Effect of Lifting Load on Solar Powered Screw Jack Design In Automotive Vehicles

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Abstract— Most of the present day resources of energy are limited and irreplaceable. Next generation will face acute energy crisis if alternate resources of energy are not developer concurrently. In today's developing world, the extent of automation is obviously the foremost focus of engineers. Screw jack is a device which is used to lift and support a heavy load in automotive vehicles, such as a car. Generally, human effort is required to rotate the screw, but in present work, it is eliminated by solar operated push button type equipments. A set of experiments were performed and a mathematical model was experimentally framed to predict the power requirement at a given load. The experiment showed that the model is verified for wide range of load.

Key words: Screw jack, power requirement, model, battery and solar panel, etc.

I. Introduction

Photovoltaic's is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material. In today's developing world, the extent of automation is obviously the foremost focus of engineers. But, the automation does not reach to the poorer section of the society as the automation is costly affairs.

In a screw jack, rotary motion is converted into linear motion. There are stresses like shear and tensile stresses induced in materials which are responsible for failure of screw. Screw jack must consist of an adequate factor of safety and must be of high mechanical advantage, so that it can withstand sudden jerks which are unexpected. One of the flat surfaces of the screw jack is placed on ground and another flat surface on top side is used to lift the car.

A lot of effort is required for moving the screw jack manually and many times it becomes difficult to operate for an inexperienced person. Though a lot of work has been done in automated solar powered screw jack but only limited work is available for its analysis and mathematical model in automotive vehicles. The present research work is related to design and development of toggle type automated screw jack system using solar energy.

II. Experimentation

The motor is given power by a charger that is charged by a photovoltaic solar panel (13-19V)

- Energy source = non conventional from solar panel
- Size = 345mm × 425mm
- Capacity = 15 W
- Battery Charging = 0.6 to 0.9 Ampere/hour
- Battery 12 V and 10 Ah
- DC motor = 12 V, geared.
- On- off switch = 16 Ampere toggle.
- Coefficient of limiting friction(μ) = 0.1
- Load on each tyre (assuming there are 04 tyres and 1000 kg weight of vehicle is distributed uniformly) = 250 Kg.

The battery utilized in our case is 12V, 10Ah capacity. Specification of motor used for moving the screw jack was 12V, 2.5 A DC supply. But, in our application the motor has to operate at high torque because, it has lifted the power jack. So, reduction gears were used for reducing the speed to 38 rpm. This gear box reduces the speed and increases the torque of the motor. Intermediate switches were used for lifting and lowering the load.

Power supplied by motor = V X I Watt where V is in volts and I is in Amp. …. (1)

The principle of screw jack is that of inclined plane (4). When the screw is rotated once, the load gets lifted by a height p equal to lead of the screw, α is the angle of inclination plane and ϕ is the angle of limiting friction so that $\mu = \tan\phi$, d is the mean diameter of the screw and W is the weight to be lifted.

The expression for torque (T) = (d/2) .W .tan ($\alpha + \phi$) …………(2)

$\mu = \tan\phi$

$\tan(\alpha) = p/(\pi d)$

Theoretical Power(P_{th}) = $2\pi N T / 60$ Watt ………(3)

Where N is in r.p.m. and T is in N-m.

The mechanical assembly consists of a 12 V DC, 2.5A motor with gear attached. The battery utilized in our case is 12V, 10 AH capacity. Specification of motor used for moving the screw jack was 12V, 2.5 A DC supply. But, in our application the motor has to operate at high torque because it has to lift the power jack. So, gear box is incorporated with the DC motor. This gear box reduces the speed and increases the torque of the motor. Push button switch was used for lifting and lowering the load.

III. Results and discussion

Fig.1: Screw jack operated by solar battery

A. Condition Derived For Initiating Design:

Input parameters are decided by making a study of cars specifications and various loading conditions. Some input are decided by practical analysis of the vehicles lifting condition while jacking during tyre failed condition.

- Maximum weight that screw jack has to lift = 250kg
- Ground clearance = 165 *mm.*
- Maximum lift = 50 *mm.*

B. Design of Screw:

It is observed that max load acts on jack when vehicle is on horizontal surface. Angle between the links with horizontal axis when screw bears maximum stress as show in Fig. 1.

