Combustion of Acetylene and its Performance in Valveless Pulse Jet Engine

M. Dhananiya Lakshmi Sri
PG Scholar
Department of Aeronautical Engineering
Nehru Institute of Engineering and Technology
Coimbatore, Tamil Nadu

L. Oblisamy
Assistant Professor
Department of Aeronautical Engineering
Nehru Institute of Engineering and Technology
Coimbatore, Tamil Nadu

G. Mari Prabu
Assistant Professor
Department of Aeronautical Engineering
Sri Shakthi Institute of Engineering and Technology
Coimbatore, Tamil Nadu

***Abstract*—This paper summarizes the significance of barriers involved in using acetylene as alternate fuel for valve less pulse jet engine. Acetylene gas produces 2210 to 3300 degree Celsius temperatures when allowed to combust with atmospheric air. The idea of high temperature engines is innovatory due to water thermolysis which could accompany the combustion of acetylene. The use of acetylene will reduce emission and increase combustion efficiency. The project investigates the process of combustion of acetylene stoichiometrically with atmospheric air and also with oxygen computationally with the ANSYS Fluent commercial software in a valve less Bailey Machine Services hobby scale pulse jet of 15 centimeter class. The measurement of Pressure, thrust, temperature and concentrations of Carbon monoxide, Nitrous oxide and Hydrocarbons at the exit of pulse jet with acetylene and water thermolysis, Acetylene without water thermolysis and aviation gas without water thermolysis is analyzed and calculated.**

Keywords*— Acetylene, Aviation Gas, Combustion, Water Thermolysis, Valveless Pulsejet.

I. INTRODUCTION

Pulsejet engine is the simplest type of jet engine which has no moving parts such as compressor and turbine. It is also known as pulse detonation engine. It is light in weight and it has static thrust because of compressed air hence it does not require a device for initial propulsion. In this engine the combustion occurs in pulse. The engine consist of a diffuser, valve, combustion chamber, spark plug and nozzle. The pulsejet engine is mainly classified into two types. They are valved pulsejet and valveless pulsejet. In valved pulsejet the air flow is controlled by using valve grid. In valveless pulsejet engine the air flow is controlled by using its engine geometry. Pulsejet was the power plant of Germen V-1 Bomb popularly known as 'buzz bomb' first used in world war II[11]. In pulsejet engine Thermodynamic efficiency is low compared to gas turbine engines due to the lack of mechanical compression, which results in low peak pressure. Due to this low efficiency, the pulsejet received little attention after the late 1950s. However, pulsejets with no moving parts may be advantageous for building smaller propulsion devices. The thermodynamic efficiency of conventional engine (such as gas turbines and both SI and CI engine). Decreases non-linearly with decreasing characteristic engine length scale. Also, small scale engines with moving parts are more prone to breakdown due to fatigue of the moving components. Pulsejets, especially valveless pulsejets, are attractive as candidates for miniaturization due to their extremely simple design.[7]

Fig.1. 3:10 scale down of the Bailey Machine Services (BMS) hobby-scale pulsejet

Fig.2. V-II 'Buzz bomb

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A. Thermodynamic cycle for valveless pulsejet engine

The pulse jet works on the thermodynamic cycle, viz the lenoir cycle[11],[13]

An ideal gas undergoes

1-2: constant volume(isochoric) heat addition

2-3: isentropic expansion

3-1: constant pressure(isobaric) heat rejection

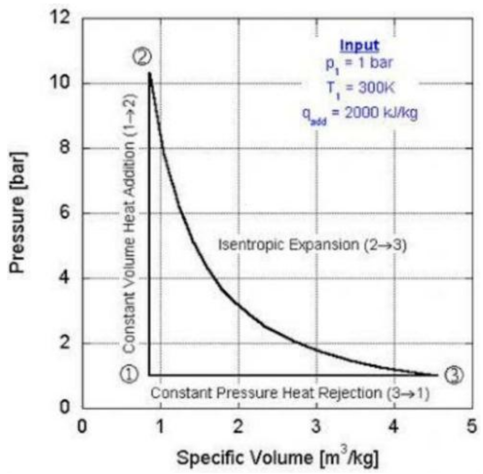

Fig 3 Thermodynamic cycle of valvess pulsejet.

