

Design and Standardization of Scissor Jack to Avoid Field Failure

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ABSTRACT

On road emergency, i.e. tire gets punctured, is a common problem observed in automobile and also it is big headache to driver. Scissor or toggle jacks are one of the best option to overcome this headache. Scissor jack is used to lift the heavy loads in which rotary motion is converted into linear motion. In this Paper, a unique design of scissor jack is compile to lift low as well as heavy load with different conditions. The main purpose and significance of this paper is to design, optimize and standardize the current toggle jack to make the task easier and reliable. Catia is used to develop and analyzed the scissor jack. Mathematical model of design procedure is also made which will suppose to help in standardization of scissor jack design by using MATLAB. The design calculation includes design of Power Screw, Link design, Design of Nut, Pin Design etc. All products from engineering should be versatile with application by maintaining its aesthetics and ergonomics. This paper mainly focused on designing and standardization of scissor jack model of automobile L.M.V. sector and trying for weight reduction of scissor jack with good strength. Also some changes are done in design procedure so that it will be useful for different models of L.M.V. in automobile industry. Car jacks are available in the market has some disadvantages such as required more energy to operate, are not suitable for woman and cannot be used on the uneven surface. So that, this design is modified for the existing car jacks in terms of its functionality and human factor consideration.

Keyword: - Scissor Jack, Standardize, MATLAB, Power Screw.

1. INTRODUCTION

A scissor jack is a device which is used to lift heavy vehicles, partially or fully in the air for breakdown and maintenance. Scissor jack includes one power screw which is rotating, two fixed nuts, four links which is connected to nuts, eight pins used to fixed that four links, two rings provided at screw end and load platform supported by upper two links.[1] Now a days, different types of car jacks are available for lifting vehicles. However available car jacks are either manually operated or using external power operated.

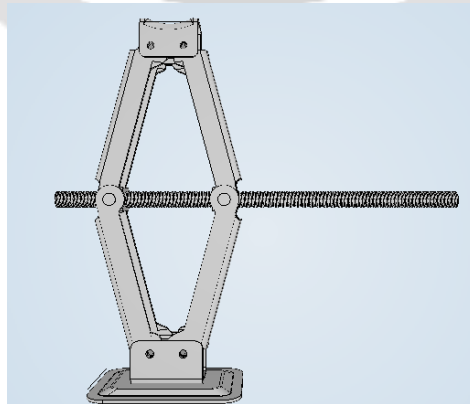


Fig.1 Toggle or Scissor Jack

A scissor jack is operated with the help of lead screw which is in rotary or turning motion. In this case on the horizontal plane a small force is applied which is used to lower or raise the load.[3] Scissor jack is a mechanism made up of nut and bolt arrangement and its principle of working is same as that of inclined plane. Where a shaft rotates in its bearing on which threads are wound around it. Mainly there are three types of Jack. i.e. Screw jack, Hydraulic jack and Toggle Jack. Out of which screw jack and toggle jack uses lead screw or power screw for their functioning and the hydraulic jack uses liquid instead of screw for the same.[4] The design of power screw used in scissor jack decreases the intensity of force required to drive the mechanism by the user. With better design of power screw it is possible to magnify the force required to rotate the screw. Power screw is nothing but the shaft which has threads around it, used to convert rotary motion into translatory motion. [6]

1.1 Problem Statement

Design of mathematical model for Scissor jack with input condition of vehicle GVW (Gross Vehicle Weight), Ground Clearance and Operating efforts.

