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Analytic Approach Model of an Automated Car Jack

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ABSTRACT

Designing an automated car jack involves creating a device that can efficiently and safely lift a vehicle with minimal human intervention. The key considerations for such a design include user safety, ease of use, reliability, durability, and cost-effectiveness. Traditional car jacks require significant manual effort and pose potential safety risks. In contrast, the automated car jack integrates advanced automation technology, including motorized lifting mechanisms and sensors for weight and stability monitoring, to provide a hands-free operation experience. This device features user-friendly controls, robust safety systems such as automatic locks and emergency shut-off functions, and is constructed from durable materials to ensure long-term reliability. By reducing physical strain and minimizing the risk of accidents, the automated car jack represents a significant improvement over traditional models, making it a valuable tool for both professional mechanics and everyday vehicle owners. This design not only aims to improve efficiency and safety but also aligns with modern expectations for automation and convenience in automotive tools. The results obtained from five repeated measurements for Load Test Analysis are shows average of 200mm on Maximum Displacement of Manuel Jack and 242mm on Maximum Displacement of Automated Jack with average of 20 sec & 32 sec for Lifting Time for Automated Jack and Manuel Jack respectively. The automated car jack represents a significant advancement in automotive tools, offering a combination of convenience, safety, and reliability that meets the demands of today's vehicle owners. In conclusion, the successful implementation of this automated car jack design can revolutionize how vehicles are lifted for repairs and maintenance, providing a modern, safe, and efficient alternative to traditional manual jacks.

Keywords: Automatic Car Jack, Automation Technology, Cost-effectiveness, Lifting Time, User-Friendly

INTRODUCTION

The design of an automated car jack aims to enhance vehicle maintenance and emergency repair processes by offering a convenient, efficient, and safe lifting solution. Automatic Hydraulic Car Jack explains about the integrated automated jack for 4 wheelers, i.e. by the single push button provided an automobile jack can be operated. The system consists of three main parts that is hydraulic pump, driven by an electric motor, hydraulic cylinder for vehicle lift.

The origin of screw jack can be dated several years ago when Richard Dudgeon, the owner and inventor of screw jack, started a machine shop. In the year 1851, he was granted a patent for his screw jack. In the year 1855, he literally amazed onlookers in New York when he drove from his abode to his place of work in a steam carriage. It produced a very weird noise that disturbed the horses and so its usage was limited to a single street. Richard made a claim that his invention had the power to carry about 10 people on a single barrel of anthracite coal at a speed of 14 m.p.h. Dudgeon deserves a special credit for his innumerable inventions including the roller boiler tube expanders, hole punches and various kinds of lifting jacks (Jayesh et al, 2017).

An electrical remote-controlled screw jack is a type of jack designed to incorporate a DC motor control and link mechanisms having an infrared transmitter and receiver circuits which processes and downward movement of the screw jack (Budyanas and Nisbett, 2015). This works in such a way that it can be used to lift heavy loads designed for it very smoothly without any impact force and also a simple operation so that even unskilled laborer can operate it perfectly with little or no instruction. This is an era of automation where it is broadly defined as the replacement of manual effort with mechanical power in all degrees. The mechanical automation remains to be an essential part of the system, although it comes with some physical changes on the jack; the degree of mechanization is greatly increased.

During the World War II, mechanical screw jacks were very common for jeeps and trucks, for example; the World War II jeeps (Willys MB and Ford GPW) were issued the "Jack, Automobile, Screw type, Capacity 1 1/2 ton", Ordinance part number 41-J-66. The virtues of using a screw as a machine (East and Orange, 1992), essentially an inclined plane wound round a cylinder, was first demonstrated by Archimedes in 200BC with his device used for pumping water. These jacks, and similar jacks for trucks were activated by using the lug wrench as a handle for the jack's ratchet action, for two of the jack. The 41-J-66 jack was carried in the jeep's tool compartment. Screw type jack's continued use for small capacity requirements, is due to low cost of production, to raise or lower it. A control tab is marked up/down and its position determines the direction of movement and almost with no maintenance (Tarachand et al, 2012). The virtues of using a screw as a machine, essentially an inclined plane wound round a cylinder, was first demonstrated by Archimedes in 200BC as the device used for pumping water.

