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Numerical simulation of a hydrocarbon fuelled valveless pulsejet

Joseph Kalyan Raj Isac[a,b,*], Logu Mohanraj[a,b], Enumula Srikar Sai[a], Vijay Kumar Kannan[a]

[a]*CD-adapco India Private Limited, Bangalore, Karnataka 560066, India*
[b]*Park College of Engineering and Technology, Coimbatore, Tamilnadu 641659, India*

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Abstract Jet propulsion technology has been limited to being identified largely with turbojets and turbo-machinery driven jet engines. Of late there has been a renewed interest in pulsejet technology and it has once again caught the imagination of academia. The specific characteristics of the pulsejet, such as easy scalability, absence of moving parts, reduced combustion temperatures; lower NO_X formation and the like make it possess varied capabilities for use in the field of jet propulsion and the most viable option for small-scale jet propulsion. In the current work, a numerical analysis encompassing feasibility and validation of a valveless pulsejet engine was attempted using CD-adapco's STAR-CCM+ CFD package. Due to lack of comprehensive established mathematical laws to govern the working of a pulsejet, most experimental work being performed is done by trial and error. This necessitates in-depth computational studies in order to shed more light on the understanding of valveless pulsejets. The results have been encouraging and in agreement with observed experimental conclusions such as, i) changes in dimensions affect the working of a pulsejet, ii) presence of a flare enhances the working of a pulsejet, and the close agreement in the frequency of operation. Through continuous study, an optimum initial condition was achieved which enabled the

*Corresponding author: Tel.: +91 9003238122.

E-mail address: josephkalyanraj@gmail.com (Joseph Kalyan Raj Isac).

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pulsejet to begin operation even before 0.05 s, thereby greatly reducing computational costs if a higher time-scale were to be used.

1. Introduction

A pulsejet is one of the simplest of engines from a design and manufacturing aspect. It should be borne in mind that there is no conclusively established comprehensive mathematical law governing the working of a pulsejet, hence all new and innovative modifications to pulsejets are done on a trial and error basis [1,2]. This greatly hinders progress since the effect of any change in the design is 'unpredictable'.

But this has not deterred academicians and scientist from attempting to develop a theoretical model of the working mechanism [3,4]. A considerable number of analyses ranging from using acoustic analogy studies to numerically solving the flow-field internal to the pulsejet have been performed in the past and though each one sheds fresh insight into a specific process/processes occurring in the pulsejet, no single theoretical model has been able to sufficiently explain all the processes. The systemic nature of the processes involved in this jet engine leaves a fragmented analysis of it wanting, hence requiring further understanding of 'how it works' and 'what makes it work' [1].

1.1. Thermodynamic cycle

The pulsejet operation cycle, as has been observed experimentally, can be summarized as:

1. Combustion occurs in the combustion chamber and the ensuing heat release increases the pressure and drives out the hot gases through the exhaust and produces thrust. The hot gases expand down the exhaust and inlet tubes, but due to a difference in the cross-sections of the inlet and exhaust pipes, a major portion of hot gases are expelled through the exhaust pipe.
2. Once the combustion gases have expanded to atmospheric pressure, over-expansion of the gases due to inertia (Kadenacy effect) inside the combustion chamber, causes the chamber pressure to decrease to sub-atmospheric levels.
3. The sub-atmospheric pressure causes fresh reactants to enter the combustion chamber through the inlet (the inlet air column has a lower inertia) and a small fraction of the exhaust gases from the exhaust tube.
4. The residual gases and heat transfer from the walls raise the temperature of the air-fuel mixture to the auto-ignition temperature thereby initiating combustion. The entire cycle repeats itself at a regular interval.

1.2. History and background

Though a lot of research had been performed prior to Marconnet by researchers like Holtzwarth and Karavodine in the field of pulsed combustion, the use of pulsed combustion as a method of direct thrust generation was first carried out by Marconnet [1] in his "reacture-pulsateur". P. Schmidt [5] applied the concepts of Marconnet's 'wave engine' to the development of an intermittent pulsejet engine, called the Schmidtrohr, directed towards use for vertical take-off and landing vehicles.

The Argus MotorenGesellschaft of Berlin, under the development of Dr. Fritz Gosslau, developed the famous Argus AS 109-014 powering the Vergeltungswaffe 1 (V-1) “Buzz Bomb” of World War-II [5]. It has been erroneously reported in numerous publications that the Argus work was in conjunction with P. Schmidt [6]. Post World War-II, research in pulsejets was undertaken by the US Navy under Project Squid. French engineers at SNECMA did extensive research on pulsejets. Lockwood of Hiller Aircraft, with the support of the French engineers, investigated the working of pulsejets and this work is a landmark achievement as it is the only completely documented, systematic study in existence. He

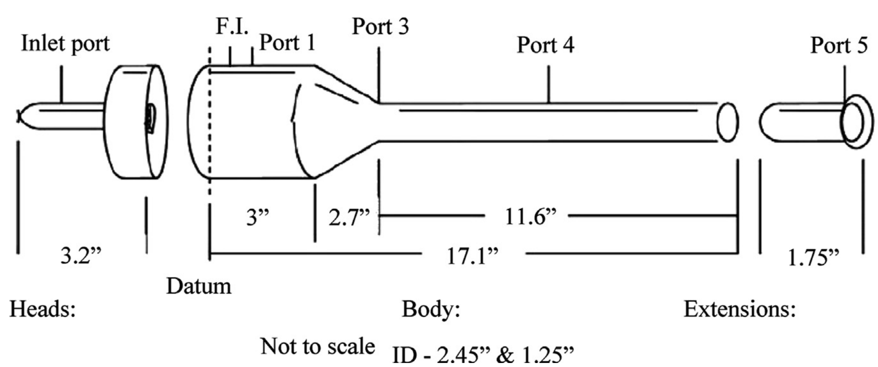

Figure 1 Experimental pulsejet model studied by Rob Ordon.