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COMPARATIVE STRUCTURAL ANALYSIS OF ACME AND SQUARE THREAD SCREW JACK

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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 project selection of two different types of screw threads namely Square and Acme threads. The square threads are named after their square geometry. They are the most efficient power screw, but also the most difficult to machine, thus most expensive. The Acme threads are machining with multipoint cutting tool on thread milling machine, it is an economical operation. Acme threads have more thickness at core diameter than of Square threads therefore a screw with Acme threads is stronger than equivalent screw with Square threads. Assumptions made in designing a Power screw are the total load is distributed among the threads i.e. of car jack of capacity 1.5 to 3 tones threads are in direct shear, various stresses in screw like tensile or compressive in the body of the screw due to an axial load. Thus, the different type of screw threads is designed as per the dimensions, experimental calculations and analyzed using Abaqus FEA software. Model developed is to be validated using experimental and analysis calculation

Keywords: CATIA, and ABAQUS FEA, Alloy Steel

INTRODUCTION

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.

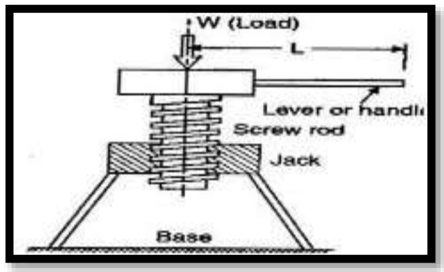

Fig.1. Simple Screw Jack

An advantage of screw jack over some other types of jack is that they are self-locking in nature that means when we removed the rotational force 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.

DETAILS EXPERIMENTAL

The performance of power screw investigation to carry out simulation technic and validated by manual calculations.

2.1 Simulation technique:

The scientific way of approaching the goals of this title is to study the existing different types of screw threads for car jack design, material and behavior towards the loading. Then the thread design and material change concept is to be applied. Various steel materials are to be compared on the basis of mechanical properties and their cost. Basically material strength and its factor of safety are the main selection criteria for materials.

Finite element analysis method is less expensive, quick and flexible than experimental methods hence it is to be carried out to predict the deformation and exact areas of deformation before laboratory testing. FEA is to be done in 3 major steps with the help of their respective software's they are

2.2 modeling of screw jack (square threads)

Solid modeling tool is available for developing idea and basic design of mechanical part and systems which can be analyses by use of FEA method. By use of above citied technique revives Occurrence of unnoticed Flaws can be minimized until phase of prototype stage.

Fig 2:- modeling of screw, handle and cap for square thread

Fig 3: modeling of screw jack frame for square thread

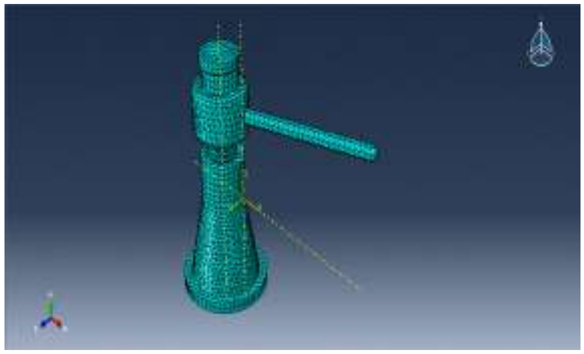

Fig 4: - Finite Element Model of screw jack for square thread - Meshed View

Meshed model with connecting rod is shown in above Fig. Model of screw jack contains 103447 elements (Tetrahedral shape).

Table- 1 : material and properties

Material selected	Alloy Steel
Modulus of elasticity, (E)	207 MPa
Poisson's Ratio	0.30
Tensile Ultimate strength	621MPa
Tensile Yield strength	483 MPa
Density	Density 7700kg/m3
Shear modulus	79GPa
Behavior	Isotropic

In this analysis modeled is analyzed under static condition case. In this case suitable loading and boundary condition applied on the screw jack and analysis is carried out.

