ISSN: 2278 – 7798
International Journal of Science, Engineering and Technology Research (IJSETR)
Volume 5, Issue 5, May 2016

KAIZEN TECHNIQUE APPLIED FOR "VALVE" USED IN PULSEJET ENGINE

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ABSTRACT

This paper was to develop a Kaizen Technique used in Carburetor of pulsejet engine. The primary design specifications of the engine were to produce ~1.5kg of thrust and to weight no more than 1kg. The engine development was divided into two phases. The first phase involved the development of an experimental engine which incorporated adjustable intake and exhaust lengths to allow for optimization. The second phase involved the design and fabrication of a Kaizen activity such as Carburetor and it's working with the pulsejet Engine. This Engine uses the Fuel 'Petrol', Air Compressor for air supply and CDI (Capacitor Discharging Ignition System) with Spark Plug for combustion process.

The Pulsejet engine represents an attractive alternative to current aerospace propulsion systems. The Pulsejet Engine is a highly reliable system which is economical to construct and maintain. Research and development of pulsejet engines has been mainly confined to enthusiast circles and small scale aerospace applications, such as UAVs.

INTRODUCTION

A pulsejet engine is essentially a hollow tube that utilizes sound waves to induce fluid flow and produce thrust.

Pulsejet engines have few moving parts making them economical to construct and maintain. This advantage makes them ideal for use in Unmanned Aerial Vehicles (UAVs); however, development within recent years has been confined to industrial projects and enthusiasts.

The pulsejet engine was first invented in 1864 (Russian inventor and artillery officer N. Teleshov) and relied on the vaporization of water. Later designs were air breathing and extensive research was conducted up until 1960 when it was concluded the design would not offer a feasible alternative to the developing turbine jet engines. After 1984, most interest was lost and interest was predominately from enthusiasts due to the limited costs. The simplicity of the engine and the possible aerospace applications provided the necessary motivation for further investigation.

This project aimed to develop a Reed valve with kaizen Technique applied for pulsejet engine that would be adapted as a propulsion system for a UAV. The primary design specifications of the engine were to produce 1.5kg of thrust and to weigh no more than 1kg. The thrust was to be measured with a universal test stand designed concurrently with the pulsejet and constructed as part of the project objectives. Prior to the design stage, a comprehensive literature review of research material was conducted on the pulsejet, including current research into the area. This helped to define possible engine configurations and the statistical data was used in the design the experimental engine. The experimental engine was adapted from an existing design, however the engine was designed to allow variability of the intake and exhaust lengths. The adjustable nature of the experimental engine allowed optimization, which provided important data for the final design.

A pulsejet simulation program was developed concurrently with design and fabrication of the experimental engine. The program predicted the thrust of the experimental engine and was used to investigate the performance of a number of different engine configurations based upon the experimental engine. This data was used in conjunction with the testing data to provide the geometric parameters for the final design.

PROJECTDEFINITION, SPECIFICATION AND OBJECTIVES

Project Definition

This project aimed to design, construct and test a pulsejet engine forthe eventual goal of developing a pulsejet powered UAV. The design wasformulated from theory and statistical data to produce an original pulsejet design.Testing was accommodated through the design of a test stand to measure thekey performance criteria of the engine during operation.

Project Specification

- The successful operation of the pulsejet design, conforming to the minimum performance criteria of a thrust of 1.5kg for an overall weight not exceeding 1kg.
- The successful operation of a thrust measurement stand capable of measuring instantaneous thrust with successful output to a computer.
- The successful operation of an experimental system and associated procedures to measure performance parameters of the engine. The parameters to be successfully measured are combustion chamber temperature and pressure, exhaust temperature, fuel flow rate and soundpressure level (SPL).
- All work must be conducted within the budget of the project.

CURRENT LITERATURE REVIEW

To gain an understanding of the pulsejet engine and to gain statistical data forthe design stage a review of current literature on pulsejets was conducted. Thissection outlines the mechanisms of pulsejet operation with a comparison to otheraerospace propulsion devices.

Valved Pulsejets

A valved pulsejet consists of four components; intake chamber, combustionchamber, exhausts runner and a mechanical valve. Figure 3-1 illustrates thelayout of a typical valved pulsejet design.