$\Theta=23^0$

Each of the two nuts carries half the total load on the jack and due to this, the link AB is subjected to tension while the square threaded screw is under pull. The magnitude of pull on square threaded screw is given by

$$F = \frac{2500}{2\times tan23} = 2945 \text{ N}$$

Similar pull also acts on the other nut, therefore total tensile pull on the square threaded rod

W_1 =2F, i.e. 5890N

Now, load on the screw (W_1),

$$5890 = \frac{\pi}{4} d_c^2 \ \boldsymbol{\sigma}_t$$

Yield point stress for C35 Steel (annealed)=300 MPa, Permissible stress for the steel(annealed) is =300/3 =100 MPa , taking factor of safety=3

d_c= 8.659mm

Screw is also subjected to torsional shear stress, therefore to account for this we take a standard value as follows:

- Core diameter (d_c) = 11.5mm
- Outer diameter (d_o) = 14mm
- Mean diameter (d_m) = 12.75mm
- Pitch of the screw (p) = 2.5mm
- Length of the screw = 350mm

Now, the helix angle is,

$$\tan\alpha = p/(\pi\ d_m) = \frac{2.5}{3.14\times 12.75} = 0.0624$$

For co- efficient of friction, $\tan\phi$ = 0.15

(Considered for steel and cast iron screw nut combination, machine oil screw combination)

Now, the effort required to rotate the screw,

$P = W_1\tan(\alpha+\phi)$= 1262 N

Torque required to rotate the screw,

T = =8045.25 N-mm

Shear stress due to torque, $\tau = \frac{16\times T}{\pi\times dc^3}$ =27MPa

Direct tensile stress in screw, $\sigma_t = \frac{5890}{(\pi/4)\times 11.5^2}$ = 56.7MPa

Maximum principle tensile stress,

$$\sigma_{t(max)} = \frac{56.7}{2} + \frac{1}{2}\sqrt{56.7^2 + 4\times 27^2} = 67.5\text{MPa}$$

Maximum shear stress

$$\tau_{max} = \frac{1}{2}\sqrt{56.7^2 + 4\times 27^2} = 39.15\text{MPa}$$

Since the maximum stresses are within safe limits, therefore the design of square threaded screw is satisfactory.

C. Design Of Nut:

n= number of thread in contact with the screw

Assuming that the load W_1 is distributed uniformly over the cross section area of the nut, therefore bearing pressure between the thread (p_b),

$$15 = \frac{5890}{\frac{\pi(14^2-11.5^2)n}{4}}$$

Solving, n= 7

thickness of nut = 7×2.5= 17.5mm

width ofnut = 1.5 d_o=21m

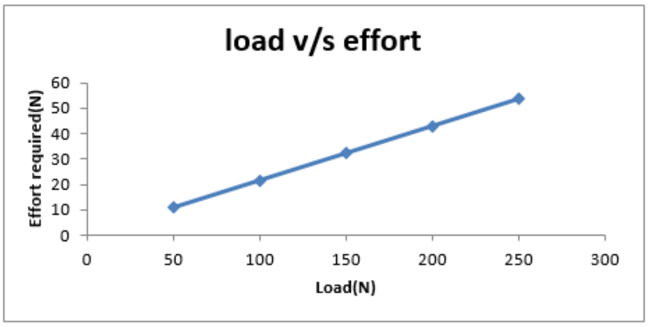

Fig. 4.2: Graph between load lifted and efford required

D. Design Of Pins In The Nuts:

d_1 = diameter of pin in the nut

since the pins are in double shear, therefore load on pins (F),

$$2945 = 2\times \frac{\pi}{4}\times d_1^2 \times\tau$$

τ(shear stress) taken as 50 MPa, then

d_1 = 6.12mm ; say 8mm

diameter of pin head = 1.5* 8= 12mm

E. Design Of Links:

mainly there are two conditions for link failure, so we have to check the design for both the conditions

Design for Buckling in vertical plane:

Load on links = F/2 = 2945/2 = 1472.5N

Assuming a factor of safety = 3, the links must be designed for a buckling load of

W_{cr} = 1472.5 * 3 =4416 N

Let t= thickness of link,
b= width of link

Assuming width of link is five times the thickness of link. Hense cross sectional area of link ,

A =$5t^2$

And moment of inertia of the cross section of the link,

$$I = \frac{1}{12} t^* b^3 = 10.41\ t^4$$

We know that, radius of gyration,

$$k^2 = \frac{I}{A} = 10.41\ t^4 / 5t^2$$

k= 1.44t

Since for buckling of the link in the vertical plane, the ends are considered as hinged, therefore equivalent length of link,

L = 160mm

and Rankine's constant, $a = \frac{1}{7500}$

According to Rankine's formula, buckling (W_{cr}),

$$4416 = \frac{\sigma c \times A}{1+a(L/k)^2} = \frac{100\times 5t^2}{1+\frac{1}{7500}\left(\frac{160}{1.44t}\right)^2}$$

t= 3.2 =4mm (say) ,b= 20mm

F. Design For Buckling In Plane Perpendicular To Vertical Plane:

In this condition ends are considered as fixed, therefore Equivalent length of the link,
L = 160/2 = 80mm
And moment of inertia (I) = $\frac{1}{12}\times$ b t^3=0.42t^4

And k^2= 0.41t^4/5t^2
k= 0.288t
k= .288*4 =1.152mm

Again according to Rankine's formula, buckling load,

$$W_{cr} = \frac{\sigma c \times A}{1+a(L/k)^2} = \frac{100\times 5(4)^2}{1+\frac{1}{7500}\left(\frac{80}{1.152}\right)^2} = 4869 \text{ N}$$

Since the buckling load is more than the calculated value, therefore the link is safe for buckling in a place perpendicular to the vertical plane.

