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"Structural Analysis of Acme and Square Thread Screw jack: A Review''

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Abstract: ***A screw jack is a device used to lift the vehicle above the ground level in order to ease repairs. A power screw is designed to translate radial motion to linear motion. Many users are familiar with manually operated car jack which still included as standard equipment in cars. A car jack is an important device in vehicle to change flat tire in our journey. Every year near about 160 injuries are associated with car jacks. The correct use of jacks can prevent the accidents and injuries. Improvement in Design of car jack is really important to make the tool more efficient and user friendly with high safety features. The objectives of this project work is to critically analyze and compare between ACME and SQUARE threads from stress and strain perspective in order to improve the performance from safety and durability point of view for developments in the field of thread design. In this paper we have different size and structures of Acme and Square Thread Screw Jack.***

I. INTRODUCTION

A. Screw Jack

A screw jack is a mechanical utility consisting of a screw mechanism used to lift or lower down the load. The principle upon this jack works is alike as of an inclined plane. Basically there are two main types of jacks-hydraulic & mechanical. A hydraulic jack deals with cylinder and piston mechanism. To raise or lower the load the movement of piston is responsible. Mechanical jacks are either hand operated or driven by power. Jacks are used normally in lifting cars so that a tire can be changed. A screw jack is mostly used in cars but also used in many other ways, including industrial machinery & even airplanes. They may be short, may be tall, fat, or thin depending on the amount of pressure they will be under and the area or the space which they need to fit into. The jack is manufactured by various types of metal, screw jacks are designed purposely for lifting or lowering loads, they are not designed or ideal for side loads, though few can withstand side loads it's all depend upon the diameter and size of the lifting screw. The Shock loads must also be minimized. Few screw jacks are built or designed with anti-backlash. The anti-backlash mechanism moderates axial backlash in the lifting Nut and Screw assembly to a regulated minimum. To have the good efficiency of the screw jack, it should be used in ambient temperatures, or else lubricants must be applied at required place. Oil lubricants purpose is to enhance the capability of equipment's. To optimize the usefulness of screw jack it is advised to employ it according to the designers or manufactures instruction Power screw is an essential component of screw jack. It is a tool to lift and lower the load of materials / goods. There is a lot of research and developments has been done related to the improvement of the design of Power Screws as well as different types of thread analysis of screw jack. To enhance the performance of the power screw, it is required to modify screw jack design and make it to reduce the effort requirement to operate screw jack equipment. Objective of design the Power screws is to minimize the amount of effort needed by the user for lifting and lowering mechanism.

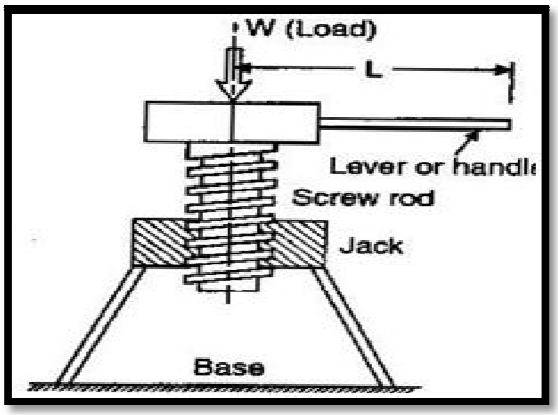

Figure 1.1: Simple Screw Jack [12]

An advantage of screw jack over some other types of jack is that they are self-locking in nature that means when the rotational force removed, it will remain motionless where it was left and its motion will not rotate backwards, irrespective of how much weight it is going to support.

B. Car Jack

A car jack is mechanical utility used for raising or lowering heavy loads. Jacks make use of a screw thread or hydraulic cylinder for applying very high forces. The Car jacks mostly do use of mechanical advantage to ease the work of human being to lift any medium segment vehicle by human effort alone. More powerful jacks make use of hydraulic power energy for providing more lift for greater distance. By making use of the Mechanical Advantage a mechanism multiplies the force or torque applied to it. Many people are in familiar with basic auto jack which still consider as standard equipment in many vehicle. People who are required to rotate the tires of their vehicle themselves or the people who required to install snow tires before the winter and remove them in the spring need to use a jack to perform the job.