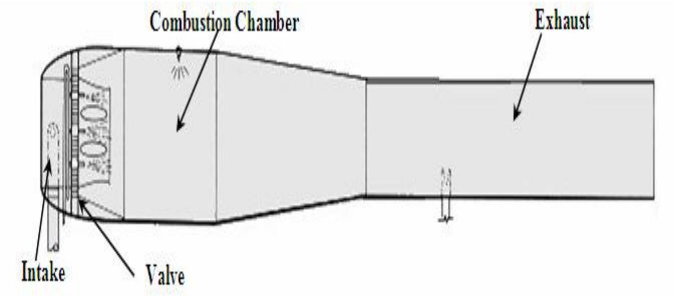


Figure Layout of Argus 014 (Luft46 2007)

A valved pulsejet works on the principal of wave rarefaction and the Kadenacyeffect. (**Michel Kadenacy** who obtained a French patent for an engine utilizing the effect in 1933)Air is introduced into the engine through the intake where it is mixed withthe fuel that is introduced through an injector. This air/fuel mixture is thentransferred through a mechanically operated valve into the combustion chamber.

Valve less Pulsejets

Principal

The principal of valveless pulsejets is much the same as for the valved case butwith the air in the intake and exhaust pipes acting as the valves to help containcombustion and increase combustion chamber pressure. Figure 3-2 illustrates asustained pulse cycle from start-up through two complete cycles.

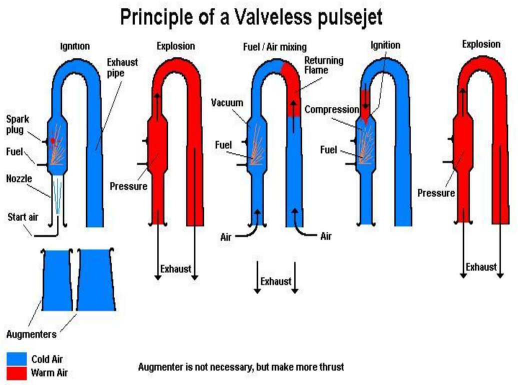


Figure Principal of a valveless pulsejet (Sunnhordvik 2007)

From Figure, the cycle starts with the initial air/fuel mixture in the combustion chamber being ignited by a spark or similar combustion initiator. Air is required toinitiate combustion and to promote the pulsating combustion. The initialexpansion of combustion chamber gas caused by combustion moves out of bothintake and exhaust runners, with the pressure waves generated by the combustion rarefacted at both ends. The intake runner is shorter than theexhaust so the intake wave is reflected first, drawing in the new charge of air thatis mixed with the fuel. The pressure wave in the exhaust is reflected causing thehot combustion gases to recede back into the combustion chamber. Ignitionoccurs in the fresh charge and the cycle repeats until the fuel is shut-off. In thiscase the intake pipe contributes to the thrust as the air can freely move throughthe pipe. Since the air is able to move freely these engines generally suffer fromlower levels of performance and efficiency as the post ignition confinement islower than valved designs (Simpson 2005).

Advantages and Disadvantages

Advantages

As with any form of aerospace propulsion, there are advantages anddisadvantages associated with pulsejet engines. The main advantage of apulsejet engine is the cost. Since there is either one moving part (valved) or nomoving parts (Reed valve), the main costs consist of the ancillary systemsrequired for operation, and the materials for engine construction. Thesecomponents are cheap to manufacture and the materials are readily available.The mechanical valves in the valved designs are also simple to manufacture andinstall. The lack of moving parts in a valveless design removes the need formaintenance and theoretically enhances reliability. This means that the enginesare cheap to purchase and cheap to maintain.

Disadvantages

The disadvantages of pulsejet engines are that they are extremely fuel inefficientwhen compared to other aerospace propulsion solutions. The specific fuelconsumption is of the order of 5.0-6.0 kg/kg/hr (Enics 2007) compared to aturbojet with 0.5-1.2 kg/kg/hr (Roskam 1985). Hence more fuel is required for anaircraft to have an appreciable range and this increases the weight of the aircraft.Another disadvantage of pulsejet engines is the pulsing action necessary foroperation, which creates high sound pressure levels and significant vibration thatemanates from the engine during operation. These vibrations contributesignificantly to fatigue in any airframe and expensive, heavy dampers arerequired to negate a substantial amount of these effects. The noise levelscreated by current pulsejet engines would result in hearing damage so adequatehearing protection is required for anyone working in the vicinity. Pulsejet enginesalso have a relatively short lifespan due to creep and fatigue due to the high material temperatures during operation. The main point of failure occurs with themechanical valves in valved pulsejets as they are under intense heat and impactstresses (Tharatt 1965). For the Reed valve pulsejet case, the main point of failureis the combustion chamber casing. The casing is subject to large thermal stress,oscillating pressure stress and therefore fatigue and creep cause a rupture afterrelatively short periods of time (Ogorolec 2005).

