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Experimental investigation on flame stabilization of a kerosene-fueled scramjet combustor with pilot hydrogen

Key words:

Pilot hydrogen, kerosene fuel, scramjet, flame stabilization

Experimental Setup

Table 1. Steady flow conditions of direct-connected supersonic combustion facility

Location	Property	Experiments			Deviation
		Case 1	Case 2	Case 3	
Nozzle entrance	P_t [MPa]	0.821	0.816	0.819	0.6%
Isolator entrance	P [MPa]	0.105	0.108	0.102	4.7%
Isolator entrance	Ma	2.011	1.982	2.02	1.4%

Schematic of tested combustor

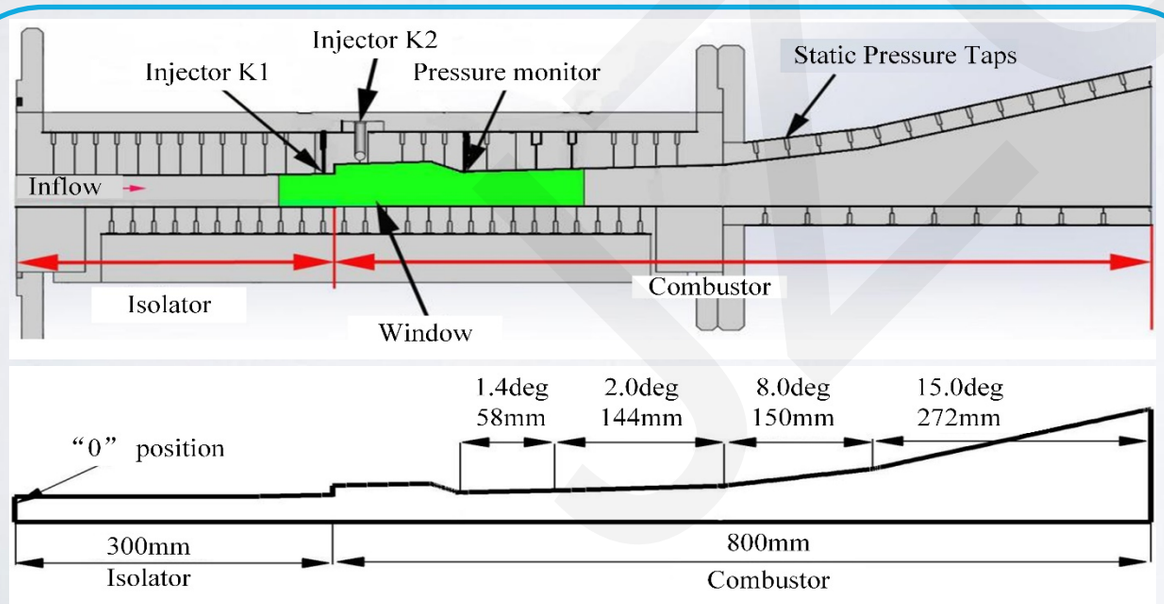


Table 2. Fuel injection strategies of different cases

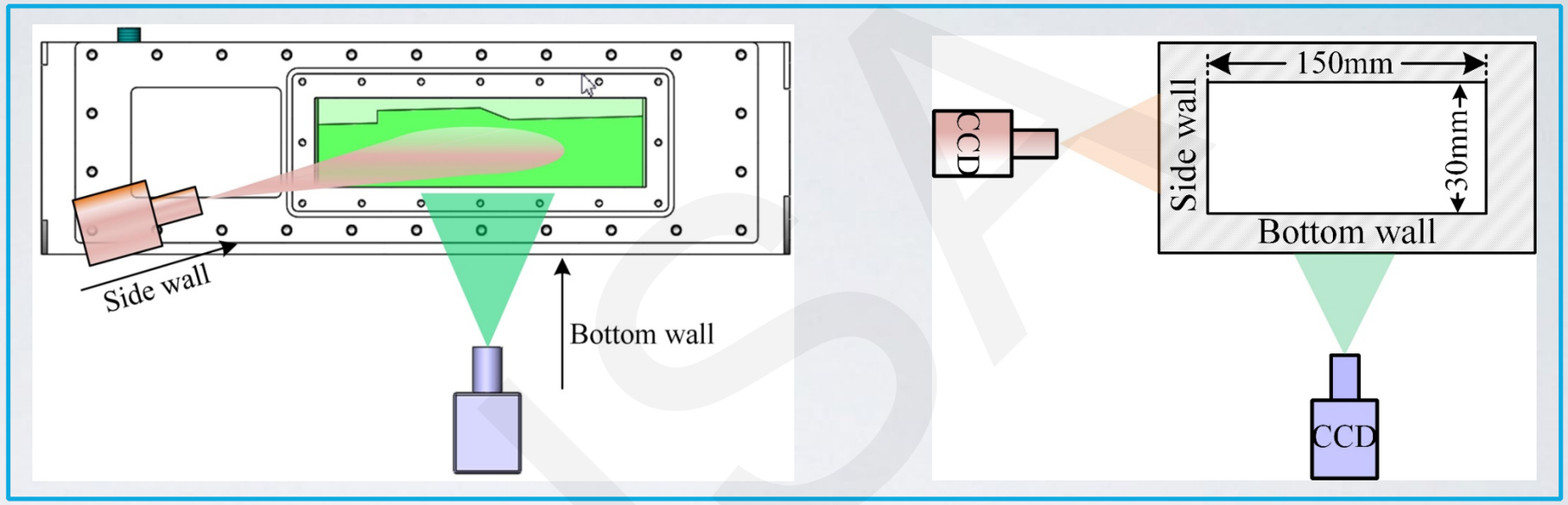
case	Hydrogen/ER	Kerosene/ER
1	0.04	0.173
2	0.08	0.173
3	0.0	0.0

To simulate the flight conditions of Mach number 4.0, a direct-connected supersonic combustion facility with stagnation temperature 950K and stagnation pressure 0.82MPa is utilized.

Instrumentation

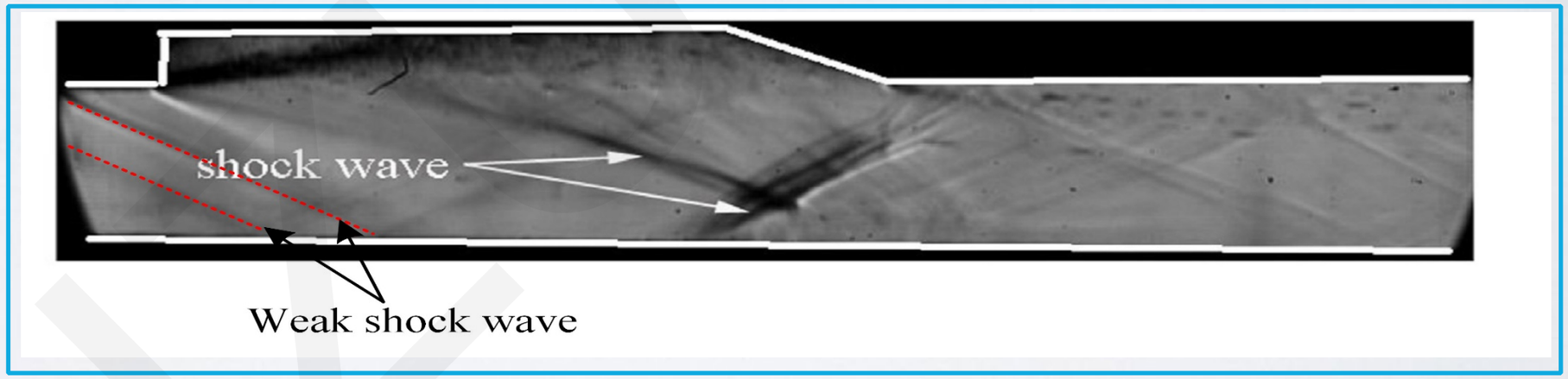
A.

