Design and Fabrication of Devising Simplified Motorized Scissor Jack

T. Ajay[1], Gihish D Jacob [2], A. Shameer [3], Dr. D. Ramalingam[4]

[1]Assistant Professor, Department of Mechanical Engineering, Ponjesly college of Engineering, Nagercoil, India.
[2]PG Student, Department of Mechanical Engineering, Ponjesly college of Engineering, Nagercoil, India.
[3]PG Student, Department of Mechanical Engineering, Ponjesly college of Engineering, Nagercoil, India.
[4]Professor& Principal, Mahakavi Bharathiyar College of Engineering & Technology, Tirunelveli, India.

ABSTRACT

Scissor jacks are simple mechanisms used to drive large loads for short distances. The power screw design of a common scissor jack reduces the amount of force required by the user to drive the mechanism. Most scissor jacks are similar in design, consisting of four main members driven by a power screw. The work in this study is design & fabrication of, an electrically operated scissor jack. A scissor jack, electrically operated by switch buttons consists of a motor, four arms, a load engaging head and stabilizer base. The motor will be the lifting mechanism. When the car needs to be lifted, just press the button and release the button at the desired height level. The common problem faced by the mechanical car jack in the market is it is manually operated and needed physical effort to lift the vehicle. The developed automatic car jack is based on the result and analysis part to lift loaded car, van (approximately 2 tones).

1 INTRODUCTION

An automotive jack is a device used to raise all or part of a vehicle into the air in order to facilitate repairs [1]. Most people are familiar with the basic car jack (manually operated) that is still included as standard equipment with most new cars. These days, a car jack is an important tool to have in our vehicle due to unknown upcoming event such as flat tire in our journey. Even so, people who like to rotate their tires themselves or who may install snow tires before the winter and remove them in the spring need to use a jack to perform the job. Changing a flat tire is not a very pleasant experience [2].

Furthermore, available jacks are typically large, heavy and also difficult to store, transport, carry or move into the proper position under an automobile. In addition, to the difficulties in assembling and setting up jacks, such jacks are generally not adapted to be readily disassembled and stored after automobile repairs have been completed [3]. Car jacks must be easy to use even for women or whoever had problem with the tire in the middle of nowhere.

In light of such inherent disadvantages, commercial automobile repair and service stations are commonly equipped with large and hi-tech car lift, wherein such lifts are raised and lowered via electrically or hydraulically powered systems. However, due to their sheer size and high costs of purchasing and maintaining electrically-powered car lifts, such lifts are not available to the average car owner. Engineering is about making things simpler and effective [1]. Such electrical-powered portable jacks not only remove the arduous task of lifting an automobile via manually-operated jacks, but further decrease the time needed to repair the automobile. Such a feature can be especially advantageous when it is necessary to repair an automobile on the side of a roadway or under other hazardous conditions.

Available jacks present difficulties for the elderly, women and are especially disadvantageous under adverse weather conditions. They further require the operator to remain in prolonged bent or squatting position to operate the jack [4]. Hydraulic systems that do not have the necessary hydraulic fluids will not function, which becomes a problem when a leak occurs. You must repair the leak so the hydraulic fluids can continue to produce flow; otherwise, the hydraulic system will begin to slow down. Areas that have leakage will also have hotter internal temperatures. This phenomenon can prove beneficial; since these temperatures can help the operators of the hydraulic systems locate the leak, prevent leaks by using proper procedures and the correct materials, and by performing regular preventative maintenance. You must filter oils in hydraulic systems on a regular basis to ensure that the hydraulic fluid contains no broken particles, as well as to eliminate harmful damaging air pockets.

Scissor jacks have several key advantages over both hydraulic jacks and manual labor methods:

a. The jack is light and compact.
b. Making it easy to stow in the trunk of any size vehicle.
c. The jack's lightweight design makes it user friendly for people of all strengths and physical abilities.
d. A scissor jack will not suddenly "leak" and drop down like some hydraulic jacks.
e. The precision of these jacks allows for extremely precise lifting capabilities.

