USE OF PULSE JET ENGINE IN FUMIGATION PROCESS

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Abstract – *Jet engines are generally used to create thrust force. We have used pulse jet engine technology for the development of the agro product for the purpose of fumigation. In this paper, we are going to discuss design methodology, method of operation and results of this technology.*

Key Words:- *Jet engines, Thrust Force, Agro product, Fumigation, Design methodology.*

1. INTRODUCTION

In agricultural farms insects feed on crops and tend to damage them. The insecticides are sprayed on the plant/crop and this method is called fumigation. The conventional method of fumigation is to spray a mixture of water and insecticide on the plant. The apparatus consists of air blower that blows the mixture on the crop. When this mixture is sprayed on the crop it affects the digestive system of the plant and decreases productivity to large extent.

This gives rise to design of a system that can satisfy all the above needs of agricultural field. One such system is using a pulse jet engine. Jet engines are generally used to create thrust force. Instead of continuous combustion the combustion in pulse jet is in the form of pulse.

The mediator used here can be diesel. The combustion thrust force of pulse jet engine is generally 800° C. Using a cooling jacket by natural convection the temperature can be brought down to about 200° C, at this temperature diesel will get half burnt giving smoke as a byproduct consisting of CO_2. When a mixture of diesel and insecticide is sprayed on the plant it creates a mist that will suffocate the insect and force it to come on the upper portion of the leaf for atmospheric air. The diesel being light in weight will evaporate and insecticide will act on the insect and kill it. CO_2 will by plant/crop for photosynthesis.

2. WORKING OF PULSEJET ENGINE

Pulsejets are very simple engines but their operation is not always easily understood -- after all, how an almost empty pipe can run as a jet engine. This page is an attempt to explain the four basic phases in the pulsejet's operational cycle.

1. **Ignition**
   This is the instant that the fuel and air in the pulsejet are ignited. The effect is that a fireball is produced inside the engine which creates a great deal of heat and pressure. The reed valves are held closed by this pressure, effectively leaving the flame and hot gases only one place to go.
2. **Combustion**
   After ignition, the air and fuel continue to burn and expand in a phase called the combustion phase. During this phase the burning gases expand and travel down the tailpipe, exiting at the rear of the engine. The force of the gases leaving the engine in a rearwards direction creates an equal and opposite force that tries to move the engine forwards -- this is thrust.
3. **Intake**
   Because gases are elastic (they can be compressed and stretched) and because they have mass, the rapidly exiting exhaust gases have a tendency to keep moving -- even after the pressure inside the engine drops below the pressure outside. This causes a partial vacuum to be created inside the engine.
4. **Compression**
   As mentioned above, gases are elastic -- so now, having been stretched out to create a partial vacuum, some of the hot exhaust gases are now drawn back towards the front of the engine by the vacuum that was created. Once again, because they have momentum, the gases in the tailpipe continue to move even after the pressure inside and outside the engine is equalized. This means that the gases continue heading towards the front of the engine -- towards the fresh charge of air and fuel that has just been drawn in. Of course, as soon as the pressure inside the engine becomes higher than the air pressure outside, the reed valves slam shut -- stopping the air/fuel mixture from escaping.

This continued movement of the exhaust gases causes the air-fuel mixture to be compressed -- until the hot gases finally travel so far up the pipe that they touch the explosive air/fuel mixture and -- back to step one!

This cycle repeats hundreds of times a second -- producing the characteristic buzzing sound of the pulsejet engine.

1.2 SCHEMATIC REPRESENTATION

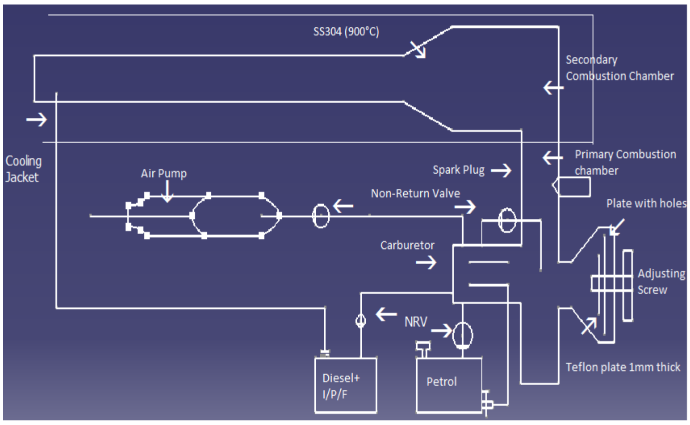

Fig 3.2.1: SCHEMATIC REPRESENTATION OF PROJECT WORKING

3. DESCRIPTION OF PARTS

3.1. Venturi

Venturi works as fuel injector similar to a carburettor. It is a pressure reducing device. The throat of venturi has lateral holes present in it, through which the fuel gets injected in the throat of venturi. As per the Bernoulli's principle, there is pressure reduction in the throat of the venturi due to which fuel gets sucked in through the holes. Venturi is placed in a casing that contains petrol.

