Important Torsional Vibrations Formulas PDF

Formulas
Examples
with Units

List of 29
Important Torsional Vibrations Formulas

1) Effect of Inertia of Constraint on Torsional Vibrations Formulas

1.1) Angular Velocity of Element Formula

Evaluate Formula

Formula

$$\omega = \frac{\omega_f \cdot x}{l}$$

Example with Units

$$11.2347\,\text{rad/s} = \frac{22.5\,\text{rad/s} \cdot 3.66\,\text{mm}}{7.33\,\text{mm}}$$

1.2) Angular Velocity of Free End using Kinetic Energy of Constraint Formula

Evaluate Formula

Formula

$$\omega_f = \sqrt{\frac{6 \cdot KE}{I_c}}$$

Example with Units

$$22.5176\,\text{rad/s} = \sqrt{\frac{6 \cdot 900\,\text{J}}{10.65\,\text{kg·m}^2}}$$

1.3) Kinetic Energy Possessed by Element Formula

Evaluate Formula

Formula

$$KE = \frac{I_c \cdot \left(\omega_f \cdot x\right)^2 \cdot \delta x}{2 \cdot l^3}$$

Example with Units

$$900.4226\,\text{J} = \frac{10.65\,\text{kg·m}^2 \cdot \left(22.5\,\text{rad/s} \cdot 3.66\,\text{mm}\right)^2 \cdot 9.82\,\text{mm}}{2 \cdot 7.33\,\text{mm}^3}$$

1.4) Mass Moment of Inertia of Element Formula

Evaluate Formula

Formula

$$I = \frac{\delta x \cdot I_c}{l}$$

Example with Units

$$14.2678\,\text{kg·m}^2 = \frac{9.82\,\text{mm} \cdot 10.65\,\text{kg·m}^2}{7.33\,\text{mm}}$$

1.5) Natural Frequency of Torsional Vibration due to Effect of Inertia of Constraint Formula

Evaluate Formula

Formula

$$f = \frac{\sqrt{\frac{q}{I_{disc} + \frac{I_c}{3}}}}{2 \cdot \pi}$$

Example with Units

$$0.1184\,\text{Hz} = \frac{\sqrt{\frac{5.4\,\text{N/m}}{6.2\,\text{kg·m}^2 + \frac{10.65\,\text{kg·m}^2}{3}}}}{2 \cdot 3.1416}$$

1.6) Torsional Stiffness of Shaft due to Effect of Constraint on Torsional Vibrations Formula

Evaluate Formula

Formula

$$q = \left(2 \cdot \pi \cdot f\right)^2 \cdot \left(I_{disc} + \frac{I_c}{3}\right)$$

Example with Units

$$5.5428\,\text{N/m} = \left(2 \cdot 3.1416 \cdot 0.120\,\text{Hz}\right)^2 \cdot \left(6.2\,\text{kg·m²} + \frac{10.65\,\text{kg·m²}}{3}\right)$$

1.7) Total Kinetic Energy of Constraint Formula

Evaluate Formula

Formula

$$KE = \frac{I_c \cdot \omega_f^2}{6}$$

Example with Units

$$898.5938\,\text{J} = \frac{10.65\,\text{kg·m²} \cdot 22.5\,\text{rad/s}^2}{6}$$

1.8) Total Mass Moment of Inertia of Constraint given Kinetic Energy of Constraint Formula

Evaluate Formula

Formula

$$I_c = \frac{6 \cdot KE}{\omega_f^2}$$

Example with Units

$$10.6667\,\text{kg·m²} = \frac{6 \cdot 900\,\text{J}}{22.5\,\text{rad/s}^2}$$

2) Free Torsional Vibrations of Rotor Systems Formulas

2.1) Free Torsional Vibrations of Single Rotor System Formulas

2.1.1) Modulus of Rigidity of Shaft for Free Torsional Vibration of Single Rotor System Formula

Evaluate Formula

Formula

$$G = \frac{\left(2 \cdot \pi \cdot f\right)^2 \cdot L \cdot I_{shaft}}{J_{shaft}}$$

