DESIGN AND FABRICATION OF RACK AND PINION JACK

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Abstract - *A screw jack is a type of jack which functions by the turning of a lead screw. It is commonly used to lift heavy load to a certain height. A good example is the car-jacks. In the case of a screw jack, a small force applied in the horizontal plane is used to raise or lower load. A good number of operational staff in manufacturing, bottling, oil and gas and other multi-national companies perform task in a squatting or cowering position for a long period. These results to inefficiency at workplace due to ergonomically imbalance position they encounter which often give rise to back ache and poor body architecture in the future. These present available jacks further require the operator to remain in prolonged bent or squatting position to operate the jack. Due to its difficulties, body pains, back ache and others can emerge because of continuous turning of the wrench or crank shaft in an uncomfortable position for a long period. The statement of problem has led to the motivation of designing a modified quick lifting screw jack with gear arrangement. The introduction of the bevel gear will help reduce difficulty in operation with a handle incorporated in the design and reduce time spent to a very minimum.*

Key Words: **Rack and Pinion, Ratchet and Pawl mechanism, jack**

INTRODUCTION

Over the years, engineers, scientist and ergonomist have extolled the scissors jacks being very efficient yet continue to seek new designs to increase reliability and reduce its shortcomings and maintenance costs. Screw application is used in the elevation of vehicles or objects. The operation of the screw jack is such that it comprises a handle for driving Lead Screw manually to adjust the height of the jack to elevate a vehicle or an object. Existing jacks are of great disadvantage to elderly women especially under unfavorable weather condition. A mechanical jack is a device which lifts weights or heavy equipment and vehicles so that maintenance can be carried out underneath at workplace or manufacturing setting.

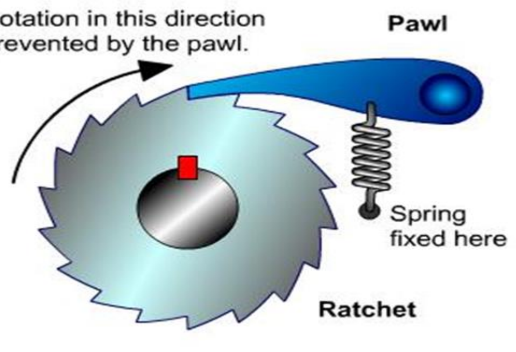
WORKING PRINCIPLE:

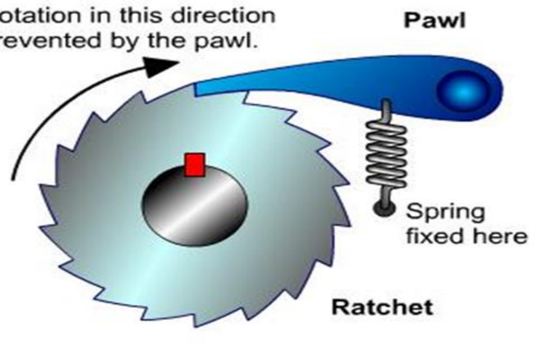
The jack's screw rod is fixed to the spear gear its combined more gears in one rod. The manual source power keys are interface with handle rod. Using this equipment, we can easily access the lifting of load in various purpose of our need. By alternating the power transmission with higher torque, the jack can lift heavy load easily.

During usage, the screw jack is working commonly two mechanisms, the screw thread provides both one with the conversion of rotational motion into linear motion and the other with the amplification of the applied force by the threads on the lead screw. In accordance with our survey in several automobile garages, revealed the facts that mostly some difficult methods were adopted in lifting the vehicles for reconditioning. All the gears are fixed together in on single rod mechanisms are working to manual force. Ratchet and pawl mechanism using here lock the reverse direction during the lifting process. Now the research paper has mainly concentrated on this difficulty, and hence a suitable device has been designed, such that the vehicle can be lifted from the floor land without application of any impact force. The fabrication part of it has been considered with almost case for its simplicity and economy, such that this can be accommodated as one of the essential tools on automobile garages or even for household purposes.

