Design Fabrication And Performance Analysis Of Subsonic RAMJET Engine

Dr.J.V.Sai Prasanna Kumar[1], Revathi.K, Sabarigirinathan.R, Santhosh Kumar.M, UdhayaKumar.T, Viswanath.S [2]

Head of the Department, Department of Aeronautical Engineering, GKMCET [1]
Students, Department of Aeronautical Engineering, GKMCET, Tamil nadu, India [2].

Abstract - *The aviation industry, in the past few decades, is interested in the supersonic flight. The defense sector of almost all the nations are involved in the design of modern supersonic fighter aircraft, ICBMs and innovations in faster air transport. Even most of the space agencies are interested in finding out the newer technologies of launching the satellites. In brief, Aeronautics has stepped into the next generation of explorations and innovations. Ramjet is one of the main sources of power for supersonic flight. Ramjet powered missiles, Ram Rocket, Ramjet assisted supersonic fighter will lead the aviation sector in the near future.In this project we are going to study the performance analysis of the Ramjet engine using different types of fuel and also using compressor and blower. Temperature, velocity and pressure distribution, along the longitudinal axis of the engine are measured using the Thermal sensor and Pitot - static tube.*

***Key Words* - Supersonic fighter, Ramjet, Aviation, Compressor, Blower, Thermal sensor, Pitot-static tube.**

1.INTRODUCTION

Propulsion in a broad sense is the act of changing the motion of the body. Propulsion mechanisms provide a force that moves bodies that are initially at rest, changes momentum, or overcomes retarding forces when a body is propelled through a medium.

- Rocket Propulsion is a class of Jet propulsion that produces thrust by ejecting stored matter called the propellant.
- Duct propulsion is a class of jet propulsion and includes turbojets and ramjets (air breathing engines). Duct Propulsion devices utilises mostly the surrounding medium as the working fluid together with somestored fuel.

1.1 KEY OBJECTIVES

- Design and Manufacture of a miniature ramjet engine.
- Design and Assembly of a flame holder and fuel system.
- Design and Assembly of a static test rig to test and measure performance.
- Analysis and interpretation of test results to improve engine performance.

2. SUBSONIC RAMJET ENGINE

In this section the ramjet engine along with it's various components will be reviewed in the context of this project.

The ramjet engine consists of three major components:

- Body Structure
- Flame stabilization system
- Fuel injection and ignition system

2.1 BODY STRUCTURE

The engine body consists of the following regions as seen in Figure 2.

- Diffuser

- Combustion Chamber
- Nozzle

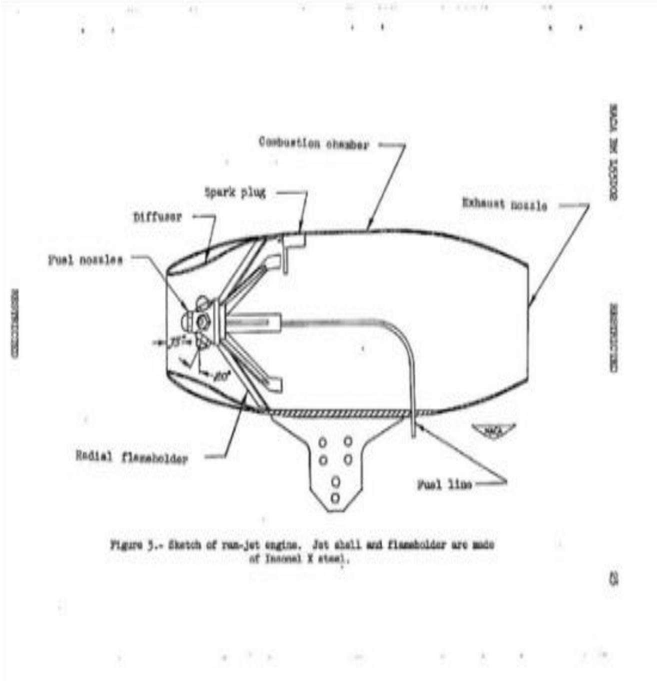


Fig-1: Design of body structure

2.2 FLAME STABILISATION SYSTEM

Along with the careful design of these three, the choice of material and method of manufacture play a significant role in creating an efficient engine.