2.3 Modeling of screw jack (acme threads):-Solid modeling tool is available for developing idea and basic design of mechanical part and systems which can be analyses by use of FEA method. By use of above citied technique revives Occurrence of unnoticed Flaws can be minimized until phase of prototype stage

Fig.5:- modeling of screw, handle and cap for Acme thread

Fig.6:- modeling of screw jack frame for Acme thread

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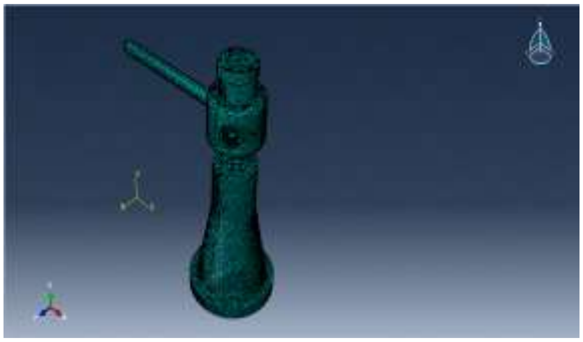

Fig.7:- Finite Element Model of screw jack - Meshed View for Acme thread

The meshed model with connecting rod is shown in above Fig. The model of screw jack contains elements (Tetrahedral shape).

Table: 2 material and properties for acme threaded screw jack

Material selected	Alloy Steel
Modulus of elasticity, (E)	207 MPa
Poisson's Ratio	0.30
Tensile Ultimate strength	621MPa
Tensile Yield strength	483 MPa
Density	Density 7700kg/m3
Shear modulus	79GPa
Behavior	Isotropic

In this analysis modeled is analyzed under static condition case. In this case suitable loading and boundary condition applied on the screw jack and analysis is carried out.

RESULTS AND DISCUSSION

3.1 Result from ABAQUS FEA software for Square thread: -

FEA for Square Thread:-

A. Results for Static Analysis:-Outputs of static analysis are shown via stresses, strain under the effects of applied load.

B. FEA results for static analysis that is Von-Misses stress max. Principal stress, min. principal and Strain are shown in Fig. below respectively.

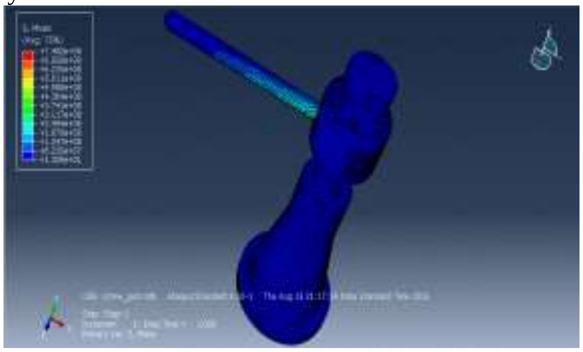

Fig.8:- Finite Element Model of square thread screw jack – Von mises Stres

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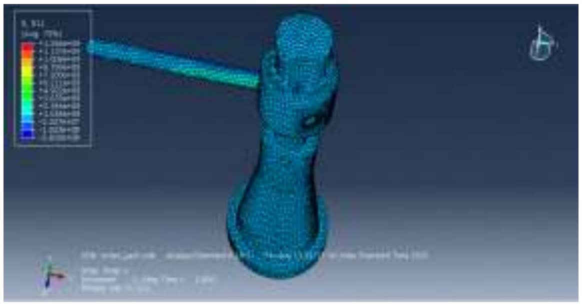

Fig. 9:- Finite Element Model of Square thread screw jack –Stress along xx direction