1. RACTHET AND PAWL MECHANISM:

Ratchet and Pawl the purpose of a ratchet and pawl is to allow a shaft to rotate in one direction only. A ratchet is a wheel with a shape like a circular saw blade or horizontal milling cutter. A ratchet fits onto a shaft and is locked onto the shaft by a "key". The key fits into slots in the shaft and ratchet wheel. These slots are called "keyways".



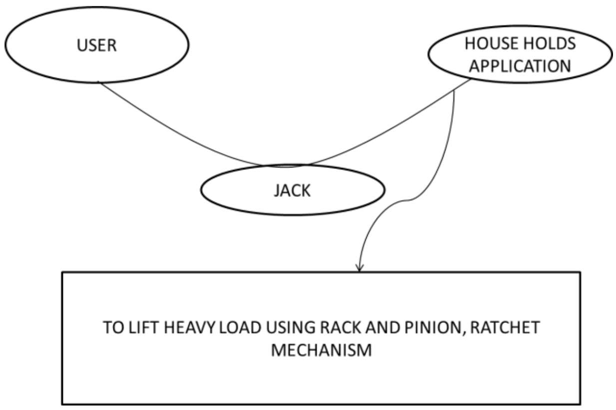


A pawl is a metal part that rests on the ratchet. As the ratchet rotates, the pawl drops onto each of the steps on the ratchet rim, preventing the ratchet from turning in the direction of the pawl. Sometimes a spring is used to keep the pawl in contact with the ratchet. The ratchet and pawl mechanism are used wherever rotation is required in one direction only, e.g. in yacht winches and fishing reels.

2. NEED ANALYSIS

2.1 BULL DIAGRAM:

A jack finds its purpose to lift or re-position an object to a different location. It is applicable in the maintenance department of the automotive industry; our project aims in fulfilling the same motive for household needs. The enhancement in the maneuverability and mobility helps our project in achieving the purpose of using it for household needs.



3. FUNCTIONAL ANALYSIS

3.1 OCTOPUS DIAGRAM:

Octopus diagram is applied after analyzing of the costumer need where functional analysis determines the functional requirements. Primary Function (P.F): Interaction of the product with elements of the surroundings. The first step is to investigate on the connections between the product and the external environment. Here, the patient and the floor are the external agents in contact with the wheel chair. Constraint Function (CF): refers to presents adoption or action of the product, in means of either the product has to be adopted with an element or it acts on an element. The constraint functions linked with the Jack are observed as follows:

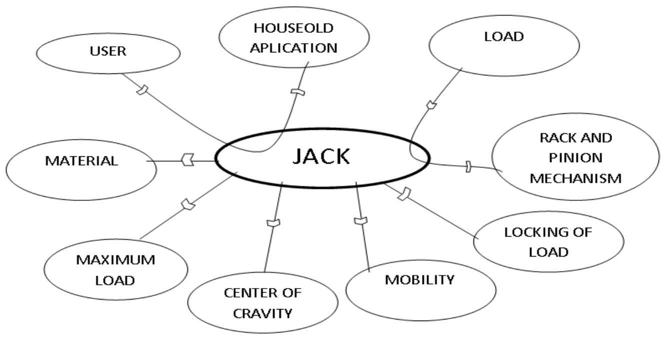
CF 1: The material to be used for the project should be of less weight to compensate maneuverability.

CF 2: The reversing mechanism of the Rack during the absence of torque from the gear or due to application of load on the load bearing plate.

CF 3: The mobility is required to transport the project to the desired work location.

CF 4: The center of gravity of the object should be within the dimensions of the load bearing plate.

CF 5: The maximum load carrying capacity is restricted to 50 kilograms.