3.2. Spark plug

The fuel used for the joule cycle to produce the thrust force is petrol. A spark plug is used to ignite the air-fuel mixture for the first cycle. The spark plug is given a supply of 12V DC battery. The spark plug must be turned off after the first cycle.

3.3. Petrol and Diesel tank

Petrol tank stores petrol that is used to run the pulse jet engine. Diesel tank stores a mixture of diesel and pesticide. Diesel is used as a secondary fuel, used for the production of fog which contains smoke and particles of pesticide.

3.4. Reed Valve

Reed Valve consists of two plates with holes and a Teflon sheet. Air is sucked in through the reed valve from the second cycle. The distance between the plate with holes and Teflon sheet is used to adjust the Air-Fuel ratio.

3.5. Combustion Chamber

Combustion of the mixture takes place in this chamber. It is made of SS304. SS304 has a property of retaining heat when it gets red hot. This retained heat is used to keep the cycle running.

3.6 Nozzle

It used to direct and modify the flow of exhaust gases.

3.7. Nozzle Pipe

It is placed after the nozzle. As the exhaust gases move out of the nozzle pipe it creates a back pressure because of which a fresh mixture if sucked into the secondary combustion chamber. This helps to keep the cycle running.

4. DESIGN METHODOLOGY

4.1 DESIGN OF NOZZLE

MATERIAL SELECTED: SS 304

Yield strength=215 MPa

SS 304 has good thermal resistance. Once the material gets red hot it does not allow the heat to go out.

Design parameters:

Mass flow rate of inlet air = 0.75kg/hr

Inlet pressure P1 = 8000 kg/m2

Inlet air velocity C1 = 3.5 m/s

Inlet Temperature T1 = 800° C

Outlet Pressure P2 = 4300 kg/m2

Exhaust gas velocity C2 = 35 m/s

Outlet Temperature T2 = 600° C

Gas constant R = 0.287 kJ/kg °K

We know,

$$Pv = mRT$$

M= mass flow rate kg/sec

T= Temperature in °K

V=AC

Where A= Area in m^2

To calculate inlet area of nozzle

A1 = (mRT1) / (P1C1)

= (0.75*287*1073)/(8000*3.5*3600)

= $2.29*10^3$ m^2

A1 = $\pi/4$ $d1^2$

d 1= 54mm.

Outlet diameter can be calculate from continuity equation,

Q = A1*C1=A2*C2

d2 = d 1 (C1 / C2)½

= 54(3.5*35)½

= 17.076 mm

Taking d 2= 18mm

Which is inside the diameter of diffuser outlet?

Taking t = 1.5mm

Therefore outer diameter = d2 + 2*t

= 21mm

4.2 DESIGN OF NOZZLE PIPE

MATERIAL SELECTED: SS 304

Yield strength=215 MPa

Our taken c/s for nozzle pipe is having

O.D.= 25mm

I.D. = 20.5mm

t = 2.25mm

D/t =25/2.25 = 11.11 >10

Hence design is based on thin cylinders.

Maximum hoop stress

$$\sigma_\tau = \frac{Pdi}{2t}$$

$$= \frac{1.5 * .0205}{2 * .00225}$$

=6.833 MPa << 215 MPa

So design is safe.

Note: The pressure in nozzle pipe is assumed to same as combustion pressure for design purpose. In an actual case, it is less than 15 Kg/cm^2 because of conversion of pressure head into velocity head in diffuser section.

4.3 DESIGN OF MANIFOLD PIPE

MATERIAL SELECTED: SS 304

Yield strength=215 MPa

SS 304 has good thermal resistance. Once the material gets red hot it does not allow the heat to go out.

Inlet pressure of air is pressure applied by hand pump which is same as the pressure in manifold & also in the combustion chamber as the operation of this engine is based on joules cycle.

Here pressure at pt 2 = pressure in manifold = combustion chamber, 1. 5 MPa

Consider manifold pipe as thin cylinder, checking for hoops stress in pipe

$$\sigma_\tau = \frac{P * di}{2t}$$

Where,

P = pressure in manifold

d_i= inner diameter of manifold = 24mm

t = thickness of manifold = 1.5 mm

$$= \frac{1.5 * 24}{2 * 1.5}$$

= 12 MPa <<< 53.75 MPa

Note :

Our selected material is SS 304.

It is having yield strength of 215MPa.

Allowable stress = yield stress / factor of safety

Taking fos =4

Allowable stress =53.75 MPa

Thus 12MPa is much less than allowable stress.

4.4 DESIGN OF COMBUSTION CHAMBER

Material selected Is SS 304

Allowable stress = σ_τ = fos =1000/4 =250 MPa

We first select dimensions for combustion chamber

O.D. = 50mm

I.D. = 44mm

t = 3mm

D/t =50/3 = 16.67 >10

Hence design is based on thin cylinders.

Maximum hoop stress

$$\sigma_\tau = \frac{Pdi}{2t}$$

$$= \frac{1.5 * .4.4}{2 * 0.3}$$

=110 Mpa << 250 Mpa (allowable)

So design is safe.

