Coriolis Mass Flowmeter

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CORIOLIS FORCE

- An object that moves within a rotating reference frame experience a pseudo force called coriolis force. The acceleration that causes this force is referred to as coriolis acceleration.

$$a_c = 2wv$$

$$F_c = mass \times acceleration = 2\,m\,vw$$

$$Coriolis\ Force = Mass\ Flowrate \times Angular\ Speed$$

- Where w = angular speed

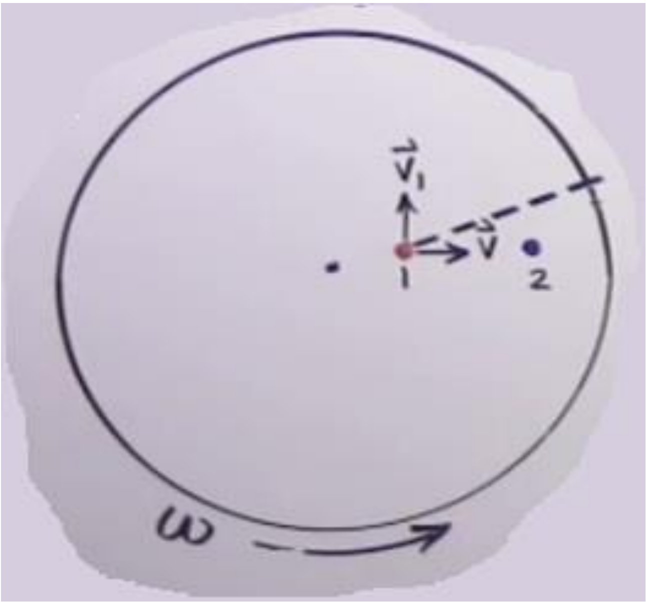
  v = object speed parallel to the axis of rotation

  m = mass of the object

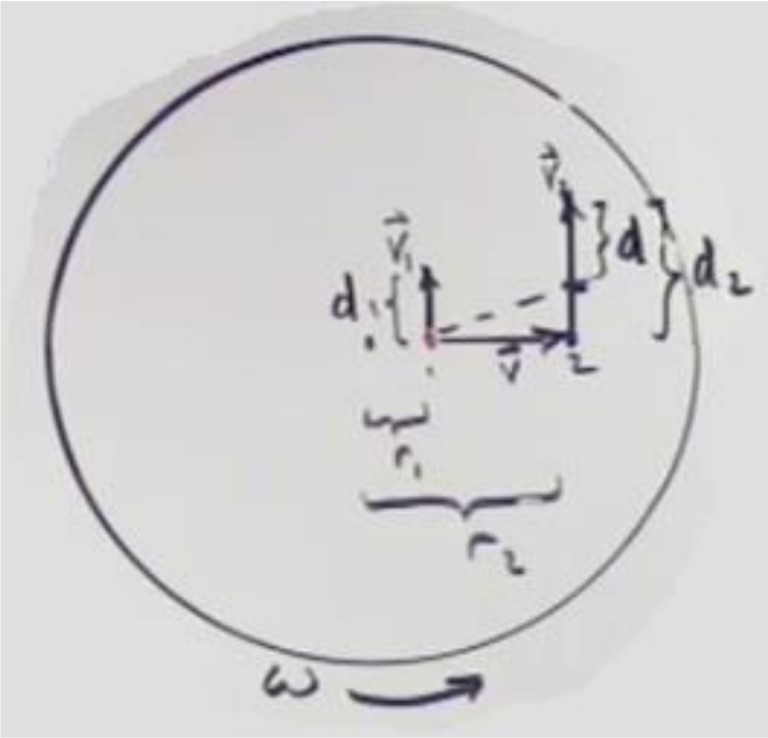
  m x v = Mass x Velocity = Mass Flowrate

DERIVATION OF CORIOLIS FORCE:

- Imagine that two people are on the rotating platform, one at point 1 and second at point 2. The person at point 1 rolls a ball will velocity $\vec{v}$ to person at point 2 but because the platform is rotating, it has another velocity $\overrightarrow{v_1}$ that points upward (tangential velocity). These velocities add up to cause ball to move along dashed line.



- Recall that the velocity of object on rotating dish is given by v = rw. Since person 2 is farther away from axis of rotation, they have a greater velocity then person at point 1. Therefore, when the ball reaches the outer edge, it will reach a point which person 2 has already gone by.
- Velocity of person 1 $v_1 = r_1 w$
- Velocity of person 2 $v_2 = r_2 w$



