Solar Power Operated Rotary Gas Engine

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Abstract: ***Shortage of fossil fuels, the associate cost and pollution effects are major demerits of IC engine. So it is inevitable to shift towards the use of other alternative energy resources such as renewable energy, Green energy, bio fuels which can reduce pollution. A real gas has in it a property that at constant volume the pressure variation is proportional to the temperature variation. This property of gas is used for the rotary motion of the rotor in the engine. Due to the continuous use of the same gas (nitrogen here) there are no harmful emission and pollution effects. Due to elimination of pollution, this new technology is easy to adopt. Rotary engine can work at very high efficiency when compared with conventional IC engines. In nearby future it may replace the IC engine and take one step towards the pollution free environment.***

Keywords: CSP- Centralised Solar Power; ICE- Internal Combustion Engine

1. Introduction

Due to the growing population, demand for energy sources has been increasing day by day. In recent years environmental pollution has been to a rise and the fossil fuels are in a diminishing stage. A lot of renewable energy technologies have been developed in an attempt to reduce the pollution and meet the growing energy demand. Renewable energy technologies range from solar power, wind power, hydroelectric power, biogas and biomass. "SOLAR OPERATED ROTARY GAS ENGINE" is an alternative to IC Engine. It works on the property of gas that in a closed volume the pressure variation is proportional to the temperature variation. This engine works eco-friendly and is very efficient when compared to other fossil fuel operated one.

Temperature and pressure are directly proportional to each other. This means that as the temperature increases, the pressure increases, also as the temperature decreases the pressure also decreases. When the speed of the gas molecules increases, the gas molecules hit the container more often. The more frequently the gas impacts the container wall the higher is the pressure. In rotary gas engine, gas in the sump tank is heated by the Sun's radiation and this increased temperature in turn increases the pressure of the gas. Now due to the pressure difference between the sump and the volume space in the engine air is allowed to flow inward. During its flow the air is passed through the Nozzle. Here in the nozzle, the velocity of the gas increases at the expense of the pressure energy.

The engine block consists of the triangular rotor which has been given a hemispherical notch at each of its vertex. The air jet from the nozzle has a very high velocity. High force is exerted by the jet on the hemispherical notch which in turn moves the rotor in a circular manner.

The main advantage of rotary gas engine is its zero pollution. Further, due to the principle of its operation, the engine has a very efficiency when compared with the conventional IC Engine. Hence rotary gas engine works at a high efficiency and has zero polluting emissions.

2. Working Principle

The working principle of Rotary gas engine is based on the property of gas. The intermolecular forces between the molecules of gases are less when compared to the other two states of matter. As the temperature of the gas molecules increases the kinetic energy also increases and thus the pressure on the container increases. Every particle try to move from unstable region (high pressure) to stable region (low pressure), and is a Universal law. During this movement from high pressure to low pressure, if the gas, in this case, is allowed to move from a nozzle the kinetic energy increases at the expense of its pressure energy. This increased velocity of gas impacts the rotor and a large force is applied. So the idea is to move the rotor in a circular manner with synchronized impact through the nozzle per cycle.

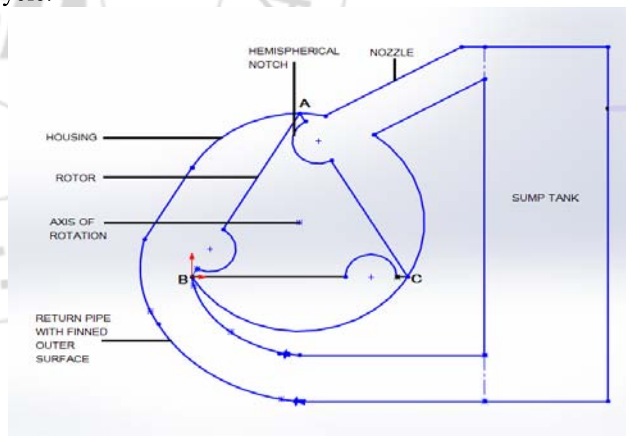

Figure 1: The detailed View of rotary engine.

The gas in the sump tank is heated by the Centralized Solar Power. To start, let us begin from the situation when one of the vertexes of the rotor is at point A. When the nozzle is opened for the first time the fluid jet impacts the vertex of the rotor and the rotor starts moving about the center. The hot air is allowed to move out of the housing in between point A and B to the downward portion of the sump tank. After one revolution up to the point A the nozzle is again opened and the fluid jet impacts the vertex making another complete revolution of the rotor. A shaft is attached to the rotor and this shaft revolution can be easily used for various applications.

