Design and Finite Element Analysis of Screw Jack

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Abstract: 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.A screw jack is an example of a power screw in which a small force applied in a horizontal plane is used to raise or lower a large load. The principle on which it works is similar to that of an inclined plane. The mechanical advantage of a screw jack is the ratio of the load applied to the effort applied. The screw jack is operated by turning a lead screw. The height of the jack is adjusted by turning a lead screw and this adjustment can be done either manually or by integrating an electric motor.In this project, screw jack with different geometrical holes on the body is created for weight reduction and also two different types of analysis has been carried out to see the behavior of screw jack under loading conditions. Under loading stress and deformation is calculated for different geometrical holes and different materials.

KEYWORDS:Screw jack, Stress, Deformation, CAE Analysis.

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INTRODUCTION:

This paper deals with the design and modification of screw jack which is used for lifting heavy automobiles. The project helps in reducing the weight of screw jack body in comparison to the ordinary screw jack. A screw jack's compressive force is obtainedthrough the tension force applied by its lead screw. A square thread is most often used, as this thread is very strong and can resist the large loads imposed. These types are self-locking, which makes them more intrinsically safe than other jack technologies. This type of screw jack will be helpful for women and adolescents during the puncture to lift the vehicle when they have no means to serve. In a screw jack, rotary motion is converted into linear motion. There are stresses like shear and tensile stresses induced in materials which are responsible for failure of screw. Screw jack must consist of an adequate factor of safety and must be of high mechanical advantage, so that it can withstand sudden jerks which are unexpected.

OBJECTIVE

A Screw jack 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.

PROBLEM STATEMENT

The problem statement 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.

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.

SOLIDWORKS

SOLIDWORKSuses a 3D designapproach.As you designa part, from the initial sketchto the final result,you createa 3D model.From this model,you can create2D drawingsor mate componentsconsistingof parts or subassembliesto create3D assemblies.Youcan also create2D drawings of 3D assemblies.When designinga modelusing SOLIDWORKS, you can visualize it in three dimensions,the way the modelexists once it is manufactured.

The format of the SolidWorks window reflects that of windows itself. The same is true for any Solid Works document. Once opened a document appears split into two panels. The right is the graphics window, where your model or drawing appears. You can create and manipulate the document in the graphics window.

Solid Modelling

A solid model is the most complete type of geometric model used in CAD systems. It contains all the wire frame and surface geometry necessary to fully describe the edges and faces of the model. In addition to the geometric information, it has the information called topology that relates the geometry together. An example of topology would be which faces (surfaces) meet at which edge (curve). This intelligence makes operations such a filleting as easy as selecting an edge and specifying a radius.

ANSYS

Using ANSYS Fluent fluid flow systems in ANSYS Workbench to set up and solvea three-dimensional turbulent fluid-flow and heat-transfer problem in a mixing elbow. It is designed tointroduce you to the ANSYS Workbench tool set using a simple geometry. Guided by the steps thatfollow, you will create the elbow geometry and the corresponding computational mesh using thegeometry and meshing tools within ANSYS Workbench.You will use ANSYS Fluent to set up and solvethe CFD problem, then visualize the results in both ANSYS Fluent and in the CFD-Post processingtool. Some capabilities of ANSYS Workbench (for example, duplicating fluid flow systems, connectingsystems, and comparing multiple data sets) are also examined in this tutorial.

ANSYS Design Modeler

For the geometry of your fluid flow analysis, you can create a geometry in ANSYS DesignModeler, ANSYSSpaceClaim Direct Modeler, or import the appropriate geometry file. In this step, you will create thegeometry in ANSYS DesignModeler, then review the list of files generated by ANSYS Workbench.

PROPOSED METHODOLOGY

MATERIALS SELECTION

Material selection is an important process in design processes. Selecting materials is a process that is design-led in that the material selection process uses the design requirements as the input so as to come up with materials that have the desired properties for the part to be designed to function well.

The common engineering materials used in making machine components include;

- Cast iron,
- Steel (all types ofsteel),
- Copper and itsalloys,
- Aluminum and itsalloys,
- Plastics.

