IJMTST is UGC Approved Journal with Journal Id: 43137

International Journal for Modern Trends in Science and Technology, 8(S06): 53-58, 2022

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST08S0709
Available online at: https://www.ijmtst.com/vol8si07.html

Performance Analysis of Ramjet Engine Combustion Chamber

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To Cite this Article
Shaik Nayeem, Raavi Raja, Devada Naveen, Bagadi Mohan Vamsi and Yerubandi V. V. S. Mani Shankar. Performance Analysis of Ramjet Engine Combustion Chamber. International Journal for Modern Trends in Science and Technology 2022, 8(S06), pp. 53-58. https://doi.org/10.46501/IJMTST08S0709

Article Info
Received: 26 April 2022; Accepted: 24 May 2022; Published: 30 May 2022.

ABSTRACT

Today's aircraft are powered by a variety of engines that generate thrust depending on the application. Each aircraft has a different type of engine depending on its intended use. One of the most important sources of supersonic flight power is the ramjet. In the near future, missiles powered by Ramjets will lead the aviation market. Ramjet combustion has a variety of issues, including combustion instability and enhanced fuel mixing. Compressed air and pressurised fuel both are mixed and burned in the combustion chamber. The gases which are produced inside the combustion chamber will create thrust at the exit of divergent nozzle. Thus ramjet will move in forward direction. In this project air and fuel are burned in a combustion chamber in a small scale of ramjet engine. The performance analysis of ramjet engine combustion chamber will be analyzed.

KEYWORDS: Ramjet, Combustion chamber, Convergent nozzle, Air-Fuel supply system.

1. INTRODUCTION

Today's aircraft are powered by a variety of engines that generates thrust depending on the application. Each aircraft jet engine has its own collection of benefits and drawbacks. Each aircraft has a different type of engine depending on its intended use. One of the most important sources of supersonic flight power is the ramjet. The Ramjet and the Supersonic Combustion Ramjet (Scramjet) Engine Cycle an invention attributed to Rene Lorin of France in 1913 (Hallion, 1995), the ramjet is remarkable air-breathing engine in its conceptual simplicity.

Generally the ramjet engines works with the help of Air and Fuel mixture. Ramjet engine is an air-breathing engine it takes Atmospheric air as a air supply system. The Fuel used in ramjet engines are Liquid Hydrogen. The air entering to ramjet engine with super sonic speed is slowdown to sonic velocity in the supersonic diffuser, increasing air pressure the air pressure is further increased in the subsonic diffuser increasing also the temperature of air. The outlet pressure of the air at the exit of the diffuser is increased when compared to inlet of diffuser(P2>P1). The diffuser section is designed to get correct ram effect its job is to decrease the velocity and increases pressure of incoming air. The Fuel is stored in a closed container with a calculated value, a common pipe which connected to the mixing chamber which is having both Air and Fuel. In the mixing chamber both air and fuel is well mixed and then passed to the combustion chamber. In the combustion chamber the air-fuel mixture which comes from the mixing chamber is get ignited with the help of spark. Due to the combustion the air and fuel burned in the combustion chamber and it is gaseous form. These gases having high temperature, high pressure, low velocity. The gases are comes out from the combustion chamber and goes into the convergent

nozzle. The main aim of the nozzle is to converting pressure energy into kinetic energy. Thegases at the exit of the nozzle having high velocity, low temperature, low pressure. These gases are goes into the divergent nozzle. In the divergent nozzle the velocity of gases is further increased. The high velocity gas leaving the nozzle provides required thrust to ramjet.

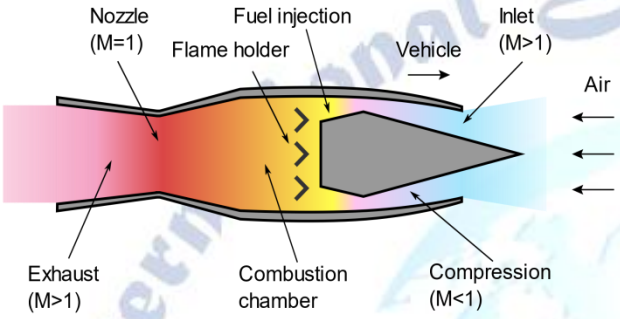


Fig 1 : Ramjet Engine.

