the oil is pushed into the cylinder. At this point the suction valve within the chamber remains closed and oil pressure builds up within the cylinder (Majumdar, 2002; Sainath et al. 2014). Hydraulic jacks can be classified into three categories depending on their design and capacity and this includes bottle jacks, scissor jacks and floor jacks respectively. Lifting equipment is usually require in automotive and motorcycle workshops, and one of the major lifting equipment used in a typical automotive and motorcycle workshop is the bottle jack. This type of jack is widely known for its versatility, and it is not only applicable in raising up vehicles to the required height, but can equally play a vital role in pushing vehicles around. A typical bottle jack is compact in size, but are designed and built for maximum performance and efficiency. In recent times, the hydraulic jack design is replaced by a bottle Jack which takes the shape of a bottle, having a cylindrical body and neck from which the hydraulic ram emerges. In the bottle jack, a vertical piston directly supports a bearing pad which in turn serves as a supports for the load being lifted. With a single action of the piston, the lift is slightly less than twice the collapsed height of the jack (Deepa et al. 2016). In terms of portability, bottle jacks are a step up from scissor jacks. These jacks use a hydraulic mechanism and its principles to provide a lot of lift. They are designed in a wide range of sizes that can still fit into car trunks, and are more ideal for larger vehicle such as trucks or Sport Utility Vehicles (SUVs). Scissor jack is one the most common type of jack that is compatible with a wide range of cars. It is simple to lift and often found in the spare tire compartment of new cars. Scissor jacks operate by turning a large screw, which causes the two sides to “scissor” together and raise the car to the desired height. Scissor jack uses an arm to allow the car owner to lift the car. The lug nuts must be loosened if the car is jacked or raised up when changing tyres. The scissor jack is designed to turn the screw with the arm in a clockwise motion to raise the platform that the car rests on or the notch that fits into a hard point on the car's undercarriage (Oghenekome et al. 2014). They are usually lightweight and compact, so they make great additions to emergency kits. However, Floor jacks are mostly used in garages with jack stands. They are incorporated with wheels for easy movement, since they tend to be much heavier and unwieldy. These jacks are workhorses, particularly known for their durability and reliability, and are somewhat expensive than scissor or bottle jacks. Floor jacks will likely not be needed unless in cases where maintenance is performed often. Comparably, while a compact scissor jack is great for cars and convenient to tote around, equipment slightly beefier, such as the hydraulic floor jack might be necessary for vehicle that is on the larger side but bottle jack has a huge three-ton capacity and a height range of eleven to twenty-one inches, making it ideal for trucks, SUVs, and other large, heavy-duty vehicles.

2. METHODOLOGY

The power source was tapped from 12V battery in each of the cars the remotely controlled hydraulic jack was tested on. Electric cables with high corrosion resistance were used as extension wires from the cathode (-) and anode (+) of the battery and for connection between electric motor and micro-controllers. Prime mover of 12V, 312 watt, 2650 rpm electric motor was incorporated into the system to generate the torque transmitted to a pair of meshed spur gear. The gear system (driver and driven gear) was introduced for the purposes of transmitting rotary motion of the prime mover to the crank link. Crank mechanism was installed in between the gear and the hydraulic cylinder to convert the rotary motion of the gear to linear motion required for the upward and downward movement of the jack plunger. Electronic Control Unit (ECU) was also added to the design to serve as control medium between the user and the device through a remote or switch controlled operation. The main function of the hydraulic system is to drive the bottle jack, a principle based on Pascal's law. For the base, a steel plate was cut and welded with external dimension as 216mmx216mmx30mm and 4mm thickness. After the complete construction work the unit was tested. Vehicle scale at nearby auto shop was used to determine the curb weight of several vehicles listed in this study. The control circuit was housed in a miniature panel casing. The design setup is shown in Figure 1 and 2.

