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RESEARCH ARTICLE

ESTIMATION OF MECHANICAL PROPERTIES OF WATER AUGMENTED PULSE JET ENGINE

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Abstract

The objective of this project work is to understand the thermodynamic characteristics of conventional pulse jet. The geometrical parameters and performance aspects of the engine were studied including specific fuel consumption, thrust. Calculation was made on geometrical parameters for a design of a pulse jet engine of 100lb thrust. We use the valve less pulse jet engine to simplify engine complexity. We use the MAT LAB to analysis the pulse jet engine.

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Introduction:-

A pulsejet engine (or pulse jet) is a type of jet engine in which combustion occurs in pulses. A pulsejet engine can be made with few or no moving parts, and is capable of running statically. Pulsejet engines are a lightweight form of jet propulsion, but usually have a poor compression ratio, and hence give a low specific impulse. One notable line of research of pulsejet engines includes the pulse detonation engine, which involves repeated detonations in the engine, and which can potentially give high compression and reasonably good efficiency.

Objective:-

The research objective of this work was to investigate the fluid mechanic, acoustic, and thermodynamic processes of a generic valved pulsejets. Computational techniques using MATLAB are used to provide physical insights into the pulsejet's operation and help experimental personnel to build a micro scale pulsejet. The operating cycle of the pulsejet designs is studied and a more complex acoustic model that accounts for the combustion chamber volume, inlet and exhaust pipe geometry is proposed. This research uses a computational approach to investigate the characteristics of pulsejets which is then compared with established pulsejet engine data to validate the program. The information and formulae used are based on collections of scientific papers, books and literatures from Russia, United States and European countries. Based on published data of known pulsejet, a comparison of published data and calculated data are studied to validate the computer results.

The objective of this research is to investigate the possibility of using pulsejets in certain applications where the pulsejet can trade its low efficiency with low cost, simple design, and light weight. The research objectives include the principles of valved pulsejet design; optimize valved pulsejet geometries and the effect of geometry of inlet, combustion chamber and tailpipe.

To achieve this objective, the following goals are carried out:

1. To write a MATLAB program to calculate size and dimension of main parts of engine (valve, valve head, valve retainer, combustion chamber, exhaust) using fundamental and derived equations to produce a pulsejet engine.

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2. To calculate design parameters and to design required pulsejet engine using CAD/CAM program provided.
3. To validate the computer program by comparing computed data with published data of selected pulsejet engines.
4. Provide guidelines for designing a small-scale pulse jet engine.

Methodology:-

This paper summarizes the design and performance of pulse jet engine analysis in drag performance on MAT LAB software analysis of pulse jet engine. This paper specifies how the pulse jet engine is analyzed and the analysis of the maximum thrust and various parameters.

Work flow:**Step 1:****Study of journals in:**

1. In Pulse jet engine.
2. In Nozzle.

Step 2:**Study to choosing materials for model making in:**

1. Pulse jet engine.
2. Suitable stand.
3. Material used for stand.
4. Circuit used for pulse jet engine.

Step 3:

To design and calculate the effective dimension for the pulse jet engine.

Step 4:

Analysis the previous result of the pulse jet engine.

Step 5:

To create the CAD model.

Step 5:

Then analysis the model using MAT LAB.

Step 6:

Then compare the results with various parameters.

Step 7:

Then check the efficiency of the engine.

Function:

The combustion cycle comprises five or six phases depending on the engine: Induction, Compression, (optional) Fuel Injection, Ignition, Combustion, and Exhaust.

Starting with ignition within the combustion chamber, a high pressure is raised by the combustion of the fuel-air mixture. The pressurized gas from combustion cannot exit forward through the one-way intake valve and so exits only to the rear through the exhaust tube.

The inertial reaction of this gas flow causes the engine to provide thrust, this force being used to propel an airframe or a rotor blade. The inertia of the traveling exhaust gas causes a low pressure in the combustion chamber. This pressure is less than the inlet pressure (upstream of the one-way valve), and so the induction phase of the cycle begins.

In the simplest of pulsejet engines this intake is through a venturi, which causes fuel to be drawn from a fuel supply. In more complex engines the fuel may be injected directly into the combustion chamber. When the induction phase

is under way, fuel in atomized form is injected into the combustion chamber to fill the vacuum formed by the departing of the previous fireball; the atomized fuel tries to fill up the entire tube including the tailpipe. This causes atomized fuel at the rear of the combustion chamber to "flash" as it comes in contact with the hot gases of the preceding column of gas—this resulting flash "slams" the reed-valves shut or in the case of valveless designs, stops the flow of fuel until a vacuum is formed and the cycle repeats.

