Failure of Screw Jack on Inclined Surface

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***Abstract*—Screw jack is a device which converts rotary motion to translatory motion, Basically screw jack works on the principal of inclined plane. Generally jack is designed to work in ideal condition i.e when it is placed on flat surface it works smoothly but when jack is in non ideal condition i.e when it is placed on inclined surface it fails.**

***Index Terms*—Screw Jack, Inclined Plane,Optimization, Robust parameter Design.**

I. Introduction

A Screw Jack is a device which is used to lift the loads. When ideal condition is there (Horizontal Surface) the jack works smoothly but when jack is to work in non-ideal condition it fails to lift the load. As todays era demands flexibility in design it is necessary to redesign the screw jack for non- ideal condition also.

II. Screw on Flat Surface

Screw is the back bone of the screw jack ,it works on the principal of inclined plane.

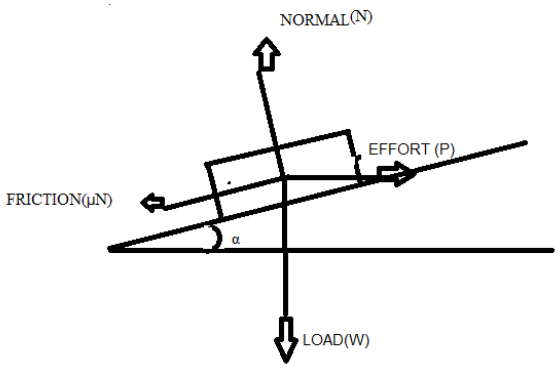

Fig.1.1 Load on Horizontal Position.

In above figure,

N=Normal Reaction, μN=Frictional Force , P= Effort required to raise the load, W= load to be lifted.

Resolving the forces along the horizontal will get,

P=NSin(α) + μNCos(α) ----------(I)

Resolving forces along the Vertical,

W= N Cos(α) – μNSin(α)----------(II)

Dividing expression I by II will get,

P = W (μ + tan (α)) /(1-μ tan(α))----------(III)

But we Know that ,

μ = tan (ϕ)

Hence,

Equation will be further modified as ,

P= W tan(ϕ + α)----------(IV)

So this is Effort required to raise the load. Now, it is necessary to consider the torque required to raise the load.

Torque requirement is given as,

Mt= Force * Perpendicular Distance

Mt= W tan(ϕ + α) *(dm/2)----------(V)

Where d_m = Mean diameter of screw jack.

III. Screw Design

Now will consider one case[1] where it is necessary to design a screw to lift 100kN load upto 500 mm

The first step in design is material selection, Generally material for screw jack is 30C8[1]

Next step in design is calculating its possible diameter,

So direct stress on screw will be given as

$$\sigma = \frac{W}{A}$$

Where W= load to be lifted,

A= area of screw

σ = Compressive Stress

The value of compressive stress is given as 400 N/mm^2 & the factor of safety Considered is 5.

Hence, σ=80 N/mm^2

Therefore,

$$\sigma = \frac{4W}{\pi * (dc) * (dc)}$$

Therefore dc =39.89 or 40mm

As a first trial 60 mm nominal diameter & pitch(p)=9mm selected

$$dc = d - 0.5 * p$$

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That will provide core diameter as 55.5mm

$$\tan(\alpha) = \frac{l}{\pi * dm}$$

As the screw is single start l=p=9 mm

Therefore α = 2.95 degree.
By using equation (IV) will get torque .

Mt =648316.03 N-m

Shear stress in screw is given as

$$\tau = \frac{16Mt}{\pi * dc * dc * dc}$$

$=24.89\ N/mm^2$

And the direct stress is given as,

$$\sigma = \frac{W}{A}$$

$=48.95\ N/mm^2$

It is also needed to calculate the Bending stress which is given as,

$$\sigma b = \frac{32Mb}{\pi * dc * dc * dc}$$

Here Mb (bending moment) is given asu

$$Mb = P * l$$

Here l is considered as lifting length & additional length which will be needed to hold the screw in assembly,

Mb=410400 N-mm

Putting this value in equation of bending stress which gives

$\sigma b = 31.51\ N/mm^2$

Here total Stress will be the effect of bending & shear stress,

$$\tau = \sqrt{(\sigma b/2)^2 + \tau}$$

$\tau = 29.46$

But factor of safety is given as

$fs = 0.5S_{yt} / \tau_{max}$

$S_{yt} = 400$

fs =6.79

As the factor of safety is more than 5 Hence the design is safe.

