Planar Detonation Initiation

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A compact device for initiating planar detonation fronts in large aspect ratio channels has been developed. The initiator uses a weak spark, a gas injection system and an array of channels to generate a planar front in a shorter distance than is achieved by existing systems. The conventional method to create a planar detonation front is by spherical or cylindrical expansion from point initiation. After a distance, the radius of curvature is approximated to be infinite and the detonation is considered planar. Existing experiments use this technique in conjunction with driver tubes or exploding wires to generate large post-shock pressures and temperatures that are capable of detonating less sensitive mixtures. Both methods are discussed below.

A driver tube is a small tube filled with an easily detonable gas that is separated from the test gas by a diaphragm. A detonation is easily established in the driver gas and then transmitted into the less sensitive gas. In an exploding wire initiator, extremely high current is discharged through a thin wire causing it explode and send a strong shock into the test mixture to initiate a detonation. Both of these initiator concepts require many tube diameters to establish and stabilize the planar detonation wave. In addition, disassembly of the experiment is required during each test to replace the diaphragm or exploding wire. The planar initiator discussed below produces a stable planar detonation wave in a shorter distance than is possible with driver tubes or exploding wires. It does not require disassembly and can be extended to repetitive operation.

The device consists of a series of recursively branching channels that terminate on a common exit plane and open into a test section area (Figure 1). The channel lengths and geometry are such that, as with earlier devices[1], a detonation traveling through the primary channel will be split and passed through a subset of channels, reaching the exit plane at the same time. These separate detonation fronts then combine into a planar detonation front that continues to propagate into the test section. Unlike earlier models[1], this device is equipped with a driver injection system that is capable of injecting a driver gas into the channels shortly before ignition. Each path through the device has identical flow resistance such that the injected flow will travel uniformly through the apparatus.

The device consists of five series of channels machined into an aluminum substrate. The dimensions of each series of square cross-section channels are shown in Table 1. Driver gas is injected through a port at the beginning of the primary channel. Ignition is achieved by a spark plug and associated discharge system of 30 mJ located just downstream of the gas injection port. Obstacles machined into the primary channel promote deflagration-to-detonation transition (DDT). The final series of channels exhaust into a 15 cm-wide test section that gradually expands from a channel exit height of 5 mm to 18 mm over a length of 67 mm. Three pressure transducers are located at the end of the expansion to facilitate pressure and planarity measurements. The top portion of the device is sealed with an aluminum plate and 2 mm thick copper gasket.

During operation, the entire inner volume of the test section and channels are filled with a hydrogen-oxygen or hydrocarbon-oxygen test mixture that is diluted with argon or nitrogen. A volume of premixed equimolar acetylene-oxygen driver gas at a supply pressure of 2 bars is injected into the primary channel for 700 ms such that it fills all channels up to the test section inlet. The mixture is ignited after a 1 second delay. The resulting planar detonation emerges into the test section and passes into the test gas.

Preliminary results indicate that in acetylene-oxygen driver mixtures at 0.20 bar initial pressure, the device produces a wave that is planar to within 3 mm over a 15 cm length[2]. The initiator is currently in use at Caltech as a component of a narrow (17 x 150 mm) channel test facility. An annular version has been constructed for use as an initiator in pulse detonation engines. The annular version creates an imploding wave, which enables the initiation of even more insensitive mixtures. Results presented will include the range of pressures in which a planar detonation can be created along with chemiluminescence images of the detonation front.

References

[1]S.I. Jackson and J.E. Shepherd, "Initiation Systems for Pulse Detonation Engines," 38th AIAA/ASME/SAE/ASEE Joint Propulsion Conference, July 7-10, 2002, Indianapolis, IN, AIAA 2002-3627.

[2]J.Austin and M. Grunthaner, Work in progress at Caltech, 2002.

Series number	Number of channels	Width	Arc length/channel
1	1	10.2 mm	152.4 mm
2	2	8.53 mm	115.7 mm
3	4	7.19 mm	89.4 mm
4	8	6.05 mm	53.8 mm
5	16	5.08 mm	35.6 mm

Table 1: Channel dimensions.

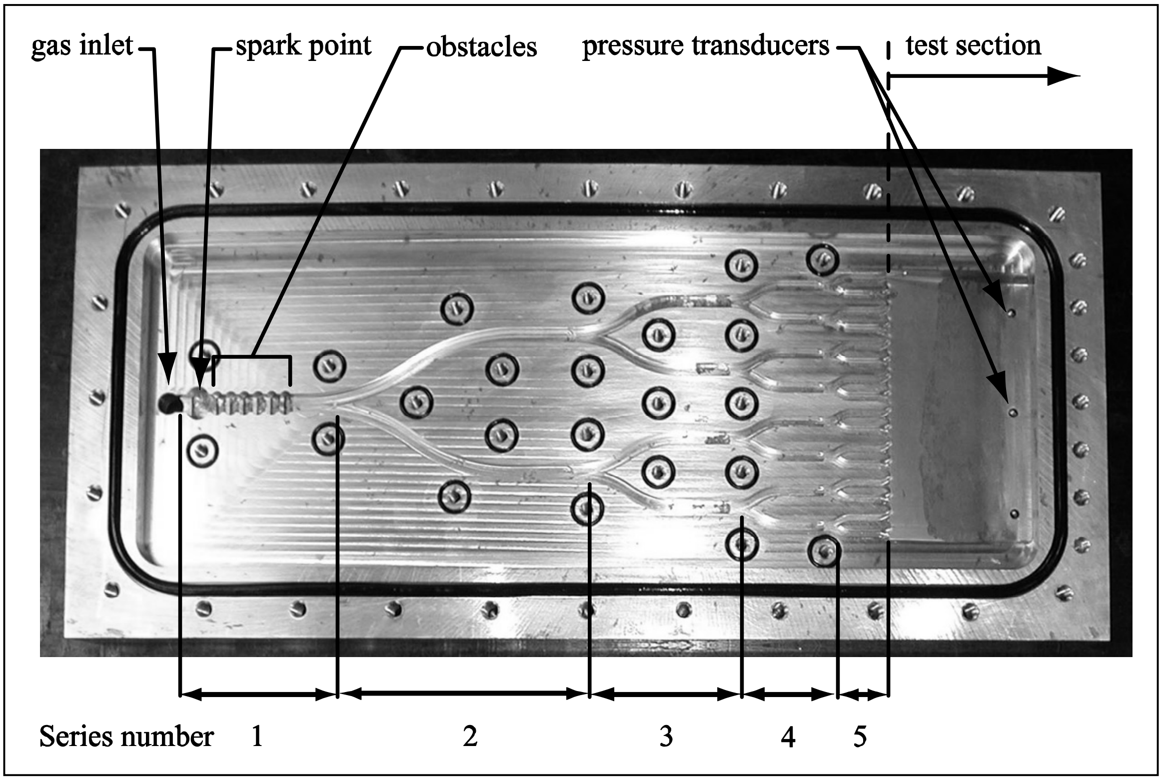

Figure 1: The channel configuration. The many small circles are bolt holes used to attach the top cover.