DESIGN AND OPTIMIZATION OF SCISSOR JACK

[1]Chetan S.Dhamak, [2]D.S.Bajaj, [3]V.S.Aher
Department of Mechanical Engineering, Amrutvahini College of Engineering,
Sangamner. [MS], Savitribai Phule Pune University
Email: [1]dhamakchetan@gmail.com, [2]dipakbajaj@yahoo.com, [3]vsa_arya@rediffmail.com

Abstract— Every engineering product involve cost effective manufacturing and its versatility in application maintaining its aesthetics as well as assign service life without failure keeping those parameters in mind we focused our intention on designing and analyzing the scissor jack model for actual loads for varying models of automobile L.M.V. sectors. Automobile sectors are very keen at their productivity and customer satisfaction. We also keen at designing and optimization of scissor jack at the same time maintaining its strength and service life. After studying failure modes we made a mathematical model analytically and by using software's thereby made a new versatile scissor jack that can be used for varying models of L.M.V automobile sector. Also modeling made by CATIA and mathematical model made by Visual Basic software can be tested by ANSYS software.

Index Terms-Mathematical Model, Optimization and Scissor.

I. INTRODUCTION

Car jack is a device used to lift up the cars while changing the tires during an emergency. Car jacks are available at the market has some disadvantages such as requiring more energy to operate, are not suitable for women and cannot be used on the uneven surface. The purpose of this project is to modify the design of the existing car jack in terms of its functionality and also human factors considerations.

The day to day usage of cars is keeping on increasing as the world moves on to a hectic stage. One big problem everyone faces is a flat tyre on a voyage to any destination. If the tyre gets punctured the driver has to undergo a lot of pressure and rigorous mechanical work to lift the car using a screw jack. Then the changing of a tyre is a job that can be done systematically and relatively easy.

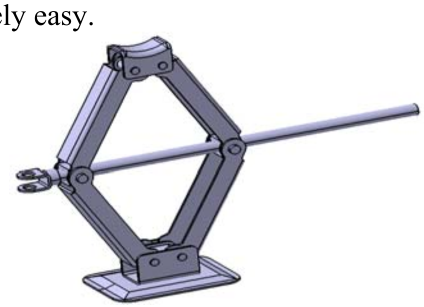


Fig.Scissor Jack

Today, many people are familiar with the jack that is included with their vehicle. Some vehicles bear screw jacks and others carry a hydraulic jack. Automotive jacks are of three types mainly:-

1. Screw Jacks
2. Trolley Jacks
3. Bottle Jacks

Each has its own advantages and disadvantages. Screw jack is lesser in cost, as compared to trolley jacks and bottle jacks. While trolley jack and bottle jack can provide a greater lift with lesser application of force. [5]

With the increasing levels of technology, the efforts being put to produce any kind of work has been continuously decreasing. The efforts required in achieving the desired output can be effectively and economically be decreased by the implementation of better designs.

Scissor or Toggle Jack

A toggle or Scissor 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. Car jacks usually use toggle advantage to allow a human to lift a vehicle by manual force alone. More powerful jacks use hydraulic power to provide more lift over greater distances.

There is a one screw in the toggle jack which is rotating.

There are two nuts which are fixed.

There are four links connected to both nuts and eight pins to fix all links.

There are two rings at both ends of the screw.

There is a one platform which is connected to the upper two links for put load.

Working of Toggle Jack

• The jack can be raised and lowered with a metal bar that is inserted into the jack.

