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Theories of Failure Formulas

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List of 20 Theories of Failure Formulas

Theories of Failure

Maximum Principal Stress Theory

1) Allowable Stress in Brittle Material under Compressive Loading

$$\text{fx } \sigma_{al} = \frac{S_{uc}}{f_s}$$

[Open Calculator !\[\]\(de95854c7ee024cfadc48187bbb781b2_img.jpg\)](#)

$$\text{ex } 62.5\text{N/mm}^2 = \frac{125\text{N/mm}^2}{2}$$

2) Allowable Stress in Brittle Material under Tensile Loading

$$\text{fx } \sigma_{al} = \frac{S_{ut}}{f_s}$$

[Open Calculator !\[\]\(6a9b39b98eb945faa14c645ec99e4eaa_img.jpg\)](#)

$$\text{ex } 61\text{N/mm}^2 = \frac{122\text{N/mm}^2}{2}$$

3) Allowable Stress in Ductile Material under Compressive Loading

$$\text{fx } \sigma_{al} = \frac{S_{yc}}{f_s}$$

[Open Calculator !\[\]\(f1c5da15572e3e09d343161be98f508d_img.jpg\)](#)

$$\text{ex } 52.5\text{N/mm}^2 = \frac{105\text{N/mm}^2}{2}$$

4) Allowable Stress in Ductile Material under Tensile Loading

$$\text{fx } \sigma_{al} = \frac{\sigma_y}{f_s}$$

[Open Calculator !\[\]\(166772600a13ad0a433053f90fe45649_img.jpg\)](#)

$$\text{ex } 42.5\text{N/mm}^2 = \frac{85\text{N/mm}^2}{2}$$



Maximum Shear Stress Theory

5) Shear Yield Strength by Maximum Shear Stress Theory

$$f_x \quad S_{sy} = \frac{\sigma_y}{2}$$

[Open Calculator !\[\]\(a03a7eb2f4046e1d3c76772003e549ea_img.jpg\)](#)

$$ex \quad 42.5 \text{ N/mm}^2 = \frac{85 \text{ N/mm}^2}{2}$$

6) Shear Yield Strength given Tensile Yield Strength

$$f_x \quad S_{sy} = \frac{\sigma_y}{2}$$

[Open Calculator !\[\]\(5361750c22c4e047a52f4eac1ec2d4cc_img.jpg\)](#)

$$ex \quad 42.5 \text{ N/mm}^2 = \frac{85 \text{ N/mm}^2}{2}$$

7) Tensile Yield Strength given Shear Yield Strength

$$f_x \quad \sigma_y = 2 \cdot S_{sy}$$

[Open Calculator !\[\]\(b792654f2cef9719eabeb6c5be00811e_img.jpg\)](#)

$$ex \quad 85 \text{ N/mm}^2 = 2 \cdot 42.5 \text{ N/mm}^2$$

Distortion Energy Theory

8) Distortion Strain Energy

$$f_x \quad U_d = \frac{(1 + \nu)}{6 \cdot E} \cdot \left((\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 \right)$$

[Open Calculator !\[\]\(28f72b996fc97883dfd9d4e8b1b16b4e_img.jpg\)](#)

ex

$$1.540933 \text{ kJ/m}^3 = \frac{(1 + 0.3)}{6 \cdot 190 \text{ GPa}} \cdot \left((35.2 \text{ N/mm}^2 - 47 \text{ N/mm}^2)^2 + (47 \text{ N/mm}^2 - 65 \text{ N/mm}^2)^2 + (65 \text{ N/mm}^2 - 35.2 \text{ N/mm}^2)^2 \right)$$

9) Distortion Strain Energy for Yielding

$$f_x \quad U_d = \frac{(1 + \nu)}{3 \cdot E} \cdot \sigma_y^2$$

[Open Calculator !\[\]\(4c9516d2c24d0d513bc9f84c2e013d65_img.jpg\)](#)

$$ex \quad 16.47807 \text{ kJ/m}^3 = \frac{(1 + 0.3)}{3 \cdot 190 \text{ GPa}} \cdot (85 \text{ N/mm}^2)^2$$


10) Shear Yield Strength by Maximum Distortion Energy Theorem

$$f_x \quad S_{sy} = 0.577 \cdot \sigma_y$$

[Open Calculator !\[\]\(0aaea5eb29549a0c507a518cbdd818a0_img.jpg\)](#)

$$ex \quad 49.045 \text{ N/mm}^2 = 0.577 \cdot 85 \text{ N/mm}^2$$




11) Shear Yield Strength by Maximum Distortion Energy Theory 

$$f_x \sigma_{sy} = 0.577 \cdot \sigma_y$$

Open Calculator 

$$ex \ 49.045 \text{N/mm}^2 = 0.577 \cdot 85 \text{N/mm}^2$$

12) Strain Energy due to Change in Volume given Principal Stresses 

$$f_x U_v = \frac{(1 - 2 \cdot \nu)}{6 \cdot E} \cdot (\sigma_1 + \sigma_2 + \sigma_3)^2$$

Open Calculator 


$$ex \ 7.602751 \text{kJ/m}^3 = \frac{(1 - 2 \cdot 0.3)}{6 \cdot 190 \text{GPa}} \cdot (35.2 \text{N/mm}^2 + 47 \text{N/mm}^2 + 65 \text{N/mm}^2)^2$$

