Exercise 9: Non-premixed combustion, Turbulent combustion

Problem 1:

A combustion chamber has two inlets. Methane, CH_4, is supplied in Inlet (1), while air is supplied in Inlet (2).
Determine the stoichiometric mixture fraction, ξ_s, that is, the mixture fraction for a stoichiometric mixture.

Answer: $\xi_s = 0{,}055$

Problem 2:

For the combustion chamber in Problem 1, we let the temperature be a function of the mixture fraction:

$$T = T(\xi) = \begin{cases} T_2 + (T_s - T_2)\dfrac{\xi}{\xi_s} & \text{when } 0 \leq \xi \leq \xi_s \\ \\ T_1 + (T_s - T_1)\dfrac{\xi - 1}{\xi_s - 1} & \text{when } \xi_s \leq \xi \leq 1 \end{cases}$$

Here, T_1 is the temperature of Inlet (1) (fuel) and T_2 is the temperature of Inlet (2) (air). ξ_s is the stoichiometric mixture fraction (Problem 1) and T_s is the temperature for the stoichiometric mixture; $T_s = T(\xi_s)$.

Data: $T_1 = T_2 = 300\text{K}$ and $T_s = 2000\text{K}$

At a location, we have determined that $\overline{\xi} = 0{,}5$ and $\overline{\xi'^2} = 0{,}05$. Use the β probability density function and determine the mean temperature of this location.

Hint: First, determine the parameters a and b (Answer: $a = b = 2$)

Answer: $\overline{T} = 1194$ K

Problem 3:

For the combustion chamber in Problems 1 and 2: Determine the mass fractions of fuel, air (oxidizer) and product as functions of the mixing fraction. That is $Y_{\text{br}} = Y_{\text{br}}(\xi)$, $Y_{\text{oks}} = Y_{\text{oks}}(\xi)$ and $Y_{\text{pr}} = Y_{\text{pr}}(\xi)$, similar to $T = T(\xi)$ in Problem 2.

We can assume the reactions as complete and fast.

Problem 4:

We are going to model turbulent combustion (non-premixed) with
a) the Eddy Dissipation Model (1976 verision)
b) a prescribed-pdf model.
In both models we assume that the reactions can be modeled as
fuel + oxidizer to product, where reactions are fast and complete.

– List all the equations for which we have to solve partial differential equations (PEDs) for a) and b).
– List other equations needed (non-PDE) and other quantities that have to be modeled/expressed. Include mean motion, turbulence, reactions and material properties.