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A Study on Design and Fabrication of Screw Jack Lifter using Ratchet and Pawl Mechanism

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ABSTRACT: This paper presents a Screw Jack lifter using in Ratchet and Pawl Mechanism working based on the ratchet pawl. Detailed design procedure of a quick lifting screw jack is discussed. The design is fundamentally a modification of the conventional scissor jack. The problems associated with the conventional jacks are the ergonomic snags experienced by operators due to prolonged bending or squatting positions during operation. These problems of waist pain and backaches are as a result of continuous turning of the wrench or rack and pinion with ratchet and pawl in an uncomfortable position for a long period. These led to the design and modification of quick lifting screw jack with gear arrangements that are safe, reliable and capable of raising or lowering heavy load with little effort. The results showed that the introduction of the crank and gear mechanism would help reduce difficulty in operation, reduce time, increase efficiency and effectively control the difficulties concomitant with Ergonomics - which is an ultimate sensitivity in design process.

KEYWORDS: Screw Jack, Ratchet, Pawl mechanism.

I. INTRODUCTION

A Jack screw is a type of jack which functions by turning a lead screw. It is commonly used to lift heavy load to a 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 large 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 times 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 as a result 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 also reduce time spent to a very minimum.

Over the years, engineers, scientist and ergonomist have extolled the conventional automobile screw jack (scissors jack) as 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 a bolt element (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 [1].

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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.

II. RELATED WORK

Screw type mechanical jacks were very common for jeeps and trucks of World War II vintage. For example, the World War II jeeps (Willys MB and Ford GPW) were issued the "Jack, Automobile, Screw type, Capacity 1 1/2 ton", Ordnance part number 41-J-66.

This jacks, and similar jacks for trucks, were activated by using the lug wrench as a handle for the jack's ratchet action of the jack. The 41-J-66 jack was carried in the jeep's tool compartment. Screw type jack's continued in use for small capacity requirements due to low cost of production raise or lower it. A control tab is marked up/down and its position determines the direction of movement and almost no maintenance. The virtues of using a screw as a machine, essentially an inclined plane wound round a cylinder, was first demonstrated by Archimedes in 200BC with his device used for pumping water.

There is evidence of the use of screws in the Ancient Roman world but it was the great Leonardo ad Vinci, in the late 1400s, who first demonstrated the use of a screw jack for lifting loads. Leonardo"s design used a threaded worm gear, supported on bearings, that rotated by the turning of a worm shaft to drive a lifting screw to move the load - instantly recognizable as the principle we use today. We can't be sure of the intended application of his invention, but it seems to have been relegated to the history books, along with the helicopter and tank, for almost four centuries. It is not until the late 1800s that we have evidence of the product being developed further.

With the industrial revolution of the late 18th and 19th centuries came the first use of screws in machine tools, via English inventors such as John Wilkinson and Henry Medley The most notable inventor in mechanical engineering from the early 1800s was undoubtedly the mechanical genius Joseph Whitworth, who recognized the need for precision had become as important in industry as the provision of power.

While he would eventually have over 60 British patents with titles ranging from knitting machines to rifles, it was Whitworth's work on screw cutting machines, accurate measuring instruments and standards covering the angle and pitch of screw threads that would most influence our industry today. Whitworth's tools had become internationally famous for their precision and quality and dominated the market from the 1850s. Inspired young engineers began to put Whitworth's machine tools to new uses.

During the early 1880s in Coaticook, a small town near Quebec, a 24- year-old inventor named Frank Henry Sleeper designed a lifting jack. Like ad Vinci's jack, it was a technological innovation because it was based on the principle of the ball bearing for supporting a load and transferred rotary motion, through gearing and a screw, into linear motion for moving the load.

The device was efficient, reliable and easy to operate. It was used in the construction of bridges, but mostly by the railroad industry, where it was able to lift locomotives and railway cars. Local Coati cook industrialist, Arthur Osmoses Norton, spotted the potential for Sleeper's design and in 1886 hired the young man and purchased the patent. The Norton" jack was born.

Over the coming years the famous "Norton" jacks were manufactured at plants in Boston, Coati cook and Moline, Illinois. Meanwhile, in Alleghany County near Pittsburgh in 1883, an enterprising Mississippi river boat captain named Josiah Barrett had an idea for a ratchet jack that would pull barges together to form a „tow". The idea was based on the familiar lever and fulcrum principle and he needed someone to manufacture it.

