

Investigation of Small Scale Pulsed Detonation Engines and Feasibility Study for Implementation with Disposable Unmanned Aerial Systems

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ABSTRACT

Significant efforts have been made in the research of Pulsed Detonation Engines (PDEs) to increase the reliability and longevity of detonation based propulsion systems for use in manned aircraft. However, the efficiency, durability, and low mechanical complexity of PDEs opens up potential for use in disposable unmanned-vehicles. This paper details the steps taken for producing a miniaturized pulse detonation engine at West Virginia University (WVU) to investigate the numerically generated constraining dimensions for Deflagration to Detonation Transition (DDT) cited in this paper. Initial dimensions for the WVU PDE Demonstrator were calculated using fuel specific DDT spatial properties featured in the work of Dr. Phillip Koshy Panicker, of The University of Texas at Arlington. The WVU demonstrator was powered using oxygen and acetylene mixed in stoichiometric proportions. A low-energy spark initiates deflagration and the formation of a pressure front that propagates towards the aft end of the PDE. Capacitive discharge microphones are used to locate and measure the speed of the resulting shock wave, where supersonic wave propagation is indicative of successful transition to detonation. Additional attention was given to simple flow obstruction designs and the potential for accelerated DDT.

CITATION: Cain, R., Browning, P., Huebsch, W., and Wilhelm, J., "Investigation of Small Scale Pulsed Detonation Engines and Feasibility Study for Implementation with Disposable Unmanned Aerial Systems," *SAE Int. J. Aerosp.* 6(2): 2013, doi:10.4271/2013-01-2304.

INTRODUCTION

While a significant amount Pulsed Detonation Research is aimed at development for larger-manned aircraft, this paper emphasizes the applicability of Pulsed Detonation Engines for low-cost, disposable UAVs.

Pulsed Detonation Engine

A pulsed detonation engine (PDE) is a jet engine design that combusts fuel through a detonation process rather than deflagration to increase fuel efficiency. Similar to pulse jets, PDEs lack a mechanical compressor seen on most other jet designs. Instead, PDEs utilize the pressure generated by fuel combustion to reach optimum burn conditions in a long, narrow tube filled with reactants. Since the engine needs to be refilled at the beginning of each cycle, the PDE produces thrust in pulses rather than continuously produce thrust as conventional jet engines do.

Detonation vs. deflagration

Traditional combustion engines generate energy through deflagration, a low energy, subsonic flame front. Detonation, by contrast, is a supersonic flame front. Detonations take considerably more energy to initiate under the same conditions but possess a higher thermal efficiency than deflagrations.

Detonation initiation techniques

It is possible to directly initiate detonation within a near stoichiometric fuel and oxidizer mixture by raising the energy levels to the detonation point of the reactants using high voltage arcs. Complete detonation of all fuel gives direct initiation the highest potential energy efficiency out of conventional ignition techniques.

Detonation to Deflagration Transition (DDT) serves as an alternative to direct initiation. Combustion begins with a low energy spark that starts a deflagration wave moving towards the open end of the engine. As the flame front moves down the engine tube, energy from combustion steadily increases

temperature and pressure inside the chamber until a detonation wave spontaneously occurs and the flame front transitions to a supersonic detonation wave.

MAIN SECTION

Advantages of the PDE

Pulsed detonation engines more closely approximate Constant Volume processes and produce less entropy than conventional engines. (A) Additionally, the speed of the flame front prevents unburned fuel from being pushed out of the PDE before combustion despite the lack of any physical barrier; reducing the number of mechanical components required for operation.

A study conducted by Paul J. Litke and his associates compares the efficiency of a Pulsed Detonation Engine with that of a Solar PJ32 Pulsejet. Typical specific fuel impulse for a pulsejet falls in the range of 1400s to 1500s. Litke produced an estimated Isp between 6800s and 8000s with a PDE operating under similar conditions, demonstrating the large gap in the efficiency potential.^[1] Additionally, T. R. A. Bussing provides data, see [Figure 1](#), on the potential efficiency of PDEs compared to more conventional propulsion systems.