Synchronous flame luminosity



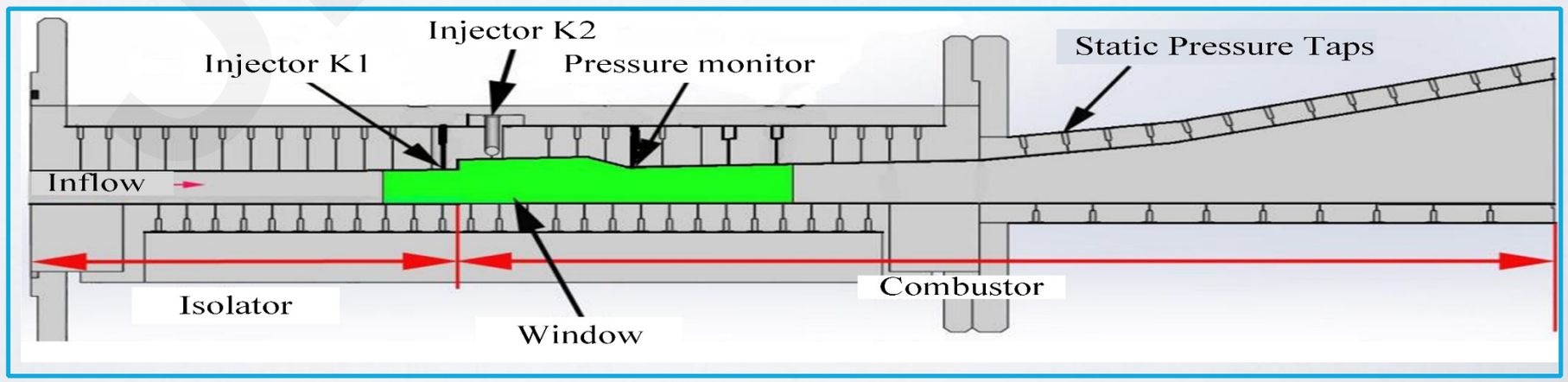
B.

