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ECO-TWINGINE

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Abstract— ECO-TWINGINE could be the solution to the problem of rising price of fossil fuels, their depletion and the harm caused to the environment. The rising demand for more fuel efficient and green automobiles has forced the think tanks all over the world to contrive an alternate source of energy. Water is used as the alternate source of energy here; however gasoline is used for the initiation of the process. We intend to make the normal gasoline powered car more efficient, green and cheap in the long run.

Keywords- *Petrol Engine, Stirling Engine, Water, Thermal Sensor, Heating Coils, Dual Cycl.*

I. INTRODUCTION

The name 'ECO-TWINGINE' stands for Eco-friendly Twin Engine. This engine comprises of combination of Petrol engine and Stirling engine, working on water as fuel to a greater extent.

1. PETROL ENGINE

Otto cycle is an air standard cycle of spark ignition engine [1]. In most spark ignition engines, the piston executes four complete strokes within the cylinder, and the crankshaft completes two revolutions for each thermodynamic cycle. These engines are four stroke internal combustion (IC) engines shown in fig. 1.

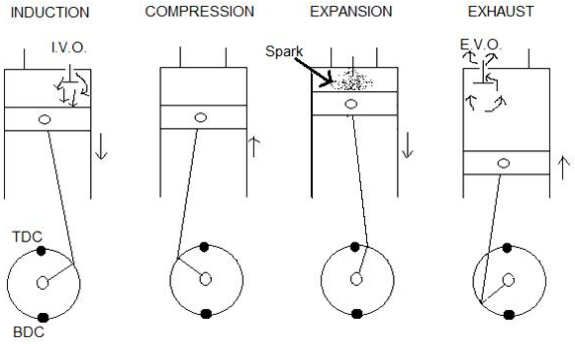

Fig. 1: Four strokes of an IC Engine

Timing diagram [2] of a four stroke internal combustion petrol engine is shown in fig. 2.

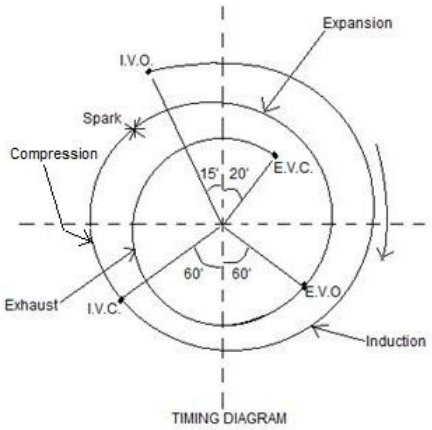

Fig. 2: Timing Diagram of a Petrol Engine

Fig. 3 shows an air standard cycle (Otto cycle) corresponding to above engine consisting of two reversible adiabatics and two reversible isochores [1].

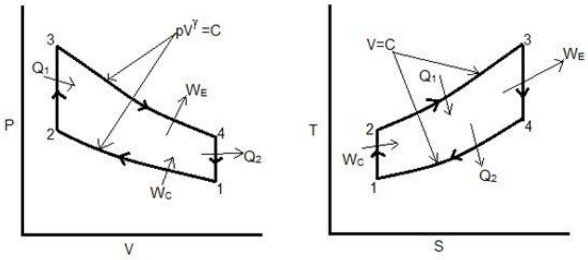

Fig. 3: Otto Cycle

Efficiency of Otto cycle,

$$\eta_{otto} = 1 - (1/r_k^{\gamma-1})$$

Where γ = specific heat ratio for air = 1.4,

Compression ratio, $r_k = V_1/V_2$,

V_1 = Volume at the beginning of compression,

V_2 = Volume at the end of compression.

The efficiency of the air standard Otto cycle [1] is thus a function of the compression ratio only, independent of the temperature levels at which the cycle operates.

