

Suggested solutions TEP4170 Heat and combustion technology 9 August 2010
 by Ivar S. Ertesvåg, with contributions from and Khanh-Quang Tran (Problem 11-12).
 Revised 12 August 2010.

2)

The quantity $-\rho \overline{Y'_k u'_2}$ is known as the turbulence mass flux of species k .

Assume a flow with a velocity gradient in x_2 -direction similar to that of the textbook where Prandtl's model is developed. In addition, assume that there is also a gradient of the mass fraction. Let the "balls" move to set up deviations in mass fraction (similar to the deviations in velocity). The motions x_2 -direction are still represented by u'_2 . Conduct the development of the mass flux similar to the momentum flux (aka. turbulence shear stress). The result is something like

$$-\rho \overline{Y'_k u'_2} = \rho \ell_Y^2 \left| \frac{\partial \bar{u}_2}{\partial x_2} \right| \frac{\partial \bar{Y}_k}{\partial x_2}$$

where ℓ_Y is a mixing length for the species.

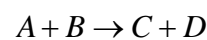
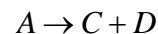
The turbulence flux can also be modelled by using the already known turbulence viscosity.

$$-\rho \overline{Y'_k u'_2} = \Gamma_{Y,t} \frac{\partial \bar{Y}_k}{\partial x_2} = \frac{\mu_t}{\sigma_Y} \frac{\partial \bar{Y}_k}{\partial x_2}$$

The reason for using this relation, is that both species mass and momentum are transported by the same eddying motions, and hence they can be assumed to have corresponding transport properties.

7)

Unimolecular, bi-molecular and ter-molecular reactions can be written



The reaction rate for species A is expressed

$$\frac{d[A]}{dt} = -k[A]^a[B]^b[M]^m$$

where a , b and m are the reaction orders with respect to species A, B and M, and k is the rate coefficient of the reaction. For the unimolecular elementary reaction, $a = 1$ and $b = m = 0$, which means that the reaction order of the reaction is unity. For the bi-molecular elementary reaction, $a = b = 1$ and $m = 0$, and the reaction order is 2. For the tri-molecular elementary reaction $a = b = m = 1$, and the reaction order is 3.

8)

See Figs. 9.15 (configuration and flame), 9.15 (species) and 9.16 (Temperature) in the textbook (Turns).

9)

From Marie Bysveen's lecture on engines:

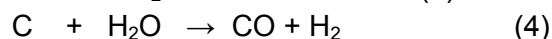
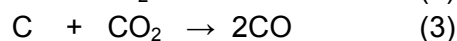
HCCI

Has characteristics of the two most popular forms of combustion used in IC engines

- Homogeneous charge spark ignition (gasoline engines)
- Stratified charge compression ignition (diesel engines)
- As in homogeneous charge spark ignition, the fuel and oxidizer are mixed together
- Rather than using an electric discharge to ignite a portion of the mixture, the density and temperature of the mixture are raised by compression until the entire mixture reacts spontaneously
- Stratified charge compression ignition also relies on temperature and density increase resulting from compression, but combustion occurs at the boundary of fuel-air mixing, caused by an injection event, to initiate combustion.
- Much less NOx

10)

The 4 global surface (heterogeneous):



Main difference between the film and shrinking-core models: The film model looks at reactions within the gas-solid boundary layer, assuming that the intra-particle diffusion is ignored, whereas the shrinking-core model treats carbon fuel as a porous material and looks at reactions within the particle in which ash diffusion is important.

12)

Let 1 refer to particles of size R , and 2 refer to particle of size $2R$. Then

$$\tau_2 = 3\tau_1 \quad (1)$$

As it is assumed that film diffusion does not give any resistance

$$\tau_1 = \tau_{1,\text{ash}} + \tau_{1,\text{reaction}} \quad (2)$$

$$\tau_2 = \tau_{2,\text{ash}} + \tau_{2,\text{reaction}} \quad (3)$$

But from Eq. (17) and (22) in Table 25.1

$$\tau_{2,\text{ash}} = 4\tau_{1,\text{ash}} \quad (4)$$

$$\tau_{2,\text{reaction}} = 2\tau_{1,\text{reaction}} \quad (5)$$

Replace (4), (5) and (1) in (3) gives

$$3\tau_1 = 4\tau_{1,\text{ash}} + 2\tau_{1,\text{reaction}} \quad (6)$$

From (2) and (6) we find that $\tau_{1,\text{ash}} = \tau_{1,\text{reaction}}$

The % contribution of ash diffusion to the overall resistance for particles of size R is 50%.