Schlieren images

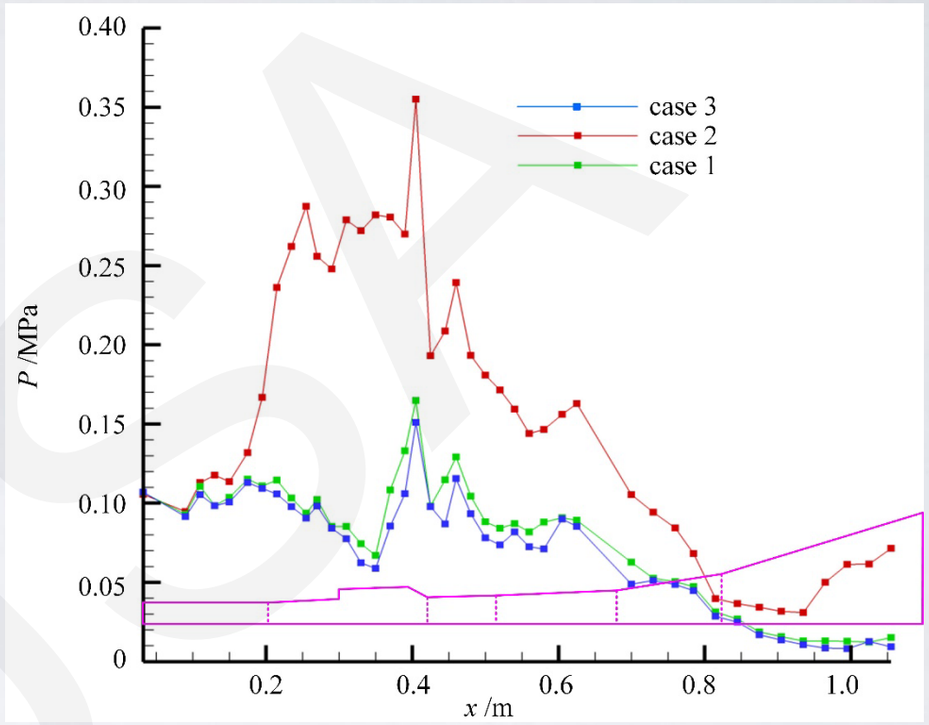


C.

Pressure monitor



Results



By comparing the results of different cases, the successful ignition of kerosene can be achieved when the equivalence ratio of pilot hydrogen reaches 0.08.

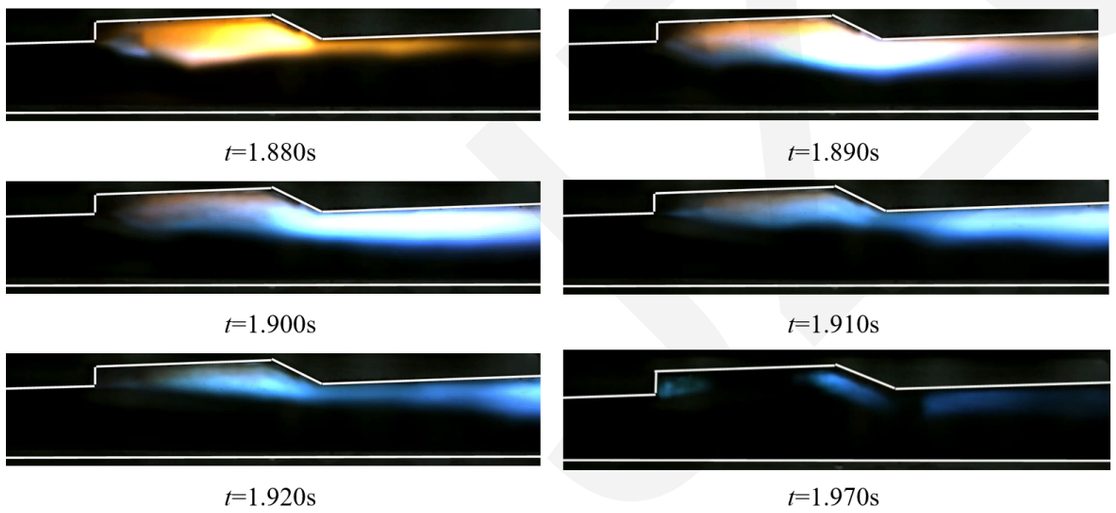


Figure 6. Flame luminosity images of case 1 at different times (view from the side wall)

