Critical Speed of a Shaft

When the system's rotational speed corresponds with the natural frequency of lateral/transverse vibrations, the shaft bows out with a considerable amplitude, this is called critical/whirling speed. The critical speed of a shaft is used for formulating NAT questions in the GATE ME question paper.

Critical Speed of a Shaft Definition

The whirling speed or critical speed of a shaft is the speed at which a spinning shaft will tend to vibrate strongly in the transverse direction if rotated horizontally. In other terms, the crucial speed or whirling speed is the speed at which resonance occurs. As a result, we may say that shaft whirling happens when the natural frequency of transverse vibration equals the frequency of a rotating shaft.

The critical or whirling speed is the speed at which the shaft travels so that the extra deviation of the post from the axis of rotation becomes infinite. the critical speed of a shaft depends on the degree and location of the shaft unbalance, the length and diameter of the shaft, and the type of bearing support

Critical Speed of the Shaft Formula

The frequency of traversal vibrations is the same as the critical speed. the critical speed of the shaft is expressed as the natural frequency of the shaft. The critical speed of a shaft is used to formulate the MCQ-based question in the GATE question paper, where m is the presumed single-point concentration of the shaft's mass.

The centrifugal force on the shaft $= m\omega^2(y + e)$, and

the shaft's inward pull $= y(48EI / L^3)$.

Factors Affecting Critical Speed

The critical speed is determined by the degree and location of the shaft unbalance, the length and diameter of the shaft, and the type of bearing support. The critical speed of the shaft is an important part of the GATE ME syllabus and essentially depends on the following Factors:

- Critical or whirling, or whipping speed is the speed at which the shaft tends to vibrate violently in the transverse direction.
- The eccentricity of the C.G of the rotating masses from the axis of rotation of the shaft.
- Diameter of the disc
- Span (length) of the shaft, and
- Type of supports connections at its ends.

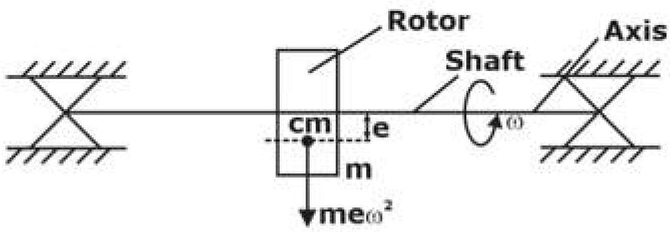
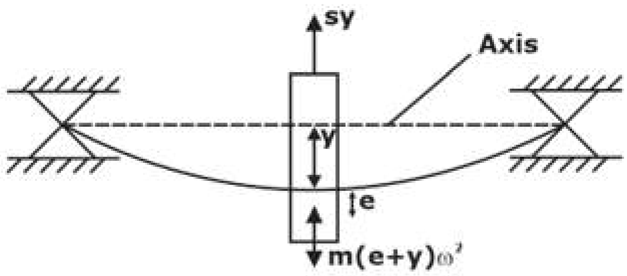


Fig.1: shaft rotor system

After Some Time



Under equilibrium:

$m(y+e)^{2} = sy$

$my^{2} + me^{2} = sy$

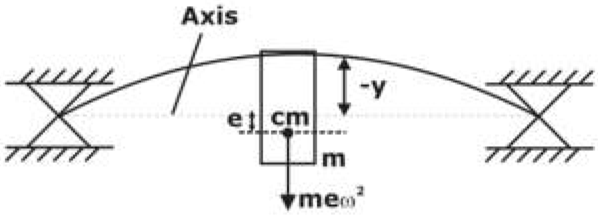
$(m^{2} - s)\, y = -me^{2}$

$$y = \frac{e}{\left(\frac{s}{m\omega^2} - 1\right)}$$

$$y = \left[\frac{e}{\left(\frac{\omega_n}{\omega}\right)^2 - 1}\right]$$

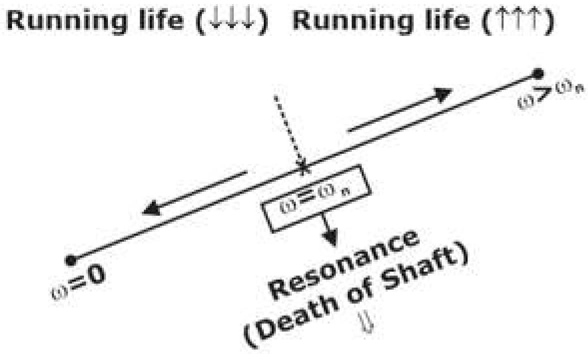
if $\omega > \omega_n \Rightarrow y = \text{negative}$

$\Rightarrow$ Shaft will bend in opposite direction.



and hence, eccentricity will decrease ⇒ unbalanced forced will decrease ⇒ Vibrations decrease rapidly.

At, $\omega = \omega_n$: $y \to \infty$ and hence very dangerous Vibrations will be induced in the shaft and causing whipping of shafts.

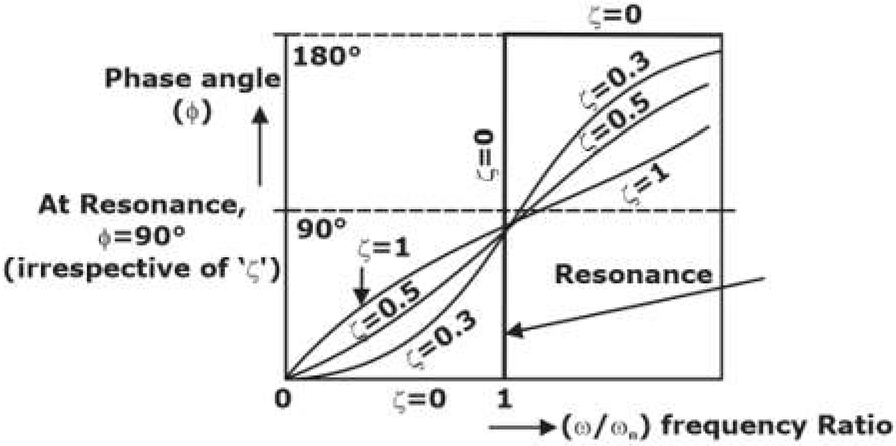


Coulomb/Dry Friction Damping

Coulomb/Dry Friction is important for the GATE exam, and it is responsible for various things in the movement of the shaft, which are mentioned below:

- The amplitude of Vibrations decreases with time linearly.
- The frequency and time period of oscillations do not change.
- Dissipates energy constantly because of sliding friction.
- A system with friction damping is Non-linear because; frictional force always opposes the Dish of Motion of the System.

Variation Phase Angle vs $\left(\frac{\omega}{\omega_n}\right)$



Critical Speed for a Multi-Rotor System

A rotor's critical speed is the angular speed that corresponds to one of its natural frequencies. On the other hand, finding the inherent frequencies of a stationary rotor is insufficient for determining the critical speed. The main difficulty stems from the fact that the rotor's angular speed determines the rotor's natural frequency.

If n = no of rotors

- of natural Frequencies in n-Rotor system = (n-1)
- of node Points = (n-1).