4. TECHNICAL ANALYSIS

4.1 FAST DIAGRAM:

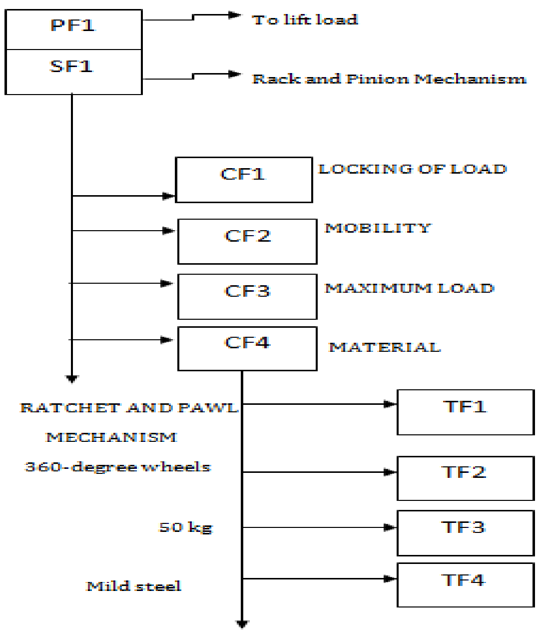
The development of a FAST diagram helps to develop a shared understanding of the project and identify the missing functions.

4.2 VERTICAL MOVEMENT:

The movement of the load bearing plate is governed by the Rack and Pinion movement, the Ratchet and Pawl mechanism prevents the returning action of the Rack when subjected to loading.

4.3 MANUEVERABLITY:

The torque required to turn the shaft is produced by a Handle which induces the rotary motion in the main shaft which is then used to drive the Rack and Pinion arrangement. Under each leg a 360-degree turning wheel is bolted down to facilitate mobility of the project.



5. CALCULATION

5.1ORGANIZATION OF CALCULATION

DESIGN OF RATCHET AND PAWL MECHANISM

Material for ratchet – Steel
Material for Pawl – Steel(Hardened)
Since both ratchet and pawl are made of steel material, the design stress of them is considered as

$$[\sigma_b] = 50N/mm^2$$

$$T = F \times d$$
$$=100kg*9.81*0.5m$$
$$=490.5Nm$$

Torque to be arrested, M_t=500Nm=500×10^3 Nmm
Calculation of Ratchet Dimensions
Number of teeth, Z= 14

(i)Module(m) = $2 \times \sqrt[3]{\frac{M_t}{Z\times\Psi\times[\sigma_b]}}$

Assuming $\Psi = \frac{b}{m}$ =2.5 & $[\sigma_b] = 50N/mm^2$

$$m = 2 \times \sqrt[3]{\frac{500\times10^3}{14\times2.5\times50}} = 13.17 \approx 14mm$$

(ii)Outer Diameter of ratchet, D:

$$D = m \times Z = 14\times14 = 196mm$$

(iii)Face width of teeth, b:

$$b = \Psi\times m = 2.5\times14 = 35mm$$

Checking for edge pressure(i.e.,)unit pressure

unit pressure, $p = \frac{P}{b}$
where P = Peripheral force

$$P = \frac{2\times M_t}{D} = \frac{2\times500\times10^3}{196} = 510$$

$$\therefore p = \frac{5102}{35} = 145.77N/mm$$

Since this pressure is far less than the max pressure(i.e.,300N/mm),our design is safe

(iv)Tooth thickness, a = m = 14mm
(v)Tooth height, h = $0.75 \times m$ = 10.5mm
(vi)Circular pitch,p_c = $\pi\times m$ = 43.98mm

Pawl dimensions:

(vii)The diameter of pawl-pin is given by

$$d = 2.71\times\sqrt[3]{\frac{P}{2[\sigma_{b1}]}\left(\frac{b}{2}+a_1\right)}$$

Assuming $[\sigma_{b1}] = 50N/mm^2$(Design bending stress for pawl material)
a_1= 10mm(Clearance between ratchet and frame)

$$d = 2.71\times\sqrt[3]{\frac{5102}{2\times50}\left(\frac{35}{2}+10\right)} = 30.33mm$$

(viii) Length of pawl, L:
Using the formula,

$$\tan\phi > \mu + \frac{\mu_1 d}{2L\cos^2\phi}$$

Assuming ϕ = Ratchet tooth angle = 15^0
μ = Coefficient of friction between ratchet tooth and pawl = 0.1
μ_1= coefficient of friction between pawl and pin = 0.1

$$\tan 15 > 0.1 + \frac{0.1\times30}{2L\cos^2 15}$$
$$0.268 > 0.1 + \frac{1.607}{L}$$
$$L > 9.56$$