C. Existing Car Jack

The most common types of jacks are car jacks and floor jack or may be garage jack which raise or lift vehicle as well as can lower it so that maintenance of the vehicle can be performed

Car jacks usually use mechanical advantage to allow a human to lift a vehicle by manual force alone. More powerful jacks in available screw jack make use of hydraulic power to for more lift over greater distances. Mechanical car jacks usually rated for a maximum lifting capacity of 1.5 tons or 3 tons. The jack shown in below figure 1.2 is made mainly for a modern medium segment vehicle it consists of a handle, power screw cup, base etc.

Where,

F_L = load force on screw

F_E = effort force on handle

D_L = distance moved by load

R= length of handle

DE= distance moved by effort

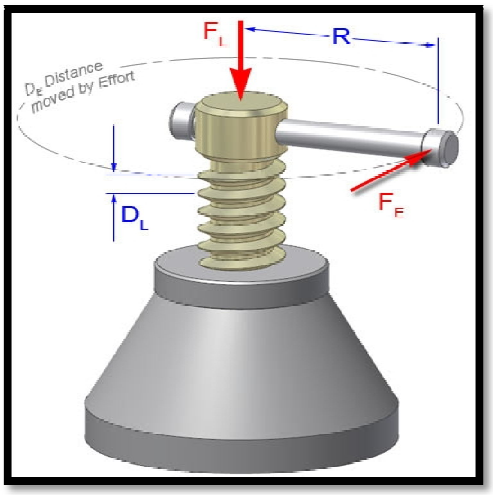

Figure: 1.2 Basic design of screw jack [13]

The screw jacks should have simple mechanisms used to lift large or heavy loads or mechanism for lifting and supporting loads usually of large size. The important part of screw jack is power screw, The design of a power screw of common screw jack is such that it must reduce the amount of force required by the user to drive the mechanism.

D. Types of Jacks:

There are typically two type's screw jacks

These two jacks vary in their size depending upon how much load they are going to lift

1) *Mechanical Jacks***:** The mechanical jack lifts heavy load of equipment. The most common form of mechanical jack is a car jack, a floor jack or a jack used in garage

There are two types of mechanical jacks:

2) *Scissor Jacks:* Scissors jacks are a typical mechanical jack and it has been used at least since the 1930s.

A scissor jack is a device or utility constructed by making use of a cross-hatch mechanism, much like a scissor, this jack is mainly used for lifting up a vehicle or any car for repair or maintenance of vehicle or storage of goods at greater heights. thisscissor jack typically works in just a vertical manner that is it only work along vertical direction. This jack opens and can be fold close, by

applying pressure at the base supports along the way of crossed pattern to perform the required lift, and when closed, it has a diamond shape.

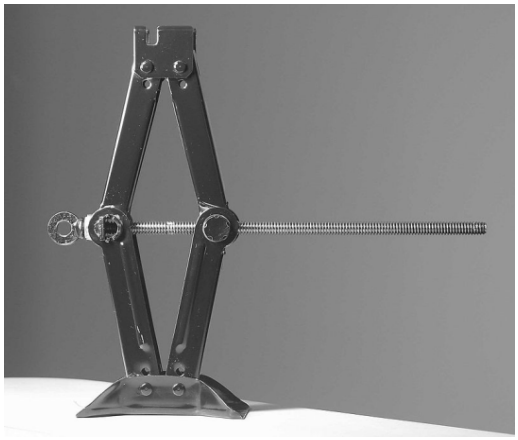

Figure: 1.3 Scissor Car Jack [13]

Scissor jacks are simple mechanisms used to drive large loads for short distances. The power screw design of a common scissor jack reduces the amount of force required by the user to drive the mechanism. Most scissor jacks are similar in design, consisting of four main members driven by a power screw.

These kinds of jack put in to working simply by rotating a small crank which is inserted through the one of the end of the scissor jack. This crank is look like 'Z' shaped component. The end fits into a of ring hole which is fixed at the end of the screw, and the object is placed on the scissor jack. When we are going to turn this crank, then the screw turns, and this mechanism ultimately raises the jack. The screw in this mechanism exactly acts like atypical gear mechanism. It has we called this as teeth (the screw thread), which turn & ultimately move the two arms, producing required work. Just by doing the rotating motion of screw thread, we see that the scissor jack ultimately going to lift the vehicle that is of weight several thousand pounds.