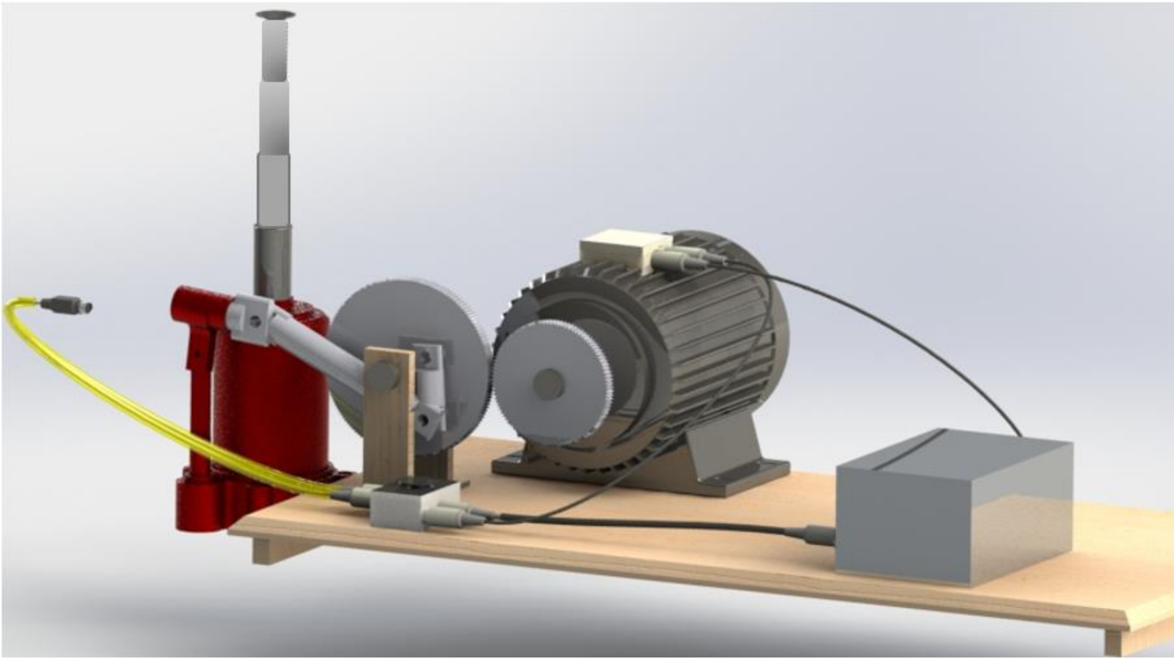


Figure 1. Front View of the Design Setup

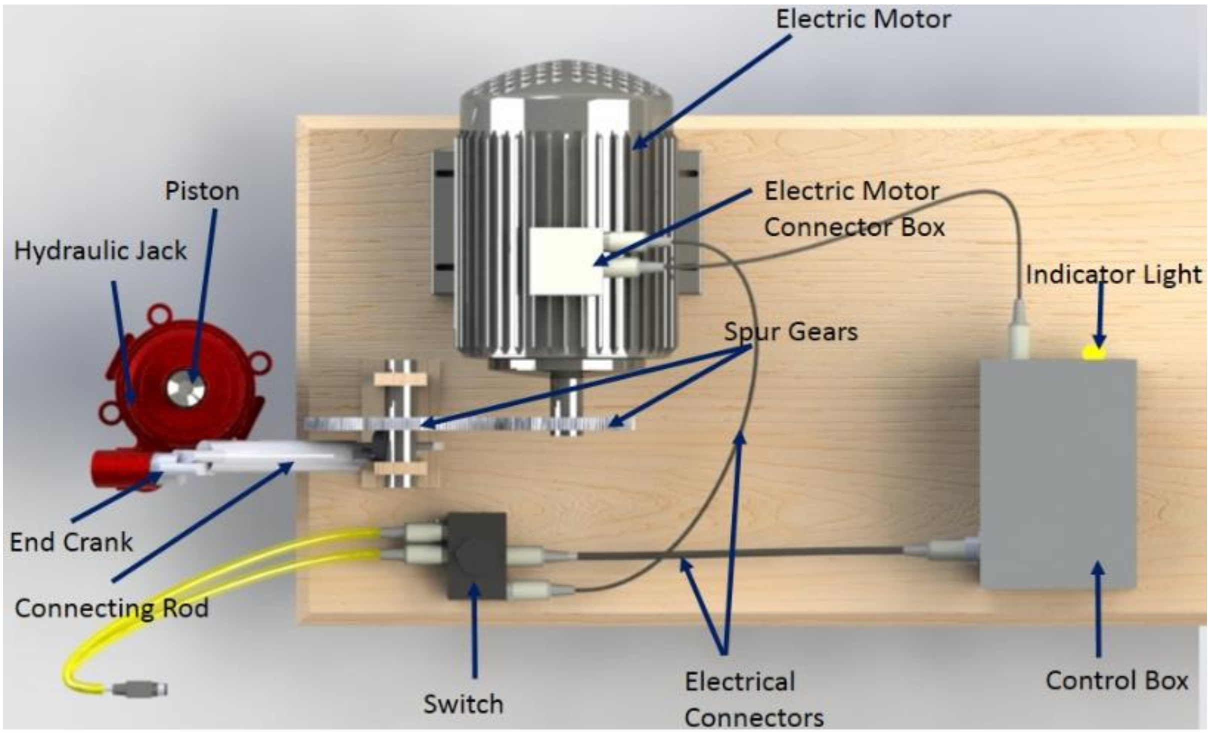


Figure 2. Plan View of the Design Setup

2.1. Working Principles

The motor connection cables are connected to the car battery terminals which provides power for the jack operation immediately after the power button is switched on. The jack consists of an electric circuit, electric motor, a switch, a control box, and the jacking assembly. The motor is supplied power through the electrical leads. When the switch is turned on, current flows to the control box, to power it on. Meanwhile majority of the current flows to the motor to start the rotation of its shaft, the driving gear is connected to a larger driven gear for torque amplification. This rotation causes the four bar crank mechanism on the driven gear to rock the lever on the push rod to and fro thus pumping the fluid in the jack cylinder and by Paschal principle of pressure transmission, thus the piston begins to rise raising any load in its path. The control box has the following functions:

i. Checks the current flowing to the motor.
ii. Checks the condition of the motor during operation by measuring the working condition of the motor.