2. REALATED WORK

The combustion in ramjet is modeled using a non-uniform volumetric heat source distributed across the combustor. In the combustion chamber the gaseous products having low velocity, high pressure and high temperature. At the exit of the nozzle these gaseous products having high velocity, low pressure and low temperature. The outcome drawn by the numerous researchers has been complied by considering different types of ramjet combustor geometry since this engine does not utilise any moving parts. Minor changes in the combustor geometry influence the performance of the engine. Nonetheless combustion modes are also influenced by altering the geometry as well as the fuel injection strategy. With expand of above literature survey numerous points are considered and summarized below, which can be further utilised as future work [3]. In order to do the better air and fuel mixing we explored from A J Sriganapathy et al [1]. The performance analysis of ramjet engine was explored from Min Oua et al [2]. Through that research we knew that the ramjet having high-speed flying capacity but the performance of the ramjet engine based on mach number and flight height [2]. Mixing performance and Combustion efficiency has been explored from Kumari Ambe Verma et al [3]. Heat addition and Supersonic air intake and internal flow and the performance of air intake and combustion chamber has been explored from G. Raja Singh Thangadurai et al [4]. Nozzle design and Nozzle concepts and Analysis of nozzle section has been explored from Andrew Micheal Carter [5]. Analysis of Air intake system and inlet of ramjet and mixed compression and total pressure recovery has been explored from Abdelmola Albadwi Alkhalifa et al [6]. For future study process a full 3-dimensional simulation in transient process will modeled [8].

3. PROPOSED WORK

The main aim of this research is to supply air and fuel to the combustion chamber to do combustion. In this we designed our own combustion chamber according to our work. To to combustion process there are two main supply systems are required that is air supply system and fuel supply system.

3.1 AIR SUPPLY SYSTEM

In this, the air supply system is done with the 5kilograms Mildsteel gas cylinder. For this cylinder we attached an air pressure gauge which shows the pressure of air in the units of $^{kg}/_{cm^2}$ or *PSI* . And then we inserted an air pin to the cylinder to fill air into the cylinder. We attached a regulator at the top of the cylinder, which is used to control the flow of air as per our requirement. We fill the air with a calculated pressure of **2.941Bar**.

Fig 2 : Thin cylinder

Fig 3 : Cylinder with arragements

3.1.1 SPECIFICATIONS OF CYLINDER

- Type of Cylinder : Thin Cylinder
- Material of Cylinder : Mildsteel
- Quantity of Cylinder : 5kg's
- Thickness of Cylinder : 2mm
- Diameter of Cylinder : 680mm
- Factor of Safety for Pressure Vessels : 3.5-6

3.1.2 SPECIFICATIONS OF PRESSURE GAUGE

- Units of pressure gauge : PSI & $^{kg}/_{cm^2}$

Fig 4 : Air Pressure Gauge

3.1.3 DESIGNED CALCULATIONS OF AIR SUPPLY SYSTEM.

PRESSURE FOR THIN CYLINDERS:

$$\sigma_H = \frac{Pd}{2t}$$

$$P \times d = 2t \times \sigma_H$$

$$P = \frac{2t \times \sigma_H}{d}$$

$t = Thickness\ of\ Cylinder\ in\ mm$

$d = Diameter\ of\ cylinder\ in\ mm$

$\sigma_H = Hoop\ Stress$

Product – Mild Steel

Yield strength for Mild steel (σ) = 250Mpa

Factor of safety for pressure vessel = 3.5 to 6

Thickness of Gas Cylinder = 2mm

Diameter of Gas Cylinder = 680mm

$$\sigma_H = \frac{\sigma}{Factor\ of\ Safety}$$

$$\sigma_H = \frac{250}{5}$$

$$\sigma_H = 50Mpa$$

W.K.T

$$P = \frac{2t \times \sigma_H}{d}$$

$$P = \frac{2 \times 2 \times 50}{680}$$

$$P = 0.2941Mpa$$

$$P = 2.941\ bar \qquad (1\ Mpa = 10\ bar)$$

Conversions:

$Bar\ to\ {}^{kg}/_{cm^2}$

$1\ Bar = 1.02\ {}^{kg}/_{cm^2}$

$2.941 \times 1.02 = 2.99982\ {}^{kg}/_{cm^2}$

$bar\ to\ PSI$

$1bar = 14.504PSI$

$2.941 \times 14.504 = 42.656264PSI$

TABULAR FORM

S. No	FS	BAR	KG/CM2	PSI
1	3.5	4.201	4.284	60.93
2	4	3.676	3.748	53.31
3	4.5	3.268	3.332	47.39
4	5	2.941	2.999	42.65
5	5.5	2.673	2.725	38.77
6	6	2.451	2.499	35.55

3.2 FUEL SUPPLY SYSTEM

In this supply system we used petrol as a fuel. Because petrol having high firing capacity when compared to other fuels.

- Petrol has high capacity to mix readily with air.

- Petrol has high energy of combustion capacity.
- Petrol provides a stable energy resources.

A gear type arrangement which is called as crankshaft arrangement, the fuel pump which is seated on the crank shaft. The crank shaft gets the rotary motion with the help of electrical motor. When the crank shaft rotates the rotary motion of the crank shaft is converted into reciprocating motion of the pump. The main aim of the pump is to increase the pressure of the fuel. This pressurized fuel is passed to the combustion chamber through a pipe.