Valveless design:

The second type of pulsejet is known as the valveless pulsejet. Technically the term for this engine is the acoustic-type pulsejet, or aerodynamically valved pulsejet.

Valveless pulsejets come in a number of shapes and sizes, with different designs being suited for different functions. A typical valveless engine will have one or more intake tubes, a combustion chamber section, and one or more exhaust tube sections.

The intake tube takes in air and mixes it with fuel to combust, and also controls the expulsion of exhaust gas, like a valve, limiting the flow but not stopping it altogether. While the fuel-air mixture burns, most of the expanding gas is forced out of the exhaust pipe of the engine. Because the intake tube(s) also expel gas during the exhaust cycle of the engine, most valveless engines have the intakes facing backwards so that the thrust created add to the overall thrust, rather than reducing it.

The combustion creates two pressure wave fronts, one traveling down the longer exhaust tube and one down the short intake tube. By properly 'tuning' the system (by designing the engine dimensions properly), a resonating combustion process can be achieved.

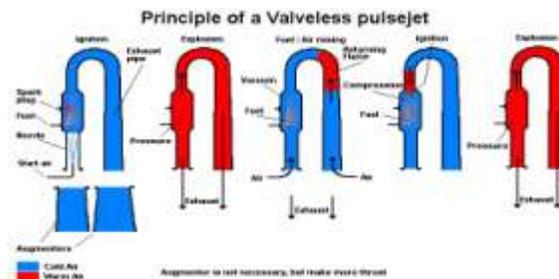


Figure 1:- Working U-Shaped Valveless Pulse Jet Engine.

While some valveless engines are known for being extremely fuel-hungry, other designs use significantly less fuel than a valved pulsejet, and a properly designed system with advanced components and techniques can rival or exceed the fuel efficiency of small turbojet engines.

In 1909, Georges Marconnet developed the first pulsating combustor without valves. It was the grandfather of all valveless pulsejets. The valveless pulsejet was experimented with by the French propulsion research group SNECMA (Société Nationale d'Étude et de Construction de Moteurs d'Aviation), in the late 1940s.

The valveless pulsejet's first widespread use was the Dutch drone Aviolanda AT-21. A properly designed valveless engine will excel in flight as it does not have valves, and ram air pressure from traveling at high speed does not cause the engine to stop running like a valved engine. They can achieve higher top speeds, with some advanced designs being capable of operating at Mach 0.7 or possibly higher.

The advantage of the acoustic-type pulsejet is simplicity. Since there are no moving parts to wear out, they are easier to maintain and simpler to construct.

Thermodynamic cycle operation:

Lenoir cycle:

The Lenoir cycle is an idealized thermodynamic cycle often used to model a pulse jet engine. It is based on the operation of an engine patented by Jean Joseph Etienne Lenoir in 1860. This engine is often thought of as the first

commercially produced internal combustion engine. The absence of any compression process in the design leads to lower thermal efficiency than the more well-known Otto cycle and Diesel cycle.

The cycle:

In the cycle, an ideal gas undergoes

1-2: Constant volume (isochoric) heat addition;

2-3: Isentropic expansion;

3-1: Constant pressure (isobaric) heat rejection.

The expansion process is isentropic and hence involves no heat interaction. Energy is absorbed as heat during the isochoric heating and rejected as work during the isentropic expansion. Waste heat is rejected during the isobaric cooling which consumes some work.

Cycle Diagrams:

P-V diagram:

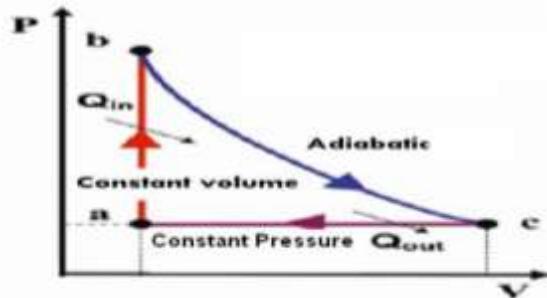


Figure 2:- P-V Diagram.

T-S diagram:

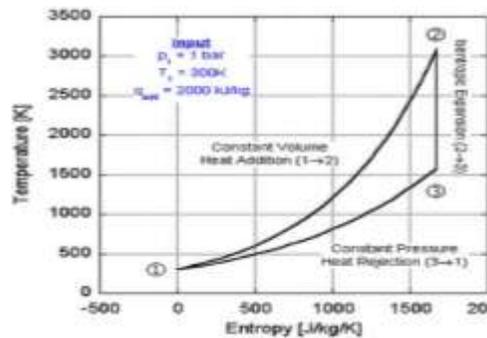


Figure 3:- T-S Diagram.

