A Review on Fuel Injection System of Scramjet Engine

Anjali Patel1, Gopal Sahu2, Prakash Kumar Sen3
1Student, Mechanical Engineering, Kirodimal Institute of Technology, Raigarh (C.G.), INDIA
2,3Lecturer, Mechanical Engineering, Kirodimal Institute of Technology, Raigarh (C.G.), INDIA

ABSTRACT

Fuel injection system into scramjet engines are a field that is still developing today. The fuel used in scramjet is generally either liquid or a gas. In a scramjet engine the fuel and air should mixed to approximately stoichiometric proportions for effective combustion. The major problem of scramjet fuel injection is that the air flow is quite fast. Meaning that there is minimum time for the fuel to mix with the air and ignite to produce thrust. The main fuel that is used for combustion is hydrogen. Hydrocarbons present more of a difficult compared to hydrogen due to longer ignition delay and the requirement for more advanced mixing techniques.

Keywords---- Fuel injection, Scramjet, Thrust, combustion, Fuel.

I. INTRODUCTION

A scramjet is a variation of a ramjet air breathing jet engine. The desire for faster response times or cheap access to space drives both government program requirements and industry driven innovation in propulsion. The Supersonic Combustion Ramjet (SCRAMJET) engine has been recognized as the most promising air breathing propulsion system for the hypersonic flight. In recent years, the research and development of scramjet engine has promoted the study of combustion in supersonic flows. Extensive research is being carried out over the world for realizing the scramjet technology with hydrogen fuel with significant attention focused on new generations of space launchers and global fast-reaction reconnaissance missions. However, application for the scramjet concept using high heat sink and hydrogen fuels offers significantly enhanced mission potential for future military tactical missiles. Scramjet being an air-breathing engine, the performance of the missile system based on the scramjet propulsion is envisaged to enhance the payload weight and missile range. Supersonic combustion ramjet engine for an air-breathing propulsion system has been realized and demonstrated by USA on ground and in flight. X-43 vehicle used hydrogen fuel. Hydrocarbon fuel scramjet engine is still under study and research.

II. DESIGN OF SCRAMJET ENGINE

The scramjet engine is composed of three basic components :-
1. Converging inlet
2. Combustor
3. Diverging nozzle

Converging inlet- A converging inlet, where incoming air is compressed and decelerated.
Combustor- A combustor, where gaseous fuel is burned with atmospheric oxygen to produce heat.
Diverging nozzle- A diverging nozzle, where the heated air is accelerated to produce thrust.

Figure 1. : A two dimensional scramjet engine

Unlike a typical jet engine, such as a turbojet or turbofan engine, a scramjet does not use rotating, fan-like components to compress the air, rather, the achievable speed of the aircraft moving through the atmosphere causes the air to compress within the inlet. The scramjet engine having no any moving parts. As such, no moving parts are needed. Scramjets are designed to operate in the hypersonic flight regime. Due to the nature of their design, scramjet operation is limited to near-hypersonic velocities. As they lack mechanical compressors, scramjets require the high kinetic energy of a hypersonic flow to compress the incoming air to operational conditions. Thus, a scramjet powered vehicle must be accelerated to the required
velocity by some other means of propulsion, such as turbojet, rail gun, or rocket engines. Maintaining combustion in the supersonic flow presents additional challenges, as the fuel must be injected, mixed, ignited, and burned within milliseconds. While scramjet technology has been under development since the 1950s, only very recently have scramjets successfully achieved powered flight.

III. FUEL INJECTION SYSTEM

Fuel injection is a system for injecting the fuel into combustor. To promote fuel and air mixing combustor of a scramjet engine, fuel is injected as a succession of pulses into the airstream through the combustor. There are several key issues that must be considered in the design of an efficient fuel injector. Of particular importance are the total pressure losses created by the injector and the injection processes, that must be minimized since the losses reduce the thrust of the engine. The injector design also must produce rapid mixing and combustion of the fuel and air. A fuel injection system for a scramjet engine including a combustor having a supersonic airstream flowing longitudinally. Rapid mixing and combustion allow the combustor length and weight to be minimized, and they provide the heat release for conversion to thrust by the engine nozzle. The fuel injector distribution in the engine also should result in as uniform a combustor profile as possible entering the nozzle so as to produce an enceinte nozzle expansion process. Intrusive injection devices can provide good fuel dispersal into the surrounding air, but they require active cooling of the injector structure.

IV. TYPES OF FUEL INJECTION SYSTEM

Some traditional approaches for injecting fuel are described below.

