

Design and Analysis of Valveless Based Pulse Detonation Engine

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Abstract - The Pulse Detonation Engine (PDE) has the ability to be a propulsion system of modern aircrafts. Structural simplicity and performance reliability enabled pulsejet to be exemplary for the use in mini aerospace vehicle. The objective of the present study is to model an efficient Pulse Detonation Engine. A number of simulations are done in order to understand the flow field variation and PDE performance. CFD software FLUENT is used to simulate the performance of a PDE, when fuel inlets are placed at different places on the combustion chamber a comparative study has been done. A PDE is a type of propulsion system that can potentially operate from subsonic up to hypersonic speeds. Pulse detonation engines are simple in construction, light weight and produce large thrust. The PDE has a simple geometry, consisting of a tube which is filled with fuel and oxidizer.

KeyWords: Pulse Detonation Engine, Inlet sections, convergent, divergent, pressure, velocity, CFD analysis, etc...

1. INTRODUCTION

Since the advent of the gas turbine engine, there has not been a major revolution in aircraft engine technology. Most chemical propulsion systems in use today rely on constant pressure combustion processes to convert chemical energy into useful thermal and kinetic energy as a means of generating thrust. Compared to other current engine technologies, pulsed detonation engines (PDE) is one of a number of recent concepts that has the capability to offer mechanical simplicity, improved fuel efficiency, higher thrust-to-weight ratios, lower cost and a wide flight operation envelope. For example, a comparison of specific impulse vs. Mach number regimes of various propulsion systems is shown in Figure 1. This Figure clearly shows the superior propulsive performance of PDEs.

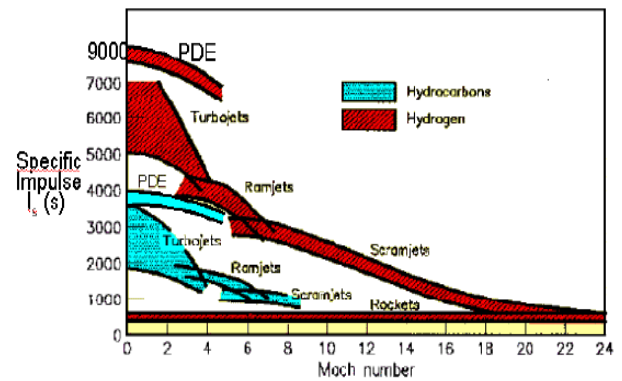


Fig-1 Specific impulse vs. Mach number regime of various propulsion systems.

A PDE is a type of propulsion system that can potentially operate from subsonic up to hypersonic speeds. Pulse detonation engines are simple in construction, light weight and produce large thrust. The PDE has a simple geometry, consisting of a tube which is filled with fuel and oxidizer. The PDE operates on the supersonic detonation of fuel. The basic block diagram of PDE is shown in the Figure 2.

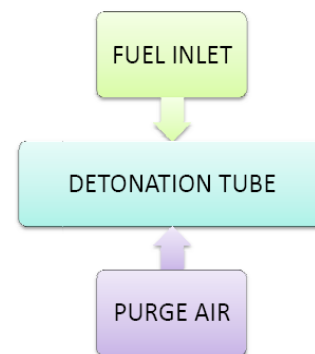


Fig-2 Block diagram of a pulse detonation engine

1.1 Detonation Process

This process takes place after the filling process. In this process the detonation wave is created which moves through the mixture and causes the pressure and temperature behind it to rapidly shoot up. Compared with the filling process, detonation takes place at a fraction of a millisecond. The velocity with which the detonation wave

travels from the closed end to the open end is termed the detonation velocity.

1.2 Purging process

This is the final process in a pulse detonation cycle. Fresh air is blown through to clean and cool the tube before the fill stage starts again. The time taken for this process is calculated along the same lines as the filling process. The higher the purge velocity, the lower the purge time and ultimately, the faster the cycle times. The purging process is very important as this cools the tube and prevents the fresh fuel /oxidizer mixture from auto-igniting.

2. OBJECTIVE OF THE WORK

The main problem in the PDE is to obtain a viable design. Even though it has a simple design of cylindrical tube for its combustion chamber, the ratio of length to diameter, frequency to length, and various other parameters are interrelated to one another. The various operating conditions under which it performs have to be considered for the design of PDE and the performance difficulty under which it sustains needs to be found. All the above results has to be compared to overview the design and performance of the engine.

3. DESIGN

Design of an existing pulse detonation engine is taken and modification is done based on the results of each analysis.

