DESIGN AND CFD ANALYSIS OF PULSE JET ENGINE

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ABSTRACT

Pulse jet engines or Pulsejets are family of internal combustion engine that have few or no moving parts. The project design and analysis of pulsejet engine is based on thrust produce in form of pulses. This is a powerful jet unit and one which can be made by anyone with access to lathe and welding facilities with few or no moving parts. The main purpose to design pulse jet engine is to produce high amount of thrust by performing analysis on jet engine. These engines are an efficient and simple way to convert fuel into heat. Pulsejets are used today in target drone aircraft, home heating equipment, fog generation purpose and many more. The reason they are called pulse jets, is due to how they produce intermittent pulses of thrust. The Main Purpose of this project is to design PJ15 pulse Jet Engine and analysis it on different Mass Flow rate at different Pressures. Pulsejets can be fitted with specially shaped ducts called Thrust Augmenters, which increase thrust output by harnessing aerodynamic forces, exhaust gas heat, and providing a reactive surface for high velocity pulses of exhaust to pull in additional air and transfer momentum to it. and for selecting the best material for making pulse jet engine we have consider mainly two materials titanium and monel mainly. The pulse jet body will be designed and analysis will be done using the SOLID WORKS 2016.

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 fewor no moving parts, and is capable of running statically (i.e. it does not need to have air forced into its inlet typically by forward motion). 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 good efficiency.

Fig 1.1 Process Of Combustion

Literature Review:
Current research status Although in pilot tests and technical reports of pulse combustion dryers, short drying time, high energy efficiency and product quality are generally reported, there are few theoretical studies of the pulse combustion drying process. Liu et al (2001) demonstrated experimentally that the pressure amplitude and the oscillating frequency of the unsteady flow, generated by Helmholtz pulse combustor, enhanced the convective heat transfer coefficient. Smucrowicz (1999) carried out research on in-situ analysis of the mechanism of the pulse combustion spray drying process. There are a number of attempts at mathematical modeling of the conventional spray drying processes (Masters, 1994; Kuts, 1996; Bahu, 1999; Walton, 2000; Huang, et al, 2003), while there are only a few attempts to model the pulse combustion spray drying process. Smucrowicz (1999) and Wu et al (2002) have conducted CFD modeling of the pulse combustion spray drying process. Experimental and simulation results showed the complex nature of the pulsating flow in the drying chamber and the very rapid decrease of material moisture content in the intensive drying. Some possible mechanisms enhancing the drying process were also discussed. Wu et al (2002) have also conducted experiments in which the pulsating gas jet from pulse combustor was used to directly atomize and dry the slurry (a solution of 10% NaCl). Size distribution of droplets atomized by the pulsating gas jet was also measured at the China Agricultural University, Beijing. To improve the fundamental understanding of the pulse combustion spray drying process, more R&D effort is required. It is still not known how the high temperature, pulsating flow field generated by a pulse combustor enhances the mass and heat transfer in the drying process. Also, there is still uncertainty about the use of the appropriate turbulence model for the strongly pulsing, high temperature, highly turbulent flows.

THEORETICAL BACKGROUND

Pulse combustion:

Historical development Pulse combustion is not a new concept. Heat-excited acoustic oscillations were first reported by Higgins in 1777, who observed the so-called hydrogen “singing” flames in tubes (Tyndall, 1897). Later, in 1859, Rijke discovered that strong acoustic oscillations appeared when a heated metallic grid was positioned in the lower half of a vertical tube opened at both ends (Lord Rayleigh, 1945). The pulse combustor with mechanical valves was first built by Esnault-Pelterie in France in 1906 and it was used as a drive for a gas turbine. In 1909, Marconnet constructed the first pulse combustor with an aerodynamic valve for propulsion. Although his basic patent was for a mechanically-valved unit, his design (Figure 2.1) is similar to many aero-valved current units. It consisted of two diffusers: inlet and outlet. The recirculation of fuel and air flows in this configuration resulted in the specific combustion chamber where the combustible mixture was ignited by spark plug.

![Fig: Marconnet pulse combustor](image-url)

In 1931, Paul Schmidt obtained a German patent on the pulse combustor shown in Figure 2.2. A new feature of this combustor is the injection of the fuel downstream of the mechanical valve rather than...
upstream of it (Putnam et al., 1986). This design of essentially uniform cross section through the combustion chamber and resonance tube became known as the Schmidt design. The pulse combustion technology developed by Schmidt was utilized to produce thrust for propulsion of the German V-1 “buzz” flying bomb during the Second World War (or the Cruise missile in more modern terms) (Wojcicki, 1962).

In the following years, the interest in pulse combustion declined due to relatively poor specific fuel consumption, and low specific thrust produced by pulse combustors compared with the more modern thrust producers such as the turbojets or turbofans. A major development in the field of pulse combustor was made in the 1950’s when the mechanical valves were replaced by an inertial gas valve. Since the 1970’s, the pulse combustion technology has been re-examined for use in different applications, e.g. boilers, heat exchangers, dryers, etc, where high combustion efficiency and low toxic components of the combustion gases is necessary. A detailed review of various pulse combustion applications is presented in Section 2.1.5

2.2 Operating principle:

Although pulse combustion systems have been known for many years, a detailed fundamental understanding of their operations is still lacking. Taking the “Helmholtz” type pulse combustor as an example, let us analyze the basic mechanism of the pulse combustion process. Figure 2.3 shows a schematic diagram of a “Helmholtz” type pulse combustor and the sequence of processes that result in pulse combustion.