Selection of materials in engineering design involves the following steps (Prof. F.M. Oduori, 2016):

- Translation of design requirements into specifications for amaterial.
- Screening out those materials that do not meet the specifications in order to leave onlythe viablecandidates.
- Ranking of the surviving materials to identify those that have the greatestpotential.
- Using supporting information to finally arrive at the choice of material to beused.

The first three steps involve mathematical analysis, use of various charts and graphs of specific property such as specific strength, wear resistance, buckling resistance and affordability. The materials are compared, ranked as per the indices of merit and available supporting information is used to reach the final decision (Ashby, 2005).

In this project, information from case studies on previous designs of similar products is used in material selection for the screw jack components/parts. However, other factors such as availability of the candidate materials, purchase price of the candidate materials, manufacturing processes and properties, forms and sizes in which the materials are available are also considered.

Components and their Specific Materials Selected

The goal of material selection is to come up with an appropriate material that best meets the design requirements. The approach is to identify the connection between functional requirements and the material properties so as to help us reduce the number of candidate materials from which to select from.

The following are components and materials required in the design of a power screw (screw jack):

Frame(Body)

Most of the frames are in conical shape and hollow internally to accommodate both the nut and screw assembly. The frame works to ensure that the screw jack is safe and has a complete reston the ground. The purpose of the frame is to support the screw jack and enable it to withstand compressive load exerted on it.

The frame is a bit complex and thus requires casting as a manufacturing process. For this reason, grey cast iron as a material is selected for the frame. This is also evident from the case study on previous design of the same product (Nyangasi, 18 December, 2006). Cast iron is cheap and it can give any complex shape without involving costly machining operations. Cast iron has higher compressive strength compared to steel. Therefore, it is technically and economically advantageous to use cast iron for the frame. Graphite flakes cast iron with an ultimate tensile strength of 220MPa is considered suitable for the design of the frame. The graphite flakes improve the ability to resist compressive load.

Mechanical properties	British Standard Specification
Tensile strength (MPa)	220
Compressive strength (MPa)	766
Shear strength (MPa)	284
Endurance limit (MPa)	96
Young's modulus (GPa)	89 – 114
Modulus of rigidity (GPa)	36 – 45
Hardness number (HB)	196

Table 1: Mechanical Properties of Cast iron – Appendix A (Marshek, 2012)

Screw

The screw is subjected to torsional moment, compressive force and bending moment. The screw profile is square type because of its higher efficiency and self-locking but not compared to trapezoidal threads. Square threads are usually turned on lathes using a single point cutting tool also square threads are weak at the root and this leads to use of free cutting steel. Screws are usually made of steel where great resistance to weather or corrosion is required. Most fasteners close to 90% use carbon steel because steel has excellent workability, offers abroad range of attainable combinations of strength properties and it is less expensive. Medium plain carbon steel can be heat treated for the purpose of improving properties such as hardness, strength (tensile and yield), the desired results are therefore obtained (Fasteners, 2005). This leads to the use of plain carbon steels.

Material	British standard	Production in process	Maximum section size, mm	Yield strength MPa	Tensile strength, MPa	Elongatio n %	Hardness Number, HB
0.30C	080M30	Hardened & Tempered	63	385	550 – 700	13	152 - 207

Table 2: Mechanical Properties of Plain carbon steel – Appendix B (Nyangasi, 18 December, 2006)

Nut

There exists a relative motion between the screw and the nut which causes friction, friction in turn causes wear of the material used for screw and nut. Therefore, it requires one of the two members to be softer. A suitable material for the nut is therefore phosphor bronze which is a copper alloy with small percentage of lead and has the following advantages;

- Good corrosionresistance.
- Low coefficient offriction.
- High tensilestrength.

Bronze has 0.2% phosphor to increase tensile strength and the yield stresses may be takenas; tension = 125MPa, compression = 150MPa, yield stress in shear = 105MPa with safe bearing pressure of 15MPa, ultimate tensile strength is 190MPa and a coefficient of friction of0.1.

Type of power Screw	Screw material	Nut material	Bearing pressures	Rubbing speed
Screw jack	Steel	Bronze	11-17MPa	3m/s

Table 3: Safe Bearing Pressures for Power screws – Appendix C (Nyangasi, 18 December, 2006) & (Gupta,2005)

Handle

The handle is subjected to bending moments so plain carbon steel of BS 080M30 with yield strength of 385MPa can also be used. It has the same mechanical properties and process as in Table .2.