B. ACETYLENE

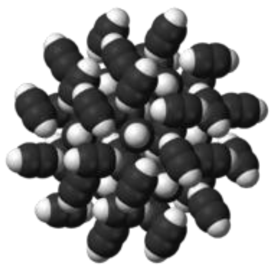

Fig 4 Acetylene and 3D Model.[9]

Acetylene(systematic name:Ethyne) is the chemical compound with the formula c_2h_2. It is a hydrocarbon and the simplest alkyne. This colorless gas is widely used as a fuel and a chemical building block. It is unstable in pure form and thus is usually handled as a solution. Commercial grades usually have a marked odor due to impurities.As an alkyne, acetylene is unsaturated because its two carbon atoms are bonded together in a triple bond. the carbon–carbon triple bond places all four atoms in the same straight line, with cch bond angles of180°.[9]

Acetylene gas produces 2220°c to 3600°c temperature in air and 2807°c to 3600^{0}c in oxygen. Acetylene ignites at 305^{0}c but burns at 3300°c. It is one of the most explosive gas.[5]

C. Physical properties of acetylene[10]

- Formula C2H2
- Molecular Weight (lb/mol) 26.04
- Critical Temp. (°F) 96.0
- Critical Pressure (psi) 906.0
- Boiling Point (°F) -119.6
- Melting Point (°F) -113.4
- Psat @ 70°F (psia) 586.2
- Liquid Density @ 70°F (lb/ft^3) 23.61
- Gas Density @ 70°F 1 atm (lb/ft^3) 0.0677
- Specific Volume @ 70°F 1 atm (ft^3/lb) 14.76
- Specific Gravity 0.920
- Specific Heat @ 70°F (Btu/lbmol-°F) 10.53

D. Water thermolysis

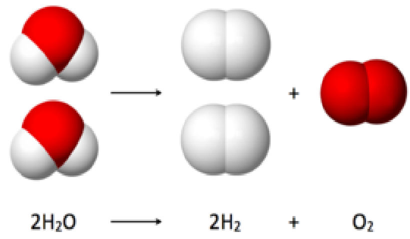

Fig 5. Water Thermolysis[14]

Diagram of the chemical equation of the electrolysis of water, a form of water splitting.

Water splitting is the general term for a chemical reaction in which water is separated into oxygen and hydrogen. Efficient and economical water splitting would be a key technology component of a hydrogen economy[14]

In this paper water thermolysis method is used inside combustion chamber to reduce the temperature when acetylene is used as fuel in valveless pulsejet engine.

II. GEOMETRICAL CONFIGURATION

Valveless pulsejet in CATIA-v5-R20 was been shown in figure 6 &7

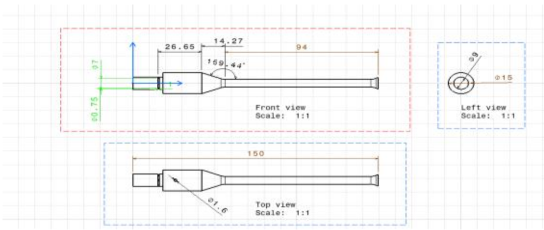

Fig 6 valveless pulsejet Drafted model

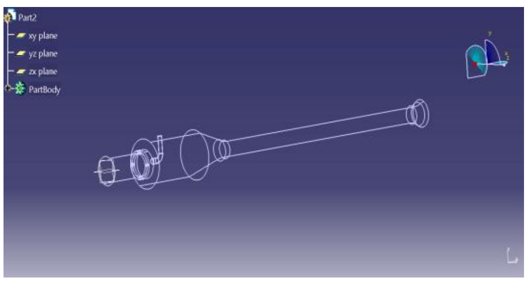

Fig.7 3D View of valveless pulsejet

A . GRID GENERATION

A fine tetrahedron mesh is generated for valveless pulsejet as shown in figure 8 & 9. Triangle grid is preferred for 2-D solid structures. Tetrahedron grid is preferred for 3-D solid structures. Totally 31732 nodes and 161453 elements are generated for the control volume which is used for flow field analysis as shown in figure 9&10.

