Sharif University of Technology
School of Mechanical Engineering
Center of Excellence in Energy Conversion

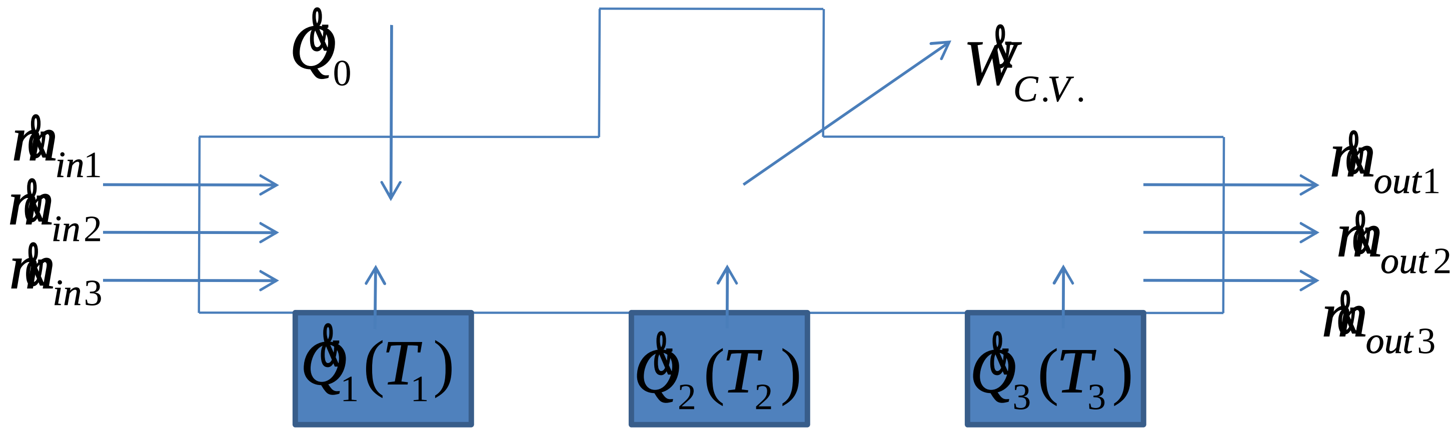
Advanced Thermodynamics

Lecture 12

Dr. M. H. Saidi

2011

Exergy Analysis for a C.V.



- Thermodynamic analysis

$$\frac{dm_{C.V.}}{dt} = \sum_{in} \dot{m} - \sum_{out} \dot{m} \Rightarrow \Delta_{1-2} m_{C.V.} = \sum \int_{t1}^{t2} \dot{m}_{in} dt - \sum \int_{t1}^{t2} \dot{m}_{out} dt$$

- Energy Eq. (Heat balance) or 1st law $\quad \left(h^* = h + \frac{v^2}{2} + gz\right)$

$$\frac{dE_{C.V.}}{dt} = \sum_{i=0}^{n} \dot{Q}_i - \dot{W}_{C.V.} + \sum_{in} \dot{m} h^* - \sum_{out} \dot{m} h^* \quad \text{Eq. (1)}$$

- Entropy principle (2nd law)

$$\frac{dS_{C.V.}}{dt} = \sum_{i=0}^{n} \frac{\dot{Q}_i}{T_i} + \sum_{in} \dot{m} S - \sum_{out} \dot{m} S + \dot{S}_{gen} \quad \text{Eq. (2)}$$

- From Eq. (1) $\dot{Q}_0 = \frac{dE_{C.V.}}{dt} + \sum_{i=1}^{n} \dot{Q}_i - \dot{W}_{C.V.} + \sum_{in} \dot{m} h^* - \sum_{out} \dot{m} h^*$
- From Eq. (2)

$$\dot{Q}_0 = T_0 \frac{dS_{C.V.}}{dt} - T_0 \sum_{i=0}^{n} \frac{\dot{Q}_i}{T_i} - T_0 \sum_{in} \dot{m} S + T_0 \sum_{out} \dot{m} S - T_0 \dot{S}_{gen}$$

$$\Rightarrow \frac{dE_{C.V.}}{dt} + P_0 \frac{dV}{dt} - T_0 \frac{dS_{C.V.}}{dt} = \sum_{i=1}^{n} \left(1 - \frac{T_0}{T}\right) \dot{Q}_i - \left(\dot{W}_{C.V.} - P_0 \frac{dV}{dt}\right)$$

$$+ \sum_{in} \dot{m} (h^* - T_0 S) - \sum_{out} \dot{m} (h^* - T_0 S) - T_0 \dot{S}_{gen}$$

- Since and are considered constant

$$\frac{d}{dt}\left[E_{C.V.} + P_0 dV - T_0 S_{C.V.}\right] = \frac{d(Exergy)}{dt} = \frac{d(Availability)}{dt} = \frac{dy}{dt}$$

$$\underbrace{\frac{dy}{dt}}_{I}=\underbrace{\sum_{i=1}^{n}\left(1-\frac{T_0}{T}\right)\dot{Q}_i}_{II}-\underbrace{\left(\dot{W}_{C.V.}-P_0\frac{dV}{dt}\right)}_{III}+\underbrace{\sum_{in}\dot{m}b-\sum_{out}\dot{m}b}_{IV}-\underbrace{T_0\dot{S}_{gen}}_{V}$$

- Where $b=(h^{*}-T_0S)$
- *I*: Rate of change of exergy (availability) of C.V. with the time.
- *II*: Exergy transferred into C.V. with heat, note that
- *III*: Rate of available work produced by the C.V.
- *IV*: Net availability convected into the C.V. with mass flow, also called physical exergy.
- *V*: Exergy destruction due to internal irreversibility.

$$\underbrace{\frac{dy}{dt}}_{I} = \sum_{i=1}^{n} \underbrace{\left(1-\frac{T_0}{T}\right)\dot{Q}_i}_{II} - \underbrace{\left(\dot{W}_{C.V.} - P_0\frac{dV}{dt}\right)}_{III} + \underbrace{\sum_{in}\dot{m}b - \sum_{out}\dot{m}b}_{IV} - \underbrace{T_0\dot{S}_{gen}}_{V}$$

- Observations:
  - Exergy is simply a combination of the 1st and 2nd laws.
  - exergy (availability) is completely rigrous, there are new assumptions in deriving its statement.