Compressible flow.

Incompressible flow:- Its that type of flow in which density is constant for the fluid flow.

$\rho =$ constant

* If the change in volume or density during the flow is less than 5%. ($\leq 5\%$)

* incompressible upto Mach no 0.3

Compressible flow!- The density of the fluid changes during the flow. All real fluids are compressible to some extent.

ex. Flow of gases through nozzles, orifices, compressor. Flight of areoplanes and projectile moving at higher altitudes, water hammer.

Basic equation of the compressible flow-

(i) continuity equation.

(ii) Birnoulli's equation

(iii) Momentum equation.

(iv) Equation of state.

i) Continuity equation! Assumption - 1D flow, Isentropic flow, steady flow.

For. 1D flow

$\rho AV =$ constant

$d(\rho AV) = d(c)$.

$\rho . dAV + AVd\rho = 0$.

$\rho [A . dv + v dA] + AVd\rho = 0$.

divided by ρAV.

$$\boxed{\frac{dv}{V} + \frac{dA}{A} + \frac{d\rho}{\rho} = 0}$$

continuity eqn in differential form.

ii) Bernoulli's eqn :-

Euler's eqn. $\frac{dP}{\rho} + vdv + gdz = 0$.

$$\int \frac{dP}{\rho} + \int vdv + g\int dz = \text{const}.$$

$$\boxed{\int \frac{dP}{\rho} + \frac{v^2}{2} + gz = \text{const}}$$

a) For isothermal process:-

$$\frac{P}{\rho} = \text{constant} \Rightarrow \rho = \frac{P}{C_1}$$

$$\int \frac{dP}{\rho} = \int \frac{dP}{P/C_1}$$

$$= C_1 \int \frac{1}{P} dP \Rightarrow C_1 \log_e P.$$

$$= \frac{P}{\rho} \log_e P.$$

$$\Rightarrow \frac{P}{\rho g} \log_e P + \frac{v^2}{2g} + z = \text{constant}$$

b) For adiabatic process:

$$\frac{P}{\rho^K} = \text{constant} \Rightarrow C_2 = \frac{P}{\rho^K} \Rightarrow \rho = \left(\frac{P}{C_2}\right)^{1/K}$$

$$\int \frac{dP}{\rho} = \int \frac{dP}{(P/C_2)^{1/K}} \Rightarrow \int \frac{C_2^{1/K}}{P^{1/K}}\, dP$$

$$\frac{P}{\rho^K} = C_2$$

$$(C_2)^{1/K} = \frac{P^{1/K}}{\rho}$$

$$= C_2^{1/K} \cdot \frac{P^{(-1/K+1)}}{\left(-\frac{1}{K}+1\right)}$$

$$= \frac{C_2^{1/K} \cdot P^{\left(\frac{K-1}{K}\right)}}{\left(\frac{K-1}{K}\right)} \Rightarrow \frac{K}{K-1} \times \frac{P^{1/K}}{\rho} \times P^{\frac{K-1}{K}}$$

$$= \frac{K}{K-1} \times \frac{P}{\rho}$$

$$\boxed{\frac{K}{K-1} \times \frac{P}{\rho g} + \frac{V^2}{2g} + Z = \text{cont}}$$

Q- Gas is flowing through a horizontal pipe. On a section where C/s area is 50 cm², the pressure and temp are found to be 3 bar (Gauge) and 20°C respectively. At another section where the area of the C/s is 25 cm², the pressure is recorded 2 bar (gauge). If the mass rate of flow of gas through the pipe is 0.6 kg/s, find the velocities of the gas at these section, assuming the isothermal changes.

Sol^n 4

$P = \rho RT$, $P_1 = \rho_1 RT_1$

$P_1 = 3+1 = 4$ bar $= 4 \times 10^5 N/m^2$

$P_2 = 2+1 = 3$ bar $= 3 \times 10^5 N/m^2$

$A_1 = 50 \times 10^{-4} m^2$

$A_2 = 25 \times 10^{-4} m^2$

$\dot{m} = 0.6 kg/s$.

$T_1 = 20 + 273 = 293 K$.

$$\rho_1 = \frac{P}{RT_1} = \frac{4 \times 10^5}{287 \times 293} = 4.757 kg/m^3.$$

$m = \rho_1 A_1 V_1$

$$V_1 = \frac{m}{\rho_1 A_1} = \frac{0.6}{4.757 \times 50 \times 10^{-4}}$$

$= 25.22 m/s$.

$$\rho_2 = \frac{P_2}{RT_2} = \frac{3 \times 10^5}{287 \times 293} = 3.567 kg/m^3.$$

$m = \rho_2 A V_2$

$$V_2 = \frac{0.6}{3.567 \times 25 \times 10^{-4}} = 67.28 m/s.$$

Q → Density variation with pressure!.

Fluid	temp(°C)	Pr.(MPa)	density (kg/m³)	change in density %)
Air	25	0.1	1.1685	9981.3.
		10	117.80.	
water	25	.1	997.05	0.446
		10	1001.5	

... at same temp. find the ...?