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Laser Absorption Diagnostics Applied to an Experimental Multi-cycle PDE

By

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The extraction of species concentrations from laser absorption measurements has been well established [1]; especially using what is known as second harmonic detection [2]. This technique has also been successfully extended to high-speed applications such as flows behind shock waves [3]. Together with direct detection methods [4], this technology has been used in developing sensors that track various aspects of pulsed detonation engine gas dynamics [5]. An issue of particular interest in PDE studies is the filling of the engine tubes with combustible mixture, especially in multi-cycle operation. The thrust obtained is, of course, directly affected by the degree to which the PDE has been filled [6]. Mixture non-uniformities also affect thrust and performance of the PDE. In the present study, laser absorption is used to detect species concentration levels and thereby investigate the effects of partial filling and mixture non-uniformities in an experimental multi-cycle PDE facility [7].

Direct absorption detection at 3.39-microns (He-Ne gas laser) was used to detect propane, and wavelength modulation of a 760 nm VCSEL diode laser was used to detect oxygen. Species concentration levels, (line-of-sight averaged), were monitored at various stations within the engine, during multi-cycle operation. The valves for the gas flows into the engine at the head end are of dual overhead cam (DOHC) type, which allow the valve operation timing within the cycle to be adjusted. Figure 1 shows the relative angular positions of the cams for these tests. An optical pick-up is used to detect the point 10 degrees after the closure of the intake valve, to produce the firing signal for the ignition. The intake valve is used for flowing in the test mixture, while the exhaust is used to flow in the buffer gas (nitrogen). Figure 2 shows typical raw data from the oxygen second harmonic detection (the individual peaks from each 1 ms sweep are shown) during the operation of the multi-cycle PDE with no ignition (with nitrogen as the buffer gas). Figures 3 and 4 show results from direct absorption detection of propane at a station 26 cm from the head-end for a fixed flow rate and cycle frequencies of 10.6 and 13.2 Hz (again without ignition). Comparison between these traces and those obtained at a second station further downstream (35 cm from the head end, figures 5 and 6) at the same flow-rate indicates that a cycle frequency of 13.2 Hz is inadequate to fill up to the second station. This is established by the location of the firing signal, which should occur after the concentration levels at that station are not changing significantly. At 10.6 Hz, this flow rate seems adequate for filling the tube with the test mixture, up to the 35 cm station.

In the final presentation, limitations of the equipment and technique, in conjunction with multi-cycle PDE operation, will be discussed.

References:

1) R. K. Hanson, Recent Advances in Laser-Based Combustion Diagnostics, AIAA paper 97-0115, 35th AIAA Aerospace Sciences Meeting & Exhibit, January 1997, Reno, Nevada, U.S.A.

2) J. Reid and D. Labrie, Second Harmonic Detection with Tunable Diode Lasers- Comparison of Experiment and Theory, Applied Physics B., #26, pp. 203-210, 1981.

3) L. C. Philippe and R. K. Hanson, Laser Diode Wavelength Modulation Spectroscopy for Simultaneous Measurement of Temperature, Pressure and Velocity in Shock-Heated Oxygen Flows, Applied Optics, vol. 32, No. 30, October 1993.

4) D. B. Olson, W. G. Mallard and W. C. Gardiner Jr., High Temperature Absorption of the 3.39 micron He-Ne Laser Line by Small Hydrocarbons, Applied Spectroscopy, vol. 32, #5, 1978.

5) S. T. Sanders, T. P. Jenkins, J. A. Baldwin, D. S. Baer and R. K. Hanson, Diode-Laser Absorption Sensor for Measurements in Pulse Detonation Engines, AIAA paper 2000-0358, 38th AIAA Aerospace Sciences Meeting and Exhibit, January 2000, Reno, Nevada, U.S.A.

6) F. Schauer, J. Stutrud and R. Bradley, Detonation Initiation Studies and Performance Results for Pulsed Detonation Engine Applications, AIAA paper 2001-1129, 39th AIAA Aerospace Sciences Meeting and Exhibit, 8-11 January 2001, Reno Nevada, USA.

7) R. Farinaccio, R. A. Stowe, P.G. Harris, R. Akbar and E. LaRochelle, Multi-Pulse Detonation Experiments with Propane and Oxygen, AIAA paper 2002-4070, 38th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, July 2002, Indianapolis, Indiana, USA.

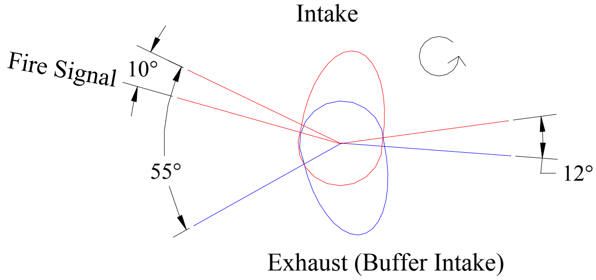

Figure 1: Relative angular positions of the valve overhead cams.

