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Application of CFD in Combustion Analysis of Pulsejet Engine

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Abstract: The pulsejet engines have low weight and high thrust which makes it good choice for missiles and rockets. The objective of this research is to investigate the thermal characteristics and thrust generation of pulsejet engine using techniques of Computational Fluid Dynamics. The CFD simulation on pulsejet engine is conducted using ANSYS CFX software. From the CFD analysis the effect of multiple fuel inlets is investigated using eddy dissipation combustion model. The CFD analysis results have shown that outlet pressure and thrust force increases with increase in number of fuel inlets.

IndexTerms **- Pulsejet, Fuel Inlet, Combustion, CFD, Thrust**

I. INTRODUCTION

The pulsejet engine has good thrust generation capability. The good thrust to weight ratio makes it suitable for drones and missile systems. The ramjet engine has certain limitations (low thrust) as compared to pulsejet engines. The low thrust of ramjet engine makes it less suitable as propulsion systems. For "short-term operation and applications where the turbojet is not the main propulsion and used only, for the take-off, the obvious advantages of pulse jet engines used as start booster which outweigh other disadvantages. Moreover, such engines offer the possibility to operate one combustor in ram-, pulse- and rocket-mode" [1].

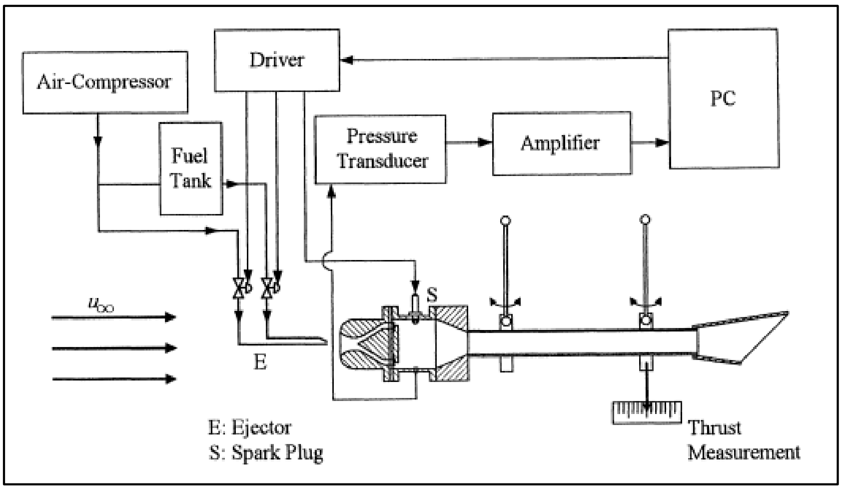

Figure 1: Schematic of pulsejet system

The schematic of pulsejet engine is shown in figure 1 above. The pulsejet engine comprises of different electronic systems and combustion chamber. The fuel injection system comprises of air compressor, fuel tank. The PC systems and driver governs the fuel flow and air flow inside the combustion chamber.

II. LITERATURE REVIEW

O'Brien, John Grant [1] have conducted review on pulsejet engine with respect to its operational capabilities and performance parameters. The all new design prospects related to improvement in thrust generation is also presented.

Christian Talbot McCalley [2] have conducted research on propulsion system of UAV system. The feasibility of propane fuel, gasoline fuel is investigated. The research findings have shown that propane fuel has higher thrust generation as compared to gasoline fuel.

Michael Schoen [3] have conducted experimental investigation on micro-scaled pulse jet engine in order to evaluate the physical phenomenon inside combustion chamber. The effect of pulsejet design type on thrust generation is evaluated. The research findings have shown that highly reactive fuel should be used for pulsejet engine.

Adam Kiker[4] have conducted experimental investigation on 8cm micro-scaled pulsejet engine. The fuel used for analysis is hydrogen. The research findings have shown that thrust generation of pulsejet engine increases by 50% with tripling the chamber length of pulsejet engine.

Rob Ordon[5] have conducted research on 50cm long pulsejet engine using experimental techniques. The fuel used for the analysis of pulsejet engine is propane/ethanol. The experimental investigation results were in close agreement with analytical results for determination of operating frequency.

Daniel Paxson[6] have conducted research on various dimensional parameters of pulsejet engine using experimental techniques. The analysis is conducted on 50cm model to determine to evaluate thrust force. The dimensional parameters analyzed are exhaust diameter, chamber dimensions on average thrust force generation.