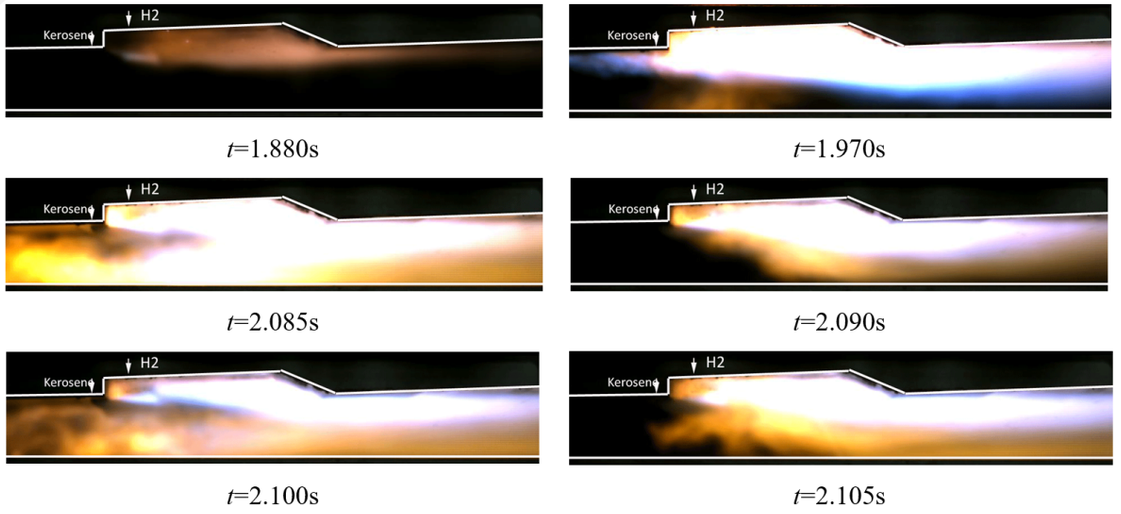


Figure 7. Flame luminosity images of case 2 at different times (view from the side wall)

