Battery Operated Toggle Jack

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Abstract - Today's world requires speed on each and every front. Nowadays, for achieving rapidness, various machines and the equipment's are manufactured by the human being. Engineers are constantly conformed to the challenges of bringing ideas and design into reality. New machines and techniques are being developed continuously to manufacture various products at economical rates and high quality. As a part of reducing the manual effort, it is proposed to modify the jack available in the market which is operated manually into electric operated jack. In fast-moving world, time is very important that's why we decide to manufacture electric operated jack which can remove the punctured car tyre in shortest time. Also, the other need of jack is easy to handle and having compact size. Less man power required to operate this jack. So, women can also easily remove the car tyre by using this jack.

Key Words: Toggle Jack, Battery, Switches, Cables, lead screw etc

1. INTRODUCTION

In the olden days the energy or effort was the manual effort. But, over the years new technologies have been developed and implemented in each and every field. These techniques/devices help in great extent to reduce the manual effort. Mechanical machine toggle jack is one such device commonly employed to reduce the manual effort.

Mechanical machine toggle jacks are available in standard ranges and the capacities vary from 5kN to1000kN. Standard classic and symmetric toggle jack configurations include upright or inverted translating toggle units with top plate, clevis or threaded end on lifting toggle jack and upright or inverted rotating toggle with flanged lifting nut. Machine toggle jacks are useful for positive mechanical actuation, precise positioning and uniform lifting speeds and can be use to push, pull or apply pressure or as linear actuators.

2. CONSTRUCTION OF THE JACK

2.1 Worm Gear operated toggle jack:

It consists of the following different components:

1) **Lead toggle**: It is the component at the top of which a load raising plate is installed on which the concentrated load to be raised, is resting. It manufacture from plain carbon steel material followed by heat treatment of case hardening.

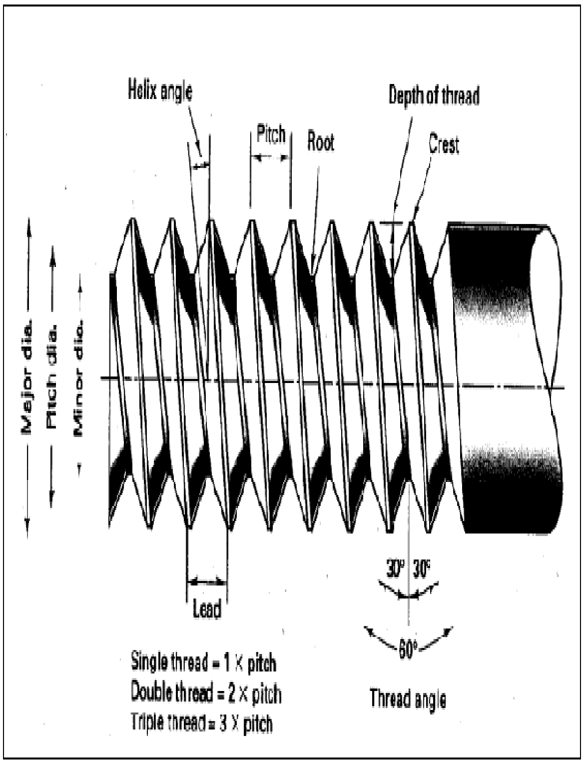


Fig.no. 1: Standard screw thread nomenclature

2) Nut: It is the component which is rotated by the worm shaft because the nut is installed on the worm gear. The load raising lead toggle advances through this nut UP and DOWN. It is applied with the lubricating grease to have its smooth functioning.

3) Worm shaft: It is that component which actually rotates the worm gear along with the nut to advance the toggle. It is rotated manually using the tommy lever. It perfectly meshes with the worm gear.

4) Worm gear wheel: It the component being rotated by the worm shaft. It is used to transmit the power between shafts with the perpendicular, non intersecting axes. The worm wheel is essentially a helical gear with a face curved to fit a portion of worm periphery.

5) Plate box: It is manufactured from the 4 mm thick mild steel plates to form a rigid body of the worm geared jack instead of casting body. It is installed with the worm and

worm gearing along with the lead toggle and nut arrangement hold firmly.