2.2. Gear System

To maintain the revolution speed of the motor, a spur gear system with the following specification was adopted.

For the driving gear;

No of teeth (N) = 9
Pitch diameter (d_p) = 10mm
Gear Module (m) = $\frac{d_p}{N} = 1.11mm$ (1)
For the driving gear;
No of teeth (N) = 62
Pitch diameter (d_p) = 69mm
Circular pitch (p) = $\frac{\pi d_p}{N} = \pi m = 3.5$ (2)
Using a gear motor with power rating of 6000W, the torque was calculated using equation 3;

$$T = \frac{P60}{2\pi n_p} = \frac{6000*60}{2*3.142*1850} = 31Nm \quad (3)$$

Where, n_p is the rotational Speed of the gear motor in rpm

2.3. Crank System

This operates on variable degree of freedom which is the number of independent parameters required to define the position of every link in the mechanism. This does not depend on the length of the link but on the number of links, number of joints, types of joints and their distribution. The general equation for degree of freedom is given by equation 4;

$$F = \lambda[L - j - i] + \Sigma_{i=j} f_i \quad (4)$$

Where F = Degree of freedom, L = Number of links, f_i = Degree of freedom of joints in the mechanism, j = Number of joints, λ = Degree of freedom of space (constant for the entire linkage). The kinematics analysis of a four bar linkage mechanism adopted for the hydraulic jack design in this study is based on Freudenstein equation (Ghosal, 2010) given by equation 5;

$$R_1 cos\, \emptyset - R_2 cos\, \psi + R_3 = cos\,(\emptyset - \psi) \quad (5)$$

Where, $\emptyset$ is the input angle, ψ is the output angle.

Figure 3 depicts the crank system showing the operating linkages, where, A, B, C, D, E, F, are the link lengths.

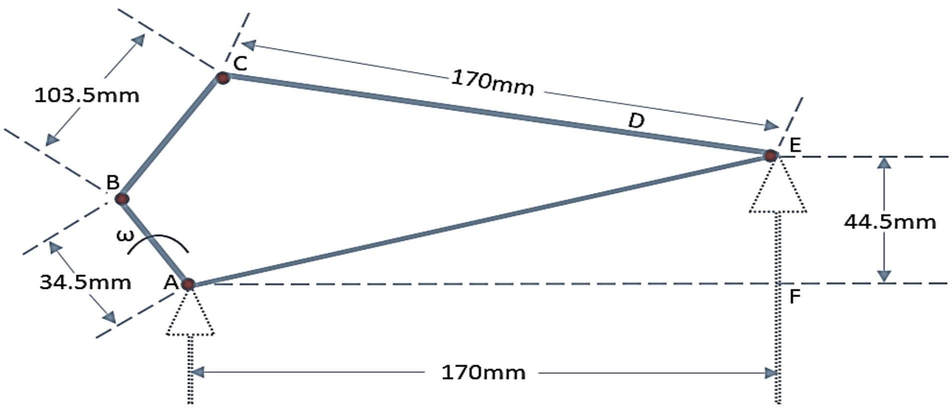


Figure 3: Operating Linkage of a Crank system

AB = Crank = 34.5mm
BC = Connecting Rod = 103.5mm
CE = Lever arm = 170mm
EF Distance between axis along x-axis = 44.5mm
AF = Distance between axis along y-axis = 170mm

For optimal operation, it is important to consider the critical load at which the hydraulic jack can carry. The maximum load that can subject the jack plunger to a state of unstable equilibrium is known as critical load (P_{cr}), and can be calculated based on the following assumptions;

i. Loading is only axial, therefore the centre of gravity of loading passes through the centre of gravity of the cross section.
ii. Material is linearly elastic.
iii. The material is free from initial stress.
iv. Pin joints are frictionless and fixed ends are rigid.

Given by equation 6, the formula for determining critical load (longitudinal compression load on a column) was derived in 1757 by a Swiss mathematician known as Leonhard Euler.

$$P_{cr} = \frac{\pi^2 EI}{L^2} \quad (6)$$

Where *E* is the modulus of elasticity of the plunger material, P_{cr} is Euler's critical load, L is unsupported length of the plunger and *I* is the minimum area moment of inertia of the cross section of the plunger given by equation 7;

$$I = \frac{\pi D^4}{64} \quad (7)$$

Where D is the diameter of the plunger = 50mm, $E = 200x10^3 N/mm^2$ for A36 steel and the Length (L) at full extension = 180mm. Substituting these values into equation (6) gives;
P_{cr} = 18691090.93N

2.4. Design Parameters for Cylinder

i. Inner diameter of cylinder = 43 mm
ii. Outer diameter of cylinder = 55 mm
iii. Thickness of the cylinder = 3 mm
iv. Pressure inside the cylinder = 9.6 N/mm^2

2.5. Power Supply

The circuit needs a power supply of +5V for the control circuit. The power source of the circuit is from the car battery which 12V dc. Figure 4 shows the power supply diagram. RL is a current limiting resistance for the regulator. To obtain the regulated +5V, a voltage regulator was used in the design to get the desired voltage.