Results

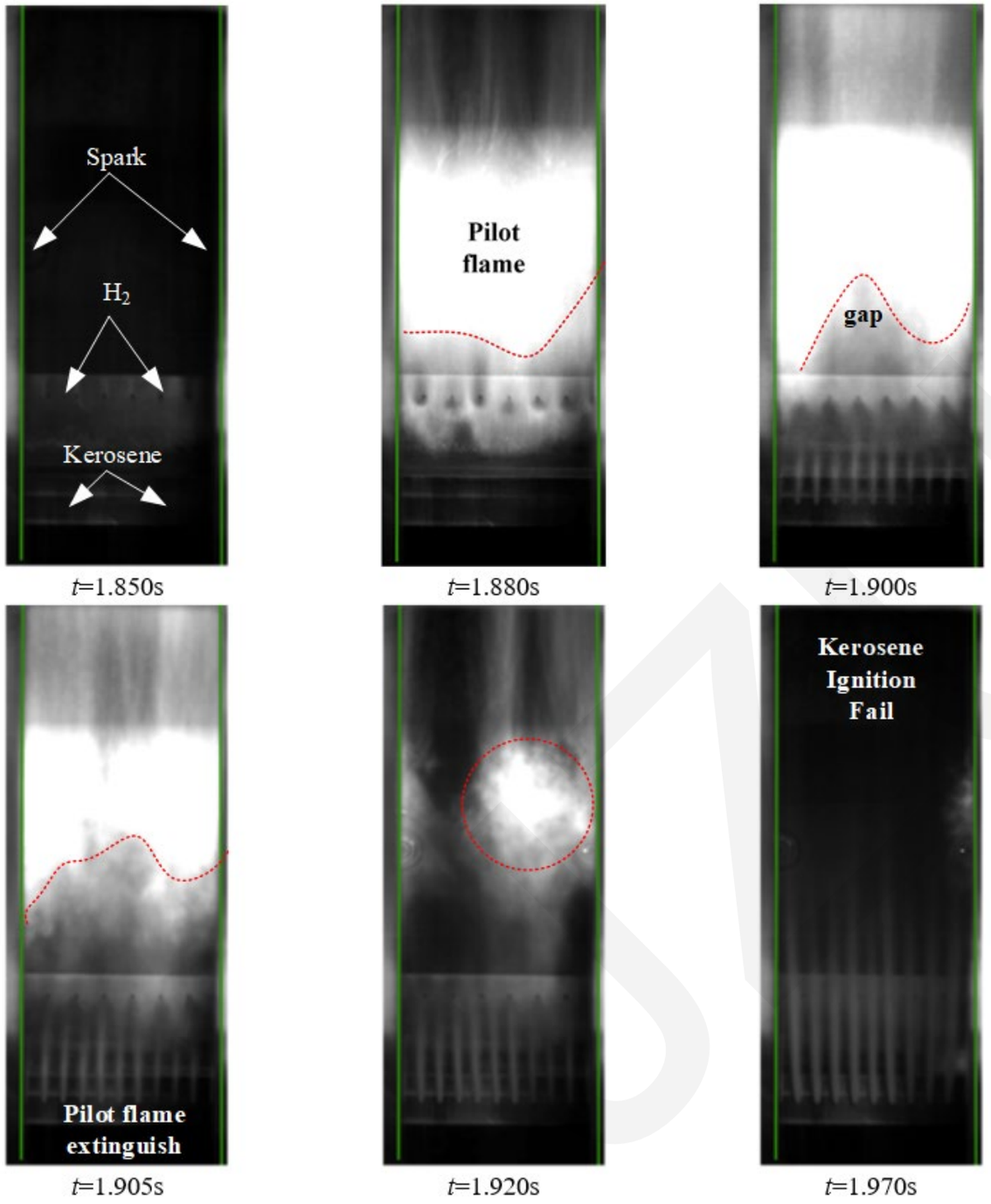


Figure 8. Flame luminosity images of case 1 at different times (view from the bottom wall)

