10. SHAFTS

SHAFT: A Shaft is a cylindrical machine element which is used to support the transmission elements for the transmission of power. Shafts are made of ductile material.

Power Transmitting Elements: 1) Gear, 2) Sprocket, 3) Pully

TYPES OF SHAFT	
Stationary Shaft	Rotating Shaft
1. Axle: Shaft At rest. Subjected to bending. Zero Twisting.	1. Counter Shaft: Opposite Direction Motion 2. Jack Shaft: 3. Spindly: Short in length.

SHAFTS SUBJECTED TO DIFFERENT LOADS:

Loading Condition	**Solid Shaft**	**Hollow Shaft**
Axial Loading	$\sigma_a = \frac{F}{(\pi/4)d^2}$	$\sigma_a = \frac{F}{(\pi/4)(d_o^2 - d_i^2)}$
Bending Moment	$\sigma_b = \frac{32\,M}{\pi d^3}$	$\sigma_b = \frac{32\,M}{\pi\, d_o^3\,(1-K^4)}, K = \frac{d_i}{d_o}$
Twisting Moment	$\tau = \frac{16\,T}{\pi d^3}$	$\tau = \frac{16\,T}{\pi d_o^3\,(1-K^4)}, K = \frac{d_i}{d_o}$
Where, d = Shaft Diameter	d_o= Outer Diameter of Shaft	d_i= Inner Diameter of Shaft

DESIGN OF SHAFT

UNI-DIRECTIONAL LOADING

Pure Normal Stress Condition Design	**Pure Shear Stress Condition Design**
$\max\{\sigma_a, \sigma_b, \sigma_a \pm \sigma_b\} = \sigma_{yt}/FOS$	$\tau = \tau_{yt}/FOS$

BI-DIRECTIONAL LOADING

1. **Strength Based Design:**

   $\boldsymbol{\sigma_x} = \sigma_a\ (Axial) or\ \sigma_b(Bending)\ or\ \sigma_a \pm \sigma_b(Combined)$ And $\boldsymbol{\tau_{xy}} = \tau$

MPST	**MSST**	**DET**
$\max\{\sigma_1, \sigma_2, \sigma_3\} = \sigma_{yt}/FOS$	$\max\{\tau_{12}, \tau_{23}, \tau_{31}\} = \tau_{yt}/FOS$	$\sqrt{\sigma_x^2 + 3\tau_{xy}^2} = \sigma_{yt}/FOS$
$M_{eq} = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right]$	$T_{eq} = \sqrt{M^2 + T^2}$	

2. **Stiffness Based Design:**

$$\boldsymbol{\theta \le \theta_{permissible}, where, \theta = \frac{TL}{GJ}}$$

ASME THEORY:

$$M_{eq} = \frac{1}{2}\left[K_b\,M + \sqrt{(K_b\,M)^2 + (K_t T)^2}\right]$$

$$T_{eq} = \sqrt{(K_b\,M)^2 + (K_t T)^2}$$

K_b and K_t represents combined shock and fatigue load factors in bending and twisting.

For No Keys,

$\tau_{yt} = 0.3\,\sigma_{yt}, for\ Ductile\ material$

$\tau_{yt} = 0.18\,\sigma_{ut}, for\ Brittle\ material$

For No Keys,

$\tau_{yt} = \tau_{yt\ With\ Keys}$