G. Gear Design:

A gear arrangement is used for increasing the torque provided by the motor. There is a worm gear arrangement with a compound gear.
Consider the worm gear efficiency= 90%
And spur gear efficiency = 100%
Speed reduction ratio was 38 and motor rpm =1440.
Torque multiplication ratio = 1440/38= 37.89

H. Motor Selection:

In this automated screw jack the torque required to rotate the screw is provided by a dc motor. Such kind of dc motors is available in different power rating models. For this kind of screw jack a relationship between power and load lifted was developed using different formulas which are used above:

Load lifted (N)	Torque after gear reduction (N mm)	Motor torque Required (N mm)	Power of motor(watt)
500	1611	42.4	6.50
1000	3222	84.8	13.0
1250	4028	106	16.25
2500	8056	212	32.5

Table : Load and power relation

But according to requirement one can use different size of motor. It is established through experiments that 17W dc motor lift upto a load of 125kg that can be used with 3 wheeler automobiles and other similar vehicles. However, it even lifted a car of load 250 kg when the battery was fully charged because of higher factor of safety but may not be used for reliability of the system.

Power (Watt) =2 x π x N x T/60 where N (38 in present analysis) is rpm and T is the torque.

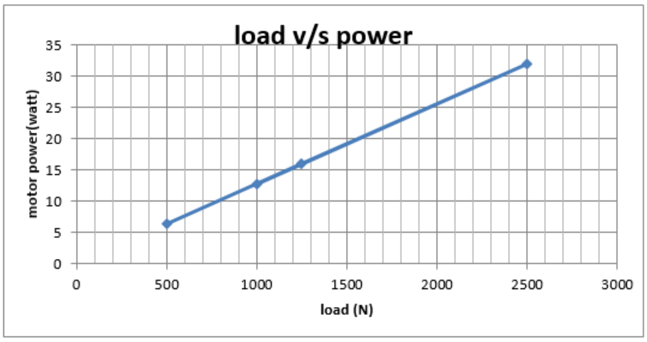

Fig. 4.3: Graph between load lifted and motor power

I. Mathematical Model:

Graph between power and load is straight line. The equation of line in Y=mX+c where c is intercept and m is the slope of the line. For the present case it may be written as Y= 0.013x X as c=0 and slope (m= dy/dx=0.013)
Motor Power (W) = 0.013 x Load (N) …………………(4)

This mathematical model gives solar operated motor power for any load and therefore, solar system can be designed accordingly.

J. Specifications Of Battery:

12 V, D.C. battery
Current rating = 7.5 A
Charging time = 10.7 hours
(Average current supply of P-V panel= 0.7 A/h, so $\frac{7.5}{.7}$ = 10.7 h)

Such a solar panel battery system is sufficient to 0.7 A current at 12V supply nearly for 10 hours at good maintenance condition which is sufficient for screw jack application and other small applications like mobile charging,lighting applications.

The biggest advantage of using Solar Power is that it is an inexhaustible source of energy. Once you have installed the system, you don't have to worry that you would ever be without electricity because the sun is always going to be there. The next advantage of using solar energy is that it doesn't emit any pollution into the environment. Solar panels don't release any emissions into the atmosphere while generating electricity. Total cost of solar electromechanical device was Rs.3000 but there was no running cost. Besides D.C.motor, other solar lighting devices such as CFL, LED's and mobile chargers were also operated from the energy stored in battery from solar panel(Fig.1).

IV. CONCLUSIONS

The solar driven automated toggle screw jack is put under various force analysis so that its performance criterion will not fail in operation. Following conclusion are determined through the appropriate calculations and practical demonstrations:

- A mathematical model was framed to estimate the power requirement at various loading conditions. The model worked effectively in wide range of loading conditions to estimate the power requirement and experimentally validated.
- Torque required decreases with increase in load.

- Stepwise all the design parameters were calculated and verified.
- It is multifunctional in terms of energy fulfillment requirement at small scale such as charging the mobile phones, CFL lights etc.
- Screw jack is solar powered and therefore, there is drastic reduction in human effort as the movement of screw jack is automatic.
- Solar energy is cheaper and available free of cost.

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