CH_5

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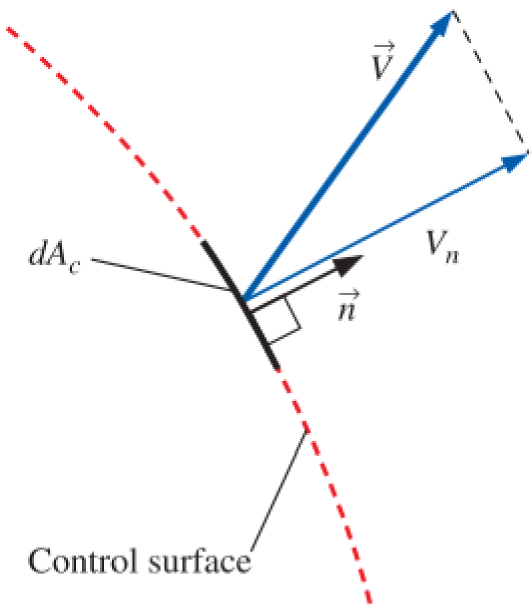
5.1 Conversion of Mass

Mass and Volume Flow Rates

mass flow rate

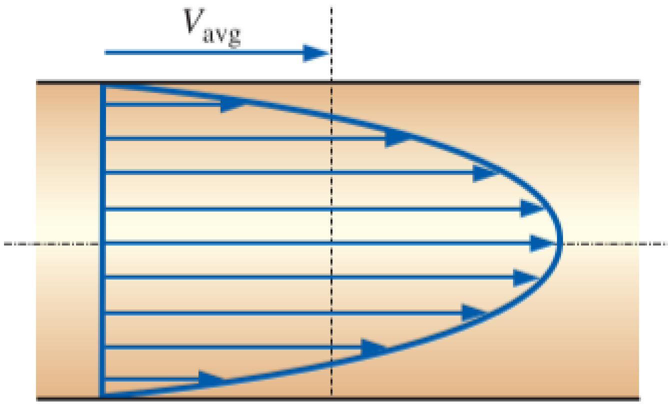


$$\delta \dot{m} = \rho V_n \mathrm{d}A_c$$

$$\dot{m} = \int_{A_c} \delta \dot{m} = \int_{A_c} \rho V_n \mathrm{d}A_c$$

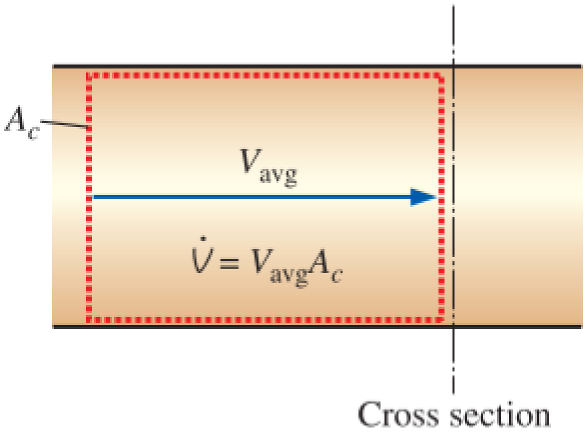
$$\dot{m} = \rho V_{avg} A_c$$

average velocity



$$V_{avg} = \frac{1}{A_c} \int_{A_c} V_n \mathrm{d}A_c$$

volume flow rate



$$\dot{V} = \int_{A_c} V_n]\mathrm{d}A_c = V_{avg}A_c = VA_c$$

$$\dot{m} = \rho\dot{V} = \frac{\dot{V}}{\nu}$$

Conversion of Mass Principle

mass balance

$$m_{in} - m_{out} = \Delta m_{CV}$$

$$\dot{m}_{in} - \dot{m}_{out} = \frac{\mathrm{d}m_{CV}}{\mathrm{d}t}$$

general conversion of mass

$$\frac{\mathrm{d}}{\mathrm{d}t}\int_{CV}\rho\mathrm{d}V + \int_{CS}\rho(\vec{V}\cdot\vec{n})\mathrm{d}A = 0$$

$$\frac{\mathrm{d}}{\mathrm{d}t}\int_{CV}\rho\mathrm{d}V = \sum_{in}\dot{m} - \sum_{out}\dot{m} \qquad \frac{\mathrm{d}m_{CV}}{\mathrm{d}t} = \sum_{in}\dot{m} - \sum_{out}\dot{m}$$

