Ganesh Motekar, 2021, 9:2
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

Combustion Analysis of Pulsejet Engine Using CFD

M. Tech. Scholar Ganesh Motekar, Prof. G.R. Kesheorey (Supervisor & HOD), Dr. A.J. Siddiqui (Executive Director)
Department of ME,
Vindhya Institute of Technology & Science,
Indore,MMMP,,India
Ganesh26motekar@gmail.com, grkvitsin@gmail.com

Abstract- The performance of pulsejet engine is significantly affected by efficiency of combustion taking place. The efficiency of combustion depends on type of fuel inlet configuration and number of fuel inlets. The current research investigates the combustion characteristics of single fuel inlet, double fuel inlet type and three fuel inlet type designs in vertical configuration. The combustion analysis is conducted using Computational Fluid Dynamics and with eddy dissipation combustion model. The CAD model is developed in Creo design software and CFD analysis is conducted using ANSYS CFX software. The static enthalpy, pressure and thrust generated are evaluated for all the three designs. The CFD analysis has shown that three fuel inlet design configurations resulted in significant increase in thrust generation as compared to two fuel inlet design.

Keywords:- Pulsejet, Fuel Inlet, Combustion, CFD, Thrust.

I. INTRODUCTION

A pulsejet engine is a type of jet engine in which combustion occurs in pulses. A pulsejet engine can be made with fewer no parts and is capable of running statically.

Pulsejet engines are a lightweight form of jet propulsion, but usually have a poor compression ratio, and hence give a low specific impulse. The pulsejet is one of the simplest forms of propulsion known to man. They are known for having little to no moving parts, scalability, relatively low cost, ease of use, and extremely high noise.

II. LITERATURE REVIEW

Rob Ordon[1] 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. This work was a significant contribution in further understanding the characteristics of the hobby-scale pulse jets and allowed Schoen and Kiker to complete the respective projects.

Daniel Paxson[2] from the NASA Glenn research center conducted another noteworthy study which used a hobby-scale pulse jet similar to that of Ordon’s (50cm). This Jet however ran on gasoline and was used as a model for unsteady combustion to test thrust augmenters for use in the pulsed detonation engines. Paxson focused on the relationship between the exhaust diameter, pressure of the combustion chamber, and average thrust produced.

U. Sreekanth, Subba Rao B [3] has conducted work to understand the working of the pulse jet and employs a numerical approach in doing so. The fluid mechanics and acoustic properties are analyzed in a numerical manner in order to better understand the complete physics involved in the operation of the pulse jet. The study was directed to improve the already existent model design for valve less pulse jets, obtain the basic data on thrust of the model pulse jets, and also examine how the intake and exhaust lengths affect the thrust produced by the Jets.

Hussain Sadig Hussain [4] conducted a thorough research of the thermodynamic characteristics of conventional pulse jet engines and then a conceptual design and calculations of a pulse jet engine generating 100 lbs. of thrust is formulated, keeping the geometrical aspects (specific fuel consumption, thrust and frequency limitations) in frame.

The objective was to estimate the dimensions of each part of the pulse jet in the simplest possible fashion. Important aspects such as inlet diffuser and exhaust nozzles effects that are significant in real applications have not been considered in this research.

Liu Min[5] directed his experimental research that resulted in providing the practical fundament in order to improve the performance of small jet engines. The research was carried out on an air breathing engine experimental bench that includes the fuel supply system, test collection system, ignition valve type pulse jet engine.

In order to measure the characteristics of the engine including wall temperature, the concentration of the combustion products, the gas temperature and the pulse pressure, infrared thermal imaging system along with flue gas analyzer were used.

III. OBJECTIVE

The current research investigates the application of CFD in determining thrust and enthalpy generated on pulsejet engine using circular design configuration and vertical design configuration. The CAD model is developed in Creo design software and CFD analysis is conducted in ANSYS CFX software.

IV. METHODOLOGY

The CAD model of pulsejet engine is modelled using dimensions as shown in figure 6.1 below.