A screw jack is a mechanical device used as a lifting device to lift heavy loads or apply great forces while lifting objects. It could however be classified in the form of levers where a small force lifts a big load, which makes use of screw thread or threads to carry heavy load. It can carry load which can never be imagined considering the effort applied in lifting the load. This is as a screw mechanical jack employs the mechanism of a screw treaded system in the lifting of heavy equipment or loads (Boston, 2008).The most common form is a car jack, floor jack or garage jack which lifts vehicles or trucks so that maintenance can be performed. Screw jacks are usually rated based on its maximum lifting capacity which could include: 1.5-ton, 3-ton, 20 ton or ton (Budyanas and Nisbett, 2008).

The aim of this research is to design a car jack and incorporate it with an electric DC motor to the screw jack to make the operation easier, effortless, safer, faster and more reliable with specific objectives, To:

i. Design an electric remote-controlled system for a screw jack,
ii. Design a screw jack that saves stress and energy
iii. Develop a car screw jack that is powered by internal car power and fully automated with a knob control system
iv. Design a car jack that is safe, reliable and able to raise and lower the height level.
v. Develop a car jack that is powered electrically through the Cigarette lighter receptacle

Operational Definition of Terms

Screw Jack: it is a device that is commonly used to lift moderately heavy weights, such as vehicle.

D.C Motor: it is a rotatory electrical motor that converts electrical energy to mechanical energy

Fabrication: it is the process of carving out something from semi-finished or raw materials

Automated: it an act of reducing human stress by the use of technology.

Knob remote control: A control knob is a rotary device used to provide manual input adjustments to a mechanical/electrical system when grasped and turned by a human operator, so that differing extent of knob rotation corresponds to different desired input.

Cigarette lighter receptacle: The cigarette lighter receptacle in an automobile was initially designed to power an electrically heated cigarette lighter, but became a DC connector to supply electrical power for portable accessories used in or near an automobile.

MATERIALS AND METHODS

Materials

i. Motor
ii. knob remote control
iii. Power screw
iv. Cigarette lighter receptacle

Design Analysis and Calculation

To obtain the degree of freedom (m)

Where n=8 and J =10

M = 3(n-1) - 2J

M = 3(8-1) – 2 × 10

M = 3(7) – 20

M = 21 – 20

M = 1

The angle of inclination at a particular height of lift

$$\cos\theta = (\frac{x1}{2} - b2)/l_1 \quad (1)$$

Where w_1 =350, b_2=36, l_2=185

$$\cos\theta = (\frac{350}{2} - 36)/185$$

$$\frac{175-36}{185}$$

$$\cos\theta = 0.75$$

$$\theta = cos^{-1}0.75$$

$$\theta = 41.1^0$$

The magnitude of the pull thread

$$F = \frac{w}{2\tan\theta} \quad (2)$$

Where w (weight of the car) = 1471.907kg

$$\frac{1471.907 \times 9.81}{2\tan\theta}$$

$$\therefore F = \frac{14.43}{2\tan 41.1}$$

$$F = \frac{14.43}{1.7632}$$

= 8183.9N or 8.184KN

Tensile pull on the square threaded rod

w_1= 2 × 8183.9 = 16367.8N

But load on the screw is given by

$$w_1 = \frac{\pi}{4}(d_c)^2\sigma_t \qquad (3)$$

The tensile and shear strength of mild steel screw may be taken to be 448MPa and 224MPa respectively

