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Design and Development of Electric Jack

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ABSTRACT: The huge amount of effort is required for manual operation of jacks, so for that reason there is a need of innovation. For the repair and maintenance of an automobile vehicle, it is require lifting that automobile for changing the wheel or accessing the bottom of vehicle. According to that several kinds of jacks are used for lifting automobile from ground surface. In side road emergences like tyre puncture or vehicle maintenance and repair, conventional car jacks used mechanical advantage to allow human power to raise the vehicle by manual force. This project shows modification of current mechanical manual jack with the use of an electric DC motor in the screw in order to make load lifting easier with the use of car battery.

KEYWORDS: Gear ratio, Power screw, jack, DC motor, Car battery

I. INTRODUCTION

Nowadays, mechanical artefacts are commonly found in general routine life. They are widely used in many fields of appeal such as office, industrial automation, hospital operation, security systems and military task. It is easy to observe that the mechanical designs and instruments plays very wide role in assisting human life.

The mechanical jack is used to lift the car during side road emergency i.e. tyre puncher. A mechanical toggle jack is a device which is used to lift bulky equipment and all or part of a vehicle into the air in order to facilitate vehicle for its maintenances or breakdown repair. Changing a flat tire is not a very good experience. Nowadays, different kinds of types of car jacks have been developed for lifting an automobile from a ground surface. Available car jacks, however, are generally manually operated; therefore require substantial laborious physical effort on the part of the user. These are such relevant difficulties of jack for the elderly and handicapped people. It further requires the operator to remain in prolonged bent or squatting position to operate that jack. Doing work in a squatting or bent position for a long period of time is not suitable for human body. It will arise body problems like back ache problems.

A mechanical toggle jack is operated by rotation of lead screw. In this case of a jack, a small force applied in the horizontal plane is used to lift very large weight. The compressive force of jackscrew is obtained through the tension force applied by its lead screw.

The significance and main idea of this project is to modify the existing car jack in order to make the operation easier, safer and more reliable in order to save individual internal energy and avoid health risks especially back ache problems associated with doing work in a bent position for a long period of time. That's all concerning about why electric jack is needed.

This paper shows the modification of the current mechanical toggle jack to electric jack by incorporating an electric DC motor with the screw in order to make load lifting simple for emergency use of lifting a vehicle using power of car battery.

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II. MATERIALS AND METHODS

2.1 Materials

Material selection is a very important step in the process of designing any physical object. In the ambience of product design, the main objective of material selection is to minimize cost while meeting product performance goals. Well-ordered selection of the best material for a given application begins with properties and cost of applicant material. For withstanding against heavy loads, toggle jacks are generally made of materials which are very strong. The two common materials used for making quality jacks are Aluminium and Steel. When selecting the material appropriate for the development of the toggle jack one has to consider the properties that will make it to function with no foreseeable failure and at the same time the weight and ease of machining the product. Therefore the main orientations that can be categorized in this case are the strength of the ease, material, cost and weight of manufacturing. The light weight and low melting point of aluminium makes it easier and efficient to machine than steel. Aluminium's fatigue performance is 1/2nd that of steel, which is an advantage steel, has over aluminium in car jack life durability. Therefore Steel is the most suitable material selected for the manufacture of the mechanical toggle jack.

2.2 Methods

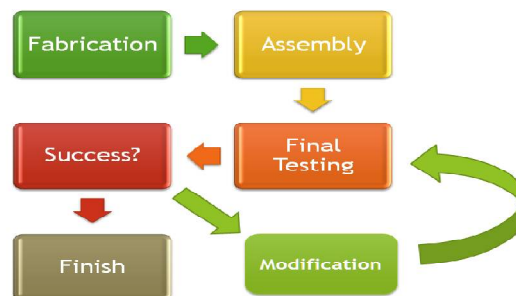


Figure 2.2 Flow of manufacturing stage

Once designing stage is completed, the manufacturing methods should be selected. The various kinds of fabrication methods like milling for gear manufacturing, cutting plates for gear box, drilling in plates, welding etc., are to be applied for manufacturing various parts of product. Following fabrication stage there is assembly stage, where assembly should be done for getting final product. The various kinds of testing should be done for performance check of the product according to design calculation. After this if product seems reliable and promising than work is finished and if it's not then product goes through modification stage following by final testing. This process continuous until final test results is positive for the product.