In addition to automotive applications, the scissor jack can also be used in construction and remodeling. Building a deck is a great opportunity to employ a scissor jack outside of the garage. Regardless of the nature of the project, a scissor jack is a quick, safe, and easy way to elevate heavy objects.

An electric car jack which has a frame type of design by using electricity from the car battery or separate battery will be developed. Operator only needs to press the button from the controller without working in a bent or squatting position for a long period of time to change the tire. In order to fulfill the needs of present car jack, some improvement must be made based on the problems statement [5]. To design a car jack that is safe, reliable and able to raise and lower the height level. To develop a car jack that is powered by internal car power and fully automated with a button system.

2 LITERATURE REVIEW

In this section, the important terminologies in this proposed method are presented.

a. Jack

A mechanical jack is a device which lifts heavy equipment. The most common form is a car jack, floor jack or garage jack which lifts vehicles so that maintenance can be performed [6]. Car jacks usually use mechanical advantage to allow a human to lift a vehicle. More powerful jacks use hydraulic power to provide more lift over greater distances. Mechanical jacks are usually rated for a maximum lifting capacity (for example, 1 tons or 2 tons).

b. Scissor jack

A scissor jack is a simple and effective tool used to elevate vehicles, stabilize trailers, and lift a variety of heavy items with little physical effort. A scissor-jack is a type of platform which usually only does work in one plane. The scissor jack shown in figure 1 lifts against the vehicle weight in the vertical direction. If oriented vertically, the scissor jack would move up and down in the vertical plane. Consequently, if oriented horizontally, the lift would move side to side in the horizontal plane. The mechanism to achieve this is the use of linked; folding supports in a criss-cross 'X' pattern that pivot where the legs cross. Most scissor jacks are oriented vertically and are used to create an aerial work platform, which raises vehicles high. A compound scissor jack involves multiple stacked 'X' patterns which greatly increases the stroke of the lift in a very small footprint.

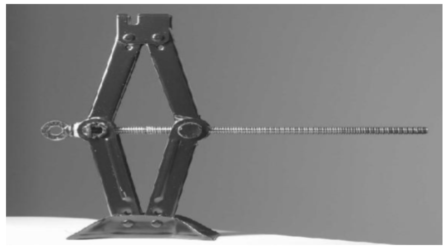

Figure 2.1. The scissor jack

c. Self-Locking Power Screw:

Due to the arrangement of the scissor jack, it would also be advantageous for the power screw to be self-locking. If a power screw were self-locking, no magnitude of axial force would allow the screw to rotate [8]. Without this feature, the gear motor would be responsible for holding the power screw in place during the vehicle loading process when the power screw is rotated to the top extreme height and during idle operation when the load reaction forces are pushing against the power screw at full length. It would also result in an input of work into the system with no work output from the system. The power screw driving the scissor jack will self-lock as long as the coefficient of friction between the collar and trapezoidal rod is greater than 0.06.[9]

In this case, the power screw is self-locking with a 0.25 coefficient of friction.

3 PROPOSED METHODOLOGY

The scissor jack design consists of four main lifting members, four connection members, a power screw and a crank. Members 1 through 8 are all primarily c-shapes with ideal pin connections. Members 1 and 5 both have additional details to account for the contact surfaces. The power screw is single threaded with a collar at the member 3connection. The following is a summary of the design features for our proposed SCISSOR jack.

a. Main Lifting Members:

These members are made from simple c-shapes. The web of the members is cut out near the pin connections to allow proper serviceability of the scissor jack at its maximum and minimum heights. Members 4 and 6 have ideal gear connections to balance the load between the left and right side. The flanges of the channels are to wrap around the flanges of the sleeve members. The lifting members are greater in length and are subjected to compression. Lifting member flanges on the outside of the sleeve flanges is to compensate for slenderness ratio by increasing the moment of inertia of the lifting members.