Where:

$$d_c = \frac{\sqrt{4w_1}}{\pi\sigma_t}$$

$$d_c = \sqrt{\frac{4 \times 16367.8}{3.142 \times 448}}$$

$$d_c = \sqrt{\frac{65471.2}{1407.616}}$$

$$d_c = \sqrt{46.5121}$$

$$\frac{255.873}{1407.616}$$

$$d_c = 6.82mm$$

Outer diameter of the screw

$$d_0 = d_c + p \qquad (4)$$

Where p (pitch) = 5mm

$$d_0 = 6.825 + 5 = 11.825mm$$

Also mean diameter

$$d_m = d_0 - \frac{p}{2}$$

$$= 11.825 - \frac{5}{2}$$

$$= 11.825 - 2.5$$

$$d_m = 9.325$$

The effort required to rotate the screw

$$p = w_1 \tan(\alpha + \theta) = \frac{w_1(tan\alpha + tan\theta)}{1 - tan\alpha.tan\theta} \quad (5)$$

where $\tan\alpha = \frac{p}{\pi d_m}$

$$\tan\alpha = \frac{5}{3.142 \times 9.325}$$

$$\frac{5}{29.29915}$$

$$\tan\alpha = 0.17$$

$$\alpha = tan^{-1} 0.17$$

$$\alpha = 9.6^0$$

$$Effort\ (p) = \frac{w_1(tan\alpha + tan\theta)}{1 - tan\alpha.tan\theta} \quad (6)$$

$$= \frac{16367.8(tan9.6 + tan41.4)}{1 - tan9.6.tan41.4}$$

$$\frac{16367.8(0.1691 + 0.8816)}{1 - 0.1691 \times 0.8816}$$

$$\frac{16367.8(1.0507)}{1 - 0.1491}$$

$$\frac{17197.6}{0.8509}$$

$$= 20211N$$

Torque required to rotates the screw

$$T = P \times \frac{d}{2} \tag{7}$$

$$20211 \times \frac{9.325}{2}$$

$$T = 94233.8NM$$

Shear stress in the screw due to torque is given by:

$$\tau = \frac{16T}{\pi(d_c)^3} \tag{8}$$

$$\tau = \frac{16 \times 94233.8}{3.142 \times (6.82)^3}$$

$$\frac{1507740.8}{996.69}$$

$$= 1513N/M^2$$

Direct tensile stress in the screw

$$\delta t = \frac{w_1}{\frac{\pi}{4}(d_c)^2} = \frac{4w_1}{\pi d^2} \tag{9}$$

$$= \frac{4 \times 16367.8}{3.142 \times (6.82)^2}$$

$$\delta t = \frac{65471.2}{146.14}$$

$$\delta t = 448N/M^2$$

Maximum Principal (tensile) stress

$$\sigma_{t(max)} = \frac{\sigma_t}{2} + \frac{1}{2}\sqrt{[(\sigma_t)^2 + 4\tau^2]} \quad (10)$$

$$\sigma_{t(max)} = \frac{448}{2} + \frac{1}{2}\sqrt{[(448)^2 + 4(1513)^2]}$$

$$\sigma_{t(max)} = \frac{448}{2} + \frac{1}{2}\sqrt{[200704 + 9156676]}$$

$$\sigma_{t(max)} = 224 + 1529.5$$

$\sigma_{t(max)} = 1753.5$MPa

$$\tau_{t(max)} = \frac{1}{2}\sqrt{[(448)^2 + 4(1513)^2]}$$

$$\tau_{t(max)} = \frac{1}{2}\sqrt{[200704 + 9156676]}$$

$\tau_{t(max)} = 1529.5$MPa

Efficiency of the screw jack

$$\eta = \frac{tan\theta}{\tan(\alpha+\theta)} \quad (11)$$

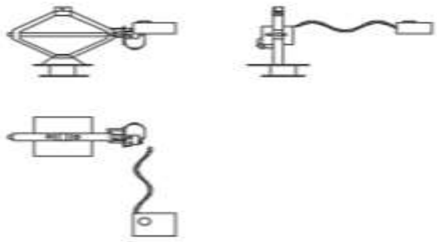
$$\eta = \frac{\tan 41.4}{\tan(9.6 + 41.4)}$$