Cup

Shape of cup is complex and thus requires casting process. It also has the same properties as in Table 1. Taking graphite flakes cast iron with an ultimate tensile strength of 200MPa. The graphite flakes improve the ability to resist compressive load.

Set Screw and Lock nut +Washer

The purpose of the set screw is to resist motion of nut with screw. The lock nut + washer on the other hand is used to provide uniform force by enlarging the area under the action of the force. We can use plain carbon steel for both and they have the same manufacturing process and properties as in Table 2.

Designing of Screw Jack in Solid Works

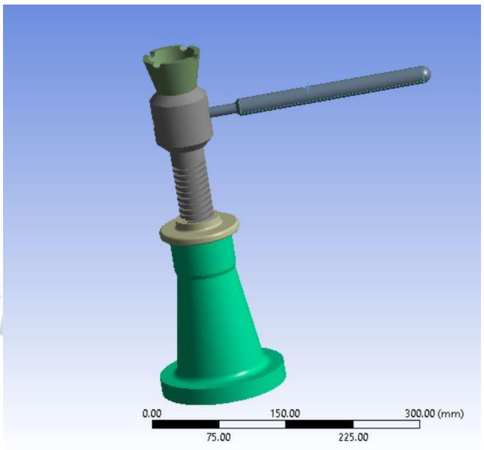

Fig 1: Assembly of Screw Jack

Fig 2: Assembly of Screw Jack with Circular holes

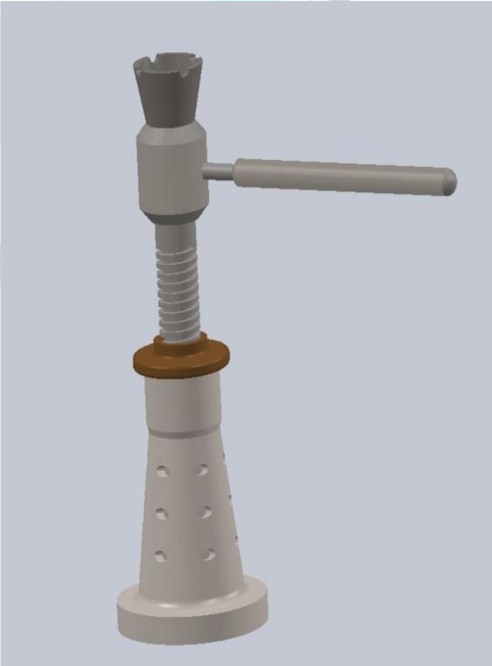

Fig 3: Assembly of Screw Jack with elliptical holes