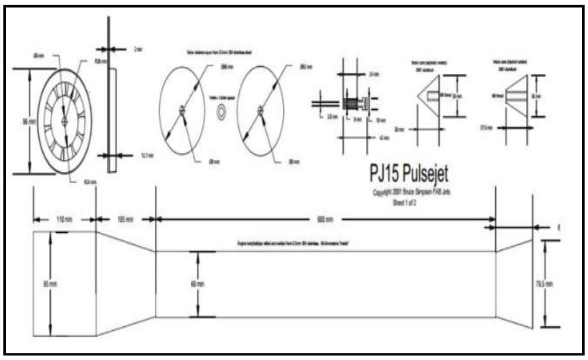

Fig 1. Dimensions of pulsejet engine. [6]

The schematic shown below shows length of pulsejet 600mm and opening nozzle 79.5mm , inlet nozzle 95mm. 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. 6.8. 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.

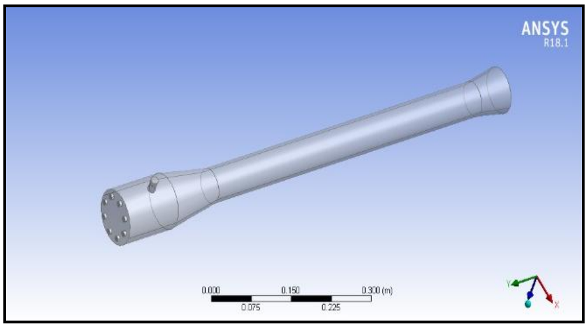

Fig 2. CAD model of pulsejet engine.

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 120 as shown in fig 3

International Journal of Science, Engineering and Technology

An Open Access Journal

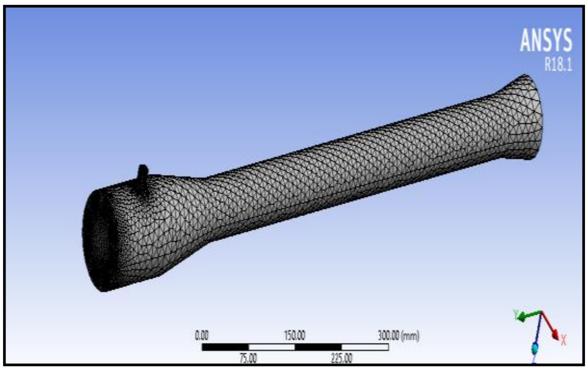

Fig 3. Meshing.

We have to define single domain as fluid where in chemical reaction i.e. combustion takes place and material definition as reacting mixture to simulate combustion analysis.

The heat transfer model is taken as thermal energy as temperature variation will take place and reaction is jet air with eddy dissipation model for combustion. The domain is defined as fluid. Reference pressure is set to 1atm.

Two variable k-epsilon turbulence model is set for analysis and inlet velocity is set to 1 atm at inlet as opening of inlet valve will account for 1 atm air pressure. The inlet boundary condition is defined with different mass fraction composition of gases and same for fuel inlet also.

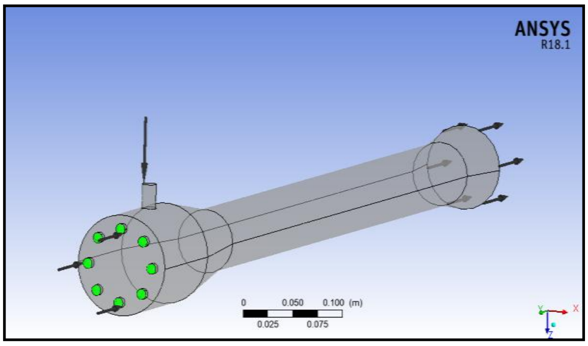

Fig 4. Air inlet definition.

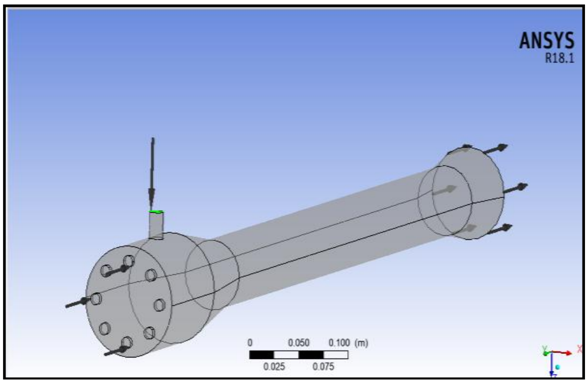

Fig 5. Fuel inlet definition.

The inlet for fuel is taken as velocity with .25m/s and temperature 300K with different mass fraction as shown in figure 5 above.