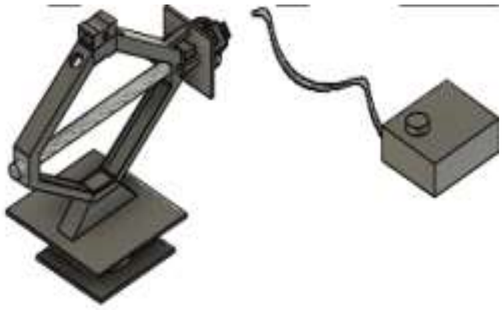
$$\eta = \frac{\tan 41.1}{\tan(9.6 + 41.4)}$$

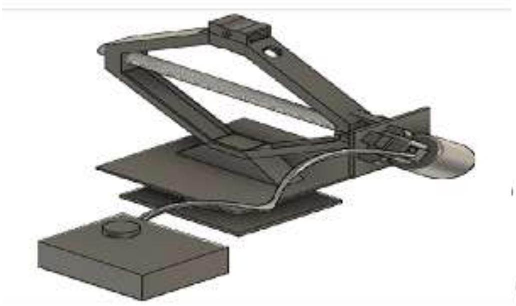
$$\eta = \frac{0.8816}{1.2348}$$

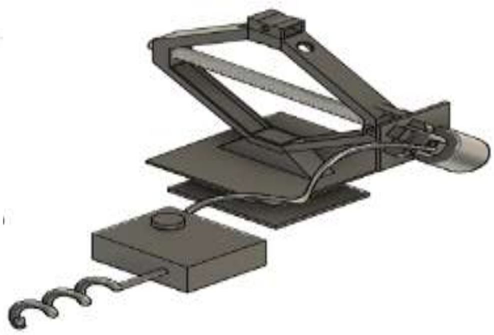
$$\eta = 0.71 \times 100$$

= 71%









RESULTS AND DISCUSSION

The results obtained from five repeated measurements for Load Test Analysis are shows average of 200mm on Maximum Displacement of Manuel Jack and 242mm on Maximum Displacement of Automated Jack with average of 20 sec & 32 sec for Lifting Time for Automated Jack and Manuel Jack respectively (Ipilakyaa et al, 2017) as shown in Tables 1.

Table 1: Load Test Analysis

Number of test	Maximum Displacement of Manuel Jack (mm)	Maximum Displacement of Automated Jack (mm)	Lifting Time for Automated Jack (sec)	Lifting Time for Manuel Jack (sec)
1	100	120	10	16
2	150	180	15	21
3	200	250	20	32
4	250	300	25	40
5	300	360	30	51
Average	200	242	20	32

