Characterization of a Rotating Detonation Engine Exhaust Flowfield

Russo, Rachel; Fievisohn, Rob; and Schauer, Fred

United States Air Force, Wright Patterson Air Force Base, OH 45433 USA

Naples, Andrew; and Hoke, John

Innovative Scientific Solutions Inc. Dayton, OH 45440 USA

Detonation combustion has seen renewed interest within the past 15 years. This form of combustion is a pressure gain process and promises higher thermodynamic cycle efficiencies when compared to constant pressure combustors. Pulse detonation and rotating detonation engines are two ways of utilizing detonations for propulsion applications. Past research was focused on pulse detonation engines and how to extract useful work from them. However, the inherent unsteadiness in the exhaust flowfield made integration with conventional devices such as nozzles and turbines difficult. Recently, rotating detonation engines have been determined as a plausible candidate for integration with traditional systems. This is due to mechanical simplicity, continuous operation, and high energy density. To determine the viability of RDE integration, characterization of the exhaust flowfield becomes important in understanding how these devices interact with nozzles and turbines. Computational work by Schwer[1] has given initial insight into RDE exhaust plane flow.

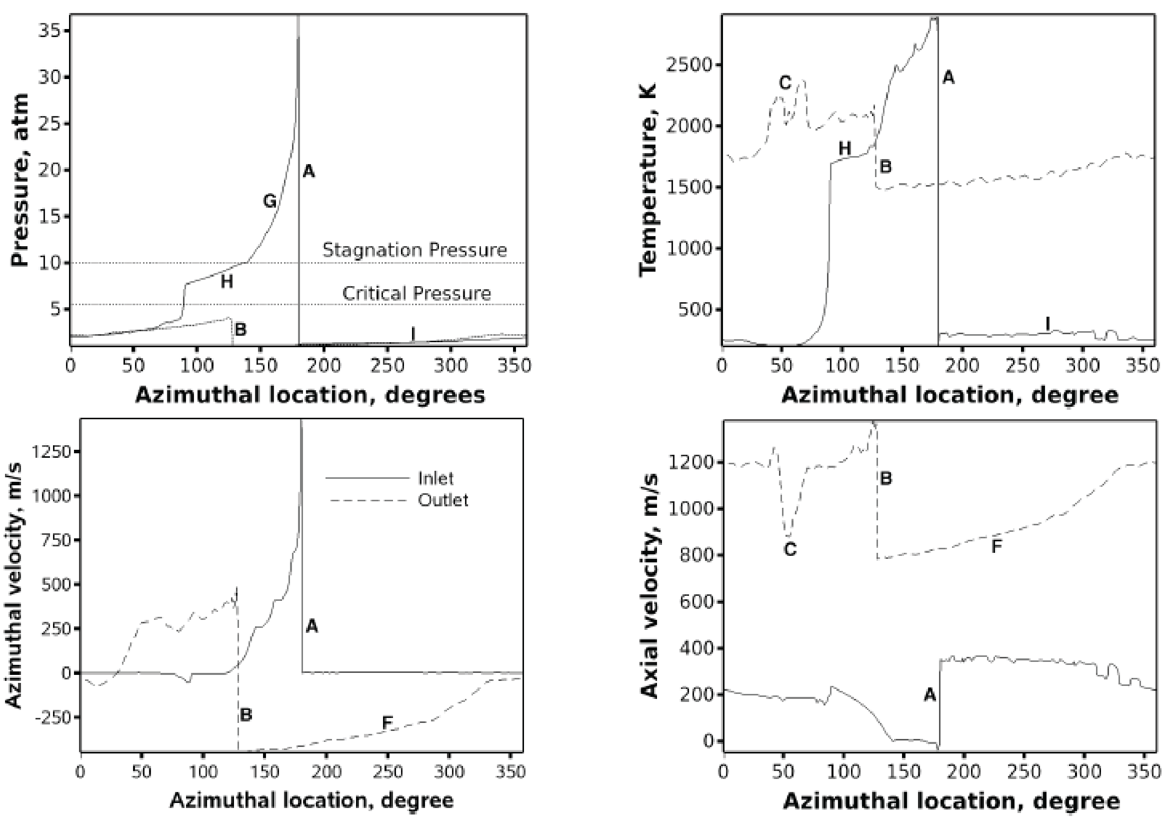


Figure 1: Inlet and outlet plane results for computational RDE (Schwer[1]).

This study shows pressure and temperature oscillations are an order of magnitude lower at the exhaust plane than in the detonation region. Also shown in this study is a substantial swirl component at the exit plane. Both of these properties can be measured through experimental means, and need to be well understood to realize RDE potential.

Multiple high speed pressure transducers have been utilized to characterize the flow as it propagates axially down the length of the annulus. In Figure 2, pressure oscillations in the detonation region are large in magnitude and similar to those found by Schwer[1]. Additionally, fast response wedge probes were placed at the exit of the RDE to determine outflow velocity components and pressures. Results are compared to previous computational results to validate current models and suggest improvements for future ones.

