Important Principal Stress Formulas PDF

Formulas
Examples
with Units

List of 32
Important Principal Stress Formulas

1) Combined Bending and Torsion Condition Formulas

1.1) Angle of Twist in Combined Bending and Torsion Formula

Evaluate Formula

Formula

$$\theta = \frac{\arctan\left(\frac{T}{M}\right)}{2}$$

Example with Units

$$30° = \frac{\arctan\left(\frac{0.116913\,\text{MPa}}{67.5\,\text{kN*m}}\right)}{2}$$

1.2) Angle of Twist in Combined Bending and Torsional Stress Formula

Evaluate Formula

Formula

$$\theta = 0.5 \cdot \arctan\left(2 \cdot \frac{T}{\sigma_b}\right)$$

Example with Units

$$8.9958° = 0.5 \cdot \arctan\left(2 \cdot \frac{0.116913\,\text{MPa}}{0.72\,\text{MPa}}\right)$$

1.3) Bending Moment given Combined Bending and Torsion Formula

Evaluate Formula

Formula

$$M = \frac{T}{\tan(2 \cdot \theta)}$$

Example with Units

$$67.4998\,\text{kN*m} = \frac{0.116913\,\text{MPa}}{\tan(2 \cdot 30°)}$$

1.4) Bending Stress given Combined Bending and Torsional Stress Formula

Evaluate Formula

Formula

$$\sigma_b = \frac{T}{\frac{\tan(2 \cdot \theta)}{2}}$$

Example with Units

$$0.135\,\text{MPa} = \frac{0.116913\,\text{MPa}}{\frac{\tan(2 \cdot 30°)}{2}}$$

1.5) Torsional Moment when Member is subjected to both Bending and Torsion Formula

Evaluate Formula

Formula

$$T = M \cdot (\tan(2 \cdot \theta))$$

Example with Units

$$0.1169\,\text{MPa} = 67.5\,\text{kN*m} \cdot (\tan(2 \cdot 30°))$$

1.6) Torsional Stress given Combined Bending and Torsional Stress Formula

Evaluate Formula

Formula

$$T = \left(\frac{\tan(2 \cdot \theta)}{2}\right) \cdot \sigma_b$$

Example with Units

$$0.6235\,\text{MPa} = \left(\frac{\tan(2 \cdot 30°)}{2}\right) \cdot 0.72\,\text{MPa}$$

2) Complementary Induced Stress Formulas

2.1) Angle of Oblique Plane using Normal Stress when Complementary Shear Stresses Induced Formula

Evaluate Formula

Formula

$$\theta = \frac{asin\left(\frac{\sigma_\theta}{\tau}\right)}{2}$$

Example with Units

$$44.4537° = \frac{asin\left(\frac{54.99\,\text{MPa}}{55\,\text{MPa}}\right)}{2}$$

2.2) Angle of Oblique Plane using Shear Stress when Complementary Shear Stresses Induced Formula

Evaluate Formula

Formula

$$\theta = 0.5 \cdot \arccos\left(\frac{\tau_\theta}{\tau}\right)$$

Example with Units

$$29.6105° = 0.5 \cdot \arccos\left(\frac{28.145\,\text{MPa}}{55\,\text{MPa}}\right)$$

2.3) Normal Stress when Complementary Shear Stresses Induced Formula

Evaluate Formula

Formula

$$\sigma_\theta = \tau \cdot \sin(2 \cdot \theta)$$

Example with Units

$$47.6314\,\text{MPa} = 55\,\text{MPa} \cdot \sin(2 \cdot 30°)$$

2.4) Shear Stress along Oblique Plane when Complementary Shear Stresses Induced Formula

Evaluate Formula

Formula

$$\tau_\theta = \tau \cdot \cos(2 \cdot \theta)$$

Example with Units

$$27.5\,\text{MPa} = 55\,\text{MPa} \cdot \cos(2 \cdot 30°)$$

2.5) Shear Stress due to Effect of Complementary Shear Stresses and Shear Stress in Oblique Plane Formula

Evaluate Formula

Formula

$$\tau = \frac{\tau_\theta}{\cos(2 \cdot \theta)}$$

Example with Units

$$56.29\,\text{MPa} = \frac{28.145\,\text{MPa}}{\cos(2 \cdot 30°)}$$

2.6) Shear Stress due to Induced Complementary Shear Stresses and Normal Stress on Oblique Plane Formula