Data analysis:

There are two methods currently used in studying the pulsejet engine design. They are experimental method which involves extensive engine testing and computer aided numerical investigations. For engine performance testing the speed range may vary from Mach number 0.2 to 0.9 in order to analyze the engine characteristic for all flight region. Difficulties arise when the test facilities are limited and involve higher cost to perform the studies.

Pulsejet engine design:

The design drawings in CATIA provide the detail dimensions and the weight of engine. The calculated (computed) result of pulsejet engine parameters are provided by MATLAB program.

Two main objectives will discuss in this chapter, i.e. calculated pulsejet engine sizes and dimensions; and the pulse jet engine performance analysis. For the first objective the calculated engine size and dimensions are compared with published pulse jet engines. For this purpose, twelve engines around the world were collected to study the engine

design and characteristics. The second objective is the engine performance analysis based on the altitude and Mach number of the vehicle that are powered by pulse jet engines.

Comparison of calculated data with published data of known pulse jet engines:

The lists of computed pulse jet design size and parameters which are based on engine thrust whilst provides published data of known pulse jet engine. The dimensions (combustion chamber diameters and length; and exhaust pipe diameters) of calculated results are plotted in Figure 4-1(Thrust VS Combustion Chamber Diameter), and Figure 4-2 (Thrust VS Exhaust Pipe Diameter)

Table 1:- Combustion Chamber Diameters And Exhaust Pipe Diameters.

Pulse jet Engine Types	Thrust (g)	COMBUSTION CHAMBER DIAMETER (original design) (mm)	COMBUSTION CHAMBER DIAMETER (calculated design) (mm)
A-5ML	700	48	47
D-65-2	1700	65	62
RAMJET1	1500	65	59
LETMO MP-250	2270	64	69

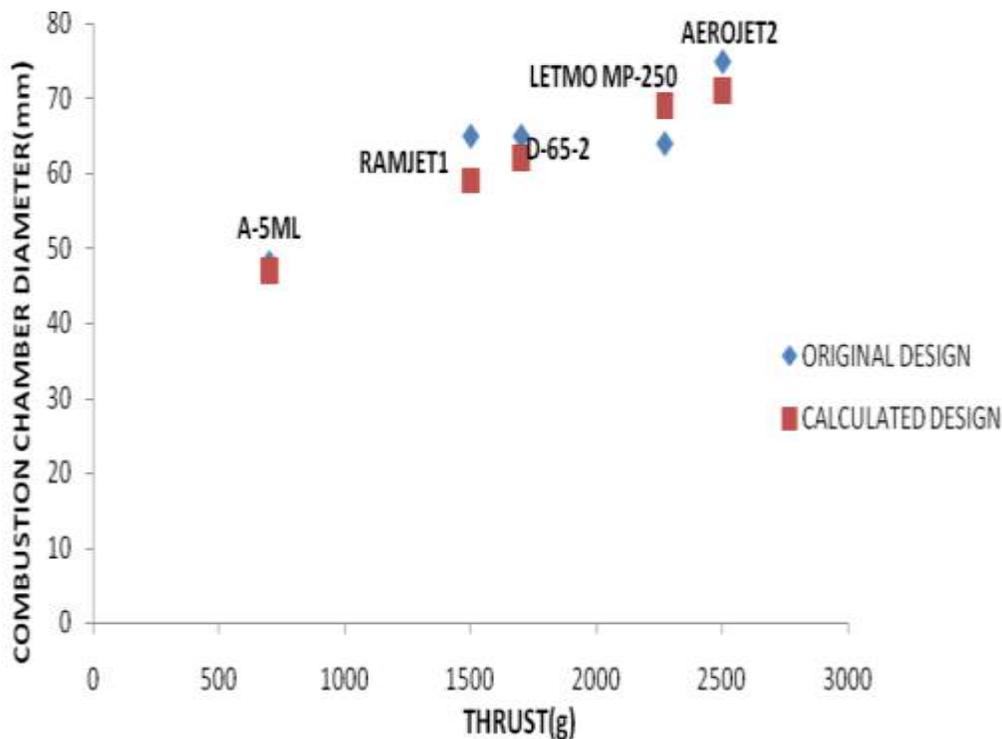


Figure 4:- Combustion chamber diameter vs thrusts showing published and calculated data.