6) Top rest: It is a trapezoidal foot rest over which all the concentrated load of the car and the jack is resting. It forms a robust top to be coupled with the car body or the axle for the complete jack.

7) Foot platform: It is the circular plate which holds the concentrated load firmly without slippage. It may be provided with the serrated area to hold the load firmly.

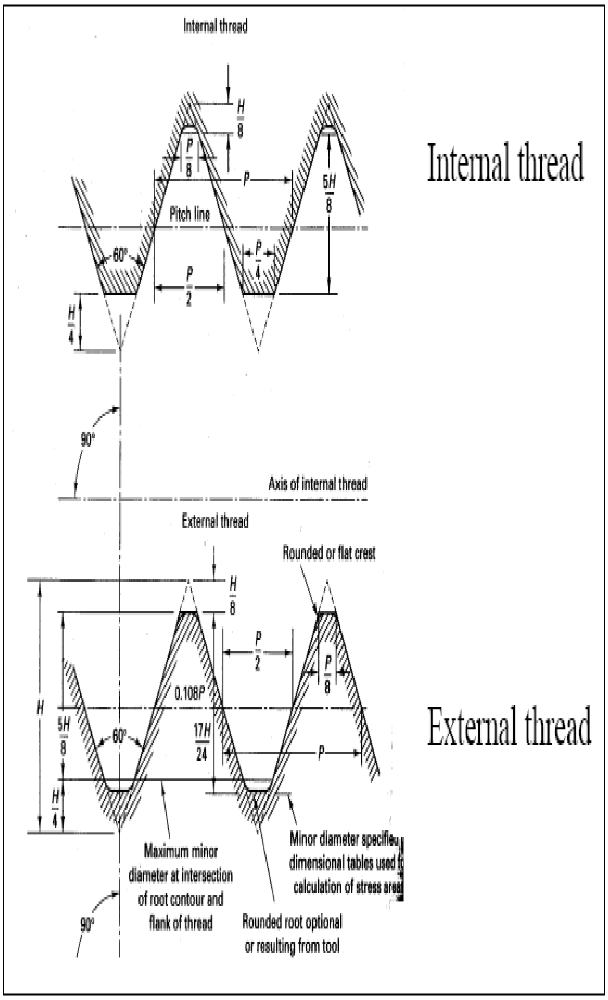


Fig. no. 2: Unified screw thread geometry form

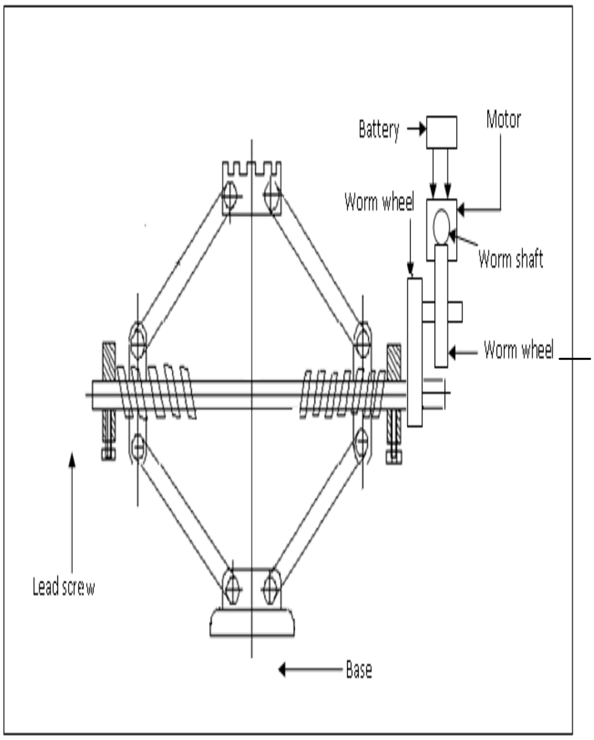


Fig. no. 3: Construction of toggle jack with worm &worm wheel

3. DESIGN

3.1 Design concept of jack:

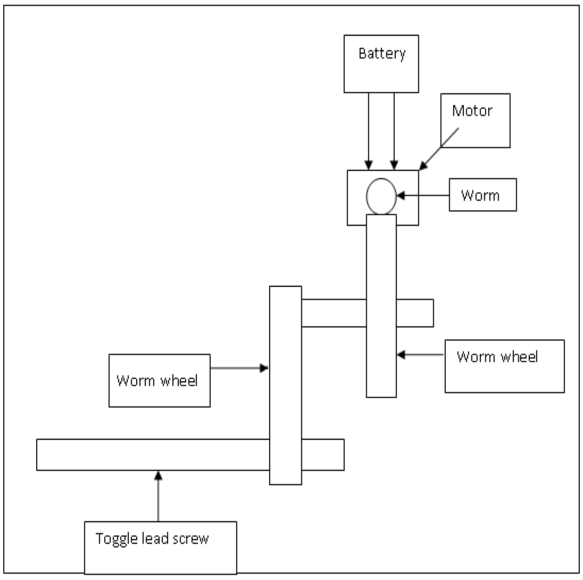


Fig.no. 4: Design concept of jack

The aim of our project is to lift the car (Maruti 800) using toggle jack with the help of DC motor which can be operaed by 12 volt battery of the car. First we have calculated the weight of the car and from this the load coming on the each wheel of the car. Then we have measured the clearance between the ground and axle. As we know the load & lifting length, we have calculated the pitch of the lead screw, then with the help of pitch & lifting length we have calculated speed of the lead screw. From the speed of the leadscrew & speed of the motor we have selected the particular speed ratio for worm gearing mechanism. From above data we have designed the toggle leadscrew, nut, pin, worm, worm wheel. After that we have designed worm wheel shaft for bending & twisting moment. By using the diameter of worm wheel shaft & radial load coming on shaft at bearing, we have selected the bearing. From this we have selected the DC motor.

3.2 Material Selection:

Following are some of the important factors on which selection of material is based:

- Availability and cost of material
- Strength and rigidity
- Resistance to fatigue
- Impact resistance
- Hardness
- Weight
- Machinability and weldability

However, the most important factor affecting the selection of material for engineering design is the properties of metals in relation to their intended use. The properties of metal define a specific characteristic of the material and behaviors of the metal under different conditions. We have selected malleable carbon steel for fabrications of various component of our project due to following properties and composition of material.

3.3 Data for Design:

Jack for maruti car

Total weight of the car: 1 ton of concentrated load with concentrated centre of

gravity.

Weight of jack : 15 kg

Maximum Lift : 430 mm from the ground level.

Minimum ground clearance for jack : 60 mm from the ground

Time required to lift wheel in upward direction: 200 mm/min

Maximum load capacity of jack: 10000 N

Design of Toggle Screw:

Fig.no.5 : Toggle lead screw

The toggle screw is made up of malleable steel for which the ultimate strength is 450 Mpa. As the toggle screw is subjected to very rough handling, we have to consider more factor of safety

The total tensile pull on the square threaded screw

W=2F

F=w/2

=10000/2

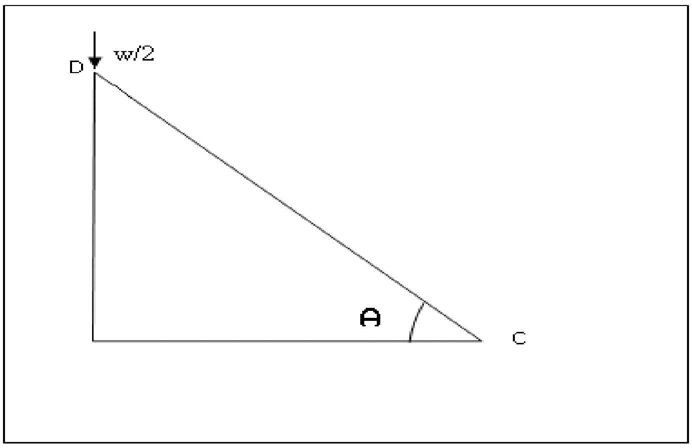


Figure no. 6: Tensile pull on threaded screw

F=5000 N

Suppose pull F acts on the left nut ,

Due to which link CD is in tension.

$$F = W / (2 \times \tan\theta)$$

$$5000 = 10000 / (2 \times \tan\theta)$$

$$\theta = 45^\circ$$

Let dc= core diameter or screw.