In fig 9 water inlet is placed inside combustion chamber. The length of water inlet is 0.5mm and diameter of water inlet is 0.3mm.

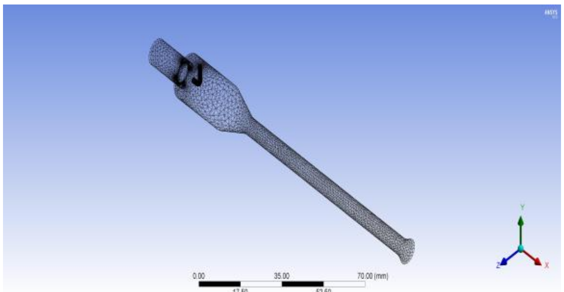

Fig 8 Meshed valveless pulseje

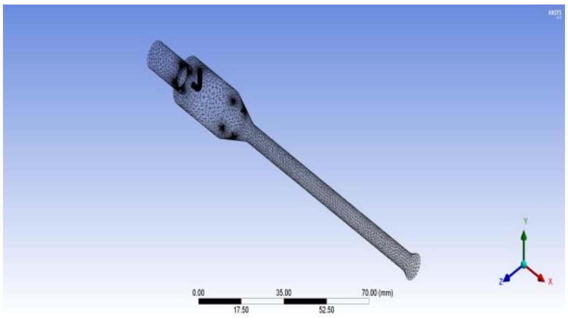

Fig 9 Meshed valveless pulsejet with three water inlet

III. RESULT AND DISCUSSION

The analysis of valveless pulsejet model is carried out using modal analysis software package. The boundary condition for analyzing valveless pulsejet model is For both inlet air velocity and fuel velovity is 30m/s because fuel and air mixes properly at the inlet.

The valveless pulsejet model are analyzed with fuel as kerosene. The contours of mass fraction , static pressure, static temperature and velocity are shown in fig 10, 11, 12,13.

TABLE I. Results with kerosene as fuel

S.No.	Field Variable	Value
1	Max. Static Pressure	116960Pa
2	Max. Temperature	2158.3K
3	Max. Velocity	471.9296m/s
4	Max. Temperature at outlet	1436.3K
5	Average velocity at outlet	143.9m/s