In order to maintain flame in any high velocity air-stream, some means of shielding the flame source is necessary. Such a shielding device is called flame holder.

The amount of air-stream blockage created by the flame holder directly affects the engine performance. With too little blockage the flame cannot be maintained. On the other hand too much blockage decreases the thrust available from the engine. The goal of the designer is to maintain combustion over a wide range of fuel flow with as little blockage as possible. A good rule of thumb is to keep the flame holder area less than 35% of the total cross sectional area of combustion chamber.

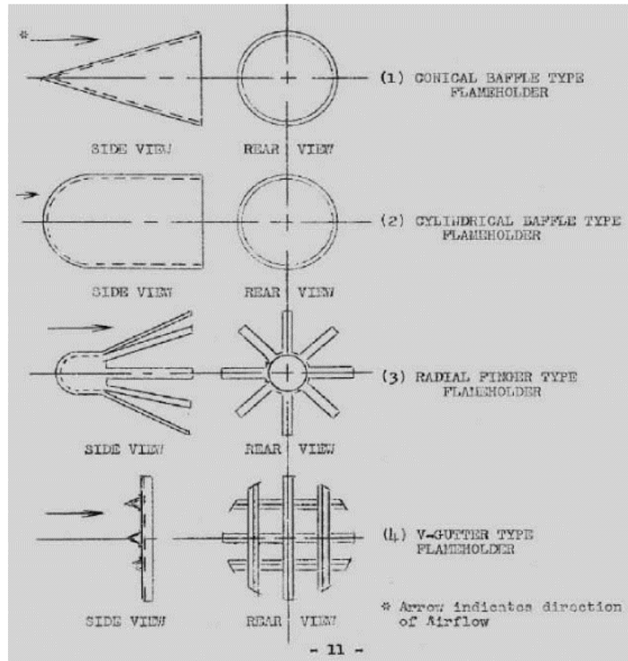


Fig-2: Various types of flame holder

2.3 FUEL INJECTION AND IGNITION SYSTEM

The functioning of the ramjet involves the injection of fuel oil in order to realize combustion that will generate the requisite thrust.

Fuel injection design depends to a great extent upon the design of the flame stabilization system but in general, a good design requires:

- A uniform mixing of the fuel and incoming air stream
- As little disturbance to the air flow as possible

In order to ignite the fuel-air mixture that flows past the flame-holder some type of igniter is required, usually a spark-plug. The exact location of the igniter presents an extremely difficult problem and is determined in most cases by trial and error. Its general location is near the aft end of the flame holder.

2.4 CHOICE OF FUEL

In this section a comparison is made among the following, gasoline and kerosene, which are the three possible fuel choices as they adequately meet the specifications of a ramjet system. Choice of the most apt fuel will vary according to criteria of respective ramjet engines.

Choice of fuels	Gasoline	Kerosene
Density(kg/m^3)	719.7	780-810
Energy density(MJ/L)	32	31
Explosion limits (volume in air)	1.4-7.6	0.6-4.9
Auto ignition(^{o}c)	280	220

Table-1: Fuel description

3. SYSTEM DESCRIPTION

In this chapter we first looked at how ramjet engine generates thrust by burning fuel, which in turn leads to high exit velocities due to release of energy. Next the body structure of ramjet was looked at, followed by the fuel stabilization, injection and ignition systems. Having gone through the physical setup of a Ramjet, the next issue that was discussed was the choice of fuel. By clearly defining the criteria that govern choice of preferred fuel, it was seen that kerosene and gasoline was justified in being the most popular fuel available today for ramjet like applications.