Example with Units

$$39.7942\,\text{N/m²} = \frac{\left(2 \cdot 3.1416 \cdot 0.120\,\text{Hz}\right)^2 \cdot 7000\,\text{mm} \cdot 100\,\text{kg·m²}}{10\,\text{m⁴}}$$

2.1.2) Natural Frequency of Free Torsional Vibration of Single Rotor System Formula

Evaluate Formula

Formula

$$f = \frac{\sqrt{\frac{G \cdot J_{shaft}}{L \cdot I_{shaft}}}}{2 \cdot \pi}$$

Example with Units

$$0.1203\,\text{Hz} = \frac{\sqrt{\frac{40\,\text{N/m²} \cdot 10\,\text{m⁴}}{7000\,\text{mm} \cdot 100\,\text{kg·m²}}}}{2 \cdot 3.1416}$$

2.2) Free Torsional Vibrations of Two Rotor System Formulas

2.2.1) Distance of Node from Rotor A, for Torsional Vibration of Two Rotor System Formula

Evaluate Formula

Formula

$$l_A = \frac{I_B \cdot l_B}{I_{A\ rotor}}$$

Example with Units

$$14.4\,\text{mm} = \frac{36\,\text{kg·m}^2 \cdot 3.2\,\text{mm}}{8\,\text{kg·m}^2}$$

2.2.2) Distance of Node from Rotor B, for Torsional Vibration of Two Rotor System Formula

Evaluate Formula

Formula

$$l_B = \frac{I_A \cdot l_A}{I_{B\ rotor}}$$

Example with Units

$$3.2977\,\text{mm} = \frac{18\,\text{kg·m}^2 \cdot 14.4\,\text{mm}}{78.6\,\text{kg·m}^2}$$

2.2.3) Mass Moment of Inertia of Rotor A, for Torsional Vibration of Two Rotor System Formula

Evaluate Formula

Formula

$$I_{A\ rotor} = \frac{I_B \cdot l_B}{l_A}$$

Example with Units

$$8\,\text{kg·m}^2 = \frac{36\,\text{kg·m}^2 \cdot 3.2\,\text{mm}}{14.4\,\text{mm}}$$

2.2.4) Mass Moment of Inertia of Rotor B, for Torsional Vibration of Two Rotor System Formula

Evaluate Formula

Formula

$$I_{B\ rotor} = \frac{I_A \cdot l_A}{l_B}$$

Example with Units

$$81\,\text{kg·m}^2 = \frac{18\,\text{kg·m}^2 \cdot 14.4\,\text{mm}}{3.2\,\text{mm}}$$

2.2.5) Natural Frequency of Free Torsional Vibration for Rotor A of Two Rotor System Formula

Evaluate Formula

Formula

$$f = \frac{\sqrt{\frac{G \cdot J}{l_A \cdot I_{A\ rotor}}}}{2 \cdot \pi}$$

Example with Units

$$0.2966\,\text{Hz} = \frac{\sqrt{\frac{40\,\text{N/m}^2 \cdot 0.01\,\text{m}^4}{14.4\,\text{mm} \cdot 8\,\text{kg·m}^2}}}{2 \cdot 3.1416}$$

2.2.6) Natural Frequency of Free Torsional Vibration for Rotor B of Two Rotor System Formula

Evaluate Formula

Formula

$$f = \frac{\sqrt{\frac{G \cdot J}{l_B \cdot I_{B\ rotor}}}}{2 \cdot \pi}$$

Example with Units

$$0.2007\,\text{Hz} = \frac{\sqrt{\frac{40\,\text{N/m}^2 \cdot 0.01\,\text{m}^4}{3.2\,\text{mm} \cdot 78.6\,\text{kg·m}^2}}}{2 \cdot 3.1416}$$