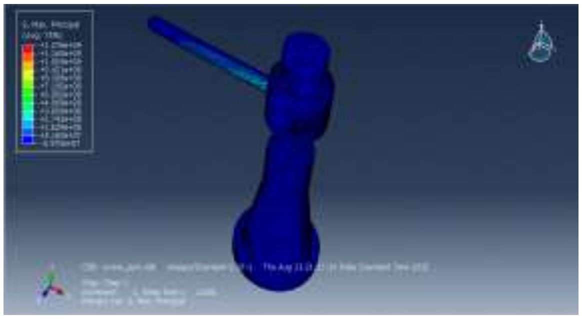

Fig.10:- Finite Element Model of screw jack – Max. principal Stress

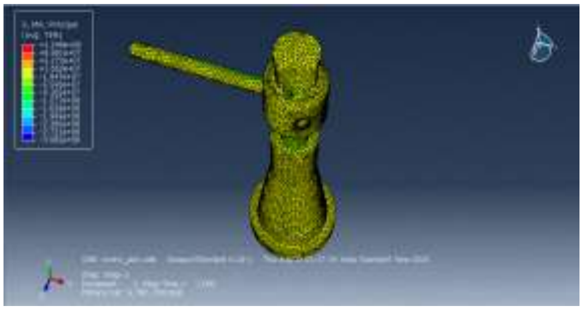

Fig.11:- Finite Element Model of screw jack – Min. principal Stress

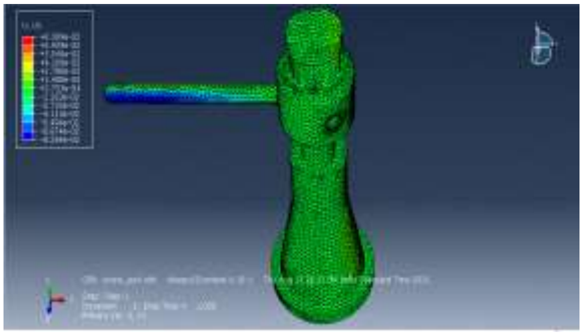

Fig.12: - Finite Element Model of screw jack – Strain magnitude

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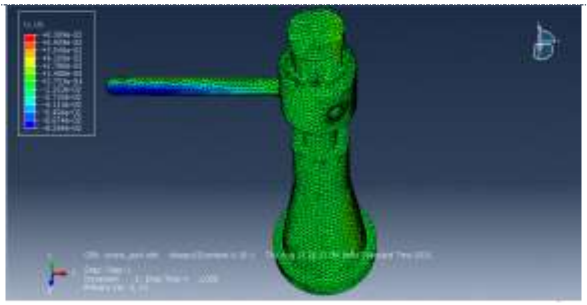

Fig.13:- Finite Element Model of Connecting Rod – Strain along in x direction

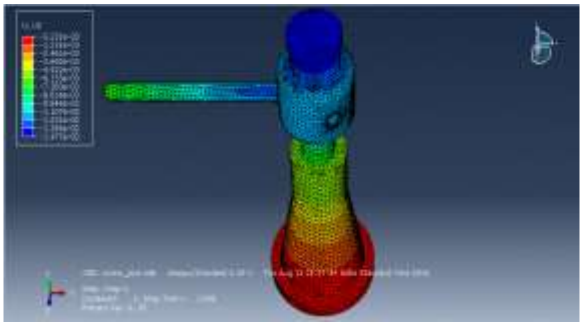

Fig 14: - Finite Element Model of screw jack – Strain along in y direction

3.2 Result from ABAQUS FEA software for acme thread: -

FEA FOR ACME THREADS

A. Results for Static Analysis:-Outputs of static analysis are shown via stresses, strain under the effects of applied load.
B. FEA results for static analysis that is Von-Misses stress max. Principal stress, min. principal and Strain are shown in Fig. below respectively.

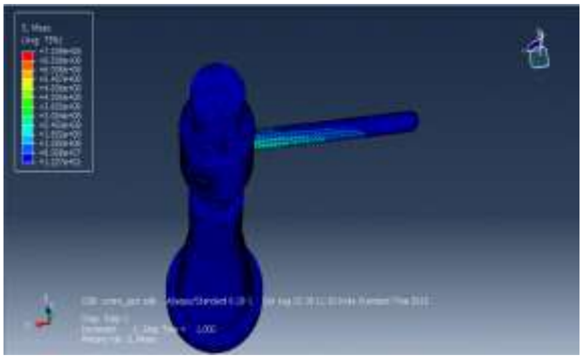

Fig.15:- Finite Element Model of Acme thread screw jack – Von mises Stress

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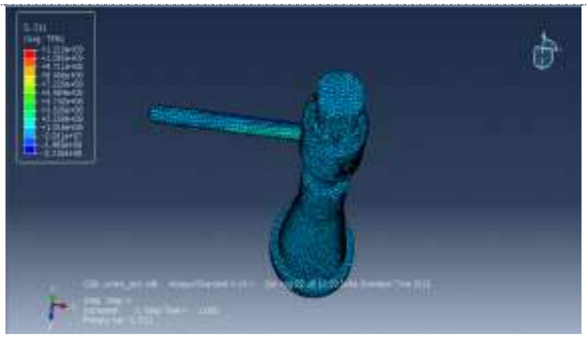