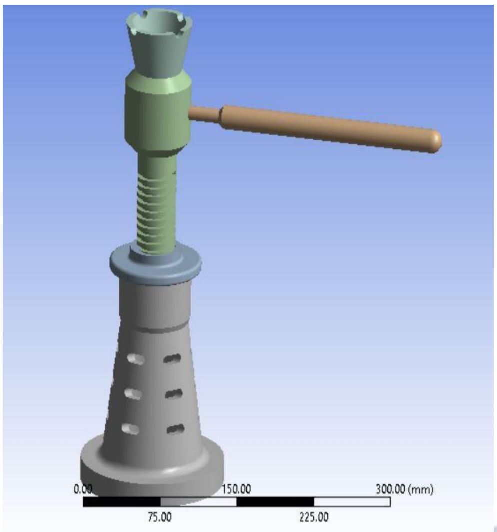

Fig 4: Assembly of Screw Jack with elongated holes

SIMULATION RESULTS

Ansys Result

Structural analysis of Screw jack without holes

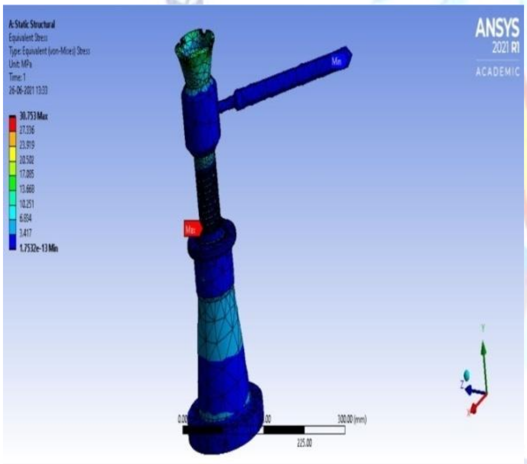

Fig 5: Stress distribution of screw jack without holes with structural steel

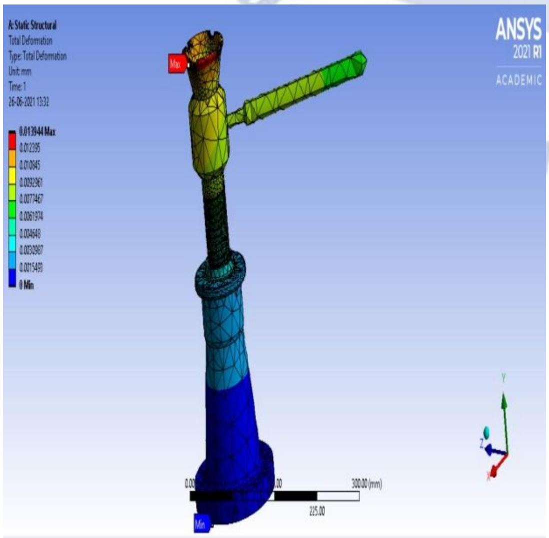

Fig 6: Deformation of screw jack without holes with structural steel

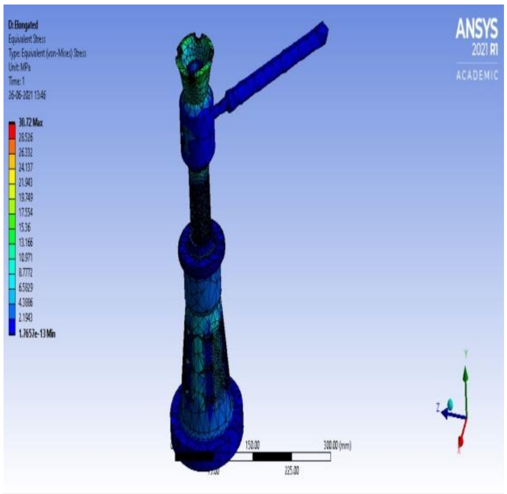

Fig 7: Stress distribution of screw jack without holes with grey cast iron

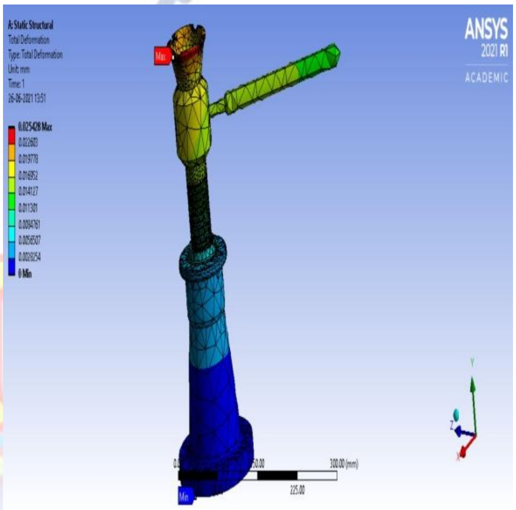

Fig 8: Deformation of screw jack without holes with grey cast iron

Structural analysis of screw jack with circular holes

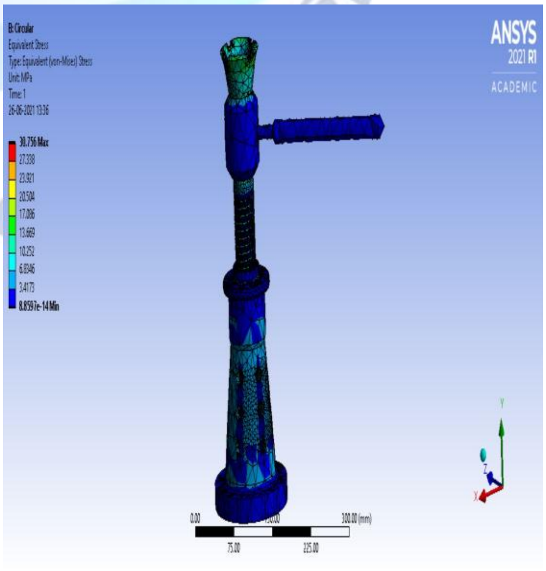

Fig 9: Stress distribution of screw jack with circular holes with structural steel

