Global stability analysis of microcombustion

Michele Alessandro Bucci[1], Jean-Christophe Robinet[1] & Sergio Chibbaro[2]

[1] ENSAM, DynFluid, Arts et Métiers ParisTech, 151, Bd. de l'Hopital, 75013 Paris, France
[2] Sorbonne Universités, UPMC Univ Paris 06, CNRS, UMR7190, Institut Jean Le Rond d'Alembert, F-75005 Paris, France
michele.bucci@ensam.fr

The improvement of the fabrication techniques has encouraged the miniaturization of mechanical and electro-mechanical devices, following the trend previously initiated by other technological areas, such as electronics or biomechanics. The reduction of the engine size brings new challenges that need to be specifically treated to improve the engine performance, such as increasing heat losses, flame instabilities or flame quenching [1]. In a recent work, it has been shown that a simple 2-D model successfully reproduces most of the physical features of combustion in small channels [2]. In particular, as in experiments, it has been highlighted the arise of complex instabilities above a certain gas speed. in this case, the flame starts a regime of repetitive extinction and ignition (FREI). We report on the numerical study of the global linear stability analysis of such system for the two stability threshold of the FREI condition.
First, the steady solution was found using the filtering method. We show that initializing the direct simulation of the complete nonlinear model with the basic state, the solution remains steady. Adding a noise to the basic state in a regime of unstable speed, the most unstable mode is pointed out. The time evolution shows an exponential increase of the oscillations amplitude of temperature and concentration. The growth rate is constant during the first time steps of the time evolution. Performing a Fourier analysis of the temperature and concentration signals, where the amplitude increases exponentially, only one mode is present.
Then, we carry out the linearization of the system and we solve the corresponding eigenvalue problem, computing the spectrum of the most relevant stable and unstable modes. Through the numerical simulations, we show that the spectrum exhibits just one unstable mode, when the system undergoes the FREI instability. The growth rate, which coincides with the real part of the unstable eigenvalue, turns out to be quite in agreement with that calculated via DNS of the complete system as shown in tab. 1. The pulsation of the oscillation is also computed and coincides with the imaginary part of the unstable eigenvalue. Moreover we show that the real part of the unstable mode increases linearly decreasing the speed, the bifurcation point is supercritical and there is a non-linear saturation of the amplitude oscillation of the flame position close to the threshold instability moving to the FREI regime.

	first bifurcation $U_0 = 37cm/s$		second bifurcation $U_0 = 9.955cm/s$	
DNS	σ	ω	σ	ω
	4.2	257	0.43	81.68
SA	σ	ω	σ	ω
	4.189	256.8	0.427	82.64

Table 1. σ and ω comparison obtained by different way : DNS and Stability Analysis

Références

1. Kaisare, N.S., Vlachos, D.G., . Lagrangian temperature, velocity, and local heat flux measurement in rayleigh-bénard convection. *Prog. Energy Combust. Sci.* , 38, 321D359, 2012.
2. Bianco, F., Chibbaro, S., and Legros, G. Low-dimensional modeling of flame dynamics in heated microchannels. *Chemical Engineering Science*, 122, 533-544, 2015.