# Combustion Analysis of Pulsejet Engine using Techniques of CFD and Analytical Modelling

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***Abstract :***Combustion in pulsejet engine takes place in pulses. This paper investigates the various fuel inlet design configurations of in pulsejet engine using techniques of CFD . Three different fuel inlet configurations used for analysis are one, three and five using ANSYS CFX software. The combustion model used for analysis is eddy dissipation and CAD model is developed using Creo 2.0 software. The comparative study is conducted by parameters like thrust force generated and static enthalpy. The turbulence model used is two variable k-epsilon.

**Keywords:** CFD, pulsejet engine, inlet configuration

## I. INTRODUCTION

The combustion in pulsejet engine takes in pulses and can be made with very few parts. The weight of pulsejet engines are very low and but the compression ratio is very poor. The pulsejet engines were invented in early 1900s and can operate with or without valves (valveless). It consists of open inlet heading to combustion chamber and exhausting outlet by exhaust tube. The major demerit of pulsejet engines is back thrust developed due to significant loss pf product through front of jet.

## II. LITERATURE REVIEW

O'Brien, John Grant[1] has stated that no specific laws are present which could describe the working of pulsejet engine and new modifications are done on trial and error basis. Also lack of mathematical model has limited the potential of pulsejet engines in upscaling. This has hindered the development or improvement of engine performance.

Christian Talbot McCalley [2] has investigated pulsejet engine used in UAVs driven with gasoline and propane.After successful operation, all the data was acquired and the modifications were thoroughly studies and analyzed for optimum understanding. And it was understood that both the hobby scale pulse jets ran smooth upon using kerosene as fuel.

Michael Schoen[3] directed his research towards the miniaturization of valve less pulse jets in order to bridge the gap between hobby-scale and micro-scaled Pulse Jets. This work was done to understand the physical effect that the changes in Jet geometry have on the performance of the engine. The jet performance improved with changes made in tail pipe length and use of divergent exit nozzle. Reducing the size of the jets gives way to a rise in its inherent operating frequency.

Adam Kiker[4] directed his focus towards developing micro-scale pulse jets. He managed to design and operate a record 8cm long pulse jet fuelled by hydrogen. It was observed that the frequency of the jet measures as one over the length. It was also observed that tripling the inlet length had the same effect as increasing the overall length by 50%. Furthermore, it was recorded that although the exhaust diameter did not have any considerable impact on the operating frequency. Kiker also recorded that with increase in fuel flow rate, the operating frequency and peak pressure also rise.

Rob Ordon[5] focused on the hobby-scale pulse jet. It had a length of 50cm and worked on either ethanol or propane. One of the highlights of this project was that Ordon had managed to make use of both valved and valve less pulse jets. The contribution of this project also led to the design of an analytical model which could predict the operating frequency of any valve less Pulse Jet. This model paved the way to finding the parameters that govern the design of Pulse Jets.

## III. PROPOSED WORK

The current research is intended to improve thrust generated from pulsejet engine using different fuel inlet configurations. Three different fuel inlet configurations are used to analyze pulsejet engine with constant air intake. The CFD ( Computational Fluid Dynamics) is used for analysis of pulsejet engine.

## IV. METHODOLOGY

The CAD model of pulsejet engine is modelled using dimensions as shown in figure 1 below. The schematic shown below shows length of pulsejet 600mm and opening nozzle 79.5mm , inlet nozzle 95mm.
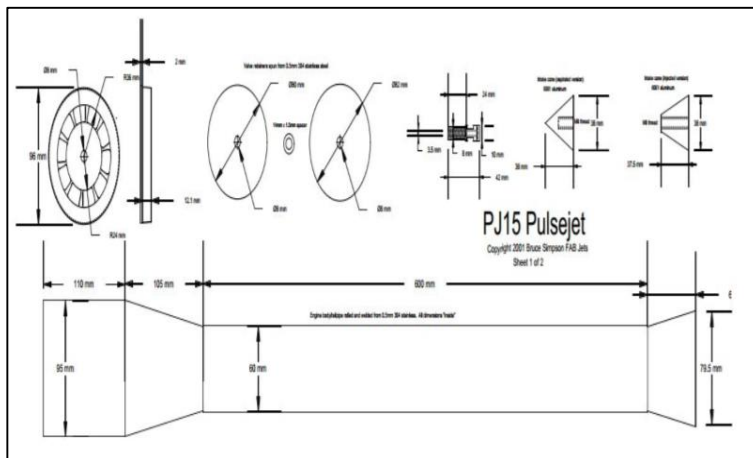


Figure 1: Dimensions of pulsejet engine

The fuel inlet configuration of pulsejet engine are taken as 1, 3 and 5 to increase rate of combustion and hence increase pressure generated which in turn increases thrust. The computational domain is modelled using Creo 2.0 which is sketch based, feature based parametric 3d modelling software developed by PTC. The CAD model is prepared using extrude, pattern, blend and revolve tools.
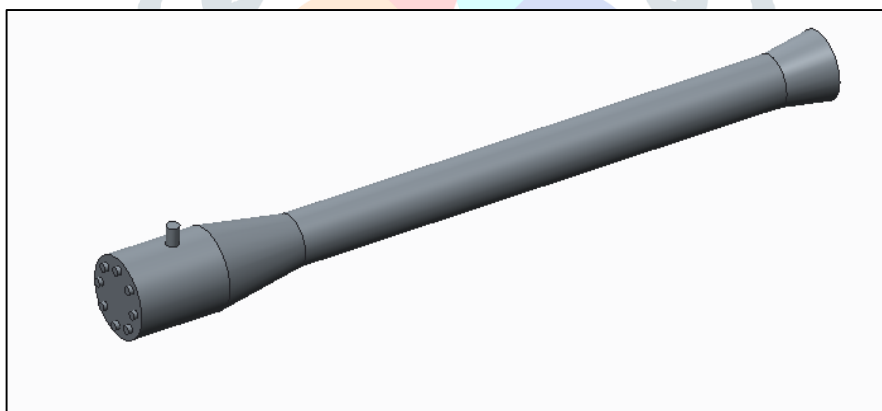


