A Unique Camera System To Study the High-Speed Dynamics of Premixed Flames

by Michael Gorman

ABSTRACT — Instabilities of the reacting front of commercial combustion systems limit their performance, decrease their efficiencies, and increase their pollution. We have assembled a unique, high-speed camera system with a micro-channel plate intensifier to study this dynamics.

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The Institute for Space Systems Operations support for research in combustion dynamics continues to play a crucial role in our studies. The combustion front of an engine or a gas turbine combustor near its lean burn limit can become unstable to dynamic modes of propagation in which the steady front is replaced by a front that varies in both space and time.

The characteristic oscillation frequencies are 25–75 Hz, which are above the Nyquist frequency of videotape, 15 Hz. As the frame rate of the camera is increased, the light per frame decreases. A micro-channel plate image intensifier, capable of gains adjustable to 60,000, is used to amplify the signal so that the images are clearly visible to the operator. The ISSO funds were used to repair this image intensifier, which had been damaged.

Figure 1 is a sequence of images of the dynamics of an annular state taken at 60 Hz in (a) and 250 Hz in (b), demonstrating the importance of using a high-speed camera in these dynamics studies. These frames show counter-propagating hot spots, which collide and annihilate between frames 1 and 2. In frames 2-4, two free hot spots propagate in the clockwise direction and one bound hot spot.

Figure 2 shows the dynamics of unusual pulsating states. These states form N-lobed structures which break along their mid-line into counter-propagating spiral arms, rotate, and annihilate with spiral arms from adjacent lobes.

This dynamics is qualitatively different from other dynamics of pulsating flames in which the circular flame front oscillates in modes similar to those of a vibrating drumhead or in spirals rotating in a circular domain. These two examples are a fraction of the pulsating dynamic states that we have observed in these studies.

Publications

Gorman, M. and R. Brockman. "Structures—Hot Spots, Cool Spots, and Wave Trains—and Events in Hydrocarbon-Oxygen Premixed Flames on an Annular Burner." (*Submitted to* Physica D; *under review*.)

Gorman, M., B. Pearson, and M. el-Hamdi. "The Dynamics of Four Ratcheting States of Cellular Flames: The Legacy States." (*Submitted to* Chaos, *under review*.)

Gorman, M. and S. Perrollier. "Unusual Pulsating States In Hydrocarbon-Oxygen Premixed Flames," *Chaos* 16 (2007) (*Forthcoming*.)

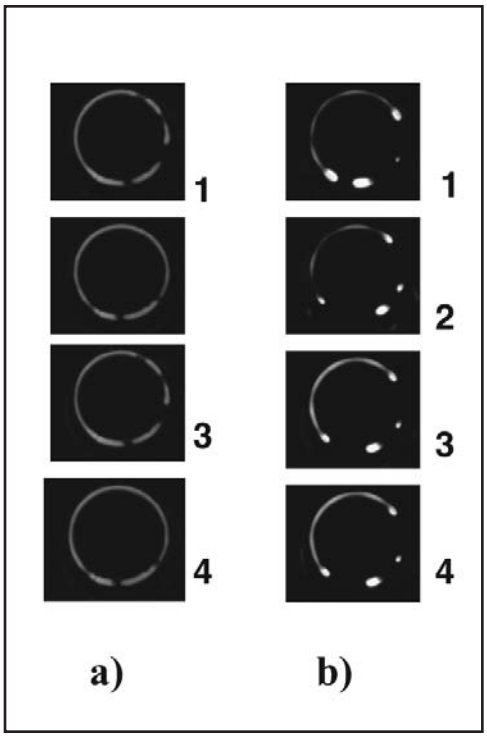

Figure 1. Dynamics of Annular States

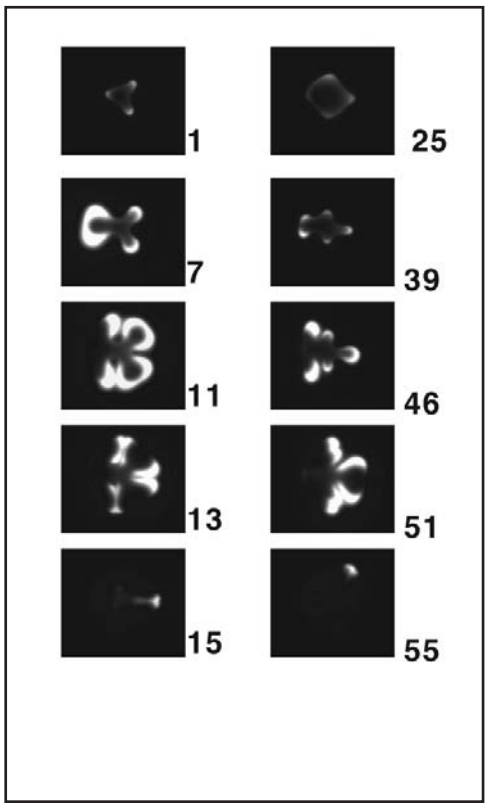

Figure 2. Dynamics of Unusual Pulsating States