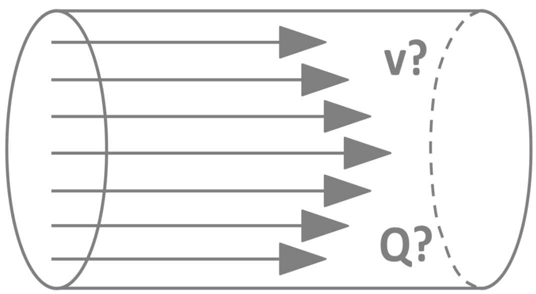
Flow rate and Friction factor calculation

This application calculate Darcy-Weishbach friction factor and Flow velocity/Volume flow rate for a straight pipe.



Laminar flow $f = \frac{64}{Rev}$

Turbulent flow $\frac{1}{\sqrt{f}} = -2 \cdot \log10\left(\frac{\frac{\epsilon}{D_{pipe}}}{3.7} + \frac{2.51}{Rey \cdot \sqrt{f}}\right)$

Fluid velocity $v = \sqrt{\frac{2 \cdot g \cdot D \cdot h_L}{f \cdot L}}$

Design parameters

In this section, the type of fluid, pressure, temperature, and the geometrical parameters are defined for the calculation later.

Fluid properties

Fluid FluidName := "water"

Pressure at Design point $P_{dp} := 14.7\ \mathbf{psi}$

Temperature at Design point $T_{dp\_F} := 60\ \mathbf{degF}$

Allowable Head loss $h_L := 0.9\ \mathbf{ft}$

Geometrical parameters

Pipe diameter $D_{pipe} := 4\ \mathbf{inch}$

Pipe roughness $\epsilon := 0.0005\ \mathbf{ft}$

Pipe length $L := 40\ \mathbf{ft}$

Others

Gravity $g := 32.17\ \frac{\mathbf{ft}}{\mathbf{s}^2}$

Fuild properties

Density and viscosity of fluid can be obtained with the fluid properties specified in the previous section.

Temperature at Design point in Kelvin

$T_{dp\_K} := \text{temperature\_conversion}\left(T_{dp\_F}, \text{"degF"}, \text{"K"}\right) = 288.706\ \mathrm{K}$

Note:
Function calls in ThermophysicalData package is better to be with temperature in Kelvin.
The unit of temperature can be converted with temperature_conversion() function defined in the Code region.

Density

$\rho := \text{ThermophysicalData:-Property}\left(\text{density}, \text{FluidName}, \text{pressure} = P_{dp}, \text{temperature} = T_{dp\_K}, \text{useunits}\right)$

$\rho = 62.367\ \frac{\mathrm{lb}}{\mathrm{ft}^3}$

Viscosity

$\mu := \text{ThermophysicalData:-Property}\left(\text{viscosity}, \text{FluidName}, \text{pressure} = P_{dp}, \text{temperature} = T_{dp\_K}, \text{useunits}\right)$

$\mu = 753.30 \times 10^{-6}\ \frac{\mathrm{lb}}{\mathrm{ft} \cdot \mathrm{s}}$

Darcy-Wiesbach friction factor and Flow velocity, Volume flow rate

Obtain Reynolds number as a function of flow velocity.

Reynolds number $$Rey := \frac{D_{pipe} \cdot \rho \cdot \left(v \frac{m}{s}\right)}{\mu} = 9.054 \times 10^{4} \cdot v$$

The friction factor for both laminar and turbulent flow can be obtained as function of flow velocity as well.

Laminar flow $$f_{laminar} := \frac{64}{Rey} = \frac{7.069 \times 10^{-4}}{v}$$

Turbulent flow $$f_{turbulent} := \frac{1}{\sqrt{f}} = -2.0 \cdot \log10\left(\frac{\frac{\epsilon}{D_{pipe}}}{3.7} + \frac{2.51}{Rey \cdot \sqrt{f}} \right)$$

$$f_{turbulent\_sol} := \text{solve}\left(f_{turbulent}, f\right)$$

Note:
Coolbrook-White equation for Darcy-Weisbach friction factor of Turbulent flow can be solved by using Lambert W function internally in Maple Flow.

$$f_{turbulent\_sol} = \frac{1.921 \times 10^{38}}{\left(1.204 \times 10^{19} \cdot \text{LambertW}\left(4.153 \times 10^{4} \cdot v \cdot e^{16.836 \cdot v}\right) - 2.027 \times 10^{20} \cdot v\right)^{2}}$$

And, the friction factor is defined based on the value of Reynolds number.

Friction factor $$f_D := \begin{cases} f_{laminar} & Rey < 4000 \\ f_{turbulent\_sol} & Rey \geq 4000 \end{cases}$$

Thus, by using a equation of flow velocity with the above friction factor, flow velocity can be obtained with fsolve() function.

Flow velocity equation $$FVeq := \left(v \frac{m}{s}\right)^{2} = \frac{2 \cdot g \cdot D_{pipe} \cdot h_L}{f_D \cdot L}$$

Flow velocity (Solution) $$v_{sol} := \text{fsolve}(FVeq) \cdot \frac{m}{s} = 4.544 \frac{ft}{s}$$

Therefore, the volume flow rate is calculated with the following equation.

Volume flow rate $$Q := v_{sol} \cdot \pi \cdot \left(\frac{D_{pipe}}{2}\right)^{2} = 0.397 \frac{ft^{3}}{s}$$