AAE 538: Air-Breathing Propulsion

Lecture 28: Combustion in Supersonic Propulsion

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Basic Injector Design

- Consider the case of two uniform, parallel flows of air and gaseous fuel from splitter plate into a constant-area duct.
  - The initial velocities are u_1 and u_2.
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- Assume:
  - Pressure and density are equal and constant
  - Boundary layers can be ignored.

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- If the two velocities differ, a _____ is generated at the interface of the two streams
- Non-dimensional local velocities are typically normalized by an average reference velocity;
- Lateral transport is _____
  - Momentum
  - Thermal, and mechanical, energy
  - Mass (molecules); for example, air and fuel.
- If the two velocities are equal, no shear stress exists between the two streams and they simply co-flow downstream at the convective velocity.
  - Even though there is no lateral transport of momentum or vorticity, there is still _____ at the interface due to molecular diffusion.

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- The rate of molecular diffusion is given by Fick's Law:
  - The time rate of change of molecular transport is proportional to the product of the interfacial area and the local concentration gradient.

  - Fick's law can be written for the diffusion of air into the fuel as:

$$j_A = -D_{FA}\frac{\partial C_A}{\partial y}$$

    - where j_A is the new molar diffusive flux of air in the y direction.
    - C_A is the concentration of air
    - $\frac{\partial C_A}{\partial y}$ is the lateral concentration gradient

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- We relate the air mole-fraction to the concentrations of fuel and air by some simple accounting:

- As a result, it can be seen that the mixing-layer thickness (δ_m) grows with the downstream distance (x) approximately as:

While the spatial profile of the air mole fraction varies in the x and y directions as approximately:

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- The mole fraction profile for $Y_A(x, y)$ is shown.
- The greatest concentration gradient, and therefore, the greatest diffusive flux, occurs
- Once the mixing layer reaches the wall, there is no pure substance anymore,

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- We can relate the total distance required for the mixing layer to reach the walls to the mixing layer thickness evolution by setting $\delta_m = 2\mathrm{b}$.

- We need to minimize L_m. How?
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