V. RESULTS AND DISCUSSION

The CFD analysis is conducte on different designs of pulsejet engine to determine pressure plot, enthalpy plot and velocity plot.

The pressure plot shown in figure 6 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.

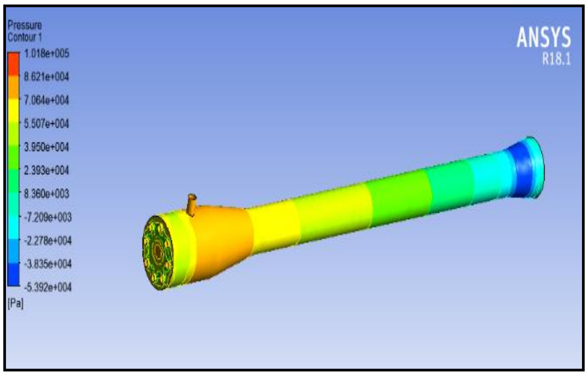

Fig 6. Pressure plot contours of single fuel inlet design.

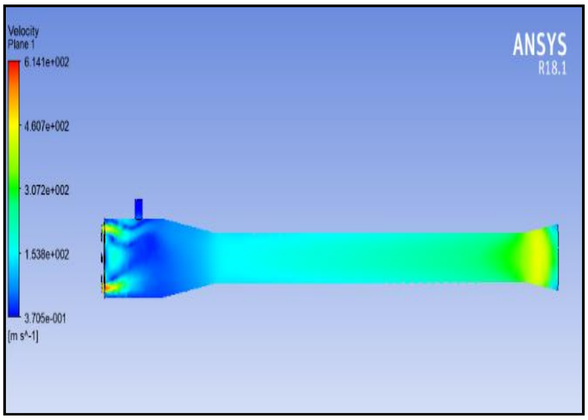

Fig 7. Velocity plot of single fuel inlet design.

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 as shown in figure 7.

International Journal of Science,
Engineering and Technology

An Open Access Journal

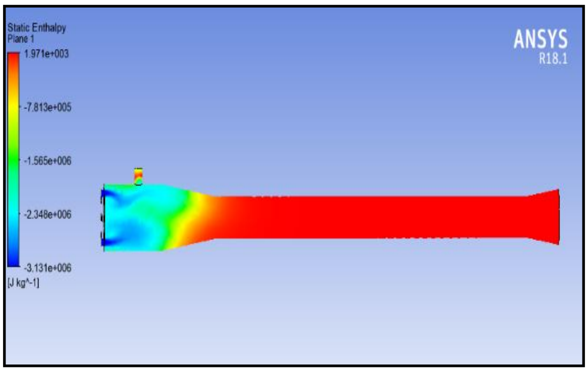

Fig 8. Static Enthalpy using single fuel inlet

The static enthalpy plot is shown in figure 8 above shows maximum value of 1971.24 J/Kg K on 2nd half of pulsejet engine.

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.

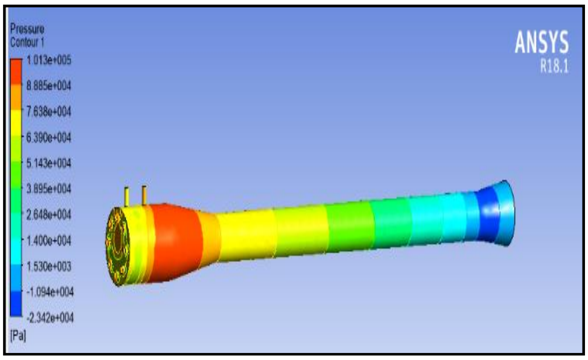

Fig 9. Pressure plot with double fuel inlet in vertical configuration.

The pressure plot shown in figure 9 above shows high pressure in combustion zone shown by dark red contour and reduces along the length of pulse jet engine on moving towards exit. The maximum pressure is 101300 Pa at the zone beside fuel inlet. The pressure on mid portion of jet is shown by light green colour with magnitue of 38950Pa. The pressure is further reduced to 1530Pa on moving towards the exit shown by light blue colour.