U. Sreekanth, Subba Rao B [7] have conducted research on valve less pulsejet engine using numerical techniques. The effect of intake length and exhaust length on thrust generation of pulsejet engine is evaluated.

Hussain Sadig Hussain [8] have conducted thermodynamic analysis on conventional pulsejet engine using experimental techniques. Different geometrical aspects affecting thrust generation on pulsejet engine is evaluated. These geometrical aspects include specific fuel consumption and chamber diameter. The research findings have shown that engine performance depends upon combustion chamber volume and chamber shape.

III. OBJECTIVE

The objective of this research is to investigate the thermal characteristics and thrust generation of pulsejet engine using techniques of Computational Fluid Dynamics. The CFD simulation on pulsejet engine is conducted using ANSYS CFX software.

IV. METHODOLOGY

The combustion zone of pulse jet engine is modeled in 3D modeling software and imported in ANSYS design modeler. The imported desig n is checked for any type of surface errors, edge errors etc. The imported design of pulsejet combustion zone is shown in figure 2.

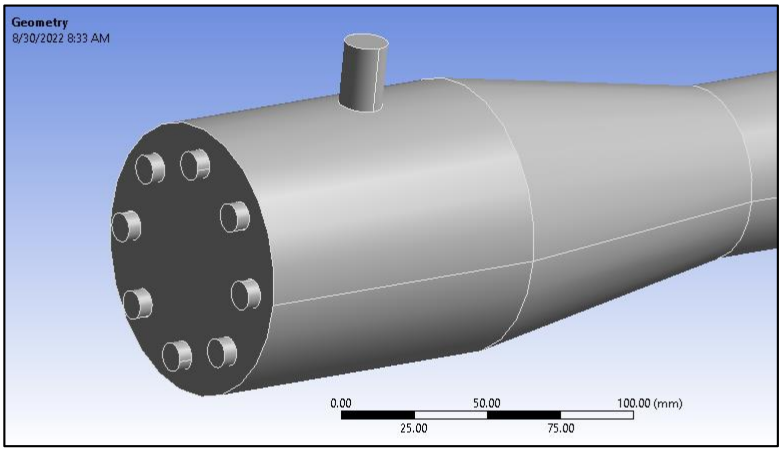

Figure 2: Imported CAD design of combustion zone

The model of combustion zone is meshed using tetrahedral element type. The elements are fine near air inlet zone and fuel inlet zone. The complexity and topological inconsistency makes it suitable for tetrahedral mesh only.

