Simplified Analysis of Pulse Detonation Rocket Engine Blowdown Gasdynamics and Performance

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ABSTRACT

Submitted to *The 38th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit*

Pulsed detonation rocket engines (PDREs) have generated considerable research interest in recent years [1] as a chemical propulsion system potentially offering improved performance and reduced complexity compared to conventional rocket engines. The detonative mode of combustion employed by these devices offers a thermodynamic advantage over the constant-pressure deflagrative combustion mode used in conventional rocket engines and gas turbines. However, while this theoretical advantage has spurred a great deal of interest in building PDRE devices, the unsteady blowdown process intrinsic to the PDRE has made realistic estimates of the actual propulsive performance problematic. The recent review article by Kailasanath [2] highlights some of the difficulties in comparing the available experimental measurements with numerical models.

The goal of this paper is to improve understanding of PDRE blowdown gasdynamics and performance issues through use of a simplified model that captures the essential features of the unsteady blowdown process, and yet remains computationally inexpensive. The PDRE system studied here is highly idealized, consisting of a constant-area detonation tube with one end closed and the other end open to the environment. The tube is pre-filled with a gaseous propellant mixture with no initial velocity or outflow to the environment. The detonation is initiated instantaneously at the closed end of the device. Chapman-Jouguet (C-J) post-detonation gas conditions are calculated using the CET89 version of the NASA thermochemical code [3]. The 1-D, unsteady method of characteristics is used to calculate the flowfield following the detonation front. See the compressible flow texts by Thompson [4] and Zucrow and Hoffman [5] for details of this method.

Parametric studies of the effect of mixture stoichiometry, fill temperature, and blowdown pressure ratio on performance are reported. A comparison of the performance of an idealized straight-tube PDRE with a conventional steady-state rocket engine is provided. The effect of constant-γ and equilibrium chemistry assumptions is also examined. Additionally, in order to form an assessment of the accuracy of the model, the flowfield time history is compared to experimental data from Stanford University [6].

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