Fig.16:- Finite Element Model of Acme thread screw jack –Stress along in xx direction

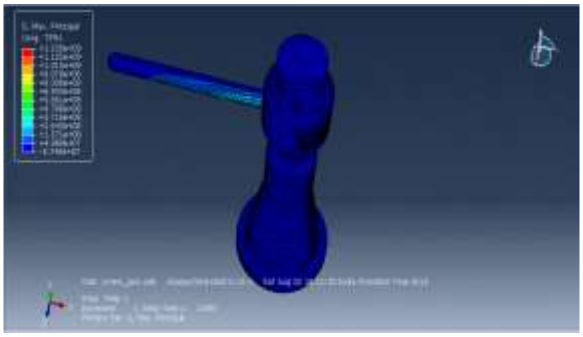

Fig.17:- Finite Element Model of Acme thread screw jack – Max. principal Stress

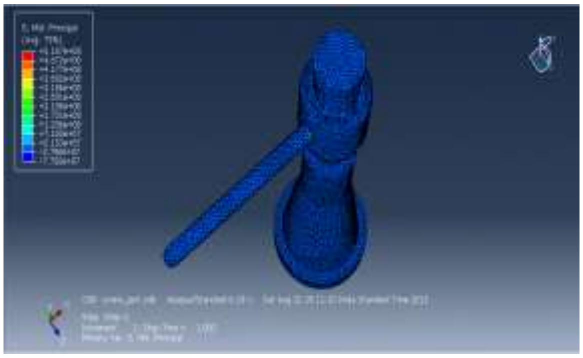

Fig.18: Finite Element Model of Acme thread screw jack – Mid. principal Stress

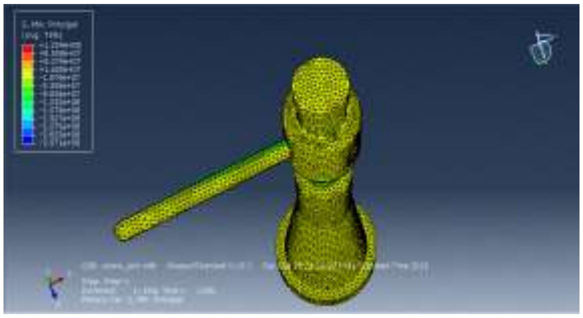

Fig.19: Finite Element Model of Acme thread screw jack – Min. principal Stress

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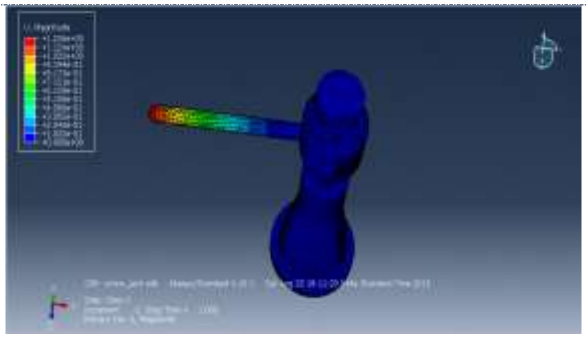

Fig.20: Finite Element Model of acme thread screw jack – Strain magnitude

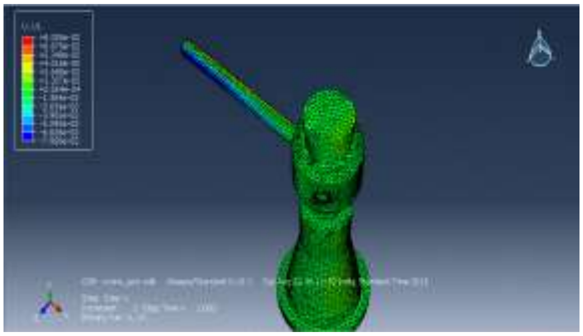

Fig. 21: Finite Element Model of Acme threaded screw jack – Strain along in x direction