II. CONSTRUCTION

A scissor jack has four main pieces of metal and two base ends. The four metal pieces are all connected at the corners with a bolt that allows the corners to swivel. A screw thread runs across this assembly and through the corners. As the screw thread is turned, the jack arms travel across it and collapse or come together, forming a straight line when closed. Then, moving back the other way, they raise and come together. When opened, the four-metal arms coming together at the middle, raising the jack, and when closed, the arms spread back apart and the jack closes or flattens out again.

A. Design and Lift:

A scissor jack makes use of a very simple theory of gears for obtaining its power. As the screw section is turned, the two ends of the jacks are approaching together or move closer to each other because the pushing of the arms takes place by the gears. The magnitude of force applied is multiplied. It requires a little amount of force for rotating the crank handle, yet that action causes the brace arms to slide across and together, as this happens the arms extend upward.

The car's gravitational weight is not enough to prevent the jack from opening or to stop the screw from turning, since it is not applying force directly to it. If you were to put pressure directly on the crank, or lean your weight against the crank, the person would not be able to turn it, even though your weight is a small percentage of the cars.

B. Bottle (cylindrical) Jacks:

Bottle screws as shown in figure [1.4]usually operate either by turning the screw when the position of nut is fixed; or may be by Rotating motion of the nut and preventing turning motion of the screw. Bottle jacks made by a screw, a nut, thrust bearings, and a body as shown below. A static platform is attached at the top of the screw. This static platform performs as a support for the load which come on it and also assists in raising or lowering of the working load. These kinds of jacks are sturdier as compared to scissor jacks and ability of these kind of jack is it can lift

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Figure: 1.4 Bottle Cylindrical Jacks [14]

C. Hydraulic Jacks

Hydraulic jacks are typically used for shop work, rather than as an emergency jack to be carried with the vehicle. Use of hydraulic jacks not designed for a specific vehicle, it requires more care in selecting ground conditions, and the jacking point on the vehicle. Hydraulic jacks are often used to lift elevators in low and medium rise buildings.

A hydraulic jack uses a fluid, which is incompressible, that is forced into a cylinder by a pump plunger. Oil is used since it is self-lubricating and stable. When the plunger pulls back, it draws oil out of the reservoir through a suction check valve into the pump chamber. When the plunger moves forward, it pushes the oil through a discharge check valve into the cylinder. The suction valve ball is within the chamber and opens with each draw of the plunger. The discharge valve ball is outside the chamber and opens when the oil is pushed into the cylinder. At this point the suction ball within the chamber is forced shut and oil pressure builds in the cylinder.

Figure: 1.5 Hydraulic Jack [14]

In thisjack piston is always in vertical position and directly supports bearing pad. Which is in contact with the object that being going to lift. The lift is somewhat little less than 2 times collapsed height of the jack, with single action piston which makes its use suitable for the vehicle for which clearance is relatively high.to lift the structure such as houses, the use of inter connection of hydraulic jacks with valve enable us for evenly distributions of forces at the time of enabling close control of lift. Thepiston in floor jack which is horizontal, pushes on short end of bell crank, and long arm providing vertical linear motion for the pad which is to be lifted is kept always horizontal with horizontal link.

The Floor jacks consist of castors & wheels, and allowing compensation for arc used by pad which is going to lift. This kind of mechanism when collapsed provides a low profile, for easy going below any vehicle, as well as to allow considerable extension

D. Types of Screw Threads

As per the terminology of screws there are many types of screw threads but for power screws and especially for the purpose of lifting loads selected: the three types of screw threads square, Acme and Buttress types of threads.

*1) Square Threads*Square thread is named mainly from their square geometry. The square threads are as shown in figure [1.6]. The screw jack is manufactured mostly by using square thread.

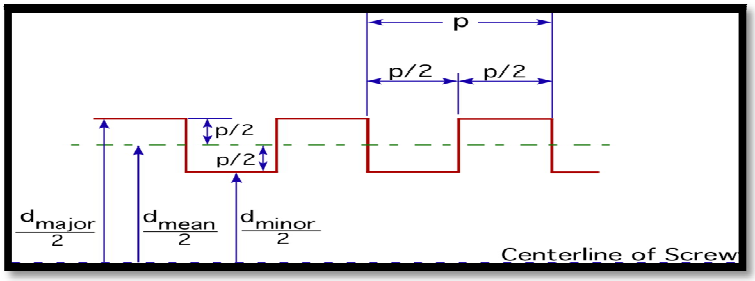

Figure: 1.6 Designs of Square Threads [13]

