Thermodynamics-1

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Chapter 5

Mass and Energy Analysis of Control Volumes
The objectives:

- Develop the **conservation of mass** principle and apply it to various systems including **steady-** and **unsteady-flow** control volumes.

- Apply the **first law of thermodynamics** to control volumes.

- Solve **energy balance** problems for common **steady-flow** devices such as nozzles, compressors, turbines, throttling, valves, mixers, heaters, and heat exchangers.

- Apply the **energy balance** to general **unsteady-flow** processes
CONSERVATION OF MASS

\[ 2 \text{ kg } H_2 + 16 \text{ kg } O_2 \rightarrow 18 \text{ kg } H_2O \]
CONSERVATION OF MASS

\[ dA_c \]

\[ V \]

\[ V_n \]

Control surface
CONSERVATION OF MASS
CONSERVATION OF MASS

\[ \dot{V} = V_{\text{avg}} A_c \]
CONSERVATION OF MASS

\[ m_{\text{in}} = 50 \text{ kg} \]

\[ \Delta m_{\text{tub}} = m_{\text{in}} - m_{\text{out}} = 20 \text{ kg} \]

\[ m_{\text{out}} = 30 \text{ kg} \]
CONSERVATION OF MASS
CONSERVATION OF MASS

\[ \dot{m}_1 = 2 \text{ kg/s} \quad \text{and} \quad \dot{m}_2 = 3 \text{ kg/s} \]

\[ \dot{m}_3 = \dot{m}_1 + \dot{m}_2 = 5 \text{ kg/s} \]
CONSERVATION OF MASS

\[ \dot{m}_2 = 2 \text{ kg/s} \]
\[ \dot{V}_2 = 0.8 \text{ m}^3/\text{s} \]

\[ \dot{m}_1 = 2 \text{ kg/s} \]
\[ \dot{V}_1 = 1.4 \text{ m}^3/\text{s} \]
CONSERVATION OF MASS
FLOW WORK
FLOW WORK
FLOW WORK

\[ w_{\text{flow}} \rightarrow P \frac{\partial V}{\partial Q} \rightarrow \text{CV} \]

(a) Before entering

\[ w_{\text{flow}} \rightarrow P \frac{\partial V}{\partial Q} \rightarrow \text{CV} \]

(b) After entering
Energy Transport by Mass

\[ \dot{m}_i, \text{kg/s} \]
\[ \theta_i, \text{kJ/kg} \]

\[ \dot{m}_i \theta_i \text{ (kW)} \]
Energy Transport by Mass
STeady-Flow Systems

Control volume

\[
m_{CV} = \text{constant}
\]

\[
E_{CV} = \text{constant}
\]

Mass in

Mass out
STEADY-FLOW SYSTEMS

Control volume
Nozzles & Diffusers

\[ V_1 \quad \text{Nozzle} \quad V_2 \gg V_1 \]

\[ V_1 \quad \text{Diffuser} \quad V_2 \ll V_1 \]
Nozzles & Diffusers

\[ P_1 = 80 \text{ kPa} \]
\[ T_1 = 10^\circ \text{C} \]
\[ V_1 = 200 \text{ m/s} \]
\[ A_1 = 0.4 \text{ m}^2 \]
\[ \dot{m} = ? \]
\[ T_2 = ? \]
Turbines & Compressors

\[ P_2 < P_1 \]

\[ P_2 > P_1 \]
Turbines & Compressors

\[ P_1 = 2 \text{ MPa} \]
\[ T_1 = 400^\circ \text{C} \]
\[ V_1 = 50 \text{ m/s} \]
\[ z_1 = 10 \text{ m} \]

\[ P_2 = 15 \text{ kPa} \]
\[ x_2 = 90\% \]
\[ V_2 = 180 \text{ m/s} \]
\[ z_2 = 6 \text{ m} \]
Throttling Valves

(a) An adjustable valve

(b) A porous plug

(c) A capillary tube
Throttling Valves

IDEAL GAS $T_1$, $h_1$ → Throttling valve

$T_2 = T_1$, $h_2 = h_1$
Mixing Chambers

[Diagram showing a mixing chamber with热水 (Hot Water) and cold water entering and mixing to create a shower head output.]

- Cold water
- T-elbow
- Hot Water
Mixing Chambers

\[ T_1 = 140^\circ F \]

\[ T_2 = 50^\circ F \]

\[ T_3 = 110^\circ F \]

\[ P = 20 \text{ psia} \]
Heat Exchangers

Fluid B
70°C

Fluid A
20°C

50°C

35°C
Heat Exchangers

(a) System: Entire heat exchanger \( Q_{CV} = 0 \)

(b) System: Fluid A \( Q_{CV} \neq 0 \)
Heat Exchangers

Water
15°C
300 kPa

R-134a
70°C
1MPa

25°C
35°C
Heat Exchangers

\[ \dot{Q}_{w,\text{in}} = \dot{Q}_{R,\text{out}} \]

R-134a

Control volume boundary
Pipe and Duct Flow

Surroundings 20°C

Q_{out}

70°C

Hot fluid
Pipe and Duct Flow
Pipe and Duct Flow

\[ \dot{Q}_{\text{out}} = 200 \text{ W} \]

\[ T_2 = ? \]

\[ T_1 = 17^\circ \text{C} \]

\[ P_1 = 100 \text{ kPa} \]

\[ \dot{V}_1 = 150 \text{ m}^3/\text{min} \]

\[ \dot{W}_{e, \text{in}} = 15 \text{ kW} \]
UNSTEADY-FLOW PROCESSES
UNSTEADY-FLOW PROCESSES
UNSTEADY-FLOW PROCESSES

\[ Q - W = \Delta U \]
UNSTEADY-FLOW PROCESSES
UNSTEADY-FLOW PROCESSES

\[ P_i = 1 \text{ MPa} \]
\[ T_i = 300^\circ\text{C} \]

\[ m_1 = 0 \]
\[ P_2 = 1 \text{ MPa} \]
\[ T_2 = ? \]

(a) Flow of steam into an evacuated tank
UNSTEADY-FLOW PROCESSES

Steam

\[ T_i = 300^\circ C \]

\[ T_2 = 456.1^\circ C \]
UNSTEADY-FLOW PROCESSES

(b) The closed-system equivalence

\[ P_1 = 1 \text{ MPa} \ (\text{constant}) \]
\[ m_i = m_2 \]
\[ P_2 = 1 \text{ MPa} \]