WEEK 8

Energy Balance

Energy Balance on Closed System

- Accumulation = input – output:
- Final system energy – Initial system energy = energy in – energy out

$$\left(U_f - U_i\right) + \left(E_{Kf} - E_{Ki}\right) + \left(E_{Pf} - E_{Pi}\right) = Q - W$$

Heat transferred to system from surrounding

Work done by system on surrounding

$$\Delta U + \Delta E_K + \Delta E_P = Q - W$$

First law of thermodynamics for a closed system

Depends on chem. Composition, temperature of system

If no heat Q = 0

Movement of system surrounding against a force

Energy Balance on Closed System

- Ex. 7.3-1 page 319
- W (+): work done by system on surrounding
- No change in T : $\Delta U = 0$
- System is stationary: $\Delta E_K = 0$
- No vertical displacement: $\Delta E_P = 0$
- No moving part: W=0

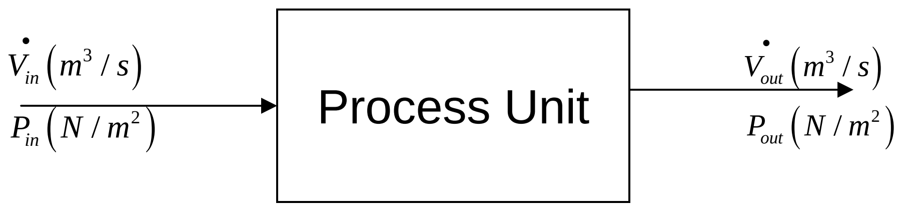
7.4 Energy Balance on Open Systems at Steady State

$$\dot{W} = \dot{W}_S + \dot{W}_{FL}$$

Flow work

Total work

Shaft work



$$\dot{W}_{in}\left(N.m/s\right) = P_{in}\left(N/m^2\right)\dot{V}_{in}\left(m^3/s\right)$$

$$\dot{W}_{out}\left(N.m/s\right) = P_{out}\left(N/m^2\right)\dot{V}_{out}\left(m^3/s\right)$$

$$\dot{W}_{FL}\left(N.m/s\right) = P_{out}\left(N/m^2\right)\dot{V}_{out}\left(m^3/s\right) - P_{in}\left(N/m^2\right)\dot{V}_{in}\left(m^3/s\right)$$

7.4 Energy Balance on Open Systems at Steady State

- Specific Enthalpy

$$\hat{H} = \hat{U} + P\hat{V}$$

$$U(J) = m(kg)\hat{U}(J/kg)$$

Internal energy

- $\hat{V}$: Specific volume

- Ex. 7.4-1, Page 322

7.4c The steady-state open-system balance

- Equation: $\dot{Q} + \sum_{\substack{input\\stream}} \dot{E}_j = \sum_{\substack{output\\stream}} \dot{E}_j + \dot{W}$

$$\dot{E}_j = \dot{U}_j + \dot{E}_{Kj} + \dot{E}_{Pj}$$

$$\dot{E}_j = \dot{m}_j \left(\hat{U}_j + \frac{U_j^2}{2} + gZ_j \right)$$

$$\dot{W} = \dot{W}_s + \sum_{output} \dot{m}_j P_j \hat{V}_j - \sum_{input} \dot{m}_j P_j \hat{V}_j$$

$$\Delta \dot{H} + \Delta \dot{E}_K + \Delta \dot{E}_P = \dot{Q} - \dot{W}_S$$

$$\Delta \dot{H} = \sum_{out} \dot{m}_j H_j - \sum_{in} \dot{m}_j H_j$$

$$\Delta \dot{E}_K = \sum_{out} \dot{m}_j \frac{U_j^2}{2} - \sum_{in} \dot{m}_j \frac{U_j^2}{2}$$

$$\Delta \dot{E}_P = \sum_{out} \dot{m}_j \, gZ_j - \sum_{in} \dot{m}_j \, gZ_j$$

Ex. 7-4.2 page 324

7.5 Table of Thermodynamic data

- Absolute enthalpies are not given.
- Reference properties are defined

$\hat{H}$ and $\hat{U}$ are state properties. They depend on initial and final states

Ex. 7-5.1, page 326

- 7.5b Steam Table, page 327.

Ex. 7-5.2

Mechanical Energy Balance

- Open system energy balance:

$$\frac{\Delta P}{\rho} + \frac{\Delta u^2}{2} + g\Delta z + \left(\Delta \hat{U} - \frac{\dot{Q}}{\dot{m}} \right) = -\frac{\dot{W}_s}{\dot{m}}$$

N/m²
kg/m³
m²/s²
m
m/s²
J/kg
J/s
J/s
kg/s

$$\hat{F} = \Delta \hat{U} - \frac{\dot{Q}}{\dot{m}}$$ Friction loss

$$\frac{\Delta P}{\rho} + \frac{\Delta u^2}{2} + g\Delta z + \hat{F} = -\frac{\dot{W}_s}{\dot{m}}$$

- No shaft work and frictionless:

HMK: **7.7, 7.9, 7.21, 7.22**

$$\frac{\Delta P}{\rho} + \frac{\Delta u^2}{2} + g\Delta z = 0$$ Bernoulli equation

Ex page 334, 7.7-1 to do in class