UTM
UNIVERSITI TEKNOLOGI MALAYSIA

No. Kad Pengenalan/No. Pasport ....
I.C. No./Passport No.

No. Soalan ....
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Jangan tulis apa-apa di ruangan ini
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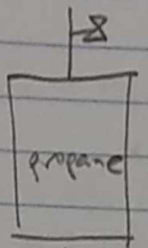
(1)



$V = 200\ L$

$pV^{1.4} = c$

(1) → (2)

$T_1 = 400\ K$

$P_1 = 3.5\ MPa$

$m_2 = 0.5\ m_1$

Calculate heat transfer during process.

Transient flow

Ideal gas. $R = 0.18855\ \frac{kJ}{kg.K}$

$$m_1 = \frac{PV}{RT} = \frac{3500\ (200 \times 10^{-3})\ m^3}{0.18855\ (400)} = 9.281\ kg$$

$$v_1 = \frac{V_1}{m_1} = 0.0215\ \frac{m^3}{kg}$$

$$m_2 = 4.641\ kg$$

$$v_2 = \frac{V_2}{m_2} = \frac{200 \times 10^{-3}}{4.641} = 0.0431\ \frac{m^3}{kg}$$

$$\therefore P_2 v_2^{1.4} = P_1 v_1^{1.4}$$

$$\therefore P_2 = 1321.9\ kPa$$

Apply 1st law

$$\Delta U = Q - W + \Sigma m_{in}(h + ke + pe) - \Sigma m_{out}(h + ke + pe)$$

$$U_2 - U_1 = Q - m_{out} h_{out}$$

$$m_2 u_2 - m_1 u_1 = Q - m_{out} h_{out}$$

$$m_2 C_v T_2 - m_1 C_v T_1 = Q - m_{out} h_{out}$$

major issue: h_{out} is not constant since the temperature inside the tank is changing.

- we need a way to model this behavior

we can either:

① solve it in small increments of temperature. This requires a relationship how the temperature varies during the process.

From ideal gas eqn & $pv^{1.4} = c$, we can find this

we can also properly integrate the whole process

② Knowing T_2 from ideal gas & $pv^{1.4} = c$, we can approximate T_{out} to be the average T between T_1 & T_2.

From ideal gas & $pv^{1.4} = c$:

$$T_2 = \frac{P_2 V}{m_2 R} = \frac{(1321.9 \text{ kPa})(200 \times 10^{-3} \text{ m}^3)}{4.641 \text{ kg} \; 0.18855}$$

$$= 302.13 \text{ K}$$

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$T_{avg} = 351.06$ K

$\therefore\ m_2 C_v T_2 - m_1 C_v T_1 = Q - (m_1 - m_2) C_p T_{avg}$

$\rightarrow Q = 4.641(1.4909)(302.13)$
$\quad - 9.281(1.4909)(400)$
$\quad + 4.641(1.6794)(351.06)$

$= -708.1$ kJ $\qquad Q_{loss} = 708.1$ kJ

— or using method ①.

$du = \delta Q - dH$

$\int_{T_1}^{T_2} m C_v dT = \int \delta Q - \int_{T_1}^{T_2} m C_p dT$ $\qquad$ assuming C_v, C_p constant

$C_v \int m dT = Q - C_p \int m dT$ $\qquad$ we need $m = f(T)$

$m = \dfrac{pV}{RT}$, $\quad p v^{1.4} = C$

$p = \dfrac{C}{v^{1.4}} = \dfrac{C}{\left(\frac{V}{m}\right)^{1.4}}$

$= \dfrac{C m^{1.4}}{V^{1.4}}$

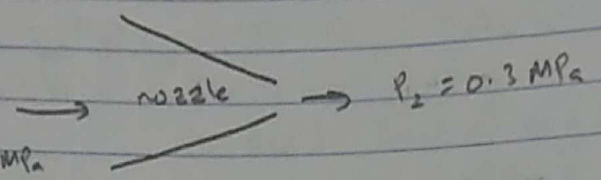
$\rightarrow m = \dfrac{C m^{1.4}}{V^{1.4}} \dfrac{V}{RT}$

$m^{-0.4} = \dfrac{C V^{-0.4}}{RT}$

$m = \left(\dfrac{C}{R}\right)^{-\frac{1}{0.4}} V\, T^{\frac{1}{0.4}}$ //

put this into integral & solve analytically or numerically.