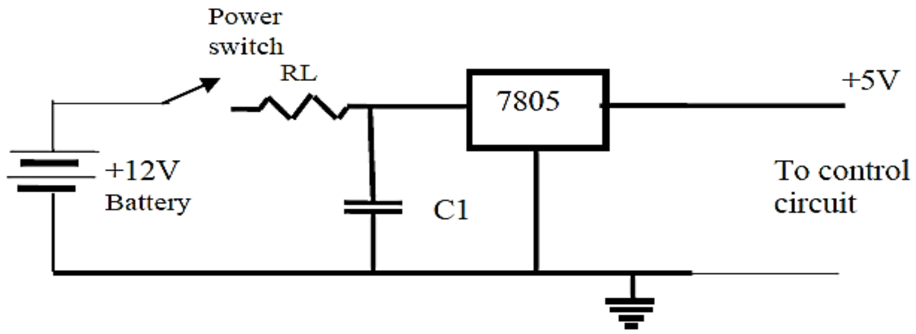


Figure 4: Power Supply Circuit

Specification for the7805 Voltage Regulator is as follows;
Maximum input voltage = 35V
Output voltage = 5V
Drop out voltage = 2V
Minimum input voltage = 7V
Output current = 1A
Supply voltage V_{cc} = 12V
Regulator voltage V_{reg} = 5V
Load current Ia = 0.3A
R_L is a current limiting resistance for the regulator given as equation 8;

$$R_L = \frac{V_{CC} - V_{reg}}{I_a} = \frac{12-5}{0.3} = 23.3\Omega \quad (8)$$

The Infra-red Transmitter circuit is shown in Figure 5.

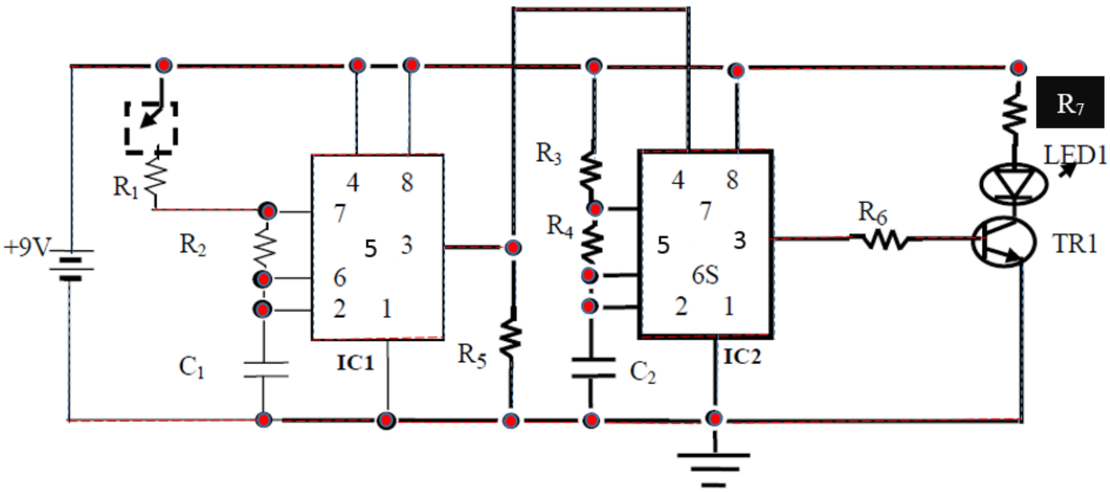


Figure 5: Infra-red Transmitter Circuit

The infra-red LED TIL131 has the following specifications;
Forward voltage drop Vd = 3V
Forward current Ic = 15mA
LED current Ic = 15mA
Supply voltage V_{cc} = 9V
RL which is a current limiting resistance (R7) for the circuit is given by equation 9;

$$\text{Limiting resistance } R_7 = \frac{V_{cc} - V_d}{I_c} = \frac{9-3}{15 \text{ x } 10^{-3}} \quad (9)$$

R7 = 400Ω

Figure 6 illustrates the DC motor-actuator control circuit incorporated in the jack assembly design

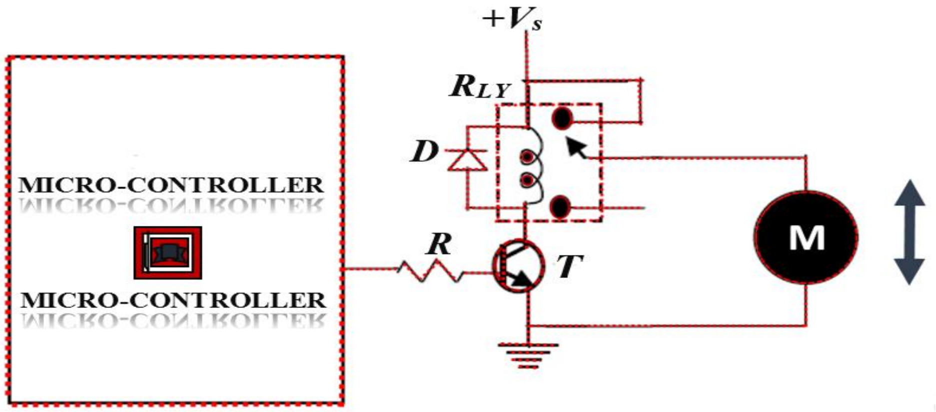


Figure 6: DC motor-actuator Control circuit

Incorporated with the motor-actuator control circuit is a transistor-relay switch that transmits power to the d.c motor to enable movement of the car jack. In other words, operation of the hydraulic jack is aided by a dc motor actuator via an infra-red transmitter which transmits a modulated infra-red beam to the receiver. The receiver amplifies and modulates the signal to suite the coded language of the microcontroller for upward and downward movement of the hydraulic jack. Figure 7 shows testing of the jack after the final design phase.