2) Merits of the square threads: Following are the main advantages of square threads compared to trapezoidal treads:

a) The square thread possess more efficiency as compared to the trapezoidal threads.

b) Nut cannot have radial pressure. As there isn't side thrust, also motion of nut is Uniform. Life of nut with square thread is more

The actual 3-dimentional view of square threads is shown in figure [1.7]

Figure: 1.7 3D Square Threads [13]

3) Demerits of square thread: Following are the demerits of square thread:

a) Manufacturing of square threads is difficult. usually square threads turned on lathe by making use of single-point cutting tool.so as cost point of view manufacturing with single point cutting tool is costly than cutting tool having multi point.

b) Strength of square thread is less

c) Load carry capacity with square threads is less.

d) The wear of the thread with square geometry is more than that of trapezoidal threads.

4) Acme (Trapezoidal) Threads: Acme threads have a 29^0 thread angle which is easier to machine than square thread acme threads are generally stronger than square thread due to their trapezoidal thread profile which provide greater load-bearing capabilities

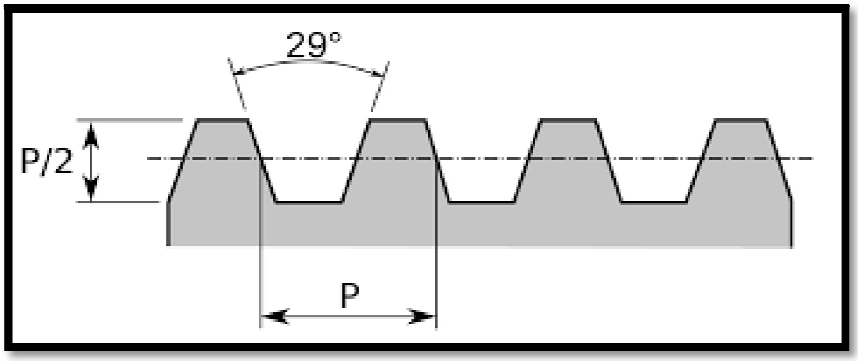

Figure: 1.8 Designs of Acme Threads [12]

5) *Merits of Acme (Trapezoidal) threads over square threads:*

a) Trapezoidal threads manufactured by tool having multipoint for cutting. Machining by multipoint tool is cheaper in operation to that of cutting tool which is making use of single point for cutting.

b) Acme thread have greater thickness at the core than that of Square thread so these threads have more strength than that of equivalent capacity of Square threads.

c) The axial wear on face of the trapezoidal threads is compensated using split-type nut.

6) *Demerits of Acme (Trapezoidal) Threads:* The following are the demerits of Acme threads:

a) Acme threads have less efficiency compared to the equivalent square thread.

b) In Acme threads problem of thrust by sides or pressure along radial way on the nut is a major problem because it affects its performance.

7) *Buttress Threads:* Buttress threads are of triangular shape these are used where the load force on the screw is applied in one direction

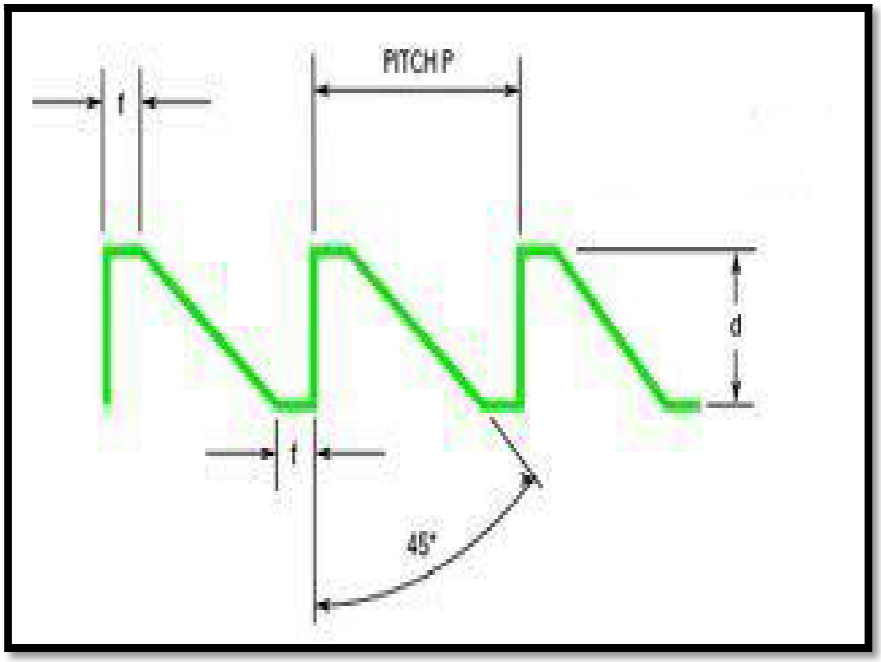

Figure: 1.9 Buttress Threads [12]

E. Advantages of buttress threads

1) It has higher efficiency compared to Acme threads.