Table 2:- Exhaust Pipe Diameter (Calculated and Published Data).

pulsejet engines types	thrust (g)	exhaust pipe diameter (original design) (mm)	exhaust pipe diameter (calculated design)
d-65-2	1700	33	31
ramjet2	2500	38	35
mew-307	1360	32	29
tigerjet m1	800	22	24

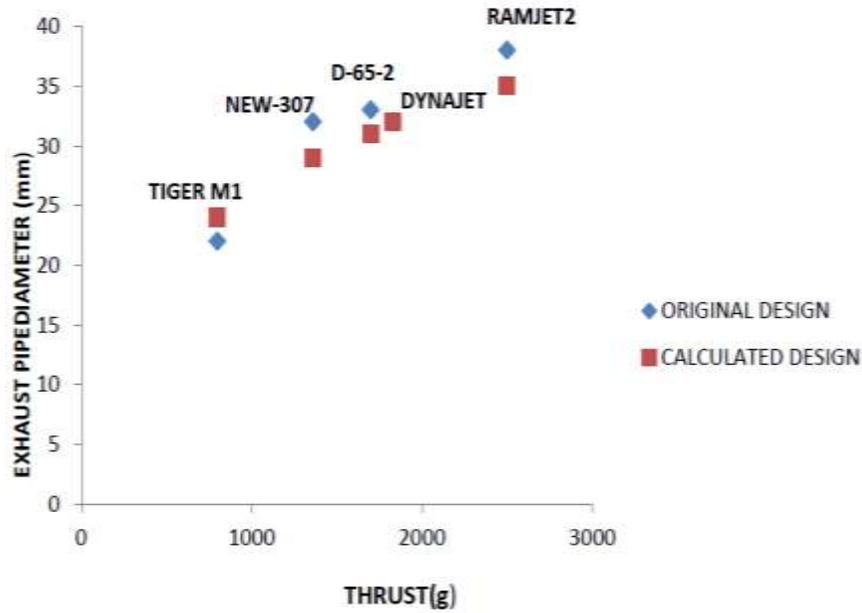


Figure 5:- Exhaust pipe diameter vs thrusts showing published and calculated data.

Both Figures 8 and figure 9 shows good resemblance of calculated results with the published data of the specific pulse jet engines. This provides a better assurance of the MATLAB program in terms of its accuracies and representations of real pulsejet engine that had been tested and used in various propulsion applications.

Result:-

Given data for engine analysis:

Table 3:- Exhaust pipe diameter (calculated and published data).

1)	M	Mach number	0.2 -0.9
2)	R	Universal gas constant	287 (J/Kg.J)
3)	C_D	Drag coefficient	0.7
4)	Γ	Specific heat ratio for air	1.7
5)	γ_m	Specific heat ratio for mixture	1.4
6)	LCV	Lower calorific value	44(MJ)
7)	H	Combustion efficiency	95%

Pulsejet engine performance data (mean sea level) and (Mach number=0.2):

Table 4: Performance Data

No	Symbol	Definition	Result (metric)
1	F_i	Thrust	71N
2	V	Flight speed	68 m/s
3	m_a	Mass of air	4.2 kg
4	m_f	Mass of fuel	0.28kg
5	m_m	Mass of mixture	4.5 kg
6	P_0	Free atmospheric pressure	2938 (kpa)
7	P_1	Pressure after closing valve	3021(kpa)
8	T_1	Temperature after closing valve	290K
9	P_2	Pressure in combustion chamber	1510(kpa)
10	T_2	Temperature in combustion chamber	290k
11	T_3	Temperature at the end of combustion	2840k

12	P_3	pressure at the end of combustion	14777(kpa)
13	M_e	Exit mach number	9.8
14	P_e	Exit pressure	843(kpa)
15	T_e	Exit temperature	253k
16	Q_{in}	Internal heat	301 m/s
17	h	Specific enthalpy	12627 Kj

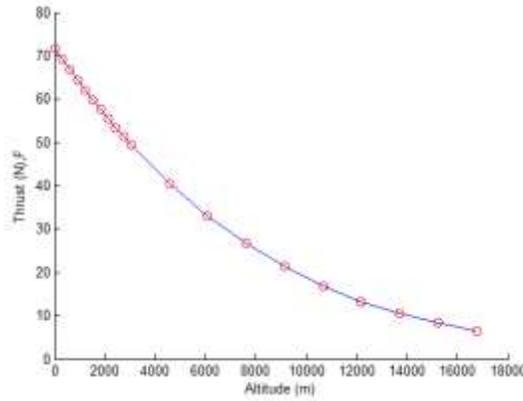


Figure 6:- Thrust Vs Altitude Graphs.