4.5. DESIGN OF VENTURI

Material selected: BRASS

Brass has good malleability. It can be easily machined to very minute and accurate dimensions.

It also has good corrosion resistance.

Design parameters

Mass flow rate of inlet air = 0.75kg/hr

Inlet pressureP1 = 4000 kg/m2

D_{in}/D_{out} = 2

Taper Angle = 21°

$$\tan\left(\text{Taper Angle}/2\right) = \frac{D_{in}/2}{L}$$

Assume, L=0.08m

$$D_{in} = 2 * 0.08 * \tan\left(21/2\right)$$

$$D_{in} = 0.031\,m$$

$$D_{out} = 0.015\,m$$

$$\text{Mass flow rate} = \rho * A * C$$

$$0.75 = 1200 * \frac{\pi}{4} D_{in}^2 * C_1$$

$$C_1 = 0.828\ m/s$$

Applying continuity equation at sections 1 and 2

$$a_1 C_1 = a_2 C_2$$

$$C_2 = \frac{\pi/4 * D_{in}^2 * C_1}{\pi/4 * D_{out}^2}$$

$$C_2 = 3.5\ m/s$$

Applying Bernoulli's Equation,

$$\frac{P_1 - P_2}{\rho g} = \frac{C_1^2}{2g} - \frac{C_2^2}{2g}$$

$$P_1 = \frac{40 * 10^5}{1000 * 9.81}$$

$P_1 =$ 40.77 m of water

$$P_2 = 40.77 - \frac{3.5^2 - 0.82^2}{2 * 9.81}$$

$$P_2 = -\ 3.94 \text{ bar}$$

4.7. DESIGN OF FUEL TANK:

Design Parameters:

Pressure in tank P	=	8 bar
Diameter of tank Di	=	80 mm
Thickness of tank t	=	0.7 mm

Consider the tank as thin cylinder, checking for hoop stresses,

$$\sigma_t = \frac{PD_i}{2t}$$

$$\sigma_t = \frac{0.8 * 80}{2 * 0.7}$$

$$\sigma_t = 45.7 \text{ MPa}$$

Note:

Our material selected is *Mild Steel*, having a yield strength of 250 MPa.

$$\text{Permissible stress} = \text{yiels strength}/s$$

$$\text{Factor of safety} = 4$$

$$\text{Permissible stress} = 250/4$$

$$\text{Permissible stress} = 62.5 \text{ MPa}$$

From calculations, we get permissible stress as 45.7 MPa which is within the allowable range.

5. NOMENCLATURE:

Symbol	Description	Value/Unit
M	mass flow rate	kg/hr
P	Pressure	MPa
C	air velocity	m/s
T	Temperature	° C
R	Gas constant	0.287 kJ/kg °K
Q	the volume flow rate	kg/m3
d 1	outer diameter	Mm
d 2	Inner diameter	Mm
T	Thickness	Mm
Στ	Hoop Stress	MPa
Fos	Factor of safety	--------
Δ	Density	
L	Length	Mm
Cp	specific heat	kJ/kg K
K	Thermal conductivity	W/Mk
μ	Coefficient of viscosity	Ns/m2
Gr no	Grashoffs number	……….
Nu	Nussle Number	……….
H	Heat transfer coefficient	W/m2k
Am	Mean peripheral area	m2
U	Overall heat transfer coefficient	W/m2k
LMTD	Logarithmic mean temperature difference	° C
W	Work done	Joule
η	Air standard efficiency	……….
S	Entropy	W/k

6. METHOD OF OPERATION:

1) Put fuel in petrol tank by opening the main cock.
2) For initial starting purpose the hand pump is operated & ignition switch is kept „ON" position.
3) As fuel pump is given 2-3 strokes by hand it induces back pressure which is given to petrol tank through the housing.
4) The pressure in the petrol tank is now just above atmospheric thus listing petrol tank to fuel nozzle can be varied with cock provided.

5) This enriched mixture flows to manifold as there is no other place for the mixture to escape.
6) As required voltage is given back to spark plug by pressing switch a spark is produced which initiated the combustion.
7) Once combustion is started there is no need to operate hand pump and switch ignition switch.
8) The high-pressure mixture then finds its way to exhaust pipe which consequently creates pressure in the manifold.
9) The air then sucked through air valve and back pressure is given to carburetor which eventually lifts petrol from the tank and again it supplies it to a nozzle.
10) The diesel in diesel tank is pressurized by the by the means of a flow control valve connected to the pressure line. As a result, the diesel flows to the nozzle.
11) The flow of diesel is controlled by the flow control valve.
12) This process is repeated automatically.

7. CONCLUSIONS

1) Pulsejet engines offer an attractive form of propulsion due to their simpler and cheaper construction. The essence of this project was to improve knowledge of pulsejet engine operation which is successfully achieved.
2) The experimental engine included geometry adjustability which proved advantageous in obtaining the maximum thrust of 1.745kg, 30.3% less than the desired 2.5kg but consistent with the results of the theoretical model.
3) Our main aim of development of pulse jet engine for use of fumigation purpose achieved.

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