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Consideration of Material Alternatives in Enhancement to get Unique Solution in Design of Screw Jack

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***Abstract*: Power screw is used to convert rotary motion into translation motion. 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. By analyzing different parameters in design of screw jack and by considering analytical method along with programming software enhancement is done to get the most suitable combination of thread profile and selection of best suited material for screw and nut pair at different load.**

***Keywords*: Thread Profile, Co-efficient of friction, Buckling, Efficiency.**

I. INTRODUCTION

A screw jack is a portable device consisting of a screw mechanism used to raise or lower the load. there are two types of screw jack namely hydraulic and mechanical screw jack. a hydraulic jack consists of a cylinder and piston mechanism. Mechanical jack can be either hand operated or power driven. Screw jacks are made of different type of material having different thread profiles like square, trapezoidal, acme, buttress, etc. jacks are frequently used in raising cars, industrial machinery and even airplanes.

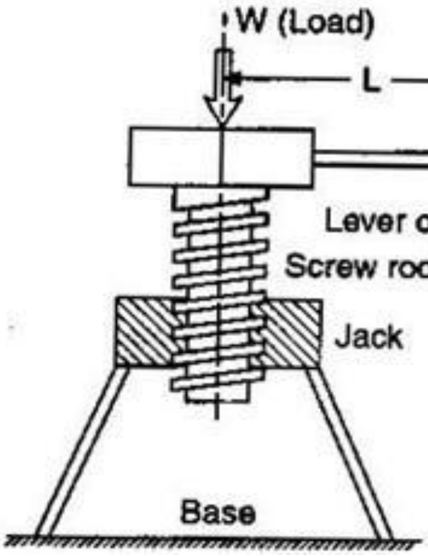

Fig. 1- Screw Jack

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II. FORMULATION OF DESIGN

A. DESIGN OF SCREW

The screw is subjected to pure compression and hence its core diameter is calculated from

$б_c = W / (\pi/4)*d_c^2$

$dc = d-p$

$dm = d-0.5p$

$\tan\alpha = l/\pi*dm$

$\tan\Phi = \mu$

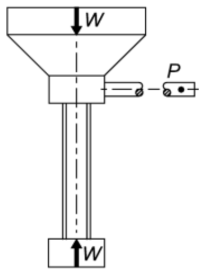

Fig. 2- Compression Of Screw

Also When $\Phi > \alpha$, screw is self locking.
Torque required to raise the load,

$M_t = W*(dm/2) * \tan(\Phi+\alpha)$

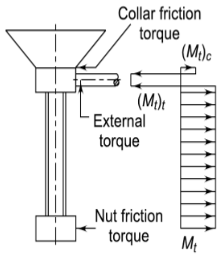

Fig.3 – Torque Diagram

At section x-x

$\tau_{max} = 16M_t / (\pi*d_c\wedge^3)$

$\tau_{perm.} = (0.5 * S_{yt}) / fs$

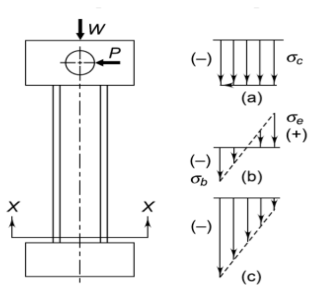

Fig.4 - Bending Moment Diagram

Stress due to bending:
Force due to hand i.e. P is responsible for bending of screw thus bending moment at any section x-x can be given as,

- $M_b = P * l_1$
- $\sigma_b = 32*M_b/(\pi d_c\wedge 3)$

The principal shear stress at X-X

- $\tau_b = \sqrt{\left(\frac{\sigma b}{2}\right)^2 + (\tau)^2}$

Buckling Criterion:-
When load is raised the screw acts as column & there are chances of buckling or crushing of it. So we have to decide whether column is long or short. Since one end of screw is fixed & other is free the end fixity coefficient is 0.25 . border line

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between short &long column is

- $S_{yt} / 2 = (\eta*\pi^2 *E) / (l/k)^2$
- $k=\sqrt{(I/A)}$
- $I=\pi/4 * dc^4$

Slenderness ratio l/K

Slenderness ratio is more than critical slenderness ratio then we treat screw as long column hence using Eulers formula.