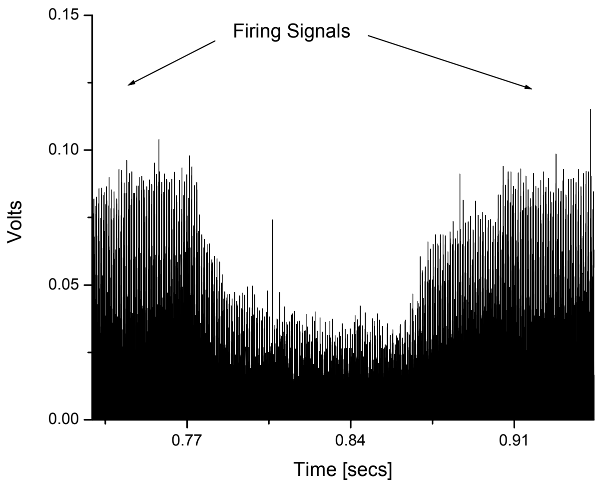

Figure 2: Second harmonic peaks from the detection of oxygen. Motored operation (no ignition) at 5.4 Hz. Measurement station is 17 cm from head end. The vertical lines are the firing signals.

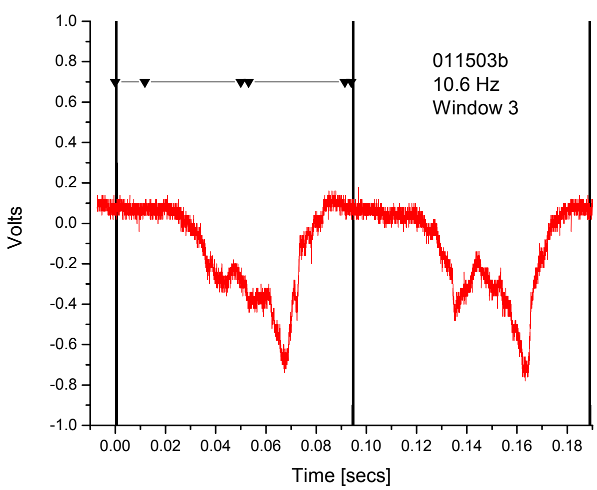

Figure 3: Propane detection, motored operation (no ignition) at 10.6 Hz. Measurement station is 26 cm from head end. The vertical lines are the firing signals and the inverted triangles indicate the valve open and closing positions corresponding to figure 1.

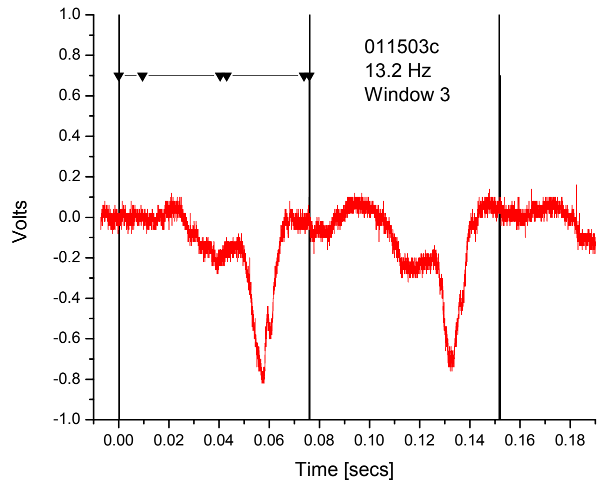

Figure 4: Propane detection, motored operation (no ignition) at 13.2 Hz. Measurement station is 26 cm from head end.

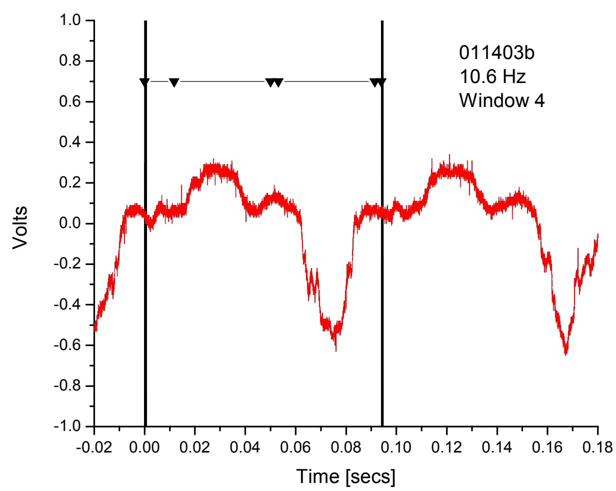

Figure 5: Propane detection, motored operation (no ignition) at 10.6 Hz. Measurement station is 35 cm from head end.

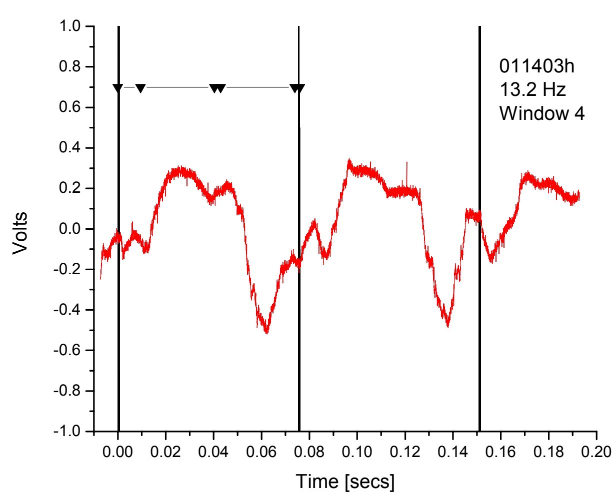

Figure 6: Propane detection, motored operation (no ignition) at 13.2 Hz. Measurement station is 35 cm from head end.