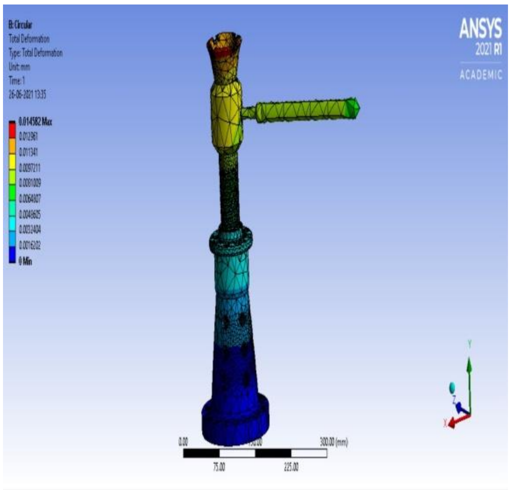

Fig 10: Deformation of screw jack with circular holes with structural steel

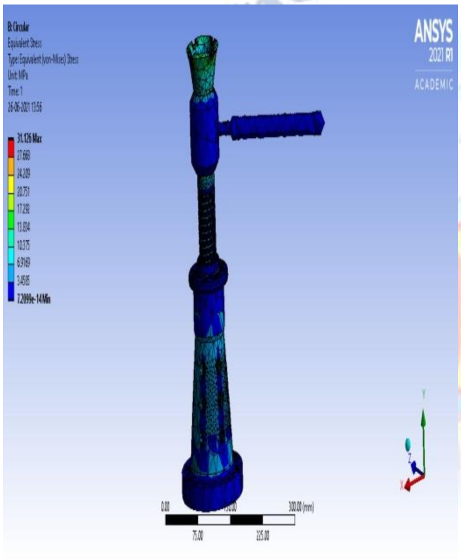

Fig 11: Stress distribution of screw jack with circular holes with grey cast iron

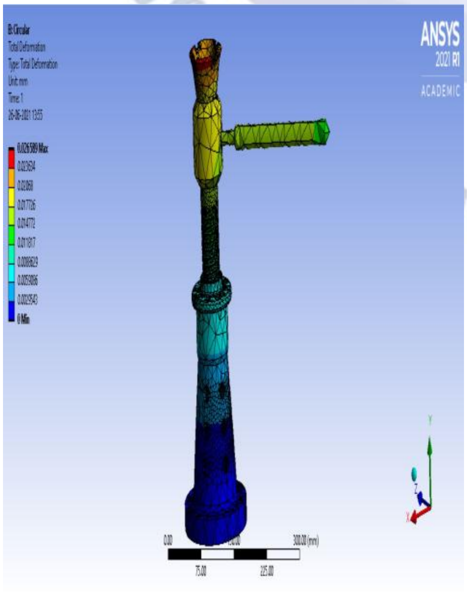

Fig 12: Deformation of screw jack with circular holes with grey cast iron

Structural analysis of screw jack with elliptical holes

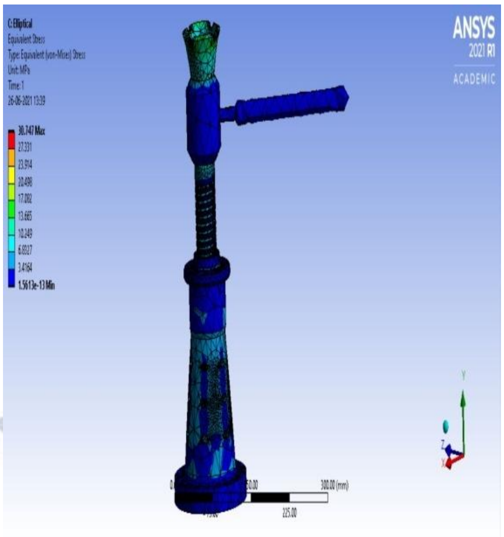

Fig 13: stress distribution of screw jack with elliptical holes with structural steel