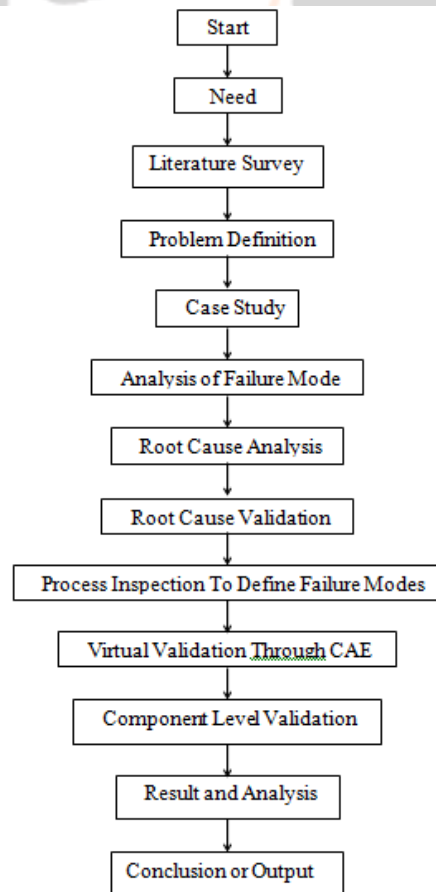
1.2 Objective

- 1) Modification in current Jack to current as well as potential failure modes.
- 2) Redesign of current wheel jack in terms of cost and quality.
- 3) Design of mathematical model for Scissor jack with input condition of vehicle GVW (Gross Vehicle Weight), Ground Clearance and Operating efforts.
- 4) To define the test procedure for Jack Assembly validation for performance and Durability

1.3 Scope

Scope of this Jack is to assess Jack for vehicles. Here the necessity lies in reducing the human effort applied during operation of the jacks and hence the need of the invention. In day to day life it is very tedious job to operate the jack and it is also a very time consuming work as well. So, to make it easier for everyone especially for aged person and for lady drivers. To provide a safe and simple automatic hydraulic jacking system without effort. But the general scope of the project is to minimize the human effort while operating the jack.

1.4 Methodology



2. FORMULATION OF DESIGN

2.1 Design of Screw

The maximum load on the screw is when the jack is in the bottom most position.

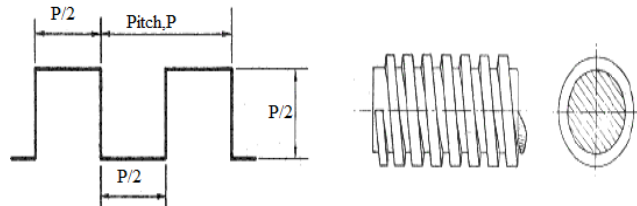


Fig.2 Geometry of Screw

- Pull in the screw,

$$F = W/2/\tan\theta$$
 Where, F= force exerted on screw
 W= load
- Total force in the screw due to both the nut,

$$P_1 = 2F$$
 Where, p_1 = total force
- For the screw to be safe in tension,

$$d_c = \sqrt{\frac{P_1 \times 4}{\pi \times \sigma_t}}$$

where, d_c = core diameter
 σ_t = tensile stress

- Now, we adopt pitch(p)= 6 mm
- Outside diameter of screw,

$$d_o = d_c + p$$
- Mean diameter of screw,

$$d_m = 1/2(d_c + d_o)$$

- Helix angle,

$$\alpha = \tan^{-1}\left(\frac{p}{\pi \times d_m}\right)$$

- Angle of friction,

$$\phi = \tan^{-1}\mu$$
 Where, μ = co-efficient of friction
- Effort required to rotate the screw(P),

$$P = P_1 \times \tan(\alpha + \phi)$$
 Where, P_1 = total force

- Torque, $T = P \times d_m/2$
- Torsional shear stress in screw,

$$\tau = \frac{16T}{\pi \times d_c^3}$$

Where, T= torque

- Direct tensile stress in screw,

$$\sigma_t = \frac{4P_1}{\pi d_c^2}$$

where, P_1 = total force

- Maximum principal stress in screw,

$$\sigma_{\max} = \frac{\sigma_t}{2} + \frac{1}{2} \sqrt{\sigma_t^2 + 4\tau^2}$$

which should be less than 100 MPa, hence safe.

- Maximum shear stress,

$$\tau_{\max} = \frac{1}{2} \sqrt{\sigma_t^2 + 4\tau^2}$$

which should be less than 50 MPa, hence safe.