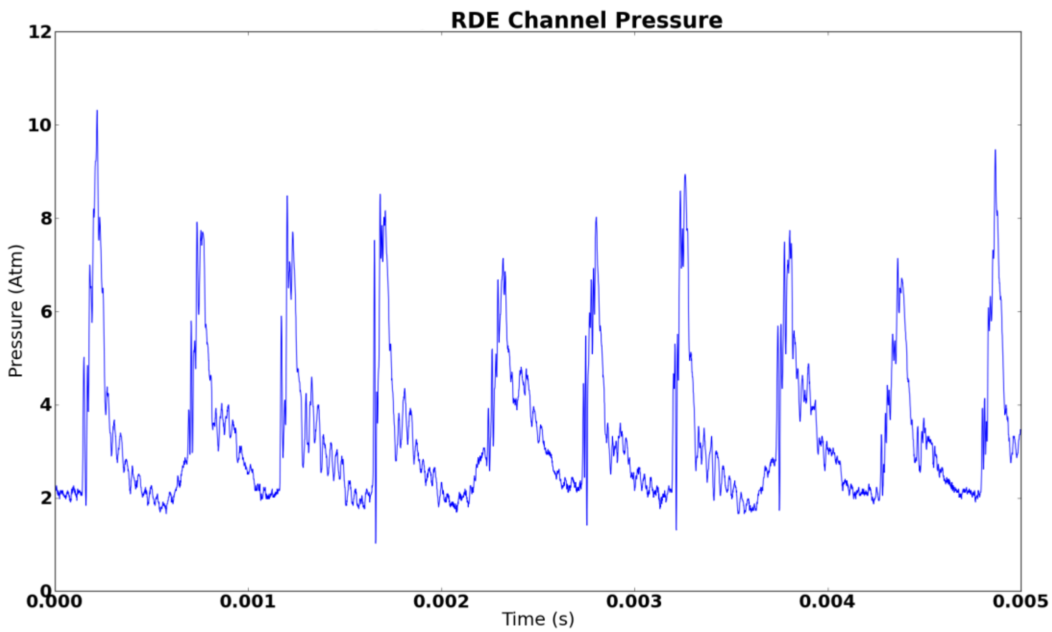
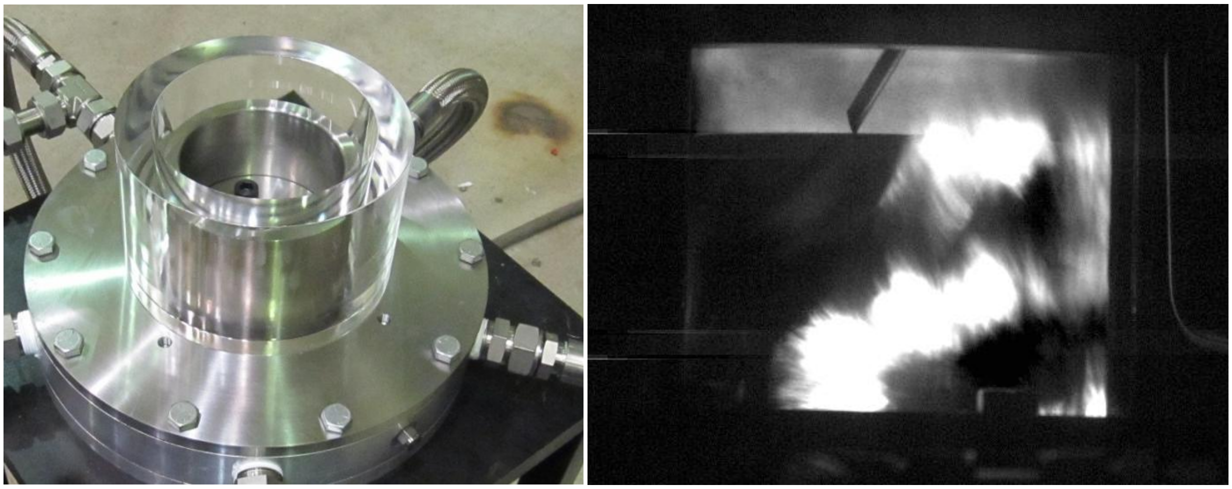


Figure 2: Detonation channel pressures in an RDE

Another technique being employed to measure velocity is high speed video and shadowgraph. To get video of the entire flowfield, an optically accessible RDE was built as shown in Figure 3(a). Figure 3(b) shows a single high speed video frame with a detonation in the channel. The vertical flame at the base of the picture is the detonation front, and above this are flow structures such as an oblique shock wave and shear layer. Using the data from the outlet plane of the RDE, flow velocities in the axial and azimuthal directions can be extracted.



(a) (b)

Figure 3: Quartz outer body RDE(a) and Flame emission single frame photo of operating RDE(b).

With measurements of a standard RDE flowfield near complete, current research is measuring the changes in pressure oscillation and flow swirl through nozzles. A simple, basic nozzle on the back end of an RDE (Figure 4) shows the pressure available from the flow acting as an under-expanded jet. Further more, a high speed video of the exhaust from the nozzle shows little flowfield oscillation. However, the exhaust undergoes a sudden expansion in the transition from the RDE to this nozzle. This large area change allows the exhaust to expand and attenuate some of the pressure oscillations. Testing of a converging-diverging nozzle which was designed to eliminate the sudden expansion will allow us to better understand the conditions of the outlet flow and the effect nozzles have on the RDE exhaust flow.

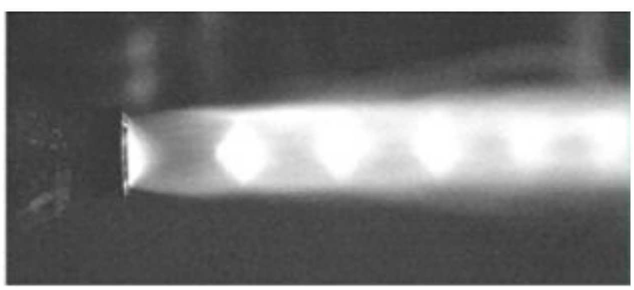


Figure 4: Mach diamonds from an under-expanded RDE outlet flow through a nozzle

1. Schwer, Douglas A, and Kailasanath, K "Numerical investigation of Rotating Detonation Engines". 46th AIAA Joint Propulsion Conference 2010, Nashville Tennessee