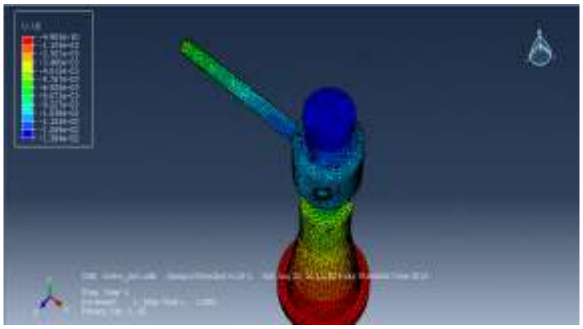

Fig.22: - Finite Element Model of Acme thread screw jack – Strain along in y direction

3.3 Analytical Design of Screw jack with Square threads 1]

Core Diameter-Diameter taken to study for compressive stress but screw is subjected for torsion as well as moments due to bending.so we increase diameter to higher values we will use screw with 30 mm nominal diameter and 5mm pitch, Load W=150kg

d = 30mm p = 5mm

d_c = 30-5 = 25mm

d_m = d-0.5p = 30-0.5(5) = 27.5mm

Tanα= p/pi d_m

=5/ (π *27.5)

α = 3.31^0

μ= tan ϕ

ϕ=8.53^0

ϕ > α

Therefore, Screw is self-looking

2] Torque required for rotating the screw

T_1= P* d_m /2

T_1= W tan (ϕ + α)*(d_m /2)

T_1=4241.66 N.mm

3] Torque required overcoming the friction at the top of screw

T_2= μ W R

R=(R1+R2)/2

=(19+17.5)/2

=18.25 mm

T2 =5370.97 N.mm

4] Total torque, to which handle will subject

T= T_1+ T_2

=9612.63 N.mm

5] Stress due to bending

Mb = P * l

Lifting height is 115mm

So, l = 115 mm

M_b = (150*9.81)*115

= 169222.2 Nmm

σ_b=32M_b/(π *dc^3)

= (32*169222.5)/ (π *25^3)

= 110.315 Mpa

6] Torsional shear stress induced due to torque

T/J =τ/R

τ = 16T/π d_C^2

= (19 * 9888.16)/(π (25^2))

=78.33Mpa

7] Direct compressive stress on screw

σ_c= W/(π/4(d_c^2))

= (150*9.81)/(π/4(25^2)) =2.99Mpa

8] According to maximum shear stress theory

τ_{max}= ½ root(σ_c ^2 +4 τ ^2 = 78.34 Mpa

9] According to maximum normal stress

σ_c = ½ σ_c + ½ root(σ_c ^2 +4 τ ^2)

=79.83 Mpa

Design of nut

1] Checking nut under bearing pressure

P_b= W/(π/4(d_0^2- d_c^2)*n

= (150*9.81)/(π/4(30^2-25^2)*5)

=1.3625Mpa

2] Check the transverse shear stress induced in the screw and nut

τ_{screw} = W/(π d_c n t)

t=pitch/2=2.5

= 1.49 Mpa

3] Check the transverse shear stress induced in the nut

τ_{nut} = W/(π d_0 n t)

=1.249 Mpa

4] Tensile failure of nut

σ_t = W/(π/4(D^2- d_0^2) =0.88 Mpa

Design of handle

1] To find bending stress acting on handle/ tommy bar

σ_b= (T*32)/(π* D_h^3)

=100.7199Mpa

3.4 Analytical design of acme threaded screw jack

1] Core diameter

Diameter taken to study for compressive stress but screw is subjected for torsion as well as moments due to bending.so we increase diameter to higher values we will use screw with 30 mm nominal diameter and 5mm pitch ,Load W=150kg

d_c = 30-5 = 25mm

d_m = d-0.5p = 30-0.5(5) = 27.5mm

w=150kg

Tanα= p/pi d_m

=5/(π *27.5)

$\alpha = 3.31^0$

μ= tan ϕ

$\phi=11.30^0$

ϕ > α

Therefore, Screw is self-looking

2] Torque required rotating the screw

T_1= P* d_m /2

T_1= W tan (ϕ + α)*(d_m /2)