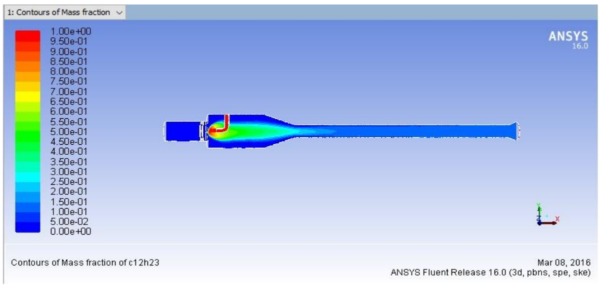

Fig 10 Contours of mass fraction of kerosene

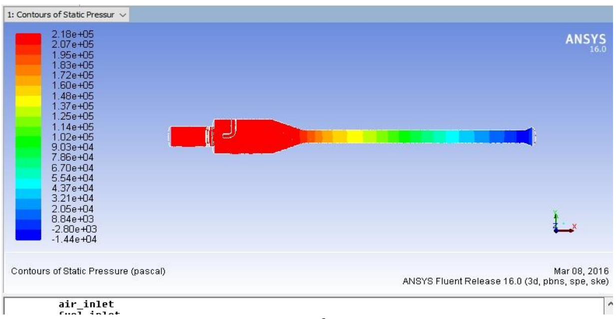

Fig 11 Contours of static pressure

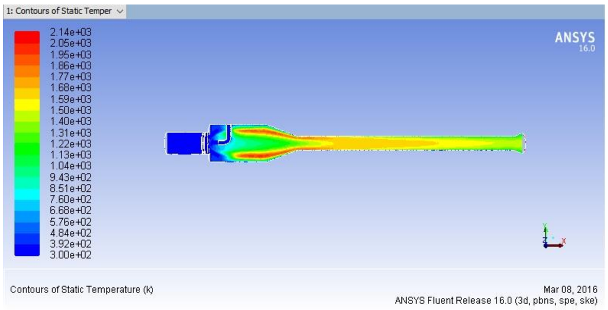

Fig 12 Contours of static temperature

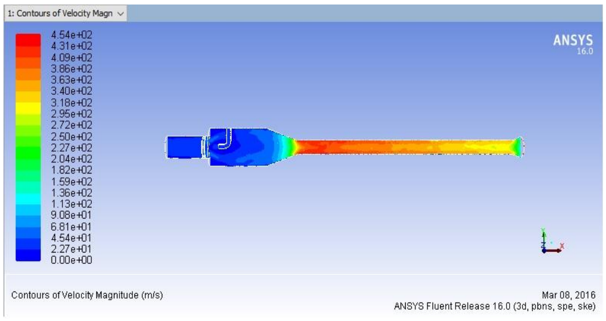

Fig 13 Contours of velocity

The valveless pulsejet model are analyzed with fuel as Acetylene. The contours of Acetylene, pressure, Rate of reaction, temperature and velocity magnitude are shown in fig 14, 15, 16, 17 & 18.

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TABLE II. Results with acetylene as fuel

S.No.	Field Variable	Value
1	Max. Static Pressure	4027.505Pa
2	Max. Temperature	2549K
3	Max. Velocity	79.6m/s
4	Max. Temperature at outlet	1534.7K
5	Average velocity at outlet	35.5m/s