III. WORKING OF ELECTRIC JACK

The electric jack will lift a vehicle chassis in contact with the top section in working condition, when the power screw is rotated through its connecting gear with the pinion after electrical power applied to the motor when plugged to the 12V battery in car. Motor transmits its rotating power to the pinion gear meshing with the bigger gear connected to the power screw to be rotated with required speed reduction and increased torque to drive the power screw connected with it. The power screw rotates within the threaded bore of side member in the clockwise direction that will cause the links to be goes along the threaded portion towards each other during load-lifting process and vice versa. Initially the jack will first be placed below the vehicle to be lifted such that at least a small clearance will exist between the top plate and the vehicle chassis to be lifted. Then after power screw will be turned so that the top section makes contact with the car chassis and the clearance space will be eliminated. As contact is made with car, load of car will be increasingly shifted to the top plate and cause forces to be developed in and transmitted through links and side

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member of the electric jack. The force transmitted through the side member will be transferred on threads of screw of electric jack. By switching circuit connected to the motor we can regulate the rising and lowering process of car.

IV. DESIGN CALCULATION

3.1 Input

Maximum weight of car = 2000 kg or 19620 N

Ground clearance = 280 mm

Maximum lift = 50 mm

3.2 Derived

Angle in upper position (θ_{\max}) = 78.23°

Angle in lower position (θ_{\min}) = 29.89°

$$\tan(\theta_{\max}) = \frac{120}{85} \Rightarrow \theta_{\max} = 78.23^{\circ}$$

$$\tan(\theta_{\min}) = \frac{57.5}{235} \Rightarrow \theta_{\min} = 29.86^{\circ}$$

3.3 selection of standard screw jack

$d_c = 13.5$ mm

$d = 18$ mm

$d_m = 15.5$ mm

$p = 4$ mm

Length of screw (l) = 450 mm

3.4 Motor selection

DC motor (13 Nm)

Power = 60 watt

Torque = 13 Nm

Voltage = 12 V

Current = 2A

3.5 Initial data

a) $T_1 = 13$ Nm

b) $N_1 = 50$ rpm

c) Output torque (T_o) = $\frac{Ff}{n}$

Helix angle (λ) = $\tan^{-1}\left(\frac{1}{\pi dm}\right) = 51.139$

$$\mu' = \frac{\mu}{\cos \beta} = 0.154$$

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Where, $\beta = 14.5^\circ$ = for acme thread

$$\mu = 0.15$$

$$\phi = \tan^{-1} \mu' = 8.80^\circ$$

$$\text{Req. torque } (T_f) = \frac{w \cdot d m}{2 \cdot \tan \theta_{\min}} * \tan (\phi + \lambda) = 23.177 \text{ Nm}$$

$$\text{Efficiency of threads } (\eta) = \frac{1 - \sin(\phi)}{1 + \sin(\phi)} = 73.46 \%$$

$$\text{Actual torque req. } (T_0) = \frac{T_f}{\eta} = 31.5511 \text{ Nm}$$

d) Gear ratio (G) = 3.88 \cong 4

e) Actual output torque (T_2) = 52 Nm

f) Output speed (N_2) = $\frac{\text{Input speed}}{G} = \frac{50}{4} \cong 13 \text{ rpm}$

3.6 Assumptions

- Number of teeth on pinion (t_p) = 13
- Number of teeth on gear (t_g) = $t_p * G = 52$
- Factor of safety (N_f) = 1.5
- Assuming 20° full depth involute tooth system, $\phi = 20^\circ$

3.7 Design of gear pair

$$\text{Lewis's form factor } (y) = 0.154 - \frac{0.192}{t}$$

$$\text{Pitch line velocity } (v) = \frac{\pi \cdot d_p \cdot N_1}{60000} = \frac{\pi \cdot 18 \cdot 50}{60000} = (0.034 \text{ m}) \text{ m/s}$$

$$\text{Velocity factor } (k_v) = \frac{6}{6+v} = \frac{6}{6+0.034 \text{ m}}$$

$$K_a = 1.0$$

$$\text{Beam strength of the tooth } (W_t) = \frac{P}{v} * K_a = \frac{1764.70}{m}, \text{ N}$$

$$\text{Ratio factor } (Q) = \frac{2 \cdot t_g}{t_g + t_p} = 1.5$$

$$\text{Load stress factor for gear } (k) = \frac{\sigma_{esg}^2 \cdot \sin \phi}{1.4} * \left(\frac{1}{E_p} + \frac{1}{E_g} \right) = 0.715$$

Where;

$$\sigma_{esg}^2 = 554.4 \text{ N/mm}^2 = \text{surface endurance stress}$$

$$E_p = 210 \text{ GPa}$$

$$E_g = 190 \text{ GPa}$$

$$W_t = \frac{P}{v} * K_a = (\sigma_{bg} * K_v) m * b * \pi * y_g$$

$$\therefore \frac{1764.70}{m} = 200 * \frac{6}{6+0.034 \text{ m}} * m * 10 \text{ m} * \pi * 0.1487$$

$$\therefore m = 2.112 \cong 3 \text{ mm}$$

3.8 Various parameters of gear pair

$$b = 10 * m = 30 \text{ mm}$$

$$d_p = m * t_p = 54 \text{ mm}$$

$$d_g = m * t_g = 162 \text{ mm}$$

$$v = 0.9832 \text{ mm/s}$$

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3.9 Check the gear for dynamic and wear load