2) By making use of tread milling machine these threads can be manufactured

3) By making use of spit-type nut we can compare the axial wear at the thread surface

4) A screw with buttress threads is stronger than equivalent screw with either square threads or trapezoidal threads. This is because of greater thickness at the base of the thread.

F. Disadvantages of buttress threads:

1) Buttress thread can transmit motion as well as power only in single direction while square and acme threads can transmit motion as well as power in both directions.

2) Trapezoidal and ACME threads mainly used for lead-screw and various energy transmission components in machine tools. Buttress threads mainly use in vices, because there we require motion only in one direction.

3) These Buttress threads basically designed for tube used for connections.

III. POWER SCREW

A power screw is mechanical utility used to convert turning motion into rectilinear motion and to transmit the power. A power screw is also called rotational or translation screw. It make use of helical translator motion of screw thread to transmit power rather than clamping components of machine.

A. Terminology of Power Screw:

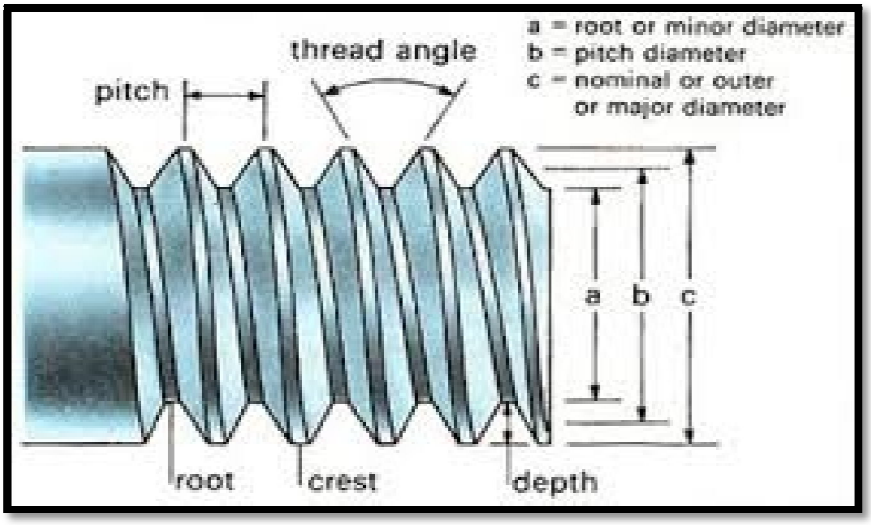

Figure 1.10: Terminology of screw threads in 3D view. [13]

Followings are the terminology

1) *Pitch:* Pitch of power screw can be defined as distance parallel to axis of screw, between two successive points. It shown by the letter ***'p'***.
2) *Lead:* "the distance covered when the nut advanced in one revolution. It is denoted using letter ***'l'. T***he lead is same as pitch for single thread screw, for double-thread screw, it is two times the pitch, and so on.