b. Sleeve Members:

The sleeve channels are to open inwards. This is so the flanges are subjected to tension instead of compression. The bending moment from the power screw creates tension on the inner edge of the sleeve and compression on the outside edge. Tension along flanges on the inside prevents the possibility of localized buckling in the flanges from compressive forces. Additionally, the threaded sleeve section is to have additional thread surface area. These additional threads safely transmit the stress from the power screw to the sleeve. Threading the thickness of the web of the channel would not be sufficient for reasonable power screw diameters. This addition is only made on the threaded sleeve section and not on the collared sleeve section. The collar transmits the stress safely to the c-shape.

c. Contact Members:

The members that make contact with ground and the service load are members 1 and 5 respectively. Member 1 has additional flanges to provide a stable base for the mechanism while servicing the load. Member 5 has an attached plate atop to provide sufficient contact area. Motorized scissor jacks have ridges which lower the area of contact. This causes stress concentrations which can damage the underside of a car.

d. Power Screw:

The Power Screw is single threaded with a collar on the side in contact with Member 3.The collar is assumed to be frictionless and the power screw has been designed to be self-locking. The primary raising method is through the power screw's shaft coupling which is common to most scissor jacks. Incorporated into our proposed design is an option for a secondary raising method. The collar on the power screw acts as a bolt with a hexagonal head.

4 DESIGN ANALYSIS

a. DESIGN OF POWER SCREW:

1. CALCULATION OF DIAMETER (dC):

To lift a weight of 2000 kg (20000 N), Mild steel being a ductile material we may take the value of tensile strength and tensional shear stress values as 130MPa and 230MPa.

$$\sigma = \frac{P}{\frac{\pi}{4}d_c^2}$$

$$130 = \frac{20000}{\frac{\pi}{4} \times {d_c}^2}$$

$$d_c = 0.014 \text{ m} \tag{4.1}$$

From the normal series Trapezoidal thread table (PSG design data book), the nominal diameter 16 mm with pitch, p = 4mm is choose.

The core diameter, dc = 14mm

The major diameter, dmaj = 16 mm

The mean diameter, dm = 15mm

2. CALCULATION OF TWISTING MOMENT (Mt):

Twisting moment required to lift the load is given by,

$$M_t = \frac{F \times d_p}{2} \times \left[\frac{\mu \pi d_p + L\cos\alpha}{\pi \times d_p \cos\alpha - \mu L}\right] + \left(\mu F \times \frac{d_c}{2}\right) \tag{4.2}$$

– Axial force (231.91N)

dp – diameter of pitch, m

L – Thread lead, m

α – thread radial angle

dc – core diameter, m

μ - co-efficient of sliding friction (0.25)

$$M_f = 231.911 \times \frac{.015}{2}\left[\frac{(.25 \times \pi \times .015) + (.004 \times \cos 30)}{(\pi \times .015 \times \cos[30) - (.25 \times .004)]}\right] + \left[\frac{.25 \times 231.911 \times .015}{2}\right]$$

$$M_t = 1.1\ Nm \qquad (4.3)$$

3. CHECK FOR SHEAR STRESS (τ):

Maximum shear stress,

$$\tau_{max} = \frac{16 \times M_t}{\pi \times {d_c}^3}$$

$$\tau_{max} = \frac{16 \times 1.1}{\pi \times .014^3}$$

$$\tau_{max} = 2.043 \times \frac{10^6 N}{m^2} \qquad (4.4)$$

The calculated value is less than the maximum value. Therefore, design is safe.

4. CHECK FOR STRENGTH:

Twisting moment on thread,

$$M_t = P\frac{d_p}{2}\tan(\beta + \rho) + M_f$$

$$M_f = P\frac{d_{red}}{2}\mu$$

$$M_f = 231.911 \times \frac{0.015}{2} \times \tan 6^{\circ}$$

$$M_f = 0.183\ N\,m$$

$$M_t = 231.911 \times \frac{0.015}{2}\tan(3.64 + 6) + 0.183$$

$$M_t = 0.478\ N\,m$$

$$\tau = (16*0.478)/(\pi*0.014\text{^}3)$$

$$\tau = 8.87*10\text{^}5\ N/m2 \qquad (4.5)$$

This value is less than theoretical value(230 MPa).

