Engineering Thermodynamics

Module -1.3

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$\Delta S_{univ} = -\frac{Q_1}{T_1} + 0 + \frac{Q_2}{T_2}$

$= -\left(\frac{Q_1}{T_1} - \frac{Q_2}{T_2}\right) = -\oint \frac{\delta Q}{T}$ $\quad \therefore \Delta S_{uni} = -\oint \frac{\delta Q}{T}$

∴ Clausius inequality and 2nd entropy principle are same.

Gibbs equation

$\delta Q = du + \delta W$ ⇒ 1) If write this law for a reversible process for a closed system with only PdV work

↑ No restriction to this Expression. This can be irr, rev, electri. any work. Heat transfer is 1 type

then $\boxed{Tds = du + Pdv}$:- ① This eqn. is dependent only on properties.

② Concept is when process is reversible and work done is pdv
∴ 1st law and this eqn. same
i.e $\delta Q = Tds$ & $\delta W = Pdv$

③ But for irrev. process
$dQ \neq Tds$ and $W \neq Pdv$
∴ it is not the first law

$H = U + PV \Rightarrow dH = dU + PdV + Vdp \Rightarrow dH = Tds + Vdp \Rightarrow \boxed{Tds = dH - Vdp}$ { V = volume, S = Total entropy

∴ These 2 relation is prop. rel valid for rev & irr process.

But for rev. process.
1st eqn is equivalent to 1st law

$Tds = du + Pdv \Rightarrow PV = mRT$ or $P = \frac{mRT}{V}$

$\Rightarrow T\,dS = dU + \frac{mRT\,dv}{V}$

or $ds = \frac{dU}{T} + \frac{mR\,dv}{V} \Rightarrow \frac{mc_v dT}{T} + \frac{mR\,dv}{v}$

$\Rightarrow \boxed{ds = mc_v \ln\frac{T_2}{T_1} + mR\ln\frac{v_2}{v_1}}$

$$Tds = dH - vdp$$

$$Tds = mc_p dT - vdp$$

$$PV = mRT \qquad v = \frac{mRT}{P}$$

$$\Rightarrow Tds = mc_p dT - \frac{mRT}{P} dp \Rightarrow \boxed{dS = mc_p \frac{dT}{T} - mR \frac{dp}{P}}$$

for specific entropy: $ds = c_p \frac{dT}{T} - RT \frac{dp}{P}$

{ specific entropy $s = mS$ }

$$\Rightarrow ds = c_p \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1}$$

the gas constant of air is R = 0.287 kPa · m3/kg · K,

7-8 · ENTROPY CHANGE OF LIQUIDS AND SOLIDS

Recall that liquids and solids can be approximated as incompressible siub sfances since their specific volumes remain nearly constant during a process. Thus,dv=0forliquidsandsolids,andEq.7-25forthiscasereducesto (7-27) since $c_p = c_v = c$ and du = c dT for incompressible substances. Then the entropy change during a process is determined by integration to be

$$\boxed{ds = c \ln \frac{T_2}{T_1}}$$

Do example 7-9.

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Heat

Heat is, in essence, a form of disorganized energy, and some disorganization (entropy) will flow with heat. Heat transfer to a system increases the entropy of that system and thus the level of molecular disorder or randomness, and heat transfer from a system decreases it. In fact, heat rejection is

The distinction between heat transfer and work is brought out by the second law: an energy interaction that is accompanied by entropy transfer is heat transfer, and an energy interaction that is not accompanied by entropy transfer is work

$$S_{heat} : \int_1^2 \frac{\delta Q}{T} = \sum_j \frac{Q_j}{T_j}$$

Mass flow :-

$$S_{mass} : m \cdot s$$

Mass contains entropy as well as energy, and the entropy and energy contents of a system are proportional to the mass. (When the mass of a system is doubled, so are the entropy and energy contents of the system.)

Closed System

The entropy of any closed system can increase in two ways:

(a) by heat interaction in which there is entropy transfer
(b) internal irreversibilities or dissipative effects in which work (or K.E.) is dissipated into internal energy increase.