Fig 5 : FUEL SUPPLY SYSTEM

3.3 COMBUSTION CHAMBER

3.3.1 WORKING PRINCIPLE OF COMBUSTION CHAMBER

The combustion process involves the oxidation of constituents in the fuel that are capable of being oxidized, and can therefore be represented by a chemical equation. During a combustion process the mass of each element remains the same. consider the reaction of methane and oxygen 8 This equation states that one mole of methane reacts with two moles of oxygen to from one mole of carbon dioxide and two moles of water. this also that 16g of methane react with 64g of oxygen to from 44g of carbon dioxide and 36g of water. All the initial substances that undergo the combustion process are called the reactants, and the substances that result from the combustion process are called the products. The above combustion reaction is an example of a stoichiometric mixture, that is, there is just enough oxygen present to chemically react with all the fuel. the highest flame temperature is achieved under these conditions however it is often desirable to operate a rocket engine at a "fuel-rich" mixture ratio and this mixture burns in the combustion chamber produces thrust and supply to the nozzle. The mixture ratio is defined as the mass flow of oxidizer divided by the mass flow of fuel.

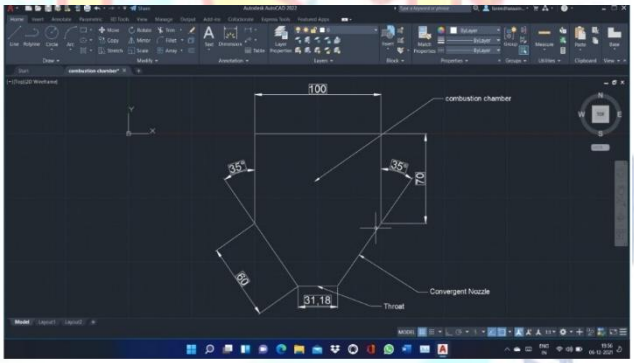


Fig 6 : Design of Combustion Chamber

Fig 7 : Actual Product of Combustion Chamber

3.4 CONVERGENT DIVERGENT NOZZLE

3.4.1 WORKING PRINCIPLE

- Gas flows through nozzle from region of high pressure (chamber) to low pressure (ambient).
- The chamber is taken as big enough so that any flow velocities are negligible.

- Gas flows from chamber into converging portion of nozzle, past the throat, through the diverging portion and then exhausts into the ambient as a jet.
- Pressure of ambient is required back pressure.

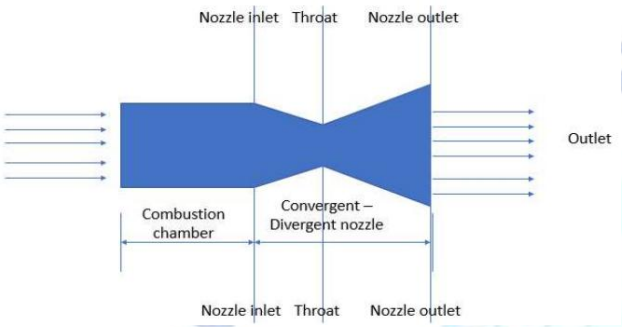


Fig 8 : Combustion chamber with convergent and divergent nozzle

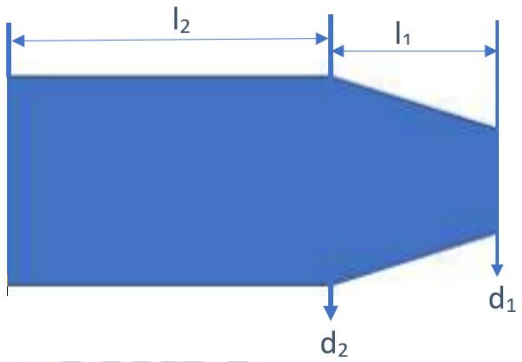
4.RESULT

We designed Air-Supply System, the air filled into the cylinder with a pressure of **2.941BAR** with factor of safety of 5. We all know that factor of safety for pressure vessels is 3.5-6. So, among those we took better factor of safety to calculate pressure of inlet air.

TABULAR FORM WITH DIFFERENT FS (factor of safety)

S. No	FS	BAR	KG/CM2	PSI
1	3.5	4.201	4.284	60.93
2	4	3.676	3.748	53.31
3	4.5	3.268	3.332	47.39
4	5	2.941	2.999	42.65
5	5.5	2.673	2.725	38.77
6	6	2.451	2.499	35.55

The outlet pipe of Air-supply system is connected to the inlet throat of the mixing chamber. So, the air in the cylinder will pases through the outlet pipe to the mixing chamber. On other side the fuel injected into the mixing chamber through nozzles at a pressure of 140 kPa/cm^2. So, both air and fuel will gets mixed in the mixing chamber then this mixture is ignited by the help of spark plug. Due to combustion process the gases are formed and then these gases are released into the atmosphere.



- Inlet diameter (d_1) = 40mm
- Outlet diameter (d_2) = 90mm
- Length of Converging Nozzle (l_1) = 53.44mm
- Length of Chamber (l_2) = 90mm

Fig 9 : Combustion chamber with convergent nozzle

5. CONCLUSION

In this paper, we analysed the performance of ramjet engine combustion chamber. We designed both air supply system and fuel supply system. As per their pressure values (air and fuel supply system), we designed the combustion chamber.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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