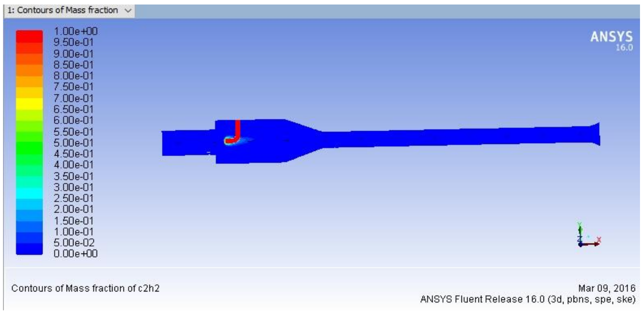

Fig 14 Contours of acetylene

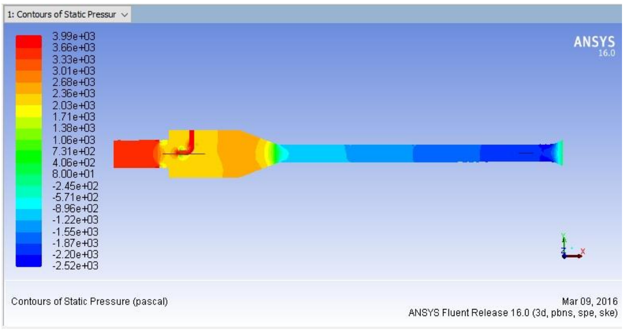

Fig 15 Contours of pressure

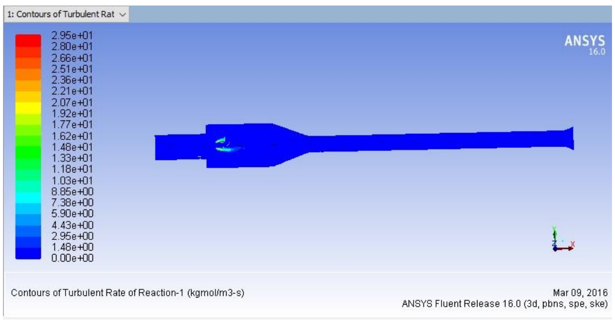

Fig 16 Contours of rate of reaction

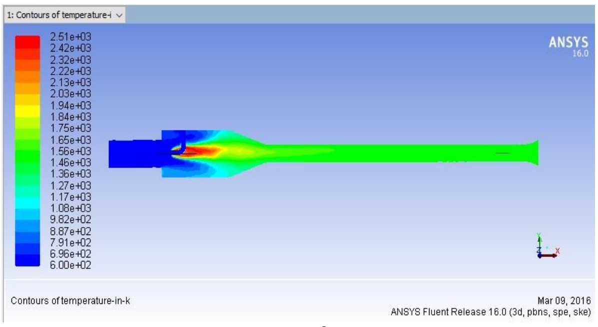

Fig 17 Contours of temperature

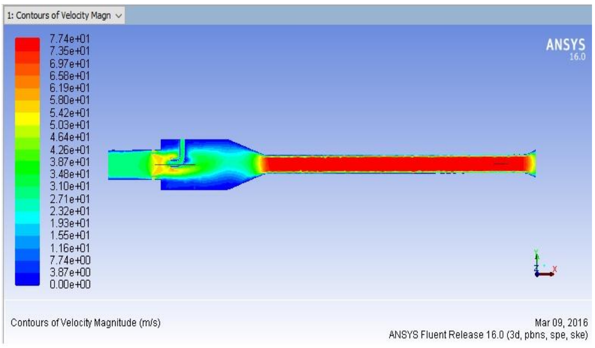

Fig 18 Contours of velocity magnitude

The valveless pulsejet model are analyzed with fuel as kerosene with water thermolysis The contours of mass fraction of kerosene, mass fraction of water, static pressure, temperature, velocity magnitudeare shown in fig 19, 20, 21, 22 & 23.

TABLE III. Results with kerosene as fuel with water thermolysis

S.No.	Field Variable	Value
1	Max. Static Pressure	4562.66Pa
2	Max. Temperature	1219.895K
3	Max. Velocity	92.2m/s
4	Max. Temperature at outlet	1020.8K
5	Average velocity at outlet	73.5m/s

