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Exploring Parametric Screw Jack Design through 3D Printing

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Abstract: A screw jack is a tool for lifting heavy loads with little effort. In this paper, the design, model and fabrication of a Screw jack using 3D Printing Technology is discussed. Digital fabrication, or 3D printing or additive manufacturing, creates physical objects from a geometrical representation by successive addition of materials. In agriculture, health care, motor vehicles, locomotives and aviation, 3D Printing is increasingly being applied for mass customization or production for all types of open-source design. Design is an important industrial activity which influences the quality of the product. The parts of a screw jack are modeled by using the modelling software Creo Parametric. The CAD model of the screw jack is then converted into. STL (Standard Tessellation Language) format in which the 3D Printer receives the printing input. The STL files are then imported to modelling software to analyze mesh and rectify errors. The rectified STL files of parts of the screw jack are imported to Makerbot software, and parts are made ready for 3D Printing using Makerbot FDM (Fused Deposition Modelling) 3D Printer. The parts printed in an FDM 3D printer are assembled based on the tolerances obtained, and the final prototype is fabricated.
Keywords: Creo parametric, Fused Deposition Modelling (FDM), Poly Lactic Acid (PLA), Screw jack,3D Printing

I. INTRODUCTION

A screw jack is a device used to raise or lower the load with little effort [1, 2].The efforts to design and produce the work are decreasing with the increase in technology levels. The implementation of improved designs can economically and effectively reduce the efforts. Rotary motion can be converted into translatory motion by a power screw. The screw jack comes under the category of power screws, in which a little force is applied to lift heavy loads.

The ratio of the load raised/lowered to the effort required is the mechanical advantage of a screw jack and is usually high. The rotation of the lead screw in the screw jack will enhance its operation. Most people prefer using the car jack, which is still a standard procedure with most new cars. Lifting the loads to maintain and replace the tyres in automobiles is often necessary. A variety of jacks has been developed for lifting the loads in automobiles.

The screw jacks are of two types, i.e. hydraulic and mechanical. In the case of a hydraulic jack, the cylinder and piston mechanism are used to lift the loads [3, 4].

The piston rod plays a vital role in raising or lowering the load. The mechanical jacks can be operated by hand; sometimes, they have a power-driven facility [5-7]. A screw jack is widely used to lift heavy industrial machinery and also used for aircraft maintenance works. The jacks are designed based on the pressure quantity, load type and available space.

A. Components and Assembly of a Screw Jack

The screw jack mainly consists of a screw and a nut. The nut remains stationary and is fixed in a frame. The rotation of a nut is prevented by a set screw which is located in the frame. The rotation of the screw is done with the help of a handle which passes through a hole which is located in the head of a screw. The head remains stationary while the screw is being rotated. The washer is assembled at the other end of the screw, which prevents the screw from being completely turned out of the nut.

B. Body

In most cases, the frame is designed in a conical shape and internally hollow to accommodate the screw and the nut. The hollow conical shape is designed so the complete jack can rest on the ground. This is the main reason the jacks are designed without legs; this legless design prevents the uneven distribution of the loads.

C. Screw Spindle

The thread of the screw is designed in a way that it can withstand a tremendous amount of pressure. Once the load is lifted, the self-locking is done automatically. The ball nut is quite recommended, as it has very little friction and withstands for a longer life. The main disadvantage of these jacks is that self-locking cannot be done. This is very risky and should be handled with care. The diameter for the power screws ranges from 22 to 100mm diameter and for the trapezoidal screws, it ranges from 24 to 100mm.

D. Thread Profile

Square threads are more efficient than trapezoidal threads since they provide more efficiency, and the motion of the threads is also uniform. The square threads are mainly done by using the turning operation with the help of a single-point cutting tool. The main drawback of the square threads is they need to be stronger in roots.

E. Nut

It is a fact that there is a relative motion between the nut and the screw, which causes friction. The selection of material is essential for making a screw and a nut. In the case of screw and nut, anyone, i.e. either nut or screw, should be made up of softer material. The screw is significantly costlier than the nut, so in this regard, the softer material is recommended for making the screw.

F. Tommy Bar

Tommy bar is subjected to bending moments. A short bar is a lever to torque a box spanner or key.

G. Washer

The washer prevents surface damage by uniformly applying the nut's pressure over the surface. It will ensure that the nut is pressed against a smooth surface and can lessen the possibility that it will gradually loosen from contact with an uneven surface, mainly a cup.

H. Cup

A cup is generally used to hold the loads that we want to lift using a screw jack.

II. DESIGN OF A SCREW JACK

Maximum load screw can lift = 600 kg.
Material: PLA (Poly lactic acid)
The properties of PLA material are given in Table 1.

Table1: Properties of PLA material [2].