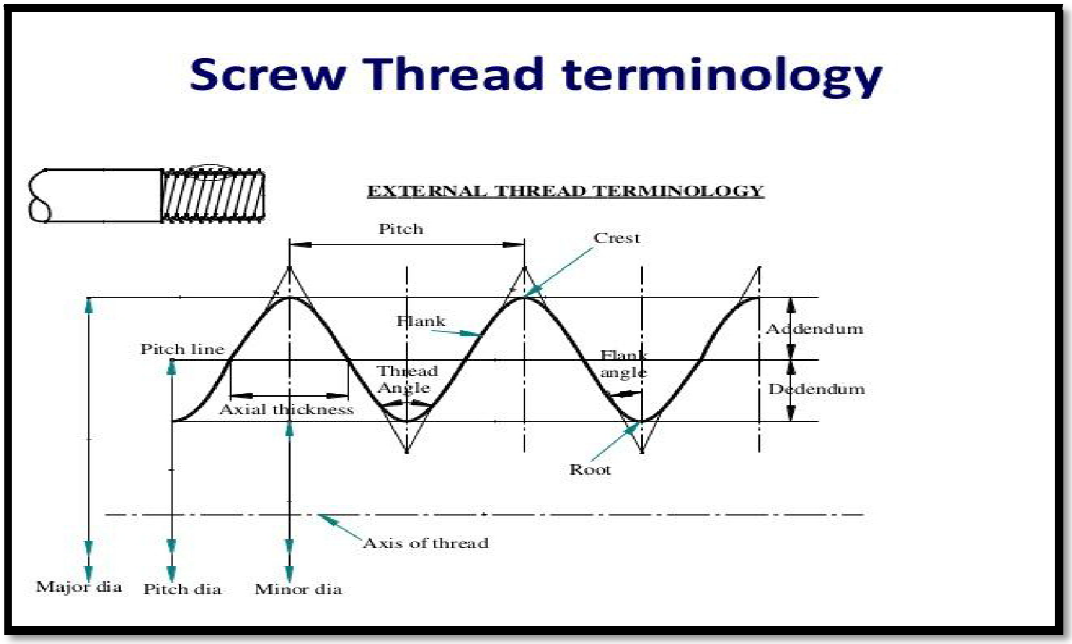

Figure 1.11 Parts of Thread [13]

3) *Nominal diameter:* Biggest diameter of screw is nominal diameter. Sometime sit is called major diameter. It shown by the letter'***d***'.
4) *Core diameter:* Diameter which is smallest of screw thread is called core diameter. Also sometimes called minor diameter. Denoted by the letters ***'dc'***.
5) *Helix angle:* Angle formed by helix of thread to a plane normal with axis of the screw. Also called lead angle. Denoted by ***'α'***.

B. Single and Multithreaded Power Screws:

Multiple threaded power screws are used in certain applications where higher travelling speed is required. They are also called multiple start screws such as double-start or triple-start screws. These screws have two or more threads cut side by side, around the rod. Multiple-start trapezoidal threads are designated by letters (Tr) followed by the nominal diameter and the lead, separated by sign (x) and in brackets the letter (P) followed by the pitch expressed in millimeters.

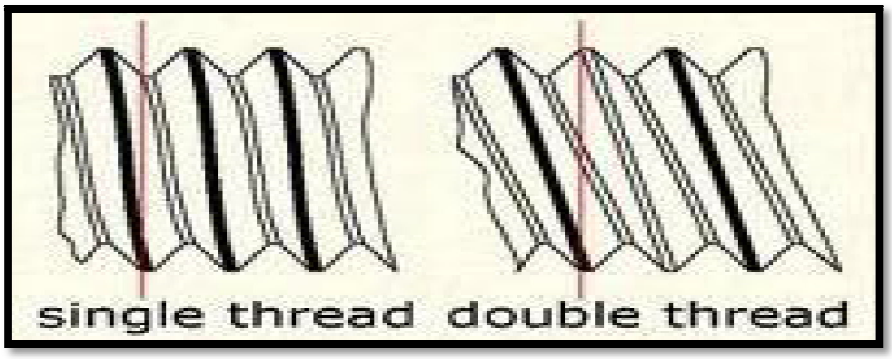

Figure:Single and Double Threads [12]

C. Applications of power screws:

1) To raise the load, e.g. screw-jack.
2) To obtain accurate motion in machining operations, e.g. lead-screw of lathe.
3) To clamp a work-piece, e.g. vice.
4) To load a specimen, e.g. universal testing machine.

