Module 2: Thermodynamics of Combustion

Lecture 7: Thermodynamic Laws

The Lecture Contains:

- Enthalpy and Internal Energy
- Effect of Temperature on Heat Capacity
- Thermodynamic Laws
- First Law
- Second Law

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Enthalpy and Internal Energy

Specific internal energy of the mixture, $\quad u_{mix} = \sum_i X_i u_i$

Mass specific internal energy of the mixture, $\quad \hat{u}_{mix} = \sum_i Y_i \hat{u}_i$

Specific enthalpy of the mixture, $\quad h_{mix} = \sum_i X_i h_i$

Mass specific enthalpy of the mixture, $\quad \hat{h}_{mix} = \sum_i Y_i \hat{h}_i$

Enthalpy of a species,

$$h^0_{i,T}(T) = \underbrace{h^0_{f,298.15}}_{\substack{\textit{Heat of formation}\\\textit{(due to bond energy)}}} + \underbrace{\int_{298.15}^{T} C_{p,i}\, dT}_{\substack{\textit{Sensible enthalpy}\\\textit{(associated with temperature)}}}$$

Internal Energy of a species, $\quad u^0_{i,T}(T) = u^0_{f,298.15} + \int_{298.15}^{T} C_{v,i}\, dT$

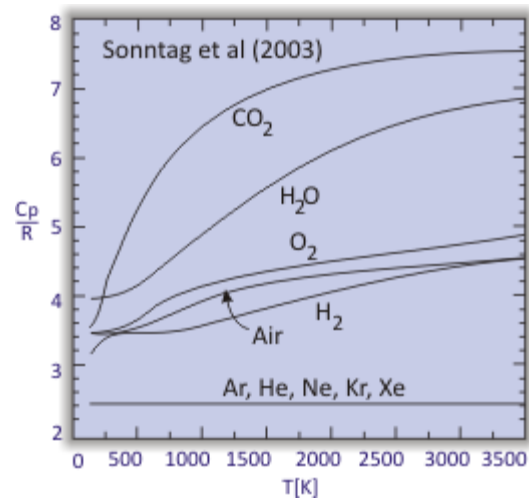◀‖ Previous   Next ‖▶

Effect of Temperature on Heat Capacity

Specific heats, C_p and C_v are functions of temperature for both ideal and real gases

Variation in sp. heat with temperature is caused by
- Vibrational energy
- Rotational energy

Sp. heat of mono **atomic gases** does not vary with temperature, why?
Their internal energy is contributed by translational energy

(Figure 7.1)

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Thermodynamic Laws

Zeroth Law	Two bodies have the same temperature as third body, when placed in thermal contact
First Law	During a cyclic process, the algebraic sum of work is proportional to heat
Second Law	Heat cannot itself transfer from lower temperature to higher temperature
Third Law	Entropy of perfect crystal is zero at absolute zero temperature

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First Law of Thermodynamics

First law applied to a closed system:

$$\delta Q - \delta W = dE$$

Where, δQ — Heat added to the system (Path Function)

δW — Work done by the system (Path Function)

dE — Total energy change in the system (Point Function)

First law applied to an open system:

$$\frac{dE}{dt} = \dot{m}_i \left[h_i + \frac{V_i^2}{2} + gZ_i \right] - \dot{m}_e \left[h_e + \frac{V_e^2}{2} + gZ_e \right] + \delta \dot{Q} - \delta \dot{W}$$

| Rate of accumulation of total energy in Shaft | Net change of total energy efflux | Heat interaction across control surface | Rate of work done by Shaft |

Where, h – Specific enthalpy

V – Velocity of flow

Z – Height of inlet and outlet port

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Second Law of Thermodynamics

Clausius inequality: For any system undergoing a cyclical process, the ratio of the sum of all heat interactions to its temperature is equal to or less than zero.

$$\oint \frac{\delta Q}{T} \leq 0$$

Increase in entropy principle: $dS_{sys} \geq \dfrac{\delta Q}{T}$

Second law of thermodynamics for control volume:

$$\frac{dS}{dt} = \dot{m}_i s_i - \dot{m}_e s_e + \frac{\delta \dot{Q}}{T} + \dot{S}_G$$

Rate of accumulation of entropy in CV

Net change of total entropy efflux

Entropy flow due to heat interaction across control surface

Rate of entropy generation in CV

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