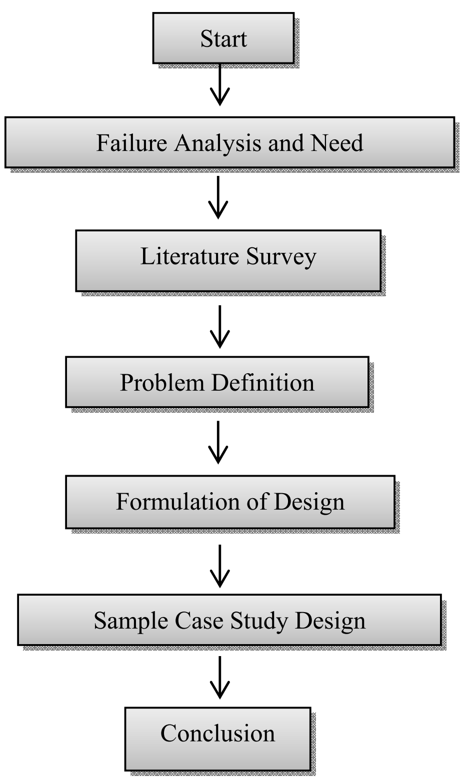
• The operator turns the bar with his hands in a clockwise direction for makes it go up.

• When the screw lifts the load on the platform which placed above will also raise.

• The bar is turned until the jack is raised to the level needed.

• To lower the jack the bar is turned in the opposite direction.

II. METHODOLOGY



III. FAILURE ANALYSIS OF SCISSOR JACK

To study the reliability and performance of scissor jack, it is tested under various conditions for failure analysis. In this case we will get to know the effectiveness & performance of scissor jack on field, when customer implements it for replacing the tire. The failure analysis is conducted under following cases.

Case I: Justification for failure analysis :

This analysis is required to be conducted due to its critical application under emergency, also it is essential due to following reasons:

A. Impact of the problem

- Impact on customer:
  1. Affecting safety of customer.
  2. Dissatisfaction of customer
- Impact on Departmental goal:
  1. Quality indicators effected.
  2. Increase in warranty cost.

Case II: Diagnosing the problem:

In this case, the actual area where the jack is failed is detected. Practical tests are conducted for this analysis by physically replacing the jack and results are calibrated for getting the solution by operating the jack for replacement of tire of Bolero. Following results are concluded by performing this case:

Failure I: Arm teeth wear:

The scissor jack is failed due to wear of teeth on both links at lower end. Due to this the jack gets toppled as shown in figure below. Due to the use of jack over and over again, the teeth starts getting wear and after certain time the jack gets toppled from actual position as shown below:

Fig. Teeth Wear of Lower Arm

Failure II: Screw Failure:

This failure is caused after using the jack for certain amount of time. Due to excessive use and high impact on screw, it starts getting wear. Due to this the jack gets toppled from its actual position as shown below:

Fig. Failure of Screw and Arm Teeth

Fig. Toppled Scissor Jack due to Arm teeth Failure

Failure III: Jack head failure:

After certain duration and use of jack the head of jack starts bending due to the fatigue load acting continuously again & again over the head as shown in figure below. This defect occurs due to improper design of shape and geometry of existing head design.

Fig. Failure of Jack Head

IV. SAMPLE DESIGN CALCULATION

Type of Vehicle = Mahindra Bolero
Weight of Vehicle =1615 kg
Assuming 65-35 Distribution
Weight on Front Axle = 1050 kg
Weight on Each Wheel of Front Axle = 525 kg
For Safe Design we take maximum capacity of jack = 700kg
Since while jack is used other three wheels are in contact with ground so assumption of 700 kg is safe.
Ground Clearance of Vehicle = 280 mm
According tyre dimension, we take lift of jack as 100 mm
Maximum Height of Jack = 355.4 mm
Minimum height of jack = 254 mm

Assumption:-

Material for Link, Screw, Pin, Bracket is selected as Medium Carbon Steel (30C8)
Since links are in tension-compression and bending mode, higher yield strength as well as less elongation is primary requirement.
Medium Carbon Steel has good yield strength (S_{yt}) as well as due to medium carbon content (0.30%) has good hardness and toughness.
For Nut, Phosphor Bronze (Bearing Pressure = 10 Mpa) is Selected. Since in case of wear with screw, nut will fail and costly screw will be saved from failure.

