Power Screws and Bolted Connections

ME4020 - Applied Machine Design

Mechanical Engineering

Tennessee Technological University

Power Screws

Power Screws

- Overview and Applications
- Threads for Power Transmission
- Force and Torque Analysis
- Friction and Efficiency
- Design Considerations

Overview and Applications

A power screw is a machine component that converts rotational motion into linear motion. This is neccesary in variety of applications.

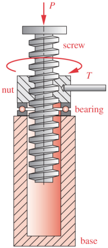
Leadscrews are used to raise and lower the front door of the Boeing 747-8F Freighter aircraft

images: wikimedia, wikipedia

Overview and Applications

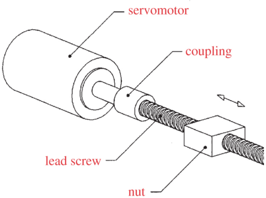
Common Applications:

- automotive jack and jack post
- machining tool positioning
- automatic doors and gates
- aircraft control surfaces
- automation/production machines



Overview and Applications

Machining Tool Positioning - 3 Axis Mill



Overview and Applications

Linear Actuator - General Purpose Machine Component

wikipedia: animation

Overview and Applications

Advantages:

- large mechanical advantage possible
- capable of lifting or moving large loads
- suitable for precision motion control
- self locking or back-drivable

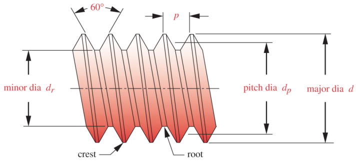
Disadvantages:

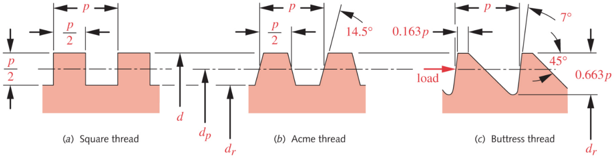
- Low Efficiency due to high friction
- High wear possible

Threads for Power Transmission

The standard thread form is not strong enough for high load applications. Many power screw applications use a square, acme, or other type of thread for power transmission.

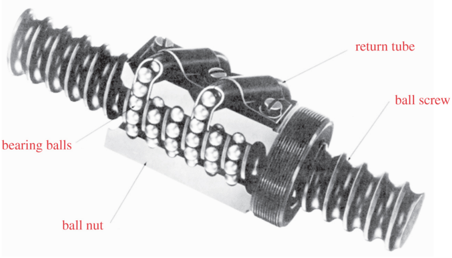
UN and ISO Standard Thread Form





Threads for Power Transmission

Lubrication is required for smooth operation and to avoid excessive wear. Ball Screws are used to reduce friction. This adds mechanical complexity, but can increase machine life.

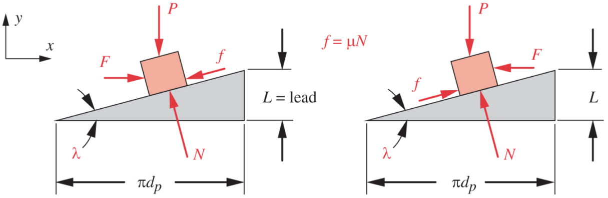


Courtesy of Thompson Industries Inc., Wood Dale, I L

Threads for Power Transmission

Force and Torque Analysis

Consider unwinding a single rotation of a square thread. The nut and power screw can be modeled as a block in contact with an inclined plane as shown in the image.



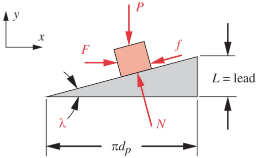
(a) Lifting the load up the plane (b) Lowering the load down the plane

The **lead angle** λ can be easily found through trigonometry:

$$tan(\lambda) = \frac{L}{\pi d_p}$$

Force and Torque Analysis

Write a static force balance for the lifting case.



(a) Lifting the load up the plane

$$\Sigma F_x = 0 = F - f cos\lambda - N sin\lambda = F - \mu N cos\lambda - N sin\lambda$$

$$F = N(\mu cos\lambda - sin\lambda)$$

$$\Sigma F_y = 0 = N cos\lambda - f sin\lambda - P = N cos\lambda - \mu N sin\lambda - P$$

$$N = \frac{P}{cos\lambda - \mu sin\lambda}$$

Force and Torque Analysis

Combine the results of the previous equations to get an expression relating the forces on the nut. The relationship is dependent on the friction coeffient and lead angle of the screw.

$$F = P\left(\frac{\mu cos\lambda + sin\lambda}{cos\lambda - \mu sin\lambda}\right)$$

The screw torque required to lift the load can be found as the force in the x direction F times the half pitch diameter.

$$T_{s_u} = F\frac{d_p}{2} = \frac{Pd_p}{2}\left(\frac{\mu cos\lambda + sin\lambda}{cos\lambda - \mu sin\lambda}\right)$$

Friction and Efficiency

Design Considerations

Design Considerations