2.2 Design of Nut

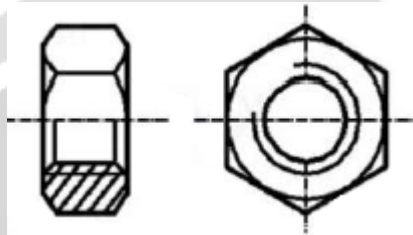


Fig.3 Geometry of Nut

Let n = number of threads on nut.

Designing the nut in bearing of threads,

- Thickness of threads, $t = p/2$

$$n = \frac{F_t}{\pi \times d_m \times t \times \sigma_p}$$

We adopt $n=4$

- Height of nut, $h = np$

To prevent movement of nuts beyond 200 mm, rings of 8 mm thickness are provided on the screw on both sides and fixed by set screws.

- Length of screw = $200 + h + 2 \times \text{thickness of rings} + 30$ mm for spanner

- Length of spanner:

Let the operator apply a force of 50 N to the end of a spanner l mm long.

$$L = T/50$$

2.3 Design of Pins in Nut

- The pins are in double shear. If d_p is the diameter of pins then,

$$d_p = \sqrt{\frac{4F}{2\pi\tau}}$$

- Diameter of pin head = $1.5 d_p$

Thickness of pin head is taken as 3 mm.

Split pins are used to keep the pins in position.

2.3 Design of Links

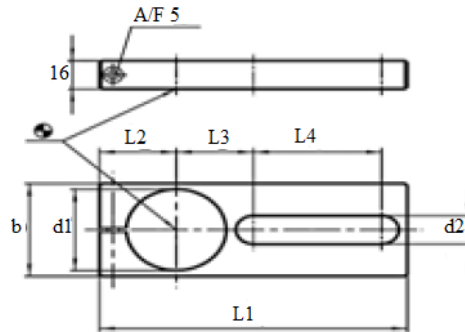


Fig.4 Geometry of Link

- Load on each link = $F/2$
 Let b_1 = width of link and t_1 = thickness of link
 Assuming $b_1=3t_1$
- Area of cross-section of link,
 $A=3t_1^2$
- Moment of inertia,

$$I_{yy} = \frac{t_1 b_1^3}{12}$$
- Least radius of gyration,

$$k_{yy}^2 = \frac{I_{yy}}{A}$$
- For buckling of links in the vertical plane, the ends are considered hinged. Therefore, using Rankine-Gordon formula,
 For critical load,

$$P_{cr1} = \frac{300t_1^4}{t_1^2 + 215}$$

 For design load, $P_{cr1} = F.O.S \times F$
 Critical Load Should Be More Than Design Load So Design Is Safe.

