Shock-Flame Complexes and Their Role in Explosions
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The term *shock-flame complex* has been used to describe a combustion state comprised of a shock followed by to a flame or deflagration. This is not a detonation in which the reaction front and is closely attached to the leading shock. In the case of the shock-flame complex, the deflagration and the shock are much more loosely coupled. The distinguishing feature of the complex is that a usually turbulent flame is moving in the flow generated behind a shock wave. Thus the flame is moving supersonically with respect to the laboratory frame of reference, but usually at a subsonic if turbulent flame speed with respect to the flow behind the shock wave.

The complex has sometimes been referred to as a "fast flame" because the flame moves supersonically with respect to the laboratory frame of reference. A laminar flame speed for a gaseous fuel may range from about 10 to 400 cm/s; a turbulent flame speed may be 10–20 times faster; and a fast flame appears as though it is moving at speeds substantially over supersonic with respect to the observer, and can move at speeds approaching the detonation speed. In a shock-flame complex, the mean separation distance between the shock and the flame varies from centimeters (for hydrogen-air) to many meters (for dust explosions).

Figure 1 is an example of a shock-flame complex consisting of a leading shock, followed by a turbulent, shock-laden region of heated and compressed gas, whch in turn is followed by a turbulent flame [1]. The figure was taken from a simulation of the evolution of a flame in a lean methane-air mixture.

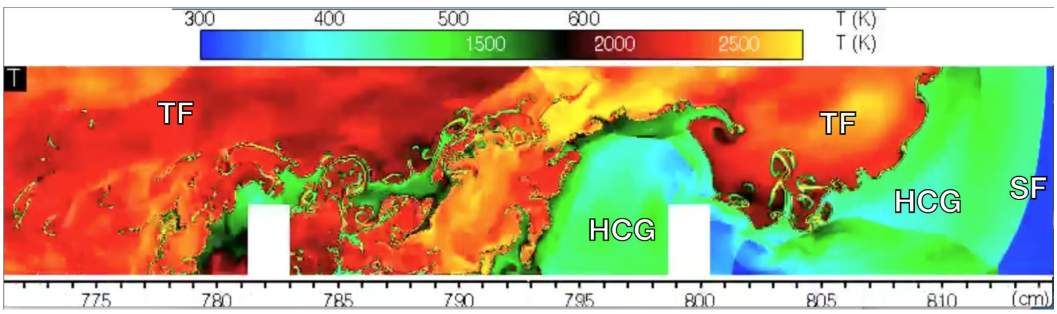

Figure 1. Frame from a simulation of a turbulent flame generated in a mixture of lean methane and air at atmospheric conditions in an obstacle-laded channel [1]. The complex is traveling from left to right. SF: shock front. HCG: region of heated and compressed gas. TF: region of turbulent flame. Symmetry conditions apply on the upper boundary. Two temperature scales: upper for unreacted fas and lower for reacted gas.}

Often a shock-flame complex appears as an intermediate, transient state, existing for a short time after a turbulent flame forms and before a transition to a detonation. In these cases, its importance is that it creates the background conditions in which a detonation can arise. (In some very large-scale accidental explosions, it is a regime in which large fire tornadoes might form.) Sometimes, however, a complex persists and may be the final state that exists until the reaction wave is quenched.

Recent granular-gas simulations of shock interactions with dust layers have shown a type of shock-flame complexes that could appear behind a leading shock followed by a turbulent dust flame [2]. Figure 2 shows an example in which such a complex could eventually evolve to a dust explosion.

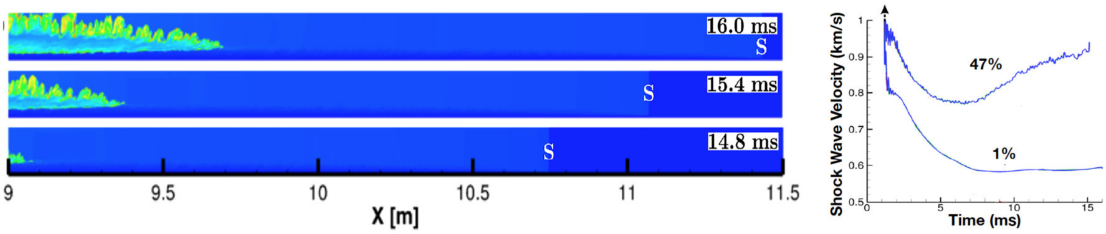

Figure 2. Left panels: Three frames showing temperature and location of shock (white S) at three times. X-axis in in meters, vertical axis is 5 cm. Dust packing is 47%. Right figure: Profiles of shock velocity as a function of time (ms) for two packing fractions, upper curve 1%, lower curve 47%. (See [2].)

This presentation describes a subset of shock-flame complexes observed in confined gaseous and mixed granular-gaseous flows that characterize dust explosions. In addition, it discusses the possibilities that arise when these occur in partially confinement on very large scales.

[1] Kessler, D.A., Gamezo, V.N., Oran, E.S.: Simulations of Flame Acceleration and deflagration-to-Detonation transitions in Methane-Air Systems. *Combustion and Flame,* 157, 2063-2077, 2010.

[2] Houim, R. W., Oran, E.S.: Numerical Simulation of Dilute and Dense Layered Coal-Dust Explosions. *Proceedings of the Combustion Institute*, 25, 2083-2090, 2015.