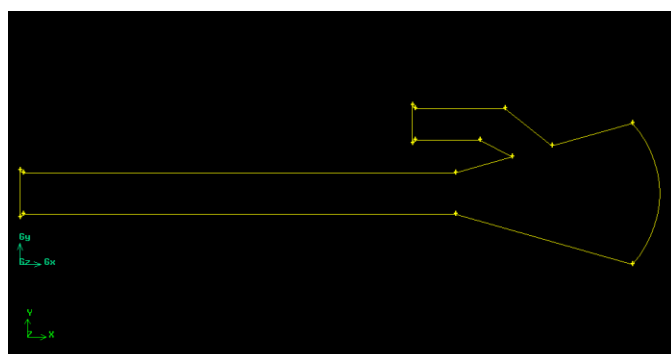


Fig -3 Design of one inlet PDE in GAMBIT

The above design shows the pulsejet with a single inlet. The geometry is drawn in gambit. A divergent inlet and outlet is taken for the inlet and a curved combustion chamber.

All the geometries of the PDE are modelled based on design drawing before any meshing is done to the model. Above figures shows the 2D model of the PDE before meshing.

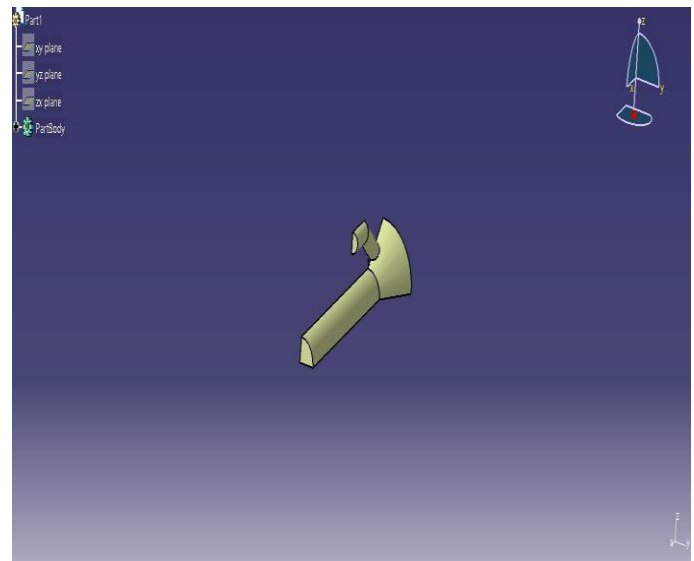


Fig-4 Design of 3D PDE in CATIA



Fig-5 2D Boundary condition of a PDE

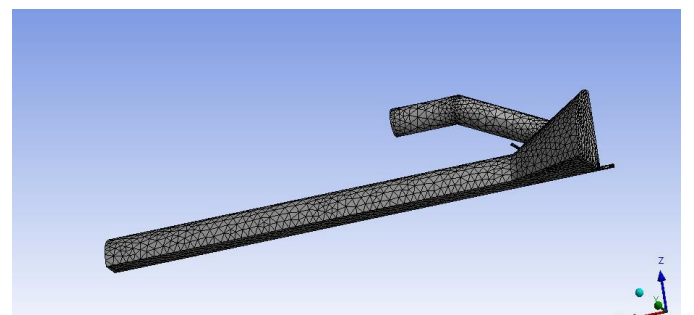


Fig-6 Meshing in 3D PDE

4. CFD APPLICATION

For the CFD analysis, the inlet is assumed to have no losses. Admission of air occurs with no entropy generation. In fact, for the analysis, it is assumed that the detonation chamber is closed at the front end for analysis. However, in order to perform the CFD analysis a description of the geometry at the downstream end is required. In the absence of any specific design, it is assumed that the detonation chamber is open at the downstream end and has a constant diameter throughout and discharges. Air is taken as the fluid medium for analysis as common. FLUENT employed in the present work. It uses a finite volume scheme to solve the continuity, momentum and energy equations with associated boundary conditions. The mesh file was imported into ANSYS FLUENT, where the modelling equations and boundary conditions are set and analysed. The finite volume method was used to solve the partial differential equations of the model. Boundary conditions are applied. K-ε and laminar model with default setting is preferred. Air inlet boundary condition was set as Velocity Inlet. The direction of the flow was normal to the inlet boundary. The outlet was specified as pressure outlet.

5. FLOW ANALYSIS

In this project, FLUENT is used to analyse the flow. The main objective is to visualize the flow pattern of the PDE by setting up the input parameter of the actual testing such as the inlet pressure, inlet size, outlet size and other potential input that will affect the output of the analysis.