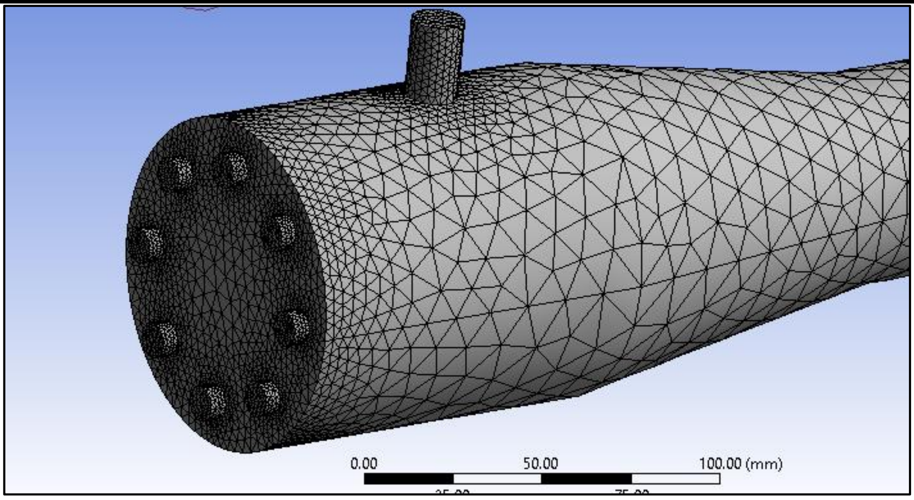

Figure 2: Meshed model of combustion zone

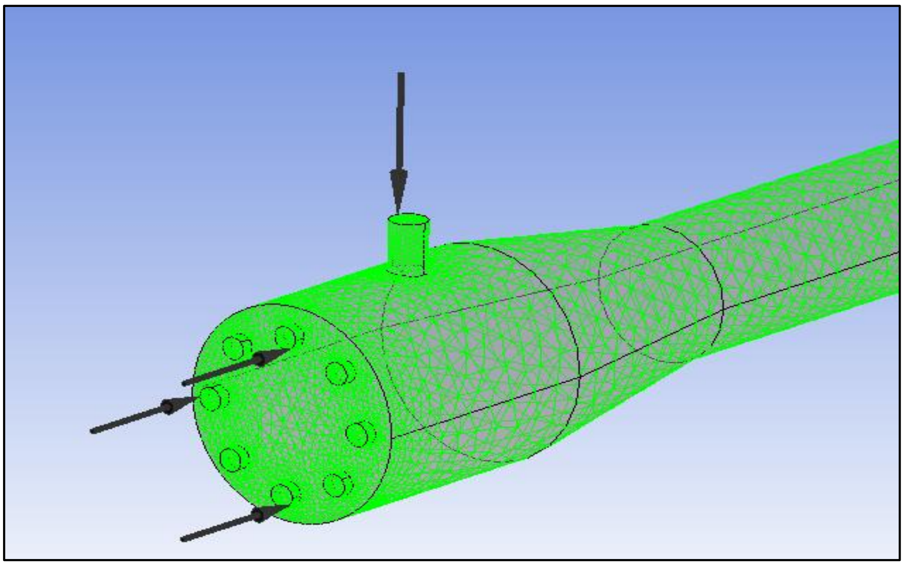

Figure 3: Boundary conditions

The domain is defined for combustion zone. The combustion zone is defined as reacting mixture with reference pressure set to 1atm. The fluid model for the analysis is set to thermal energy with eddy dissipation combustion model. The combustion definition is shown in figure 4.

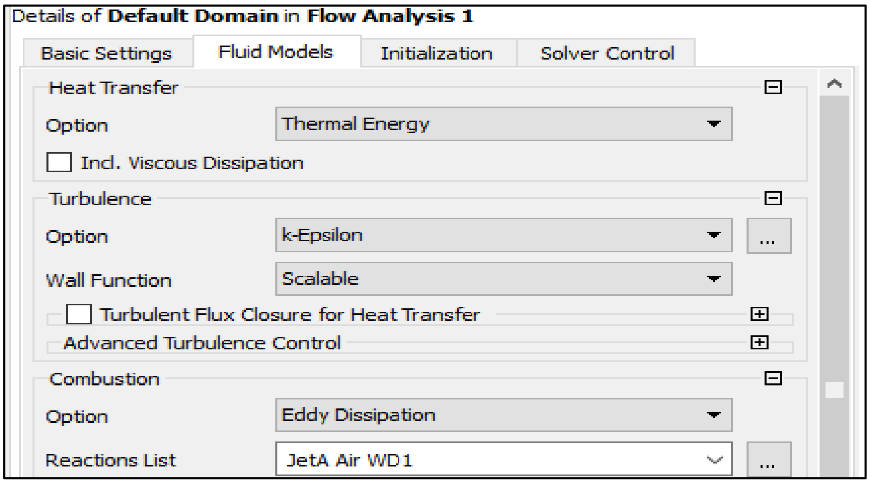

Figure 4: Combustion model definition

For the combustion zone, the inlet and outlet boundary conditions are defined. The air inlet boundary condition is shown in figure 5. The inlet boundary for air is defined in terms of mass fraction. The air inlet mass fraction is defined for oxygen which is 0.8 as shown in figure 5.

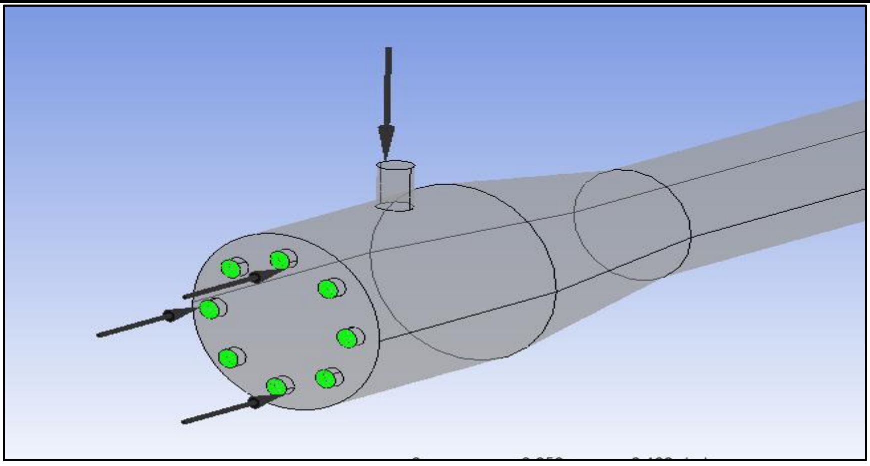

Figure 5: Air inlet for combustion zone

The jet fuel inlet is defined as shown in figure 6. The JetA fuel is used which is hydrocarbon fuel. The molar mass, temperature limits, viscosity and thermal conductivity is defined and available in CFX library. The material properties are shown in figure 7.