13) Strain Energy due to Change in Volume given Volumetric Stress 

$$f_x U_v = \frac{3}{2} \cdot \sigma_v \cdot \varepsilon_v$$

Open Calculator 


$$ex \ 101.4 \text{kJ/m}^3 = \frac{3}{2} \cdot 52 \text{N/mm}^2 \cdot 0.0013$$

14) Strain Energy due to Change in Volume with No Distortion 


$$f_x U_v = \frac{3}{2} \cdot \frac{(1 - 2 \cdot \nu) \cdot \sigma_v^2}{E}$$

Open Calculator 

$$ex \ 8.538947 \text{kJ/m}^3 = \frac{3}{2} \cdot \frac{(1 - 2 \cdot 0.3) \cdot (52 \text{N/mm}^2)^2}{190 \text{GPa}}$$

15) Stress due to Change in Volume with No Distortion 

$$f_x \sigma_v = \frac{\sigma_1 + \sigma_2 + \sigma_3}{3}$$

Open Calculator 

$$ex \ 49.06667 \text{N/mm}^2 = \frac{35.2 \text{N/mm}^2 + 47 \text{N/mm}^2 + 65 \text{N/mm}^2}{3}$$


16) Tensile Yield Strength by Distortion Energy Theorem 

$$f_x \sigma_y = \sqrt{\frac{1}{2} \cdot \left((\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 \right)}$$

Open Calculator 

$$ex \ 25.99308 \text{N/mm}^2 = \sqrt{\frac{1}{2} \cdot \left((35.2 \text{N/mm}^2 - 47 \text{N/mm}^2)^2 + (47 \text{N/mm}^2 - 65 \text{N/mm}^2)^2 + (65 \text{N/mm}^2 - 35.2 \text{N/mm}^2)^2 \right)}$$



17) Tensile Yield Strength by Distortion Energy Theorem Considering Factor of Safety [Open Calculator](#) 

$$f_x \sigma_y = f_s \cdot \sqrt{\frac{1}{2} \cdot \left((\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 \right)}$$

ex


$$51.98615 \text{N/mm}^2 = 2 \cdot \sqrt{\frac{1}{2} \cdot \left((35.2 \text{N/mm}^2 - 47 \text{N/mm}^2)^2 + (47 \text{N/mm}^2 - 65 \text{N/mm}^2)^2 + (65 \text{N/mm}^2 - 35.2 \text{N/mm}^2)^2 \right)}$$

18) Tensile Yield Strength for Biaxial Stress by Distortion Energy Theorem Considering Factor of Safety [Open Calculator](#) 

$$f_x \sigma_y = f_s \cdot \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1 \cdot \sigma_2}$$

ex


$$84.70277 \text{N/mm}^2 = 2 \cdot \sqrt{(35.2 \text{N/mm}^2)^2 + (47 \text{N/mm}^2)^2 - 35.2 \text{N/mm}^2 \cdot 47 \text{N/mm}^2}$$

19) Total Strain Energy per Unit Volume [Open Calculator](#) 

$$f_x U_{\text{Total}} = U_d + U_v$$

ex

$$31 \text{kJ/m}^3 = 15 \text{kJ/m}^3 + 16 \text{kJ/m}^3$$

20) Volumetric Strain with No Distortion [Open Calculator](#) 

$$f_x \varepsilon_v = \frac{(1 - 2 \cdot \nu) \cdot \sigma_v}{E}$$

ex

$$0.000109 = \frac{(1 - 2 \cdot 0.3) \cdot 52 \text{N/mm}^2}{190 \text{GPa}}$$






Variables Used

- **E** Young's Modulus of Specimen (Gigapascal)
- **f_s** Factor of Safety
- **S_{sy}** Shear Yield Strength (Newton per Square Millimeter)
- **S_{uc}** Ultimate Compressive Stress (Newton per Square Millimeter)
- **S_{ut}** Ultimate Tensile Strength (Newton per Square Millimeter)
- **S_{yc}** Compressive Yield Strength (Newton per Square Millimeter)
- **U_d** Strain Energy for Distortion (Kilojoule per Cubic Meter)
- **U_{Total}** Total Strain Energy (Kilojoule per Cubic Meter)
- **U_v** Strain Energy for Volume Change (Kilojoule per Cubic Meter)
- **ε_v** Strain for Volume Change
- **σ₁** First Principal Stress (Newton per Square Millimeter)
- **σ₂** Second Principal Stress (Newton per Square Millimeter)
- **σ₃** Third Principal Stress (Newton per Square Millimeter)
- **σ_{al}** Allowable Stress for Static Load (Newton per Square Millimeter)
- **σ_v** Stress for Volume Change (Newton per Square Millimeter)
- **σ_y** Tensile Yield Strength (Newton per Square Millimeter)
- **ν** Poisson's Ratio




Constants, Functions, Measurements used

- **Function:** **sqrt**, $\text{sqrt}(\text{Number})$
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:** **Pressure** in Gigapascal (GPa)
Pressure Unit Conversion 
- **Measurement:** **Energy Density** in Kilojoule per Cubic Meter (kJ/m^3)
Energy Density Unit Conversion 
- **Measurement:** **Stress** in Newton per Square Millimeter (N/mm^2)
Stress Unit Conversion 



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