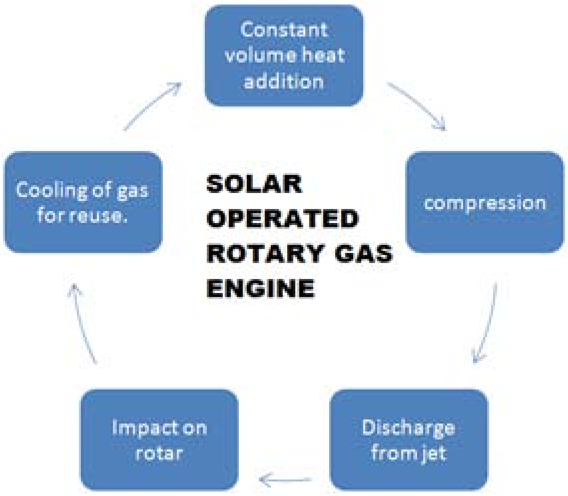

Figure 2: Block diagram of the process

The force exerted on rotor by nozzle is directly proportional to amount of irradiation at the sump tank. Speed of the rotor is also proportional to the irradiation.

Design

1. Power calculation

Real gas equation

$(P+n^2a/V^2)(V-nb) = nRT$

P- Absolute pressure (bar)

N-No. Of moles

V-Volume (m^3)

T-Temperature (K)

a-Measure of attraction between particles

b-Volume excluded by moles of particles

R- Universal Gas Constant

2. Properties of Nitrogen-

δ- 4.9 Kg/m^3

Molar mass- 28 g/mol

No. of moles (n) - 0.4

Mass- 11.2 g

Volume of chamber (V) - 100 cc

a-0.1408 J*m^3/mol^2

b- 3.91* 10^{-5} m^3/mol

At 60^0 C

By using real gas equation,

Pressure generated is 108 bars

For nozzle,

D- 20mm

$Q_n = 28.9*D^2*\sqrt{P}$

Where,

D-Nozzle diameter (in)

P- Pressure (Psi)

Q_n - Discharge (Gpm)

Discharge at 60^0 C & 108 bar for 20 mm diameter is 2686.8 lpm is equal to the 0.044 m^3/s.

Area - 3.141 * 10^{-4} m^2

Q = A*V

V- Velocity (m/s)

V= Q/A

= 0.044/3.141 * 10^{-4} m^2

= 140.12 m/s

Force on rotor by impact of jet is= 2*δ*A*V^2

= 60.44 N

Rotor radius- 7.4 cm

Torque = Force * radius

= 60.44 * 7.4*0.01

= 4.47 N.m

Power = 2πNT / 60

= 56.17 W @ 120 RPM

2. Design of solar collector

Heat energy required by the generator through the solar collector =215.64 Watts

Generally the total radiation (specula + diffused) on any surface on earth = 955 W/m^2

Taking the inclination of flat plate collector at 40^0 placed N-S

Total energy received by the earth -

Assuming the earth a spherical body, the energy received by it will be proportional to the perpendicular to the projected area, i.e., that of a circle = π* r_e^2

Energy received by the earth = 1.736* 10^{17} W

The direct energy reaching the earth is = (1 - 0.42) * 1349.6

= 782.77 W/m^2

The diffusion radiation = 0.22 * 782.77

= 172.21 W / m^2

Total radiation = 172.21 + 782.77 = 955 W/m^2

The projected area = A * cosθ

= 0.4*0.4 cos40^0

= 0.110 m^2

Therefore energy received by solar collector -

= 955 * 0.110

=105 W

3. Efficiency

η = o/p power / i/p power

=56.17 / 105

= 53 %

4. Design of fins

RPM= 120

RPS= 2

Volume space is 100cc and the discharge is very high so every ½ of a sec volume from the sump tank will be sufficient to fill the 100cc space.

Velocity of each gas particle (tangentially) V= r * w

V= 0.0433 * $\frac{2*\pi*120}{60}$[r- average distance of the gas particle from the point of rotation]

V= 0.5441 m/s

If straight line is considered then distance travelled in 1 cycle

D= 0.5441 * ½ of a sec

D= 0.272 m

But the flow of the gas in the return pipe is a curvilinear path.

Sufficient volume of the sump tank is provided so as to have continuous flow of the gas.

