Global stability analysis of micro-combustion

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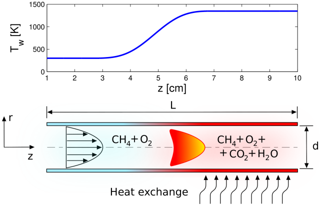
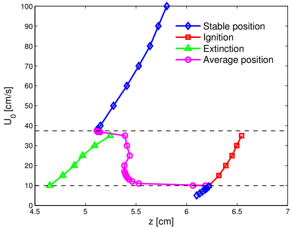


Sketch of the problem.

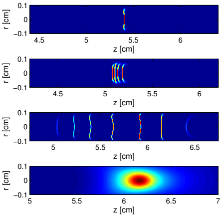
$$\frac{\partial Y}{\partial t} + u_z \frac{\partial Y}{\partial z} = D\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial Y}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 Y}{\partial \theta^2} + \frac{\partial^2 Y}{\partial z^2}\right] - A^* Y \exp\left(-\frac{T_a}{T}\right)$$

$$\frac{\partial T}{\partial t} + u_z \frac{\partial T}{\partial z} = D\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 T}{\partial \theta^2} + \frac{\partial^2 T}{\partial z^2}\right] + \frac{Q}{C_p} A^* Y \exp\left(-\frac{T_a}{T}\right)$$

Combustion model proposed by *F. Bianco et al.* 2015. **D** and $\mathbf{A}^*$ values calibrated to fit the experiments *Y. Tsuboi et al.* 2009.



Flame position $z_{pos}(U_0)$.

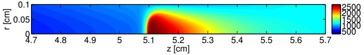


Temperature production.

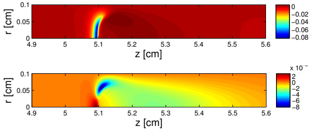
- $\hookrightarrow$ $U_0 > 37.4 cm/s$ **Stable** flame
- $\hookrightarrow$ $37.4 \geq U_0 > 36.8 cm/s$ **Oscillating** flame
- $\hookrightarrow$ $36.8 \geq U_0 > 9.9 cm/s$ Flame with Rapid Extinction and Ignition (**FREI**)
- $\hookrightarrow$ $U_0 < 9.9 cm/s$ **Weak flame** condition

Global stability

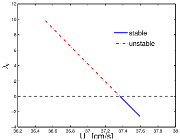
$\mathbf{q}(r,\theta,z,t) = \mathbf{Q}_b(r,z) + \varepsilon \mathbf{q}'(r,\theta,z,t)$ **perturbation** evolution onto a **basic state**



Steady solution $\mathbf{Q_b}$ at $U_0 = 37 cm/s$ reached by Selective Frequencies Damping (**SFD**). Perturbation solution in normal mode: $\mathbf{q}'(r,\theta,z,t) = \hat{\mathbf{q}}(r,z;m,\lambda)e^{im\theta+\lambda t} + c.c.$ $\Longrightarrow$ **Eigenvalue problem**.

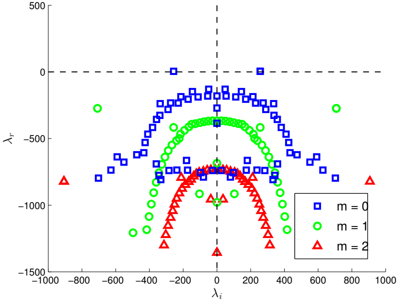


Real and imaginary part of temperature perturbation for $m = 0$.

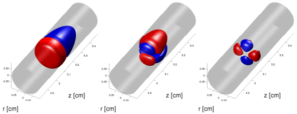


Decreasing U_0 the mode is more unstable. The unstable dynamic validated by direct numerical simulation of the model.

U_0	$37 cm/s$		$9.955 cm/s$	
DNS	λ_r 4.2	λ_i 257	λ_r 0.43	λ_i 81.68
SA	λ_r 4.189	λ_i 256.8	λ_r 0.427	λ_i 82.64



Eigenspectrum shows one unstable mode.



Temperature perturbation for *m=0,1,2*.

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