$$\text{Average Time} = \frac{t1+t2+t3+t4+t5}{5} \quad (12)$$

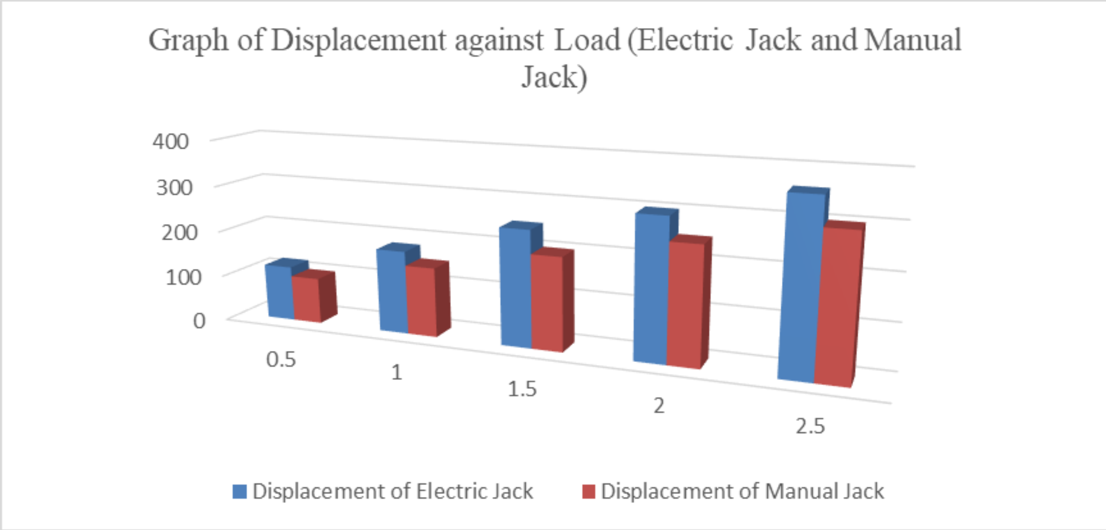


Figure 1: Load Test Analysis

The bar chart shows the difference in height of the two jacks. The reason while electric jack is higher than manual is because in the design of electric jack there is base welded to the mild steel that supports the jack to raise a load to a certain height convenient enough for the repairer to work underneath and table 2 shows the design output for the calculated parameters.

Table 2: Design Output

Parameter	Result
Degree of Freedom (m)	1
Angle of inclination at a particular height	
The magnitude of pull on the square thread screw (F)	8183.9N
Tensile pull on the square threaded rod	16367.8N
Core diameter	6.82mm
Outer diameter of the screw	11.825mm
Mean diameter	9.325mm
Effort required to rotate the screw (P)	20211N
Torque require to rotate the screw (T)	94233.8Nm
Shear stress in the screw	1513
Direct tensile stress	448
Maximum Principal tensile stress	1753.5
Efficiency	

From the calculation of the following, we obtained, the degree of freedom is 1 because it operates only on the vertical axis, angle of inclination at a particular angle, the effort required to the 2021N , the efficiency of electric jack is 71%, which means the design is of standard because is above half of 100% efficiency. However, from the comparison it is seen that the electrical control remote screw jack have more advantages than manual screw jack, efficiency of manual screw jack is less than 50% since mechanical advantage and velocity ratio is less than half.

Operation of Automated Jack

Hydraulic Jack Working is based on Pascal's principle. That is, the pressure applied to a fluid stored in a container will be distributed equally in all directions. The important components of a hydraulic jack are cylinders, a pumping system, and hydraulic fluid (oil is used commonly). As per Pascal's principle, pressure exerted at any point on liquid in a container gets transmitted to all other parts of the liquid without any loss. This means the pressure at the top of a container and the one at the bottom will be equal. This type jack is easily driven by an electric motor through a set of reduction gears instead of by a hand operated crank. It is also the smallest and lightest of the jacks that can be electrically driven, due to the gear reduction of the drive motor and the jack itself. Electrically operated car scissor jacks are powered by 12v electricity supplied directly from the cars cigarette lighter receptacle. The electrical energy is used to power these car jacks to raise and lower automatically. Electric jacks require less effort from the motorist for operation.

CONCLUSION

Designing an automated car jack involves creating a device that can efficiently and safely lift a vehicle with minimal human intervention. The key considerations for such a design include user safety, ease of use, reliability, durability, and cost-effectiveness. The automated car jack design integrates advanced technology and practical engineering to address the needs of modern vehicle users. By incorporating automated lifting mechanisms, sensor technology for weight and stability detection, and user-friendly controls, the automated car jack provides a reliable and efficient solution for vehicle maintenance and emergency situations. The emphasis on safety features, such as automatic locking systems and emergency stop capabilities, ensures that the device operates within safe parameters at all times, reducing the risk of accidents. Furthermore, the choice of materials and components ensures durability and long-term performance, making it a cost-effective investment for consumers. The automated car jack represents a significant advancement in automotive tools, offering a combination of convenience, safety, and reliability that meets the demands of today's vehicle owners. In conclusion, the successful implementation of this automated car jack design can revolutionize how vehicles are lifted for repairs and maintenance, providing a modern, safe, and efficient alternative to traditional manual jacks.

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