Pipe diameter= 28.87 mm

Cross sectional area= 2.6184 * 10^{-3} m^2

Material selection

1) Copper = 385 W/m°K
   Density = 8.96 g/cm^3
2) Aluminium = 205 W/m°K
   Density = 2.7g/cm^3

Aluminum will best suit in this case.
Thermal conductivity of nitrogen gas = 0.024 W/m°K

Heat loss to atmosphere without fins:

$$Q = \frac{\Delta T}{\sum R}$$

ΔT = Hot gas temp − atmosphere air temp
= T_h - T_a
= 513 – 300
= 213°K

$R = \frac{1}{2\pi L}\{\frac{1}{h1*r1} + \frac{1}{k1}\ln\left[\frac{r2}{r1}\right] + \frac{1}{h2*r2}\}$

Where, h1= heat transfer coefficient of nitrogen= 100 W/m^2°K
h2= heat transfer coefficient of atmospheric air = 20 W/m^2°K
k1= thermal conductivity of aluminium= 230 W/m°K
r1= 13 mm
r2= 15 mm
Q= 40 Watts

Heat transfer through fin

$Q_{fin}=\sqrt{hPKA}(T_b-T_a) * \tanh(mL)$
T_b= allowed temperature of pipe= 40° C
T_a= atmosphere temperature= 30°C
h= heat transfer coefficient of aluminium= 83 W/m^2°K
Q_{fin}= heat transfer through fin
Q= heat generated at pipe

$m=\sqrt{\frac{h*P}{k*A}}$

Q_{fin}= 0.22 Watts
No of fins=Q/Q_{fin}
No of fins= 180

Temperature (°C)	*Pressure* (BAR)	*Torque* (N.M)	*Power* (WATT)	*Efficiency* (%)
40	100	4.344865	54.5715	52.25154
60	108	4.693814	58.9543	56.44801
80	116.71	5.072208	63.70693	60.9986
100	124.6	5.41524	68.01542	65.12392
120	132.48	5.757494	72.31412	69.23987
140	140.37	6.10067	76.62442	73.36693
160	148.26	6.443542	80.93088	77.49031
180	156.14	6.786121	85.23367	81.61018
200	164.07	7.13068	89.56134	85.75387
220	171.91	7.471423	93.84108	89.85166
240	179.8	7.814257	98.14707	93.9746

Engine specification table

1	Engine type	Rotary
2	No. of rotor	1
3	Rotor radius	5.78 cm
4	Displacement	100 cc
5	Maximum Torque	7.78 Nm @240°C
6	Maximum Power	98 W @ 240°C
7	Cooling Type	Air Cooled

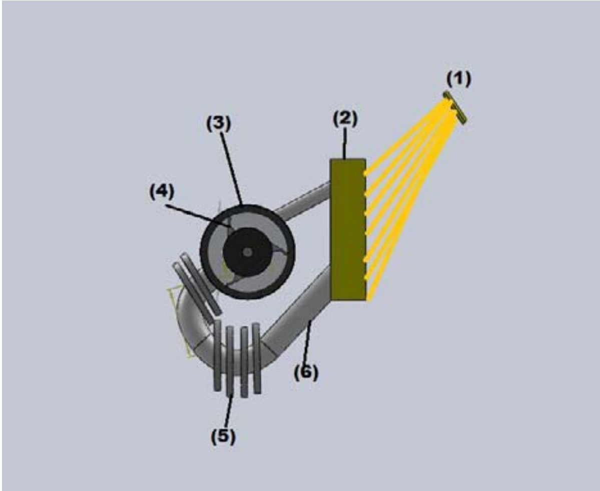

Figure 3: 3D view of engine

1) Centralized solar panel
2) Sump tank
3) Housing
4) Rotor
5) Fins
6) Circulating pipe

5. Component Design

1) Rotor
   Rotary gas engine uses only nitrogen gas as fuel for its operation. The rotor must be able to withstand the various temperature effects. Further, cylinder material should have low density and must be durable. To take care of these issues, the rotor can be made up of material such as aluminum**.** Also it has low density so that it will have low moment of inertia. The temperature generated during the process is very high and thus aluminum can be used because of its low thermal conductivity. Various machining operations can be easily performed on this material. Usage of aluminum makes engine lighter. Hence, by considering all conditions the aluminum is used for rotor.
2) Housing
   The housing is made up of aluminum of high resistivity and low thermal conductivity. There are two opening to the housing. One opening is at the nozzle end before point A as in the fig above. The other opening is to remove the hot gas in between point A and point B. The inner surface of the housing is surface finished so as to have friction free movement of the rotor.
3) Hemispherical Notch-
   The hemispherical notch has been supposedly provided on the rotor in order to make the best use of the impacting fluid flow. When compared to the force due to impact of jet on a hemispherical portion than on a flat portion, the force is twice of the force on the flat one.
4) Sump Tank
   The sump tank is made to have a sufficient gas flow to the engine volume space. The outer surface is exposed to the Solar Irradiation for heating the gas. The surface material is to have a high thermal conductivity so as to heat the gas efficiently.
5) Return Pipe (with finned surface)-

In order to reduce the pressure of the gas the temperature of the gas has to be reduced drastically. So the return pipe up to the sump tank is finned making sure there is best possible heat removal from the hot gas.