Figure 2: CAD model of pulsejet engine with single inlet
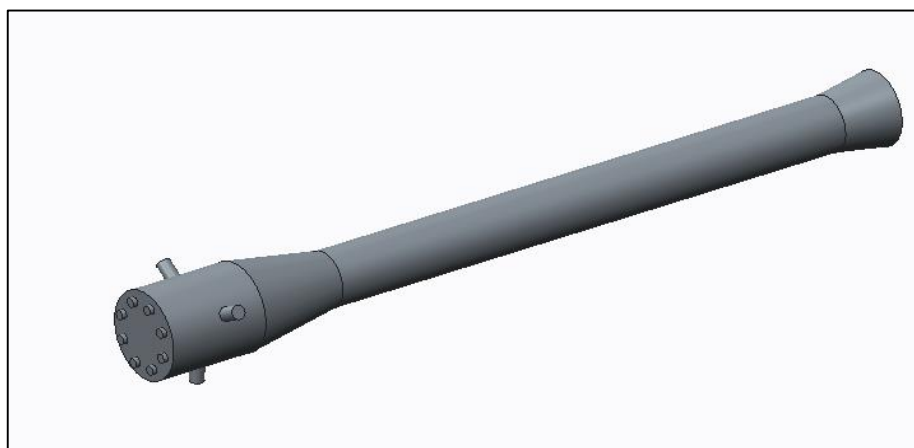


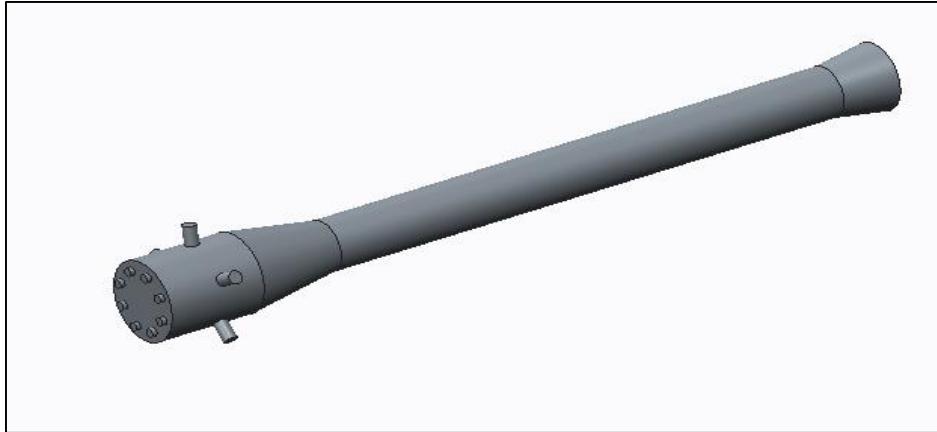Figure 3: CAD model of pulsejet engine with 3 fuel inlet

Figure 4: CAD model of pulsejet engine with 5 fuel inlet

The CAD model is imported in ANSYS workbench (. iges format) and meshed. The meshing work was accomplished on commercially available ANSYS meshing software. The geometry created was imported in ANSYS meshing. The meshed domain consisted mostly of uniform sized cells as shown in Fig. 5. Fine meshing was completed near the absorber plate walls in order to solve the concerned governing differential equations accurately in the laminar sub-layers at these regions. The mesh size increased towards the centre. The size of the grid was constant lengthwise in entrance and exit sections of the duct.
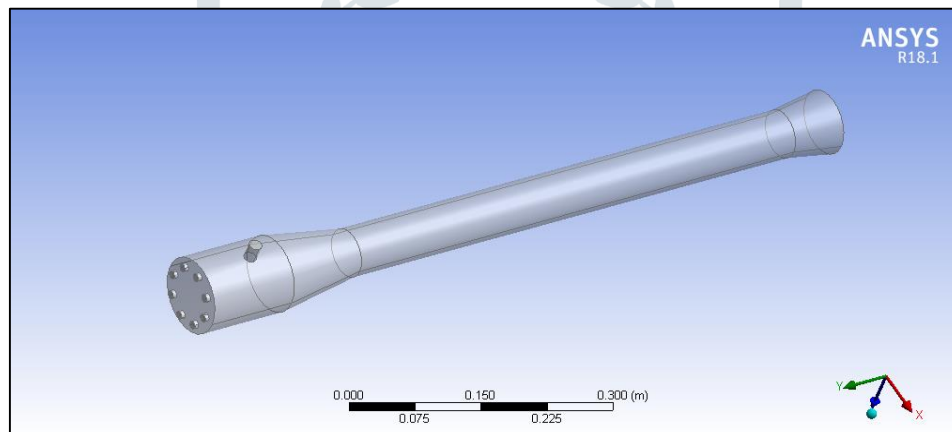