Ignition System

Ignition of the air/fuel mixture requires an external source. Modern pulsejetengines use electrical spark ignition systems. The ignitor is only required for ashort period at start-up and hence needs to be shut off immediately after ignitionto avoid impeding the pulsating cycle. Ignition systems range in complexity,although all provide the spark for a short period of time.

Air Assist System

For initial starting a volume of moving air is required to initiate the combustion process. There are several ways this can be achieved such as a leaf blower or high velocity air flow from an air compressor.

.**Figure Leaf blower air assist start (Simpson 2005)**

Figure 3-15 shows the starting procedure for a Lockwood-Hiller pulsejet with aleaf blower. As can be seen, this method requires the operator to be standing behind the engine at point of ignition and results in a large fireball directedtowards the operator. For our purposes this would be too dangerous. Converselythe flow from a compressor can be regulated from the compressor unit anddirected to the engine via a hose.

PULSEJET THEORY

The Reed valvepulsejet can essentially be approximated as a hollow tube withstrategically placed cross sectional area changes to facilitate operation. Asdiscussed in the literature review, the principles of operation behind all pulsejetdesigns are essentially the same; however, the method of achieving theoperation varies. The Reed valvepulsejet uses the intake process to seal thecombustion chamber during the combustion phase, as opposed to a valvedengine which uses a mechanical barrier. The physical principles of Reed valvepulsejet operation are extremely complicated given the simplicity of the design.The following discussion will cover the main operating principles and designconsiderations for a Reed valvepulsejet.

The underlying principle behind the success of the pulsejet as a thrust producingengine is the combustion of fuel within the engine through deflagration (Kentfield1998). Deflagration is a slow mode of combustion; therefore, without a method ofsealing of the combustion chamber, the potential pressure build up would bereleased from both the intake and exhaust. This would result in very little thrustproduction as the pressure gradient between the combustion chamber and theexhaust would be too low. To overcome this, the Reed valvepulsejet uses theKadenacy effect to contain the combustion gases from exiting through the intake.The pressure build up in the chamber produces a pressure differential betweenthe combustion chamber and the ambient conditions at the exhaust end.Assuming that v1 represents the gas velocity in the chamber and is 0m/s and v2represents the velocity by the end of the exhaust pipe, then using Bernoulli’s
Equation:

$$\frac{v_1^2}{2} + gh_1 + \frac{p_1}{\rho} = \frac{v_2^2}{2} + gh_2 + \frac{p_2}{\rho}$$

Assume height differences $(h_1 \text{ and } h_2)$ are negligible as $h_1 = h_2$ and this is africtionless, isentropic process then Equation 4.1 reduces to:

$$v_2 = \sqrt{\frac{2}{\rho}(p_1 - p_2)}$$

Since $p_1 > p_2,\ (p_1 - p_2) > 0$ and hence the velocity increases due to the pressuredifference between the points. This velocity increase provides the gas in thecombustion chamber with inertia. As the exhaust gases move from thecombustion chamber to the exhaust there is a partial vacuum within the chamber;this phenomenon is known as the Kadenacy effect (Tharratt 1965). It is thispartial vacuum which draws a fresh charge of air into the combustion chamber

through the intake and which allows the engine to be self sustaining.The inflow of fresh air into the combustion chamber provides the aerodynamicvalve for the subsequent combustion. This inflowing air is travelling at relativelyhigh velocity and the density of the gas is greater as the inflowing gastemperature is ambient temperature. Due to the momentum of the inflowing air,once combustion has been initiated, the moving air does not immediately reversedirection (Richardson, Artt, Blair 1982).

Program Structure

The method of characteristics was implemented using MATLAB which waschosen for its ease of programming, matrix handling, data logging and graphingcapabilities. Results were logged as ANSI text files and as matrices withinMATLAB in the virtual memory. Matrices were converted into graphs whereappropriate.The program consisted of one main function and twelve sub functions. Theprogram structure is shown in Figure 5-1.