Evaluate Formula

Formula

$$\tau = \frac{\sigma_\theta}{\sin(2 \cdot \theta)}$$

Example with Units

$$63.497\,\text{MPa} = \frac{54.99\,\text{MPa}}{\sin(2 \cdot 30°)}$$

3) Equivalent Bending Moment & Torque Formulas

3.1) Bending Stress of Circular Shaft given Equivalent Bending Moment Formula

Evaluate Formula

Formula

$$\sigma_b = \frac{32 \cdot M_e}{\pi \cdot (\Phi^3)}$$

Example with Units

$$0.7243\,\text{MPa} = \frac{32 \cdot 30\,\text{kN*m}}{3.1416 \cdot (750\,\text{mm}^3)}$$

3.2) Diameter of Circular Shaft for Equivalent Torque and Maximum Shear Stress Formula

Evaluate Formula

Formula

$$\Phi = \left(\frac{16 \cdot T_e}{\pi \cdot \left(\tau_{max} \right)} \right)^{\frac{1}{3}}$$

Example with Units

$$157.1413\,\text{mm} = \left(\frac{16 \cdot 32\,\text{kN*m}}{3.1416 \cdot \left(42\,\text{MPa} \right)} \right)^{\frac{1}{3}}$$

3.3) Diameter of Circular Shaft given Equivalent Bending Stress Formula

Evaluate Formula

Formula

$$\Phi = \left(\frac{32 \cdot M_e}{\pi \cdot \left(\sigma_b \right)} \right)^{\frac{1}{3}}$$

Example with Units

$$751.5011\,\text{mm} = \left(\frac{32 \cdot 30\,\text{kN*m}}{3.1416 \cdot \left(0.72\,\text{MPa} \right)} \right)^{\frac{1}{3}}$$

3.4) Equivalent Bending Moment of Circular Shaft Formula

Evaluate Formula

Formula

$$M_e = \frac{\sigma_b}{\frac{32}{\pi \cdot \left(\Phi^3 \right)}}$$

Example with Units

$$29.8206\,\text{kN*m} = \frac{0.72\,\text{MPa}}{\frac{32}{3.1416 \cdot \left(750\,\text{mm}^3 \right)}}$$

3.5) Equivalent Torque given Maximum Shear Stress Formula

Evaluate Formula

Formula

$$T_e = \frac{\tau_{max}}{\frac{16}{\pi \cdot \left(\Phi^3 \right)}}$$

Example with Units

$$3479.0684\,\text{kN*m} = \frac{42\,\text{MPa}}{\frac{16}{3.1416 \cdot \left(750\,\text{mm}^3 \right)}}$$

3.6) Location of Principal Planes Formula

Evaluate Formula

Formula

$$\theta = \left(\left(\left(\frac{1}{2} \right) \cdot atan \left(\frac{2 \cdot \tau_{xy}}{\sigma_y - \sigma_x} \right) \right) \right)$$

Example with Units

$$6.2457° = \left(\left(\left(\frac{1}{2} \right) \cdot atan \left(\frac{2 \cdot 7.2\,\text{MPa}}{110\,\text{MPa} - 45\,\text{MPa}} \right) \right) \right)$$

3.7) Maximum Shear Stress due to Equivalent Torque Formula

Evaluate Formula

Formula

$$\tau_{max} = \frac{16 \cdot T_e}{\pi \cdot \left(\Phi^3 \right)}$$

Example with Units

$$0.3863\,\text{MPa} = \frac{16 \cdot 32\,\text{kN*m}}{3.1416 \cdot \left(750\,\text{mm}^3 \right)}$$

4) Maximum Shear Stress on the Biaxial Loading Formulas

4.1) Maximum Shear Stress when Member is Subjected to like Principal Stresses Formula

Evaluate Formula

Formula

$$\tau_{max} = \frac{1}{2} \cdot \left(\sigma_y - \sigma_x \right)$$

Example with Units

$$32.5\,\text{MPa} = \frac{1}{2} \cdot \left(110\,\text{MPa} - 45\,\text{MPa} \right)$$

4.2) Stress along X-Axis when Member is Subjected to like Principal Stresses and Max Shear Stress Formula

Evaluate Formula

Formula

$$\sigma_x = \sigma_y - \left(2 \cdot \tau_{max} \right)$$

Example with Units

$$26\,\text{MPa} = 110\,\text{MPa} - \left(2 \cdot 42\,\text{MPa} \right)$$

4.3) Stress along Y-Axis when Member is Subjected to like Principal Stresses and Max Shear Stress Formula