Direct tensile or compressive stress due to axial load is given by,

$$6_c = W \div [\,[\pi/4] \times dc^2]$$

$$6_c = 100 \text{ mpa} \quad \text{(middle steel)}$$

$$100 = 10000 \div [\,[\pi/4] \times dc^2]$$

$$dc = 12 \text{ mm}$$

Nominal or outer diameter of screw;

$$do = dc + p$$

$$= 12 + 2$$

$$do = 14 \text{ mm}$$

P =pitch of screw = 2 mm (from standard table)

Mean diameter of the screw,

$$d = do - (p/2)$$

$$= 14 - (2/2)$$

$$d = 13\text{mm}$$

Let us, now check for principle stress

We know that,

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

$$= 2/\pi \times 13 = 0.048$$

$$\alpha = 2.8^\circ$$

Friction angle

$$\Psi = \tan^{-1}\mu$$

$$8.53 = \tan^{-1}\mu$$

$$\tan\psi = 0.15$$

Now we know that effect required to rotate the screw

$$P = W\tan(\alpha+\psi)$$

$$= W[(\tan\alpha + \tan\psi) \div (1 - \tan\alpha\tan\psi)]$$

$$= 10000[(0.048+0.15) \div (1 - 0.048 \times 0.15)]$$

$$P = 2002.6 \text{ N}$$

Torque required to rotate the screw

$$T = P\,(d/2)$$

$$= (2002.6 \times 13) \div 2$$

$$= 13016.9 \text{ N.mm}$$

The distance moved by the screw in 1 rotation is 2mm

Shear stress in the screw due to torque

$$\tau = (16T) \div (\pi dc^3)$$

$$= (16 \times 13016.9) \div (\pi \times 12^3)$$

$$= 38.36 \text{ mpa}$$

We know that direct tensile stress in the screw

$$6t = w \div (\pi \div 4 \times (dc^2))$$

$$= 10000 \div (0.7855(12^2))$$

$$6t = 89.03 \text{ mpa}$$

Compressive stress is less. (100>89.03).

Hence design is safe for given load.

3.3.1 Design of nut:

Let,

Pb = Bearing pressure between the thread

n = No. of thread come in contact with nut

For middle steel –

The bearing pressure in between 13 to 17 N/mm^2.

For safety we consider Pb=15 N/mm^2

$$Pb = W_1 / [(\pi/4)(d_0^2 - d_c^2) \times n]$$

$$15 = 10000 \div [(\pi/4)(14^2 - 12^2) \times n]$$

$$n = 16$$

Find the nut dimension:

t = thickness of nut

t = p x n

= 2 x16

t = 32mm

b = Width of nut

b = 1.5 x d_0

= 1.5 x14

b = 21mm

3.3.2 Design of pin:

Let,

d_1 = diameter of pin in the nut

F= 2 × (π / 4) × d_1^2 × τ

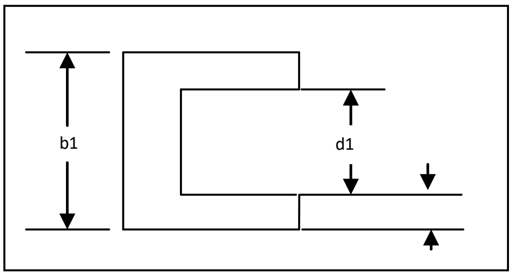
5000=2 × (π / 4) × d_1^2 × 38.36

d_1 =9.109 mm

We take, d_1 = 10mm

3.3.3 Design of link:

Due to the load, the link may buckle in two planes at right angle to each other. For buckling in the vertical plane (i.e., in the plane of the link), the link are considered hinged at both ends and for buckling in the plane perpendicular to the vertical plane, it is considered as fixed at the both ends. We know that the load on the link



t1

Fig. no. 7: Link

Load on the link = F / 2

= 5000 /2

= 2500N

Assuming a factor of safety = 5,

the link must be designed for the buckling load of

Wcr = 2500 x 5

= 15200N

Let,

t_1 = Thickness of the link

b_1= Width of the link

Assume t_1 =6mm

Assuming that the width of the link is 3times of the thickness of the link,

b_1=3t_1

b_1=18mm

K= I/A

K – Raids guration

I - Movement of inertia

A – Area of link(c/s)