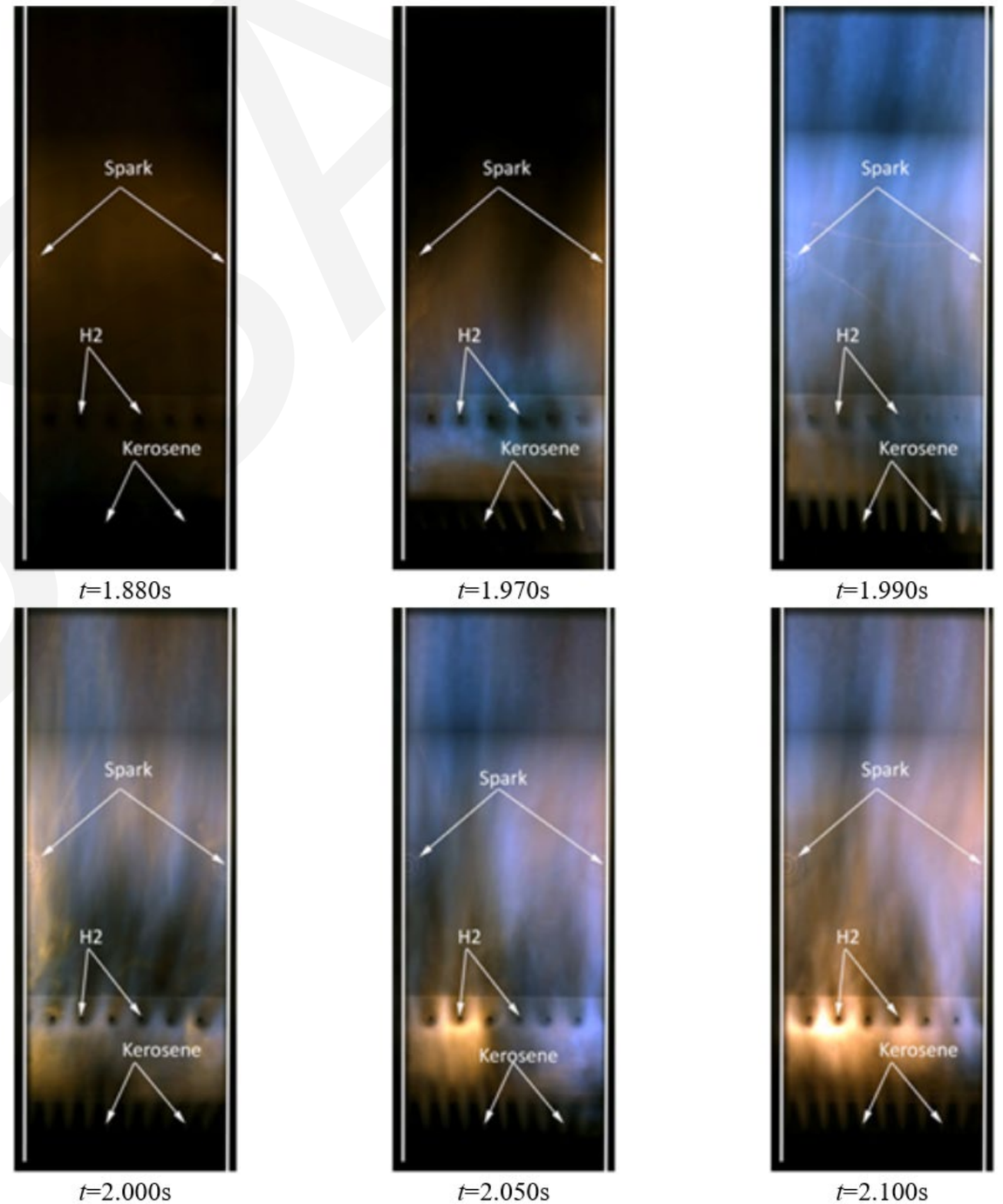


Figure 9. Flame luminosity images of case 2 at different times (view from the bottom wall)

Results

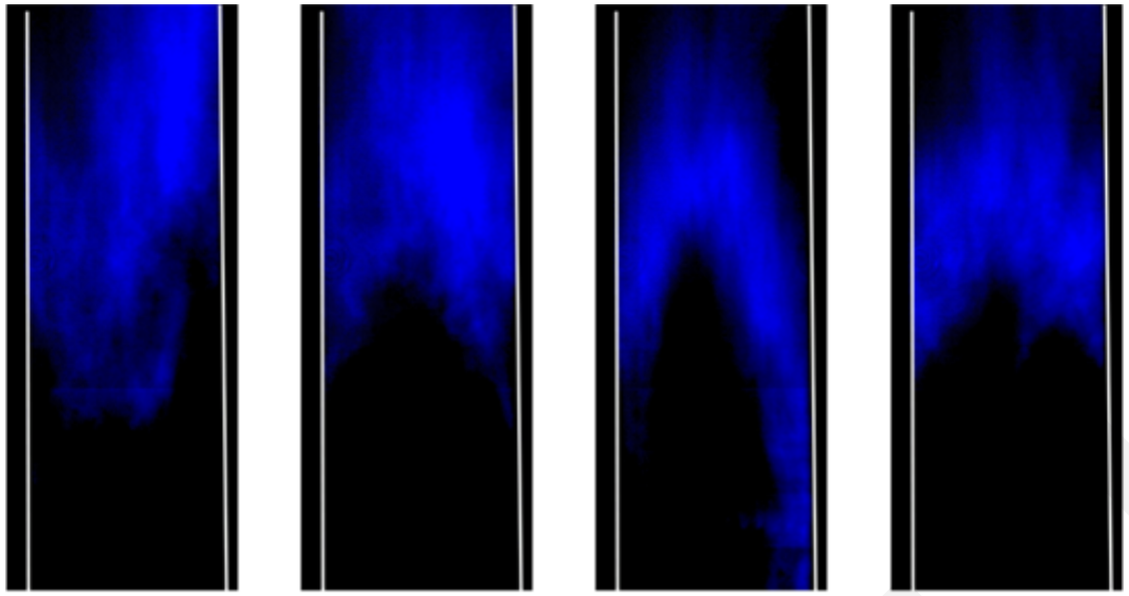


Figure 10. CH* luminosity images of case 2 at different times (view from the bottom wall)

At different times, the kerosene mostly locates in cavity shear layer, where the inflow, pilot hydrogen and kerosene mix well, and attaches to cavity ramp. Viewed from the bottom wall, the instability of kerosene flame is remarkable as the region of kerosene chemical reaction demonstrates different shapes of crescent.