Evaluate Formula

Formula

$$\sigma_y = 2 \cdot \tau_{max} + \sigma_x$$

Example with Units

$$129\,\text{MPa} = 2 \cdot 42\,\text{MPa} + 45\,\text{MPa}$$

5) Stresses in Bi-Axial Loading Formulas

5.1) Normal Stress Induced in Oblique Plane due to Biaxial Loading Formula

Evaluate Formula

Formula

$$\sigma_\theta = \left(\frac{1}{2} \cdot \left(\sigma_x + \sigma_y \right) \right) + \left(\frac{1}{2} \cdot \left(\sigma_x - \sigma_y \right) \cdot \left(\cos\left(2 \cdot \theta \right) \right) \right) + \left(\tau_{xy} \cdot \sin\left(2 \cdot \theta \right) \right)$$

Example with Units

$$67.4854\,\text{MPa} = \left(\frac{1}{2} \cdot \left(45\,\text{MPa} + 110\,\text{MPa} \right) \right) + \left(\frac{1}{2} \cdot \left(45\,\text{MPa} - 110\,\text{MPa} \right) \cdot \left(\cos\left(2 \cdot 30^\circ \right) \right) \right) + \left(7.2\,\text{MPa} \cdot \sin\left(2 \cdot 30^\circ \right) \right)$$

5.2) Shear Stress Induced in Oblique Plane due to Biaxial Loading Formula

Evaluate Formula

Formula

$$\tau_\theta = -\left(\frac{1}{2} \cdot \left(\sigma_x - \sigma_y \right) \cdot \sin\left(2 \cdot \theta \right) \right) + \left(\tau_{xy} \cdot \cos\left(2 \cdot \theta \right) \right)$$

Example with Units

$$31.7458\,\text{MPa} = -\left(\frac{1}{2} \cdot \left(45\,\text{MPa} - 110\,\text{MPa} \right) \cdot \sin\left(2 \cdot 30^\circ \right) \right) + \left(7.2\,\text{MPa} \cdot \cos\left(2 \cdot 30^\circ \right) \right)$$

5.3) Stress along X- Direction with known Shear Stress in Bi-Axial Loading Formula

Evaluate Formula

Formula

$$\sigma_x = \sigma_y - \left(\frac{\tau_\theta \cdot 2}{\sin\left(2 \cdot \theta \right)} \right)$$

Example with Units

$$45.0019\,\text{MPa} = 110\,\text{MPa} - \left(\frac{28.145\,\text{MPa} \cdot 2}{\sin\left(2 \cdot 30^\circ \right)} \right)$$

5.4) Stress along Y- Direction using Shear Stress in Bi-Axial Loading Formula

Evaluate Formula

Formula

$$\sigma_y = \sigma_x + \left(\frac{\tau_\theta \cdot 2}{\sin\left(2 \cdot \theta \right)} \right)$$

Example with Units

$$109.9981\,\text{MPa} = 45\,\text{MPa} + \left(\frac{28.145\,\text{MPa} \cdot 2}{\sin\left(2 \cdot 30^\circ \right)} \right)$$

6) Stresses of Members Subjected to Axial Loading Formulas

6.1) Angle of Oblique Plane using Shear Stress and Axial Load Formula

Evaluate Formula

Formula

$$\theta = \frac{arsin\left(\left(\frac{2 \cdot \tau_\theta}{\sigma_y}\right)\right)}{2}$$

Example with Units

$$15.3895° = \frac{arsin\left(\left(\frac{2 \cdot 28.145 \, \text{MPa}}{110 \, \text{MPa}}\right)\right)}{2}$$

6.2) Angle of Oblique plane when Member Subjected to Axial Loading Formula

Evaluate Formula

Formula

$$\theta = \frac{acos\left(\frac{\sigma_\theta}{\sigma_y}\right)}{2}$$

Example with Units

$$30.003° = \frac{acos\left(\frac{54.99 \, \text{MPa}}{110 \, \text{MPa}}\right)}{2}$$

6.3) Normal Stress when Member Subjected to Axial Load Formula

Evaluate Formula

Formula

$$\sigma_\theta = \sigma_y \cdot \cos(2 \cdot \theta)$$

Example with Units

$$55 \, \text{MPa} = 110 \, \text{MPa} \cdot \cos(2 \cdot 30°)$$

6.4) Shear Stress when Member Subjected to Axial Load Formula

Evaluate Formula

Formula

$$\tau_\theta = 0.5 \cdot \sigma_y \cdot \sin(2 \cdot \theta)$$

Example with Units

$$47.6314 \, \text{MPa} = 0.5 \cdot 110 \, \text{MPa} \cdot \sin(2 \cdot 30°)$$

6.5) Stress along Y-direction given Shear Stress in Member subjected to Axial Load Formula