- Ball moves radically outward a distance $(r_2 - r_1)$ with velocity v over the time t

$$r_2 - r_1 = vt$$

- During this time, ball moves up: $d_1 = v_1 t$
- Person at point 2 in time t moves up: $d_2 = v_2 t$
- This, the ball passes behind person 2 a distance:

$$d = d_2 - d_1$$

$$d = v_2 t - v_1 t$$

$$d = r_2 wt - r_1 wt$$

$$d = (r_2 - r_1)wt$$

$$d = (vt)wt = vwt^2$$

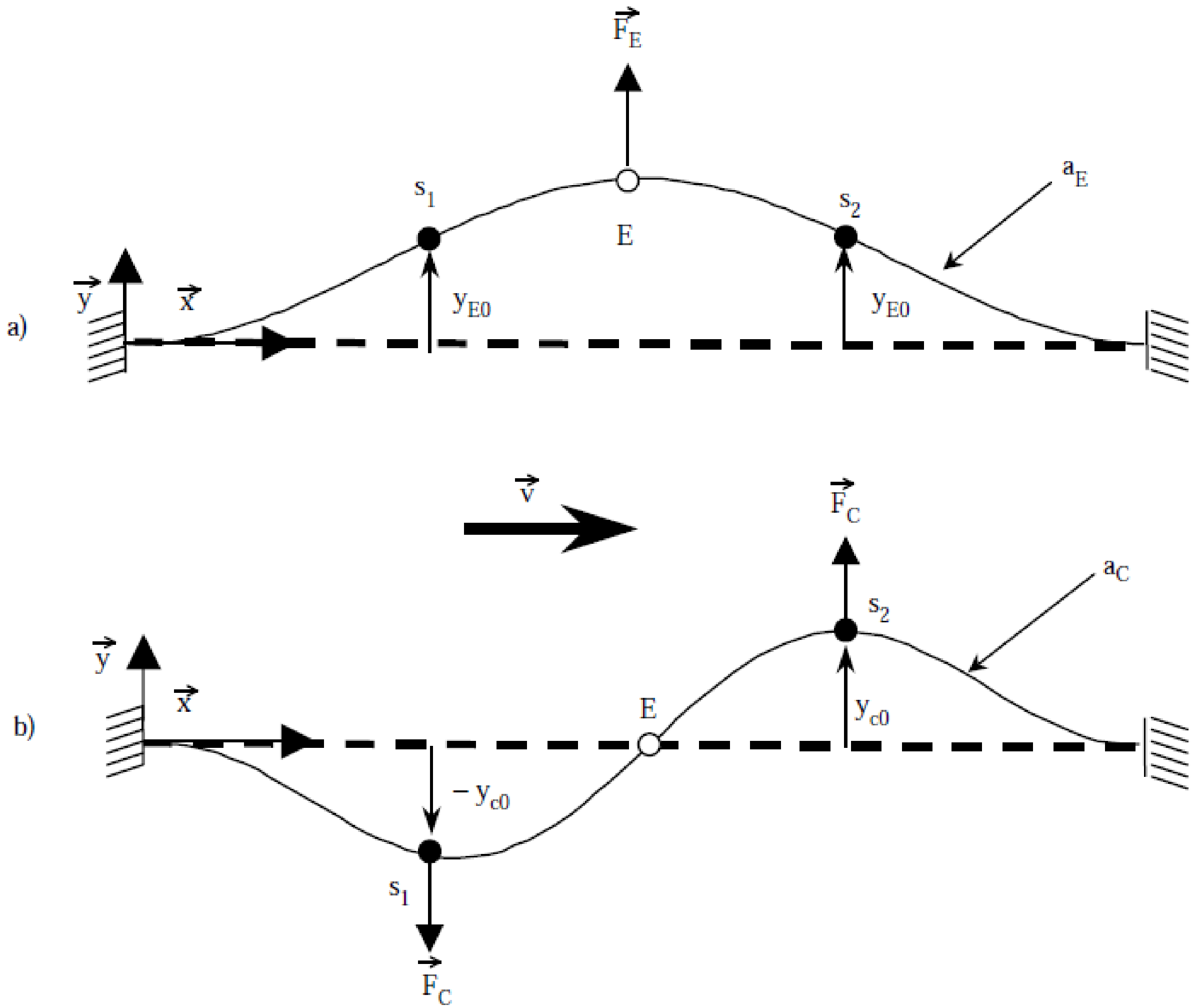
$$\frac{1}{2} at^2 = vwt^2$$

$$a_c = 2vw$$

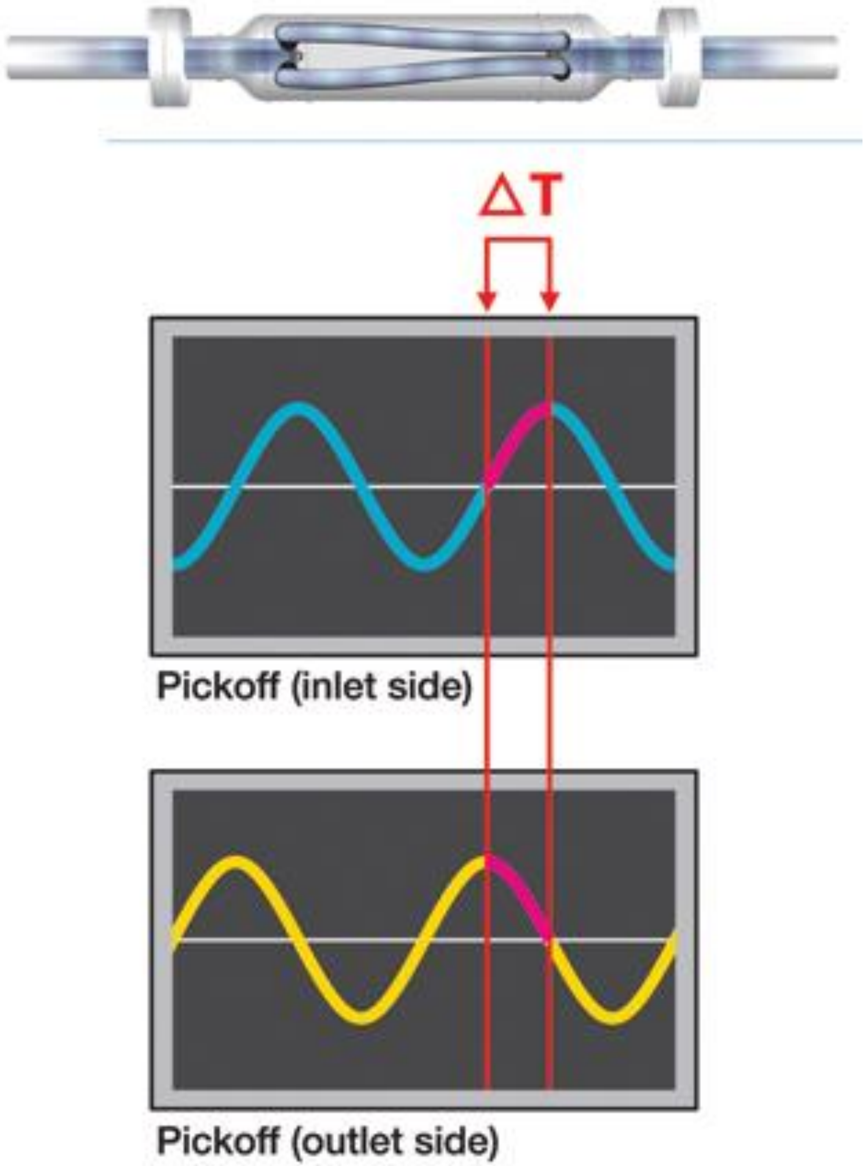
OPERATING PRINCIPLE OF CMF

- Instead of having a rotating frame of reference, Coriolis flow meters work on the principle that the inertia created by fluid flowing through an oscillating tube.
- The excitation frequency is kept at the natural frequency of the tube, which minimizes the energy needed for vibration.
- Sensors in the form of magnet and coil assemblies are mounted on the inlet and the outlet of both flow tubes.
- As the coils move through the magnetic field created by the magnet, they create a voltage in the form of a sine wave. These sine waves are the key to measuring mass flow.

OPERATING PRINCIPLE OF CMF



- Under no-flow conditions, the inlet and outlet sine waves are in phase with each other.
- When fluid is moving through the tubes, the tubes twist in proportion to mass flowrate. The amount of this twist is detected by the inlet and outlet sensors, based on a phase shift (time difference) that occurs in the sine waves formed by the two sensors.
- Since the oscillation is kept at the natural frequency of the system, the frequency changes with changing density of the fluid in the tube; i.e., the natural frequency increases with decreasing density. Therefore, by knowing the actual frequency of the system, the density of the fluid can be calculated directly.
- Mechanical properties change with temperature. This leads to changes the Young’s modulus. An increase in temperature decreases the stiffness of the tube by lowering the Young’s modulus. To compensate for the influence of thermal effects on CMF readings, each flowmeter needs to be equipped with at least one sensor to measure fluid temperature.