Hence, design is safe.

Normal stress in the screw, σ = (4P)/(π*dc3)

$$\sigma = (4*231.911)/(\pi*0.014^3)$$

$$\sigma = 1.07x\ 10^8\ N/m2 \qquad (4.6)$$

where,

Mt – torque transmitted by the screw (N m)

β – Helix angle of the screw,

ρ – Friction angle 6° to 8°

For self locking β < ρ

Mf – Friction moment on the end or support, N m

Dred – reduced diameter of friction forces on the pivot, m

μ – Co efficient of friction, tan ρ

b. DESIGN OF LIFTING MEMBERS:

Moment of inertia,

$$I = \frac{bh^3}{12}$$

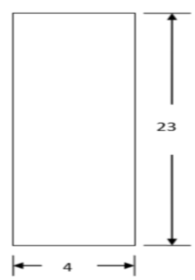

Figure 2. Cross section of links

where,

b= breadth of the member (m)

h=height of the member (m)

$$I = \frac{.004 \times .023^3}{12}$$

$$I = 4.056 \times 10^{-9}\ m^4 \qquad (4.7)$$

Crippling load,

$$P_c = \frac{\sigma_C \times A}{1 + a\left(\frac{L_e}{k}\right)^2} \qquad (4.8)$$

where,

σ_C –compressive stress (N/m2)

A- Area(m2)

Le –effective length(m)

$constant, a = \frac{1}{7500}$ (R.K.Bansal, "STRENGTH OF MATERIALS")

$$A = b \times h$$

$$A = .004 \times .023$$

$$A = 9.2 \times 10^{-5}\ m^2$$

$\sigma_c = 320 \times 10^6 \frac{N}{m^2}$ (R.K. Bansal, "STRENGTH OF MATERIALS")

$$P_c = \frac{320 \times 10^6 \times 9.2 \times 10^{-5}}{1 + \frac{1}{7500}\left(\frac{.17/2}{6.639 \times 10^{-3}}\right)^2}$$

Effective length,

$$L_e = \frac{L}{2}$$

$L_e = .17/2$

Radius of gyration, $k = \sqrt{\frac{I}{A}}$

$$k = \sqrt{\frac{4.056 \times 10^{-9}}{9.2 \times 10^{-5}}}$$

$$k = 6.639 \times 10^{-3}\ m$$

$$P_c = 28.81\ kN$$

The maximum load is 2 tons.

c. COST ESTIMATION:

Sl.no	Materials	Specifications	Cost (each In rupees)	Total cost (each In rupees)
01	Mild steel	-	120/kg	240
02	Motor	12V, DC motor	3500	3500
03	Wires	1 sq mm	10 (1 meter)	80 (8 meters)

5 CONCLUSION

Our proposed design is similar to common SCISSOR designs in some aspects, but also advantageous in others. It can safely raise a load of 7000kg to the required heights with relative ease on the user. The features of our design are lifting the required load without human effort by using 12V DC supply, to lift the heavy vehicles and making easy manufacturing. Unique to our design, however, is the manufacturability of our design, which is much simpler. Since only c-shapes are utilized, bulk material can be more efficiently purchased and used. Also, less machining is required since there are no complex sleeves for the power screw. Only simple attachments which can be welded on are proposed. Therefore, when compared to similar scissor jack designs that perform equally as well, our proposed design is recommended for its easy handling, manufacturability and lower cost. We recommend that this design will very useful at the time of tyre puncture and absence of cleaner without any human effort. It can be easily operated by ladies and handicapped. If this project is developed to high load carrying capacity, the heavy vehicles can be lift with less effort.

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