This length is so small comparing to ratchet diameter and hence using another empirical relation , L can be found out as

$$L = 2\times\pi\times m = 88mm$$

Checking the induced bending strength
The pawl is subjected to a total stress, as

$$\sigma = \frac{P}{bx} + \frac{6P.e}{bx^2}$$

Assuming x = d = 30mm

$$e = 1.5\times d = 45 mm$$

$$\sigma = \frac{5102}{35\times30} + \frac{6\times5102\times45}{45\times30^2} = 39 N/mm^2$$

since $\sigma < [\sigma_{b1}]$,our design is safe

SPECIFICATIONS:

RATCHET DIMENSIONS:

1.Material - Steel
2.Outer diameter, D - 196 mm
3.Face width, b - 35 mm
4.Tooth thickness, a - 14 mm
5.Tooth height, h - 10.5 mm
6.Circular pitch, p_c - 44 mm
7.Module, m - 14 mm

PAWL DIMENSIONS:

8.Diameter of pawl-pin, d - 30mm
9.Width of pawl, b - 35mm
10.Length of pawl, L - 88 mm
11.Pawl thickness at bend, x - 30 mm
12.Pawl axis eccentricity, e - 45 mm
13.Material for pawl - Steel(hardened)

GEAR DESIGN :

Power to be transmitted,
Gear Material = Mild Steel

$$P = \frac{2\pi NT}{60}$$

$$P = \frac{2\times\pi\times50\times500}{60} = 2.61Kw$$

No of Teeth on Pinion, Z_1= 21
No of Teeth on Wheel, Z_2= 43
Gear Ratio, i = 2.05:1
Modulus of Elasticity, E = 2.15× 10^5 N/mm^2

$$\sigma_u = 340\ N/mm^2$$

$$\sigma_{-1} = 0.35\sigma_u + 120 = 239\ N/mm^2$$

K_{bl}=1;K_σ=1.2;n=2

$$[\sigma_u] = \frac{1.4K_{bl}}{nK_\sigma}\sigma_{-1} = 139.41\ N/mm^2$$

$$[\sigma_c] = C_R \times HRC \times K_{cl} = 220\times 63 \times 0.585 = 811\ N/mm^2$$

$$[M_t] = K_o K K_d M_t = 1.5\times1.3\times500 = 975\ Nm$$

$$a \geq (i+1)\sqrt[3]{\left[\frac{0.74}{[\sigma_c]}\right]^2 \frac{E[M_t]}{i\Psi}}$$

$$\Psi = \frac{b}{a} = 0.2$$

$$a \geq (3.05)\sqrt[3]{\left[\frac{0.74}{811}\right]^2 \frac{2.15\times10^5\times975\times10^3}{3.05\times0.2}}$$

a = 201mm

$$m = \frac{2a}{Z_1+Z_2} = \frac{2\times201}{64} = 6.28mm$$

Exact Centre distance

$$a = \frac{m(Z_1+Z_2)}{2} = \frac{6(64)}{2} = 192mm$$

b = Ψ × a = 0.2×192 = 38.4mm

d_1= m×Z_1= 6×21= 126mm

d_2= m×Z_2= 6×43 = 258mm

$$\Psi_p = \frac{b}{d_1} = \frac{38.4}{126} = 0.305 = K$$

$$V = \frac{\pi\times d_1\times n_1}{60} = \frac{\pi\times0.126\times50}{60} = 0.33m/s = K_d$$

$$[M_t] = 1.5\times0.305\times0.33\times500 = 75.5Nm$$

$$\sigma_b = \frac{i+1}{amby}[M_t] = \frac{3.05}{192\times6\times38.4\times0.396} 75.5\times10^3 = 13.14N/mm^2$$

$$\sigma_c = \frac{0.74(i+1)}{a}\sqrt[3]{\frac{i+1}{ib}E[M_t]}$$

$$= \frac{0.74\times3.05}{192}\sqrt[3]{\frac{3.05\times2.15\times10^5\times75.5\times10^3}{78.72}}$$