- $P_{cr} = (\pi^2EI / (l/k)^2)$

B.DESIGN OF NUT

The permissible bearing pressure between steel screw & bronze nut is 10mpa

No. of threads required

- $P_b = W / (\pi/4 (d^2 – d_c^2)*z)$
- Height of Nut, H= z*p

Transverse shear stress at root of threads in nut is given by ,

- $\tau=W / (\pi*d*t*Z)$

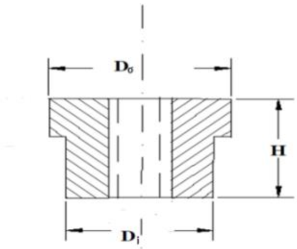

Fig. 5 - Nut

C. DESIGN OF CUP

- D = 1.6 * d
- D' = 0.8 * d

Collar Frictional Torque

- $T_f = (\mu*W/4)*(D_o+D_i)$

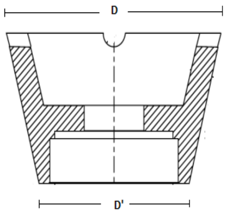

Fig. 6 - Cup

III. FLOW CHART FOR DESIGN OF SCREW JACK

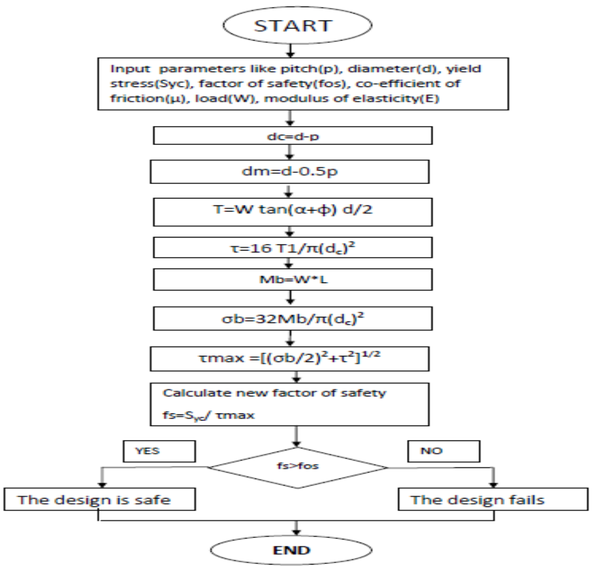

Fig.7- Flowchart for design of screw jack

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IV. PROGRAM FOR DESIGN OF SCREW JACK

```
clc;
clear all;
close all;
syc=input('Yield tensile strenght in MPa : ');
fs=input('Factor of safety : ');
p=input('Pitch in mm : ');
w=input('Load in N : ');
d=input('Nominal diameter of screw in mm : ');
u=input('Co-efficent of friction : ');
E=input('Modulus of Elasticity of screw material in Mpa : ');
P=0.9*400;
l=570;
L=550;
N=0.25;

sigmaC=syc/fs;
dc=sqrt((4*w)/(pi*sigmaC));
dc_in_mm=d-p
dm_in_mm=d-0.5*p

Helix_angle=atan(p/(pi*dm_in_mm))*(180/pi)
Friction_angle=atan(u)*(180/pi)
Torque_in_KNmm=(0.5*w*dm_in_mm*tan((Friction_angle+Helix_angle)*pi/180))/1000
sigmaS_in_MPa=((16000*Torque_in_KNmm)/(pi*(dc_in_mm^3)))
Mb_in_KNmm=P*l/1000
sigmaB_in_MPa=((32000*Mb_in_KNmm)/(pi*(dc_in_mm^3)))
Smax_in_MPa=sqrt((sigmaB_in_MPa/2)*(sigmaB_in_MPa/2)+(sigmaS_in_MPa*sigmaS_in_MPa))
FOS=(0.5*syc)/Smax_in_MPa
if (FOS>fs)
disp('The design is safe');
else
disp('The design is not safe');
end
k=dc_in_mm/4;
A=pi*dc_in_mm*dc_in_mm/4;
x=L/k;
y=sqrt(2*N*pi*pi*E/syc);
if(x<y)
C=(syc*x*x)/(4*N*pi*pi*E);
else
C=(syc*y*y)/(4*N*pi*pi*E);
end
Pcr_in_kN=(syc*A*(1-C))/1000
fos=(Pcr_in_kN*(1000)/w);
if (fos>fs)
disp('the design is safe against buckling');
else
disp('the design fails in buckling');
end
```