Figure 7: Testing of the Jack after the Final Design Phase

Effective stress also known as von-mises stress (named after Dr. R. Von Mises who contributed significantly to stress deformation theory) can be calculated theoretically using equation 10, but Finite Element Analysis (FEA) which saves more time and generates more accurate results (Ikpe et al. 2017a) was adopted in this study to determine the behaviour of the jack piston under loading condition.

$$\sigma' = \left[\frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}{2}\right]^{\frac{1}{2}} \quad (10)$$

Mesh control was applied to the heat source in order to establish some salient factors such as the element shape, midside node placement and element size. Curvature based mesh was also applied in order to refine all regions of higher curvature, as these regions are prone to stress formations due to the cylindrical shape of the heat source. These information are basically for the model development process, and can affect the accuracy of the model and subsequent analysis. Generally, the denser the mesh, the higher the accuracy of the solution. This is evidence in Table 1, where the meshed model can be visualized to be highly dense. The boundary conditions employed in the analysis are presented in Table 2.

Table 1. Selected Mechanical Properties for the Hydraulic Jack Model

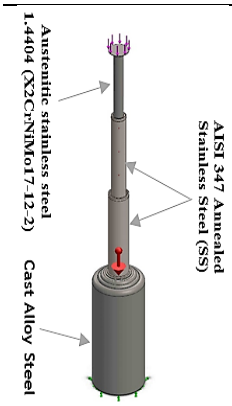
Jack Model	**Mesh Visualization (Solid Mesh)**	**Mechanical Properties**		
		Austenitic stainless steel 1.4404 (X2CrNiMo17-12-2)	**AISI 347 Annealed Stainless Steel (SS)**	**Cast Alloy Steel**
		Yield strength: 4e+008 N/m^2 Tensile strength: 6e+008 N/m^2 Elastic modulus: 2e+011 N/m^2 Mass density: 8000 kg/m^3 Thermal expansion coefficient: 1.1e-005 /Kelvin	Yield strength: 2.75e+008 N/m^2 Tensile strength: 6.55e+008 N/m^2 Elastic modulus: 1.95e+011 N/m^2 Mass density: 8000 kg/m^3 Thermal expansion coefficient: 1.7e-005 /Kelvin	Yield strength: 2.41275e+008 N/m^2 Tensile strength: 4.48082e+008 N/m^2 Elastic modulus: 1.9e+011 N/m^2 Mass density: 7300 kg/m^3 Thermal expansion coefficient: 1.5e-005 /Kelvin

Table 2. Boundary Condition Employed in the Bottle Jack Analysis

Fixtures

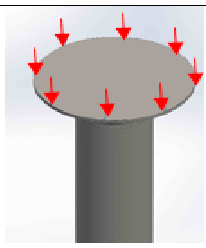
Fixture name	**Fixture Image**	**Fixture Details**
Fixed-1		Entities: 1 face (s) Type: Fixed Geometry

Resultant Forces

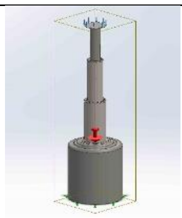
Components	**X**	**Y**	**Z**	**Resultant**
Reaction force (N)	-0.142613	34260.6	0.556175	34260.6
Reaction Moment (N.m)	0	0	0	0

Table 2 (cont). Boundary Condition Employed in the Bottle Jack Analysis

Load

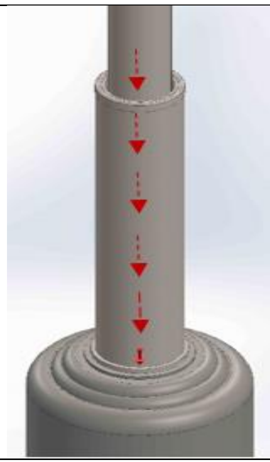
Load name	**Load Image**	**Load Details**
Pressure-1		Entities: 18 face(s) Type: Normal to selected face Value: 8 Units: N/mm^2 (MPa) Phase Angle: 0 Units: deg
Gravity-1		Reference: Top Plane Values: 0 0 -9.81 Units: m/s^2
Force-1		Entities: 1 face(s) Type: Apply normal force Value: 31137.6 N

Contact Information

Contact	**Contact Image**	**Contact Properties**
		**Type: Bonded** **Components: 1 component (s)** **Options: Compatible mesh**

In load bearing applications like the hydraulic jack, highly dense mesh implies that the load bearing capacity of the component is high. This is usually justified in a simple static analysis which will be presented later in this study. The mesh details selected in this study are presented in Table 3.