Figure 5: Imported CAD model of pulsejet engine

The meshing for EGR cooler is carried out using ANSYS Mesher. Here element shape is taken as brick and fine sizing with relevance 100. Other meshing parameters such as smoothing is set to medium, transition slow, curvature angle $12^0$ as shown in fig6
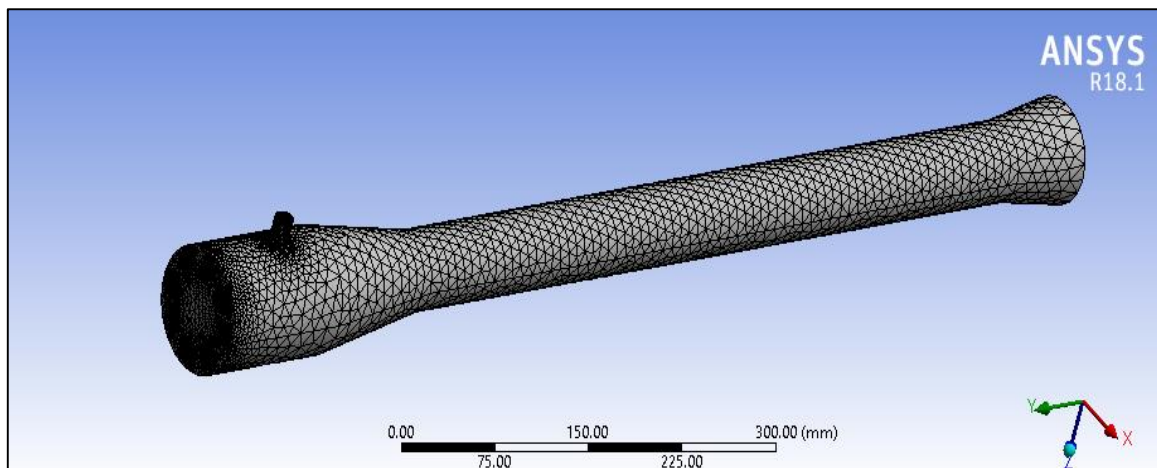
Figure 6: Meshing of EGR cooler

## V. RESULTS AND DISCUSSION

**CASE 1: Single Fuel Inlet Configuration**
The results of analysis from single inlet design configuration is shown in figure 6 below. The pressure plot, velocity plot and enthalpies are plotted below.
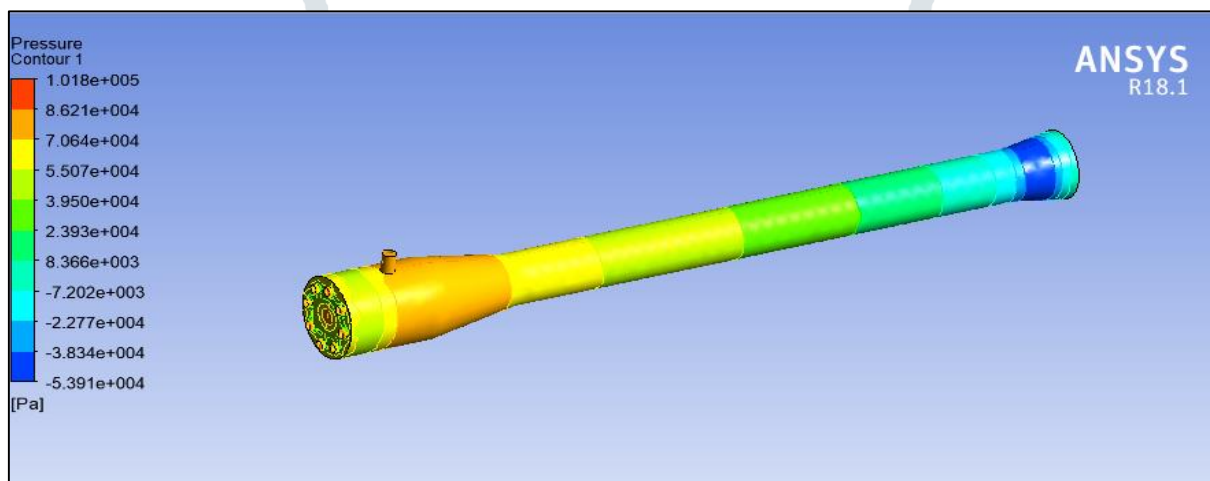


Figure 7: Pressure plot contours of single fuel inlet design

The pressure plot shown in figure 7 above shows high pressure in combustion zone shown by dark contour and reduces along the length of pulse jet engine on moving towards exit. The maximum pressure is 101800 Pa at the inlet of engine .
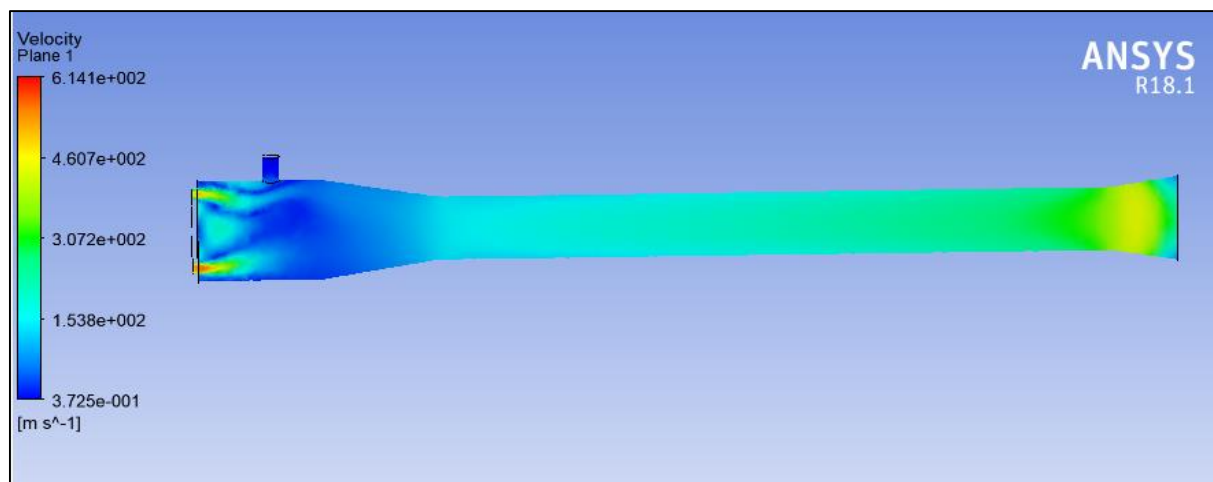
Figure 8: Velocity plot of single fuel inlet design

