

CFD Analysis for Bleed Flow through a Variable Area By-Pass Duct of a Pulse Detonation Engine

Ishaan Khunger

Department of Aerospace Engineering
University of Petroleum and Energy Studies
Dehradun

ishankhunger@gmail.com

ABSTRACT

The pulse detonation is an engine which operates on pulses. The controllers dial in the frequency of the detonation in the digital engine to determine thrust. Pulse detonation rocket engines operate by injecting propellants into long cylinders that are open on one end and closed on the other. The flow after the inlet is divided into two sections: primary flow and secondary flow. The primary flow is the flow which goes through the main engine components i.e. the pulsed engine. The engine is pulsed because the mixture must be renewed in the combustion chamber between each detonation wave initiated by an ignition source. The secondary flow is the bypassed flow or the bleed flow which has a lower thrust specific fuel consumption. The study and analysis of bleed flow under different working conditions is the main objective of this project performed using ANSYS Fluent software.

Keywords

Bleed Flow, Turbulent Flow, Reynold’s Number

1. INTRODUCTION

Pulse Detonation Engines (PDEs) can be broken into three categories: Pure, combined cycle, and hybrid. However, the general principle of operation for each is identical: The fuel-air mixture is detonated in the engine cavity, rather than deflagrated. This violent thermodynamic process creates a pressure wave which compresses the fuel-air mixture of the following cycle; the process is repeated up to hundreds of times per second. The PDE in general has important advantages over current propulsion systems. The PDE has an inherently simpler mechanical design and a higher thermodynamic efficiency. As such, it is shown that the PDE is more efficient, in both specific thrust and specific fuel consumption, than current ramjet systems at speeds of up to approximately Mach 2.3.

This performance advantage makes the PDE an excellent choice for static thrust up to mid- Mach numbers, where a ramjet or scramjet could begin operation in a multi-stage propulsion system. Therefore, the PDE has applications to many aerospace industries: Quick and efficient intercontinental travel, safe and cost-effective spacecraft launch, and effective military operation.

To handle such operations at very high speeds deals with very high temperatures too. Thus, the cooling of the engine is also a very important aspect. Just like any other high-speed engine, the PDE also has a by-pass duct for the bleed flow to pass through. The temperature and pressure at which this flow passes through the inlet and outlet, and the temperature it maintains throughout its passage through the by-pass duct is a big concern for the engine to work efficiently.

The CFD analysis of the bleed flow is done by using the Ansys Fluent software by taking some feasible boundary conditions.

The analysis is done in continuation with the work done by *Khunger, Ishaanin* “Fanno Flow and Rayleigh Flow Calculations for Bleed Flow through a Variable Area By-Pass Duct of a Pulse Detonation Engine”.

2. EXPERIMENTAL PROCEDURE

The model of the by-pass duct of the PDE is designed in the AnsysDesignModeler. The basic two-dimensional diagram of which looks like one in Fig. 1.

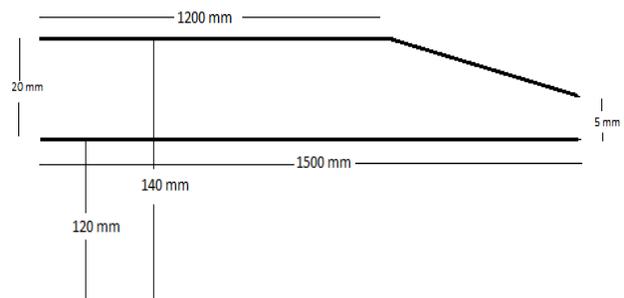


Fig. 1 2-D diagram of the by-pass duct

The area under the dark lines is the by-pass duct with the inlet being at the left side and the outlet towards the right side. The dimensions of the duct are given in the figure itself.

The three-dimensional model is shown in Fig. 2.

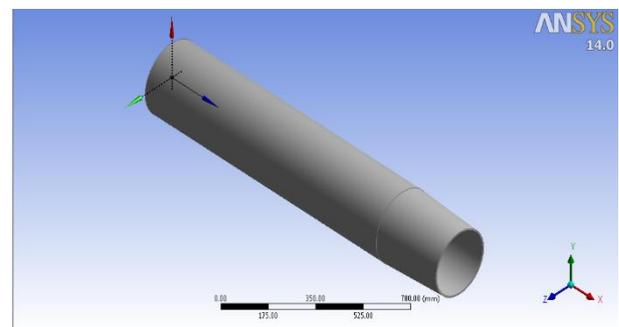


Fig. 2 3-D model of the by-pass duct.

The CFD analysis was done taking two cases, varying the Mach number of the flow. The boundary conditions for both the cases taken are:

- Inlet Pressure = 1.6 bar
- Inlet Temperature = 320 K
- Inner Wall Temperature = 450 K
- Outer Wall Temperature = 300 K
- $Re = \rho u d / \mu = 170000$

The value of Reynold's number suggests that the flow is turbulent.

The work carried out in the previous paper was divided under two categories: Fanno Flow and Rayleigh Flow, one relating the friction factor and the other relating the wall temperatures i.e. heat addition. Thus, the CFD analysis is carried out taking into consideration both the aspects

3. RESULTS AND DISCUSSIONS

The analysis was done in two cases, by varying the Mach number of the flow.