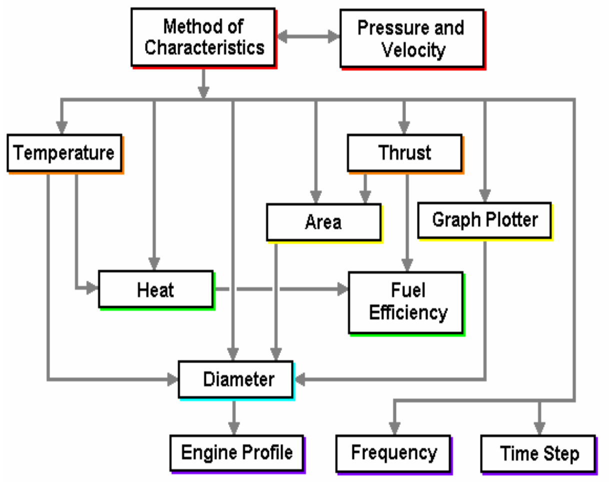


Figure 5-1 - Program block diagram

The numerous sub functions allowed specific tasks to be allocated separate functions. This condensed, and simplified, the overall program.

Mathematical Model

Fundamental Equations

The three fundamental laws which govern the model fluid dynamics are theconservation of momentum, first law of thermodynamics and continuity equation.

Continuity:

$$\frac{\partial \rho}{\partial t}+\rho\frac{\partial \rho}{\partial x}+u\frac{\partial p}{\partial x}+\frac{\rho u}{F}\frac{dF}{dx}=0 \qquad (5.1)$$

Momentum:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+\frac{1}{\rho}\frac{\partial \rho}{\partial x}+\frac{4f}{D}\frac{u^2}{|u|}=0 \qquad (5.2)$$

First law of thermodynamics:

$$q\rho F dx=\frac{\partial}{\partial t}\left[(\rho F dx)\left(C_v T+\frac{u^2}{2}\right)\right]+\frac{\partial}{\partial x}\left[\rho u F\left(C_v T+\frac{p}{\rho}+\frac{u^2}{2}\right)\right] \qquad (5.3)$$

The method of characteristics manipulates these equations using the Riemannvariables lambda (λ) and beta (β). The fundamental equations are solved alongthe lines with slope*du/dX*called characteristics. Along these lines, lambda andbeta are constant, reducing the number of system variables. The fundamentalequations, lambda, beta and the characteristics are defined below.

Lambda:

$$\lambda = A+\frac{\gamma-1}{2}U \qquad (5.4)$$

Beta:

$$\beta = A-\frac{\gamma-1}{2}U \qquad (5.5)$$

Characteristics:

$$\frac{dX}{dU}=U \pm A \qquad (5.6)$$

In this model, the lambda characteristic is used to solve rightward along the ductand the beta characteristic leftward.

To reduce the complexity of the analysis, the assumptions made for this modelare:

- The flow was quasi one-dimensional with uniform properties over any cross-section.
- Air is an ideal gas.
- Atmospheric conditions at pulsejet intake and exhaust ends.
- Bends in the pulsejet geometry were simplified as straight sections.
- Atmospheric conditions were constant.

Analysis

To determine if the model was a valid representation of a working pulsejet,several key parameters were identified. The major parameters were thecombustion chamber pressure profile, thrust history, particle tracing andfrequency.

Combustion Chamber Pressure

Combustion chamber pressure history was the most valuable piece of data as itwas used to estimate the maximum and minimum engine pressures, anddetermine the frequency of the pulsejet. Figure 5-6 shows the combustionchamber pressure profile for one completecombustion.

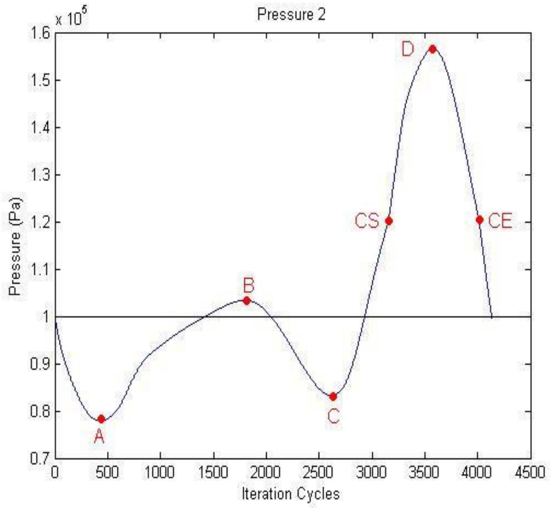


Figure- Combustion chamber pressure history

This diagram represents one complete cycle which took approximately 4300iteration cycles. The points of interest were:

- **A** – Rarefaction wave from initial pressure wave reflecting off intake.
- **B** – Positive pressure due to the Kadency Effect.
- **C** – Rarefaction wave from initial pressure wave reflecting off exhaust.
- **D** – The positive pressure wave from wave **B** reflecting off the exhaustand the positive pressure wave from wave **C** reflecting off the intakesuperimposing combined with the Kadency Effect.
- **CS** – Combustion starts.
- **CE** – Combustion ends.