Property	In PSI	In Mpa
Compressive Strength(σc)	2600	17.93
Tensile Strength(σt)	6783	46.77

1) Design of a Screw Spindle

Core diameter (d_c) = $(F/ (3.14\times\sigma c/ (4\times n))$ (1)

= 45.72mm

Consider Factor of safety (n) =5

From the chart of regular series square threads, the nearest standard core diameter (d_c) = 47mm Pitch = 3 mm d_{maj}=50.5mm

Mean diameter (d_{mean}) = $(d_{maj} + d_c)/2$ (2)

= 48.75mm.

The torque required to raise the load is given by

= $F\times (d_{m/2}) \times ((l+ \mu \pi d_m)/ (\pi d_m-\mu_l)$ (3)

Where l = n× p;

N=number of starts μ = 0.6

Consider a single start thread, so l = (1) p; ⇒ l = 3mm.
D_m= 48.75mm Torque=40.3Nm
Check for combined stress
The screw is subjected to direct compressive stress 6_c and torsional shear stress τ. The stresses are given by
$\sigma_c = 4F/ (\pi\times d_{c2})$ (4)
= 3.155Mpa.
$\tau=16\times T/ (\pi\times d_{c3})$ (5)
= 1.77Mpa.
The principal stress will be given by
σ1, 2 = (σc/2) +√(σc/2 2 + τ2) (6)
Substituting values in the above equation, we get
σ1 = 3.948Mpa
σ2 = -2.370Mpa
Maximum Shear Stress τmax= 2.37MPa (σ1- σ2).
Buckling of Screw
Length of the screw = Lifting height + H
= 150 +24
L = 174mm.
For, dn=50.5mm,
I = (π/4) × dn4
= 3.066×10 -7mm4.
K= √I/A = 0.0125mm.
Slenderness ratio (ƛ) = L/K = 27.42mm as ƛ< 40mm, there is no buckling.

2) *Design of Nut*

Nut moves the screw spindle up and down with the help of a screw mechanism. The pitch and height of the nut are calculated below. From Table 1
σc=17.93Mpa
σt = 46.77Mpa
Safe bearing pressure (Pb) = 3.4Mpa
F= (π/4)(dmaj2–dc2) P_b × n' (7)
n ' = 6.46 ⇒ n'=8
H = n' × p =24mm.
Crushing Failure:
Shear and crushing are also applied to the nut threads, and the results are computed below
F = (n`×π/4) (dmaj2–dc2) σc (8)
σc= 2.74Mpa < 17.93Mpa
So, there is no crush.
The nut needs to be tested for tension as well because of the screw loading, and we might write.
Correlation factor(C) =1.3
We have,
CF=(π/4)(D12–dc2)σt (9)
D1=49.16mm.
But D1 must be more significant than dmaj, so
D1=52mm.
Considering the crushing of the collar of the nut and to avoid this, we can write as
F= (π/4) (D22 – D12) σc
D2=55.87mm.
To allow collar margin, we take D2 as 65.87mm. D2= 65.87mm.

3) Design of Tommy Bar

Tommy bar is subjected to bending moments. The length and diameter of the tommy bar are calculated below.
Torque (T) = 40.3 Nm.
Length of tommy bar (l`) = L1 + D3
The maximum force applied to the tommy bar is taken as 40N.
T=F1×l`
l`=250mm
It may be subjected to a bending moment.
$\Pi\times d13\times\sigma t/32=F$ (10)
d1 =2.06mm.
We take d2= 12.06mm. (Greater than d1)
Other dimensions
D3 = 1.63 ×d
D3=79.46mm
D4 = D3/2
D4=39.73mm
Let L1=20mm, t4= 3mm.
Body
t1 = 0.25× dmaj
t1=13mm.
D5 = 2.25×D2
D5= 148.2mm.
D6= 1.74D5
D6=259.36mm.
t3= t1/2
t3= 6.5mm.
Torque (T) = 40.3 Nm.
Length of tommy bar (l`) = L1 + D3
The maximum force applied to the tommy bar is taken as 40N.
T=F1×l`
l`=250mm
It may be subjected to a bending moment.
$\Pi\times d13\times\sigma t/32=F$ (10)
d1 =2.06mm.
We take d2= 12.06mm. (Greater than d1)
Other dimensions
D3 = 1.63 ×d
D3=79.46mm
D4 = D3/2
D4=39.73mm
Let L1=20mm, t4= 3mm.
Body
t1 = 0.25× dmaj
t1=13mm.
D5 = 2.25×D2
D5= 148.2mm.
D6= 1.74D5
D6=259.36mm.
t3= t1/2
t3= 6.5mm.

