CentraleSupelec	Numerical Methods, S8

Project #02: Stabilization of a flame

The coupling of advection and diffusion transport phenomena with a source term can generate propagative solutions with a resulting intrinsic propagation speed S_l. Such propagative fronts are met in chemical processes, life science or combustion. Here, the combustion of a premixed mixture of air and a given fuel is modeled by the transport equation of a progress variable:

$$\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} = D\frac{\partial^2 c}{\partial x^2} + Ac^2(1-c),$$

where the progress variable c is zero in the fresh gases and unity in the burnt gases (see Fig. 1). This transport equation is composed of an unsteady term, an advection term, a diffusion term and a source term $Ac^2(1-c)$ describing the chemical reactions. Neglecting variations of density for the sake of simplicity, the advection velocity u is constant. $D = 2.0 \times 10^{-5}$ m^2/s is the diffusivity of the progress variable. The reaction coefficient for the studied condition is $A = 8000$ s^{-1}.

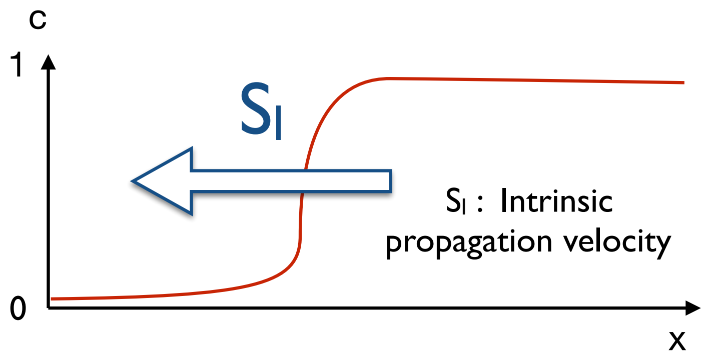

Figure 1: Profile of progress variable. Without any injection velocity ($u = 0$), the flame propagates from right (burnt gases side) to left (fresh gases side).

The flame propagates against the incoming velocity u with the propagation speed S_l. The absolute speed of the flame in a fixed framework is then $u - S_l$. Three conditions are then possible:

- $u > S_l$: The flame is blown away.
- $u = S_l$: The flame is stabilized and then steady.
- $u < S_l$: The flame flashes-back.

Stabilizing such a flame in a 1D flow is unrealistic in practice because matching $u = S_l$ strictly is not possible experimentally. Nonetheless, knowing whether the flame flashes back or if it is blown out is critical for safety reasons.

$$\boxed{\textbf{Question: Is setting } u = 0.3 \textbf{ m/s enough to prevent flash-back of the flame?}}$$

N.B. : Impose an initial solution similar to Fig. 1 with a profile thickness of the correct order of magnitude so that the numerical solution remains captured on the chosen mesh. This flame thickness can be estimated by dimensional analysis.