Important Rolling Process Formulas PDF

Formulas
Examples
with Units

List of 18
Important Rolling Process Formulas

1) Analysis at Entry Region Formulas

1.1) Mean Yield Shear Stress given Pressure on Entry Side Formula

Evaluate Formula

Formula

$$S_e = \frac{P_{en} \cdot \frac{h_{in}}{h_e}}{\exp\left(\mu_{rp} \cdot \left(H_{in} - H_x\right)\right)}$$

Example with Units

$$4359.6965\,\mathrm{Pa} = \frac{0.0000099\,\mathrm{N/mm^2} \cdot \frac{3.5\,\mathrm{mm}}{0.011\,\mathrm{mm}}}{\exp\left(0.5 \cdot \left(3.35 - 4\right)\right)}$$

1.2) Pressure Acting on Rolls from Entry Side Formula

Evaluate Formula

Formula

$$P_{en} = S_e \cdot \frac{h_e}{h_{in}} \cdot \exp\left(\mu_{rp} \cdot \left(2 \cdot \sqrt{\frac{R_{roller}}{h_f}} \cdot \mathrm{atan}\left(\Theta_r \cdot \sqrt{\frac{R_{roller}}{h_f}}\right) - 2 \cdot \sqrt{\frac{R_{roller}}{h_f}} \cdot \mathrm{atan}\left(\alpha_{bite} \cdot \sqrt{\frac{R_{roller}}{h_f}}\right)\right)\right)$$

Example with Units

$$3.5\mathrm{E}{-6}\,\mathrm{N/mm^2} = 4359.69\,\mathrm{Pa} \cdot \frac{0.011\,\mathrm{mm}}{3.5\,\mathrm{mm}} \cdot \exp\left(0.5 \cdot \left(2 \cdot \sqrt{\frac{104\,\mathrm{mm}}{7.5\,\mathrm{mm}}} \cdot \mathrm{atan}\left(18.5° \cdot \sqrt{\frac{104\,\mathrm{mm}}{7.5\,\mathrm{mm}}}\right) - 2 \cdot \sqrt{\frac{104\,\mathrm{mm}}{7.5\,\mathrm{mm}}} \cdot \mathrm{atan}\left(45.00° \cdot \sqrt{\frac{104\,\mathrm{mm}}{7.5\,\mathrm{mm}}}\right)\right)\right)$$

1.3) Pressure on Rolls given H (Entry Side) Formula

Evaluate Formula

Formula

$$P_{en} = S_e \cdot \frac{h_e}{h_{in}} \cdot \exp\left(\mu_{rp} \cdot \left(H_{in} - H_x\right)\right)$$

Example with Units

$$9.9\mathrm{E}{-6}\,\mathrm{N/mm^2} = 4359.69\,\mathrm{Pa} \cdot \frac{0.011\,\mathrm{mm}}{3.5\,\mathrm{mm}} \cdot \exp\left(0.5 \cdot \left(3.35 - 4\right)\right)$$

1.4) Thickness of Stock at given Point on Entry Side Formula

Evaluate Formula

Formula

$$h_e = \frac{P_{en} \cdot h_{in}}{S_e \cdot \exp\left(\mu_{rp} \cdot \left(H_{in} - H_x\right)\right)}$$

Example with Units

$$0.011\,\mathrm{mm} = \frac{0.0000099\,\mathrm{N/mm^2} \cdot 3.5\,\mathrm{mm}}{4359.69\,\mathrm{Pa} \cdot \exp\left(0.5 \cdot \left(3.35 - 4\right)\right)}$$

2) Analysis at Exit Region Formulas

2.1) Mean Yield Shear Stress using Pressure on Exit Side Formula

Evaluate Formula

Formula

$$S_y = \frac{P_{rolls} \cdot h_{ft}}{h_x \cdot \exp\left(\mu_r \cdot H\right)}$$

Example with Units

$$22027.006\,\mathrm{Pa} = \frac{0.000190\,\mathrm{N/mm^2} \cdot 7.3\,\mathrm{mm}}{0.003135\,\mathrm{mm} \cdot \exp\left(0.6 \cdot 5\right)}$$

2.2) Pressure Acting on Rolls in Exit Region Formula

Evaluate Formula

Formula

$$P_{ex} = S_y \cdot \frac{h_x}{h_{ft}} \cdot \exp\left(\mu_r \cdot 2 \cdot \sqrt{\frac{R_{roll}}{h_{ft}}} \cdot atan\left(\Theta_r \cdot \sqrt{\frac{R_{roll}}{h_{ft}}}\right)\right)$$