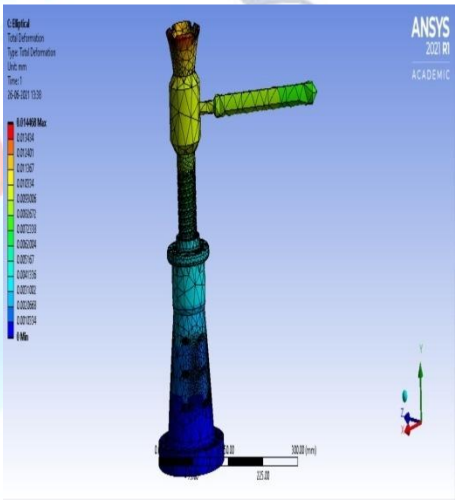

Fig 14: Deformation of screw jack with elliptical holes with structural steel

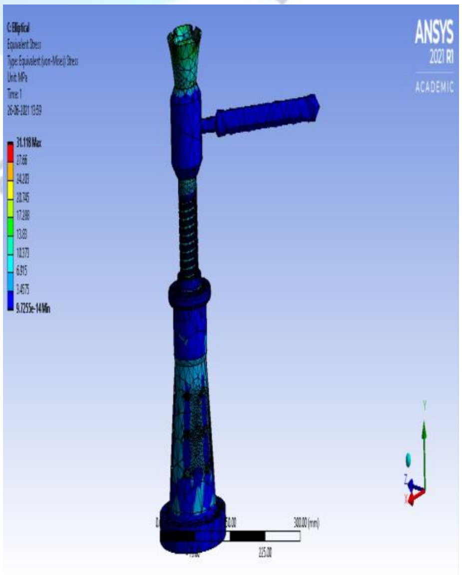

Fig 15: Stress distribution of screw jack with elliptical holes with grey cast iron

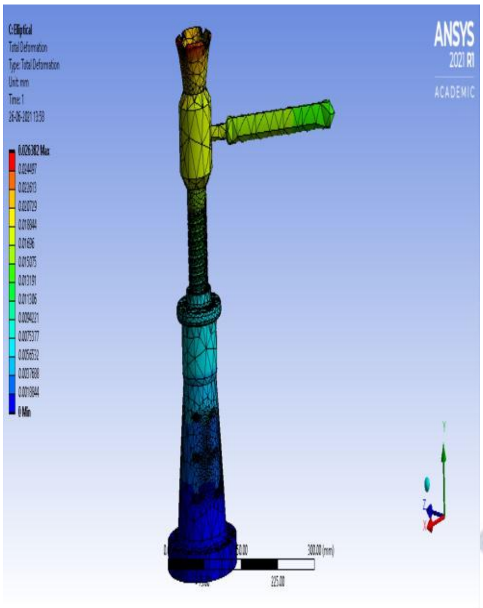

Fig 16: Deformation of screw jack with elliptical holes with grey cast iron

Structural analysis of screw jack with elongated holes

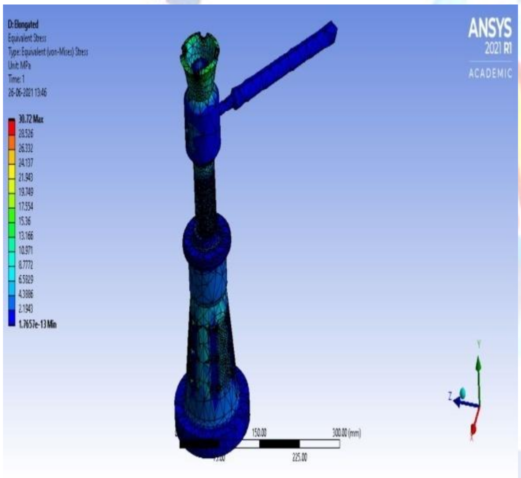

Fig 17: stress distribution of screw jack with elongated holes with structural steel