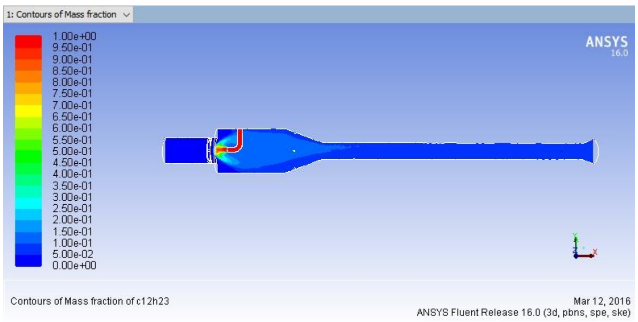

Fig 19 Contours of mass fraction of kerosene

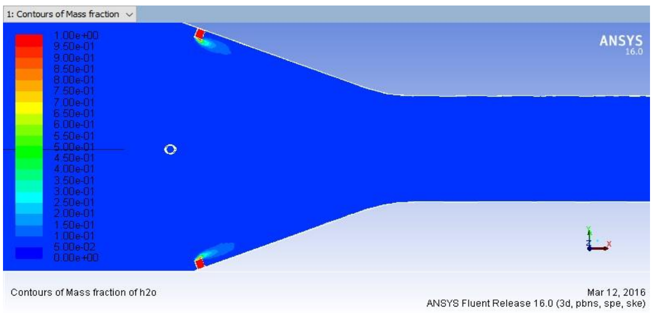

Fig 20 Contours of mass fraction of water

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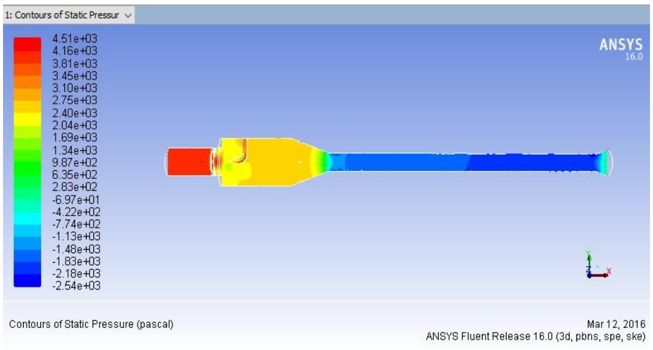

Fig 21 Contours of static pressure

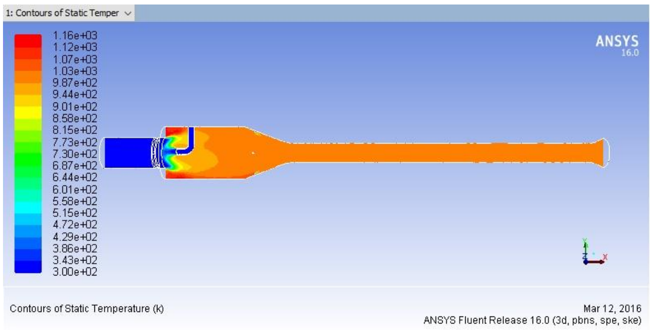

Fig 22 Contours of temperature

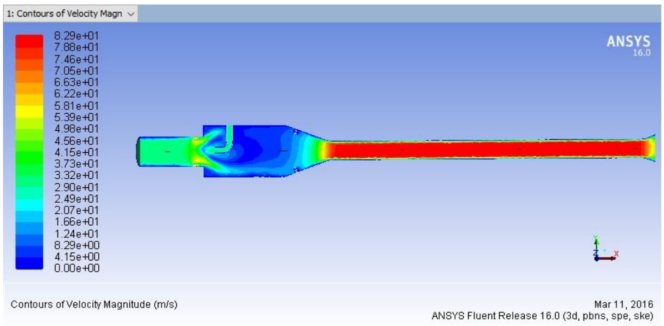

Fig 23 Contours of velocity magnitude

The valveless pulsejet model are analyzed with fuel as Acetylene with water thermolysis The contours mass fraction of acetylene, mass fraction of water, static pressure, temperature and velocity are shown in fig 24, 25, 26, 27 & 28

TABLE IV. Results with acetylene as fuel with water thermoysis

S.No.	Field Variable	Value
1	Max. Static Pressure	4072.506Pa
2	Max. Temperature	1364.768K
3	Max. Velocity	77.9m/s
4	Max. Temperature at outlet	843.9K
5	Average velocity at outlet	35.6m/s