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That person was Samuel Duff, proprietor of a local machine shop, together, they created the Duff Manufacturing Company, which by 1890 had developed new applications for the original "Barrett Jack" and extended the product line to seven models in varying capacities. Over the next 30 years the Duff Manufacturing Company became the largest manufacturer of lifting jacks in the world, developing many new types of jack for various applications including its own version of the ball bearing screw jack [3].

It was only natural that in 1928, The Duff Manufacturing Company Inc. merged with A.O. Norton to create the Duff-Norton Manufacturing Company. Both companies had offered manually operated screw jacks but the first new product manufactured under the joint venture was the air motor-operated power jack that appeared in 1929. With the aid of the relatively new portable compressor technology, users now could move and position loads without manual effort. The jack, used predominantly in the railway industry, incorporated an air motor manufactured by The Chicago Pneumatic Tool.

III. SCRW JACK LIFTER

Screw jack is used in applications where linear motion is required. Lifting of any load, pushing or pulling of mechanical equipment, adjusting of tight clearances of mechanical parts can be done by screw jacks.

Mechanical capacity of screw jacks is between 5kN and 2000kN. Jack screws can be used as linear motors, linear actuators, or mechanical lifts depending on type of motion. Main components of screw jacks are; trapezoidal lifting screw, worm screw, worm gear and gear housing. Worm screw is rotated manually or by motor. Worm gear is rotated by worm screw. The lifting screw moves through the rotating worm gear. The linear motion speed of lifting screw depends on thread size and rotation ratio of worm gears.

In some models of jack screws, the lifting screw does not move up and down. It only rotates around its axis. A lifting nut (also known as travelling nut) moves along the screw. The lifting nut of jack screw is made of bronze to decrease friction.

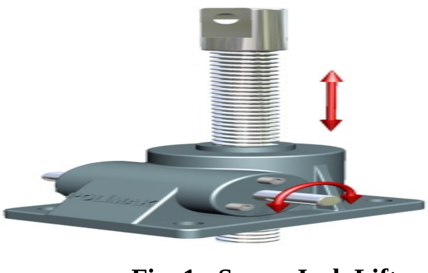

Fig. 1 : Screw Jack Lifter

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 "Try" followed by the nominal diameter and lead, separated by sign "x" and in brackets the letter "P" followed by the pitch expressed in millimeters. For example, A screw jack is a portable device consisting of a screw mechanism used to raise or lower the load. The principle on which the screw jack works is similar to that of an inclined plane. There're mainly two types of jacks-hydraulic and mechanical.

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A hydraulic jack consists of a cylinder and piston mechanism. The movement of the piston rod is used to raise or lower the load. Mechanical jacks can be either hand operated or power driven. Jacks are used frequently in raising cars so that a tire can be changed.

A screw jack is commonly used with cars but is also used in many other ways, including industrial machinery and even airplanes. They can be short, tall, fat, or thin depending on the amount of pressure they will bounder and the space that they need to fit into [2].

The jack is made out of various types of metal; butte screw itself is generally made out of lead. While screw jacks are designed purposely for raising and lowering loads, they are not ideal foreside loads, although some can withstand side loads depending on the diameter and size of the lifting screw. Shock loads should also be avoided or minimized. Some screw jacks are built within-backlash [4].

Fig. 2 : Ratchet and Pawl

3.1 BENEFITS

Equipping motorists with car jacks has provided many benefits to those who are on the road. Most importantly, jacks have equipped drivers with the ability to change a tire in an emergency situation without having to call for assistance, which can save service fees and potential towing fees as well.

Car jacks also provide the home auto enthusiast with a tool to use in maintenance of their own vehicle with the simpler tasks such as changing brake pads, oil and belts. When used appropriately with safety in mind, car jacks are an essential resource for anyone owning or operating a motorized vehicle.

3.2 TYPES

Jacks are of mainly two types- mechanical and hydraulic. They vary in size depending on the load that they are used to lift.

3.2.1 MECHANICAL JACKS

A mechanical 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 mechanical 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. Mechanical jacks are usually rated for maximum lifting capacity. There are two types of mechanical jacks

3.2.2. SCISSOR JACKS

Scissors jacks are also mechanical and have been in use at least since the 1930s. A scissor jack is a device constructed with a cross-hatch mechanism, much like a scissor, to lift up a vehicle for repair or storage. It typically works in just a vertical manner.

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The jack opens and folds closed, applying pressure to the bottom supports along the crossed pattern to move the lift. When closed, they have a diamond shape. Scissor jacks are simple mechanisms used to drive large loads 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.