Phosphor Bronze is softer than Medium Carbon Steel (30C8)
Length of link = 200 mm

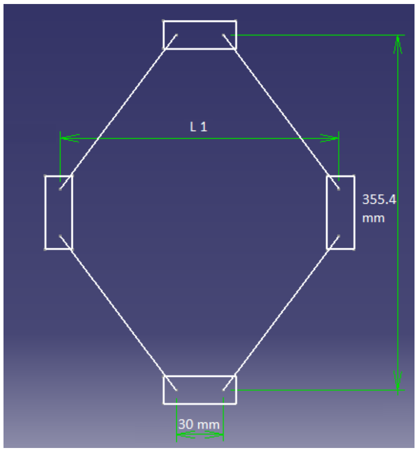


Fig. Jack Is In Top Most Position

$$L_1 = 30 + 2\sqrt{(200)^2 - (355.4/2)^2}$$

L_1= 216 mm

And Similarly, When Jack is in lowest position-

$$L_2 = 30 + 2\sqrt{(200)^2 - (254/2)^2}$$

L_2= 339 mm

A. Design of Screw:-

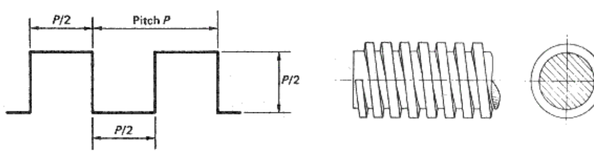


Fig. Geometry of Screw

Maximum load on screw will occurs when the jack is at bottom most position. The load in the screw will be tensile.

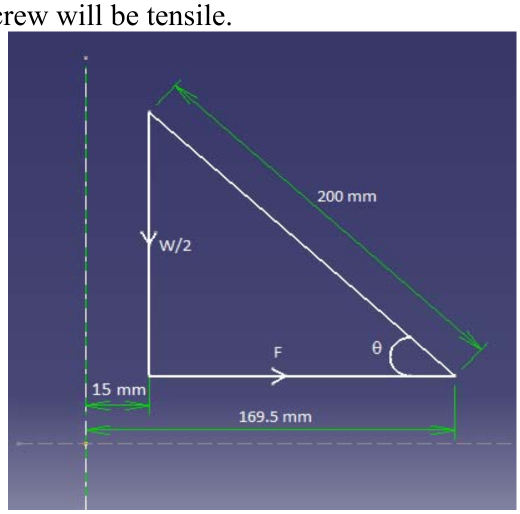


Fig. Diagram of Top Corner Link

When the jack is in bottom position, the link will be inclined at an angle

$$\cos\theta = \frac{169.5 - 15}{200}$$

θ =39.42°
Maximum Capacity of Jack is 700 kg,
So that Load (W) =700×9.81=6867 N=7000 N (Approx.)
Load (W) = 7000 N
By Calculating Pull in the Screw, Total Force due to upper and lower link, Core Diameter, Outer Diameter, Mean Diameter, Helix Angle, Friction Angle, Effort Required to Rotate the Screw, Torque Required, Torsional Shear Stress, Maximum Principle Stress and Maximum Shear Stress etc.following results are obtained.

Material Selected for Screw= Medium Carbon Steel (30C8)
S_{yt} = 400 MPa
F.O.S. = 4
Permissible Tensile Stress (σ_t)=100 MPa
Permissible Shear Stress (S_{sy}) =0.5(S_{yt}) =50 MPa
∴Our Calculated Value,
τ= 30.84 < 50 MPa ∴ τ is Safe.
σ_t= 42.34 <100 MPa ∴ σ_t is Safe.
σ_{max}= 58.57 <100 MPa ∴ σ_{max} is Safe.
τ_{max}= 37.40 <50 MPa ∴ τ_{max} is Safe.