3) Natural Frequency of Free Torsional Vibrations Formulas

3.1) Accelerating Force Formula

Evaluate Formula

Formula

$$F = I_{disc} \cdot \alpha$$

Example with Units

$$9.92\,\text{N} = 6.2\,\text{kg·m²} \cdot 1.6\,\text{rad/s²}$$

3.2) Angular Displacement of Shaft from Mean Position Formula

Evaluate Formula

Formula

$$\theta = \frac{F_{restoring}}{q}$$

Example with Units

$$12.037\,\text{rad} = \frac{65\,\text{N}}{5.4\,\text{N/m}}$$

3.3) Angular Velocity of Shaft Formula

Evaluate Formula

Formula

$$\omega = \sqrt{\frac{q_{shaft}}{I_{disc}}}$$

Example with Units

$$11.1948\,\text{rad/s} = \sqrt{\frac{777\,\text{N/m}}{6.2\,\text{kg·m²}}}$$

3.4) Moment of Inertia of Disc given Angular Velocity Formula

Evaluate Formula

Formula

$$I_{disc} = \frac{q_{shaft}}{\omega^2}$$

Example with Units

$$6.1942\,\text{kg·m²} = \frac{777\,\text{N/m}}{11.2\,\text{rad/s}^2}$$

3.5) Moment of Inertia of Disc given Time Period of Vibration Formula

Evaluate Formula

Formula

$$I_{disc} = \frac{t_p^2 \cdot q}{(2 \cdot \pi)^2}$$

Example with Units

$$1.2311\,\text{kg·m²} = \frac{3\,\text{s}^2 \cdot 5.4\,\text{N/m}}{(2 \cdot 3.1416)^2}$$

3.6) Moment of Inertia of Disc using Natural Frequency of Vibration Formula

Evaluate Formula

Formula

$$I_{disc} = \frac{q}{(2 \cdot \pi \cdot f)^2}$$

Example with Units

$$9.4989\,\text{kg·m²} = \frac{5.4\,\text{N/m}}{(2 \cdot 3.1416 \cdot 0.120\,\text{Hz})^2}$$

3.7) Natural Frequency of Vibration Formula

Evaluate Formula

Formula

$$f = \frac{\sqrt{\frac{q}{I_{disc}}}}{2 \cdot \pi}$$

Example with Units

$$0.1485\,\text{Hz} = \frac{\sqrt{\frac{5.4\,\text{N/m}}{6.2\,\text{kg·m²}}}}{2 \cdot 3.1416}$$

3.8) Restoring Force for Free Torsional Vibrations Formula

Evaluate Formula

Formula

$$F_{restoring} = q \cdot \theta$$

Example with Units

$$64.8\,\text{N} = 5.4\,\text{N/m} \cdot 12\,\text{rad}$$

3.9) Time Period for Vibrations Formula

Evaluate Formula

Formula

$$t_p = 2 \cdot \pi \cdot \sqrt{\frac{I_{disc}}{q}}$$

Example with Units

$$6.7325\,\text{s} = 2 \cdot 3.1416 \cdot \sqrt{\frac{6.2\,\text{kg·m²}}{5.4\,\text{N/m}}}$$

3.10) Torsional Stiffness of Shaft Formula

Evaluate Formula

Formula

$$q = \frac{F_{restoring}}{\theta}$$

Example with Units

$$5.4167\,\text{N/m} = \frac{65\,\text{N}}{12\,\text{rad}}$$

3.11) Torsional Stiffness of Shaft given Angular Velocity Formula

Evaluate Formula

Formula

$$q_{shaft} = \omega^2 \cdot I_{disc}$$

Example with Units

$$777.728\,\text{N/m} = 11.2\,\text{rad/s}^2 \cdot 6.2\,\text{kg·m²}$$

3.12) Torsional Stiffness of Shaft given Natural Frequency of Vibration Formula

Evaluate Formula

Formula

$$q = \left(2 \cdot \pi \cdot f\right)^2 \cdot I_{disc}$$

Example with Units

$$3.5246\,\text{N/m} = \left(2 \cdot 3.1416 \cdot 0.120\,\text{Hz}\right)^2 \cdot 6.2\,\text{kg·m²}$$

