Industrial Instrumentation
Class-Test 3

Pratyush Jaiswal
18EE35014

Q1: (a) (i) Though electromagnetic flow meters are designed for volumetric flow measurement, they can also be used to measure mass. If the density of the fluid is entered into the meter, it can use the data to calculate mass flow. For the meter to make these calculations, the density value must be stable & constant.

(ii) In general the electrical conductivity of liquid under measurement should have minimum of 5 micro siemens per cm conductivity. But carefully designed transmitters and primary flow sensors can measure flow rates of liquids having conductivity as low as 1 micro siemens per cm. But the conductivity of liquids under questions are nearing to almost zero. E.g the conductivity of kerosene is in pico sieamens, where even carefully designed meters also cannot measure the liquid flow. So, it cannot be used for the required purpose.

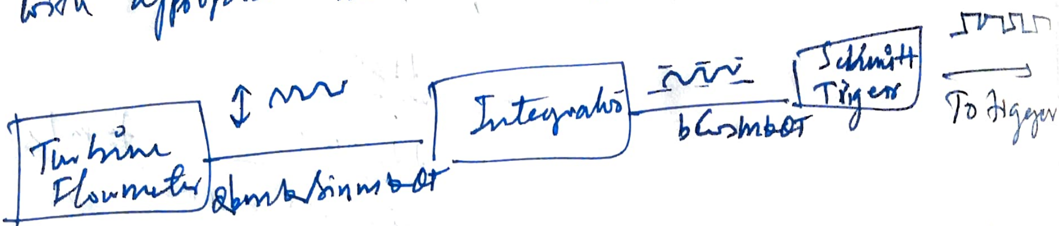
(b) The orifice plates create a sudden constriction in the water flow path, disturbing the flow & creating a permanent pressure drop of magnitude much more than the venturi tube. This is the main reason.

Mathematically, for constriction of circular cross-section and diameter d, the effective area for venturi tubes & orifice plates are $0.99\pi\frac{d^2}{4}$ & $0.6\pi\frac{d^2}{4}$ respectively. Therefore, it is preferable to use a venturi tube only when a large pressure drop is acceptable.

(c). During the constant current mode, it is possible that the sense wire may not heat up sufficiently to operate in the desired characteristic for which meter is designed. If the cooling action of the fluid is too low, we are at risk of burning the wire too. Hence constant current mode is preferred for a hotwire anemometers.

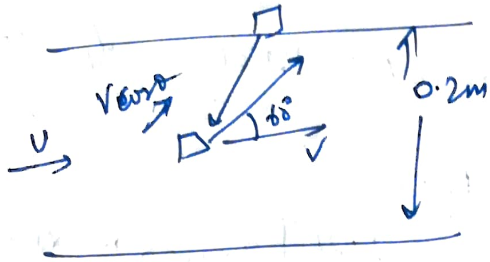
Q 20

Turbine flowmeter is a multi-bladed meter suspended in the fluid stream; the rotation is parallel to the flow direction. The fluid in pipes on the blade, rotates them & flow rate is measured. Block diagram representation of flowmeter with appropriate blocks are given as below.



The principle of variable reluctance tachogenerator is used here to infer that the ~~fo~~ flow of water through voltage varies. There is a pickup coil in the flowmeter that picks up the voltage which runs through rotating blades.

Q 3: (a).



diameter = d = 0.2m.

C = 1.56m/s. → speed of sound in slurry.

~~tes~~ Let the frequency of emission be ~~ef~~ f from pipe to electric crystal.

The frequency of reception f' for slurry is

$$f' = f\left(\frac{c + v\cos\theta}{c}\right)$$

The frequency of transmission for slurry particle is

$$f'' = f'\left(\frac{c}{c - v\cos\theta}\right)$$

$$f'' = f\left(\frac{c + v\cos\theta}{c - v\cos\theta}\right)$$

$$\Delta f = f'' - f$$

$$= f\left(\frac{c + v\cos\theta}{c - v\cos\theta}\right) - f$$

$$= \frac{2fv\cos\theta}{c - v\cos\theta}.$$

$Q = 1130\ m^3/h.$

$A v = Q$

$A = \frac{\pi d^2}{4}$

$\pi \times \frac{(0.2)^2}{4} \times v = 1130$

$v = \frac{1130 \times 4}{\pi \times (0.2)^2}\ m/hr. = 35969.017\ m/hr$

$= \cancel{1130 \times 4}$

$\frac{1130 \times 4}{\pi \times (0.2)^2 \times 3600}\ m/s$

$= 9.991\ m/s \simeq 10\ m/s.$

$\frac{v}{c} << 1$ hence.

$\Delta f = 2 f \frac{v}{c} \cos\theta$

$= 2 \times 10^6 \times \frac{10}{1.5 \times 10^3} \times \cos 60°$

$= \frac{2 \times 10^7}{1.5 \times 10^3} \times \frac{1}{2} = 6666.67\ Hz$

(b). Assumption :-

→ Matching layer is present at pipe interfaces

→ No turbulent flow

→ fluid is not clear

Ultrasonic wave doesn't disturb flow.