Entropy generation

$S_2 - S_1 = \int_1^2 \frac{\delta Q}{T} + \Delta S_{irr}$ or S_{gen} or $S_2 - S_1 = \sum_j \frac{Q_j}{T_j} + S_{gen}$

(ΔS_{irr}: entropy transferred due to irreversibility (b); $\int \frac{\delta Q}{T}$: (a))

$\Delta S_{sys} - \sum \frac{\delta Q}{T} = S_{gen}$ or $\frac{dS}{dt} = \dot{S}_{in} - \dot{S}_{out} + \dot{S}_{gen}$ { In rate form

($\dot{S}_{in} - \dot{S}_{out}$: net rate of entropy transfer)

or $S_{gen} = \Delta S_{sys} - \sum \frac{\delta Q}{T}$ for a rev. process: $S_{gen} = 0$ or $\Delta S_{sys} = \sum_j \frac{Q_j}{T_j}$

For an adiabatic process :-
$\delta Q = 0$

Do eg 7.17 of Cengel.

$\therefore S_{gen} = \Delta S_{system}$

For an isolated system :- $\delta Q = 0$

$\therefore$ $S_{gen} = \Delta S_{isolated\ system}$ { emp.

or for an universe :

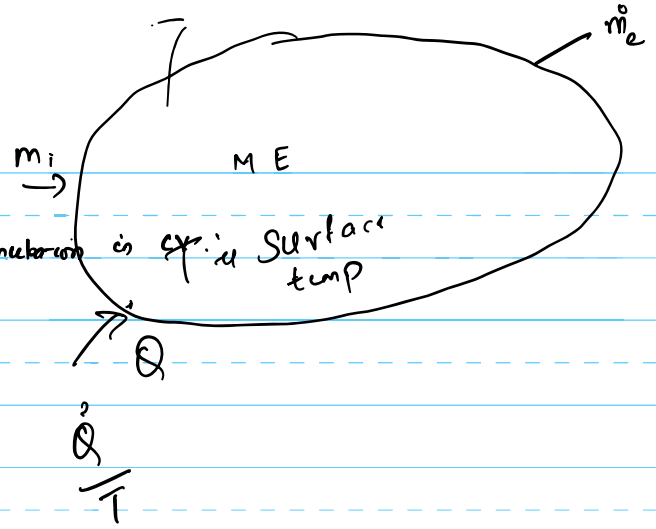
$S_{gen} = \Delta S_{universe} = \Delta S_{system} + \Delta S_{surrounding}$

Entropy generation depends on the path

The amount of entropy generation shows the irreversibility associated with the process

Entropy generation in an open system :-

Open System



The continuity equation gives :-

$$\Sigma \dot{m}_i - \Sigma \dot{m}_e = \frac{\partial M}{\partial t}$$

net mass transfer rate — rate of mass accumulation in C.V.

The energy equation :-

$$\dot{Q} - \dot{W} + \dot{m}_i e_i - \dot{m}_o e_{out} = \frac{\partial E}{\partial t}$$

for steady state $\frac{\partial E}{\partial t} = 0$

$$\therefore \dot{Q} - \dot{W} = E_2 - E_1$$

where $E_2 - E_1 = \dot{m}_2\left(h_2 + \frac{v_2^2}{2} + z_2\right) - \dot{m}_1\left[h_1 + \frac{v_1^2}{2} + gz_1\right]$

The second law inequality or the entropy principle gives :

$$\Sigma \dot{m}_i s_i - \Sigma \dot{m}_e s_e + \Sigma \frac{\dot{Q}_j}{T_j} + \dot{S}_{gen} = \frac{\partial S}{\partial t}$$

net entropy transfer — entropy generated — net rate of increase of entropy of C.V.

In a steady state process :- $\frac{\partial S}{\partial t} = 0$

$$\therefore \dot{S}_{gen} = \Sigma \dot{m}_e s_e - \Sigma \dot{m}_i s_i - \Sigma \frac{\dot{Q}_j}{T_j}$$

For case with 1 inlet and 1 exit and steady, eqn reduces to

$$m s_1 - m s_2 + \frac{Q_1}{T_1} + S_{gen} = 0$$

$$s_2 - s_1 = \frac{1}{m}\left(\frac{Q_1}{T}\right) + \frac{S_{gen}}{m}$$

** Do ques 7.9 from Nag.