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V. RESULTS & DISCUSSION

In power transmission a square thread profiles are mainly used. They play significant role as efficiency of screw is associated with type of thread profile and coefficient of friction. For power screw especially for screw jack different types of square thread profiles are available like square, trapezoidal, acme and buttress and modified square. In the present work, a screw jack is design analytically. In this jack, screw and nut are most significant components. A screw is designed based on maximum tensile stress and maximum shear stress. For maximum load it is necessary to keep both values within limit for safe design. Nut is a stationary part in which a screw rotates. Therefore a bearing pressure is also considered. For both the components, if we take combination of different materials for each pair of screw and nut so we can find better possibilities to get suitable solution. The standard material combinations are (1) Hardened Steel-Bronze, $\mu = 0.08$ (2) Soft Steel-Bronze, $\mu = 0.10$ (3) Hardened Steel-Cast Iron, $\mu = 0.15$ (4) Soft Steel-Cast Iron, $\mu = 0.17$

CALCULATED VALUES OF PARAMETERS FOR DIFFERENT SCREW-NUT COMBINATIONS

In the design of screw thread, a square thread profile is considered for screw & nut. The design is done for a constant load of 30KN. However, the standard pitches (5 to 12mm) & standard nominal diameters (22 to 100mm) are taken in order to calculate efficiency of different types of thread profiles. Moreover for screw-nut material combination standard values of coefficient of friction are taken as a reference parameter:

In this design a screw is a primary element (i.e. the most critical part) while a nut is a secondary element. So the stresses developed on these elements are calculated. Moreover, torque transmission and critical load on screw are also found. Eventually, the calculated values and standard values are compared to find out better material for each component.

Table 1 - Efficiency of different thread profiles
For $\mu = 0.08$ (Hardened Steel-Bronze)

Pitch (mm)	Nominal diameter (mm)	Square thread	Trapezoidal thread	Acme thread	Modified square thread	Buttress thread
		η(%)				
5	22	**50.0000**	49.2983	49.3562	50.0749	49.9825
	28	**43.6068**	42.7519	42.8084	43.5126	43.4220
6	30	**46.6614**	45.7946	45.8420	46.5659	46.4741
	36	**41.7819**	40.9371	40.9929	41.6887	41.5992
7	40	**43.0694**	42.2173	42.2736	42.9755	42.8852
	44	**40.5686**	39.7319	39.7871	40.4760	40.3876
8	48	**41.7819**	40.9371	40.9929	41.6887	41.5992
	52	**39.7037**	38.8733	38.9281	39.6121	39.5240
9	55	**41.3016**	40.4599	40.5155	41.2088	41.1195
	60	**39.0560**	38.2306	38.2851	38.9649	38.8773
10	65	**39.7037**	38.8733	38.9281	39.6121	39.5240
	80	**34.5449**	33.7626	33.8141	34.4584	35.3753
12	85	**37.5251**	36.7128	36.7664	37.4355	37.3492
	100	**33.5749**	32.8037	32.8545	33.4897	33.4077