Example with Units

$$0.0005\,\text{N/mm}^2 = 22027.01\,\text{Pa} \cdot \frac{0.003135\,\text{mm}}{7.3\,\text{mm}} \cdot \exp\left(0.6 \cdot 2 \cdot \sqrt{\frac{100\,\text{mm}}{7.3\,\text{mm}}} \cdot atan\left(18.5° \cdot \sqrt{\frac{100\,\text{mm}}{7.3\,\text{mm}}}\right)\right)$$

2.3) Pressure on Rolls given H (Exit Side) Formula

Evaluate Formula

Formula

$$P_{rolls} = S_y \cdot \frac{h_x}{h_{ft}} \cdot \exp\left(\mu_r \cdot H\right)$$

Example with Units

$$0.0002\,\text{N/mm}^2 = 22027.01\,\text{Pa} \cdot \frac{0.003135\,\text{mm}}{7.3\,\text{mm}} \cdot \exp\left(0.6 \cdot 5\right)$$

2.4) Thickness of Stock at given Point on Exit Side Formula

Evaluate Formula

Formula

$$h_x = \frac{P_{rolls} \cdot h_{ft}}{S_y \cdot \exp\left(\mu_r \cdot H\right)}$$

Example with Units

$$0.0031\,\text{mm} = \frac{0.000190\,\text{N/mm}^2 \cdot 7.3\,\text{mm}}{22027.01\,\text{Pa} \cdot \exp\left(0.6 \cdot 5\right)}$$

3) Rolling Analysis Formulas

3.1) Angle Subtended by Neutral Point Formula

Evaluate Formula

Formula

$$\varphi_n = \sqrt{\frac{h_{fi}}{R}} \cdot \tan\left(\frac{H_n}{2} \cdot \sqrt{\frac{h_{fi}}{R}}\right)$$

Example with Units

$$5.5182° = \sqrt{\frac{7.2\,\text{mm}}{102\,\text{mm}}} \cdot \tan\left(\frac{2.617882}{2} \cdot \sqrt{\frac{7.2\,\text{mm}}{102\,\text{mm}}}\right)$$

3.2) Bite Angle Formula

Evaluate Formula

Formula

$$\alpha_b = acos\left(1 - \frac{h}{2 \cdot R}\right)$$

Example with Units

$$30.0388° = acos\left(1 - \frac{27.4\,\text{mm}}{2 \cdot 102\,\text{mm}}\right)$$

3.3) Factor H at Neutral Point Formula

Evaluate Formula

Formula

$$H_n = \frac{H_i - \frac{\ln\left(\frac{h_i}{h_{fi}}\right)}{\mu_f}}{2}$$

Example with Units

$$2.6179 = \frac{3.36 - \frac{\ln\left(\frac{3.4\,\text{mm}}{7.2\,\text{mm}}\right)}{0.4}}{2}$$

3.4) Factor H used in Rolling Calculations Formula

Evaluate Formula

Formula

$$H_r = 2 \cdot \sqrt{\frac{R}{h_{fi}}} \cdot atan\left(\sqrt{\frac{R}{h_{fi}}}\right) \cdot \Theta_r$$

Example with Units

$$3.1868 = 2 \cdot \sqrt{\frac{102\,\text{mm}}{7.2\,\text{mm}}} \cdot atan\left(\sqrt{\frac{102\,\text{mm}}{7.2\,\text{mm}}}\right) \cdot 18.5°$$

3.5) Initial Stock Thickness given Pressure on Rolls Formula

Evaluate Formula

Formula

$$h_t = \frac{S \cdot h_s \cdot \exp\left(\mu_f \cdot \left(H_i - H_r\right)\right)}{P}$$

Example with Units

$$1.0472\,\text{mm} = \frac{58730\,\text{Pa} \cdot 0.00313577819561353\,\text{mm} \cdot \exp\left(0.4 \cdot \left(3.36 - 3.18\right)\right)}{0.000189\,\text{N/mm}^2}$$

3.6) Maximum Reduction in Thickness Possible Formula

Evaluate Formula

Formula

$$\Delta t = {\mu_f}^2 \cdot R$$

Example with Units

$$16.32\,\text{mm} = 0.4^2 \cdot 102\,\text{mm}$$

3.7) Pressure Considering Rolling Similar to Plane-Strain-Upsetting Process Formula

Evaluate Formula

Formula

$$P_r = b \cdot \frac{2 \cdot \sigma}{\sqrt{3}} \cdot \left(1 + \frac{\mu_{sf} \cdot R \cdot \frac{\pi}{180} \cdot \alpha_b}{2 \cdot \left(h_i + h_{fi}\right)}\right) \cdot R \cdot \frac{\pi}{180} \cdot \alpha_b$$