Mass Balance for Steady-Flow Processes

$$\sum_{in}\dot{m} = \sum_{out}\dot{m}$$

$$\rho_1 V_1 A_1 = \rho_2 V_2 A_2$$

Special Case: Incompressible Flow

$$\sum_{in}\dot{\nu}_1 = \sum_{out}\dot{\nu}_2$$

$$V_1 A_1 = V_2 A_2$$

5.2 Flow Work and the Energy of a Flowing Fluid

$$w_{flow} = Pv$$

Total Energy of a Flowing Fluid

the energy for the unit mass

$$e = u + ke + pe = u + \frac{V^2}{2} + gz$$

for the flowing fluid

$$\theta = Pv + e = (Pv + u) + ke + pe = h + \frac{V^2}{2} + gz$$

Energy Transport by Mass

- Amount of energy transport: $E_{mass} = m\theta = m(h + \frac{V^2}{2} + gz)$
- Rate of Energy transport: $\dot{E}_{mass} = \dot{m}\theta = \dot{m}(h + \frac{V^2}{2} + gz)$

$$E_{in,mass} = \int_{m_i} \theta_i \delta m_i = \int_{m_i} (h_i + \frac{V_i^2}{2} + gz_i)\delta m_i$$

5.3 Energy Analysis of Steady-Flow Systems

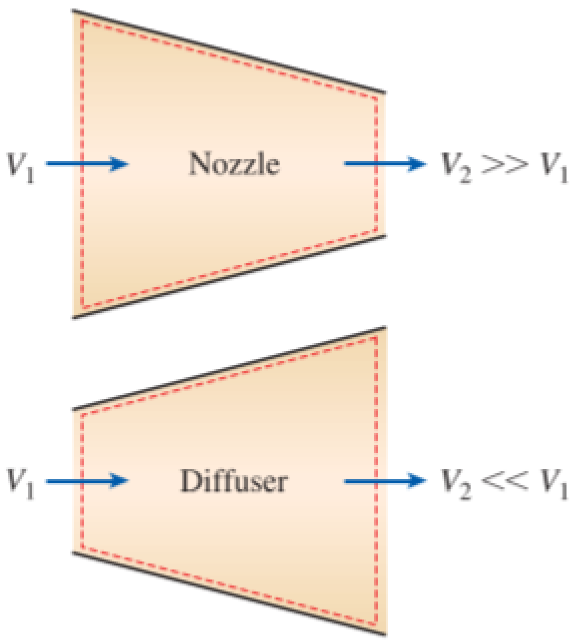
$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{Q} - \dot{W} = \dot{m}[h_2 - h_1 + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1)]$$

- $\dot{Q}$: rate of heat transfer between the control volume and its surroundings
- $\dot{W}$: power
- Δh: $h_2 - h_1$, the enthalpy change of a fluid
- Δke: $(V_2^2 - V_1^2)/2$, the kinetic energy change
- Δpe: $g(z_2 - z_1)$, the potential energy change

5.4 Some Steady-Flow Engineering Devices

1 Nozzles and Diffusers



- $\dot{Q} \approx 0$
- $\dot{W} = 0$
- $\Delta pe \approxeq 0$
- $\Delta ke \neq 0$

Nozzle

a device that **increases the velocity of a fluid** at the expense of the pressure