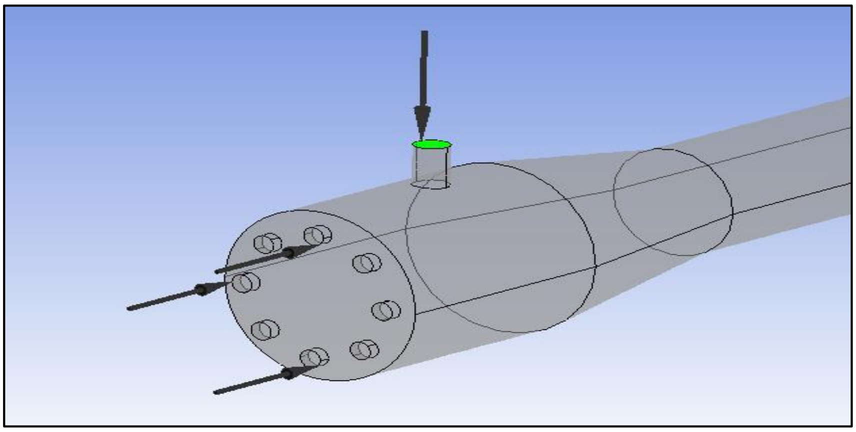

Figure 6: Jet fuel inlet

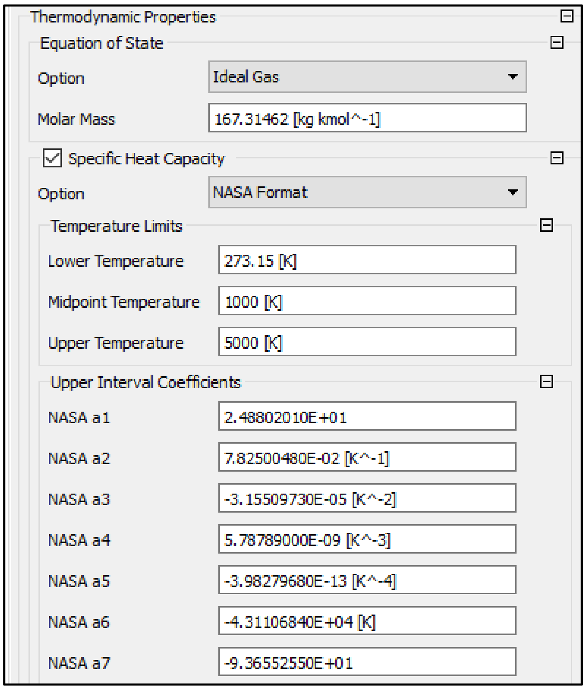

Figure 7: Jet fuel properties

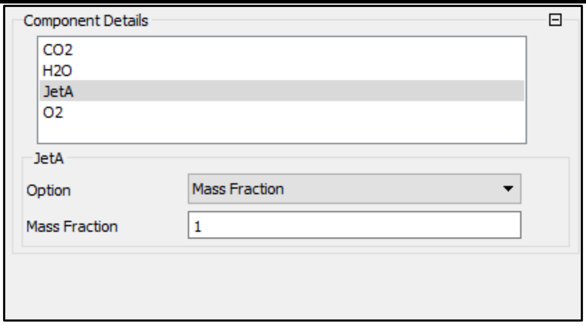

Figure 8: Jet fuel inlet definition

The mass fraction of jet fuel inlet is defined as shown in figure 8 above. The mass fraction defined is for Jet fuel is 1. After definition of boundary condition, the simulation is run which involves formulation of stiffness matrix and computing RMS residual values at each iteration.

V. RESULTS AND DISCUSSION

The CFD simulation is run to determine pressure distribution, velocity and enthalpy for generic design of combustion chamber of pulsejet engine.