Table 3. Mesh Properties and CAD Model showing the Direction of Force under Loading

Mesh Information	**Mesh Details**	**Direction of Force**
Mesh type	Solid Mesh	
Mesher Used	Curvature-based mesh	
Jacobian points	4 Points	
Maximum element size	4.07967 mm	
Minimum element size	0.815933 mm	
Mesh Quality Plot	High	
Total Nodes	266210	
Total Elements	160764	
Maximum Aspect Ratio	49.528	
% of elements with Aspect Ratio < 3	97.2	
% of elements with Aspect Ratio > 10	0.151	
% of distorted elements (Jacobian)	0	
Time to complete mesh (hh:mm:ss)	00:01:25	

3. RESULTS AND DISCUSSION

Table 4 shows the list of car models and curb weight the jack was tested with, and the overall time required to elevate a given car to desired height. Curb weight of several vehicles was considered in this study which involved vehicle weights with all fluids and components without the driver, passengers, and cargo. A vehicle scale at nearby auto shop was used to determine the curb weight of different vehicles.

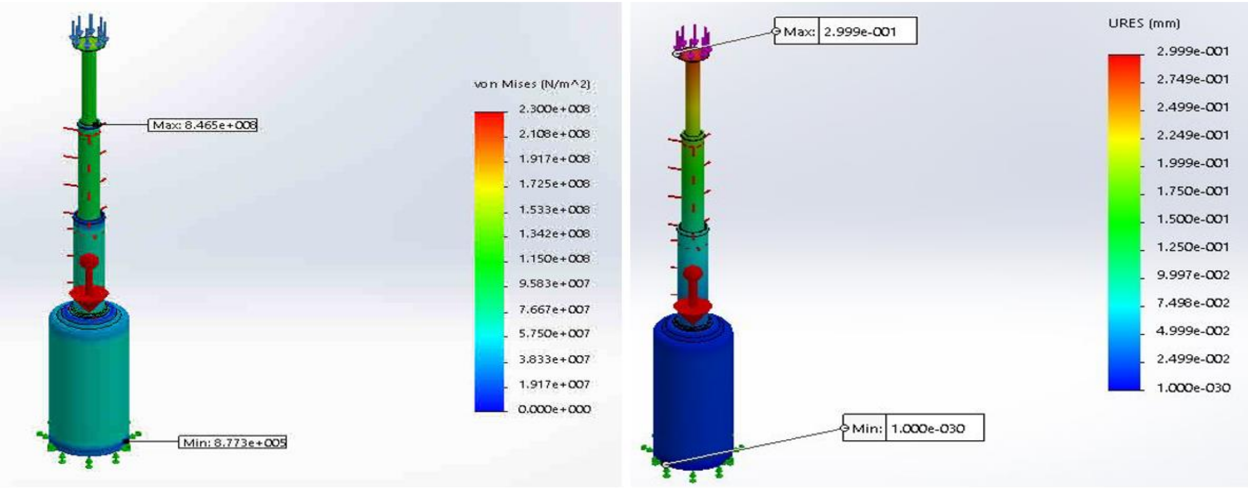
Table 4. List of Car Models and curb weight used for testing the Jack

S/N	Car Model	Curb Weight (Kg)	Height above ground (mm)	Time (Minute)
1	2012 Toyota Avalon	1620	120	1.32
2	2012 Toyota Camry	1446	130	1.28
3	2012 Toyota Prius	1379	135	1.19
4	2013 Toyota Matrix	1309	135	1.22
5	2013 Chevrolet Malibu	1539	125	1.30
6	2013 Chevrolet Corvette	1455	130	1.26
7	2013 Chevrolet Equinox LS	1713	115	1.39
8	2012 Subaru Outback	1585	125	1.31
9	2014 Subaru Impreza	1455	130	1.30
10	2013 BMW 740i Sedan	1970	112	1.44
11	2012 Honda Civic LX Coupe	1187	145	1.9
12	2013 Hyundai Accent	1086	150	1.2
13	2013 Hyundai Elantra	1225	140	1.14
14	2012 Scion xB	1398	135	1.20
15	2012 Scion TC	1407	130	1.27
16	2013 Buick Regal	1632	120	1.33
17	2014 Buick LaCrosse	1703	115	1.38
18	2014 Buick Verano	1496	130	1.26
19	2013 Kia Optima Hybrid	1585	125	1.30
20	2014 Kia Cadenza	1663	120	1.34
21	2012 Lexus IS-F	1714	115	1.40
22	2013 Audi A6	1670	120	1.32
23	2014 BMW 5-Series	1730	115	1.39

As shown in Table 5, the forces acting on the jack piston under loading condition are observed to occur in three different directions including the X, Y and Z direction. However, the values obtained for the forces on X and Z directions were negligible and would have an insignificant effect on the geometry of the jack piston under service condition, whereas, the value obtained for the force (34260.6 N) acting on the jack piston in Y direction was significant in a manner that can incite stresses, displacements and strains on the jack piston. Depending on the severity of forces acting on the material, deformations may ensue that can result in failure of the piston when subjected to intense loading condition. Reaction forces acting on all the three (3) directions and the resultant force are presented in Table 5. Figure 8 represents the von-mises stress and displacement distribution on the Jack Piston while Figure 9 represents the strain and factor of safety distribution on the jack piston.