Case 1: Mach 0.2

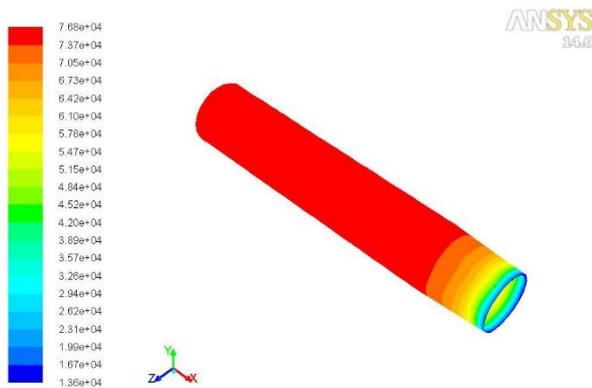


Fig. 3 Contours of Static Pressure (Pascal)

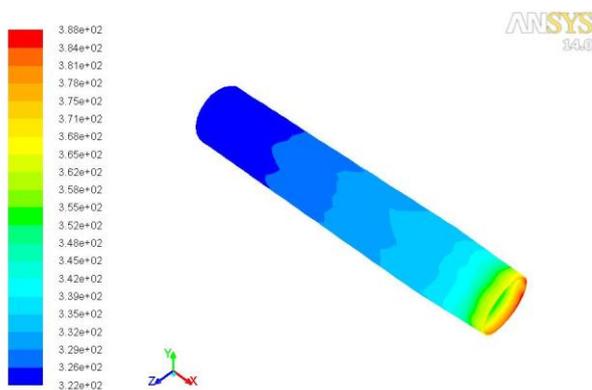


Fig. 4 Contours of Total Temperature (K)

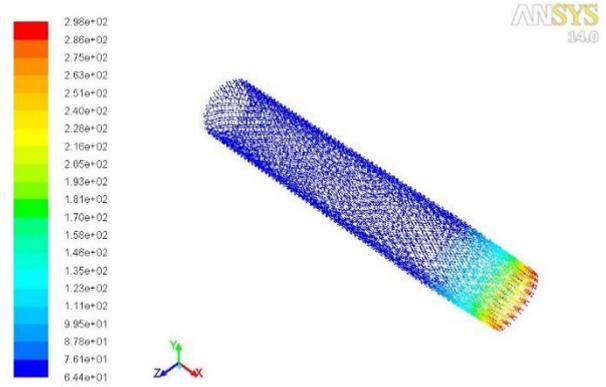


Fig. 5 Contours of Velocity Magnitude (m/sec)

Case 1: Mach 0.4

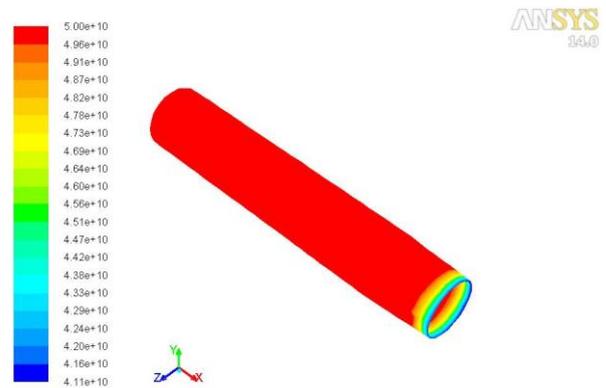


Fig. 6 Contours of Static Pressure (Pascal)

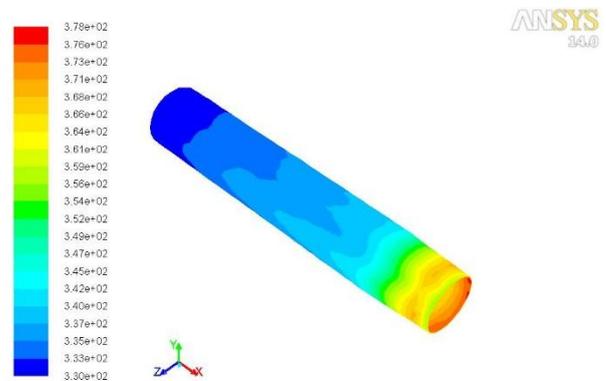


Fig. 7 Contours of Total Temperature (K)

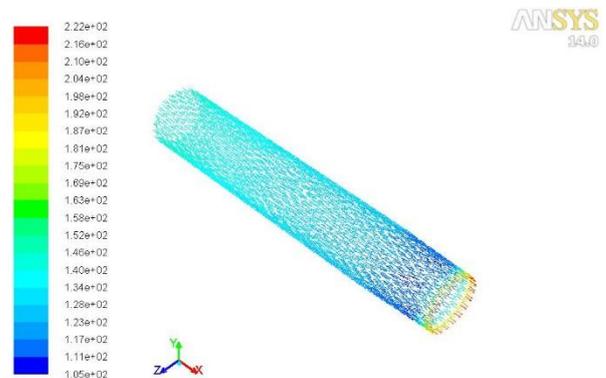


Fig. 8 Contours of Velocity Magnitude (m/sec)

4. CONCLUSIONS

From the ongoing study following conclusion were drawn:

- The pressure drop in the case of Mach number 0.4 is more as compared to Mach number 0.2. This can be due to the compressibility effects which occur normally at Mach number greater than 0.3.
- The temperature drop in the case of Mach number 0.4 is less than in Mach number 0.2. This means that at higher flow velocity, the temperature also remains higher, this can be due to large energy interactions and higher entropy.
- The final velocity in the case of Mach number 0.4 is more as compared to Mach number 0.2. This can be due to the initial velocity being higher. But at the same time, the frictional effects and variable area flow also come into play. Thus, the velocity decrease is significant where the flow passes through the variable area passage.

5. REFERENCES

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