Development of Pulse Jet Engine Based Fumigation System for Agricultural Application

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Abstract- **This paper describes the development of Pulse Jet Engine based fumigation system for effective killing of insects, pests and germs on the crop. With the help of this system, an insecticide mixed with half burn diesel can be applied in the form of fog. A provision is made to measure the thrust of fog.**

Keywords: Pulse jet engine, fumigation, insecticide, thrust

I. INTRODUCTION

Total land availability on earth is 30% and rest 70% is occupied by oceans. Out of this available land only a small percentage of land is arable and is used for an agricultural activity. Population is also increasing day by day. Enough feeding capacity to all the animals and mankind is a supreme challenge now a days. India is agricultural based country and around 62% of land is under total agricultural use. There are many factors which affect the crop productivity. One of them is insects[1], allied fungal infection and pests. The insects feed on crops and tend to damage them. In order to protect crop from damage, the insects must be diverted from the crop or killed. Insecticides are used to kill the insects. The insecticides are sprayed on the plant/crop and this method is called spaying insecticide. Conventional method is to spray a mixture of water and insecticide/pesticide/fungicide on the plant. The apparatus used for this process consists of an air blower which blows the mixture on the crop. However, this process has a few disadvantages:

- When this mixture is sprayed on the crop, it affects the digestive system of the plant
- If the mixture is sprayed during the day, due to heat of sunlight, the water gets evaporated and the effectiveness of the insecticide decreases as the day progresses.
- During day time the insects generally hide below the leaves to protect themselves from direct heat of sunlight. The mixture is normally sprayed on the top. It affects only the digestive system of crop. Hence, it needs to be sprayed multiple times.

The drawbacks of the conventional system encouraged us to design and manufacture a fumigation machine which is simple to use, economical and efficient. Also, it must satisfy the needs of a farmer. An attempt is made to develop fog based fumigation system using a pulse jet engine technology[2] for better coverage of fumigation area

This engine is generally used to create thrust force in the form of pulses due to its inherent nature of non continuous combustion cycle.

The operation of Pulse Jet Engine is not continuous but it is pulsating in nature. It is because of the time lag in starting of new combustion cycle. All the engine strokes are carried out in the single pipe which acts as a combustion chamber. The time lag is due to the process of expelling one part of flue gases out and for pulling the remaining part of flue gases inside the tube for starting a new cycle. In the combustion process[10], the gases are thrust out through exhaust and pressure drops inside the tube. This causes a part of the exhaust gases to get pulled inside and the temperature of the same is utilized for initiating the combustion of freshly inducted charge of air and fuel mixture.

In the second World War, for the first time this technology was utilized by Germans in their famous Buzz Bomb against England[3]. Due to high power to weight ratio in spite of high specific fuel combustion it is used in helicopters and military applications like Drones (Manless spy aeroplanes).

Practically it is the simplest form of engine which is available in two types –

1. With valve – In this type there is only one moving part in the form of air breathing valve.
2. Without valve – In this type there is no moving part as valve is not present.[8]

Pulse Jet Engine are used due to inherent advantages.

- Simple in construction
- Absence of heavy transmission system, shaft and gearing
- Less wear and tear
- Easy for manufacturing
- Use of any combustible fuel
- High power to weight ratio

The disadvantages of this type of engine are:

1. Noisy operation

2. High specific fuel consumption
3. Low efficiency in between 35-45%

But the improved combustion technique has proved that the noise level can be reduced to a reasonable level.

Pulse Jet Engine is the heart of the fumigation system designed by us. In this system, diesel has been used as a carrier for an oil based liquid insecticide/pesticide and is half burnt. Due to half burning of diesel, a fog is produced which has following advantages:

- A fog pushed by thrust provides better coverage area of fumigation.

In the process of burning, CO_2 is evolved and it is utilized by the plant for photosynthesis. When a mixture of diesel and insecticide/pesticide/fungicide is directed through exhaust pipe around the plant/crop, it creates a mist that suffocates the insects and forces them to come on the upper portion of the leaf for breathing. The diesel being light in weight evaporates fast and insecticide attacks the insects and kills them.

Pulse Jet Engine[9] is the principal part of this fumigation system (Fig.1) . Initial cycle starts with pumping action. The mixture of air and gasoline is pumped inside the carburetor. Mixture of Air and fuel then moves towards the primary combustion chamber . By manually activating the spark plug circuit, a spark is ignited and fire ball is produced. The mixture of air and fuel then expands and moves to the secondary combustion chamber After the secondary combustion chamber it passes through the nozzle where there is drop in pressure and increase in velocity. High velocity gases then exit from the nozzle pipe in the form of thrust. Meanwhile diesel mixed with the insecticide, enters the exhaust pipe. Due to 250^0 C temperature of the exhaust gases, diesel is half burnt and exits in the form of Fog along with the insecticide. The Fog then mixes with the air and diesel gets evaporated. While the insecticide remains on the leaves.