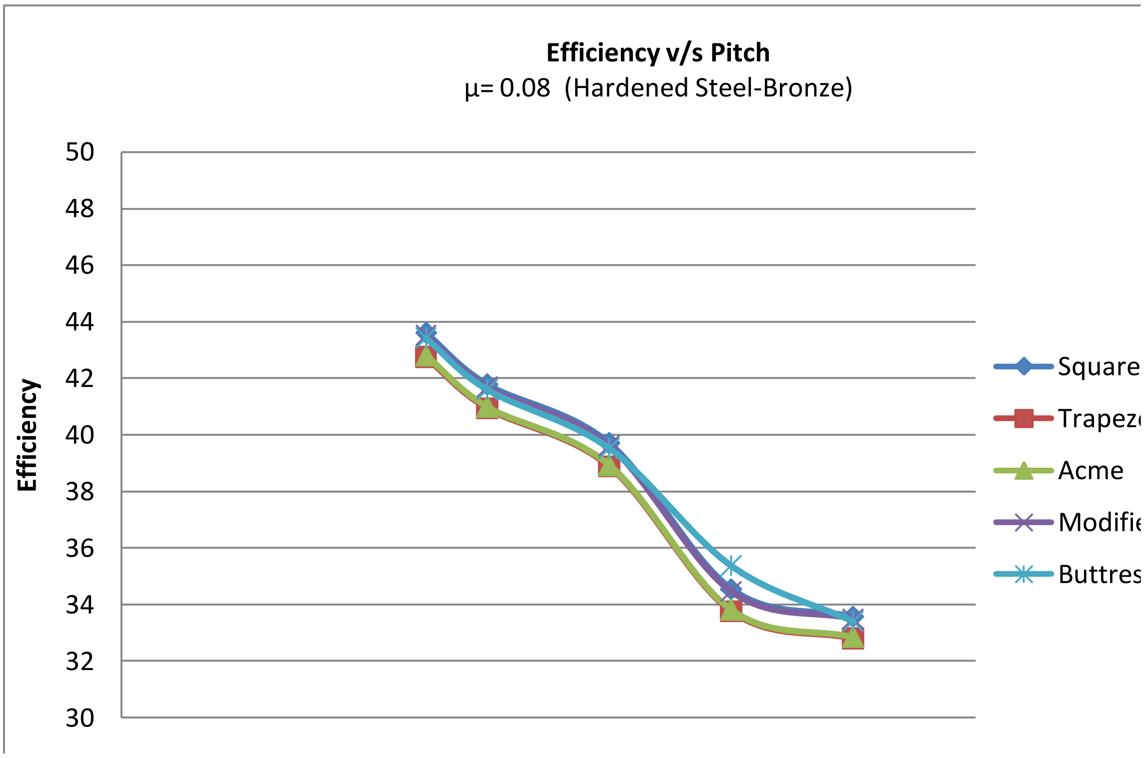

Chart 1- Efficiency v/s Pitch for standard thread profiles

Table -1 and corresponding Chart -1 show the efficiency of different thread profiles at different standard pitch. From various four material combinations, Hardened Steel-Bronze (μ= 0.08) gives higher efficiencies in different thread profiles while for a square thread, it is maximum. i.e.50%.

The following material combinations are taken to do analytical calculations.

[1] EN 24 – C.I. μ =0.15

[2] EN24 – SI BRONZE/ PH. BRONZE, μ =0.08

[3] EN 8 – C.I. , μ =0.15

[4] EN8 – SI BRONZE/ PH. BRONZE , μ =0.08

[5] C55Mn75 – C.I , μ =0.15

[6] C55Mn75 – SI BRONZE/ PH. BRONZE , μ =0.08

[7] AISI- 409, SS – C.I., μ =0.17

[8] AISI- 409, SS – PH. BRONZE / SI BRONZE μ =0.10

[9] C20 – C.I. μ =0.17

[10] C20 – PH. BRONZE / SI BRONZE μ =0.10

Now, for various screw-nut material combinations, different parameters of screw and nut are design. From the combinations, we will get design parameters in tabular format. The above table is created based on various screw-nut material combinations and hence coefficient of friction between them. For design of screw, the standard materials like EN24, EN8, C55Mn75, AISI409 (SS) and C20. While for a nut the materials like CI, silicon bronze and phosphorous bronze are considered. For a particular load, EN24 is better material for screw. It induces lower value of σ_{smax} and σ_{cmax}. While for a nut CI is better. It induces lower value of σ_{smax} and Pb. For both the materials the above values are generalized lower as compared to their maximum values.

