Coriolis Flowmeter

About Us | Trade Show | Career | News | Chat | InfoStore | SpecSearch® | Ask an Expert

Design Home

- **Sensors**
  - Sensor Home
  - Instruments/Devices
  - Methods/Principles
  - Displacement
  - Stress & Strain
  - Pressure
  - Fluid Flow
  - Flowmeter
    - Introduction
    - Categorization
    - Selection
    - Coriolis
    - Differential Pressure
    - Magnetic
    - Positive Displacement
    - Target
    - Thermal
    - Turbine
    - Ultrasonic
      - Transit Time
      - Doppler
    - Variable Area
    - Vortex
  - Temperature
- **Resources**
  - Bibliography
- **Free Magazines**
  - PartSpec (CD)
  - CADBlocks (CD)
  - Desktop Engineering
  - Machine Lubrication
  - Processing Magazine
  - Portable Design
  - Reinforced Plastics
  - more...

Login

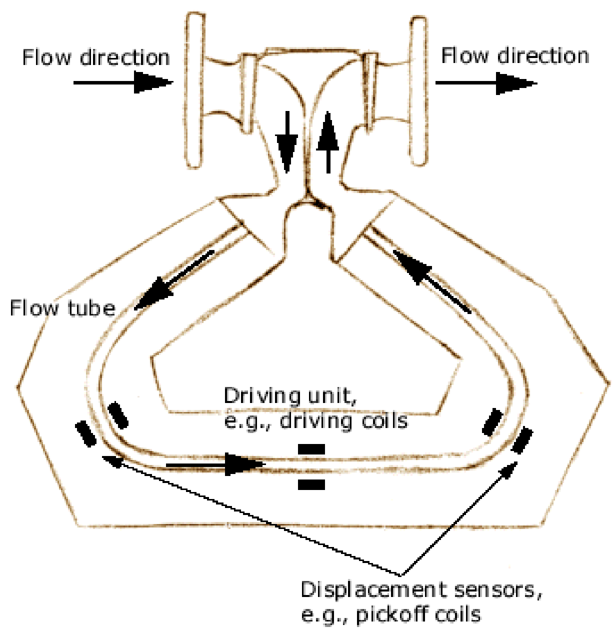
Search All for Go

Home | Membership | Palm Store | Forum | Search Member | What's New | Calculators

Materials | Design | Processes | Units | Formulas | Math

Overview

Coriolis flowmeters are relatively new compared to other flowmeters. They were not seen in industrial applications until 1980's. Coriolis meters are available in a number of different designs. A popular configuration consists of one or two U-shaped, horseshoe-shaped, or tennis-racket-shaped (generalized U-shaped) flow tube with inlet on one side and outlet on the other enclosed in a sensor housing connected to an electronics unit.



The flow is guided into the U-shaped tube. When an osillating excitation force is applied to the tube causing it to vibrate, the fluid flowing through the tube will induce a rotation or twist to the tube because of the Coriolis acceleration acting in opposite directions on either side of the applied force. For example, when the tube is moving upward during the first half of a cycle, the fluid flowing into the meter resists being forced up by pushing down on the tube. On the opposite side, the liquid flowing out of the meter resists having its vertical motion decreased by pushing up on the tube. This action causes the tube to twist. When the tube is moving downward during the second half of the vibration cycle, it twists in the opposite direction. This twist results in a phase difference (time lag) between the inlet side and the outlet side and this phase difference is directly affected by the mass passing through the tube.

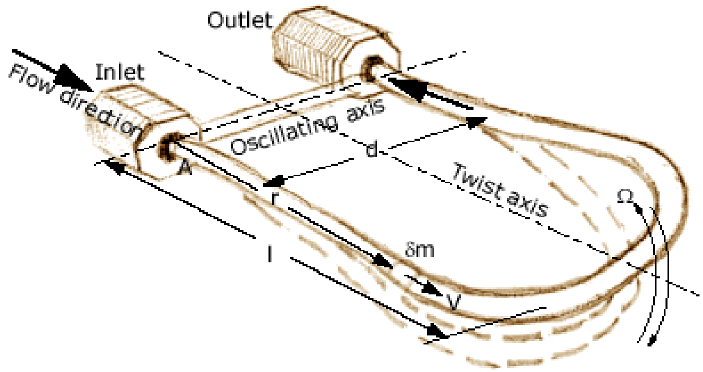
A more rescent single straight tube design is available to measure some dirty and/or abrasive liquids that may clog the older U-shaped design.

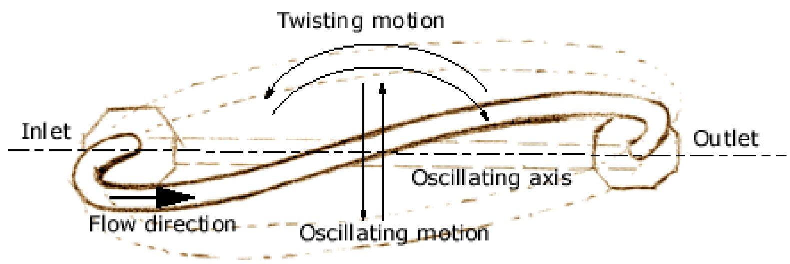
An advantage of Coriolis flowmeters is that it measures the mass flow rate directly which eliminates the need to compensate for changing temperature, viscosity, and pressure conditions. Please also note that the vibration of Coriolis flowmeters has very samll amplitude, usually less than 2.5 mm (0.1 in), and the frequency is near the natural frequency of the device, usually around 80 Hz. Finally, the vibration is commonly introduced by electric coils and measured by megnetic sensors.