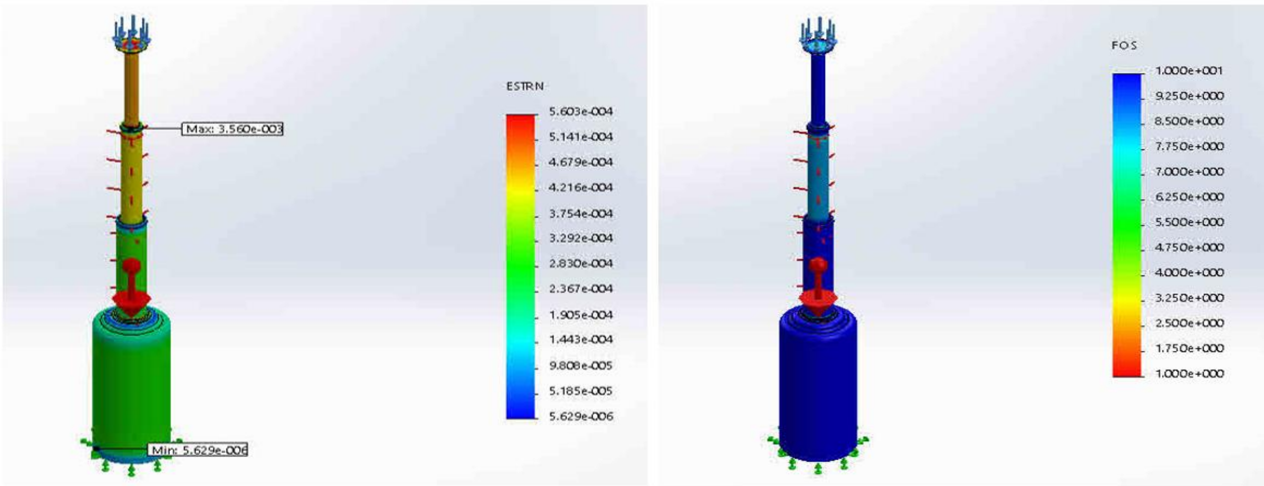
Table 5. Forces Acting on the Jack Piston under Loading Condition

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant Force (per Force point)
Entire Model	N	-0.142613	34260.6	0.556175	34260.6



(a) Von-mises Stress (b) Displacement

Figure 8. Von-mises stress and Displacement Distribution on the Jack Piston



(c) EStrain (d) Factor of Safety

Figure 9. Strain and Factor of Safety Distribution on the Jack Piston

Program for the circuit was written in assembler language MPASM. The codes were computed and downloaded to the PIC16F84A. The infra-red beam is directed towards the receiver unit where the signal is received by infra-red module and demodulates it to produce an output which is transferred to the microcontroller. A code was also generated for the microcontroller to monitor the output of the infrared sensor and decode it for the upward movement of the jack. The microcontroller on reception of pulses checks for frequency and if it is 68Hz, allows the motor to control the jack for upward movement by sending a pulse to TR3. TR3 in turn conducts and activate the relay (RLY). The jack is controlled downwards by manually adjusting the valve for downward movement control of the jack. An optimal synthesis of a four-bar linkage by method of controlled deviations was adopted. The advantage of this approximate method is that it allows control of motion of the coupler in the four-bar linkage such that the path of the coupler is in lined with the desired direction. The curb weight for 2013 BMW 740i Sedan (1970 kg) which was the highest among all the car models was divided into two halves and one half of the curb weight (985 kg) was assumed to be the weight handled by the jack at each phase of operation. This is because, the jack is designed to jack-up only one side of the vehicle at a time and that weight is one half of the vehicle curb weight (985 kg). Assuming the jack is subjected to a load of 985 kg in each operational phase, it is therefore important to check the stress distributions around the jack piston which is constrained from the top to the bottom (base) in its service condition. According to Ikpe et al. (2017b), Von Mises stress is the design criterion used in ductile materials to analyse failure. It is a stress deformation theory that helps verify how a given design will perform under the influence of forces and helps in predicting whether or not failure will occur. Therefore if at any point in the model, von-mises stress induced in a material is higher than the yield strength of the material in a design, there is high tendency of failure occurrence and vice versa. Static analysis was carried out using SOLIDWORKS 2017 version to determine the stresses induced on the piston under one sided vehicle load of 985 kg to determine if the jack component design is safe under the influence of the aforementioned load case. Under the aforementioned vehicle load, maximum von-mises stress of 8.465×10^6 N/mm^2 (MPa) and minimum von-mises stress of 8.773×10^5 N/mm^2 was obtained from the analysis presented in Figure 8a. Making reference to von-mises stress deformation theory, maximum von-mises stress obtained from the analysis was below the yield strength of all the three (3) materials presented earlier in Table 1, implying that the design is safe under the specified conditions. Furthermore, maximum and minimum displacement of 2.999×10^{-1} mm and 1×10^{-30} mm was obtained as shown in Figure 8b with maximum and minimum equivalent strain of 3.56×10^{-3} and 5.629×10^{-6} as shown in Figure 9c. From the maximum strain value, it can be observed that the rate at which elongation occurred on the jack piston as a result of the applied load was within tolerable level that will not result in the displacement value being outrageous. Factor of safety plays a vital role in mechanical engineering designs, as users of engineering components oftentimes overload the components beyond their design limit which eventually exposes the component to premature failure during service condition. However, selection of low Factor of Safety (FOS) in engineering design implies that such design may not always meet its design life expectancy due to poor design considerations and low integrity and vice versa (Ikpe et al. 2016). As presented in Figure 9d, FOS plot shows the distribution of the FOS about the entire model. The FOS is defined by the ratio of the Design load to the von-mises stress. From the distribution about the model in Figure 9d, a scale of 1-10 can be observed for the FOS in which case a very low factor of safety is prone to failure and vice versa. The distribution chart however indicated that a factor of safety between one (1) and two (2) may likely be prone to failure under half weight of 1970 kg which was assumed as the weight on one side of the vehicle. From the colour distribution chart in Figure 9d, areas with FOS between three (3) and six (6) was designated by yellow and pear green colours which implied that areas with these colours are most likely safe but may not withstand further service loads acting on them. In addition, areas with FOS between seven (7) and ten (10) was designated by turquoise blue and royal blue colours which indicated that areas with these colours are safe and can withstand further service loads acting on them. However, carefully observing the FEA jack model from the colour distribution chart from the top of the piston to the base of the hydraulic jack presented in Figure 9d, royal blue colour was predominant with little traces of turquoise blue on the mid-section of the upward projecting piston. This was a clear indication that the design FOS was between the range of 7 and 10, and this is very much safe considering the colour distribution factor.