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TABLE-2 Comparison of calculated and design stress
Screw-nut combination: EN 24 – CI.(μ =0.15)

SCREW								NUT			
Pitch mm	Dia. mm	Torque KN mm	σs (cal) N/mm²	σs (allow) N/mm²	σc (cal) N/mm²	σc (allow) N/mm²	Wcr KN	Pb (cal) N/mm²	Pb (allow) N/mm²	σs (cal)) N/mm²	σs (allow) N/mm²
5	22	68.59	224.28		437.00		73.77	12		11	
	24	73.06	161.73		314.10		92.14	11		10	
	26	77.53	121.63		233.48		112.57	10		9	
	28	82.02	92.50		178.39		135.03	9		9	
6	30	90.36	82.60		158.20		147.03	9		8	
	32	94.83	65.50		124.96		172.55	8		8	
	34	99.32	52.89		100.50		200.12	8		7	
	36	103.80	43.38		82.08		229.73	7		7	
7	40	116.62	33.45		62.53		277.97	7		6	
	42	121.10	28.30		52.68		312.68	6		6	
	44	125.58	24.19	65	44.82	130	349.44	6	15	6	40
8	48	138.40	19.70		36.03		408.41	5		5	
	50	142.88	17.18		31.30		450.27	5		5	
	52	147.37	15.10		27.37		494.17	5		5	
9	55	157.94	13.55		24.29		540.12	5		4	
	60	169.16	10.21		18.09		663.92	4		4	
10	65	184.21	8.44		14.72		772.14	4		4	
	70	195.43	6.68		11.52		1062.9	4		3	
	75	206.66	5.40		9.21		1382.00	4		3	
	80	217.88	4.44		7.49		1726.6	4		3	
12	85	236.76	4.10		6.78		1945.6	4		3	
	90	247.98	3.45		5.66		2331.0	4		3	
	95	259.21	2.94		4.77		2742.0	4		2	
	100	270.44	2.54		4.07		3178.5	4		2	