A scissor jack is operated simply by turning a small crank that is inserted into one end of the scissor jack. This crank is usually "Z" shaped. The end fits into a ring hole mounted on the end of the screw, which is the object of force on the scissor jack. When this cranks turned, the screw turns, and this raises the jack. The screw acts like a gear mechanism. It has teeth (the screw thread), which turn and move the two arms, producing work. Just by turning this screw thread, the scissor jack can lift a vehicle that is several thousand pounds.

IV. 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 a cross 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 contract together, coming together at the middle, raising the jack. When closed, the arms spread back apart and the jack closes or flattens out again.

The anti-backlash device moderates the axial backlash in the lifting screw and nut assembly to a regulated minimum. A large amount of heat is generated in the screw jack and long lifts can cause serious overheating. To retain the efficiency of the screw jack, it must be used under ambient temperatures, otherwise lubricants must be applied. There is oil lubricants intended to enhance the equipment’s capabilities.

Apart from proper maintenance, to optimize the capability and Usefulness of a screw jack it is imperative to employ it according to its design and manufacture Rest instruction. Ensure that you follow the speed, load capacity, temperature.

The screw has a thread designed to withstand an enormous amount of pressure. This is due to the fact that it is generally holding up heavy object for an extended amount of time. Once up them normally self lock so that won’t fall if the operator lets go, and they hold up well to the wear of repeated use. If they are made with a ball nut, they will last longer because there is less friction created with this type of jack.

However they will not self lock. This can be dangerous and handled carefully A scissor jack uses a simple theory of to get its power. As the screw section is turned, two end of the jack move closer together. Because the gear of the screw is pushing up the arm the amount of force being applied is multiplied. 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 form turning, since it is not applying force directly to it. If you were to put pressure 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 [5].

V. RATCHET 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 similar to 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. Theseslots are called "keyways".

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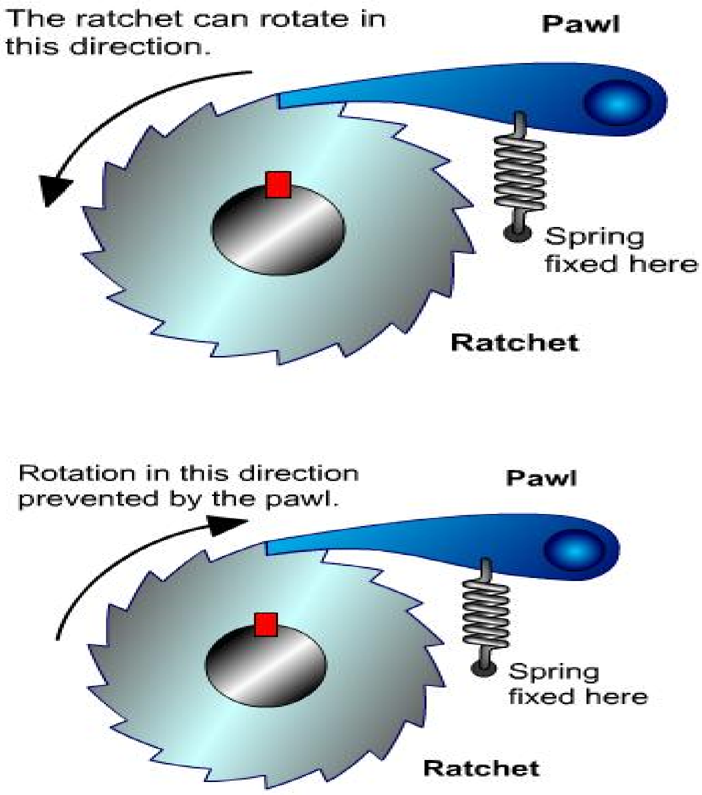

Fig. 3 : Ratchet and Pawl working

A pawl is a metal part that rests on the ratchet. As the ratchet rotates, the pawl drops A pawl is a metal part that rests on the ratchet. As the ratchet rotates, the pawl drops direction of the pawl. Sometimes a spring is used to keep the pawl in contact with the ratchet. The ratchet and pawl mechanism is used wherever rotation is required in one direction only, e.g. in yacht winches and fishing reels [6].

VI. **HOW A RATCHET WORKS**

We discuss, how a ratchet and pawl works, it is a very simple device which allows a shaft to turn only one way. The possibility of having something turn only one way requires some detailed and careful analysis, and there are some very interesting consequences. The plan of the discussion came about in attempting to devise an elementary explanation, from the molecular or kinetic point of view, for the fact that there is a maximum amount of work which can be extracted from a heat engine.