Next step is buckling consideration,
For that slenderness ratio is required ,

Slenderness ratio = l/k

Where,l= length of screw

k= Radius of gyration

$$k = \sqrt{I/A}$$

Therefore k =43.14

Since the one end is fixed & other end is free the end fixity coefficient is 0.25.The borderline between short & long column is given by,

$$\frac{Syt}{2} = \frac{n * \pi^2 * E}{(\frac{l}{k})}$$

Therefore l\k becomes 50.33

Hence the value 43.14 is less than 50.33 Hence the column is short one.
Hence we can use Here Johnsons Equation Here to find Out the Critical Load(Pcr).

$$Pcr = Syt * A[1 - \frac{Syt}{(4 * n * \pi^2 * E)} * (\frac{l}{k})]$$

Pcr =5193860.04 N

The factor of safety from buckling consideration is ivem as,

$$fs = \frac{Pcr}{W}$$

From buckling consideration factor of safety is 5.19, again the design is safe.

IV. SCREW ON INCLINED SURFACE

When the above designed screw is placed on inclined surface let us assume that the inclination of the ground with the horizontal is β , The exact figure will look like

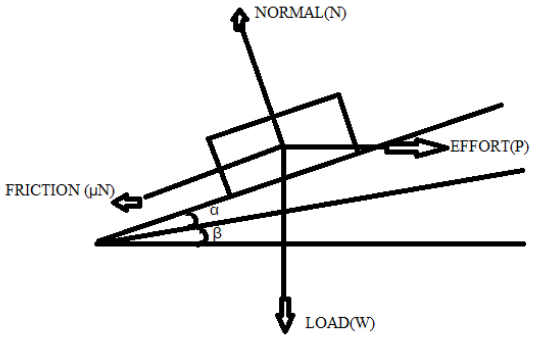

Fig.2.Screw On inclined Surface

Hence above equations(I,II,III,IV) will modify as below,

P=NSin(α+β) + μNCos(α+β) ----------(VI)

Resolving forces along the Vertical,

W= N Cos(α+β) – μNSin(α+β) ----------(VII)

Dividing expression I by II will get,

P = W (μ + tan (α+β)) /(1-μ tan(α+β))----------(VIII)

But we Know that ,

μ = tan (ϕ)

Hence,
Equation will be further modified as ,

P= W tan(ϕ + α+β)----------(IX)

So this is Effort required to raise the load. Now, it is necessary to consider the torque required to raise the load.

Torque requirement is given as,

Mt= Force * Perpendicular Distance

Mt= W tan(ϕ + α +β) *(dm/2)----------(X)

Where d_m = Mean diameter of screw jack.

V. FAILURE OF SCREW ON INCLINED SURFACE

Now let us assume that the screw is placed on inclined surface this inclination is 15°

Therefore,

β= 15°

Therefore Effort required from Equation VI will become,

P= $100*10^3$(tan(10.20+2.95+15))

P=53507.22 N

Hence the equation of torque (X)

Mt=1484825.522 N-mm

Mt= 1484.825 K N-mm

This torque is very much more as compared to torque on Horizontal Surface.

Now Shear Stress is Given As

$$\tau = \frac{16Mt}{\pi * dc * dc * dc}$$

τ= 57.03N/mm^2

Bending Stress is given As,

$$\sigma b = \frac{32Mb}{\pi * dc * dc * dc}$$

But Mb is equal to,

Mb=P*l

Mb=0.9*2*400*570

Mb=410400 N-mm

Putting this value in formula for bending stress we will get

$$\sigma b = \frac{32Mb}{\pi * dc * dc * dc}$$

σb = 31.51 N-mm

Again this stress is far more as compared to bending stress obtained on Horozontal surface.

Total Principal Shear stress is given as

$$\tau = \sqrt{(\sigma b/2)^2 + \tau}$$

τ_{max}= 59.19 N/mm^2

Factor of safety is given as,

$fs=0.5S_{yt}/\tau_{max}$

fs =(0.5*400)/59.19

fs=3.37

As this factor of safety is quit lesser than 5 Hence we can conclude that the Designed Screw will fail at an inclination of 15° . Hence We can conclude that screw is need to be Redesigned.

VI. CONCLUSION

As the stresses induced on Inclined surface are much more as that of horizontal urface hence it is very necessary to redesign this screw,results obtained from the calculations are summarized below

Parameter	Horozontal Surface	Inclined Surface (β = 15°)
Shear Stress (τ)	29.46 N/mm^2	57.03N/mm^2
Bending Stress (σ)	31.51 N/mm^2	31.51 N/mm^2
Maximum Shear Stress (τ_{max})	29.46N/mm^2	59.19N/mm^2
Factor of Saftey	6.79	3.37

Hence from the above table we can conlude that the Design Will fail for inclined surface.

VII. FUTURE SCOPE

As the screw is failing to lift the load on inclined surface it is necessary to redesign the screw, for redesigning the screw it very necessary to optimize the design parameters . For optimization process we can use Taguchi's Robust parameter Design Method [6] , In order to get optimal settings of the design parameters.

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