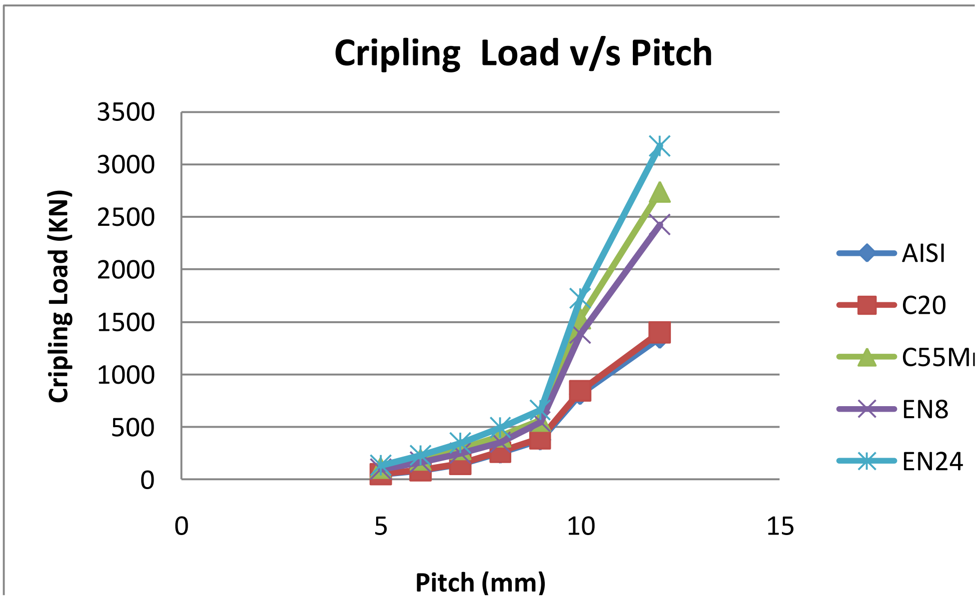

Chart 2- Cripling Load v/s Pitch for standard thread profiles

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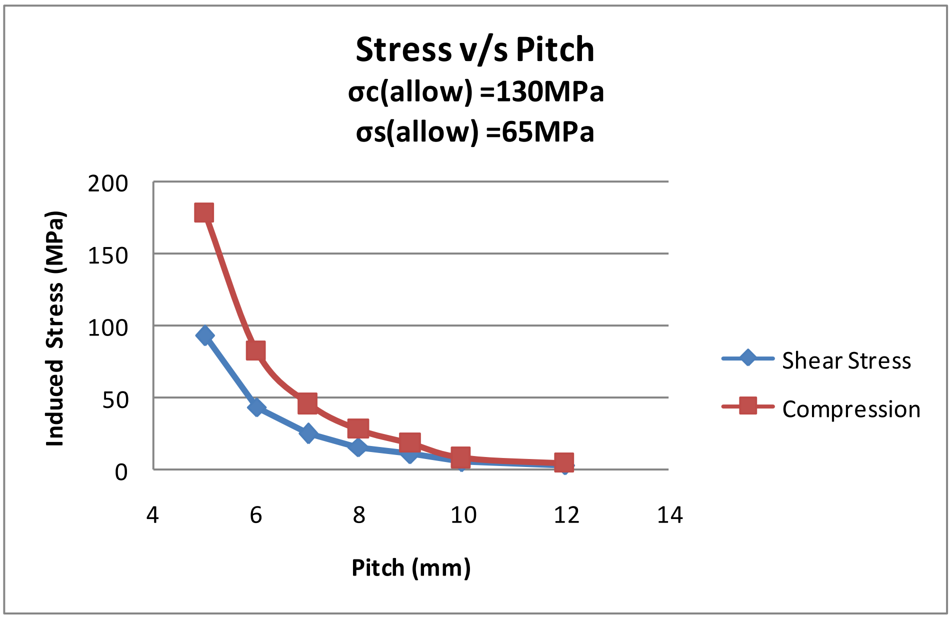

Chart 3- Stress v/s Pitch for standard thread profiles

VI. CONCLUSION

In this work a successful attempt is made to design a screw jack. The design is done by varying different parameters like thread profile, screw-nut material combination, pitch and diameter. Different stress values have been obtained by using MATLAB software. The whole design focuses on how the values of efficiency, stresses, crippling load, torque varies with coefficient of friction and pitch. Here, the basic concept is established for choosing the best material combination and thread profile for given load.

In design of screw jack thread profile is very much important. A square thread gives maximum efficiency of screw up to 50%. For low coefficient of friction, it is maximum i.e. μ = 0.08. In screw-nut material combinations, hard steel - bronze gives minimum torque required to be applied as compared to other groups. For higher value of μ torque applied will be higher.

A screw has number of alternatives for material. From them, EN 24 is better material than other materials. It develops low σ_{smax} and σ_{cmax} which causes large margin of stresses between induced value and standard value i.e. 64 N/mm^2 in shear and 126 N/mm^2 in compression.

A nut also number of alternatives of materials. From them, CI is better material. It develops low σ_{smax} and P_b which causes large margin of stresses between induced value and standard value i.e. 38 N/mm^2 in shear and 11 N/mm^2 for bearing pressure.
So, EN 24-CI is the best combination of screw-nut pair in screw jack.

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