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III. MODELING OF A SCREW JACK

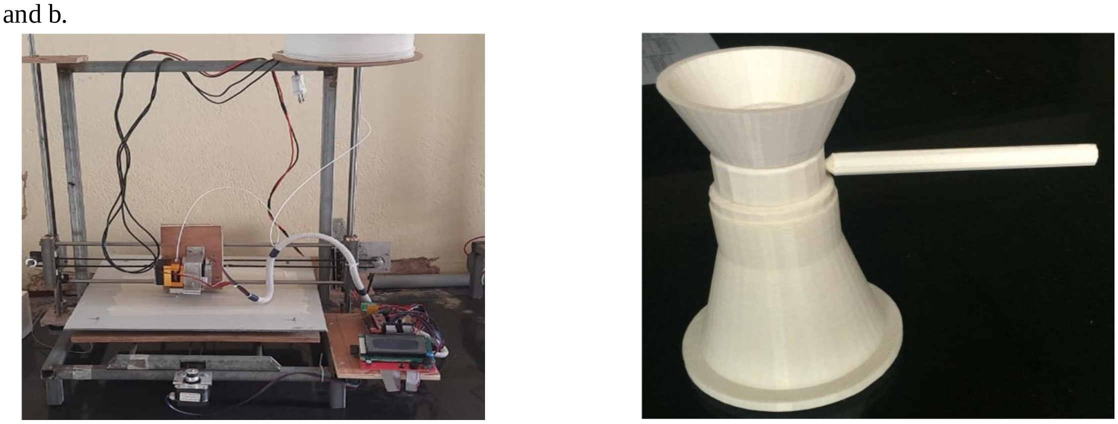
The modelling of the screw jack is done with the designed dimensions in Creo Parametric software. The software comprises various workbenches such as sketcher, part design, wireframe, etc. The modelling of screw jack parts is done in part model. The modeled screw jack is shown in Fig. 1.

IV. FABRICATION OF A SCREW JACK

3D printing or additive manufacturing process is a layer-by-layer manufacturing process that can be used to print almost any shape of a 3D model, communicated in electronic information [8-10]. Converting the modelling file into .STL configuration is crucial for these types of processes. This is done with the help of "Slicer", which converts the model into thin layers. These layers will act as virtual cross-segments for the CAD model. The most attractive thing about this 3D Printing is that it can print almost any complex geometry. The broad classification of 3D Printing is as follows- Fused Deposition Melting (FDM), Stereo lithography (SLA), Selective Laser Sintering (SLS), Direct Laser Deposition (DLD) and other methods such as Three Dimensional Printing (3DP), Polyjet Printing, Electron Beam Melting (EBM), and Laminated Object Manufacturing (LOM). The technique which is selected for making the screw jack is Fused Deposition Modelling (FDM).

A. *STL Format for 3D Printing*

STL (Standard Tessellation Language) is a file format native to the Stereo-lithography CAD software created by 3D systems [11-15]. Many other software packages support this file format, which is widely used for Rapid Prototyping and Computer Aided Manufacturing. Using a three-dimensional Cartesian coordinate system, an STL file represents a raw, unstructured triangulated surface by the triangles' unit standard and vertices (right-hand thumb rule). The units are arbitrary, the STL coordinates must be positive integers, and there is no scaling information. The model is thus saved in STL format, supported by the 3D Printer. Makerbot Replicator Z 18 3D Printer is used for printing the screw jack. The 3D Printer and the printed screw jack model are shown in Fig. 2 a and b.



(a) *(b)*

Figure 2: (a) Makerbot replicator Z 18 3D printers; (b) fabricated screw jack.

V. CONCLUSION

3D Printed prototypes allow for better decisions. Before proceeding with full-scale production, designers and engineers can test, validate, and improve their ideas through the crucial prototyping stage in the product development process. Prototyping has experienced a revolutionary change since the development of 3D printing technology, offering many advantages that speed up the design iteration process and foster creativity. The three main elements of the testing phase of product development are functional testing, design verification, and assembly interconnection testing. Designers can imitate real-world settings and assess how well the design functions by creating functioning prototypes with qualities comparable to the final product. This allows designers to detect any defects or areas for improvement early in the development process. Design verification makes it possible to find and fix design flaws, evaluate proportions, and confirm that the specifications are met as planned. Functionality in many goods depends on component interconnection and correct assembly. Early detection of assembly difficulties or other problems allows designers to make the required corrections and guarantee smooth component integration. The screw jack's components are created, sculpted, and 3D printed using PLA (polylactic acid) material on a Fused Deposition Modelling Makerbot Replicator Z18 3D printer. The 3D-printed parts are then combined, and testing shows that the 3D-printed screw jack functions and has good dimensional accuracy. 3D printing prototyping has many advantages that transform the field of product creation. It permits customization and optimization while decreasing expenses, lowering risks, and speeding up design iterations. The goal of the 3D printed prototype is to provide a clear vision that includes the product's precise shape, user-centric design, enhanced communication, and later iterative development.

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