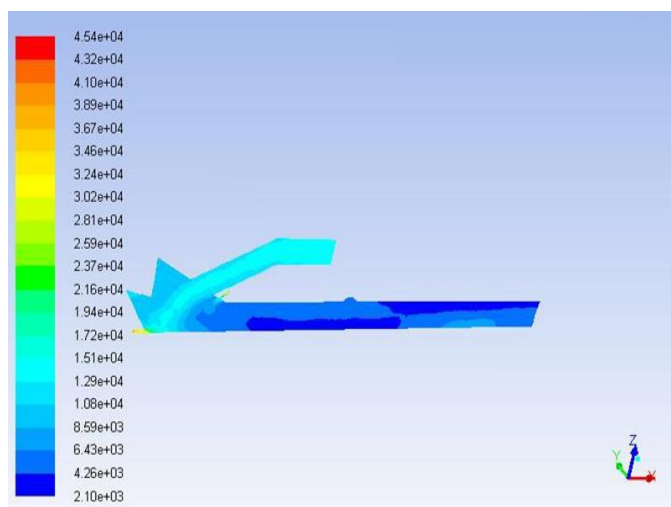


Fig-7 Contours of Total Pressure for 3D model

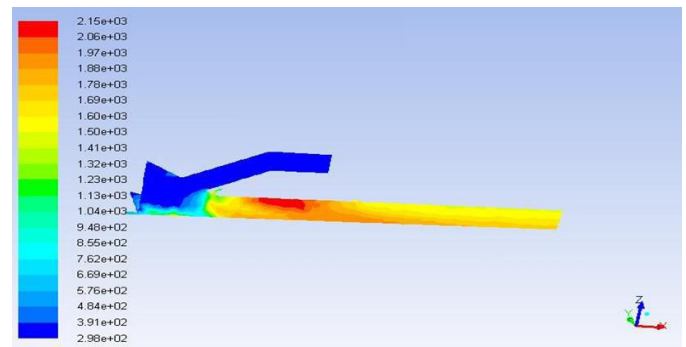


Fig-8 Contours of Total Temperature for 3D model

From the tabulation and charts that are obtained from the software FLUENT, analysis is carried out namely between the contours of velocity magnitude, static pressure, total pressure, velocity vector colored by velocity magnitude. All the cases are taken into account and the results are found out.

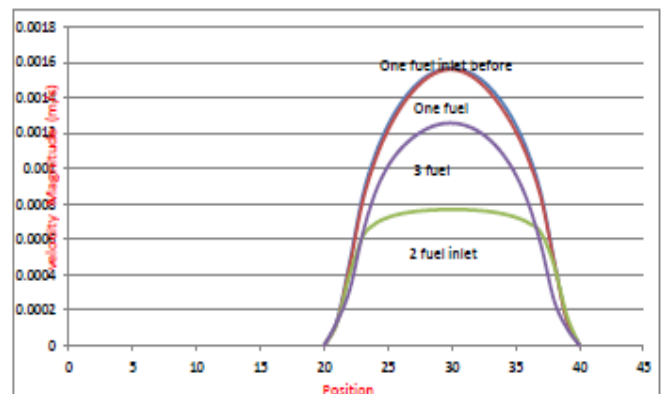


Fig-9 Fuel inlet velocity vs position

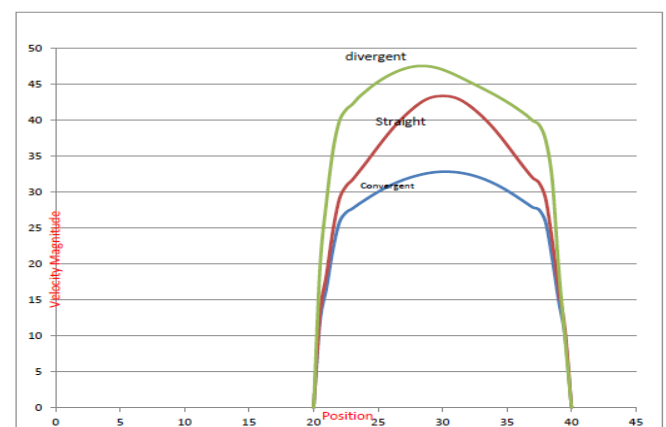


Fig-10 Comparative study of convergent, straight and divergent inlet section.

6. CONCLUSIONS

The work on valve less pulse detonation engines presents an interesting view on how the flow inside the PDE takes place. This also leads to future work that can be done to experimentally test these jets based on the CFD presented. CFD analysis of the model shows the flow pattern that can be used as a great benefit for the future work.

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