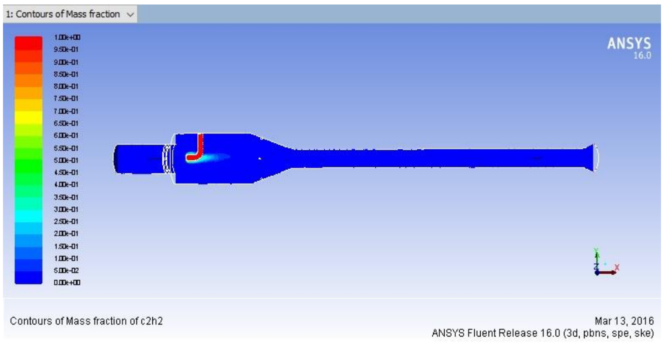

Fig 24 Contours of mass fraction of Acetylene

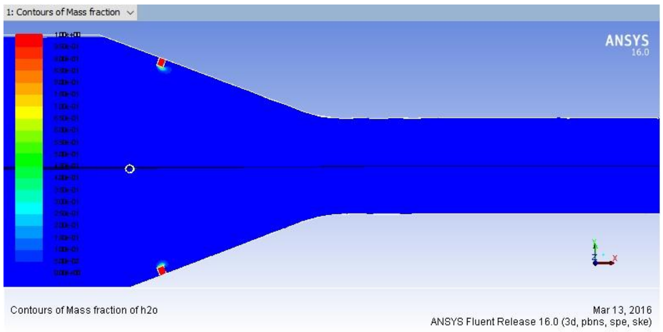

Fig 25 Contours of mass fraction of water

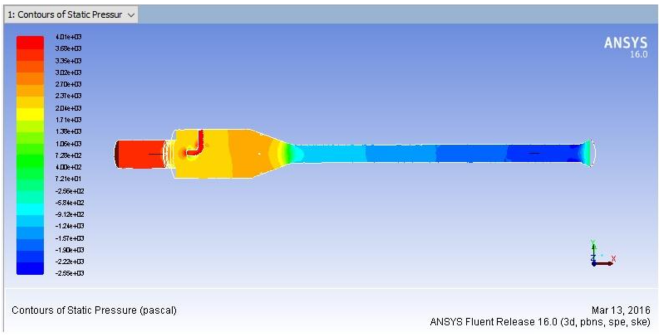

Fig 26 Contours of static pressure

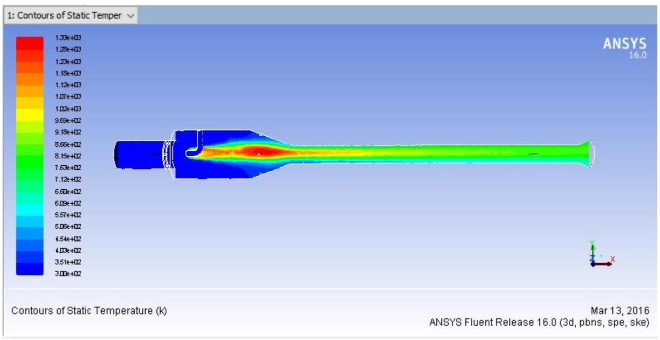

Fig 27 Contours of temperature

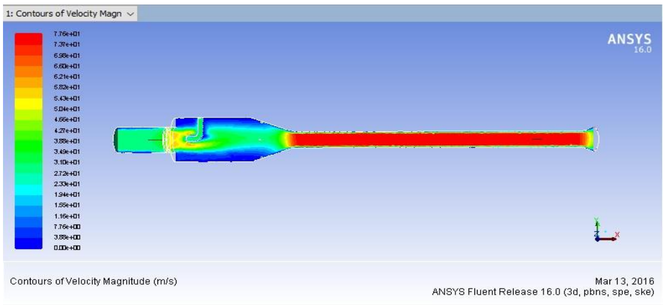

Fig 28 Contours of velocity

IV. CONCLUSION

In the present study computations were carried out for valveless pulsejet model with fuel as kerosene and acetylene. With kerosene as fuel the proper combustion occurs in combustion chamber, but air and fuel does not mix properly. With acetylene as fuel the temperature is very high in combustion chamber but acetylene has less density when compared to kerosene hence acetylene mixes with air better than kerosene. water thermolysis method is used when acetylene is used as fuel in valveless pulsejet engine to reduce temperature inside the combustion chamber. Fuel effiency increases when acetylene is used as fuel.

The future scope of work include the analysis of valveless pulsejet model with acetylene as fuel by placing water inlet with various geometry inside the combustion chamber.

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