Module 6: Diffusion Flame

Lecture 34: Solid Fuel Combustion

The Lecture Contains:

Previous Next

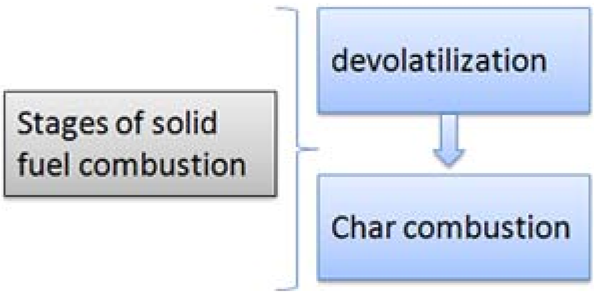
Solid Fuel Combustion

Factors influencing solid fuel burning

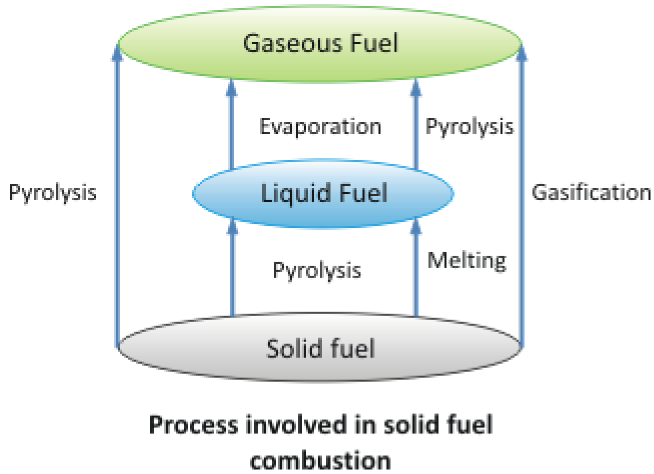
- Nature of the solid fuel
- Type of application

Previous Next

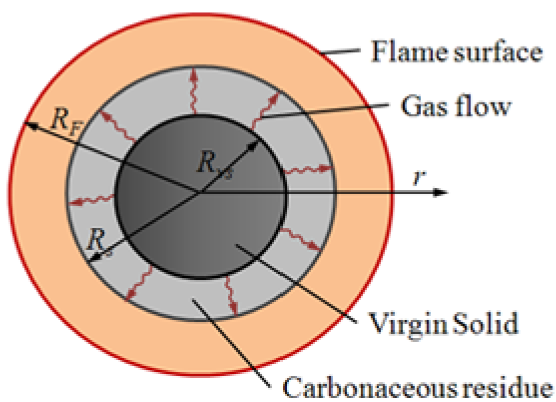
Solid Fuel Combustion



(Figure 34.1)



(Figure 34.2)



(Figure 34.3)

Previous Next

Solid Fuel Combustion

Overall process of char combustion	➢ Transport of oxygen molecule to fuel surface
	➢ Adsorption of oxygen molecule on the fuel surface
	➢ Reaction of oxygen with solid fuel
	➢ Diffusion of generated products back to fuel
	➢ Transport of products away from the fuel surface

Previous Next

Theory For Single Coal Combustion

1. Burning process is quasi steady.
2. Burning takes place in quiescent, infinite ambient air medium.
3. No interaction with other particles.
4. Effect of natural convection is ignored.
5. Burning is diffusion controlled.
6. Constant thermodynamic properties
7. Unity Lewis number
8. Gaseous species do not enter into gaseous species
9. No radiation heat transfer
10. Ideal gas law

Previous Next

Theory For Single Coal Combustion

Mass conservation

$$\frac{d}{dr}(\rho V_r r^2) = 0 \Rightarrow \dot{m}'' r^2 = \text{constant} \qquad \text{--------(1)}$$

Oxidizer species conservation

$$(\dot{m}'' r^2)\frac{dY_{Ox}}{dr} = \rho D_{12}\frac{d}{dr}\left(r^2\frac{dY_{Ox}}{dr}\right) \qquad \text{--------(2)}$$

Energy conservation

$$\dot{m}'' r^2 C_p \frac{dT}{dr} = k_g \frac{d}{dr}\left(r^2\frac{dT}{dr}\right) \qquad \text{--------(3)}$$

Stoichiometric fuel-air ratio

$$f = \dot{m}''_s / \dot{m}''_{Ox,s} \qquad \text{--------(4)}$$

Boundary Conditions:

$$\text{At free stream r}, = \infty; \mathrm{Y}_{\mathrm{Ox}} = \mathrm{Y}_{\mathrm{Ox},\infty} \qquad \text{--------(5)}$$

$$At\ solid\ surface\ r, = R;\ \dot{m}''_{Ox,s} = \rho D_{12}\left.\frac{dY_{Ox}}{dr}\right|_s - \dot{m}''_s Y_{Ox,s} \qquad \text{--------(6)}$$

Combining Eq. 4 and 6,

$$\frac{\dot{m}''_s}{f} = \rho D_{12}\left.\frac{dY_{Ox}}{dr}\right|_s - \dot{\mathrm{m}}''\mathrm{Y}_{\mathrm{Ox}} \qquad \text{--------(7)}$$

Previous Next

Theory For Single Coal Combustion

Integrating Eq. 2 and applying b.c.,

$$(r^2\rho D_{12})\frac{dY_{Ox}}{dr} - \dot{m}_s'' R^2\left(Y_{Ox}+\frac{1}{f}\right) = 0 \qquad \text{--------(8)}$$

Integrating the above equation further,

$$ln\left(Y_{Ox}+\frac{1}{f}\right) = -\frac{\dot{m}_s'' R^2}{r^2\rho D_{12}} + C \qquad \text{--------(9)}$$

Applying the boundary condition,

$$ln\left(\frac{Y_{Ox}+1/f}{Y_{Ox,\infty}+1/f}\right) = -\frac{\dot{m}_s'' R^2}{r\rho D_{12}} \qquad \text{--------(10)}$$

Y_{Ox} increases exponentially with the increase in radius
$Y_{Ox} = Y_{Ox,s}$ at the solid surface

Previous Next

Theory For Single Coal Combustion

At moderate temperature and for small particle, the oxygen mass fraction at the surface is given by

$$\frac{\dot{m}_s'' R}{\rho D_{12}} ln\left(\frac{Y_{Ox,\infty} + 1/f}{1/f}\right) = ln(B_c + 1) \quad \text{--------(11)}$$

B is the mass transfer number $B = fY_{Ox,\infty}$

$$Y_{Ox} = \frac{(B_c + 1)^{(1-R/r)} - 1}{f} \quad \text{--------(12)}$$

The carbon sphere burning rate is also governed by D^2 Law

$D^2(t) = D_0^2 - K_c t$ where K_c is the carbon burning constant.

Table: Combustion properties of slid spheres [7]

Fuel	ρ_{fuel} (g/cm^3)	MW$_{fuel}$	B.P$_{fuel}$ (ºC)	f	B$_{oxygen}$	B$_{air}$
Aluminium	2.70	27.0	2.467	1.12	1.12	0.26
Boron	2.34	10.8	2.550	0.451	0.451	0.105
Carbon	1.50	12.0	4.827	0.75	0.750	0.174
Carbon	1.50	12.0	4.827	0.375	0.375	0.087
Magnesium	1.74	24.3	1.107	1.107	1.520	0.353
Zirconium	6.44	91.2	3.578	3.578	2.850	0.662

Previous Next