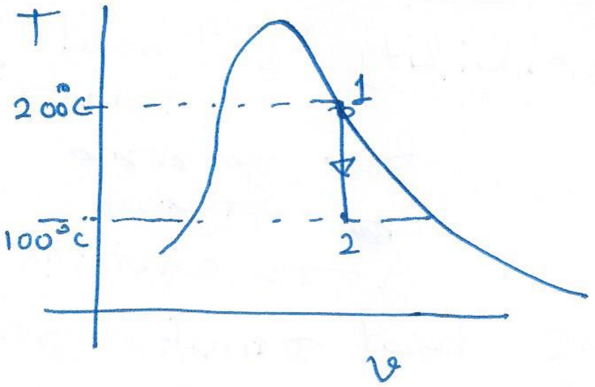
Assignment - 6 (Solution)

(1) **a** rigid tank $\Delta v = 0$, using first law on steam

$$Q_{1-2} = \Delta U = m(u_2 - u_1)$$

closed & rigid system container



hence $v_1 = v_2$

$$v_g \text{ at } 200^\circ C = v_{g,100} X + v_{l,100}(1-X)$$

from steam table using values:

$$X = 0.07543$$

$u_1 = h_1 - p_1 v_1$ from steam table

$u_2 = h_2 - p_2 v_2$ "

$$h_2 = h_{g,100} X + h_{l,100}(1-X)$$

hence $Q_{1-2} = m(u_2 - u_1) = -15860.2$ kJ

b $\Delta S_{total} = \Delta S_{steam} + \Delta S_{HR}$ (environment)

$$= m(s_2 - s_1) + \frac{|Q_{12}|}{T_{HR}} \quad T_{HR} \to T_0 = 300k$$

$$= m(s_2 - s_1) + \frac{m(u_1 - u_2)}{T_0}$$

Hence Lost work $= T_0 \Delta S_{total}$

$$= m\{(u_1 - u_2) + T_0(s_2 - s_1)\}$$

$$= m\{(u_1 - u_2) - T_0(s_1 - s_2)\}$$

using steam table put all values,

Lost work = 4885.1 kJ

what we learn here,

as ΔS_{total} is +ive, hence Lost work is +ive

& implies process is irreversible.

Further phase change is always reversible, then the only source of irreversibility is "heat transfer" from ~~reservoir~~ Steam ~~to~~ to environment.

→ which is true because heat transfer from steam to environment is taking place by the ~~b~~ virtue of a finite temp. difference

heat heat transfer is irreversible.

Availability approach (we can solve same problem with another approach)

for a closed system,

$$\delta Q = dU + \delta W \quad \text{(a)} \quad (\delta Q \text{ given to system from heat reservoir})$$

for a ~~rr~~ reversible process, $ds_{(system)} + ds_{HR} = 0$

$$ds_{HR} \rightarrow -\frac{\delta Q}{T_{HR}}$$

$$\Rightarrow \quad ds_{sys} = \frac{\delta Q}{T_{HR}} \quad \text{(b)}$$

from eqn (a) & (b)

$$T_{HR}\, ds = du + \delta W_{(by\ sys)}$$

as process is reversible $\delta W_{(by\ sys)}$ will be maximum (we have discussed

hence $T_{HR}\, ds = du + \delta W_{max}$

$$\delta W_{max} = \cancel{d\ldots}\ T_{HR}\, ds - du$$

δW_{max} (due to reversible proces) $= T_{HR}\, ds - dU$

it means if there is any irreversibility

$W_{sys} < \underbrace{W_{max}}$

Now $\underline{\underline{W_{max}}}$ also depends on T_{HR}, lets say $T_{HR} = T_0$ is temp of environment (P_0 is pressure)

$\Rightarrow \delta W_{max} = T_0\, ds - dU$ (Note down system is going from $S, u \to$ to S_0, u_0)

$\Rightarrow W_{max} = \cancel{T_0(S_0 - S) - (u_0 - u)} = T_0(S_0 - S) - (u_0 - u)$

* ~~However this work also~~ this is the work which will be given by system, if system goes from its initial state (S, V) to environmental condition reversibly $\to (S_0, V_0)$ (T_0, P_0 & corresponding v_0 of system)

However W_{max} also includes expansion work against environment.

Hence $W_{max\ useful} = W_{max} -$ work against environment

$= \underbrace{W_{max}} - P_0(v_0 - v)$

Thus. $W_{max\ useful} = T_0(S_0 - S) - (u_0 - u) - P_0(v_0 - v)$

hence $W_{max\ useful} = (u + P_0 v - T_0 s) - (u_0 + P_0 v_0 - T_0 s_0)$

this term is known as Availability per unit mass termed as ϕ

so ϕ (Availability) $= (u + P_0 v - T_0 s) - (u_0 + P_0 v_0 - T_0 s_0)$

so if a system is going from state 1 to state 2 by interacting with environment (at T_0, P_0) & v_0 is the specific volume of system at T_0, P_0

then

change in availability $= \phi_2 - \phi_1$

$$= \left[(u_2 + P_0 v_2 - T_0 s_2) - \cancel{(u_0 + P_0 v_0 - T_0 s_0)}\right] - \left[(u_1 + P_0 v_1 - T_0 s_1) - \cancel{(u_0 + P_0 v_0 - T_0 s_0)}\right]$$

$$= (u_2 + P_0 v_2 - T_0 s_2) - (u_1 + P_0 v_1 - T_0 s_1)$$

change in availability means change in quality of energy (per unit mass)

hence loss in availability $= -$ (change in availability)

$$= \phi_1 - \phi_2$$

hence loss in availability for mass $(m) = m(\phi_1 - \phi_2)$

known as Exergy loss $= m(\phi_1 - \phi_2)$

this is also equal to lost work

or degradation of quality of energy.

so if we use concept of Exergy loss for problem (1) of assign-6

we have Lost work = Exergy loss $= m(\phi_1 - \phi_2)$

$$= m[(u_1 - T_0 s_1) - (u_2 - T_0 s_2)]$$

(identical to our previous answer) $= m[(u_1 - u_2) - T_0(s_1 - s_2)]$