Important Flow over Airfoils and Wings Formulas PDF

Formulas
Examples
with Units

List of 26
Important Flow over Airfoils and Wings Formulas

1) Flow over Airfoils Formulas

1.1) Boundary Layer Thickness for Laminar Flow Formula

Evaluate Formula

Formula

$$\delta_L = 5 \cdot \frac{x}{\sqrt{Re_L}}$$

Example with Units

$$0.2475\,\mathrm{m} = 5 \cdot \frac{2.10\,\mathrm{m}}{\sqrt{1800}}$$

1.2) Boundary Layer Thickness for Turbulent Flow Formula

Evaluate Formula

Formula

$$\delta_T = 0.37 \cdot \frac{x}{Re_T^{\frac{1}{5}}}$$

Example with Units

$$0.1519\,\mathrm{m} = 0.37 \cdot \frac{2.10\,\mathrm{m}}{3500^{\frac{1}{5}}}$$

1.3) Center of Pressure Location for Cambered Airfoil Formula

Evaluate Formula

Formula

$$x_{cp} = -\frac{C_{m,le} \cdot c}{C_L}$$

Example with Units

$$0.75\,\mathrm{m} = -\frac{-0.3 \cdot 3\,\mathrm{m}}{1.2}$$

1.4) Lift Coefficient for Cambered Airfoil Formula

Evaluate Formula

Formula

$$C_{L,cam} = 2 \cdot \pi \cdot \left(\left(\alpha \right) - \left(\alpha_0 \right) \right)$$

Example with Units

$$1.419 = 2 \cdot 3.1416 \cdot \left(\left(10.94° \right) - \left(-2° \right) \right)$$

1.5) Lift Coefficient for Symmetrical Airfoil by Thin Airfoil Theory Formula

Evaluate Formula

Formula

$$C_L = 2 \cdot \pi \cdot \alpha$$

Example with Units

$$1.1997 = 2 \cdot 3.1416 \cdot 10.94°$$

1.6) Moment Coefficient about Leading-Edge for Symmetrical Airfoil by Thin Airfoil Theory Formula

Evaluate Formula

Formula

$$C_{m,le} = -\frac{C_L}{4}$$

Example

$$-0.3 = -\frac{1.2}{4}$$

1.7) Skin Friction Drag Coefficient for Flat Plate in Laminar Flow Formula

Evaluate Formula

Formula

$$C_f = \frac{1.328}{\sqrt{Re_L}}$$

Example

$$0.0313 = \frac{1.328}{\sqrt{1800}}$$

1.8) Skin Friction Drag Coefficient for Flat Plate in Turbulent Flow Formula

Evaluate Formula

Formula

$$C_f = \frac{0.074}{Re_T^{\frac{1}{5}}}$$

Example

$$0.0145 = \frac{0.074}{3500^{\frac{1}{5}}}$$

2) Flow over Wings Formulas

2.1) 2D Lift Curve Slope of Airfoil given Lift Slope of Elliptic Finite Wing Formula

Evaluate Formula

Formula

$$a_0 = \frac{a_{C,l}}{1 - \frac{a_{C,l}}{\pi \cdot AR}}$$

Example with Units

$$6.2781\,\text{rad}^{-1} = \frac{5.54\,\text{rad}^{-1}}{1 - \frac{5.54\,\text{rad}^{-1}}{3.1416 \cdot 15}}$$

2.2) 2D Lift Curve Slope of Airfoil given Lift Slope of Finite Wing Formula

Evaluate Formula

Formula

$$a_0 = \frac{a_{C,l}}{1 - \frac{a_{C,l} \cdot (1 + \tau)}{\pi \cdot AR}}$$

Example with Units

$$6.3244\,\text{rad}^{-1} = \frac{5.54\,\text{rad}^{-1}}{1 - \frac{5.54\,\text{rad}^{-1} \cdot (1 + 0.055)}{3.1416 \cdot 15}}$$