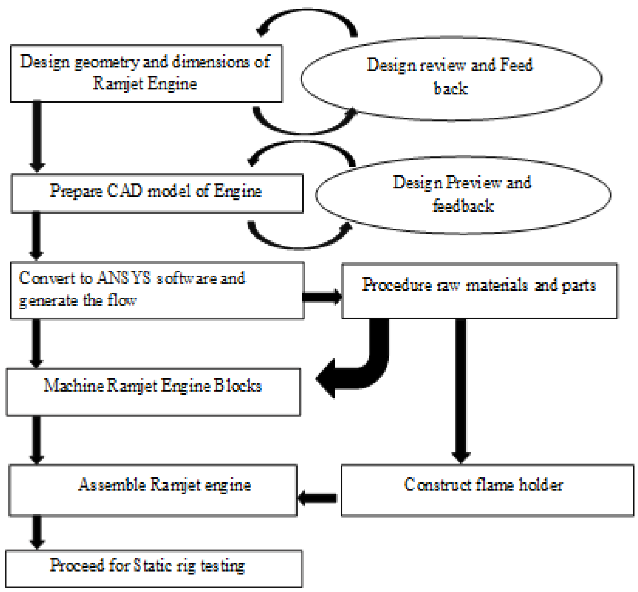
Fig-3: Fabrication of Ramjet Engine

Fig-4: Fuel injector

Fig-5: Spark plug

PROCEDURE ADOPTED

The Flow chart below gives an overview of the procedure adopted to build a ramjet engine.



The following are the specifications made for the design and fabrication of subsonic ramjet engine.In order to obtain the required Mach number we have considered the following specifications.

Using U-tube Manometer,

h=68.5 h1=66

$\Delta h = h - h1$

$\Delta h = 2.5$

Initial Velocity V= $\frac{\sqrt{2g\Delta h(\rho m-\rho)}}{\rho}$

V= $\sqrt{2} \times 9.81 \times 2.5 \times \frac{1000-1.29}{1.29}$

V=194.77m/s

Mach Number M=V/a, where a= $\sqrt{\gamma RT}$

R=287 T=303k

a= $\sqrt{1.4 \times 287 \times 303}$

a= $\sqrt{121745.4}$

a=348.92m/s

M=194.77/348.92

=0.56

Mach Number=0.5

3.1 DESIGN OF DIFFUSER

Diffusers are very common in heating, ventilating, and air-conditioning systems. Diffusers are used on both all-air and air-water HVAC systems, as part of room air distribution subsystems, and serve several purposes:

- To deliver both conditioning and ventilating air
- Evenly distribute the flow of air, in the desired directions
- To enhance mixing of room air into the primary air being discharged
- Often to cause the air jet(s) to attach to a ceiling or other surface, taking advantage of the Coanda effect
- To create low-velocity air movement in the occupied portion of room
- Accomplish the above while producing the minimum amount of noise

DIFFUSER CALCULATION

Inlet diameter=67.22mm

$A_1/A^* = 1/M_1[2/\gamma+1(1+\left(\frac{\gamma-1}{2}\right)M_1^2)]^{[\frac{\gamma+1}{2(\gamma-1)}]}$

$A_1/A^* = 1/0.5[2/2.4(1+(0.4/2)(0.5)^2)]^{[\frac{2.4}{2(0.4)}]}$

$A_1/A^* = 1.33984376$

$A_1 = \pi r_1^2$

$A_1 = \pi(33.61)^2$

A_1=3550.88mm²

A_1/A*=1.33984

A*=2650.22

$A_2/A^*=1/M_2[2/\gamma+1(1+\left(\frac{\gamma-1}{2}\right)M_2^2)]^{\left[\frac{\gamma+1}{2(\gamma-1)}\right]}$

$A_2/A^*=1/0.2[2/2.4(1+(0.4/2)(0.2)^2)]^{\left[\frac{2.4}{2(0.4)}\right]}$

A_2/A*=2.96352

A_2=2.96352×2650.22

A_2=7853.979mm²

$A_2=\pi r_2^2$

r_2^2=2501.267

r_2=50.012mm

Exit Diameter=100.02mm

TO FIND LENGTH

Tan θ=(d_2-d_1)/2L

Tan 9°=(100-60)/2L

0.15838=20/L

L=126.28mm

3.2 DESIGN OF COMBUSTION CHAMBER

Chamber within which combustion occurs: such as

- The space in some boiler furnaces where the gases from the fire become more thoroughly mixed with air and burned
- The clearance space in the cylinder of an internal-combustion engine where the charge is compressed and ignited
- The part of a jet engine or gas turbine in which the propulsive power is developed by combustion of the injected fuel and the expansive force of the resulting gases.

