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A Review on Ram Jet Engine

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Abstract

Power augmented ram (PAR) engine is a popular equipment to reduce the requirement of power for takeoff and improve aerodynamic performance. To provide detailed insight into the aerodynamic characteristics of wing-in-ground effect (WIG) craft with PAR engine, numerical simulations are carried out on WIG craft models in cruise. Simplified engine models are applied to the simulations. Two cruise modes for PAR engine are considered. The aerodynamic characteristics of the WIG craft and other features are studied. Comparisons with WIG craft model without PAR show that shutoff of PAR engine results in an increase in drag and less change in lift. Accordingly for the work of PAR engine, the air flow blown from the engineaccelerates the flow around the upper surface and a high-speed attached flow near the trailing edge is recorded. With the schemed PAR flow, more suction force is realized and the flow features over the wing vary noticeably. It is also shown that the Coanda effect, provided with an attached flow, introduces an appropriate and practical flow mode for WIG craft with PARengine in cruise. The results refresh our understanding on aerodynamic characteristics of WIG craft.

1. INTRODUCTION

Today, we will extend that jet engine coverage to working of ramjets and pulsejets, in which the basic cycle understanding that you have acquired for jet engines would be useful. We will also look at the cycles of ramjets and pulsejets which are similar to the cycles that you have done;so, that would be quite easy for you to extend your understanding. The ramjets and pulsejets actually historically precede those of the turbojet engines. They had actually been used for flying aircraft during the World War 2 and as a result of it understanding of how ramjets and pulsejets actually work, had been created quite some time back. However, the advent of turbojets and various kinds of turbofans actually put the ramjets and pulsejets in some kind of a backburner. Over the years, people realized that they have their utilities, especially the ramjets and the modern version of ramjets known as scramjets, which are used for high speed aircraft typically supersonic or even hypersonic aircraft, where actually you cannot use the turbojets. The turbojets: they have their utility value from subsonic to supersonic up to maybe, about Mach 3 and then beyond that you need different kind of engines or thrusters to create thrust for aircraft orflying vehicles flying at those kind of Mach numbers. So, the ramjets and scramjets have been revived and various versions of them are now under development in various countries all over the world and some of these fundamental issues of these ramjets. [1]

1.1 ***Ramjet engine***

To ram means to force in. In ramjet air is forced into the engine air intake by the sheer drive of thespeed of flight. Ramjet, in principle, can work at subsonic speed but it can be practical only at supersonic speed.

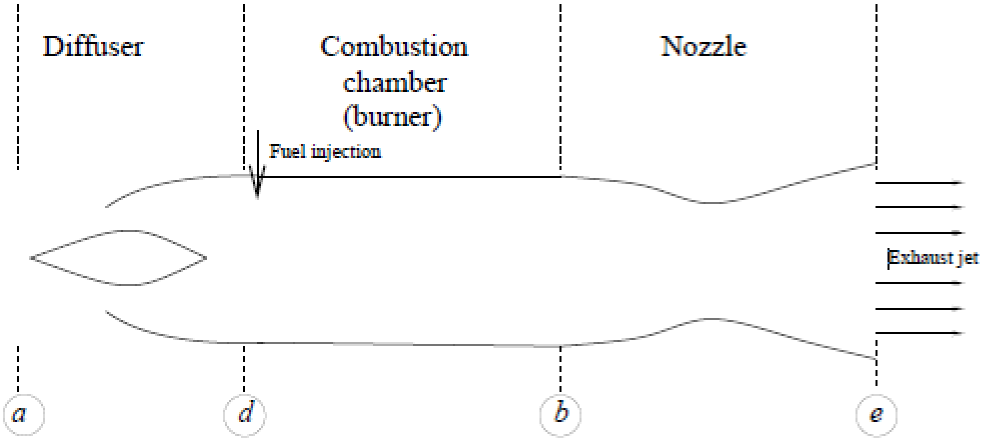


fig: ram jet

In a ramjet, air undergoes compression in the diffuser, then fuel is added and burnt in the burner, andthen the combustion products expand through the nozzle. It is helpful to consider first a simplified model of an ideal ramjet. For ideal ramjet it is assumed that compression and expansion processes are reversible and adiabatic, that combustion occurs at constant pressure, that the air/combustion products properties (specific heat ratio ϒ and the gas constant R) are constant throughout the engine, and, although this is not necessary, that the outlet pressure is equal to the ambient pressure, in other words, that the nozzle is in the design regime. The usual tool for analysis of the processes in engines is the so-called enthalpy-entropy diagram. The thermodynamic state of air is determined by two independent parameters. If a point in h-s diagram is given then all other parameters, like pressure, temperature, density, internal energy etc. can be calculated. When a unit mass of air moves through the engine the properties are changing and the point that indicates the state is moving accordingly. The use of the enthalpy h and entropy s is especially convenient for the following reasons. In adiabatic reversible process s remains constant, and, therefore, the path of such a process is a vertical line in h – s diagram. Since irreversibility usually lead to deterioration of performance, engines are designed so as to be as close to reversible processes as possible. If the process is irreversiblethen entropy at the end of it is greater than entropy at the end of the corresponding reversible process.Therefore, in h – s diagram it is easy to anticipate the effect of irreversibility on the shape of the diagram. The advantage of using enthalpy as the other parameter follows from the form of the energy conservation law for open steady-state system.