This pulse combustor consists of a fuel and air inlet (flapper valves), a cylindrical combustion chamber and long tailpipe. When the engine is ignited, the fuel and air mixture in the chamber combusts explosively,
resulting in a rapid gas pressure rise from Point A to B. In this stage, valves are closed due to the higher gas pressure in the combustion chamber than the ambient one. The hot flue gases are forced through the tailpipe to the applicator. Then, the continuing outward momentum and depleting of fuel causes the pressure in the chamber to decrease gradually toward Point C. Eventually, the pressure falls below atmospheric pressure and vacuum forms in the combustion chamber. In phase 3, Purge and Recharge, vacuum in the chamber will result in (1) valve starts to open and admit fresh charge of air and fuel into the combustion chamber (2) the outwards moving flue gas slows down and some combustion gas in tailpipe is sucked back. In phase 4, Recharge and Compress, fuel and air re-enters from its inlet ports respectively. The influx of fresh mixture and some hot flue sucked back causes the pressure to rise above ambient. At the same time, this new charge of air and fuel mixture ignites itself due to contact with hot flue gases sucked back. Now, the combustor is in Phase 1 and a combustion cycle is achieved. This cycle repeats itself at a natural frequency depending on the geometry of the combustion chamber and characteristics of the tailpipe-applicator system. Although the construction of the pulse combustor shown in Figure 2.3 is simple, the processes that occur in the pulse combustor are very complicated: they involve a three-dimensional, transient flow field that is turbulent, and has variable physical properties, a resonant acoustic pressure field, and a large transient energy release. To sustain the oscillation of the combustion process, all aspects of the combustor system are highly coupled. Rayleigh’s criterion until now, no special criterion has been derived for the design of pulse combustors.

Introduction To Solid Works:

Solid works mechanical design automation software is a feature-based, parametric solid modeling design tool which advantage of the easy to learn windows™ graphical user interface. We can create fully associate 3-D solid models with or without while utilizing automatic or user defined relations to capture design intent.

Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Numeric parameters can be associated with each other through the use of relations, which allow them to capture design intent. Design intent is how the creator of the part wants it to respond to changes and updates.

Designing Of Pulse Jet Engine:

Fig: Drawing for a pulse jet engine

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SOLIDWORKS FLOW SIMULATION
Solid Works Flow Simulation 2010 is a fluid flow analysis add-in package that is available for Solid Works in order to obtain solutions to the full Navier-Stokes equations that govern the motion of fluids. Other packages that can be added to Solid Works include Solid Works Motion and SolidWorks Simulation. A fluid flow analysis using Flow Simulation involves a number of basic steps that are shown in the following flowchart in figure.

Fig: Modeling of a pulse jet engine

Fig: Cross sectional view of a pulse jet engine

Fig: Different views of a pulse jet engine

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CFD ANALYSIS ON PULSE JET ENGINE

Boundary conditions:
Inlet mass flow rate: 10kg/s
Type of fuel: air + propane mixture
Gas temperature in combustion chamber; 1073k
Pulse jet Tube material; titanium
Outlet pressure opening; atmospheric pressure

Material properties of titanium:
Density = 4505 kg/m$^3$
Specific heat = 548 J/kg-k
Thermal conductivity = 20 W/m-k
Melting temperature = 1881.2k

Material properties of Monel:
Density = 8840 kg/m$^3$
Specific Heat = 354.955 J/Kg-K
Thermal Conductivity = 43 W/m-K
Melting Temperature = 1603.15k

RESULTS:
After giving the proper boundary conditions solid works flow simulation run the analysis in cut plots we can check the results. Flow simulation is done with two materials titanium and monel the results for
both material taken for thermal characteristics of pulse jet engine.

Pressure cut plot:

Velocity plot:

Temperature of fluid

Temperature of solid

Mach number

Material: Monel

Pressure

Velocity cut plot

Temperature of fluid plot
Temperature of solid

Mach number plot

Graphs generated for titanium material pulse jet engine

Pressure

Velocity

fig: velocity vs length graph

Temperature of fluid

fig: temperature of fluid vs length graph

Mach number

fig: mach vs length graph

Conclusion:
Designing and analysis of pulse jet engine is done in solid works software.

Designing of pulse jet engine is done by using various commands in solid works software.

Analysis is done in CFD in solid works flow simulation.

CFD analysis is done on pulse jet engine with two different materials such as titanium and monel has done at inlet mass flow rate 10kg/sec and 800°C.

Maximum pressure, velocity, mach number, temperature of fluid, and temperature of solid are determined.

From cfd analysis results we can observe clearly pulses of combustion gases in pulse jet engine are observed in pressure and velocity counters.

These pulses can effect the overall thrust of the engine. Thrust is depend upon velocity and momentum of combustion gases.

By observing the temperature of solid counters we can figure out that titanium has shown less temperature it means it does not radiate the heat to atmosphere quickly rather it maintain less heat losses after combustion process. And it has high melting point it can use for high temperature operating conditions.

Monel is light weight alloy but it has poor thermal characteristics coming to high temperature operating conditions.

From the results we can conclude that titanium is showing best results.

Thus CFD analysis on pulse jet engine at given mass flow a rate with different materials is done by using solid works flow simulation.

References:

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