3.13) Torsional Stiffness of Shaft given Time Period of Vibration Formula

Evaluate Formula

Formula

$$q = \frac{\left(2 \cdot \pi\right)^2 \cdot I_{disc}}{\left(t_p\right)^2}$$

Example with Units

$$27.1962\,\text{N/m} = \frac{\left(2 \cdot 3.1416\right)^2 \cdot 6.2\,\text{kg·m²}}{\left(3\,\text{s}\right)^2}$$

Variables used in list of Torsional Vibrations Formulas above

- **f** Frequency *(Hertz)*
- **F** Force *(Newton)*
- $F_{restoring}$ Restoring Force *(Newton)*
- **G** Modulus of Rigidity *(Newton per Square Meter)*
- **I** Moment of Inertia *(Kilogram Square Meter)*
- $I_{A\ rotor}$ Mass Moment of Inertia of Rotor A *(Kilogram Square Meter)*
- I_A Mass Moment of Inertia of Mass Attached to Shaft A *(Kilogram Square Meter)*
- $I_{B\ rotor}$ Mass Moment of Inertia of Rotor B *(Kilogram Square Meter)*
- I_B Mass Moment of Inertia of Mass Attached to Shaft B *(Kilogram Square Meter)*
- I_c Total Mass Moment of Inertia *(Kilogram Square Meter)*
- I_{disc} Mass Moment of Inertia of Disc *(Kilogram Square Meter)*
- I_{shaft} Moment of inertia of Shaft *(Kilogram Square Meter)*
- **J** Polar Moment of Inertia *(Meter⁴)*
- J_{shaft} Polar Moment of Inertia of Shaft *(Meter⁴)*
- **KE** Kinetic Energy *(Joule)*
- **l** Length of Constraint *(Millimeter)*
- **L** Length of Shaft *(Millimeter)*
- l_A Distance of Node from Rotor A *(Millimeter)*
- l_B Distance of Node from Rotor B *(Millimeter)*
- **q** Torsional Stiffness *(Newton per Meter)*
- q_{shaft} Torsional Stiffness of Shaft *(Newton per Meter)*
- t_p Time Period *(Second)*
- **x** Distance between Small Element and Fixed End *(Millimeter)*
- **α** Angular Acceleration *(Radian per Square Second)*
- **δx** Length of Small Element *(Millimeter)*
- **θ** Angular Displacement of Shaft *(Radian)*

Constants, Functions, Measurements used in list of Torsional Vibrations Formulas above

- constant(s): **pi**, 3.14159265358979323846264338327950288 *Archimedes' constant*
- Functions: **sqrt**, sqrt(Number) *A square root function is a function that takes a non-negative number as an input and returns the square root of the given input number.*
- Measurement: **Length** in Millimeter (mm) *Length Unit Conversion*
- Measurement: **Time** in Second (s) *Time Unit Conversion*
- Measurement: **Pressure** in Newton per Square Meter (N/m²) *Pressure Unit Conversion*
- Measurement: **Energy** in Joule (J) *Energy Unit Conversion*
- Measurement: **Force** in Newton (N) *Force Unit Conversion*
- Measurement: **Angle** in Radian (rad) *Angle Unit Conversion*
- Measurement: **Frequency** in Hertz (Hz) *Frequency Unit Conversion*
- Measurement: **Angular Velocity** in Radian per Second (rad/s) *Angular Velocity Unit Conversion*
- Measurement: **Moment of Inertia** in Kilogram Square Meter (kg·m²) *Moment of Inertia Unit Conversion*
- Measurement: **Angular Acceleration** in Radian per Square Second (rad/s²) *Angular Acceleration Unit Conversion*
- Measurement: **Second Moment of Area** in Meter⁴ (m⁴) *Second Moment of Area Unit Conversion*
- Measurement: **Stiffness Constant** in Newton per Meter (N/m) *Stiffness Constant Unit Conversion*

- **ω** Angular Velocity *(Radian per Second)*
- **ω_f** Angular Velocity of Free End *(Radian per Second)*

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