II. EXPERIMENTAL SET UP

Schematic Representation of Fumigation System

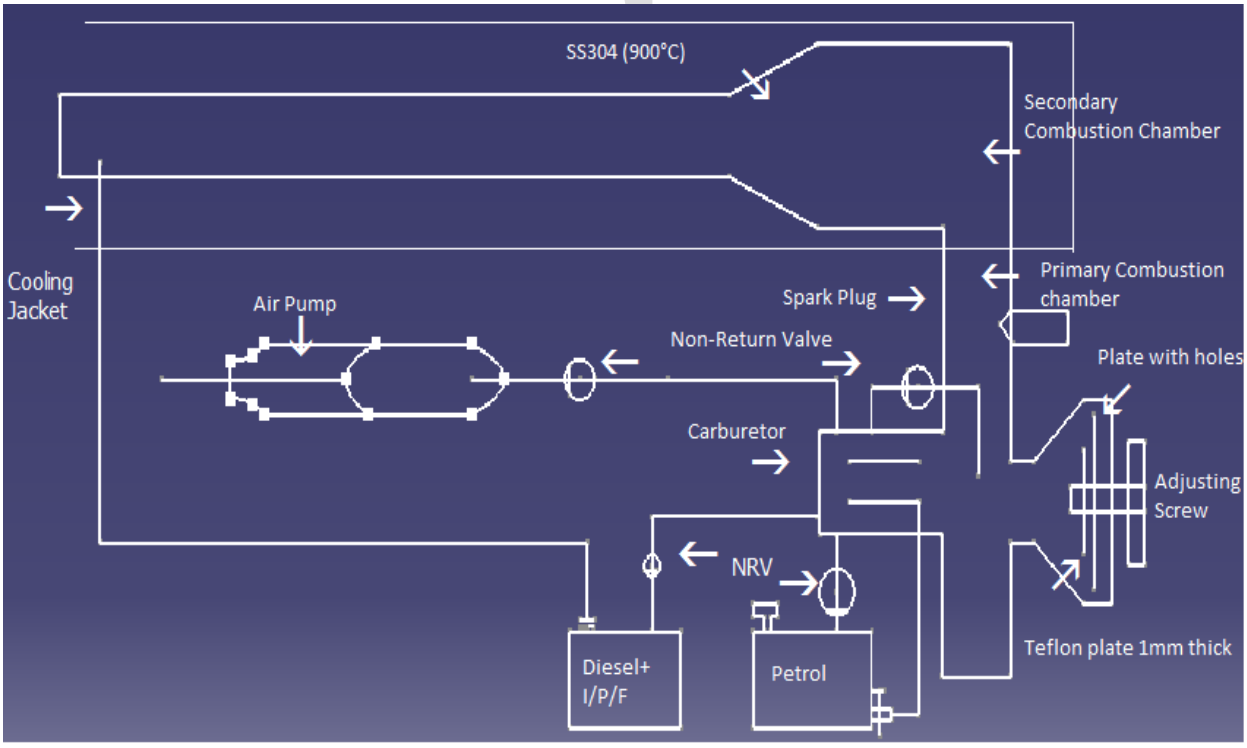

Figure 1 : Schematic Representation Of Fumigation System

Figure 2 : Experimental Set Up

Gas continues to exit from the nozzle pipe and partial vacuum is created inside the engine. Due to this partial exhaust gases come back to the combustion chamber. At the same time due to drop in pressure below atmospheric pressure, fresh air and Fuel are inducted inside. Combustion takes place due to temperature of returned exhaust gases. The cycle continues till the fuel is available in the tank. A Reed Valve is preset to the marked position to maintain the constant air and fuel ratio.

NRV s are employed to avoid the return flow of air and fuel mixture and also it helps to maintain the pressure. A Gasoline fuel is fed through the pipe to the combustion chamber by brown colored tank mounted on the blue colored base frame.. A red hot nozzle pipe indicates the intense heating due to expansion of exhaust gases and immense thrust can be seen in the form of exhaust gases as shown in the figure. Other assemblies to form a fog will be added to this to form a full fledge fumigation system.

Figure 2 shows a complete assembly of the system, ready for testing at shop floor. Various instruments like pressure gauge, flow meter ,thermocouple based temperature gauge, and thrust measurement equipment are used to measure various parameters of the system.