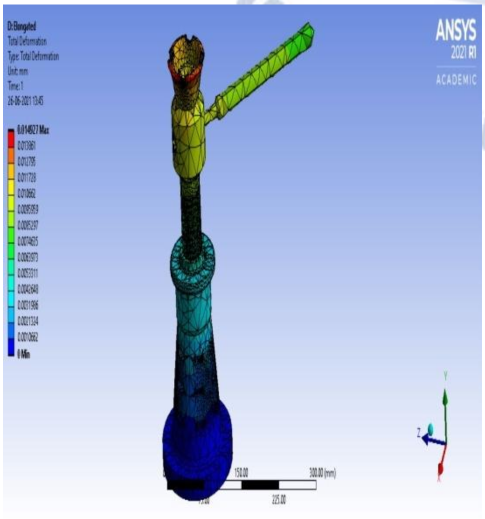

Fig 18: Deformation of screw jack with elongated holes with structural steel

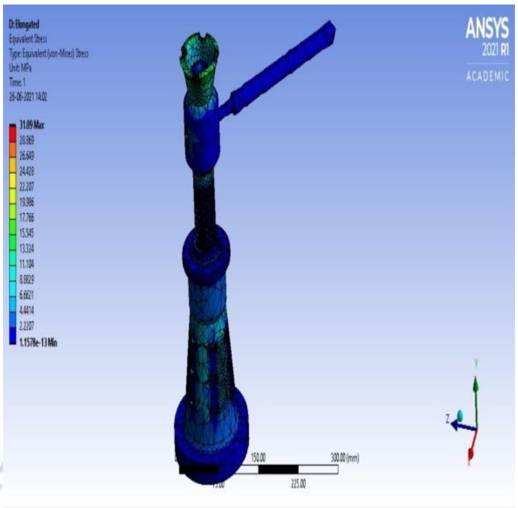

Fig 19: Stress distribution of screw jack with elongated holes with grey cast iron

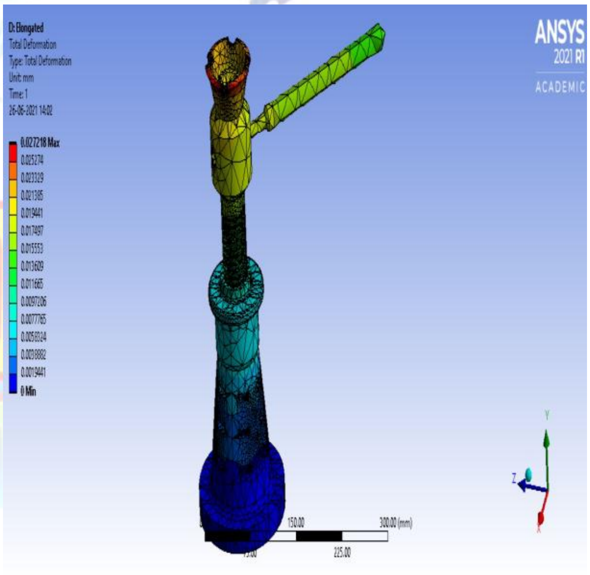

Fig 20: Deformation of screw jack with elongated holes with grey cast iron

COMPARISON TABLE

S/no	Parameters	Weight	Deformation	stress	material
1	Without hole	3.9969	0.025428	31.11	Gray cast iron
2	With Circular hole	3.8025	0.026589	31.26	Gray cast iron
3	With elliptical hole	3.8950	0.026382	31.118	Gray cast iron
4	With elongated hole	3.8335	0.027218	31.09	Gray cast iron

CONCLUSION

Screw Jacks are the ideal product to push, pull, lift, lower and position loads of anything from a couple of kilograms to hundreds of tons. It is highly desirable that a jack become available that can be operated alternatively from inside the vehicle or from a location of safety off the road on which the vehicle is located. Such a jack should desirably be light enough and be compact enough so that it can be stored in an automobile trunk, can be lifted up and carried by most adults to its position of use, and yet be capable of lifting a wheel of a 800 kg vehicle off the ground. The analysis has been done for circular, elliptical and elongated holes with Structural steel and grey cast iron. Among all the geometries screw jack with elongated holes with grey cast iron giving better stress distribution. Further, it should be stable and easily controllable by a switch so that jacking can be done from a position of safety. It should be easily movable either to a position underneath the axle of the vehicle or some other reinforced support surface designed to be engaged by a jack.

FUTURE SCOPE

In the future we would like to reduce the thickness of the body to reduce the weight of the screw jack. Since all the analysis values are very close to the screw jack without holes. For further we can reduce the thickness of the body and we can increase the no of holes to reduce the weight and improve the better stress distribution and deformation.

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