FUTURE ASPECTS OF VALVELESS PULSE JET ENGINE

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ABSTRACT

Today there has been a renewed interest among the defense industry in pulsejet technology. With the increasing popularity of the unmanned aerial vehicle, they are trying to find ways to propel these small, lightweight aircrafts with efficient, affordable and durable engines. Pulsejets, because of their simplicity, offer a unique solution to this demand. The main aim of this paper is to study the future aspects of valveless pulsejet engine which can be used as propulsion source.

Keywords: Carburetor; Pulsejet Engine; Thrust; Unmanned Aerial Vehicle; Valveless Pulsejet

I. INTRODUCTION

A pulsejet is a simple form of an air breathing engine. Pulsejet engines can be made with few or no moving parts and are capable of running statically. With valveless pulsejet which have no moving parts it becomes hard for one of these machines to fail in operation .The lack of hardware in pulsejets makes for an engine that is lightweight and dependable. Pulsejets are also known for their exemplary throttle response, as there are no turbines to spool up or flywheels to slow down quickly. Also these machines can take quite a beating and still prove operable. In an environment as demanding as a war zone it is possible for a pulsejet to take a bullet and keep on running.The reason behind choosing valveless pulsejet engine for this paper is the simplicity and robustness of these engines.

There are two main types of pulsejet engines, both of which use resonant combustion. The first is a valved design, in which the combustion process is controlled by valves. This type of enginecontains more parts due to which there is a potential for problems. The second type is known as valveless system, in which there are no moving parts. This results an easier construction and are cheaper than the valved ones. In this paper our main focus is on valveless pulsejet system.

II. HISTORY AND BACKGROUND

The pulsejet gained its recognition during world war-II when it was used as the propulsion device for the first cruise missile. This was the German v-1 "buzz-bomb" named for its loud, obnoxious cyclical sound. It operated at 50 Hz, producing a maximum thrust of approximately 360kg. The implementation of the v-1 marked the successful application of a pulsejet as a propulsion device.

Development of pulsating combustion began around 17th century. Christian Huyghens, a renowned mathematician and physicist designed a pulsating engine powered by gun powder.

2.1 Current Approaches

One of the most attractive project on pulsejet engine technology going on is a proprietary developed by Boeing known as the Pulse Ejector Thrust Augmenter (PETA), which proposes to use pulse jet engines for vertical lift in military and commercial vertical take-off and landing aircraft (VTOL). The Boeing design embeds the pulse jet inside a thrust augmenting duct which entrains surrounding air into the exhaust stream. This entrained air improves thrust and cools the pulse jet.

Fig. 1: An Aircraft with Pulse Ejector Thrust Augmenter (PETA) Modules

III. WORKING OF PULSEJET

The primary effect behind the function of a pulsejet is the fact that gases are compressible and tend to act like a spring. This springiness is crucial to the way a pulsejet draws in a fresh mixture of air and fuel then expels the hot burning gasses that are generated when that fuel is ignited. The two most popular theories to describe the pulsejet engine cycle are the kadenacy effect and acoustical resonance.

- The kadenacy effect describes the movement of the gases through pressure waves and the inertia of the gases. It is named after Michel kadenacy who obtained a patent for an engine in 1933. To understand this effect let us take an example, now something very similar happens when we take a sealed container and fill it with compressed air. If we suddenly release that pressure by removing the cork, the compressed air will rush out but even once the pressure inside falls to match the pressure outside, the air will continue to flow out.
- This will cause the pressure inside the container to fall below the pressure outside and then the gas will flow back inwards. This cycle of increasing and decreasing pressure will repeat a number of times, decreasing in magnitude each time.
- That's the kadenacy effect in action driven by the springiness of air.

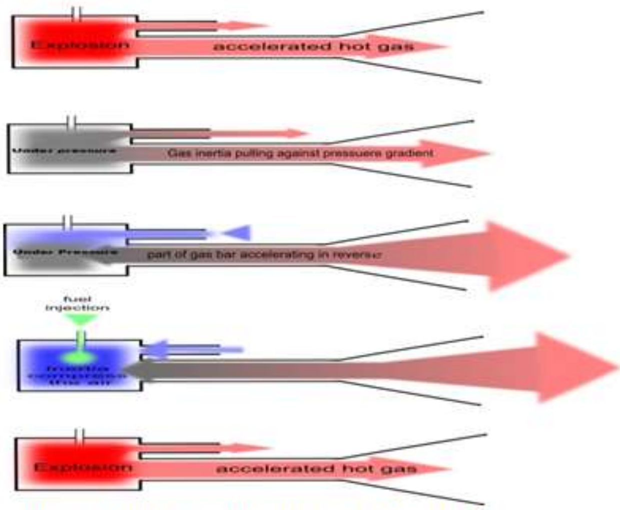

Fig. 2: WORKING OF PULSEJET ENGINE

3.1 Pulsejet Cycle

A pulsejets operates by combination of two cycles: the Lenoir cycle and the Humphrey cycle

The Lenoir cycle consists of the intake of air and fuel at a point a, isochoric combustion from a to b, and an adiabatic expansion to c.

