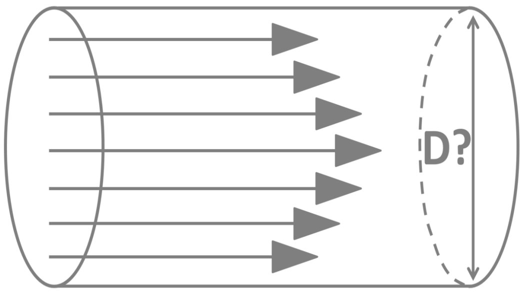
Diameter and Friction factor calculation

This application calculate Darcy-Weishbach friction factor and Diameter for a straight pipe.



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

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

Diameter $D = f \cdot \frac{L}{h_L} \cdot \frac{v^2}{2 \cdot g}$

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 $P_{dp} := 14.7\ psi$

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

Allowable Head loss $h_L := 20\ ft$

Pipe flow rate $Q := 0.6\ \frac{ft^3}{s}$

Geometrical parameters

Pipe roughness $\epsilon := 0.0005\ ft$

Pipe length $L := 100\ ft$

Others

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

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

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

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

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

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

Viscosity

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

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

Darcy-Wiesbach friction factor and Diameter

Obtain Reynolds number as a function of flow velocity.

Flow velocity

$$v := \frac{Q}{\pi \cdot \left(\frac{D_{pipe}}{2} \cdot \mathbf{ft}\right)^2} = \frac{0.764\ \frac{\mathbf{ft}}{\mathbf{s}}}{D_{pipe}^{\,2}}$$

Reynolds number

$$Rey := \frac{\left(D_{pipe} \cdot \mathbf{ft}\right) \cdot \rho \cdot v}{\mu} = \frac{6.325 \times 10^4}{D_{pipe}}$$

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

Laminar flow

$$f_{laminar} := \frac{64}{Rey} = 0.001 \cdot D_{pipe}$$

Turbulent flow

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

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

Note:
Coolbrook-White equation for Darcy-Weisbach friction factor of Turbulent flow can be solved

$$f_{turbulent\_sol} = \frac{9.843 \times 10^{37} \cdot D_{pipe}^{4}}{\left(8.618 \times 10^{18} \cdot LambertW\left(\frac{2.901 \times 10^{4} \cdot e^{\frac{3.920}{D_{pipe}^{2}}}}{D_{pipe}}\right) \cdot D_{pipe}^{2} - 3.378 \times 10^{19}\right)^{2}}$$

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 Diameter with the above friction factor, Diameter can be obtained with fsolve() function.

Diameter equation

$$Deq := \left(D_{pipe} \cdot ft\right) = f_D \cdot \frac{L}{h_L} \cdot \frac{v^2}{2 \cdot g}$$

Diameter (solution)

$$D_{res} := fsolve\left(Deq, D_{pipe}, 0..2\right) \cdot ft = 0.256\ ft$$

$$D_{res} = 3.066\ in$$