T_1=5274.10 N.mm

3] Torque required overcoming the friction at the top of screw

T_2= μ W R

R=(R1+R2)/2

=(19+17.5)/2

=18.25 mm

T2 =5370.97 N.mm

4] Total torque, to which handle will subject

T= T_1+ T_2

=10645.07 N.mm

5]Stress due to bending

Mb = P * l

Lifting height is 115mm

So, l = 115 mm

M_b = (150*9.81)*115

= 169222.2 Nmm

σ_b=32M_b/(π *dc^3)

= (32*169222.5)/ (π *25^3)

= 110.315 Mpa

6]Torsional shear stress induced due to torque

T/J =τ/R

τ = 16T/π d_C^2

= (16 * 10645.07)/(π (25^2))

=86.74 Mpa

7]Direct compressive stress on screw

σ_c= W/(π/4(d_c^2))

= (150*9.81)/(π/4(25^2))

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=2.99Mpa

8]According to maximum shear stress theory

τ_{max}= ½ root(σ_c ^2 +4 τ ^2)
= 86.75 Mpa

9]According to maximum normal stress

σ_c = ½ σ_c + ½ root(σ_c ^2 +4 τ ^2)
=88.24 Mpa

Design of nut

1]Checking nut under bearing pressure

P_b= W/(π/4(d_0^2- d_c^2)*n
= (150*9.81)/(π/4(30^2-25^2)*5)
=1.3625Mpa

2] Check the transverse shear stress induced in the screw and nut

τ_{screw} = W/(π d_c n t)
t=pitch/2=2.5
= 1.49 Mpa

3] Check the transverse shear stress induced in the nut

τ_{nut} = W/(π d_0 n t)
=1.249 Mpa

4]Tensile failure of nut

σ_t = W/(π/4(D^2- d_0^2)
=0.88 Mpa

Design of handle

1]To find bending stress acting on handle/ tommy bar

σ_b= (T*32)/(π* D_h^3)
=108.42 Mpa

3.5 COMPARISION OF FEA & ANALYTICAL ANALYSIS FOR THREAD

For Square thread: -

- Maximum von-misses stress from ABAQUS is 249 MPa for maximum load for a torque of 12 N-m including all the parameters
- Maximum stress coming from analytical method is 79.83*3(stress concentration plus other discontinuity effects as per ASTM standards)
  =239.49MPa which matches closely with each other. Same is the observations for dynamic case as per industry standards.

Torque of 12 N-m has been purposely considered for the analysis as this is usual benchmarking for screw design

For ACME thread: -

- Maximum von-misses stress from ABAQUS is 240 Mpa for maximum load for a torque of 12 N-m including all the parameters
- Maximum stress coming from analytical method is 88.2*3(stress concentration plus other discontinuity effects as per ASTM standards)
  =264.6MPa which matches closely with each other. Same is the observations for dynamic case as per industry standards.

Torque of 12 N-m has been purposely considered for the analysis as this is usual benchmarking for screw design

CONCLUSIONS

Comparison of square and acme thread by different stress & strain parameters

Table-3 Comparison of square and acme thread

Parameter	Square	Acme
Von misses stress	124Mpa	180Mpa
Max.U1	$8.30*10^{-2}$ m	$8.02*10^{-2}$ m
Max, Principal	274Mpa	264Mpa
Min Principal	127Mpa	215Mpa

From this comparison we can deduce following CONCLUSION

- If cycle of operation is more for screw jack then Acme thread is to be used though Max. von misses stress more for acme thread, for analysis is to be safe. For fatigue point of view Acme threads are preferred
- if fatigue is not a problem then square threads are recommended
- on an average max displacement for square thread is always more than Acme thread for same load
- If tolerance is not an issue and length is of no concern square thread should be recommended
- Average minimum Principle stress for square thread is always less than that of Acme thread so stress fluctuation and positioning fluctuation are always more for square thread
- If we need same stress level square thread will be least weight as compared to acme thread hence design will be conservative of square thread which will be comfortable to ladies
- Sudden failures chances of square thread are higher so in risky or corrosive environment square thread should not be recommended & design modification required in future

Note:-Dynamic analysis is not performed since operation at very low speed, which is situation close to static case so only static analysis should be sufficient.

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