The velocity plot shows highest magnitude near inlet of pulsejet engine with magnitude of 614 m/sec and reduces along length on moving towards exit.
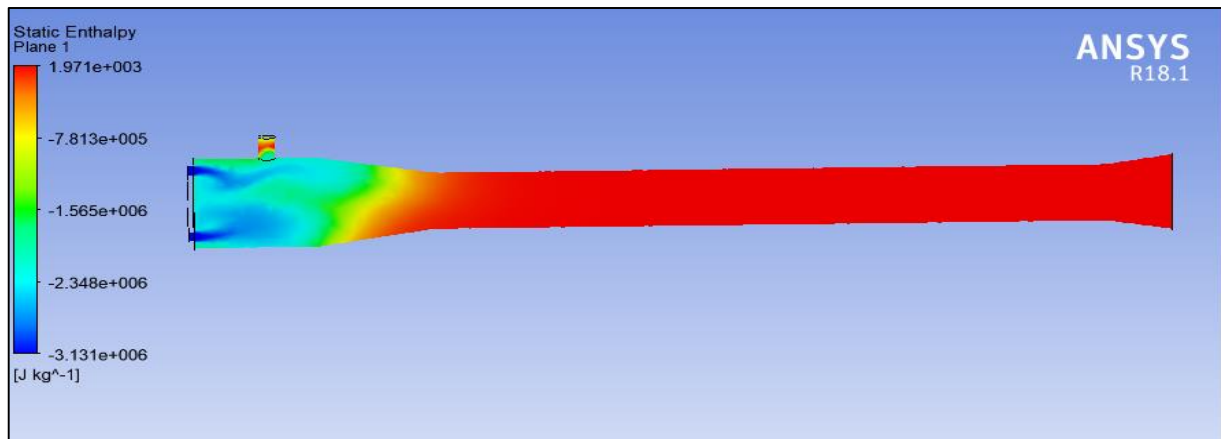


Figure 9: Static Enthalpy using single fuel inlet

The static enthalpy plot is shown in figure 9 above shows maximum value of 1971 J/Kg K on 2$^{nd}$ half of pulsejet engine.

**CASE 2: Three Fuel Inlet Configuration**

The results of analysis from single inlet design configuration is shown in figure 9 below. The pressure plot, velocity plot and enthalpies are plotted below.
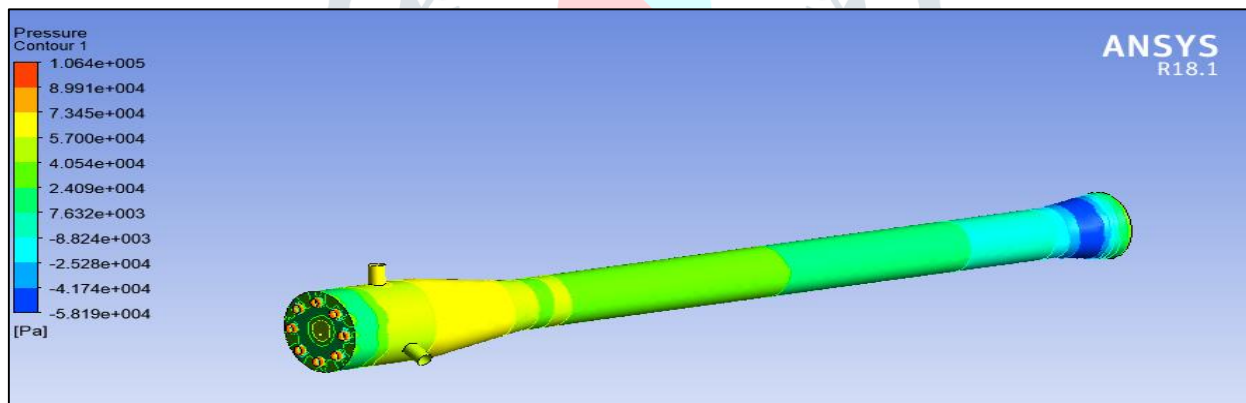