Design analysis

To analyze the Rotary engine an experimental analysis was conducted. The input parameter which was varied to obtain different readings of temperature. The variation of temperature was done with the help of Temperature control unit.

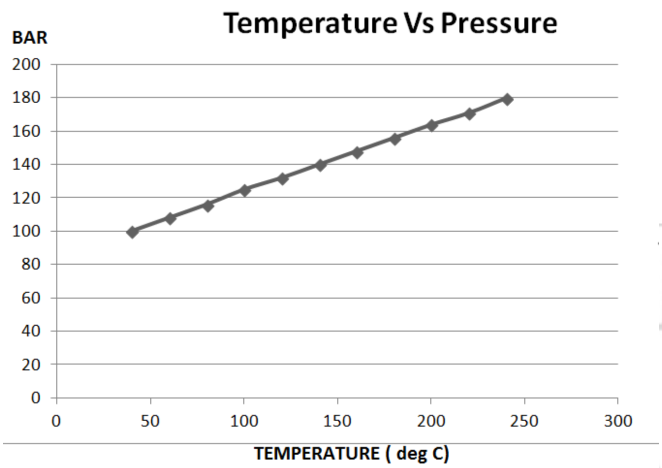

Figure 6: Temperature vs. Pressure graph

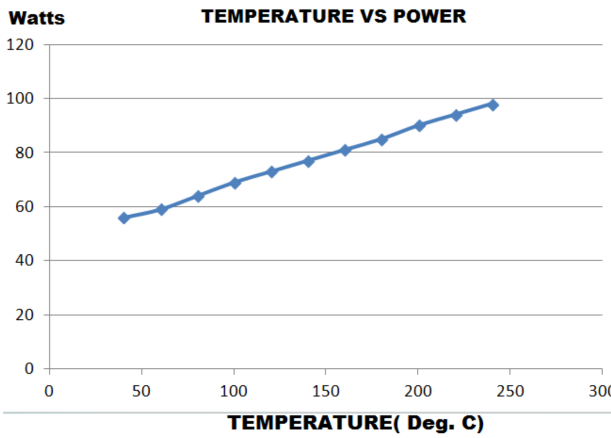

Figure 7: Temperature vs. Power graph

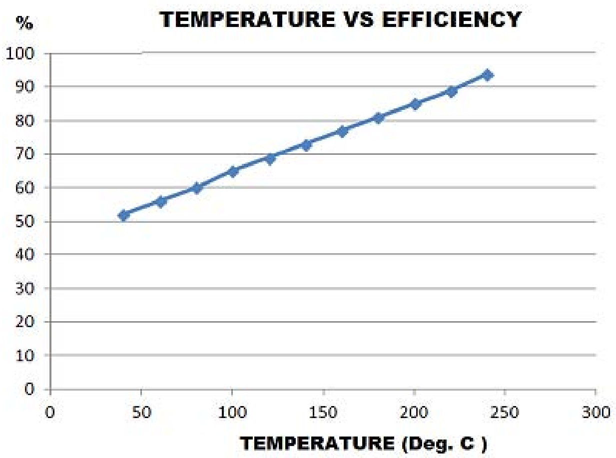

Figure 8: Temperature vs. Efficiency

6. Conclusion

The rotary gas engine has various advantages over the internal combustion engines. The main advantage is, no fuel is being used in the engine. Also there is no pollution which is very desirable in the today's World. As gas force is being used the need for supply system, fuel filter, fuel injector, fuel pump, valves etc. are eliminated and the design of the engine is made simple. The weight of the engine can be easily reduced by using aluminum. Less noise is produce during working. The disadvantage By slight modification in design and by the use of better hands the engine can be modified to generate more power, thereby increasing its efficiency, so that it can be used in commercial vehicle and for other application.

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Definition /Abbreviations

CSP - CONCENTRATED SOLAR POWER.
IC ENGINE- INTERNAL COMBUSTION ENGINE.