ΔT
Pickoff (inlet side)
Pickoff (outlet side)

INFLUENCES ON THE CMF READING:

- Temperature
- In-Line Pressure
- Mounting
- Vibration
- Humidity

ADVANTAGES OF CMFS:

- One of most important advantages of CMFs is that mass flow is measured directly. This can be performed with high accuracy, typically with 0.1% error.
- CMF rangeability is extremely high.
- In addition to direct measurement of mass flow, temperature and density are measured directly. Knowledge about density allows us to convert mass flow data into volume flow data.
- The measuring principle is independent of the flow profile of the fluid or gas.
- The accuracy of a CMF is independent of fluid properties such as viscosity or density.
- CMFs are designed to measure forward and reverse flows with high accuracy.

LIMITATIONS OF CMFs

- CMF prices are rather high as compared to other measuring device types. However, to measure mass flow with a volumetric meter, it is often necessary to install an in-line densitometer, which brings the cost up to roughly the equivalent of a CMF alone.
- There are no CMFs available for medium temperatures above 800°F (426°C).
- CMFs are not available for large pipelines.
- CMFs are not suitable for gas applications with low in-line pressure, since low-pressure gases have low densities. To generate enough mass flow to provide a sufficient Coriolis signal, the velocity of the gas must be quite high.
- CMFs cannot be used for liquids with any significant gas content.

APPLICATION OF CMFs:

- CMFs are currently used in many areas, including chemical, petroleum, petrochemical, pharmaceutical, food and beverage, and pulp and paper industries. Because of their versatility, CMFs are used for process control, batching, inventory, precision filling of containers, custody transfer, and other applications.