Fig. 4 : Variation of Ratchet and Pawl Action

Of course we have seen the essence of Carol’s argument, but it would be nice to find an explanation which is elementary in the sense that we can see what is happening physically. Now, there are complicated mathematical demonstrations which follow from Newton's laws to demonstrate that we can get only a certain amount of work out when heat flows from one place to another, but there is great difficulty in converting this into an elementary demonstration. In short, we do not understand it, although we can follow the mathematics.

In Carol’s argument, the fact that more than a certain amount of work cannot be extracted in going from one temperature to another is deduced from another axiom, which is that if everything is at the same temperature, heat cannot be converted to work by means of a cyclic process. First, let us back up and try to see, in at least one elementary example, why this simpler statement is true. Let us try to invent a device which will violate the Second Law of Thermodynamics, that is, a gadget which will generate work from a heat reservoir with everything at the same temperature. Let us say we have a box of gas at a certain temperature, and inside there is an axle with vanes in it. But take T I = T:I = T, say.) Because of the bombardments of gas molecules on the vane, the vane oscillates and jiggles [7].

All we have to do is to hook onto the other end of the axle a wheel which can turn only one way-the ratchet and pawl. Then when the shaft tries to jiggle one way, it will not turn, and when it jiggles the other, it will turn. Then the wheel will slowly turn, and perhaps we might even tie a flea onto a string hanging from a drum on the shaft, and lift the flea! Now let us ask if this is possible. According to Carol’s hypothesis, it is impossible. But if we just look at it, we see, primajacie, that it seems quite possible. So we must look more closely. Indeed, if we look at the ratchet and pawl, we see a number of complications. First. our idealized ratchet is as simple as possible, but even so, there is a pawl, and there must be a spring in the pawl. The pawl must return after coming off a tooth, so the spring is necessary. Another feature of this ratchet and pawl, not shown in the figure, is quite essential. Suppose the device were made of perfectly elastic parts.

After the pawl is lifted off the end of the tooth and is pushed back by the spring, it will bounce against the wheel and continue to bounce. Then, when another fluctuation came, the wheel could turn the other way, because the tooth could get underneath during the moment when the pawl was up! Therefore an essential part of the irreversibility of our wheel is a damping or deadening mechanism which stops the bouncing.

When the damping happens, of course, the energy that was in the pawl goes into the wheel and shows up as heat. So, as it turns, the wheel will get hotter and hotter. To make the thing simpler, we can put a gas around the wheel to take up some of the heat. Anyway, let us say the gas keeps rising in temperature, along with the wheel. Will it go on forever ? No! The pawl and wheel, both at some temperature.

VII. DESIGN CALCULATION

Name : Ratchet Pawl • Material Name: C20 (Steel Forging)

1) Tensile Strength : 425 MPa
2) Poisson Ratio: 0.27 – 0.30
3) Modulus of elasticity (E) : 190 - 210 GPa
4) Specific Heat Capacity: 0.46

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5) Density : 7.85 g/cm3
6) Thermal conductivity : 58.6 W/m.k
7) Bulk modulus : 140 MPa
8) Yield strength : 360 MPa
9) Hardness :156 HB
10) Shear modulus :80 MPa International Journal of Engineering Research and General Science Volume 3, Issue 4, Part-2, July-August, 2015 ISSN 2091-2730 464 www.ijergs.org • Part Name : Ratchet wheel • Material Name: EN9 (Normalize)
1) Tensile Strength : 700 MPa
2) Yield Strength : 355 MPa
3) Elongation % : 13%
4) Modulus of elasticity (E) : 206 x 103 N/mm2
5) Density : 7800 kg/m
6) Hardness : 201 to 255 HB

Forward: Need energy Takes from vane Does work Gives to ratchet E + LO from vane..

0.Rate = !

e-(L6+t)/kT. "T LO + E LO Backward: Needs energy E Takes from ratchet E Releases work LO Gives to vane LB + E 1 for pawl. 000

Rate = - e-t/kTz "T } ",m, " ,boY< with ,ign ,,,,,red.

If 0 ObI I h E+ LO E system is reverse, rates are equivalence --- = -. T1 Tz Heat to ratchet E Qz Tz ----- = ---'

Hence m = -. Heat from vane LB + • Q1 T 1 pushes it down against the tooth, there is a force trying to turn the wheel, because the tooth is pushing on an inclined plane. This force is doing work, and so is the force due to the weights. So both together make up the total force, and all the energy which is slowly released appears at the vane end as heat. (Of course it must, by conservation of energy, but one must be careful to think the thing through!) We notice that all these energies are exactly the same, but reversed [8].

