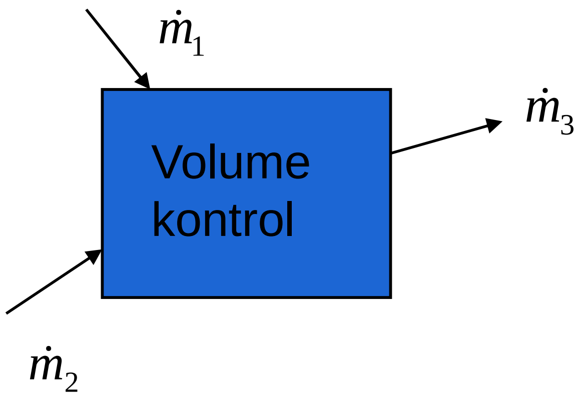
APLIKASI TERMODINAMIKA PADA PROSES ALIR

PROSES ALIR DALAM TANGKI

- *unsteady state (transient)* : keadaan berubah terhadap waktu
- *steady state* = tunak : keadaan **tidak** berubah terhadap waktu



Open systems

- Mass balance for open systems:

$$\frac{dm_{cv}}{dt} = -\Delta(\dot{m})_{fs} = -\Delta(\rho u A)_{fs} \qquad \Delta(\dot{m})_{fs} = \dot{m}_3 - \dot{m}_1 - \dot{m}_2$$

- energy balance for open systems:

$$\frac{d(mU)_{cv}}{dt} = -\Delta\left[\left(U + \frac{1}{2}u^2 + zg\right)\dot{m}\right]_{fs} + \dot{Q} + work\ rate$$

PV work + shaft work + ... etc.

$$-\Delta\left[(PV)\dot{m}\right]_{fs} + \dot{W}$$

$$\frac{d(mU)_{cv}}{dt} = -\Delta\left[\left(U + \frac{1}{2}u^2 + zg\right)\dot{m}\right]_{fs} + \dot{Q} - \Delta\left[(PV)\dot{m}\right]_{fs} + \dot{W}$$

$$\frac{d(mU)_{cv}}{dt} + \Delta\left[\left(H + \frac{1}{2}u^2 + zg\right)\dot{m}\right]_{fs} = \dot{Q} + \dot{W}$$

$$\downarrow$$

$$\frac{d(mU)_{cv}}{dt} + \Delta\left(H\dot{m}\right)_{fs} = \dot{Q} + \dot{W}$$

Example :

An evacuated tank is filled with gas from a constant-pressure line. What is the relation between the enthalpy of the gas in the entrance line and the internal energy of the gas in the tank? Neglect heat transfer between the gas and the tank.

$$\frac{d(mU)_{cv}}{dt} + \Delta\left(H\dot{m}\right)_{fs} = \dot{Q} + \dot{W}$$

No expansion work
No stirring work
No shaft work

$$\rightarrow \frac{d(mU)_{cv}}{dt} - H'\dot{m}' = 0$$

$$\frac{dm_{cv}}{dt} = -\Delta(\dot{m})_{fs} = \dot{m}'$$

$$\frac{d(mU)_{cv}}{dt} - H'\frac{dm_{cv}}{dt} = 0$$

$$\Delta(mU)_{cv} - H'\Delta m_{cv} = 0$$

$$(m_2U_2) - (m_1U_1) - H'\left(m_2 - m_1\right) = 0 \rightarrow U_2 = H'$$

Example :

An insulated, electrically heated tank for hot water contains 190 kg of liquid water at 60 °C when a power outage occurs. If water is withdrawn from the tank at a steady rate of 0.2 kg/s, how long will it take for the temperature of the water in the tank to drop from 60 to 35 °C? Assume that cold water enters the tank at 10 °C and that heat losses from the tank are negligible. For liquid water let Cv = Cp = C, independent of T and P.

$$\frac{d(mU)_{cv}}{dt} + \Delta(H\dot{m})_{fs} = \dot{Q} + \dot{W} \longrightarrow m\frac{dU}{dt} + \dot{m}(H - H_1) = 0$$

$$\frac{dU}{dt} = C\frac{dT}{dt} \qquad (H - H_1) = C(T - T_1)$$

$$dt = -\frac{m}{\dot{m}}\frac{dT}{T - T_1}$$

$$t = -\frac{m}{\dot{m}}\ln\left(\frac{T - T_1}{T_0 - T_1}\right)$$

$$t = -\frac{190}{0.2}\ln\left(\frac{35 - 10}{60 - 10}\right) = 658.5\ s$$

Example :

A 1.5 m^3 tank contains 500 kg of liquid water in equilibrium with pure water vapor, which fills the remainder of the tank. The temperature and pressure are 100°C, and 101.33 kPa. From a water line at a constant temperature of 70°C and a constant pressure somewhat above 101.33 kPa, 750 kg of liquid is bled into the tank. If the temperature and pressure in the tank are not to change as a result of the process, how much energy as heat must be transferred to the tank?

Energy balance:

$$\frac{d(mU)_{cv}}{dt} = \dot{Q} + H'\dot{m}' \rightarrow \frac{d(mU)_{cv}}{dt} = \dot{Q} + H'\frac{dm_{cv}}{dt}$$

$$Q = \Delta(mU)_{cv} - H'\Delta m_{cv}$$

$$H = U + PV$$

$$Q = \Delta(mH)_{cv} - \Delta(PmV)_{cv} - H'\Delta m_{cv}$$

$$Q = (m_2 H_2)_{cv} - (m_1 H_1)_{cv} - H'\Delta m_{cv}$$

At the end of the process, the tank still contains saturated liquid and saturated vapor in equilibrium at 100°C and 101.33 kPa.

$$Q = (m_2 H_2)_{cv} - (m_1 H_1)_{cv} - H' \Delta m_{cv}$$

$$H' = 293.0 \frac{kJ}{kg} \quad saturated\ liquid\ @\ 70^\circ C$$

$$H_{cv}^{l} = 419.1 \frac{kJ}{kg} \quad saturated\ liquid\ @100^\circ C$$

$$H_{cv}^{v} = 2676.0 \frac{kJ}{kg} \quad saturated\ vapor\ @100^\circ C$$

From the steam table, the specific volumes of saturated liquid and saturated vapor at 100°C are 0.001044 and 1.673 m^3/kg , respectively.

$$(m_1 H_1)_{cv} = m_1^l H_1^l + m_1^v H_1^v = 500(419.1) + \frac{1.5 - (500)(0.001044)}{1.673}(2676.0) = 211616 \ \ kJ$$

$$m_2 = 500 + \frac{1.5 - (500)(0.001044)}{1.673} + 750 = m_2^l + m_2^v$$

$$1.5 = 1.673 m_2^v + 0.001044 m_2^l$$

$$(m_2 H_2)_{cv} = m_2^l H_2^l + m_2^v H_2^v = 524458 \ \ kJ$$

$$Q = (m_2 H_2)_{cv} - (m_1 H_1)_{cv} - H' \Delta m_{cv} = 524458 - 211616 - (750)(293.0) = 93092 \ \ kJ$$

EXERCISE

SVNA 6^{th} edition

Problem no. 6.76

HOMEWORK

SVNA 6th edition

Problems

No. 6.71

6.72