2.3) Aspect Ratio given Span Efficiency Factor Formula

Evaluate Formula

Formula

$$AR = \frac{C_L^{\,2}}{\pi \cdot e_{span} \cdot C_{D,i}}$$

Example

$$15.0309 = \frac{1.2^2}{3.1416 \cdot 0.95 \cdot 0.0321}$$

2.4) Aspect Ratio of Wing given Lift Curve Slope of Elliptic Finite Wing Formula

Evaluate Formula

Formula

$$AR = \frac{a_0}{\pi \cdot \left(\frac{a_0}{a_{C,l}} - 1\right)}$$

Example with Units

$$14.9654 = \frac{6.28\,\text{rad}^{-1}}{3.1416 \cdot \left(\frac{6.28\,\text{rad}^{-1}}{5.54\,\text{rad}^{-1}} - 1\right)}$$

2.5) Aspect Ratio of Wing given Lift Curve Slope of Finite Wing Formula

Evaluate Formula

Formula

$$AR = \frac{a_0 \cdot (1 + \tau)}{\pi \cdot \left(\frac{a_0}{a_{C,l}} - 1 \right)}$$

Example with Units

$$15.7885 = \frac{6.28\,\text{rad}^{-1} \cdot (1 + 0.055)}{3.1416 \cdot \left(\frac{6.28\,\text{rad}^{-1}}{5.54\,\text{rad}^{-1}} - 1 \right)}$$

2.6) Effective Angle of Attack of Finite Wing Formula

Evaluate Formula

Formula

$$\alpha_{eff} = \alpha_g - \alpha_i$$

Example with Units

$$8° = 12° - 4°$$

2.7) Geometric Angle of Attack given Effective Angle of Attack Formula

Evaluate Formula

Formula

$$\alpha_g = \alpha_{eff} + \alpha_i$$

Example with Units

$$12° = 8° + 4°$$

2.8) Induced Angle of Attack given Effective Angle of Attack Formula

Evaluate Formula

Formula

$$\alpha_i = \alpha_g - \alpha_{eff}$$

Example with Units

$$4° = 12° - 8°$$

2.9) Lift Curve Slope for Elliptic Finite Wing Formula

Evaluate Formula

Formula

$$a_{C,l} = \frac{a_0}{1 + \frac{a_0}{\pi \cdot AR}}$$

Example with Units

$$5.5415\,\text{rad}^{-1} = \frac{6.28\,\text{rad}^{-1}}{1 + \frac{6.28\,\text{rad}^{-1}}{3.1416 \cdot 15}}$$

2.10) Lift Curve Slope for Finite Wing Formula

Evaluate Formula

Formula

$$a_{C,l} = \frac{a_0}{1 + \frac{a_0 \cdot (1 + \tau)}{\pi \cdot AR}}$$

Example with Units

$$5.5059\,\text{rad}^{-1} = \frac{6.28\,\text{rad}^{-1}}{1 + \frac{6.28\,\text{rad}^{-1} \cdot (1 + 0.055)}{3.1416 \cdot 15}}$$

2.11) Oswald Efficiency Factor Formula

Evaluate Formula

Formula

$$e_{osw} = 1.78 \cdot \left(1 - 0.045 \cdot AR^{0.68} \right) - 0.64$$

Example

$$0.6349 = 1.78 \cdot \left(1 - 0.045 \cdot 15^{0.68} \right) - 0.64$$

3) Induced Drag Formulas

3.1) Induced Drag Coefficient Formula

Evaluate Formula

Formula

$$C_{D,i} = \frac{D_i}{q_\infty \cdot S}$$

Example with Units

$$0.0394 = \frac{101\,\text{N}}{450\,\text{Pa} \cdot 5.7\,\text{m}^2}$$

3.2) Induced Drag Coefficient given Total Drag Coefficient Formula

Evaluate Formula

Formula

$$C_{D,i} = C_D - c_d$$

Example

$$0.0321 = 0.0771 - 0.045$$

3.3) Profile Drag Coefficient Formula

Evaluate Formula

Formula

$$c_d = \frac{F_{skin} + D_p}{q_\infty \cdot S}$$

Example with Units

$$0.0452 = \frac{100\,\text{N} + 16\,\text{N}}{450\,\text{Pa} \cdot 5.7\,\text{m}^2}$$