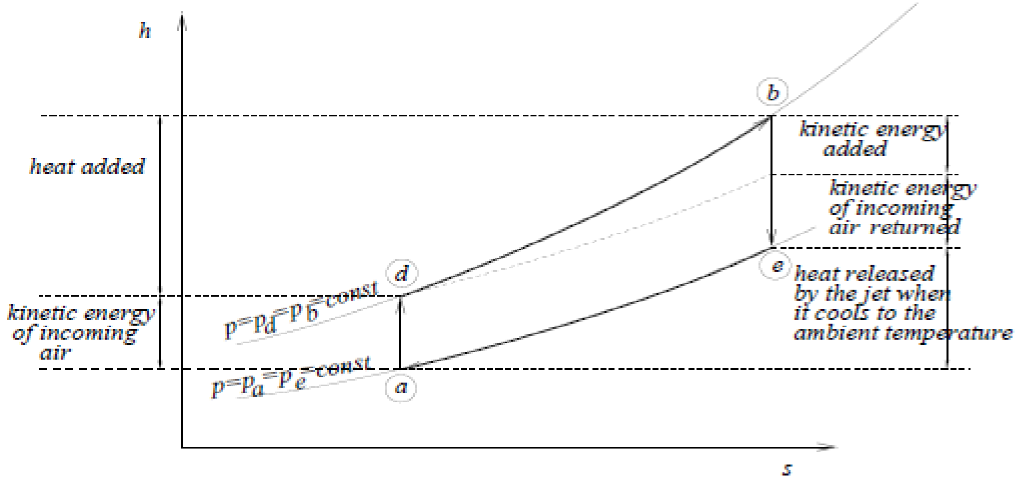


Fig: enthalpy-entropy diagram for an ideal ram jet

It is possible to calculate all characteristics of an ideal ramjet. However, the use of h–s diagram makes it possible to achieve an intuitive understanding of the engine performance, as this was illustrated above. One can now, for example, anticipate the rationale of the turbojet. Try it.[2]

1.2*Aerospace historic moments*

- first century A.D. chinese army launches gunpowder rockets
- Around 1800 ConstantinTiolkovski creates the theory of interplanetary flight
- 1910-1940: researches in both solid and liquid rocket engines-main concern: optimization of burning chamber and injection of the fuel.
- Second world war, Herman oberth and Werner Von Braun work on rockets for German army. First Successful liquid rocket engines used in military applications. [3]

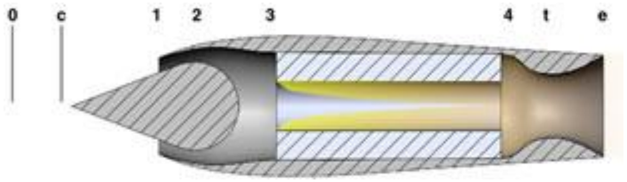
1.3*How Jets Work*

Jet engines and rocket engines all work pretty much like the balloon drawing at the right. Pressurized gasses (arrows) inside the balloon push equally in all directions. Forces trying to push the balloon in one direction are canceled by equal but opposite forces trying to move it in the opposite direction (red arrows). If the neck of the balloon is tied off, forces in all directions cancel so the balloon does not move. If the neck is open there is no balloon for forces to push against at the opening. Since there is no push against the balloon by the gasses escaping through the opening (blue arrow), the unopposed force of the green arrow pushing on the balloon causes it to move and the balloon flies away like a rocket. Rocket engines work in exactly this way. The combustion chamber is closed except for an opening at the exhaust nozzle. Burning fuel produces high pressure gasses that escape through the nozzle at the rear, and gas pressure at the front end of the engine pushes the rocket forward. Jet engines also work the same way, but they have an air inlet at the front as well as the exhaust opening at the rear. Turbojets have a compressor fan that pulls air into the engine. The compressed air inside the engine pushes against the compressor fan blades at the front of the engine and against the burning exhaust gasses at the rear. The compressed air pressure matches the exhaust gas pressure so the unopposed force is transferred to the compressor fan blades and the internal engine parts to push the jet forward. In effect, the compressed air entering the engine "plugs the hole" at the front of the engine so it works like the balloon. Ramjets are tubes open at both ends, with few internal parts and no compressor fan to force air into the engine. So what causes the combustion gasses to escape only at the rear end, and what do the exhaust gasses push against to cause forward thrust? To understand this you need to know something about how gasses behave.

1.4*Solid Fuel Ramjets*

Leveraging from its deep expertise in the field of **hybrid rocket propulsion** and the**fast burning solid fuels**, SPG has started a research and development program in the area of Solid Fuel Ramjets (SFRJ). Due to their inherent simplicity SFRJ's present a cost effective option for a wide range of applications that demand a sustained thrust force during a substantial portion of their mission profile. UAV's and target drones are believed to be the primary candidates for SFRJ propulsion. Testing program with a 2,000 lb. thrust class paraffin-based SFRJ is ongoing.