5. CONCLUSION

In this study, Remotely Controlled Hydraulic Bottle Jack was designed and tested on eighteen (18) different car models to observe its workable height on each of them. Finite Element Analysis was employed in modelling and examining the stress deformations, displacements and equivalent strains when the jack is subjected to half the curb weight of 2013 BMW 740i Sedan and it took 1.44 minute to hoist one half of the maximum curb weight (985) which was assumed as the weight on one side of the vehicle. Compared to the time and energy required to manually hoist different vehicles to workable heights, the remotely controlled hydraulic bottle jack designed in this study can save vehicle users and auto mechanics a considerable amount of time and energy, and above all provide comfort during maintenance and trouble shooting in automobiles related problems.

REFERENCES

Agu, C. S. & Igwe, J. E. (2016). Design and Construction of a Remote Control Car Jack. American Journal of Engineering Research (AJER), 5(8), 76-80.

Deepa, A., Naveen, K. B. & Sagarnath, G. (2016). Design, Development and Testing Of Novel Remote Controlled Electrically Operated Hydraulic Jack. ARPN Journal of Engineering and Applied Sciences, 11(12), 7958-7961.

Ghosal, A. (2010). The Freudenstein equation: Design of four-link mechanisms. Resonance, 15, 699-710.

Ikpe, A. E., Owunna, I. & Ebunilo, P. O. (2016). Determining the Accuracy of Finite Element Analysis when Compared to Experimental Approach for Measuring Stress and Strain on a Connecting Rod Subjected to Variable Loads Journal of Robotics, Computer Vision and Graphics, 1(1), 12-20.

Ikpe, A. E. & Owunna, I. (2017a). Design of Vehicle Compression Springs for Optimum Performance in their Service Condition, International Journal of Engineering Research in Africa, 33, 22-34.

Ikpe, A. E., Owunna, I. B. and Satope, P. (2017b). Design optimization of a B-pillar for crashworthiness of vehicle side impact, Journal of Mechanical Engineering and Sciences 11(2), 2693-2710.

Kamalakkannan, A. Kalaiselvan, P. Isaac, R. & Vijay, V. (2016). Automatic Motorized Screw Jack to Reduce Man Power. International Journal of Scientific & Engineering Research, 7 (5), 21-24.

Majumdar, S. R. (2002). Oil Hydraulics Systems: Principles and Maintenance. Tata McGraw-Hill Education, ISBN-13:9780071406697.

Oghenekome, E., Oladimeji, T. & Oshevire, P. (2014). Design and Implementation of a Remote Controlled Car Jack. Journal of Advancement in Engineering and Technology, 1(1), 1-7.

Patel, P. M., Patel, P. S., Shah, V. H. and Shah, S. R. (2016). Automatic Hydraulic Jack Inbuilt in a Four Wheeler. International Journal of Scientific & Technology Research 5(8), 156-158.

Singh, B. & Mishra, A. (2015). Analysis and Fabrication of Remote Control Lifting Jack. International Journal of Scientific Engineering and Applied Science (IJSEAS) 1 (3), 308-319.

Sainath, K., Mohd, J. B. & Mohd, S. (2014). Design of mechanical hydraulic jack. IOSR Journal of Engineering, 2278-8719.