3. MODELLING

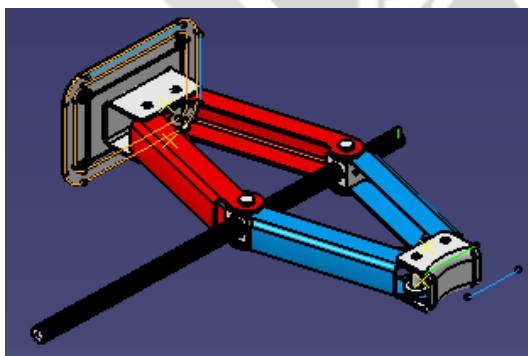


Fig.5 Assembly of Scissor Jack

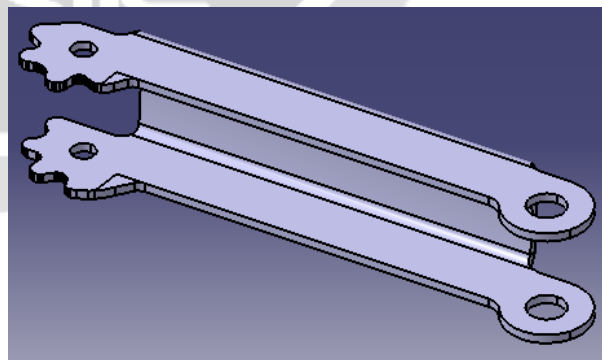


Fig.6 Link

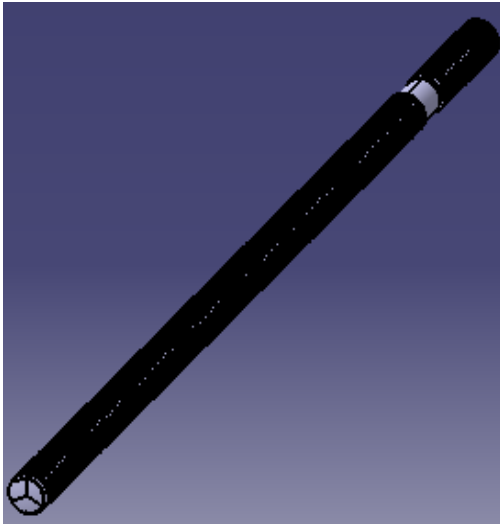


Fig.7 Screw

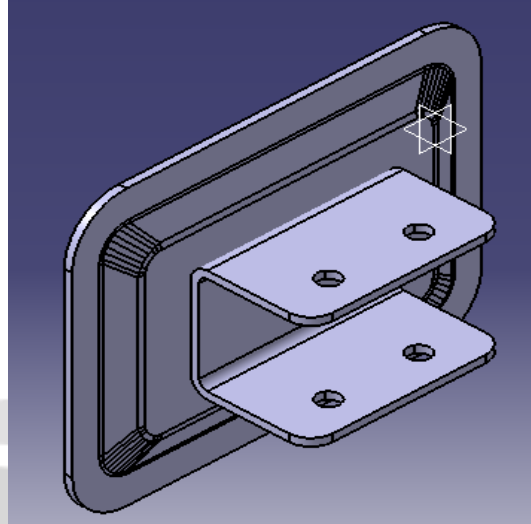


Fig.8 Base

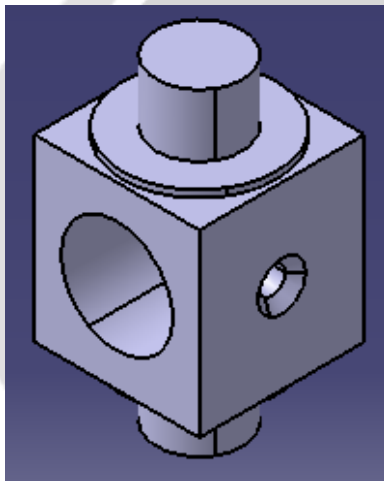


Fig.9 Nut

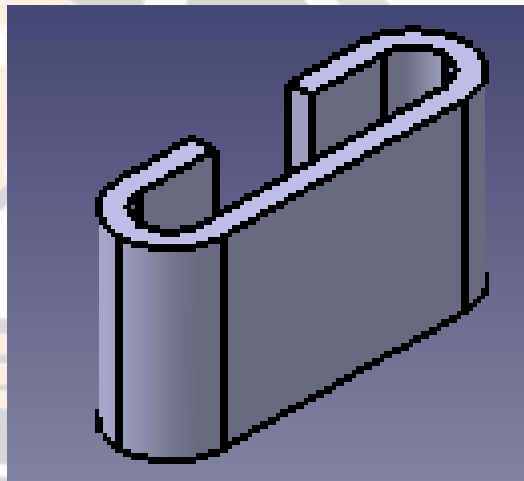


Fig.10 Cap Holder

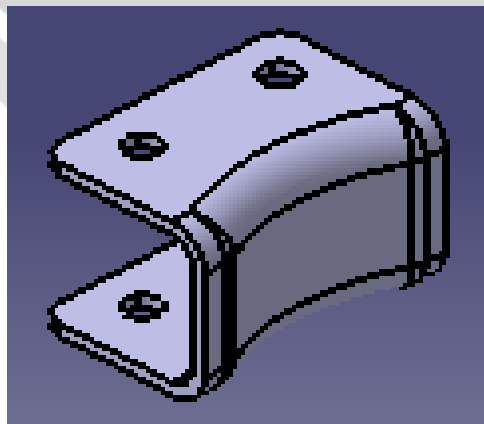


Fig.11 Top

4. SAMPLE DESIGN CASE USING MATLAB PROGRAMME

4.1 Input

- 1) Load=4 KN
- 2) Permissible Tensile Stress =100 MPa
- 3) Permissible Shear Stress = 50 MPa
- 4) Bearing Pressure =30 MPa
- 5) Length of Link =110 mm