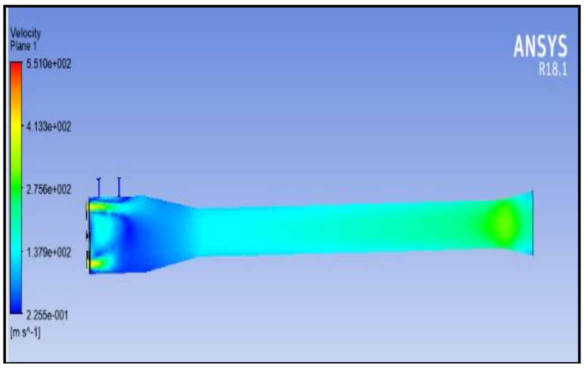

Fig 10. Velocity plot with double fuel inlet in vertical configuration.

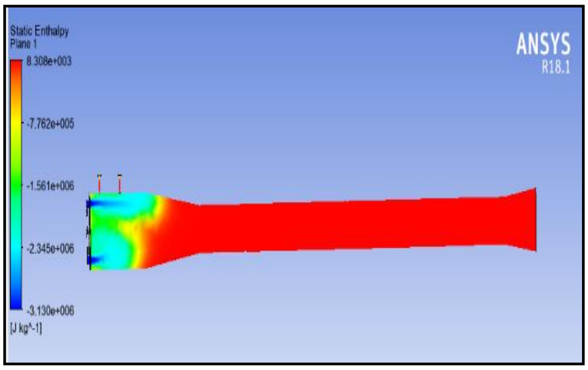

Fig 11. Static enthalpy plot with double fuel inlet in vertical configuration.

The static enthalpy plot is shown in figure 11 shows almost constant magnitude in zones starting from fuel inlet to exit as shown by red colored region.
The maximum static enthalpy (in magnitude) is observed in yellow colored region due to combustion taking place at this region. The magnitude of maximum enthalpy is 776.2 J/Kg K which is higher than other design configuration types.

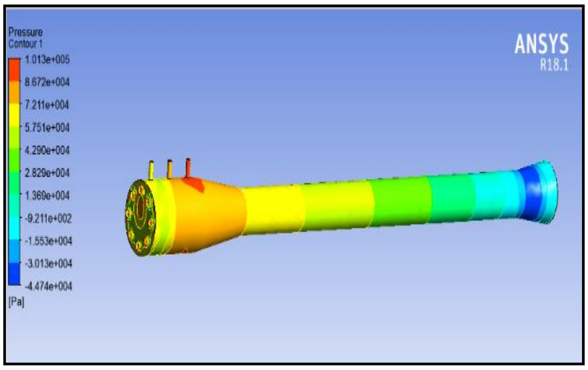

Fig 12. Pressure plot with three fuel inlet in vertical configuration.

The pressure plot shown in figure 12 above shows high pressure near 3rd fuel inlet tube shown. The maximum pressure is 101300 Pa at the zone beside fuel inlet. The pressure on mid portion of jet is shown by light green colour with magnitue of 28290Pa . The pressure is further reduced to 1369Pa on moving towards the exit shown by light blue colour.

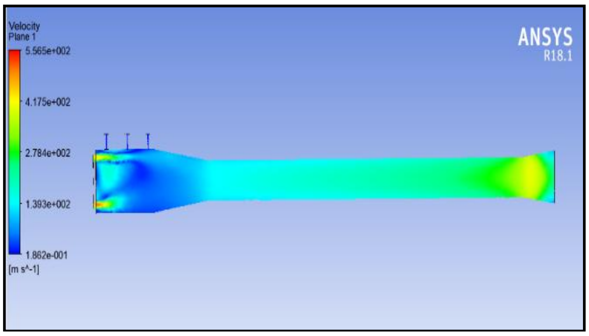

Fig 13. Velocity plot with three fuel inlet in vertical configuration

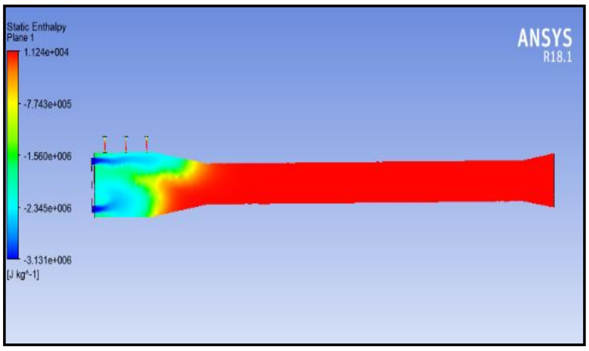

Fig 14. Static enthalpy plot with three fuel inlet in vertical configuration.