Figure 10: Pressure plot contours of three fuel inlet design

The pressure plot shown in figure 10 above shows high pressure in combustion zone shown by dark contour and reduces along the length of pulse jet engine on moving towards exit. The maximum pressure is 106400 Pa at the inlet of engine . The pressure on mid portion of jet is shown by light green colour with magnitue of 40540Pa . The pressure is further reduced to 7632Pa on moving towards the exit shown by light blue colour.
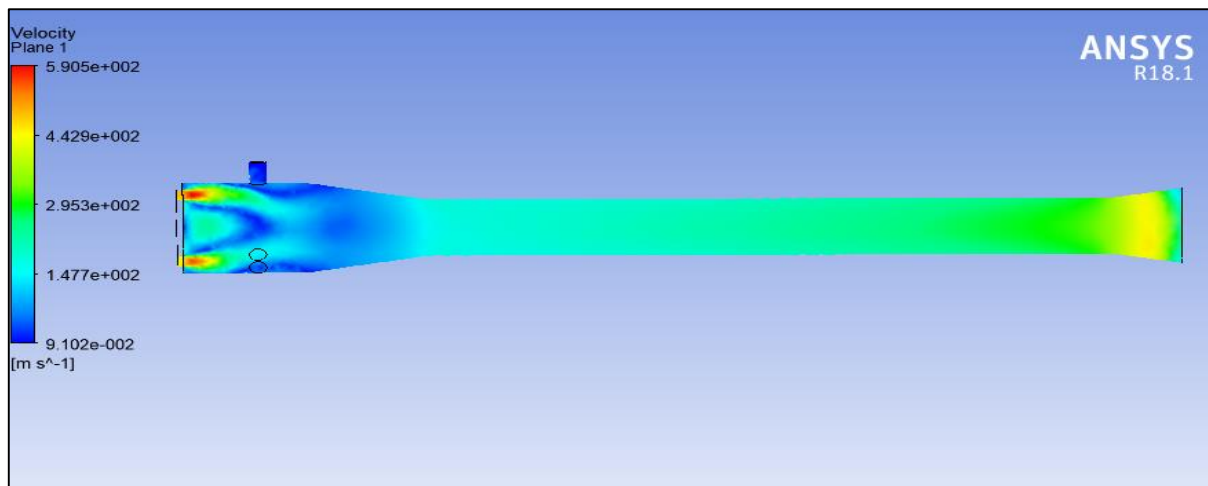
Figure 11: Velocity plot contours of three fuel inlet design

The velocity plot shows highest magnitude near inlet of pulsejet engine with magnitude of 590.5 m/sec and reduces along length on moving towards exit. The velocity further reduces along the length of tube to 188 m/sec and then increases along the length with magnitude of 429 m/sec towards the exit.
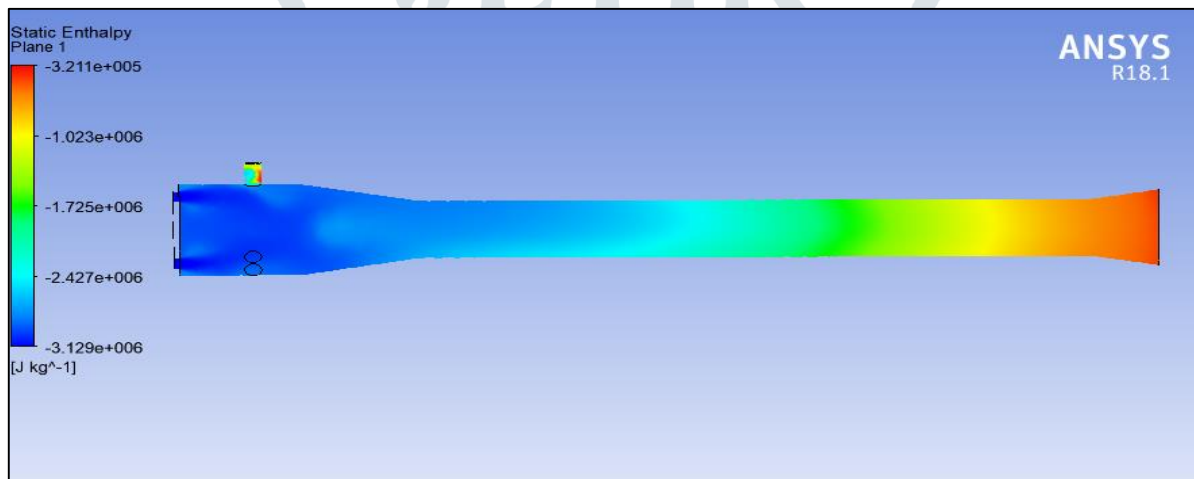


Figure 12: Static Enthalpy using 3 fuel inlet

The static enthalpy plot is shown in figure 12 shows fluctuations in enthalpy magnitude along the length of pulsejet engine. The maximum magnitude of static enthalpy is near exit of jet engine i.e. 3211J/Kg K. The enthalpy value is lower towards air inlet and higher towards outlet.

**CASE 3: Five Fuel Inlet Configuration**

The results of analysis from single inlet design configuration is shown in figure 7.9 below. The pressure plot, velocity plot and enthalpies are plotted below.
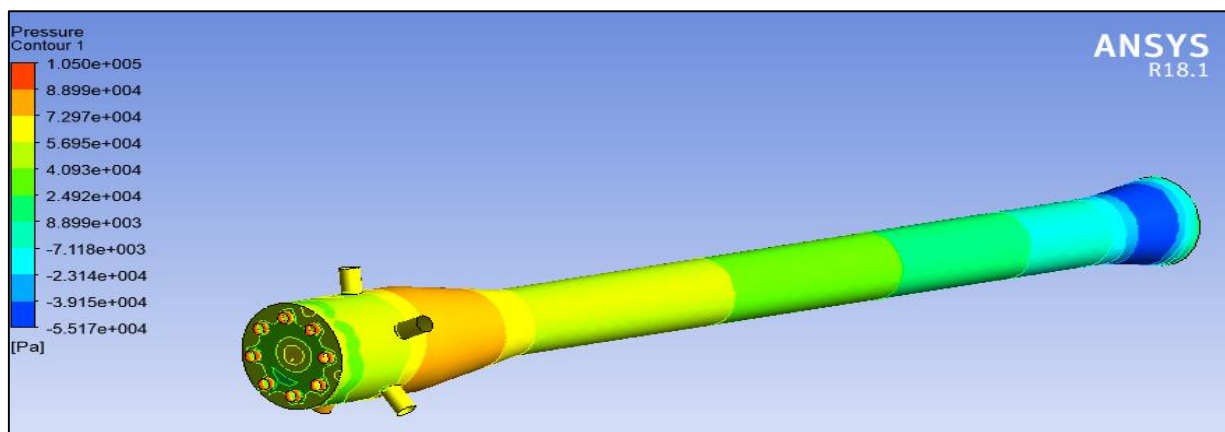
Figure 13: Pressure plot contours of five fuel inlet design