D. Related Work

1) *Thrugnanam, Amit Kumar &Lenin Rakesh (2014)* [1]*:* -This paper studies design and analysis of screw jack using Pro-E and ANSYS under torque and compressive force as loads, in this analysis determines shear stress induced at the cross section square thread under bearing pressure. Objective of this paper is to study shear stress state of power screw have been considered following design values, Pitch = 6, *Dc* = minor diameter = 30 mm, *Do* = major diameter = *dc* + pitch = 30 + 6 = 36 mm, with the help of this The power screw is designed according to the design process and analyzed using ANSYS software. Model developed is to be validated using theoretical calculations.
2) *PatilManoj,Nilesh&Udgirkar Gaurav (2014)*[2]*:*-This paper deals changing tire effort requirements and that comfort of women in the automobile 4 wheeler vehicles. Women requires more effort in the changing tires by using existing manual screw jack. This project concluded that less effort is applied with motor attachment In the modified design, the power screw is rotated through its gear power transmission using electrical power flows through it. Scope of this project is Performance enhancement need to be developed
3) *EgweroOghenekome,OladimejiTolulolope (2014)*[3]*:*- This paper involve designing system and also building a unit which could be used to raise up, any car as controlled by receiver and transmitter. Microcontroller control the receiver circuit. It also consists of designing of an infra-red transmitter circuit which can transmit coded frequency. Scope of this project is to develop the controller to operate screw jack & enhance performance and at the same time minimize the cost of screw jack system development.
4) *Gaurav ShashikantUdgirkar (2014)*[4]*:* -Described in their paper, emergency like tire puncher, is a problem mainly we see in cars. Traditional car jacks use mechanical advantage to allow a man to raise up vehicle by manual effort. In this work they used electrically operated Toggle jack using power of car battery. Lifting power increased by the gear ratio. Significance and purpose of this work is modifying existing car jack so that operation can be easier, safe & reliable so that it can save individual's energy & minimize health risks and problems associated with doing work in a bent or squatting position for long time of period.Car jack developed using software CATIA &is being analyzed by making use of FEA for checking safety factor & force acting.
5) *SonuYadav (2014)*[5]*:* -As per this research paper, discussed solar power operated screw jack and cost incurred, operating, making cost is high They used external battery power operating on solar energy,The solar driven automated toggle screw jack is put under various force analysis so that its performance criterion will not fail in operation. 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 condition.
6) *Prashant Kumar Srivastava (2013)*[6]*:* -In this project the Power screws are used to convert rotary motion into translator motion. The principle on which it works is similar to that of an inclined plane. The effort required to turn screw can be removed using 12V DC motor for operation of screw of jack; which help in easy replacement of tire. Benefit of this system is it takes

energy from battery of vehicle. For torque multiplication form by motor 2 spur gear are used. A small gear is mounted on motor shaft and a large spur gear on power screw of jack. Scope of this project is here we need to look for increase of efficiency for motorized screw jack changing helix angle so that energy drawn by motor can be decrease

7) *Prof.Nitin Chandra, R Patel (2013)[7]:* -In this paper deals that, Toggle jacks are simple mechanisms used to lift the heavy loads. Failure of screw is happening due to tensile stresses in material. The power screw design of a common Toggle jack minimizes amount of effort needed by the user for driving mechanism. Most of the Toggle jacks are almost same in design, it contains eight main members of which four are driven using power screw and remaining four by condition of loading. This paper deals with unique design of Toggle jack & used to lift heavy loads at stable state with unique condition. Scope of this project is Selection of such pair of material combination in such a way that the pair produce induced stress within safe limit.
8) *LokhandeTarachand (2012)[8]:* -As per this research paper they have used square threaded screw with different helix angle and manual operated screw jack. To quantify the effect of changing helix anglesMathematical prototype model has been done. Conclusion of this work is that efficiency become optimum at helix angle 3.69 for 10000 Kg of jack. Based on the various input parameter & mathematical model, the effect of helix angles upon various parameters studied core diameter, outer diameter, efficiency, critical load, torque to be transmitted, and pitch of threads. Friction angle of screw jack is 11.30, coefficient of friction μ=0.20 for whole study & bearing pressure were kept constant throughout the study.
9) *Pandya J Milan ,Bhattjaydeep (2005)[9]:*-This paper deals with design and analysis of simple aerial scissor lift. Traditionally a scissor lift used for raising up vehicle for changing tyre. for gaining access under the vehicle. The scope of this project is to modify further to optimize the design and analysis can also be done by finding other vital parameters related to aerial Scissor lifts. The analysis on ANSYS show that design is safe within certain accepted parameters. Also, further design improvement can be implemented for optimizing design and further analysis also be carried out.
10) *M.M. Noor et.al (2010) [10]:* - Side road emergency is always a problem especially during tire punctured. This paper deals with development of car jack for emergency usage using internal cigarette lighter power (12volts). The automatic easy car-jack utilized this power source to save individuals internal energy. Gear ratio was used to increase the lifting power. The car jacker was developed utilizing the Solidworks® and analyzed using Finite Element Analysis to check safety factor and force acting. The car jacker tested on real car and it proven it can be used commercially.