I = (1/12) (t_1 ×b_1^3)

= 2.25×6×4

I = 2916

A = 3×t^2

A = 3×6^2

A = 108mm^2

According to rankines formula bucking load (wcr)

W_{cr} = 12500N

W_{cr} = (6c×A)/ [1+a[L/K]^2]

W_{cr} = (100×108) / [1+ (1/7500)(L/5.19)^2]

L = 165mm

Length of link is 165 mm

Length of screw portion is

Cos a =x/165

x = Cos 45 ×165

x = 116

Length of screwed portion

L = 2x

L = 232mm

For safety

We have,

L = 240mm

3.3.4 Design of Worm and Worm wheel:

We know the torque on lead screw & speed of the lead screw is 13016.9 N-mm & 100 rpm respectively. So we have assumed 1220 rpm for dc motor available in the market.

From speed & torque ratio, we have calculated the torque of motor.

(100 /1220) = (Torque of motor /13016.9)

Torque of motor = 1067 N-mm

Power of the motor = (2 ×π × N × T) / 60

= (2 × 3.14 ×1220 × 1067) / 60

P = 160 watt

So we have selected motor having power 240 watts for jack.

Given Data:

From 5.1 & 5.2 table we find that for a velocity ratio of 10, the number of starts or threads on the worm.

Pressure angle (Ø) = 20^0 P = 240 watt

Velocity Ratio (V.R.) = 10:1 Center distance (x) = 34 mm

Lead Angle (λ) in Degrees.	0 - 16	16 – 25	25 - 35	35 – 45
Pressure Angle (Ǿ) in Degrees.	14.5	20	25	30

Table no.1: Recommended values of lead angle & pressure angle

Velocity ratio	36 & above	12 to 36	8 to 12	6 to12	4 to 10
No. of starts (n= Tw)	Single	Double	Triple	Quadruple	sextuple

Table no.2: No. of starts used on the worm for different velocity ratio

Design of Worm:

Let,

Ln = Normal lead and

λ = Lead angle

We know value of (λ /Ln) will be minimum corresponding to.

$\text{Cot}^3 \lambda$ = V.R. = 10

λ = 25^0

We know that,

x / Ln = (1/ 2π) × [(1/sin λ) + (V.R / cos λ)]

34/ Ln = (1/ 2π) × [(1/sin 25^0) + (10 / cos 25^0)]

Ln = 15.94mm .

And axial lead, (l) = Ln / cos (λ)

l = 17.59mm

From 5.2 table we find that for a velocity ratio of 10, the number of starts or threads on the worm.

n = Tw = 3

Axial pitch of the thread on the worm. (Pa)

Pa = (17.59/ 3)

Pa = 5.86mm

Since the axial pitch of the threads on the worm is equal to the circular pitch of teeth on the worm gear

Pa = Pc = π x m, where m is module

m = Pa / π = (5.86 /3.14)

$m = 1.87$

Let us take the std. Value of module, m = 2 mm

Axial pitch of the threads on the worm. (Pa)

$Pa = (\pi \times m) = (\pi \times 2)$

$Pa = 6.28mm$

Axial lead of the threads on the worm. (l)

$l = (Pa \times n)= 6.28 \times 3$

$l = 18.84$ mm

And normal lead of the threads on the worm. (Ln)

$Ln = (l \times \cos \lambda)$

$= (17.59 \times \cos 25^0)$

$Ln= 15.94mm$

Let,

Dw = Pitch circle dia. of the worm.

We know that

$\tan \lambda = [1 / (\pi \times Dw)]$

$Dw = [1 / (\pi \times \tan \lambda)]$

$Dw = 12.86mm$

Since the velocity Ratio is 10 and the worm has double threads therefore no. of teeth on the worm gear, (T_G) = 10 x 3

$T_G=30$

From table we find that the face length of threaded portion is (L_W) $L_W = Pc\ (4.5 + 0.02\ Tw)$ ……. (Pa = Pc)

$= 6.28\ (4.5 + 0.02 \times 3)$

$Ln = 28.63mm$

We know that depth of tooth (h)

$h = (0.623 \times Pc)$

$= 0.686 \times 6.28$

$h = 3.91mm$

And addendum (a)

$a = (0.286 \times Pc)$

$a = 1.79mm$

Outside dia. of worm (Dow)

$Dow = Dw + (2 \times a)$

$= 12.86 + (2 \times 1.79)$

$Dow = 16.44mm$

3.3.5 Design of Worm Gear:

We have used fibre material for worm gear.