Figure 11. CH* luminosity images of case 2 at different times (view from the side wall)

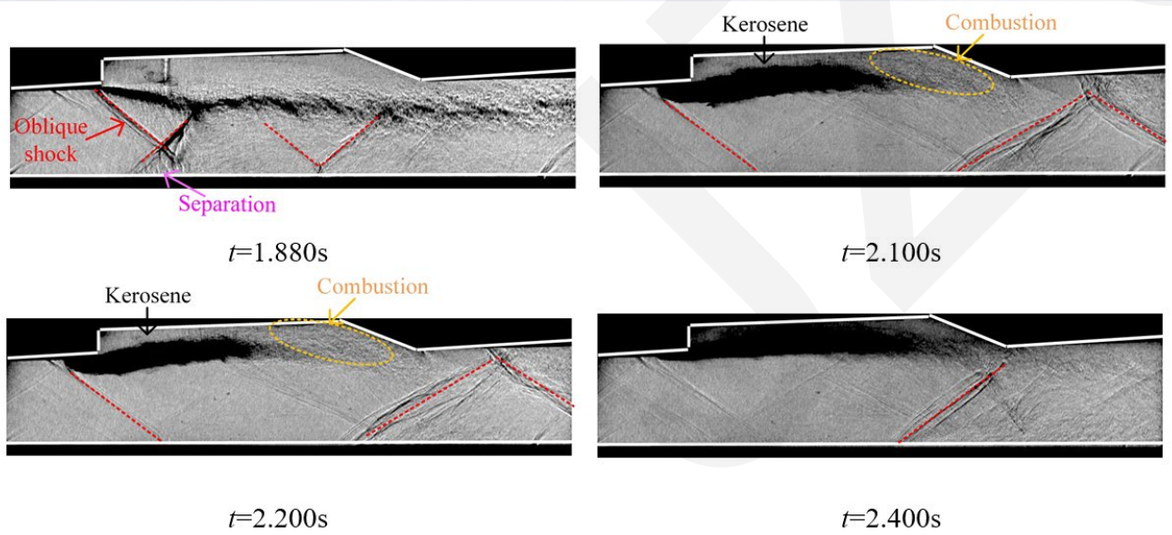


Figure 12. Schlieren images of case 2 at different times (view from the side wall)

At t=1.880s, the pilot flame stays in cavity shear layer and the inflow is compressed from the cavity step. Thus, an oblique shock wave generates from cavity step and attaches to the bottom wall of combustor causing a small size of separation. At t=2.100s and t=2.200s, the thick black region represents non-reacting kerosene and the combustion of kerosene mostly occurs around cavity ramp. When the injection of hydrogen stops, the kerosene flame is blown out at t=2.400s. Without pilot flame, the kerosene fills the whole cavity and locates near cavity bottom wall.

Conclusion

Combustor characteristics in a kerosene-fueled scramjet combustor with a cavity of *L/D*=11.0 were imaged utilizing schlieren and flame luminosity, along with wall pressure measurements.

- Comparing wall pressure distributions of case 1 and case 2, it has been discovered that the kerosene could be ignited when the *ER* of pilot hydrogen was 0.08, rather than 0.04. In case 2, the high back pressure induced by intense kerosene combustion spread into the isolator and the leading edge of shock train located at x =0.15m.
- Before the injection of kerosene, the pilot flame mostly located in cavity shear layer and caused an oblique shock. This oblique shock generated from cavity step and attached to the bottom wall of combustor, resulting in a new separation. Meanwhile, the kerosene combustion generally occurred in cavity shear layer. In case 2, the kerosene flame was asymmetrical and mainly attached to cavity ramp. Moreover, the combustion was unstable with repeated back and forth motions.

For this particular combustor, the pilot hydrogen of certain equivalence ratio is the precondition for ignition. And the evolution of flame stabilization and unstable combustion are obtained.