Major parts of the system are as follows:

- Diesel tank (white colored), where pesticide is mixed with the diesel
- Petrol tank (yellow coloured)
- Electric Junction Box (red coloured) for initial supply to spark plug
- Hand pump with red Handle for building the initial pressure for fuel pumping and air supply
- Reed valve just above the petrol tank
- Duly covered nozzle pipe
- Normally all the heating section is covered with perforated round mesh cover. It is removed to facilitate the measurement of various parameters.
- Thrust measurement gauge is with suspended weight and pointer, with half round measurement plate.

A) Testing Procedure:

1. Check the readiness of the system for the trials.
2. Put the mask and other PPEs before starting the trial.
3. Pump the system 2-3 times and keep the ignition switch ON. Adjust reed valve gap to adjust the required proportion of mixture of air and fuel. By screwing clock wise the gap can be reduced to make the mixture richer. This results into more development of thrust.
4. Engine may start after 3 -4 attempts, the exhaust gases will start coming out. There will be buzzing noise in the engine.
5. Exhaust gases will impinge on the predefined plate and the plate will deflect in half circular position to indicate the thrust.

6. Measure the pressure at the hand pump, primary manifold and secondary manifold at entry and exit of nozzle respectively
7. Measure temperature at various stages of the system with the help of high temperature thermocouple.
8. The requirement of thrust is 12 Kg. Adjust the valve till the pointer shows the reading of 3 meter.
9. Ambient temperature is measured and noted.
10. Thermocouple inserted in combustion chamber is giving digital read out of temperature at that stage, T_1 and T_2 are measured
11. P_1 and P_2 is measured with Mercury Manometer
12. Min 10 reading are noted and Average reading is taken for the design calculation purpose.

A thrust measurement gauge is fixed on the fumigation system. There is a predefined weight hanging on the pivoted joint and on the other end there is a pointer. An inscribed scale is mounted at the pivot point. when the exhaust impinge on the restricting plate, pointer deflects and indicates the available thrust at that moment. With the help of reed valve the thrust can be adjusted to required value and the valve plate is locked by locking arrangement.

III. RESULTS AND DISCUSSION

Following figures are deduced and can be taken for design purpose.

A) Pressure at Hand pump:

Normally based on the diameter and stroke the pressure can be calculated analytically. However pressure is checked with putting the press gauge. It is checked for 10 cycle and average maximum value is noted The maximum pressure is found as 4 bar This pressure is mainly developed to create the pressure difference at the carburetter. It will allow to pump the gasoline from the tank.

B) Pressure and temperature at combustion chamber before nozzle:

A metered quantity is delivered through carburetter and air is mixed through the fixed Reed valve. The Gap is defined after trial and the predefined Gap is found 0.5 mm. battery operated spark plug ignites the mixture and fire ball develop and will sweep from Primary combustion chamber to the nozzle The pressure before the nozzle is found approx 8 bar. Temperature is measured and approximated to 900^0 C

C) Pressure and temperature at combustion chamber after nozzle:

At the nozzle there is change in pressure and conversion in to velocity. Pressure is found to be 4.3 bar and temperature variation found to approximated figure of 600^0 C after nozzle to 250^0 C at the certain distance away from nozzle.

D) Fog Exhaust : Diesel is half burn at 250^0 C, an inlet of mixture of Diesel and insecticide is kept at this position and the exhaust carries the fog of mixture of half burn diesel and insecticide The trial were taken at various atmospheric temperature from 25 to 45^0C and results are noted and found satisfactory. There is drop in pressure inside the exhaust pipe. This will bring back some amount of flue gases along with fresh air and next combustion cycle will start.

E) Thrust force at the Gauge: Gauge is placed at the exhaust as shown in the figure 3 and close up in figure 4. A force is equivalent to 12.1 kg or 118.7 N (Based on Equivalent marking shown by marker).

F) Trials on crops: Field Trials were taken on Cotton, sugarcane , the reach was up to 10 feet . With 1 liter of Gasoline, 4 Liter capacity of Diesel and 200 ml insecticide last for approximately 1hour.

CONCLUSION

- Pulse jet engine is the best option due to its pulsating firing nature. This inherent characteristic of intermittent pulses create good amount of thrust and same utilized for fumigation purpose to get better coverage.
- there is practically less wear and tear and less maintenance Since there is no moving part
- Thrust is substantial is measured as average 12.1 Kg and generates to 3 meters of throw of diesel mixed insecticide. It ensures the far better coverage than conventional water based spraying system
- Gasoline consumption is 1 lit/hr and which sprays 200 ml of insecticide. Considering the average walking speed 3 Km/hr the total coverage is much more than water sprayed conventional method.
- It would be easy to fumigate the crops like cotton and dense field of sugarcane than conventional method.

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