We know that pitch circle dia. of worm gear (D_G)

$D_G = (m \times TG)$

$= (2 \times 30)$

$D_G = 60mm$

From table we find outside dia. of worm gear (D_{OG})

$D_{OG} = D_G + (0.8903 \times Pc)$

$= 60 + (0.8903 \times 6.28)$

$D_{OG} = 65.59$ mm

Throat Diameter (D_T)

$D_T = D_G + (0.572 \times Pc)$

$= 60 + (0.572 \times 6.28)$

$D_T = 63.60mm$

And face width (b)

$b = (2.15 \times Pc) + 5$

$= (2.15 \times 6.28) + 5$

$b = 18.520mm$

Let us now the check the designed worm gear from the stand point of tangential load

lent twisting moment (Te),

$Te = [M^2 + T^2]^{1/2}$

$= [(99929.2)^2 + (28.65 \times 10^3)^2]^{½}$

$Te = 103955.12$ N-mm

$Te = 3.14/16 \times t \times d^3$

$d = 20$ mm

$Me = ½ \{M + [M^2 + T^2]^{1/2}\}$

$M = 101942.16$ N-mm

$Me = 3.14 / 32 \times Sb \times d^3$

$d = 20.5$ mm

So, diameter of shaft is 20 mm.

3.3.6 Selection of Bearing:

We have considered the life (L_{10h}) of the bearing for this application which is equal to 6000 hrs.

With the help of load factor =1.5

we have selected the value of radial (X) & thrust factor (Y) from table.

X = 1 & Y = 0

Let,

P = Equivalent dynamic load (N)

Fr = Radial load = 2498.2 N

Fa = Thrust load (N)

$$P = (X \times Fr) + (Y \times Fa)$$

$$P = (1 \times 2498.2)$$

$$\boxed{P = 2498.2 \text{ N}}$$

C = Dynamic load capacity

$$C = P \times (L_{10})^{1/3}$$

$$L_{10} = (60 \times n \times L_{10h}) / 10^6$$

$$L_{10} = (60 \times 100 \times 6000) / 10^6$$

$$\boxed{L_{10} = 36 \text{ million rev.}}$$

$C = P \times (L_{10})^{1/3}$

Hence, $C = 2498.2 \times 36^{1/3}$

$C = 8248.87$ N

From diameter of the shaft & dynamic load capacity we have selected **Bearing No. 6004.**

3.3.7 Motor Selection:

D.C. Motor principles:

An Electric motor is a machine which converts electrical energy into mechanical energy. Its action is based on the principle that when current carrying conductor is placed in a magnetic field, it experiences a mechanical force whose direction is given by Fleming Left-hand Rule and whose magnitude is given by F=B x I x l Newton.

Motor selection consists of following point:

- Application: Driving chain drive
- Voltage: 12 V
- Speed: 1000 rpm
- Working condition: Continuous
- Frequency: 50 Hz

Select a motor that meet the above.

(1) Speed suitable for specifications:

Because the required speed is 100 rpm, the gear ratio that realizes a rated motor speed of 1000 rpm is 1000/100 = 10. Therefore use a gear ratio of 1/10

(2) Calculation of required torque:

By considering the speed ratio between motor and lead screw,

Torque of the motor is 1067N-mm.

From above torque, we have calculate the power of the motor as,

Power = $(2\times \pi \times N \times T) / 60 = 161$ watt.

For the more efficient performance, we select 12v DC motor having power of 240 watt.

3. CONCLUSIONS

Here concluding that, Electric operated toggle jack is used to replace the tyre of the car with no effort when it gets punctured, in shortest time, and it is easy for handling & operating, it is compact & portable. Women, children's & aged persons can operate the jack.

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