There are different types of combustion chamber. They are as follows:

- Head type
- Swirl and Squish
- Flame front

COMBUSTION CHAMBER CALCULATION

Inlet diameter of the C.C=Exit diameter of the Diffuser

=100mm

Length of the C.C=3D

=3×100

=300mm

3.3 DESIGN OF NOZZLE

The nozzle design has been narrowed down to a converging-diverging nozzle. For the scope of this project and to increase simplicity during manufacturing the nozzle will incorporate flat panels on one side of the rectangular cross-section. The objective of the nozzle section is to choke and accelerate the flow to achieve thrust.

NOZZLE CALCULATION

Inlet diameter of the nozzle=100mm

LENGTH OF THE NOZZLE

The practical designer can make the nozzle exit are approximately 1.4 times greater than the diffuser entrance area.

60×1.4=84

Exit diameter of the nozzle=84mm

The length of the nozzle is not critical and is usually no greater in value than the entrance diameter of the diffuser.

L=60mm

3.4 MATERIALS AND METHOD OF MANUFACTURE

We select the following materials for fabricating the ramjet engine:

Stainless Steel [type 347]

We choose this as the source of material as it has the capability of withstanding the high temperature. A sheet thickness of 16 gage could meet strength requirements for engine shells upto a maximum diameter of 7 inches.The recommended construction procedure for most experimenters would be to roll the combustion chamber from sheet stock in to a hollow cylinder and roll the diffuser and exhaust nozzle into cone frustums. We used Fuel Pump from Royal Enfield 550cc, Fuel Injector from Mahindra Scorpio, Spark Plug from two wheeler.

It is proposed to machine the hollow solid stainless steel material of which the engine is to be fabricated. These will be made into three segments and will be welded together after assembling the flame holder, fuel injector and other necessary instruments such as thermocouple. Gas welding is done to join the segments together. All welding beads should be ground to a smooth finish.The machined piece willweigh almostsame asthe formed one. Since all three segments will

be be welded together, the profile accuracy will be very high. Therefore, a machined piece is likely to result in a more efficient and less noisy ramjet. Rapid Manufacturing Lab has a 3-axisanda5-axisCNCmachineonwhichtheenginewillbe fabricated.

4. LIMITATIONS

The performance of the engine with different types of Fuels and nozzles with both air compressor and blower were studied.

- Insufficient atomisation of the fuel particles leads to the non uniformcombustion.
- nsufficient combustion chamber length causes the occurrence of combustion at the downstream of Nozzle which further leads to incomplete combustion.
- The Fuel injection pressure is not enough. Hence the air particles were incapable of carrying the fuel molecules along with them thereby causing more spillage of the fuel.

5. RESULTS

The above mentioned problem can be overcome by increasing the combustion chamber length of the Ramjet engine.

- Better automisation of fuel
- Igniting the fuel at correct place and on time.
- Injecting preheated fuel which may get vaporised quickly and mixed with the air stream thoroughly.

6. CONCLUSIONS

The manufacture of Ramjet engine is now ready to head into its testing phase. It saw a deviation from norm for the conventional sheet metal build was replaced by one where two from solid steel are welded together. The outer small parts like the flame holder, spark plug are fitted into yhe main frame. The fuel supply system consisting of a pressurizer will also be setup. The project will deal mainly with full assembly of testing, experimentation on Ramjet engine and analysis of temperature by using different fuels in Ramjet engine.

REFERENCE

[1] Decker, W.T., Practical Ramjet Design, First Edition, Decker Engine Works, Virginia 1954.
[2] Karunakaran,K.P.,Subsonic Ramjet Engine,Project Proposal,2012.
[3] Karunakaran,K.P.,Helicopters without Tail Rotor ,Asia Academic Seminar,2012.
[4] Horlock,J.H.,Advanced Gas Turbine Cycles,Elseviar Sciences,First Edition,2003.
[5] Turns,S.R.,An Introduction to Combustion, McGraw Hill, Second Edition, 2000
[6] Fry, R.S.A., Century of Ramjet Propulsion Technology Revolution, Journal of Propulsion and Power,Vol.20,No.1,2004.
[7] Cantwell, The Ramjet Cycle, Scramjets, http://web.stanford.edu/~cantwell/AA283_Course_Material/AA283_Course_Notes/Ch_03_Ramjet_Cycle.pdf,20/10/2014

[8] Glenn Research Centre, N.AS.A., Ramjet Propulsion, http://www.grc.nasa.gov/www/k-12/airplane/ramjet.html,20/10/2014.