Department of Energy and Process Engineering — ISE Mar16
TEP4170 Heat and combustion technology

Exercise 10:
The Eddy Dissipation Concept for turbulent combustion

Problem 1:

a)
In the EDC cascade model for energy transfer between scales of turbulent flow:
– Which fraction of the viscous dissipation occurs at the level of the smallest scales (L^*)?
Hint: geometric series.

b)
Show that

$$\varepsilon = 0{,}2\frac{u'^{\,3}}{L'} = 0{,}27\frac{u^{*\,3}}{L^*} = 0{,}67\nu\frac{u^{*\,2}}{L^{*\,2}}$$

c)
Show how to express u^*, L^* and $Re^* = u^* L^*/\nu$ from ε, ν and numerical constants (C_{D1} and C_{D2}). At the end, introduce values for the numerical constants.

d)
Develop a (simpler) expression for the product $\dot{m}^*\gamma_\lambda^2$ or γ_λ^2/τ^*.

–What does this relation show?

Problem 2:

– Put up the mass balance and the energy balance for an adiabatic fine-structure reactor.
– Use this to explain graphically how extinction occurs.

Problem 3:

In a calculation step (iteration), for a certain node (point) in the calculation domain, the following quantities are available (obtained in the previous step):
$k = 4\,\mathrm{m^2/s^2}$, $\varepsilon = 80\,\mathrm{m^2/s^3}$, $\bar{\rho} = 0{,}3\,\mathrm{kg/m^3}$, $\tilde{Y}_{\mathrm{fu}} = 0{,}05\,\mathrm{kg/kg}$, $\tilde{Y}_{\mathrm{ox}} = 0{,}70\,\mathrm{kg/kg}$, $\tilde{T} = 1100\,\mathrm{K}$, $\nu = 2\cdot 10^{-5}\,\mathrm{m^2/s}$.
The fuel is propane (hint: Exercise 4), and the subscript "ox" denotes air (oxidizer), that is oxygen O_2 and the associated nitrogen (79/21 moles N_2 per mole of O_2). The remaining mass (neither "fu" nor "ox") is product. The specific heat for the mixture can be assumed at $c_p = 1{,}3\,\mathrm{kJ/(kg\cdot K)}$

Determine the following quantities for EDC, with the assumption of fast chemistry:
Re_{T}, Re_λ, $\theta = k/\varepsilon$, γ_λ, γ^*, u^*, L^*, $\dot{m}^*$, τ^*, χ, $\tilde{Y}_{\min}$, $\overline{R}_{\mathrm{fu}}$, $\overline{R}_{\mathrm{ox}}$, T^*.