4.2 Output

4.2.1 Design of Screw

Pull in the screw in KN, $F= 2.426219$

Total force due to both the nuts in KN, $P1= 4.852438$

Core diameter of screw in mm, $d_c= 7.862220$

The screw is also subjected to torsion in addition to tension. To account for this, we adopt, New value of Core diameter of screw, $d_c= 16.000000$

Outside diameter of screw, $d_o= 22.000000$

Mean diameter of screw, $d_m= 19.000000$

Helix Angle in degree = 5.745834

Angle of friction in degree = 11.315669

Effort required to rotate the screw in KN, $P = 1.488435$

Torque required in KN-m, $T= 14.140134$

Torsional shear stress in screw (MPa) = 17.590732

Direct tensile stress in screw (MPa) = 24.146288

Maximum principle stress in screw (MPa)= 33.408435

Maximum principle stress $33.408435(\text{MPa})$ is less than permissible stress in tension $100.000000(\text{MPa})$

Hence design is safe

4.2.2 Design of Nut

Number of threads on nut, $N = 0.903721$

In order to provide stability to jack, we adopt New value of the Number of thread, $n= 4.000000$

Height of Nut in mm, $h =24.000000$

4.2.3 Design of Pins in Nut

Diameter of Pins in mm, $d_p= 9.372884$

Diameter of Pin Head, $D_p=14.059325$

Thickness of pin head is taken as 3mm

Split pins are used to keep the pins in position

4.2.4 Design of Links

Taking Factor of Safety, F.O.S.= 5.000000

For Design Load,

Actual load on Link in KN = 6.065547

Roots Are:

The First root is: -2.5720

The second root is: 2.5720

Value of the Thickness ($t1/2$), $t= 2.572003$

Real value of the Thickness in mm, $t1= 5.144005$

Width of the links in mm, $b1= 15.432015$

Critical Load in KN, $P_{cr}= 7.341706$

Design Load $6.065547(\text{KN})$ is less than Critical Load $7.341706(\text{KN})$

Hence Design Is Safe.

5. TEST PROCEDURE

5.1 Functional Dimensional Check (GVW Condition Excluding Driver & Co Driver Weight)

- 1) Use platform type load cells and arrange the load bags in the vehicle to achieve the GVW condition as per vehicle specifications excluding driver & co-Driver weight.
- 2) Replace RH front wheel with deflated (Punctured) wheel.
- 3) Measure the height between Jacking point and floor (Plain floor) using measuring tape at vehicle RH Front.
- 4) Record the measured value of height as minimum required closing height of the jack at GVW condition (Excluding driver & Co-driver weight) at FRONT.
- 5) Lift the vehicle at RH front jacking point.
- 6) Lift vehicle up to suitable height for replacement of the punctured tyre with inflated tyre (Minimum height between plain floor & tyre should be - 30 mm min)
- 7) Measure the height between Jacking point and floor (Plain floor) using measuring tape at vehicle RH Front.
- 8) Record the measured value of height at GVW condition (Excluding driver & Co-Driver weight) as required minimum opening height of the Jack.
- 9) Assemble RH front tyre back.
- 10) Repeat the test procedure 10.1.2 to 10.1.7 for Vehicle LH Front.
- 11) Record the measured value of height.
- 12) Replace the RH Rear wheel with deflated (Punctured) wheel.
- 13) Measure the gap between Jacking point and floor (Plain floor) using measuring tape at vehicle RH Rear.
- 14) Record the measured value of height. Minimum required closing height of the jack at GVW condition (Excluding driver & Co-Driver weight) at REAR should be within +0,-5mm than recorded measured value of height.
- 15) Repeat the test procedure 10.4 & 10.7 for vehicle LH Rear.
- 16) Record the measured value of height.