Wear strength (W_w) = $d_p * b * Q * k = 1737.45 \text{ N}$

Beam strength of the tooth (W_t) = $\frac{1273.24}{3} = 424.41 \text{ N}$

$W_w > W_t$, there for the design is safe from standard point of wear.

V. MATERIAL SELECTION

Table 5.1 properties of pinion and gear according to material selection

Parameter	Pinion	Gear
Material	C45	C35Mn75
Tensile strength	670 N/mm ²	600 N/mm ²
BHN	229	223
Elastic modulus	210 GPa	190 GPa

A mechanical toggle jacks are generally made of materials which are very strong and are suitable for with standing against heavy loads. The two main materials used for making good quality jacks are steel and Aluminium.

VI. RESULTS

6.1 View of product

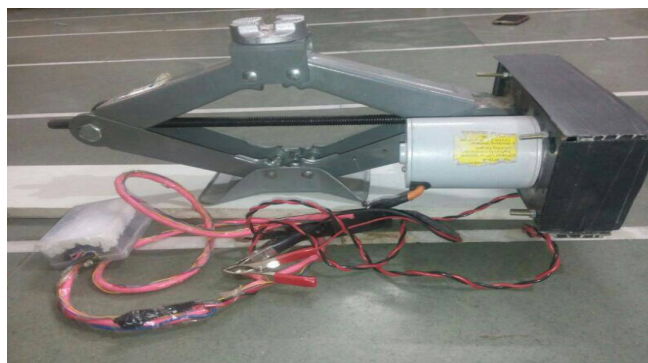


Figure 6.1 Side view of modified electric jack

Figure 5.1 shows electric jack which is modified from simple mechanical toggle jack. It shows electric motor connected parallel with power screw of jack through gear box. The electric motor is connected with remote which can use to lifting and lowering the jack.

6.2 Description of Product

- High quality 2 ton electric jack
- Simple, design for ease of use and maintenance.
- Perfect for travel use and emergency wheel / tyre changes.

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- Compact and lightweight design.
- Ideal for lifting cars and light vans.
- Plugs directly into the vehicle's cigarette lighter socket or other 12V power source.
- Long lasting and durable construction for long service life.

6.3 Product Specification

- Maximum capacity: 2 ton
- DC Voltage: 12V
- Maximum current: 13A
- Range of lift height: 120mm - 280mm
- Length of control wire: 5m

6.4 Comparison

Table 6.4 Comparison between Electric Jack and Manual Jack

Electric jack	Manual toggle jack
Can be done painless and saves time & energy	Consume a lot of time and energy
Durable and withstands high pressure / load	Durable and withstands high pressure / load
Automatic but still involves minor manual jobs	Everything needs manual work
Initial cost is slightly higher than manual jack	Cheap and equipped in almost every vehicle
The motor provides many more rotations per minute but provides less force per revolution and so less load carrying capacity	Needs much less rotations per minute but produces higher force/torque per revolution and so high load carrying capacity
High quality	High quality

VII. CONCLUSION

The existing mechanical toggle jack was modified by making small adjustment and making use of an electric motor to drive power screw, connecting gears with the pinion mounted on the shaft of motor. The automobile 12V battery source is used to operate prime mover (motor), to shallow weight lifting easier. The power screw is getting rotation through its gear when electrical power effluence through it. The benefits of this jack is it will save time, be faster and easier to operate and requires less energy of human and additional work to operate the jack. There by potent deterrent the problems associated with Ergonomics - which is a fundamental approach of design process. Considering all available car jacks in the market, this model can be improved by some other alteration on the features and design. The aspiration is to design a car jack that is reliable, free from danger and able to lift and lower the level, to design and develop a car jack that is powered by car battery is self and automated by button system.

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VIII. FUTURE SCOPE OF WORK

- Permanently mounted jack mechanism on the vehicle can be developed so that tyre change can be completely automated.
- The jack is operated by the use battery of the car, for which long wire connection are needed. So by the use of chargeable battery mounted on the jack assembly itself reduce wire length and also reduce some more manual work.
- The weight of the product is somewhat high, so by the use of some light weight material we can reduce the weight of overall product.
- The initial cost of the product seems very high compared with manual jack, so work towered reducing the cost of overall product is needed.

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