When the combustion chamber pressure history was compared with thecombustion chamber pressure history of the S.N.E.C.M.A. (SociétéNationaledetruded et de Construction de Moteursd'Aviation) Escopette shown in Figure5-7, several similarities were observed.

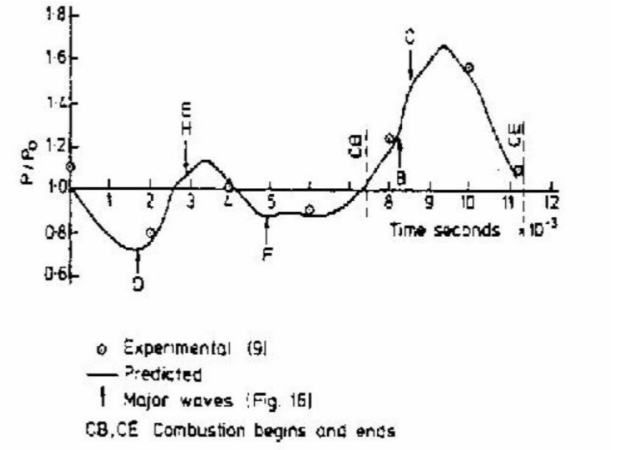


Figure- S.N.E.C.M.A. Escopette combustion chamber pressure (Benson et al 1963)

The similar combustion chamber pressure histories, indicated the programcorrectly predicted the pressure in the combustion chamber. The similarities ofnote were maximum combustion chamber pressure peaks, minimum combustionchamber pressure peaks and timing of waves entering combustion chamber.

Frequency

The program predicted an operating frequency of 82.7Hz. No data was availablefor comparison on this aspect of the engine's performance.

KAIZEN CARBURETOR

The Key Function of Kaizen Carburetor is "It act as a Carburetor as well as FuelPressure Regulator"

Carburetor

Carburetor is a device that blends air and fuel for an internal combustion engine. Carburetor is use to blend the air and fuel to the combustion chamber of an engine.

Carburetors have largely been supplanted in the automotive industry by fuel injection. They are still common on small engines for lawn mowers, rototillers, and other equipment.

The word *carburetor* comes from the French *carbure* meaning "carbide".*Carburer* means to combine with carbon (compare also carburizing). In fuel chemistry, the term has the more specific meaning of increasing the carbon (and therefore energy) content of a fluid by mixing it with a volatile hydrocarbon.

The carburetor was invented by an Italian, Luigi De Cristoforis, in 1876.A carburetor was developed by Enrico Bernardi at the University of Padua in 1882, for his MotricePia, the first petrol combustion engine (one cylinder, 121.6 cc) prototyped on 5 August 1882.

A carburetor was among the earlypatents by Karl Benz as he developed internal combustion engines and their components.

Principal

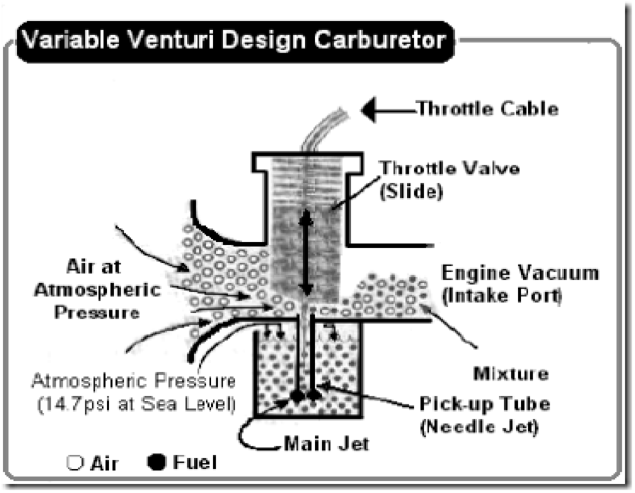
The carburetor works on Bernoulli's principle: the faster air moves, the lower its static pressure, and the higher its dynamic pressure. The throttle (accelerator) linkage does not directly control the flow of liquid fuel. Instead, it actuates carburetor mechanisms which meter the flow of air being pulled into the engine. The speed of this flow, and therefore its pressure, determines the amount of fuel drawn into the airstream.