3.4) Profile Drag Coefficient given Total Drag Coefficient Formula

Evaluate Formula

Formula

$$c_d = C_D - C_{D,i}$$

Example

$$0.045 = 0.0771 - 0.0321$$

3.5) Total Drag Coefficient for Subsonic Finite Wing Formula

Evaluate Formula

Formula

$$C_D = c_d + C_{D,i}$$

Example

$$0.0771 = 0.045 + 0.0321$$

3.6) Velocity Induced at Point by Infinite Straight Vortex Filament Formula

Evaluate Formula

Formula

$$v_i = \frac{\gamma}{2 \cdot \pi \cdot h}$$

Example with Units

$$3.9038\,\text{m/s} = \frac{13\,\text{m}^2/\text{s}}{2 \cdot 3.1416 \cdot 0.53\,\text{m}}$$

3.7) Velocity Induced at Point by Semi-infinite Straight Vortex Filament Formula

Evaluate Formula

Formula

$$v_i = \frac{\gamma}{4 \cdot \pi \cdot h}$$

Example with Units

$$1.9519\,\text{m/s} = \frac{13\,\text{m}^2/\text{s}}{4 \cdot 3.1416 \cdot 0.53\,\text{m}}$$

Variables used in list of Flow over Airfoils and Wings Formulas above

- a_0 2D Lift Curve Slope *(1 per Radian)*
- $a_{C,l}$ Lift Curve Slope *(1 per Radian)*
- **AR** Wing Aspect Ratio
- **c** Chord *(Meter)*
- c_d Profile Drag Coefficient
- C_D Total Drag Coefficient
- $C_{D,i}$ Induced Drag Coefficient
- C_f Skin Friction Drag Coefficient
- C_L Lift Coefficient
- $C_{L,cam}$ Lift Coefficient for Cambered Airfoil
- $C_{m,le}$ Moment Coefficient about Leading Edge
- D_i Induced Drag *(Newton)*
- D_p Pressure Drag Force *(Newton)*
- e_{osw} Oswald Efficiency Factor
- e_{span} Span Efficiency Factor
- F_{skin} Skin Friction Drag Force *(Newton)*
- **h** Perpendicular Distance to Vortex *(Meter)*
- q_∞ Free Stream Dynamic Pressure *(Pascal)*
- Re_L Reynolds Number for Laminar Flow
- Re_T Reynolds Number for Turbulent Flow
- **S** Reference Area *(Square Meter)*
- v_i Induced Velocity *(Meter per Second)*
- **x** Distance on X-Axis *(Meter)*
- x_{cp} Center of Pressure *(Meter)*
- α Angle of Attack *(Degree)*
- α_0 Angle of Zero Lift *(Degree)*
- α_{eff} Effective Angle of Attack *(Degree)*
- α_g Geometric Angle of Attack *(Degree)*
- α_i Induced Angle of Attack *(Degree)*
- γ Vortex Strength *(Square Meter per Second)*
- δ_L Laminar Boundary Layer Thickness *(Meter)*

Constants, Functions, Measurements used in list of Flow over Airfoils and Wings 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 Meter (m)
  Length Unit Conversion
- Measurement: **Area** in Square Meter (m²)
  Area Unit Conversion
- Measurement: **Pressure** in Pascal (Pa)
  Pressure Unit Conversion
- Measurement: **Speed** in Meter per Second (m/s)
  Speed Unit Conversion
- Measurement: **Force** in Newton (N)
  Force Unit Conversion
- Measurement: **Angle** in Degree (°)
  Angle Unit Conversion
- Measurement: **Reciprocal Angle** in 1 per Radian (rad^{-1})
  Reciprocal Angle Unit Conversion
- Measurement: **Velocity Potential** in Square Meter per Second (m^2/s)
  Velocity Potential Unit Conversion

- δ_T Turbulent Boundary Layer Thickness *(Meter)*
- τ Induced Lift Slope Factor