The pressure plot shown in figure 13 above shows high pressure in combustion zone shown by dark contour and reduces along the length of pulse jet engine on moving towards exit. The maximum pressure is 105000 Pa at the inlet of engine . The pressure on mid portion of jet is shown by light green colour with magnitue of 40930Pa . The pressure is further reduced to 7632Pa on moving towards the exit shown by light blue colour.
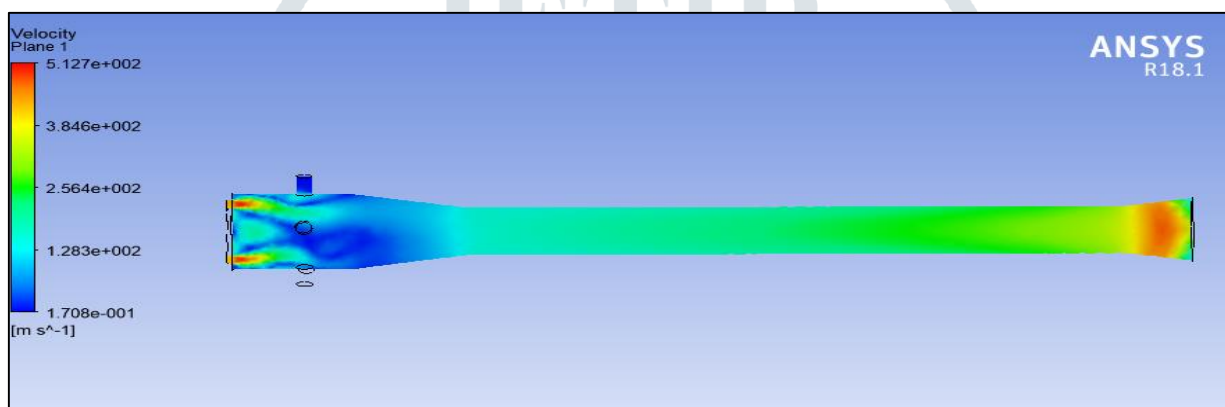


Figure 14: Velocity plot contours of five fuel inlet design

The velocity plot shows highest magnitude near inlet of pulsejet engine with magnitude of 512.7 m/sec and reduces along length on moving towards exit. The velocity further reduces along the length of tube to 256.4 m/sec and then increases along the length .
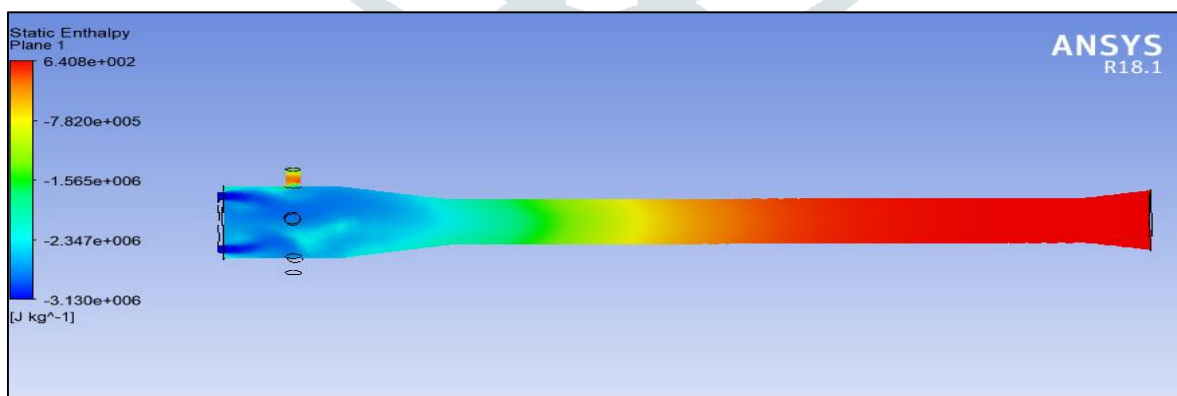


Figure 15: Static enthalpy  contours of five fuel inlet design

The static enthalpy plot is shown in figure 15 shows fluctuations in enthalpy magnitude along the length of pulsejet engine. The maximum magnitude of static enthalpy is near exit of jet engine i.e. 640.8J/Kg K. The enthalpy value is lower towards air inlet and higher towards outlet. The cross-section area of outlet as measured is 4963.91 N/mm².

Table 1: Thrust and Pressure

| Design Type | Pressure ( Pa) | Thrust (N) |
|---|---|---|

| Single Fuel Inlet | 1788.23 | 8876594 |
|---|---|---|
| Three Fuel Inlet | 4737.16 | 23514835 |
| Five fuel Inlet | 4787.16 | 23763031 |