Acceptance criteria:

Minimum closing height of the jack should be less than the measured minimum height between Jacking point and floor (Plain floor) with punctured tyre at GVW condition and Jack should be easily located at the specified Jacking point without interference. Minimum opening height of the jack should be more than the measured height between Jacking point and floor (Plain floor) to replace the punctured tyre with inflated tyre.

Example: If measured closing height required to replace the punctured tyre =80 mm; then closing height of the jack should be maximum= 80 +0,-5 mm.

Example: If measured open height required to replace the punctured tyre =100 mm; then open height of the jack should be minimum=100 +5,-0 mm.

5.2 Operating Effort & Lifting Capacity Measurement At GVW Condition:

- 1) Use platform type load cells and arrange the load bags in the vehicle to achieve the GVW condition as per vehicle specifications excluding driver & co-Driver weight. Remove the load cells once the GVW condition is achieved.
- 2) Replace RH front wheel with deflated (Punctured) wheel.
- 3) Locate the jack at specified jacking point and lift the vehicle with the help of jack three times up (to the height where tyre can be replaced) and down
- 4) Locate the Jack at specified jacking point with suitable load cell for measuring the load at jacking point. Operate the Jack with the help of torque meter. Measure and record the torque required to lift the vehicle to the suitable height, so that punctured tyre can be replaced with inflated tyre. The torque needs to be measured at start of the lifting and at the centre of the stroke.
- 5) Measure and record the load on the jack at jacking point, at suitable intervals of vehicle lifting heights.

Acceptance Criteria:

The sample Jack should locate at defined jacking points without any interference. Jack should be able to lift vehicle up-to suitable height for removal of the tyre. A normal driver should be able to operate the jack without any interference & effort.

5.3 Operating Effort & Lifting Capacity Measurement At RWUP (Over Load) Condition.

- 1) Use platform type load cells and arrange the load bags in the vehicle to achieve the overload (GVW + -- %overload as specified) condition. Remove the load cells once the Overload condition is achieved.
- 2) Repeat B.2. to B.6

Acceptance Criteria:

The sample Jack should locate at defined jacking points without any interference. Jack should be able to lift vehicle up to suitable height for removal of the tyre. A normal driver should be able to operate the jack without any interference & effort.

5.4 Inclined load Inspection Test:

- 1) Ensure the RWUP condition of the vehicle.
- 2) Locate the jack at specified jacking point on a 5 degree wedge plate below Jack and lift the vehicle with the help of jack two times up (to the height where tyre can be replaced) and down.

Acceptance Criteria:

Jack should work smoothly throughout the range without any slip & no visible damage.

5.5 Stability Test On Vehicle

- 1) Test condition:
The test shall be carried out at each prescribed jacking point of applicable vehicle, with the vehicle at its unladen mass and loaded to its axle load rating.
- 2) Test procedure:
The jack shall be applied to the prescribed jacking point and the vehicle lifted to a height sufficient to permit removal/replacement of the wheel being fitted.
With the vehicle raised, a force of 220 N shall be gradually applied to the vehicle, at a height of 0.7 m above the ground level, horizontally in any direction so as to tend to pull or push the vehicle off the jack. The force shall be sustained for at least 30 sec.
any abnormalities must be recorded.

Acceptance Criteria:

Under application of load of 220N, vehicle should not be unstable in raised condition so that it will fall.



Fig.12 View of Test Setup

6. CONCLUSION

In this work, a scissor jack is design analytically and then standardize. In this jack, Nut and Screw are the one of the most significant components. A screw is designed based on a maximum tensile stress and maximum shear stress. For maximum load it is very necessary to keep both the values within limit for safe design. Nut is a stationary part in which a screw rotates. Therefore a bearing pressure is also needs to be considered. For both the components, if we take combination of different material for each pair of screw and nut so we can find best suitable material for design at maximum load. For simplicity of current design, parameters of screw like, core diameter, helix angle and mean diameter are taken same throughout design for all loads. Also for link design standard dimensions of link cross section are considered. For material of link, same kind of material i.e Mild steel is taken.

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