→ Received signal strength is high enough.

→

Total distance travelled $= L = \frac{D}{\sin 60^\circ}$

$= \frac{0.2}{\sqrt{3}/2} = 0.1633\,m$

Attenuation $= 0.1633\,W \times 2 = 0.3266\,W$.

Reflected Energy $= 10\%$ of incident.

$\therefore$ Total energy $= (1 - 0.3266) \times 10\%$

$= 0.067\,W$.

Q4:

Given: $\boxed{\text{Water is fluid}, \; E = 1 \text{ (Liquid)}}$

Diameter of Pipe = $D = 0.15m$

Max. flow rate, $M_{vol,max} = \frac{50 m^3}{hr}$

Density of water, $\rho = 10^3 \frac{kg}{m^3}$

Viscosity of water, $\eta = 10^{-3}$ Pa.s.

Transmitter input range: (0 to 1.25×10^4 Pa)

Coefficient of discharge: $C = 0.6$.

a). Advantages of an orifice plate meter for this application:

Orifice plate has simple construction.

Orifice plate offers small pressure drop which can be recovered easily

Also since Reynold's number $> 10^4$, it is suitable. (derived in (b) part)

b). To find: orifice plate hole diameter, $d = ?$.

Now, M_{max} = Maximum mass flow rate (kg/s)

$$= \frac{50 m^3}{60 \times 60 s} \times \frac{10^3 kg}{m^3}$$

$M_{max} = 13.89$ kg/s.

ΔP_{max} = Diff. Pressure @ mass flow = upper range of diff plate transmitter.

$\Delta P_{max} = 1.25 \times 10^4$ Pa.

Calculating Reynold's number.

$$Re_D = \frac{4 M_{max}}{\pi D \eta} = \frac{4 \times 13.89}{\pi \times 0.15 \times 10^{-3}}$$

$$= 1.18 \times 10^5 > 10^4$$

We start with iteration process to determine d:

<u>Iteration 1</u>

(i) $\boxed{C = 0.6}$ $\boxed{E = 1.0}$, $E = 1.0$, $d_0 = 0$, ρ = density = 10^3 kg m^{-3}

fixed in Question. → fixed for liquid

(ii) Area of orifice hole, $A_2^m = \dfrac{M_{max}}{C \epsilon E \sqrt{2 \times \rho \times \Delta P_{max}}}$.

$$\Rightarrow A_2^m = \frac{13.89}{0.6 \times 1 \times 1 \times \sqrt{2 \times 10^3 \times 1.25 \times 10^4}}$$

$$A_2^m = 4.63 \times 10^{-3} \ m^2$$

(iii) $$d_1 = \sqrt{\frac{4 \times A_2^m}{\pi}} = \sqrt{\frac{4 \times 4.63 \times 10^{-2}}{\pi}}$$

$$\boxed{d_1 = 0.0767 \ m}$$

Updating values:

$$\beta = \frac{d}{D} = \frac{0.0767}{0.15} = 0.5113$$

$$E = \frac{1}{\sqrt{1 - \beta^4}} = 1.036$$

$\boxed{\epsilon = 1.0}$ → Fixed for liquid

$\boxed{C = 0.6}$ → fixed in question.

Iteration 2

(i) $C = 0.6$, $\epsilon = 1.0$, $E = 1.036$, $d_1 = 0.0767\,m$, $\rho = 10^3\,kg\,m^{-3}$

(ii) $$A_2^m = \frac{13.89}{0.6 \times 1 \times 1.036 \sqrt{2 \times 10^3 \times 1.25 \times 10^4}}$$

$$= 4.469 \times 10^{-3}\,m^2$$

(iii) $$d_2 = \sqrt{\frac{4 \times A_2^m}{\pi}} = \sqrt{\frac{4 \times 4.469 \times 10^{-3}}{\pi}}\,m$$

$$= 0.0754\,m.$$

$$|d_2 - d_1| = 1.3 \times 10^{-3}\,m$$

updating values,

$$\beta = \frac{d}{D} = \frac{0.0754}{0.15} = 0.5027$$

$$E = \frac{1}{\sqrt{1-\beta^4}} = 1.0335$$

Iteration 3

(i) $$A_2^m = \frac{13.89}{0.6 \times 1 \times 1.0335 \times \sqrt{2 \times 10^3 \times 1.25 \times 10^4}} = 4.48 \times 10^{-3}\,m^2$$

(ii) $$d_3 = \sqrt{\frac{4 \times 4.48 \times 10^{-3}}{\pi}}\,m = 0.0755\,m$$

$$|d_3 - d_2| = 10^{-4}\,m$$

Thus we get satisfactory convergence.

final value of $\boxed{d = 0.0755\,m = 7.55\,cm}$ even though previous values of d would suffice.