$$= 10.7\ N/mm^2$$

$$\sigma_b < [\sigma_b]$$

$$\sigma_c < [\sigma_c]$$

Our design is safe

SHAFT DESIGN

Shaft 1
Length of the shaft = L = 460mm
Diameter of the shaft = d = 28.4mm
Diameter of the gear = D = 114.1mm
Pressure angle = α =20^o
Torque to be transmitted = T = 50kg×9.81×0.5 = 245.25Nm
Tangential force on the gear

$$F_t = \frac{2T}{D}$$

$$= \frac{2\times245.25}{0.1141} = 4298.8N$$

Normal load acting on the tooth of the gear

$$W = \frac{F_t}{\cos\alpha} = \frac{4298.8}{\cos 20^o} = 4574.6N$$

Since the gear is mounted at the middle of the shaft, Therefore the maximum Bending moment at the Centre of the gear

$$M = \frac{W\times L}{4} = \frac{4574.6\times0.460}{4} = 526.079Nm$$

Equivalent Twisting moment

$$T_e = \sqrt{M^2 + T^2}$$

$$= \sqrt{526.079^2 + 245.25^2} = 580.43Nm$$

$$= 580.43 \times 10^3\ Nmm$$

Shaft 2

Length of the shaft = L = 180mm

Diameter of the shaft = d = 19.1mm

Diameter of the gear = D = 60.7mm

Pressure angle = $\alpha = 20^o$

Torque to be transmitted = T = 50kg×9.81×0.5 = 245.25Nm

Tangential force on the gear

$$F_t = \frac{2T}{D}$$

$$= \frac{2 \times 245.25}{0.0607} = 8080.72\text{N}$$

Normal load acting on the tooth of the gear

$$W = \frac{F_t}{cos\alpha} = \frac{8080.72}{\cos 20^o} = 8600\text{N}$$

Since the gear is mounted at the middle of the shaft, Therefore the maximum Bending moment at the Centre of the gear