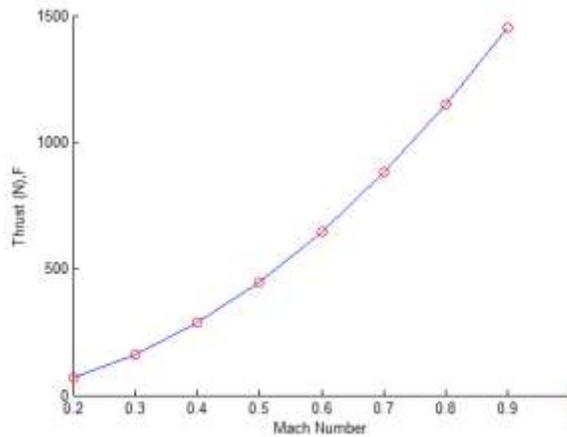


Figure 7:- Mach Number-Thrust Graphs.

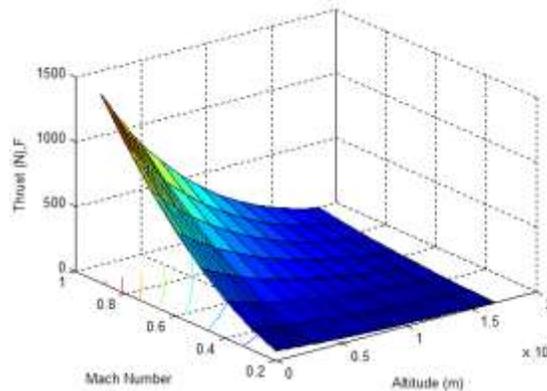


Figure 8:- Mach Number-Vs Thrust Graphs.

Figure 6 shows thrust decreases as altitude increases. Because the air is less dense at higher altitudes, drag reduces, but for the same reason thrust reduces. The balance of these two effects in any particular case determines the altitude at which the maximum envelope airspeed will be reached. In the denser air at low altitudes, both drag and thermal

heating are much greater than at high altitudes. Figure 7 shows that thrust increases with Mach number. High airspeeds in dense air are limited by airplane structure considerations.

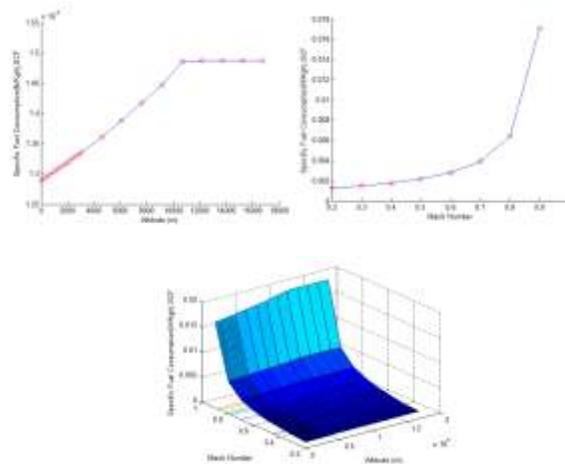


Figure 9:- Specific Fuel Consumption.

As shown in Figure 9 by increasing the amount of fuel, the thrust of the unit will increase due to higher explosion pressure. Higher explosion pressure gives better efficiency of explosion or lower specific fuel consumption.

Conclusions:-

The research accomplished in this work attempts to provide sizing and dimensions of valved pulsejet engines and to evaluate its performance. To determine characteristics of performance, chamber pressure and temperature, thrust, and operating frequency were computed and are presented for comparison with published engine data. The computed results agree well with published data. The comparisons show good agreement between computed data and published data which provides confidence in the analysis of valved pulsejet engine.

From the computer analysis presented above, the following relevant conclusions drawn from this work are as follows:

There is a direct correlation between frequencies and diameters of exhaust pipe/combustion chamber. The frequencies reduce with increase in diameters. However the frequencies reduce rapidly with increase in combustion chamber diameter as compared to that of the exhaust pipe.

There is also a direct relationship between thrust and combustion chamber diameter and length. The thrust increases with increase in chamber diameter and length. This relationship provides good trade off in choice of combustion chamber size depending on the application of the pulsejet engine.

The pulsejet engine combustor that shows a net pressure gain between the intake and the exhaust. The exhaust pressure is higher than the intake pressure. There is pressure gain across the combustor, rather than loss. This is very important, accordingly, a small percent gain in combustion pressure achieved by this method gives about the same improvement in overall efficiency as a high percent gain produced by a compressor, all other things being equal. Hence efforts in increasing combustion efficiency of pulsejet engines are the main roles of scientific research in pulse detonation engine.

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