VIII. LAYOUT DIAGRAM

The Rap mechanism described in this work was designed with the following design criteria as constraints: the ratchet wheel should advance one and only one tooth per actuation pulse; the ratchet wheel driver and restraint mechanism will be in a planar arrangement.

The ratchet mechanism should operate on as little space of the ratchet wheel as possible; stand-alone spring elements and complicated assemblies should be minimized or eliminated; moving parts should be balanced about their pivot points; the aspect ratio of parts will be 9:1 or less.

The device must be able to be actuated by a stator electromagnet; the driver mechanism will act as the rotor to the electromagnet stator by completing a magnetic circuit; the ratchet wheel will have 38 teeth; no lubricants will be considered for friction reduction; the ratchet mechanism will be designed such that it can be fabricated using micro wire EDM.

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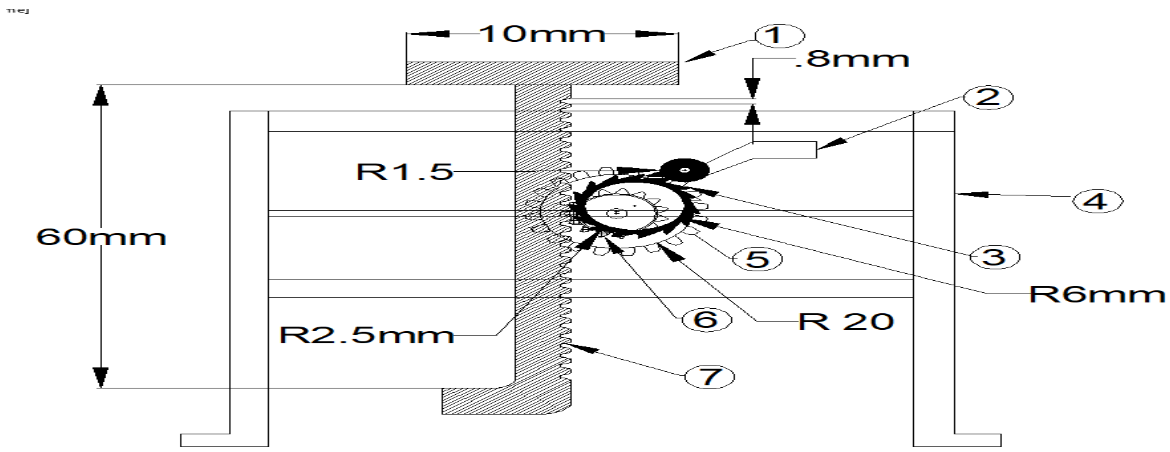

Fig. 5 : Layout Diagram

IX. RESULTS

In the design of ratchet gearing, the teeth must be designed so that the pawl will remain in engagement under ratchet-wheel loading. In ratchet gear systems, the pawl will either push the ratchet wheel or the ratchet wheel will push on the pawl and/or the pawl will pull the ratchet wheel or the ratchet wheel will pull on the pawl. See Figs. 8.1a and b for the four variations of ratchet and pawl action. In the figure, F indicates the origin and direction of the force and R indicates the reaction direction [9].

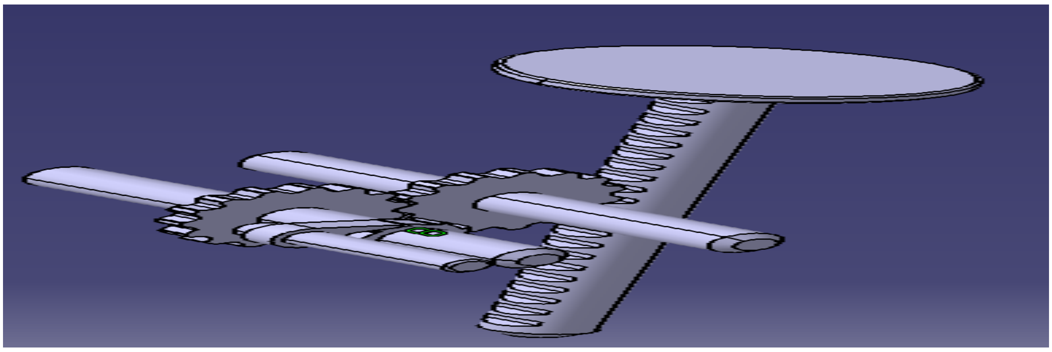

Fig. 6 : Assembly parts

X. CONCLUSION

In this paper, 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

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