Process a-b: Heat addition at constant volume

Process b-c: Isentropic expansion

Process c-a: Heat rejection at constant pressure

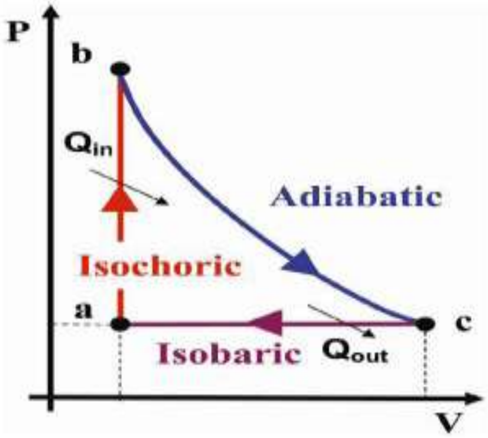

Fig. 3: LENOIR CYCLE

The Humphrey cycle is shown below, in this process it adds a small amount of compression before combustion, step a to b.

Process a-b: Isentropic compression

Process b-c: Constant volume heat addition.

Process c-d: Isentropic Expansion of the gas

Process d-a: Constant pressure heat rejection

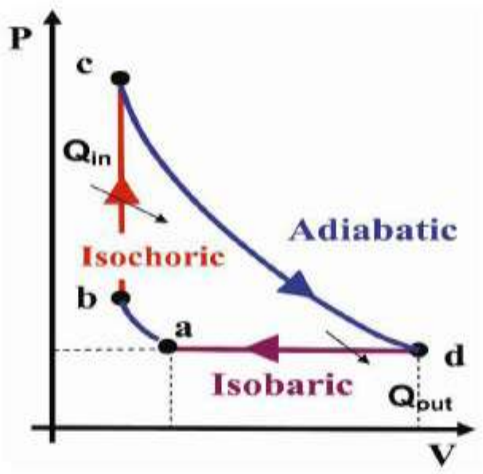

Fig. 4: HUMPHREY CYCLE

IV. DESIGN

The valveless pulsejet that has been designed is known as the thermo- jet engine. It contains no rotating or vibrating parts. The engine is being operated on petrol, methanol and variety of different liquid fuels. The length and diameter of the engine determine the frequency of the pressure pulses. Fuel, flows through the fuel nozzles at high velocity inside the carbureted inlet tubes forcing the surrounding air to also enter the inlets and mix with the fuel in a ratio of approximately 15 to 1. Fuel and air then flow into the combustion chamber where they are ignited initially by a spark plug only during starting of the engine and then from left out heat of the previous combustion.

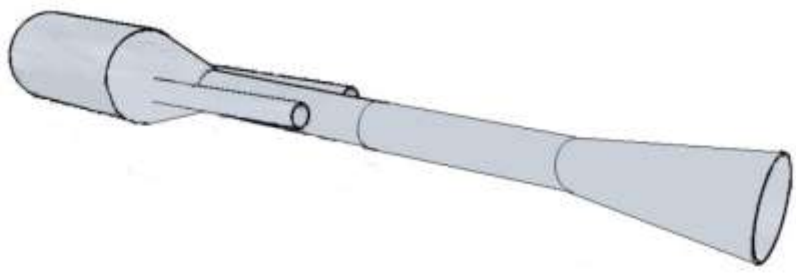

Fig. 5: PULSEJET DESIGN

4.1 Combustion Chamber

Designing the combustion chamber is the most important part of the designing. Whole engine's dimension depends on the length, diameter and volume of the combustion chamber. From statistical analysis there comes a relation through which thrust can be calculated using volume of combustion chamber.

Thrust = $4453.98V_{cc} + 1.448$

Where V_{cc} is the volume of combustion chamber.

4.2 Carburetor

A carburetor is used at an intake which will maintain air to fuel ratio of 15:1. Fuel will be automatically draws due to the vacuum created inside the carburetor. Thus the amount of air entering the carburetor will draw the required amount of fuel.

Fig. 6: CARBURATED INTAKE

4.3 Efficiency

Reviewing Lenoir and Humphrey cycle it can be understood that combustion of varying pressure and volume occurs along the line a-b in Lenoir cycle and along b-c in Humphrey cycle. Isentropic expansion along b-c in Lenoir cycle and along c-d in Humphrey cycle. The heat added is C_{PV} (T_C-T_B). C_{PV} is the effective average specific heat intermediate between C_V& C_P. Heat rejected is C_p (T_D-T_A).