Fixed-Venturi

In which the varying air velocity in the Venturi alters the fuel flow; this architecture is employed in most carburetors found on cars.

Variable-Venturi

In which the fuel jet opening is varied by the slide (which simultaneously alters air flow). In "constant depression" carburetors, this is done by a vacuum operated piston connected to a tapered needle which slides inside the fuel jet. A simpler version exists, most commonly found on small motorcycles and dirt bikes, where the slide and needle is directly controlled by the throttle position. The most common variable Venturi (constant depression) type carburetor is the sidedraftSU carburetor and similar models from Hitachi, Zenith-Stromberg and other makers.



Fuel Pressure Regulator

A **Fuel pressure regulator** is a valve that automatically cuts off the flow of a fuel at a certain pressure. Regulators are used to allow high-pressure fluid supply lines or tanks to be reduced to safe and/or usable pressures for various applications.

A Fuel pressure regulator's primary function is to match the flow of fuel through the regulator to the demand for fuel placed upon the engine. If the load flow decreases, then the regulator flow must decrease also. If the load flow increases, then the regulator flow must increase in order to keep the controlled pressure from decreasing due to a shortage of fuel in the fuel tank.

Air Fuel Ratio

Air–fuel ratio (**AFR**) is the mass ratio of air to fuel present in a combustion process such as in an internal combustion engine or industrial furnace. If exactly enough air is provided to completely burn all of the fuel, the ratio is known as the stoichiometric mixture, often abbreviated to **stoic**. For precise AFR calculations, the oxygen content of combustion air should be specified because of possible dilution by ambient water vapor or enrichment by oxygen additions. The AFR is an important measure for anti-pollution and performance-tuning reasons. The lower the AFR, the "richer" the mixture.

AFR Synopsis

In theory a stoichiometric mixture has just enough air to completely burn the available fuel. In practice this is never quite achieved, due primarily to the very short time available in an internal combustion engine for each combustion cycle. Most of the combustion process completes in approximately 4–5 milliseconds at an engine speed of 6,000 rpm. (100 revolutions per second; 10 milliseconds per revolution) This is the time that elapses from when the spark is fired until the burning of the fuel–air mix is essentially complete after some 80 degrees of crankshaft rotation. Catalytic converters are designed to work best when the exhaust gases passing through them are the result of nearly perfect combustion.

Stoichiometry of Fuel

Is the ideal combustion process where fuel is burned completely? A complete combustion is a process burning all the carbon (C) to (CO_2), all the hydrogen (H) to (H_2O) and all the sulphur (S) to (SO_2).With unburned components in the exhaust gas, such as C, H_2, CO, the combustion process is uncompleted and not stoichiometric .

To determine the **excess air** or **excess fuel** for a combustion system we starts with the stoichiometric **air-fuel ratio**. The stoichiometric ratio is the perfect ideal fuel ratio where the chemical mixing proportion is correct. When all fuel and air burned is consumed without any **excess** left over.

Process heating equipment are rarely run that way. "On-ratio" combustion used in boilers and high temperature process furnaces usually incorporates a modest amount of **excess air -** about 10 to 20% more than what is needed to burn the fuel completely.

If an insufficient amount of air is supplied to the burner, unburned fuel, soot, smoke, and carbon monoxide exhausts from the boiler - resulting in heat transfer surface fouling, pollution, lower combustion efficiency, flame instability and a **potential for explosion**.

Figure – Kaizen Carburetor used in PulseJet Engine Fixed Venturi Brass Tube

The Venturi is a restriction inside the Carburetor that forces fuel to speed up to get through a river suddenly narrows can be used to illustrate what happens inside a crab. The Water in the river speeds up as it gets near the narrowed shores and will get faster if the river narrows evermore. The same thing happens inside the carburetor. The fuel that is speeding up will cause atmospheric pressure to drop inside the carburetor. The faster the fuel moves, the lower the pressure inside the carburetor. This is called as Venturi effect.