The pressure generated at outlet and corresponding thrust force is shown by table 1 above. The thrust force generated is minimum for single fuel inlet i.e. 8876594N and increases multifold with increase in number of fuel inlet. The three-fuel inlet and five fuel inlet design configurations have shown very high thrust force. The static enthalpy table is shown in figure 7.2 below shows similar trend. The static enthalpy for single fuel inlet is 1.76889e+006 J/Kg is minimum and design with five fuel inlet shows maximum fuel inlet is 2.38226e+006 J/Kg.
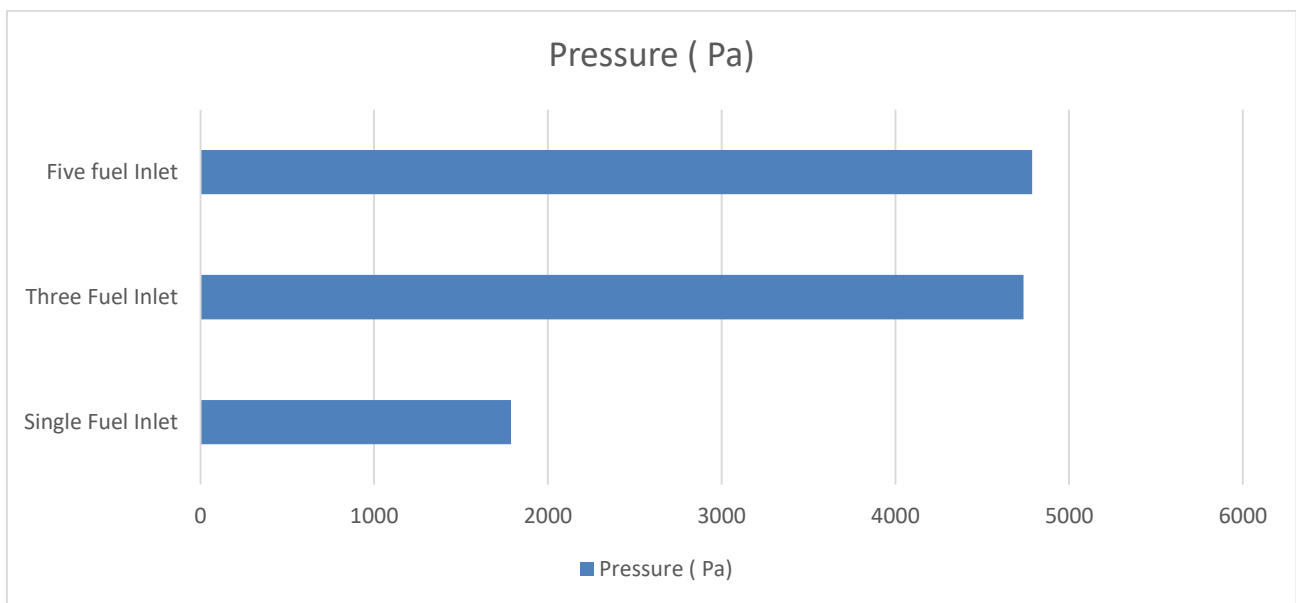


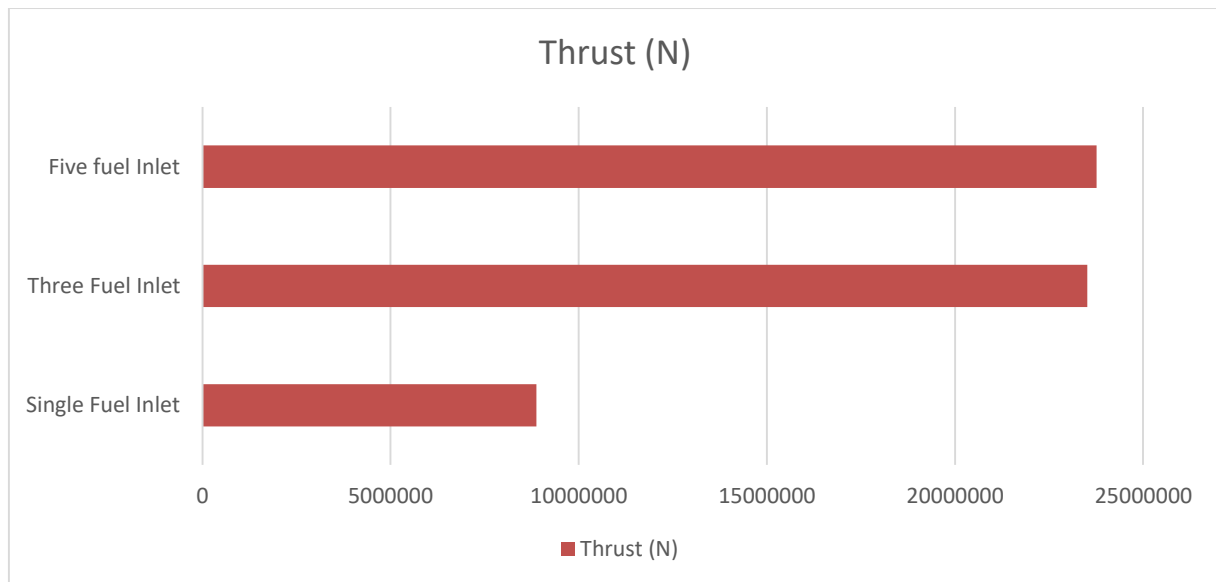Figure 16: Pressure contours of five fuel inlet design