Example with Units

$$3.3\text{E-}5\,\text{N/mm}^2 = 14.5\,\text{mm} \cdot \frac{2 \cdot 2.1\,\text{N/mm}^2}{\sqrt{3}} \cdot \left(1 + \frac{0.41 \cdot 102\,\text{mm} \cdot \frac{3.1416}{180} \cdot 30.00^\circ}{2 \cdot \left(3.4\,\text{mm} + 7.2\,\text{mm}\right)}\right) \cdot 102\,\text{mm} \cdot \frac{3.1416}{180} \cdot 30.00^\circ$$

3.8) Projected Area Formula

Evaluate Formula

Formula

$$A = w \cdot \left(R \cdot \Delta t\right)^{0.5}$$

Example with Units

$$1.224\,\text{cm}^2 = 3\,\text{mm} \cdot \left(102\,\text{mm} \cdot 16.32\,\text{mm}\right)^{0.5}$$

3.9) Projected Length Formula

Evaluate Formula

Formula

$$L = \left(R \cdot \Delta t\right)^{0.5}$$

Example with Units

$$40.8\,\text{mm} = \left(102\,\text{mm} \cdot 16.32\,\text{mm}\right)^{0.5}$$

3.10) Total Elongation of Stock Formula

Evaluate Formula

Formula

$$E = \frac{A_i}{A_f}$$

Example with Units

$$6.6667 = \frac{60\,\text{cm}^2}{9\,\text{cm}^2}$$

Variables used in list of Rolling Process Formulas above

- **A** Projected Area *(Square Centimeter)*
- **A_f** Final Cross Sectional Area *(Square Centimeter)*
- **A_i** Initial Cross Sectional Area *(Square Centimeter)*
- **b** Strip Width of Spiral Spring *(Millimeter)*
- **E** Total Stock or Workpiece Elongation
- **h** Height *(Millimeter)*
- **H** Factor H at given Point on Workpiece
- **h_e** Thickness at Entry *(Millimeter)*
- **h_f** Final Thickness after Rolling *(Millimeter)*
- **h_{fi}** Thickness after Rolling *(Millimeter)*
- **h_{ft}** Final Thickness *(Millimeter)*
- **h_i** Thickness before Rolling *(Millimeter)*
- **H_i** Factor H at Entry Point on Workpiece
- **h_{in}** Initial Thickness *(Millimeter)*
- **H_{in}** H Factor at Entry Point on Workpiece
- **H_n** Factor H at Neutral Point
- **H_r** Factor H in Rolling Calculation
- **h_s** Thickness at given Point *(Millimeter)*
- **h_t** Initial Stock Thickness *(Millimeter)*
- **h_x** Thickness at the given Point *(Millimeter)*
- **H_x** Factor H at a Point on Workpiece
- **L** Projected Length *(Millimeter)*
- **P** Pressure Acting on Rolls *(Newton per Square Millimeter)*
- **P_{en}** Pressure Acting at Entry *(Newton per Square Millimeter)*
- **P_{ex}** Pressure Acting on Exit *(Newton per Square Millimeter)*
- **P_r** Pressure Acting while Rolling *(Newton per Square Millimeter)*
- **P_{rolls}** Pressure on Roller *(Newton per Square Millimeter)*
- **R** Roller Radius *(Millimeter)*
- **R_{roll}** Roll Radius *(Millimeter)*
- **R_{roller}** Radius of Roller *(Millimeter)*
- **S** Mean Yield Shear Stress of Work Material *(Pascal)*
- **S_e** Mean Yield Shear Stress *(Pascal)*
- **S_y** Mean Yield Shear Stress at Exit *(Pascal)*
- **w** Width *(Millimeter)*
- **α_b** Bite Angle *(Degree)*
- **α_{bite}** Angle of Bite *(Degree)*
- **Δt** Change in Thickness *(Millimeter)*
- **Θ_r** Angle made by Point Roll Center and Normal *(Degree)*
- **μ_f** Friction Coefficient in Rolling Analysis

Constants, Functions, Measurements used in list of Rolling Process 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: **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: **exp**, exp(Number)
  n an exponential function, the value of the function changes by a constant factor for every unit change in the independent variable.
- Functions: **ln**, ln(Number)
  The natural logarithm, also known as the logarithm to the base e, is the inverse function of the natural exponential function.
- 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.
- 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: **Area** in Square Centimeter (cm²)
  Area Unit Conversion
- Measurement: **Pressure** in Newton per Square Millimeter (N/mm²)
  Pressure Unit Conversion
- Measurement: **Angle** in Degree (°)
  Angle Unit Conversion
- Measurement: **Stress** in Pascal (Pa)
  Stress Unit Conversion

- μ_r Friction Coefficient
- μ_{rp} Coefficient of Friction
- μ_{sf} Frictional Shear Factor
- σ Flow Stress of Work Material *(Newton per Square Millimeter)*
- φ_n Angle subtended at Neutral Point *(Degree)*

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