The cycle efficiency is then

$$= \frac{C_{PV}(T_C-T_B) - C_P(T_D-T_A)}{C_{PV}(T_C-T_B)} = 1 - \frac{C_P(T_D-T_A)}{C_{PV}(T_C-T_B)}$$

C_P is average specific heat for a constant pressure reaction. T_B is equal to T_A for a stationary thermojet. The pressure ratio P_C/P_D is relatively small, therefore the temperature T_D cannot differ much from the temperature T_C.

Thus the fraction $(T_D-T_A) / (T_C-T_B)$ cannot be much less than 1, whereas

$\mathbf{C_P / C_V}$

Is greater than 1 and the efficiency will have a low positive value. To increase the efficiency, it is necessary to increase the value of T_C, at higher aircraft velocities the compression and expansion ratios will increase , thereby improving the engine efficiency.

4.4 Exhaust Tube

This is the long tube which is connected to the combustion chamber.The exhaust tube serves two important roles.Firstly, it is this tube that accounts for around 60% of the thrust produced by an valveless engine. Hot gases from the combustion chamber exiting through this tube produce a reaction that creates the thrust.

Secondly, this is the pump that drives the engine. For this reason, its dimensions are critical. In order to provide the necessary pumping action to draw in the next charge of fresh air, the gases in the tailpipe must contain sufficient energy to create a partial vacuum in the combustion chamber. The energy or momentum of those gases is determined by their mass and their velocity using the formula.

$P = mV$

Based on observations the exhaust tube's internal diameter should be half the maximum combustion chamber's internal diameter

4.5 Intake Tubes

The intake tube's internal diameter should be around three fourth of the exhaust's internal diameter. Its shorter than the exhaust tube because it needs to be able to pass enough air to pretty much fill the combustion chamber during the engine's intake phase.if the intake tube were too long, the engine would simply end up sucking back the exhaust gasses that filled it during the last combution phase.

However, the intake tube also needs to be long enough that it can hold a large enough slug of cold, dense air to help air to contain the combustion gasses during the early phase of the combustion cycle.

Table 1 Design Dimensions

Parameter	Magnitude	Units
Internal Dia Of Combustion Chamber	7.62	Cm
Length Of CC	10.16	Cm
Volume Of CC	463.33	Cm^3
Internal Dia of Exhaust tube	3.17	Cm
Length Of Exhaust Tube	36.83	Cm
Volume Of Exhaust Tube	290.68	Cm^3
Internal Dia Of Intakes	1.27	Cm
Length Of Intakes	7.62	Cm
Volume Of Intakes	19.3	Cm^3
No Of Intakes	2	

V. DISCUSSIONS

During the operation of pulsejet it was noticed that pulsejets are highly dependent on the way the fuel is introduced to the combustion chamber, also they are sensitive to the location of the fuel injector. It is desired to achieve a high pressure drop at the injector interface so that the fuel can be sprayed into the combustion chamber at the higher velocity. This promotes turbulent flows and mixing. Flares at the exhaust and inlet aid in the operation of pulsejets.

Pulsejets are simple propulsion devices, and it is the characteristic that makes them attractive for propulsion applications. The next step in the development of valveless pulsejet engine technology is almost certainly going to be in the pulse detonation engine which will provide a useful way of propelling manned and un manned crafts to speeds well in excess of Mach 3 and with vastly greater efficiencies than existing engine technologies. Methods have been developed to make the design more predictable. This is pushing the pulsejet closer to practical applications. Those applications will come if the problem of vibration is addressed. The simplest way to cut at least some vibration is having two identical pulsejets work out of phase will cancel some of the vibrations out. Experiments made so far indicate that some useful reduction in vibration is indeed available by this method. Pairing of engines will achieve not only the reduction of vibration but also a boost of operating efficiency. Like the opposed twin piston engine, two pulsejets working together can be made to cancel the vibrations out. Next, the use of surge chambers, sound-deadening materials etc. should be considered.

VI. CONCLUSIONS

The valveless pulsejet engine can be an alternate solution for propulsion of target drones and unmanned Ariel vehicle after some more improvements in the pulsejet research. In order to further improve the pulsejet research, several things can be done during the testing phase that would enhance the results. Effects of optimum fuel to air ratios and maximizing flow into the inlets could potentially show improvements in thrust and efficiency within the engine, also tests could be done to see the effects of different fuels on the pulsejet. Finally, tests could be done to increase the engines compression ratio and decrease the level of vibrations that engine produces.

Nomenclature

T-Temperature

P -Pressure

V – Volume

V_{CC} -Volume of combustion chamber

C_{V} - Specific Heat at Constant Volume

C_{P} –Specific Heat at constant Pressure

C_{PV} –Average Specific Heat

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