Figure 17: Thrust force contours of five fuel inlet design

Table 2: Static Enthalpy

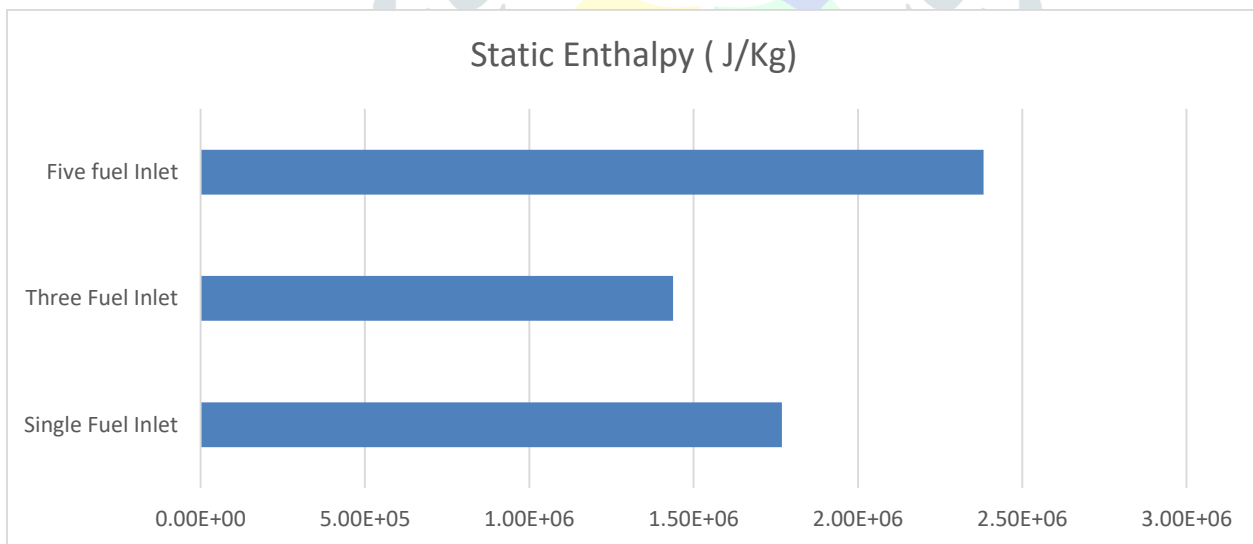| Design Type | Static Enthalpy ( J/Kg) |
|---|---|
| Single Fuel Inlet | 1.76889e+006 |
| Three Fuel Inlet | 1.43742e+006 |
| Five fuel Inlet | 2.38226e+006 |



Figure 18: Static enthalpy contours for different fuel inlet design configuration

The static enthalpy table is shown in figure 18above shows similar trend. The static enthalpy for single fuel inlet is 1.76889e+006 J/Kg is minimum and design with five fuel inlet shows maximum fuel inlet is 2.38226e+006 J/Kg.
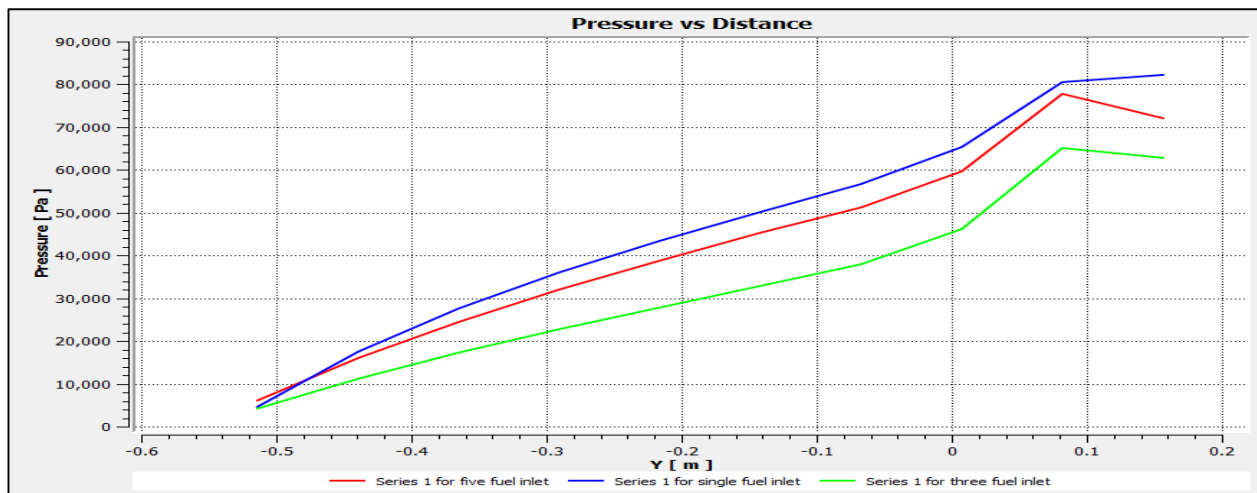
Figure 19:

Pressure vs Distance curve for 3 design configurations

The pressure curve is shown in figure 19 for all the three design configurations. The plot shows high magnitude of pressure in combustion chamber shown by rightmost end and reduce as we move towards exit of engine. The curve shows gradual decrease in pressure generated due to combustion reaction.

## VI. CONCLUSION

CFD analysis of pulsejet engine is conducted using ANSYS CFX software with varying fuel inlet design configurations. It is found that maximum thrust of 23763031 is generated using five fuel inlet design configurations followed by 3 inlet and least amount of thrust is generated using single inlet design configuration. The static enthalpy generated also shows similar trend as of thrust i.e. maximum enthalpy is generated using 5 fuel inlet configurations then 3 inlet configuration and least is with single fuel inlet configuration.

**REFERENCES**

[1]. O'Brien, John Grant (1974) "The pulsejet engine: a review of its development potential".

[2]. Christian Talbot McCalley (2006) "Experimental Investigation of Liquid Fueled Pulsejet Engines".

[3]. Schoen MA (2005) "Experimental investigations in 15 cm class pulsejet engines, M.S. Thesis, Department of Mechanical and Aerospace Engineering", NC State University, Raleigh, NC, 27695.

[4]. Kiker AP, Thesis MS (2005) "Experimental investigations on mini pulsejet engines"  Department of Mechanical and Aerospace Engineering., NC State University, Rayleigh, NC, 27695.

[5] R.L. Ordon, Thesis  MS (2006) "Experimental investigations into the operational parameters of a 50 cm class pulsejet engine"  Department of Mechanical and Aerospace Engineering, NC State University, Raleigh, NC, 27695.