Venturi Effect

The **Venturi effect** is the reduction in fluid pressure that results when a fluid flows through a constricted section of pipe. The Venturi effect is named after Giovanni Battista Venturi (1746–1822), an Italian physicist.In fluid dynamics, a fluid's velocity must *increase* as it passes through a constriction in accord with the principle of continuity, while its static pressure must *decrease* in accord with the principle of conservation of mechanical energy. Thus any gain in kinetic energy a fluid may accrue due to its increased velocity through a constriction is balanced by a drop in pressure.

By measuring the change in pressure, the flow rate can be determined, as in various flow measurement devices such as venturi meters, venturi nozzles and orifice plates.

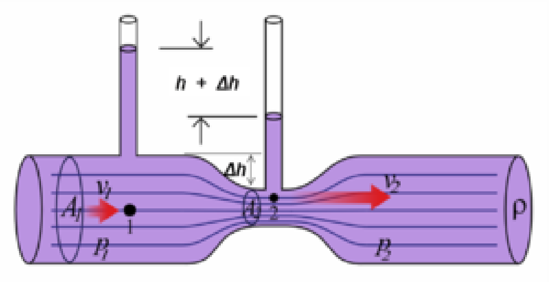


Figure –The pressure in the first measuring tube (1) is higher than at the second (2), and the fluid speed at "1" is lower than at "2", because the cross-sectional area at "1" is greater than at "2"

Air Hose with inclined source blow pipe

In order to get this "proper" mixture of gas and air, Air has to be blown in to the carburetor As air rushes through the carburetor on its way into the engine, it is forced to accelerate through a narrowed part of the carburetor called the venturi. A low pressure pocket is created at this point of the air's acceleration. The carburetor designer suspends a tube from this place and submerges it into fuel. Fuel will then wick up the tube and into the intake manifold of the engine. Just as in a plant sprayer, the fuel is encouraged up the tube by the differences in pressure. The difference between the fuel at atmospheric pressure and the venturi at less than atmospheric This seemingly magically moved fuel is being discharged in sheets. The engine doesn't like that. It prefers an air/fuel mist -- droplets -- because a mist is easier to vaporize (turn into a gas -- the engine won't burn a liquid). To get that mist, the carburetor's fuel tubes have to be drilled full of a little holes. These holes are connected to an atmospheric vent in the carburetor. This system will cause the fuel to aerate as it rises upward. It's called an air bleed, and every carburetor has two holes.

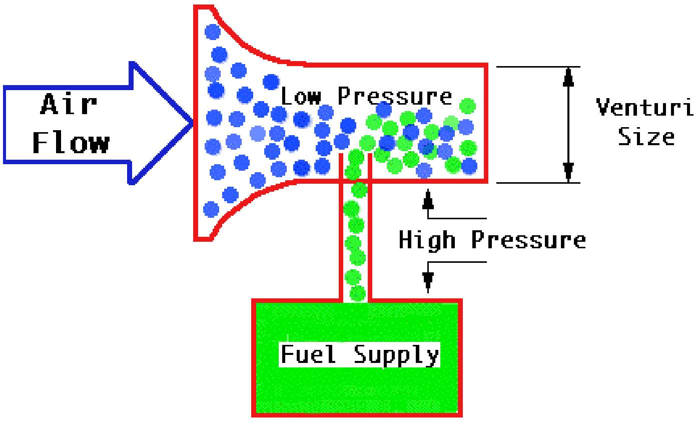


Figure Block Diagram

Parts of Pulsejet Engine

- Air Compressor or Air Supply
- Fuel Tank
- Ignition System (CDI)
- Spark Plug
- Vent Tube
- Engine