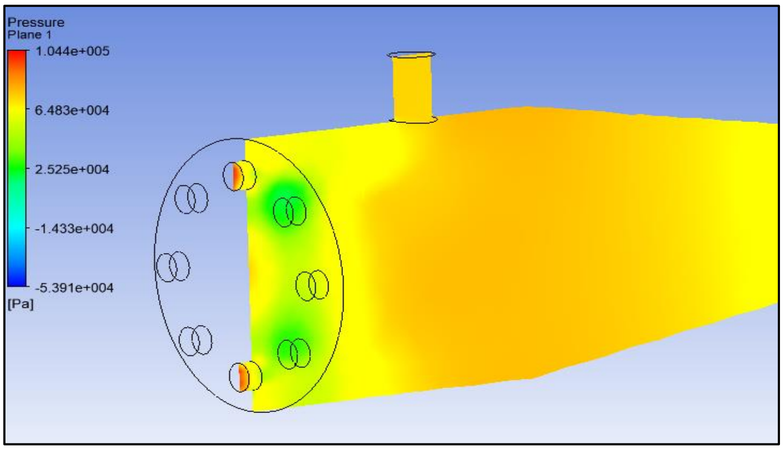

Figure 9: Pressure plot across plane

The pressure plot shows high pressure at the air inlet with magnitude of 2525Pa. The pressure at the center region i.e. combustion zone is 6483Pa. The velocity plot is shown in figure 10 which shows higher magnitude near the air inlet nozzle. The velocity magnitude is 4.6 m/s nearly.

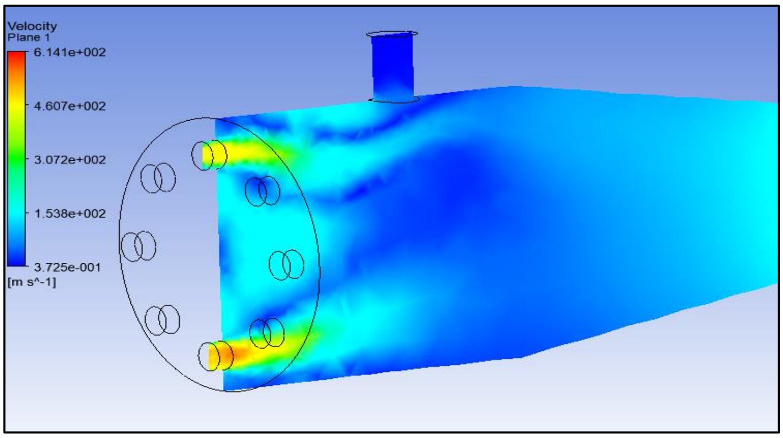

Figure 10: Velocity plot across plane

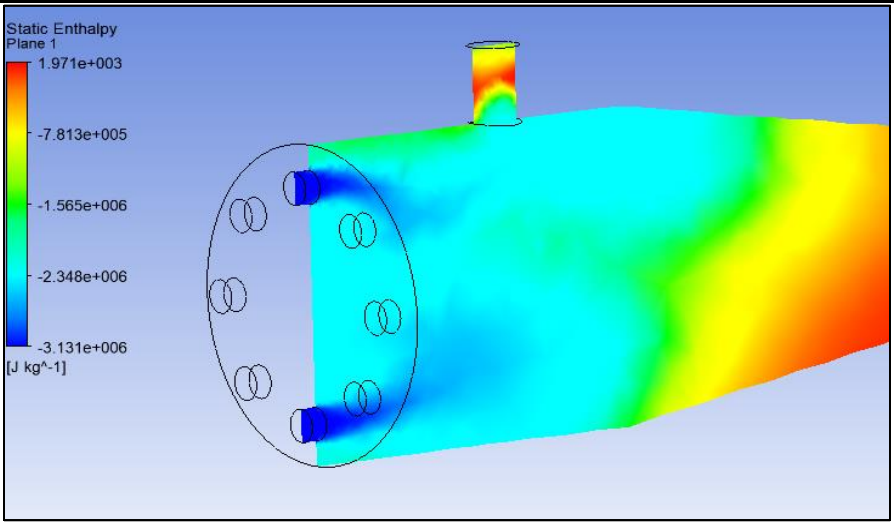

Figure 11: Static enthalpy plot across plane

The static enthalpy plot is generated across mid- section plane as shown in figure 11. The enthalpy increases at the combustion zone and reaches maximum value at the exit nozzle of pulsejet engine.

VI. CONCLUSION

The application of CFD tool enabled to determine the critical regions of high pressure and enthalpy inside combustion chamber of pulsejet engine. From the CFD analysis the effect of multiple fuel inlets is investigated using eddy dissipation combustion model. The CFD analysis results have shown that outlet pressure and thrust force increases with increase in number of fuel inlets.

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