Evaluate Formula

Formula

$$\sigma_y = \frac{\tau_\theta}{0.5 \cdot \sin(2 \cdot \theta)}$$

Example with Units

$$64.9981 \, \text{MPa} = \frac{28.145 \, \text{MPa}}{0.5 \cdot \sin(2 \cdot 30°)}$$

6.6) Stress along Y-direction when Member Subjected to Axial Load Formula

Evaluate Formula

Formula

$$\sigma_y = \frac{\sigma_\theta}{\cos(2 \cdot \theta)}$$

Example with Units

$$109.98 \, \text{MPa} = \frac{54.99 \, \text{MPa}}{\cos(2 \cdot 30°)}$$

Variables used in list of Principal Stress Formulas above

- **M** Bending Moment *(Kilonewton Meter)*
- M_e Equivalent Bending Moment *(Kilonewton Meter)*
- **T** Torsion *(Megapascal)*
- T_e Equivalent Torque *(Kilonewton Meter)*
- **θ** Theta *(Degree)*
- $σ_b$ Bending Stress *(Megapascal)*
- $σ_x$ Stress along x Direction *(Megapascal)*
- $σ_y$ Stress along y Direction *(Megapascal)*
- $σ_θ$ Normal Stress on Oblique Plane *(Megapascal)*
- **τ** Shear Stress *(Megapascal)*
- $τ_{max}$ Maximum Shear Stress *(Megapascal)*
- $τ_{xy}$ Shear Stress xy *(Megapascal)*
- $τ_θ$ Shear Stress on Oblique Plane *(Megapascal)*
- **Φ** Diameter of Circular Shaft *(Millimeter)*

Constants, Functions, Measurements used in list of Principal Stress Formulas above

- constant(s): **pi**, 3.14159265358979323846264338327950288
  Archimedes' constant
- Functions: **acos**, acos(Number)
  The inverse cosine function, is the inverse function of the cosine function. It is the function that takes a ratio as an input and returns the angle whose cosine is equal to that ratio.
- Functions: **arccos**, arccos(Number)
  Arccosine function, is the inverse function of the cosine function.It is the function that takes a ratio as an input and returns the angle whose cosine is equal to that ratio.
- Functions: **arctan**, arctan(Number)
  Inverse trigonometric functions are usually accompanied by the prefix - arc. Mathematically, we represent arctan or the inverse tangent function as tan-1 x or arctan(x).
- Functions: **arsin**, arsin(Number)
  Arcsine function, is a trigonometric function that takes a ratio of two sides of a right triangle and outputs the angle opposite the side with the given ratio.
- Functions: **asin**, asin(Number)
  The inverse sine function, is a trigonometric function that takes a ratio of two sides of a right triangle and outputs the angle opposite the side with the given ratio.
- Functions: **atan**, atan(Number)
  Inverse tan is used to calculate the angle by applying the tangent ratio of the angle, which is the opposite side divided by the adjacent side of the right triangle.
- Functions: **cos**, cos(Angle)
  Cosine of an angle is the ratio of the side adjacent to the angle to the hypotenuse of the triangle.
- Functions: **ctan**, ctan(Angle)
  Cotangent is a trigonometric function that is defined as the ratio of the adjacent side to the opposite side in a right triangle.
- Functions: **sin**, sin(Angle)
  Sine is a trigonometric function that describes the ratio of the length of the opposite side of a right triangle to the length of the hypotenuse.
- Functions: **tan**, tan(Angle)
  The tangent of an angle is a trigonometric ratio of the length of the side opposite an angle to the length of the side adjacent to an angle in a right triangle.

- Measurement: **Length** in Millimeter (mm)
  Length Unit Conversion
- Measurement: **Angle** in Degree (°)
  Angle Unit Conversion
- Measurement: **Torque** in Kilonewton Meter (kN*m)
  Torque Unit Conversion
- Measurement: **Moment of Force** in Kilonewton Meter (kN*m)
  Moment of Force Unit Conversion
- Measurement: **Stress** in Megapascal (MPa)
  Stress Unit Conversion

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