Design of shaft | basis of rigidity

DESIGN OF SHAFT ON THE BASIS OF RIGIDITY AND STRENGTH CALCULATION AND ANGLE OF TWIST

Design of Shaft:

• A shaft is a rotating member usually of circular crossection (solid or hollow), which is used to transmit power and rotational motion. Axles are non rotating member.

• Elements such as gears, pulleys (sheaves), flywheels , clutches , and sprockets are mounted on the shaft and are used to transmit power from the driving device(motor or engine) through a machine.

• The rotational force (torque) is transmitted to these elements on the shaft by press fit, keys, dowel, pins.

• The shaft rotates on rolling contact or bush bearings.

• Various types of retaining rings, thrust bearings, grooves and steps in the shaft are used to take up axial loads and locate the rotating elements.

Design of Shafts on the Basis of Rigidity:

• Shafts must be rigid enough to avoid excessive deflection

• Two types of rigidity:

§ Torsional rigidity

§ Lateral rigidity

Torsional Rigidity:

• Important for camshafts where timing of the valves are important

• Estimate the total angle of twist in radians

• Use torsion equation

Lateral Rigidity:

• Important for

§ Transmission shafting

§ Shafts running at high speed

• Lateral deflection must be minimised to avoid:

§ Gear teeth alignment problems

§ Bearing related problems

• The lateral deflection (y) and the slope (θ) may be determined by equations from the strength of materials

Design of Shafts Based on Strength: Stresses in Shafts:

• Shear stresses due to torsional load

• Bending stresses due to the forces coming from gears, pulleys, etc.

• Stresses due to combined torsional and bending loads

Angle of twist for circular members:

Angle of twist : When one end of shaft is fixed and the other end is twisted, the angle twisted is the angle of twist.

Find the relative rotation of section B-B with respect to section A-A of the solid elastic shaft as shown in the when a constant torque T is being transmitted through it. The polar moment of inertia of the cross-sectional area J is constant.

Concepts involved:

Angle of twist in circular members

Formulae used:

$\theta = \int T_x dx / JG$

Where,

φ= Angle of twist

T_x = torque at distance x

J_x = polar moment of area at distance x

G = Shear modulus

Solution:

Step 1:

Here neither torque nor J changes with x so,

$T_x = T$ and $J_x = J$

And limit is between 0 to L so we get:

$\theta = TL/JG$

Note:

In applying the above equation, note particularly that the angle φ must be expressed in radians. Also observe the great similarity of this relation equation Δ = PL/AE, for axially loaded bars. Here φ ⇔ Δ . T⇔ P, J⇔ A, and G⇔ E. By the analogy, this equation can be recast to express the torsional spring constant, or torsional stiffness, kt as

Kt = T/θ = JG /L [N-m/rad]

This constant torque required to cause a rotation of 1 radian, i. e., φ = 1. It depends only on the material properties and the size of the member. As for axially loaded bars, one can visualize torsion members as springs.

The reciprocal of kt defines the torsional flexibility ft. Hence, for a circular solid or hollow shaft.

ft = 1/kt = L / JG [rad/N-m]

This constant defines the rotation resulting from application of a unit torque, i. e., T = 1. On multiplying by the torque T, one obtains the current equation .

Shaft Design:

Shaft Design consists primarily of the determination of the correct shaft diameter to ensure satisfactory strength and rigidity when the shaft is transmitting power under various operating and loading conditions. Shafts are usually circular in cross section, and may be either hollow or solid.

Design of shafts of ductile materials, based on strength, is controlled by the maximum shear theory. And the shafts of brittle material would be designed on the basis of the maximum normal stress theory.

Various loads subjected on Shafting are torsion, bending and axial loads.

Torsional stresses: (τ)

The Torsional formula is given by:

T/J= G θ/L= τ/r

Here T= torque or Torsional moment, N-mm

J= polar moment of inertia, mm4

= π d4/32 , Where d is the solid shaft diameter.

= π(do 4- d i 4) /32 Where do and di are outer and inner diameter of the hollow shaft respectively.

G= Modulus of elasticity in shear or modulus of rigidity, MPa

θ= Angle of twist, radians

l= Length of shaft , mm

r= Distance from the Neutral axis to the top most fibre , mm

= d/2 (For solid shaft)

= do /2(For hollow shaft)

Shear (τ) stress on the outer surface of

a shaft, for a torque (T) :

For solid circular section:

· $\tau = Tr / J = 16T / \pi d3$

For hollow circular section:

· $\tau = Tr / J = 16T do / \pi do 4- d i 4)$

Design of Shafts for Fatigue (Fluctuating Loads):

• Shafts are generally subjected to fluctuating torques and bending moments – may fail due to fatigue

• Combined shock and fatigue factors must be taken into account

• Modify the equivalent twisting and bending moments.

Power Transmitting Shaft:

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* Design of shafts of ductile materials, based on strength, is controlled by the maximum shear theory. And the shafts of brittle material would be designed on the basis of the maximum normal stress theory.

* Various loads subjected on Shafting are torsion, bending and axial loads.

Crank Shaft:

* A crankshaft is used to convert reciprocating motion of the piston into rotary motion or vice versa. The crankshaft consists of the shaft parts, which revolve in the main bearings, the crank pins to which the big ends of the connecting rod are connected, the crank arms or webs, which connect the crankpins, and the shaft parts. The crankshaft, depending upon the position of crank, may be divided into the following two types.

* The crankshaft is the principal member of the crank train or crank assembly, which latter converts the reciprocating motion of the pistons into rotary motion. It is subjected to both torsional and bending stresses, and in modern high-speed, multi-cylinder engines these stresses may be greatly increased by resonance, which not only renders the engine noisy, but also may fracture the shaft. In addition, the crankshaft has both supporting bearings (or main bearings) and crankpin bearings, and all of its bearing surfaces must be sufficiently large so that the unit bearing load cannot become excessive even under the most unfavorable conditions. At high speeds the bearing loads are due in large part to dynamic forces-inertia and centrifugal. Fortunately, loads on main bearings due to centrifugal force can be reduced, and even completely eliminated, by the provision of suitable counterweights. All dynamic forces increase as the square of the speed of rotation. (i. e. FDynamic↑⇒Speed2↑)

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