IV. Conclusion

It is observed from the literature survey most of car user has difficulties in maintaining his or her vehicle breakdown specially cars in the scope of changing tyres. The normal car jack available in market is operated using bare hands & is time consuming. It also require much energy for the person to rotate the jacks. Also from literature review it has been seen that there is effort made for minimizing failure of screw jack and increasing efficiency of screw jack by varying helix angle, by using solar energy, battery energy, electrical and electronics devices, but very few works on comparative stress analysis. Hence, this problem has taken over to study, suggest improvement in the design and carry out the analysis of the same.

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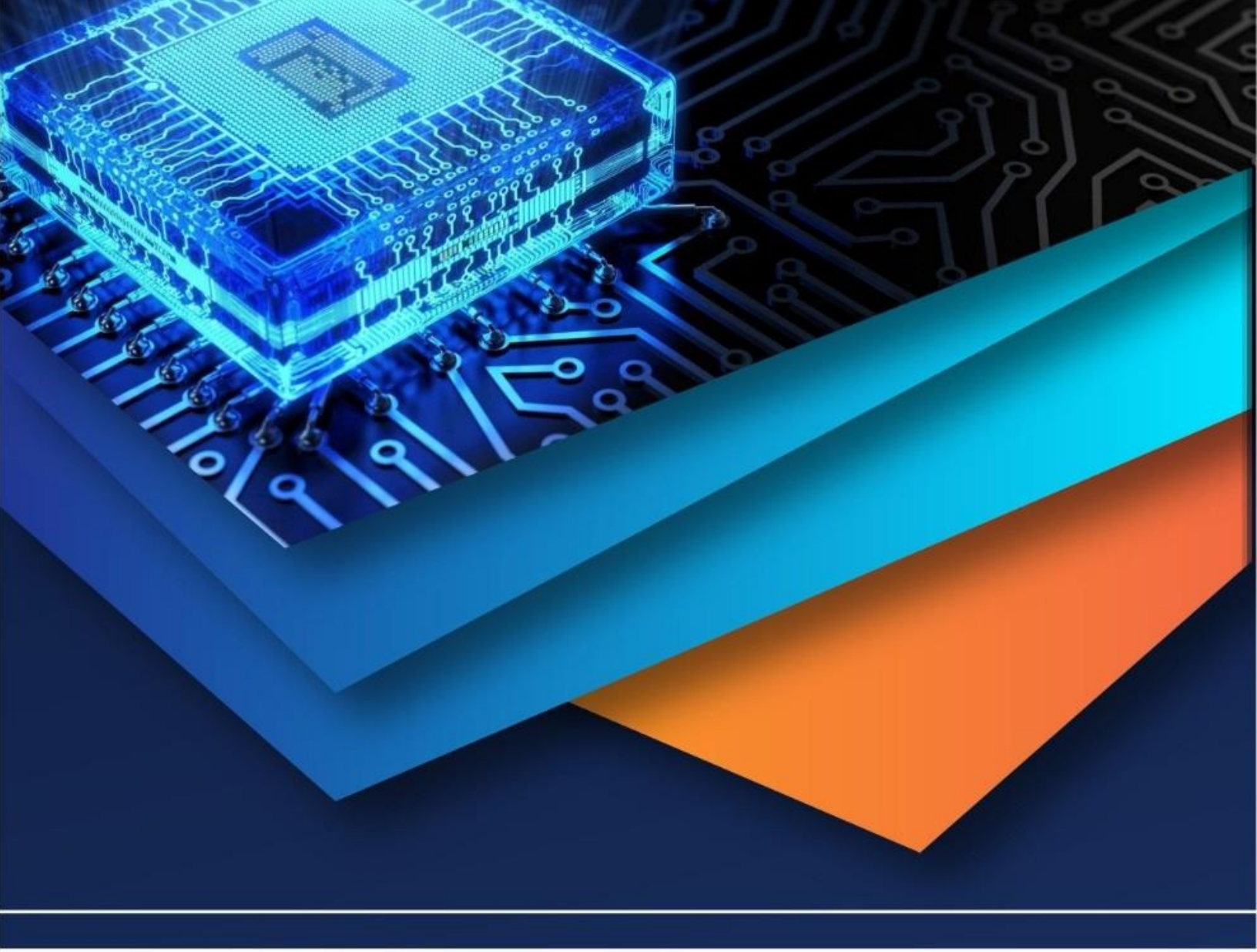

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