$$M = \frac{W \times L}{4} = \frac{8600 \times 0.180}{4} = 387\text{Nm}$$

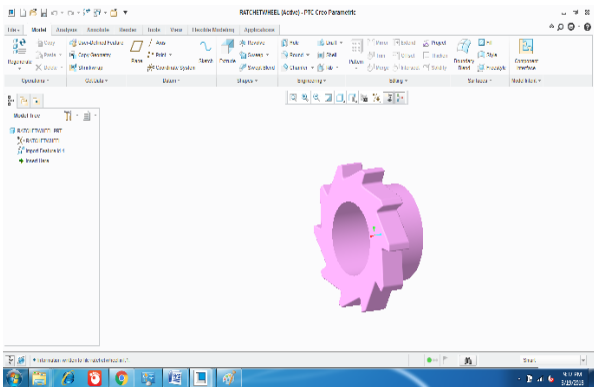
Equivalent Twisting moment

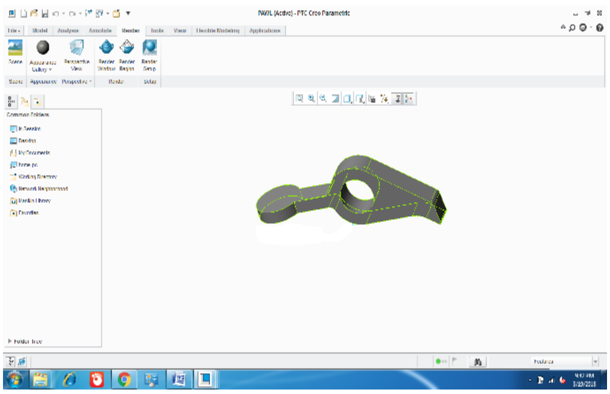
$$T_e = \sqrt{M^2 + T^2}$$

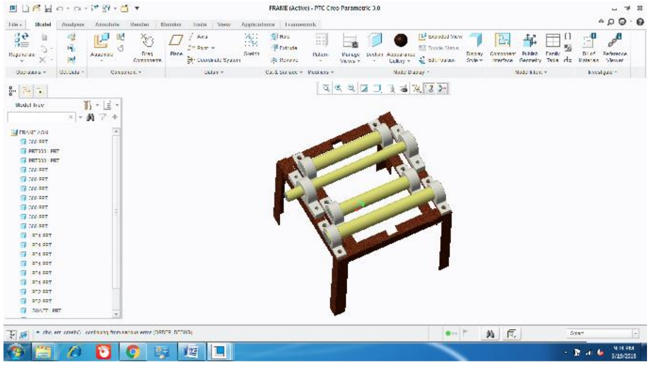
$$= \sqrt{387^2 + 245.25^2} = 458.16\text{Nm}$$

$$= 458.16 \times 10^3 \text{ Nmm}$$

6. CAD MODEL







7. FABRICATION

7.1 FRAME

The frame for the Jack was initially built by cutting a long bar of 'L' cross section (3 mm thickness and 30 mm width) into long pieces of required

dimensions using an Angle Grinder (AG). Then the ends of the length bars were grinded using a grinding tool. Finally using an arc welding machine outer rectangular frame is welded, then the horizontal bars inside the rectangular frame is welded.

7.2 TURNING AND FACING

The shaft was turned and faced using a lathe machine for the required dimensions of inner diameter of the gears, the gears were then placed along the shaft which where been positioned between the bearings.

7.3 DRILLING AND ATTACHMENT OF BEARINGS

The holes were made on the frame to fix the bearings which support the shaft. The hole is made using a 5 mm and 10 mm metal drill. Then by using 10 mm bolt, washer and nut the bearing is fixed to the frame. The rack is also placed in such a way that it meshes with the gear to facilitate raising and lowering of load.

7.4 RATCHET AND PAWL MECHANISM

The ratchet is fixed in the main shaft a small bush is placed between the Ratchet and the shaft to compensate the clearance between the both. Pawl is welded to the frame and has surface contact with the Ratchet.

7.5 FIXING OF LEGS AND WHEELS

The 'L' Bar is welded in a perpendicular direction to the rectangular frame thereby serving as legs to the jack. A rectangular base plate is welded to the bottom portion of the leg, on which the wheels are fixed using nut and bolt. A rectangular load carrying plate is also welded on the top surface of the rack for carrying the load.

7.6 ATTACHMENT OF HANDLE

A handle is attached to the larger shaft for the rotation of secondary gears, this rotating motion is converted into linear motion of the Rack.

7.7 PITFALLS

Welding of length components perpendicular to each other to form a rectangular frame.

Concept of Gear Train, we made a mistake in this concept which affected the progress of our work and we had to repeat it from scratch.

The turning and facing of the shaft is another challenge we faced, the cutting tool for the shaft material was not available in the college laboratory. We had to rent a lathe shop outside and finish the required work. This resulted in a delay in the progress of our project.

8. IMPROVEMENTS

Connecting the motor to a shaft so that it can improve the torque and lift the load.

Increasing the length of the rack so that it can lift the loads to a much better height.

Attaching an extra component to the base of the Rack to form of a fork lift, it can be used in places where there is less floor clearance.

9. PHOTO

10. CONCLUSION

In this research, a novel design for a lifting jack driven by a quick-return crank mechanism and gear drive has been designed and fabricated. The design equations for gear selection, gear drive ratios and mechanism forces have been derived from its geometry. Kinematic analysis has been performed. A design example has been given for illustrating the design process. The detailed working diagram has been explicitly explained equally. To verify the feasibility and accuracy, a prototype has been made, and then an experiment has been conducted. The proposed mechanism is capable of increasing capacity; reducing input effort; saving cost of operation and requires simple maintenance compared to conventional lever lift mechanisms of lifting jacks.

11. ACKNOWLEDGEMENT

We owe our deep gratitude to our project guide **Mrs. Queen Florence Mary** M.E., Assistant Professor, Mechanical Engineering Department, Loyola college of Engineering and Technology, who took keen interest on our project work and guided us all along, till the completion of our project work by providing all the necessary information for developing a good system.

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