A. Parallel, Normal and transverse injection

1. Parallel fuel injection

   Parallel fuel injection consists of fuel flowing parallel to the air in the engine but separated by a splitter plate. When the splitter plate ends, a shear layer is created due to the different velocities of the fuel and air. The shear Layer is the primary source of mixing the fuel with the air so that proper combustion can be achieved. When parallel fuel injection was tested with a hydrogen-fluorine fuel in air, the growth rate of the shear layer was reduced compared to theoretical rates. The reduction in growth rate is argued to be caused by the reduction of turbulent shear stress at the core of the shear layer due to the density change caused by the heat released from the combustion process.

2. Normal fuel injection

   Normal fuel injection consist of an injection port on the wall of a scramjet. The port injects the fuel normal to the flow of air in the scramjet. This type of injection system creates a detached normal shock upstream of the injector which causes separation zones upstream and downstream of the injector as shown in figure 4.

3. Transverse fuel injection

   Transverse fuel injection is a combination of parallel and normal fuel injection. In a transverse injector, the fuel is injected at an angle between normal and parallel to the flow. Transverse injection reduces some of the negatives to normal injection, but requires a larger injection pressure to achieve the same penetration height into the air flow. The increase in the injection pressure increases the total pressure loss of the scramjet which decreases the efficiency of the engine.

B. Ramp injectors

   Ramp injector using the results from parallel injection.
To add axial velocity to the flow near fuel injection, ramps were added with fuel injectors on the trailing edge of the ramp injecting fuel parallel to the flow. The flow over the ramps created counter-rotating vortices that increased the mixing. Due to the supersonic flow in the scramjet, the ramps also create shocks and expansion fans which cause pressure gradients that also increase mixing. Figure 5 shows the two types of ramps used:
1. Compression Ramp
2. Expansion Ramp

Compression ramps are elevated above the floor while expansion ramps create troughs in the floor (Figure 5). In compression ramps the shocks formed at the base of the ramp and in expansion ramps the shocks formed in the recompression region at the bottom of the trough. Due to the difference in the shock locations, the combustion efficiency and mixing for the two ramp styles differed. The results showed that compressor ramps created a stronger vortex and increased the fuel/air mixing, but expansion ramps had the higher combustion efficiency.

C. Strut injector

Another type of fuel injector tested by Desikan and Kurian in 2006 is a strut-based fuel injection system, as shown in Figure 6. Strut mixing devices cover a wide range of designs and includes both normal and parallel injection methods. Most of the struts consist of a vertical strut with a wedge leading edge. The strut is connected to both of the combustion section that is top and bottom combustion sections. The main advantage of this system is that it allows the fuel to be injected into the core of the airflow with uniform spreading in the radial direction. Also, the shock produced from the leading edge of the strut enhances the mixing of the air and fuel.

D. Baronage Injection System

The basic configuration of the Baronage injection unit is shown in Figure 8. The kerosene is injected through a central tube into a mixing zone, to which the hydrogen flows through the annular gap around the kerosene tube. In the mixing zone, gas bubbles into the liquid. Then the two-phase flow is injected into scramjet combustor through the injection orifice.

E. Pulsed Injector

Another type of fuel injection is pulsed injection conventionally; fuel is injected as a continuous stream from injection ports into the combustion chamber where it ignites. This type of injection injects the fuel in a series of pulses, which allows for greater mixing between the fuel and air. Combustion occurs more rapidly as well as more efficiently, thus producing a greater thrust output. The time between pulses is dependent on the free stream conditions, and is coordinated to achieve near stoichiometric combustion. An advantage of this method is that combustion always remains in a transient state, and never reaches a steady state condition. To promote fuel and air mixing...
combustor of a scramjet engine, fuel is injected as a succession of pulses into the airstream flowing through the combustor.

![Image](image.png)

Figure 9. Pulsed fuel injection

V. CONCLUSION

Now a day, turbine engines power is very high speed aircraft, but they can no longer be expected to provide the primary source of air breathing propulsion as speed and altitude requirements increase. Supersonic combustion scramjet propulsion provide a method of obtaining this higher performance. The major type of fuel injection used in scramjet technology today are parallel, normal, transverse, ramp, strut, pulsed and baronge injection. Each method has its advantages and disadvantages. The main issue to consider in scramjet injection is the flow speed, which has an effect on the mixing efficiency of the fuel and air. A high mixing rate increases the efficiency of a scramjet, as it reduces the combustor length, and hence the skin friction drag.

REFERENCES