** Kaizen Carburetor/Fuel Flow Regulator*

** Valve Head*

**Lock Ring*

** Reed Valve*

** Valve Plate Stopper/Releaser*

** Washer*

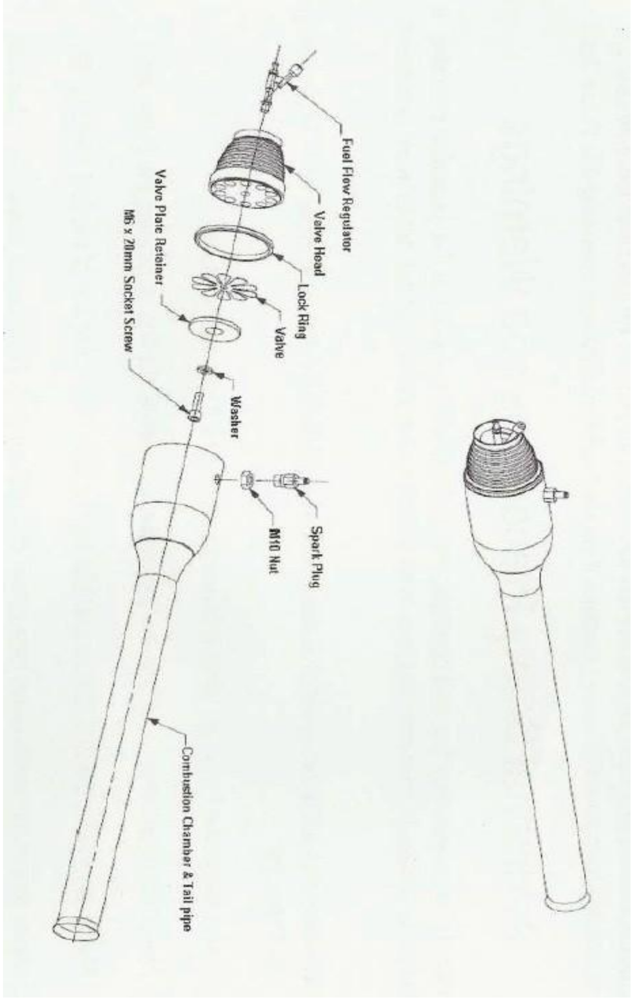
** M6 x Socket Screw*

** Spark Plug*

** Combustion Chamber with Tail Pipe*

- Engine Holder Clamps
- Engine Stand
- Hearing Protection
- Fire Extinguisher

WORKING PROCESS OF PULSEJET ENGINE



CONCLUSION

- ➢ Thus the modified design of Lockwood's pulsejet engine was analysed and the results are tabulated.
- ➢ Although there has been extensive pressure and thrust data documented in this work, there has been little work done in optimizing the pulsejet's operation based on the secondary inlet in that engine.
- ➢ By compare with the existing design of Lockwood's pulsejet engine, the modified design gives more thrust and the efficiency also increases.
- ➢ •Here the exhaust temperature will decrease. So, the engine surface will not get more heated. And the expected results are came out. When testing the pulsejet for optimal thrust,
- ➢ the jet would need to be tested in several different modes and geometries.
- ➢ Changing the overall length of the jet, exit diameter, and exit geometry would be interesting topics to investigate

REFERENCE

1) Bertin, Raymond, "Over view of the Escopette Pulsejet", SNECMA Note E.S.VII-29, http://www.pulse-jets.com/phpbb2/files/escopette.pdf, October 1951.

2) Boyarko, George A. et al.,"Catalyzed Combustion of Hydrogen - Oxygen in Platinum Tubes for Micro-Propulsion Applications." 42nc AIAAAerospace Sciences Meeting. (2004).

3) Cheung, W S and J R Tilston, "Testing of aNovel Propulsion System for Micro Air Vehicles", Proceedings of the Institution of Mechanical Engineers, Vol 215, 207 -217.

4) Dellimore, Kiran and Christopher Cadou., "Fuel-Air Mixing Challenges in Micro Power Systems", 42 Aerospace Sciences Meeting and Exhibit., (2004).

5) Emeriti, L., "Development of pulse- jet engines for a helicopter rotor system, summary report," Report No. 163 - W - 1, American Helicopter Company, January 1953.

6) Foe , J. V., Elements of Flight Propulsion, John Wiley & Sons, New York, 1960.

7) Goebel, Greg, "The V-1 Flying Bomb", http://www.axishistory.com/index.php?id=1362, August 2005.

8) Gwynn, John, "The History of the Pulse Jet ", http://waterocket.explorer.free.fr/vl flying bomb.htm, August 2005.

9) Le Bot, Dr. Jean and Gwynn, John, "Désiré ThomasPiot", http://waterocket.explorer.free.fr/piot.htm, August 2005.

10) Lockwood, R. M., "Pulse reactor lift - propulsion system development program, "final report", Advanced Research Division Report No. 508, Hiller Aircraft Company, March 1963.

11) Logan, J. G., Jr., "Summary report on valveless pulsejet investigation," Project SQUID Technical Memo No. CAL- 42, Cornell Aeronaut. Laboratory, October 1951.