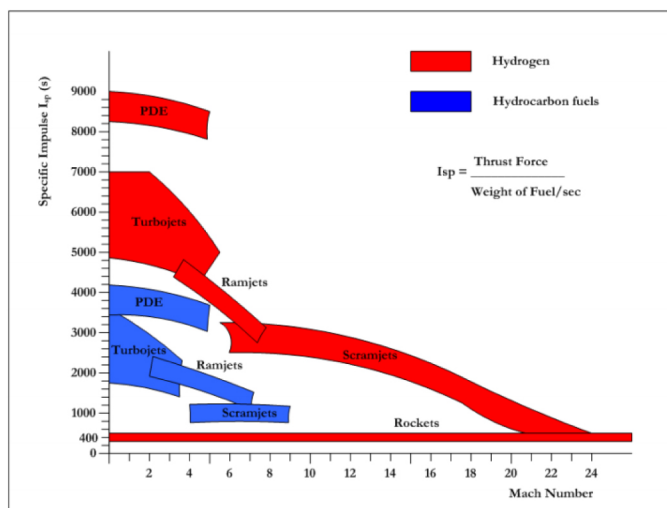


Figure1. A graphical representation of the specific impulse potential of various propulsion systems vs. Mach number.^[2]

In addition to the high efficiency, PDEs have few or no moving parts. Most rely solely on valves and spark generators to control the engine. This reduces the points of potential failure and makes the PDE a very robust engine.

Future Challenges for PDE Technology

The increase in energy output gained from detonation goes hand-in-hand with an increase of thermal output, vibrations, and mechanical wear. The temperatures generated by PDEs have the potential to deform engine frames after

only a few minutes of continuous operation; and since the engine does not continuously produce thrust, the constant variance in force produces strong vibrations.^[3]

Unmanned aircraft engines, intended for a single, short duration use, circumvent most of the problems associated with PDEs. UAVs can be hardened against mechanical vibration better than human passengers and short flight time minimizes heat build-up.

Design Considerations for the WVU PDE Demonstrator

The WVU PDE Demonstrator was developed to serve as a proof of concept and technology platform for miniature pulsed detonation engines optimized for use with disposable UAVs. This report covers the selection process for the ignition system, fuel selection, body design, flow obstruction, valves, and sensors.

Ignition system

The ignition system for the PDE Demonstrator was selected based on potential energy efficiency and minimizing the weight of the system. [Figure2](#) shows both the direct initiation and DDT Pulsed Detonation Engines outperform the pulsejet by a considerable margin when operating at similar equivalence ratios. The direct initiation PDE has slightly greater potential efficiency than the DDT; however, the energy required for direct initiation makes it unattractive for many applications.^[1]

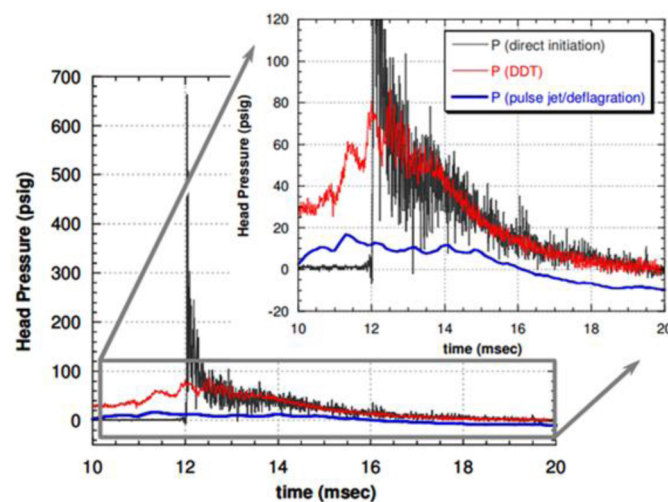


Figure2. Cycle-head pressure comparison of a direct initiation PDE, DDT PDE, and a Pulsejet^[1]

For PDEs that rely on direct initiation of detonation it would be essential to carry a bulky power source to reach the necessary energy levels for detonation. The substantial weight of the power source makes direct initiation PDEs impractical for aerospace applications. This can be circumvented by relying on Deflagration to Detonation