The static enthalpy plot is shown in figure 14 shows almost constant magnitude in zones starting from fuel inlet to exit as shown by red colored region. The maximum static enthalpy (in magnitude) is observed in yellow colored region due to combustion taking place at this region.

The magnitude of maximum enthalpy is 774.3 J/Kg K which is higher than other design configuration types.

Table 1. Thrust and Pressure using Finite Rate Chemistry Model and vertical fuel inlet.

Design Type	Pressure (Pa)	Thrust (N)
Double fuel inlet	97.84	.485
Three fuel inlet	726.19	3.601

The pressure generated at outlet and corresponding thrust force is shown by table 1 above. The thrust force generated is minimum for 2 fuel inlet with magnitude of .485N and maximum for three fuel inlet with magnitude of 3.601N.

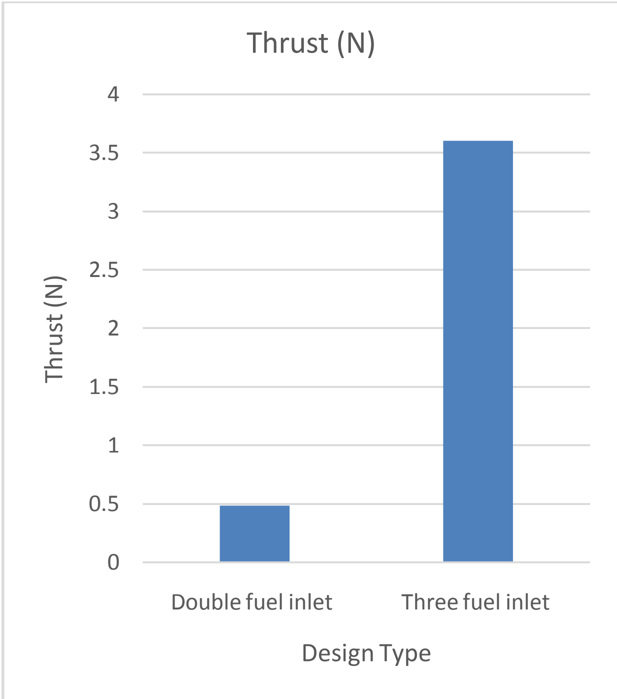

Fig 15. Thrust force comparison

The comparison plot of thrust generated using double and three fuel inlet is shown in figure 15 above. The combustion increased with increase in number of fuel inlet as it facilitates better combustion. This resulted in higher enthalpy and pressure and thus increased thrust force.

VI. CONCLUSION

The CFD is a viable tool to determine the effect of design parameters on thrust force and static enthalpy generated. The number of fuel inlet has significant effect on combustion which in turn effects enthalpy and thus thrust force generation.

The vertical fuel inlet design configuration has lower performance as compared to circular fuel inlet configuration with eddy dissipation combustion model. This is applicable to both double and three fuel inlet designs. By increasing fuel inlets from one to three the magnitude of thrust generated increased by 3.1N which is significant enhancement.

International Journal of Science, Engineering and Technology

An Open Access Journal

REFERENCES

[1] 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.

[2] Paxson DE, Litke PJ, Royce P Bradley, John L Hoke (2006) "Performance Assessment of a Large-Scale Pulsejet-Driven Ejector System," AIAA paper 2006-1021.

[3] U. Sreekanth, Subba Rao B, Nagaraju A (2017) "performance and analysis on valve less pulse jet engine" Vol-3, issue 1.

[4] Hussain sadig Hussain (2008) "Theoretical and Experimental Evaluation of Pulse Jet Engine" A thesis submitted in partial fulfillment of the requirements for the degree of M. Sc.in Energy Engineering.

[5] Liu Min, Yu Ling, Cai Wen-xiang (2016) "Experiment Analysis of Combustion Performance in Pulse Jet Engine" 3rd International Conference on Power and Energy Systems Engineering, CPESE 2016, Kitakyushu, Japan 8-10.

[6] Shaik Rafi, B. Kishore Kumar, "Design and CFD analysis of Pulsejet Engine" , International Journal of Professional Engineering Studies, Volume VII, Issue 2, Oct 2016.