Diffuser

a device that **increases the pressure of a fluid** by slowing it down

2 Turbines and Compressors

- $\dot{Q} \approx 0$
- $\dot{W} \neq 0$
- $\Delta pe \approxeq 0$
- $\Delta ke \approxeq 0$

Fan

increases the pressure of a gas slightly and is mainly used to mobilize a gas

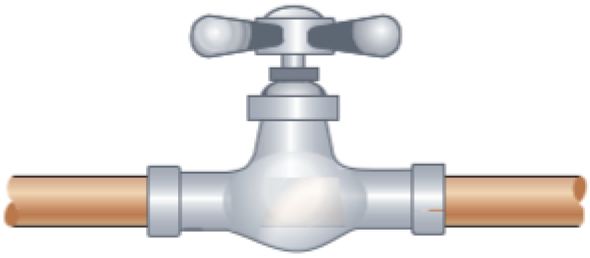
Compressor

is capable of compressing the gas to very high pressures

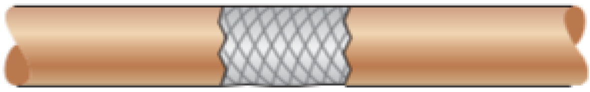
Pumps

work very much like compressors except that they handle liquids instead of gases

3 Throttling Valves



(*a*) An adjustable valve



(*b*) A porous plug

(*c*) A capillary tube

any kind of slow-restricting devices devices that cause a significant pressure drop in the fluid without involving any work

- $\dot{Q} \approx 0$
- $\dot{W} = 0$
- $\Delta pe \approxeq 0$
- $\Delta ke \approxeq 0$

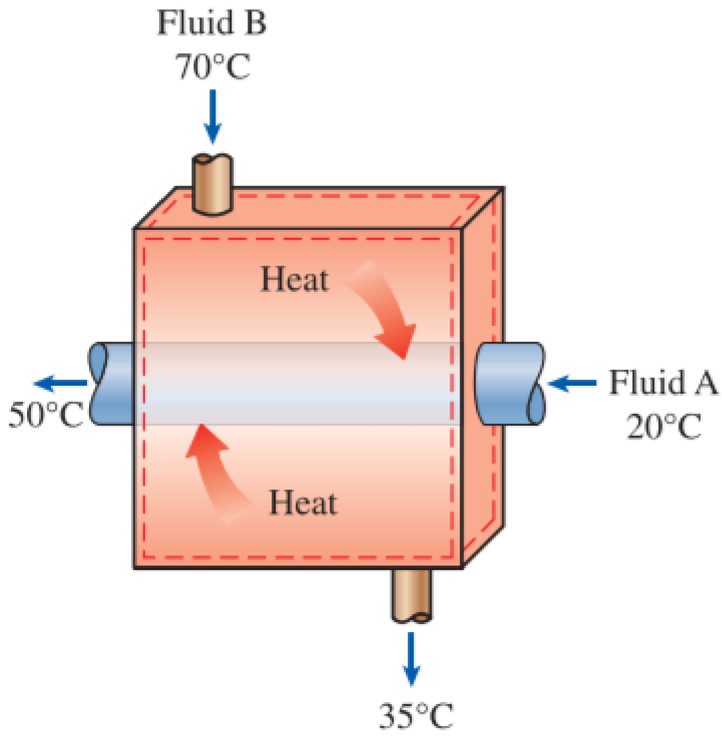
4a Mixing Chambers

the section where the mixing process takes place is commonly referred to as a mixing chamber

- $\dot{Q} \approx 0$
- $\dot{W} = 0$
- $\Delta pe \approxeq 0$
- $\Delta ke \approxeq 0$

4b Heat Exchanges

heat exchanges are device where two moving fluid streams exchange heat without mixing



- $\dot{Q}$ varies
- $\dot{W} = 0$
- $\Delta pe \approxeq 0$
- $\Delta ke \approxeq 0$

5 Pipe and Duct Flow