Background:



The SFRJ cycle is the same as the ramjet cycle except that the fuel exists in solid form within the chamber and the stoichiometry of combustion is controlled by the regression rate of the fuel. The fuel is not a propellant in the solid rocket motor sense but a pure fuel, inert without external oxidizer much like in a hybrid rocket motor. A wide range of fuels can be used from polymers such as PMMA or PE to long-chain alkanes such as paraffin or cross-linked rubbers such as HTPB. Because the fuel exists in the solid form, inclusion of solid metals is significantly easier than in a liquid fueled ramjet. SFRJ's offer some very significant advantages over liquid fuel ramjets such as:

- Extremely simple compared with liquid fueled rockets or ramjets? In its simplest form, a SFRJ is basically a tube with a fuel grain cast in it.
- Higher fuel density in the solid phase for pure hydrocarbons and even higher if metal additives are used
- Easy inclusion of metal fuels such as boron, magnesium or beryllium which raise the heat of combustion and/or the density and therefore the density impulse capability compared with liquid ramjets
- Solid fuel acts as an ablative insulator, allowing higher sustained combustion chamber exit temperature levels (and hence specific thrust) with less complexity
- Fuel is stored within the combustion chamber allowing for more efficient packaging and higher mass fractions than liquid ramjets
- No need for pumps, external tankage, injectors or plumbing for fuel delivery

Table: jet characteristics of propulsion systems

system	***Jet velocity(m/s)***
Turbo fan	200-600
Turbojet (sea-level, static)	350-600
Turbojet (Mach 2 at 36000 ft.)	900-1200
Ramjet (Mach 2 at 36000 ft.)	900-1200
Ramjet (Mach 4 at 36000 ft.)	1800-2400
Solid rocket	1500-2600
Liquid rocket	2000-3500

the following paper details the team project to build a ramjet engine per the thesis of graduate student HarrisonSykes, “Baseline Performance of Ramjet Engine”. The ramjet project is designed to be used for senior level labs and graduate level research. The working principle of the ramjet is to first decelerate high speed air flow to create high pressure and low speed, then mix and combust fuel, and finally expel hot air with burnt fuel out the converging-diverging nozzle. The ramjet engine in this work has a nominal operation point of Mach 3.3 for the inlet, a maximum static temperature of 953 Fahrenheit, and a maximum static pressure of 31.635psi.

The ramjet engine is mounted to the exit nozzle of the Supersonic Wind Tunnel (SSWT). The duct area dimensions of the ramjet engine are 4.937 inches wide by 4.785 inches high to match the exit nozzle of the Super Sonic Wind Tunnel. The overall length of the ramjet engine is six feet long. The length is broken into three equal sections of two feet for the compressor, the combustor, and the nozzle. A ramjet, once again, is a type of jet engine that uses the forward motion of the engine to compress the incomingair pre-combustion, rather than using a compressor, as seen in a typical air breathing jet engine. The three majorsections of any given ramjet are the inlet, the combustor, and the nozzle.1The inlet slows and compresses the high speed air before it passes through the combustor. A majority of ramjetsfunction in supersonic flight, and utilize shock waves to slow the flow to a suitable velocity for the combustor. Subsonic ramjets do not require such complexity to slow the flow, so a simple hole is sufficient. The combustor injects fuel into the flowing air, and then ignites it. Fuel pressure and fuel flow to the fuel injector must be high enough such that the necessary fuel to air ratio for stoichiometry is maintained. But fuel flowshould not exceed the stoichiometric range or else the flow with be saturated with fuel, or fuel rich, to the point that the flow will not ignite. The fuel injector ideally atomizes the fuel flow such that fuel can better mix with the air flowing through the engine. To maintain flame stability, a flame holder is typically used. The flame holder further slows the flow and creates a recirculation region to allow the flame to propagate. A flame holder can be as simple asa flat plate. The flame holder shelters the flame and improves fuel mixing since there is no turbine downstream, the combustor stoichiometric fuel to air ratio. Such fuel is kerosene or kerosene based jet fuel.The nozzle expels the exhaust at an accelerated rate to produce thrust. For subsonic operation a converging nozzle is ideal, while a converging-diverging nozzle is used for supersonic operation. The remainder of this report will focus on the combustor and make the assumption that the air flow entering the combustor is subsonic. [4]

CONCLUSION

We hope that this presentation of ramjet history over the past 50 years has given the reader an appreciation for the depth and extent of U.S. Navy support of supersonic and hypersonic ramjet-engine–powered vehicles. Indeed, the Navy's experience reflects the full scope and depth of ramjet and scramjet development experience accrued since World War II. It should also illustrate the substantive reductions in support for these types of vehicles in recent times, even as other nations (e.g., France, Russia, Germanyand Japan) continue to vigorously pursue the development and deployment of such vehicles and weapon systems. There appears, however, to be a rekindled interest in these systems by the Navy over the past year, but only time will determine if and when another ramjet-powered system is deployed.

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