B. Design of Nut

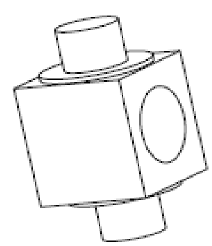


Fig.Geometry of Nut

There are two nuts in the assembly of Scissor or Toggle Jack.Nut is a stationary part having internal thread inside which is used to rotate the screw by meshing with external thread of the Screw.Nut is also used to hold the lifting arm or links at there both end.
By calculating Number of threads inside the nut, Height of nut etc. following results is obtained.
No. of Internal Thread =6
Height of Nut =36 mm

C. Design of Pin

Pins or Rivets are the most important parts in the assembly of Scissor jack or Toggle Jack which is used to make the Scissor Jack in assembled form throughout its operation and working. There are total six pins are used in the assembly of screw jack, out of that two pins are used to assemble load carrier member with upper lifting arm or links, Two pins are used to assemble base and lower lifting arm of the of the scissor jack and another two pins are used to assemble Nut and both lifting arms or links.

These pins are in Double Shear,

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

$$= \sqrt{\frac{4 \times 4.257 \times 10^3}{2\pi \times 50}}$$

$$d_p = 7.36\,mm$$

So that,

We Select Diameter of Pin =8 mm

Length of Pin =40 mm

Diameter of Pin Head (d_{ph}) = 1.5 × d_p =1.5 × 8 = 12 mm

Thickness of Pin Head (t_{ph}) = 2 mm

Split Pins are used to keep the pins in position.

D. Design of Link

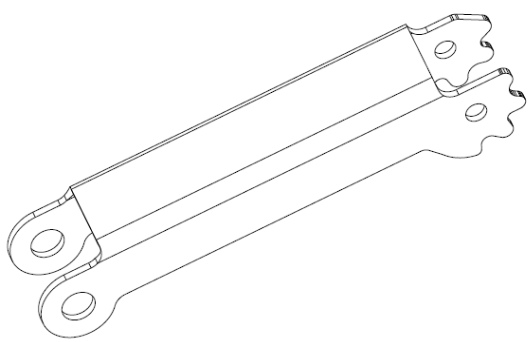


Fig. Geometry of Link

Links or Lifting Arms are the main component in the assembly of Scissor or Toggle Jack. We can say that links are the heart of Scissor Jack. There are set of four links in whole assembly out of which two links are at upper portion and another two links are at lower portion. The tooth profile on the one end of the links is used as a force and motion transmitting element like gear tooth. The whole operation of Scissor Jack i.e. movement of Scissor or Toggle Jack is basically depends on meshing of these tooth profile. If tooth gets wear due to misalignment of the jack at the time of operation then is affect on movement of the assembly of Scissor Jack.

Load on each link=F/2 sec θ

= F/2 sec 39.2

=2.7670 KN

Let b_1= width of link and t_1= thickness of link

Assuming, $b_1=3t_1$

Area of cross-section of link,

$A=3t_1^2$

For buckling of links in the vertical plane, the ends are considered hinged. Therefore by using Rankine - Gordon formula.

By calculating various values like Moment of Inertia, Least Radius of Gyration, Both critical loads etc. following results are obtained.

∴With F.O.S.=5

For design load, P_{cr} =F.O.S×(F/2) ×3

P_{cr} = 13.832 KN

Now, For Critical Load

$$P_{cr} = \frac{100 \times 24 \times 8}{1 + \frac{1}{7500}\left[\frac{200}{0.75 \times 8^2}\right]^2}$$

P_{cr} =17.28 KN

Here Critical Load (17.28 KN) > Design Load (13.832 KN)

∴Design of Link is Safe.

V. CONCLUSION

The result shows that alloy steel for screw and phosphorus bronze for nut is the best suitable combination for pair. The value shows that if there is a combination of MS – MS, it induces less magnitude of bearing stress in nut.

Based on the input parameter & result obtain from the design, As the helix angle increases the efficiency increases up to certain limit after which it decreases, the critical load decreases, the no of threads decreases, turning moment reduces, outer diameter decreases, core diameter decreases, the pitch does not change it remains constant up to certain value & then it reduces.

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