Top of Page

Further Information

Suppose that the fluid is flowing into the U-shaped tube at velocity *V* and the tube is vibrating at angular velocity Ω. Consider a small section of the fluid that is on the inlet side away from the point of flexture at distance *r.*





Please note that the amplitudes of the vibration and twist are extremely small compared to the size of the U-shaped tube. The above graphics are highly exaggerated for illustration purposes.

The Coriolis force on the small fluid section δm is

$$\delta \overrightarrow{F_c} = \delta m \cdot a_c = \delta m \cdot 2\overrightarrow{\Omega} \times \overrightarrow{V}$$

During the down cycle, the tube applys an upward resisting force to the fluid or the fluid pushes the tube down. On the outlet side, the Coriolis force has the opposite direction.

To simply the problem, we assume that the tube has a perfect U shape with a cross section area of *A*. The length and width are *l*, *d*, respectively. The opposite directions of Coriolis forces on inlet and outlet sides result in a twisting moment T_c

$$T_c = F_c \cdot d = m \cdot a_c \cdot d = \rho A l \cdot 2\Omega V \cdot d$$

A *K* factor can be introduced to compensate for the more generalized U-shape.

$$T_c = 2K\Omega\rho AVdl = 2K\Omega Q_m dl$$

where $Q_m = \rho AV$ is the mass flow rate.

The governing equation of twisting is

$$I_u \frac{d^2\theta}{dt^2} + C_u \frac{d\theta}{dt} + K_u \theta = T_c$$

where I_u is the inertia of the U-shaped tube, C_u is the damping coefficient, K_u is the stiffness, θ is the twist angle, and *t* is time.

Recall that the Coriolis flowmeters are vibrating the U-shaped tube to generate the rotation, the real angular velocity Ω is function of vibrating frequency ω :

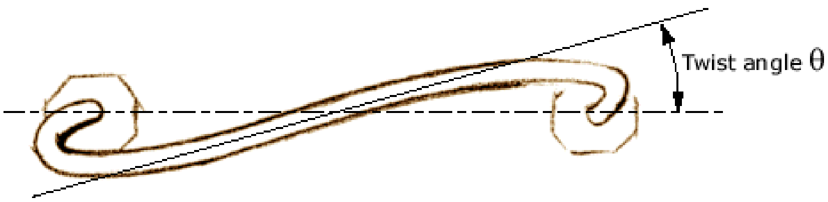
$$\Omega = \Omega_0 \cos \omega t$$

Assuming that the damping term C_u is negligible, the equation of twisting becomes

$$I_u \frac{d^2\theta}{dt^2} + K_u \theta = 2KQ_m dl\Omega_0 \cos \omega t$$

The particular solution (steady-state solution) of the twist angle is

$$\theta = \theta_0 \cos \omega t = \frac{2KQ_m \Omega_0 dl}{K_u - I_u \omega^2} \cos \omega t$$



A snapshot of flow tube inside Coriolis flowmeter

Furthermore, the velocity of the turning corners of the U-shaped tube are Ωl and the displacement difference between these two corners is $\theta d/2$. Therefore, the time lag τ between these two corners is

$$\tau = \frac{\theta d}{\Omega l} = \frac{\theta_0 d}{\Omega_0 l}$$
$$= \frac{2KQ_m d^2}{K_u - I_u \omega^2}$$

By measuring the time lag τ , the mass flow rate can be obtained

$$Q_m = \frac{K_u - I_u \omega^2}{2Kd^2} \tau$$

In vibration analysis, it is custom to use the natural frequency as a basis and normalize frequency terms against it. The natural frequency of the U-shaped tube system is (note that I_u includes the mass of the fluid in the tube)

$$\omega_u = \sqrt{\frac{K_u}{I_u}}$$

The mass flow rate then becomes

$$Q_m = \frac{K_s \left[1 - \left(\frac{\omega}{\omega_u} \right)^2 \right]}{2Kd^2} \tau$$

Top of Page

Common Specifications

Common specifications for commercially available Coriolis flowmeters are listed below:

Fluid Phase:

Score	Phase	Condition
✔	Liquid	Clean
✔		Direct Mass
✔		Dirty
✔		Non-Newtonian
✔		Viscous
✔	Slurry	Abrasive
⚠	Gas	Clean
⚠		Dirty
⚠	Liquid	Corrosive
⚠	Slurry	Fibrous

✔: Recommended
⚠: Limited applicability

Line Size: 6 ~ 200 mm (0.25 ~ 8 inch)

Turndown Ratio: 100 : 1

Top of Page

Pros and Cons

- **Pros**:
  - Higher accuracy than most flowmeters
  - Can be used in a wide range of liquid flow conditions
  - Capable of measuring hot (e.g., molten sulphur, liquid toffee) and cold (e.g., cryogenic helium, liquid nitrogen) fluid flow
  - Low pressure drop
  - Suitable for bi-directional flow

- **Cons**:
  - High initial set up cost
  - Clogging may occur and difficult to clean
  - Larger in over-all size compared to other flowmeters
  - Limited line size availability

Top of Page

Membership About Us Privacy Disclaimer Contact Advertise