(2)



$P_1 = 0.5$ MPa

$T_1 = 300°C$ steam

$\dot{m} = 0.1$ kg/s $\qquad Pv^{1.4} = c$

Find Δke & Q

1st. law:

$$\Sigma\dot{Q} - \Sigma\dot{W} = \Sigma\dot{m}(h + ke + pe) - \Sigma\dot{m}(h + ke + pe)$$

$$= \dot{m}\left[(h_2 - h_1) + \left(\frac{\vec{V}_2^2 - \vec{V}_1^2}{2}\right)\right]$$

$$= \dot{m}\left[(h_2 - h_1) + \Delta ke\right]$$

2nd law:

$$\frac{dS}{dt} = \Sigma\frac{\dot{Q}}{T} + \dot{m}(s_1 - s_2) + \dot{\sigma}_{gen}$$

0 (steady) $\qquad$ 0 (reversible)

→ $q = T\,ds$

Given $pv^{1.4} = c$.

$\left.\begin{matrix} P_1 \\ T_1 \end{matrix}\right\}$ $v_1 = ✓$, $h_1 = ✓$, $s_1 = ✓$

$\left.\begin{matrix} P_2 \\ v_2 \text{ from } pv^{1.4} = c \end{matrix}\right\}$ $h_2 = ✓$, $s_2 = ✓$

To find q, we can use $q = T ds$

but the major issue is we do not know T or the relationship between T & s to perform integration

It is suggested that:

1. we can take the average temperature between T_1 & T_2 for use in $q = T ds$

   T_2 can be found from known P_2, v_2

2. we can perform the above step in small increments of P until we reach P_2. The results of the incremental steps can be added to give a more accurate solution.

$P_1 = 0.5\,MPa$, $T_1 = 300°C$ } $h_1 = 3064.2\ kJ/kg$, $v_1 = 0.5226\ m^3/kg$, $s_1 = 7.4599\ kJ/kg.K$

$P_2 = 0.3\ MPa$

$$v_2 = \left(\frac{P_1}{P_2}\right)^{\frac{1}{1.4}} v_1 = \left(\frac{0.5}{0.3}\right)^{\frac{1}{1.4}} (0.5226)$$

$$= 0.7527\ m^3/kg$$

P_2, v_2 } superheated, interpolation;

$$\frac{\Delta h}{\Delta v} = \frac{h_2 - 2865.6}{0.7527 - 0.7163} = \frac{2967.6 - 2865.6}{0.7964 - 0.7163}$$

$$\rightarrow h_2 = 2911.95\ kJ/kg$$

$$\frac{\Delta s}{\Delta v} = \frac{s_2 - 7.3115}{0.7527 - 0.7163} = \frac{7.5166 - 7.3115}{0.7964 - 0.7163}$$

$$\rightarrow s_2 = 7.4047\ kJ/kg.K$$

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$$\frac{\Delta T}{\Delta v} = \frac{T_2 - 200}{0.7527 - 0.7163} = \frac{250 - 200}{0.7964 - 0.7163}$$

$$\rightarrow T_2 = 222.72\ ^\circ C$$

$$\therefore T_{avg} = 261.36\ ^\circ C = 534.36\ K$$

$\rightarrow$

$$Q = T_{avg} \Delta s$$
$$= 534.36\,(7.4047 - 7.4599)$$
$$= -29.50\ \frac{kJ}{kg}$$

$$\dot{Q} = Q\dot{m}$$
$$= -2.950\ kW$$

$$\therefore \Delta ke = \dot{Q} + \dot{m}(h_1 - h_2)$$
$$= -2.950 + 0.1\,(3064.2 - 2911.95)$$
$$= -2.950\ kW$$