Chapter-2 Combustion

Adiabatic flame temperature

Combustion is a sequence of exothermic chemical reactions between fuel & oxidizer to release usually Thermal energy.

Fuel: A substance, which contains Chemical energy, which can be released in the form of heat. Example Methane, Gasoline

Oxidizer: A substance which helps/promotes combustion by providing O_2 to chemical reactions. Example: Liquid Oxygen, (LOX)
Hydrogen peroxide (H_2O_2)

Gas mixture: Number of species

Mole: A mole is an amount of substance, which contains $\underbrace{6.02252 \times 10^{23}}_{\text{Avagadro number}}$ number of atoms/molecules.

Molar mass/molecular weight: Mass of one mole of any substance. g/mol, $kg/kmol$

1 mole of H_2 — 2 g

Molar mass $M_{WH_2} = 2\, g/mol$ or $2\, kg/kmol$

$M_{WC} = 12\, kg/kmol$, $M_{WO_2} = 32\, kg/kmol$

Mole fraction : χ_i , ith species.

$$\chi_i = \frac{\text{No. of moles of ith species}}{\text{Total no. of moles in the gas mixture}}$$

$$= \frac{N_i}{\sum_{j=1}^{n} N_j} \quad , \quad n - \text{total no. of species.}$$

$$\sum_{i=1}^{n} \chi_i = 1$$

Mass fraction of ith species, Y_i

$$Y_i = \frac{\text{Mass of ith species}}{\text{Total mass of gas mixture}} = \frac{m_i}{\sum_{j=1}^{n} m_j}$$

m_i - mass of ith species

$$\sum_{i=1}^{n} Y_i = 1$$

$$Y_i = \frac{X_i M_{W_i}}{M_{W_{mix}}}, \quad X_i = \frac{Y_i M_{W_{mix}}}{M_{W_i}}$$

$$M_{W_{mix}} = \sum_j X_j M_{W_j} = \frac{1}{\sum_j \left(Y_j / M_{W_j} \right)}$$

Stoichiometry is a calculation of the amount of reactants & products in a chemical reaction.

Stoichiometric quantity of oxidizer is the amount of oxidizer just required to completely burn a given amount of fuel

Methane + O_2 — Air

$$CH_4 + 2\left[O_2 + 3.76 N_2\right] \longrightarrow CO_2 + 2H_2O + 7.56 N_2$$

Balanced chemical reaction

Stoichiometric quantity of oxidizer to burn one molecule of CH_4 is 2

1 mole of CH_4 requires 2 moles of O_2

Burning in air | $O_2 - 21\%$, $N_2 - 79\%$] Volume fraction, Mole fraction

$x_{N_2}/x_{O_2} = 79/21 = 3.76$

$>2 \rightarrow$ fuel lean

$<2 \rightarrow$ fuel rich

Air to fuel ratio at stoichiometric conditions.

$$A/F\big|_s = \frac{\text{Amount of Oxidizer required (mass)}}{\text{Amount of fuel required (mass)}}$$

$$A/F\big|_s = \frac{\text{No. moles of Oxidizer} \times M_{W\,oxidizer}}{\text{No. of moles of fuel} \times M_{W\,fuel}}$$

$$= \frac{2 \times \cancel{32}^{2}}{1 \times (\cancel{16})} = \underline{4}$$

Stoichiometric Combustion

$$M_{W_{CH_4}} = 12 + 4 = 16$$

$A/F)_s$ $CH_4 + 2(O_2 + 3.76\,N_2) \longrightarrow$ products

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Equivalence ratio. ϕ

$\phi > 1$ fuel rich condition

$$\phi = \frac{A/F)_s}{A/F} = \frac{F/A}{F/A)_s}$$

$\phi = 1 \Rightarrow$ stoichiometic Condition

$\phi < 1$ fuel lean condition