2. STIRLING/HOT AIR ENGINE

A Stirling engine [3] is a heat engine operated by cyclic compression and expansion of air or other gas, the working fluid, at different temperature levels [7] such that there is a net conversion of heat energy to mechanical energy or, a closed-cyclic regenerative heat engine with a permanently gaseous working fluid , where closed-cycle is defined as a thermodynamic system in which the working fluid is permanently contained within the system and regenerative describes the use of a specific type of internal heat exchanger and thermal store, known as the regenerator. It is the inclusion of a regenerator that differentiates the Stirling engine from other closed cycle hot air engines. Advantages of Stirling engine:

- high efficiency compared to steam engines,

- quiet operation,
- compatibility with alternate and renewable energy sources has become increasingly significant due to rising prices of conventional fuel and global warming.

WORKING [8]:

1. Power piston has compressed the gas, the displacer piston has moved so that most of the gas is adjacent to the hot heat exchanger.
2. The heated gas increases in pressure and pushes the power piston to the farthest limit of the power stroke.
3. The displacer piston now moves, shunting the gas to the cold end of the cylinder.
4. The cooled gas is now compressed by the flywheel momentum. This takes less energy, since its pressure drops when it is cooled.

Different strokes of Stirling engine are shown in fig. 4.

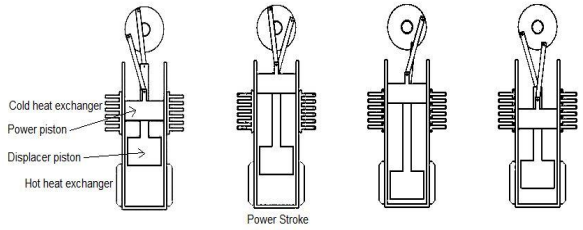

Fig. 4: Working of a Stirling Engine

Reversible processes occurring in the Stirling cycle [1] are shown in fig. 5.

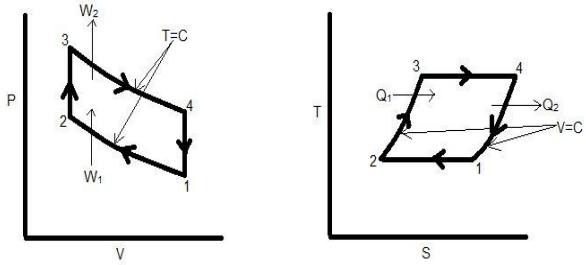

Fig. 5: Stirling Cycle

II. CONCEPT

COMBINATION OF OTTO AND STIRLING CYCLE (DUAL CYCLE)

It deals with the mechanism of utilization of water as the fuel to a greater extent and limiting the use of petrol, thus decreasing the money expenditure for petrol consumption, and water being harmless to nature, controlling the pollution/degradation of environment.

Assumptions:

- No heat loss occurs during heat addition to the Stirling engine and water tank.
- In practical use of the Stirling cycle, isotherms are impossible to occur so they are treated as adiabatic [3].

ECO-TWINGINE works on the layout shown in fig. 6.

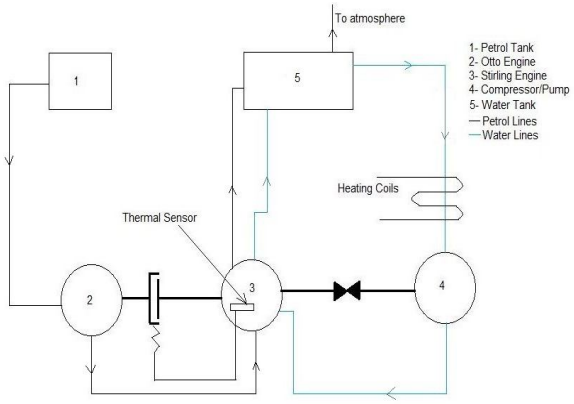

Fig. 6: Working Layout of Concept ECO-TWINGINE

The Concept ECO-TWINGINE works on combination of following two cycles:

1. OPEN PETROL CYCLE

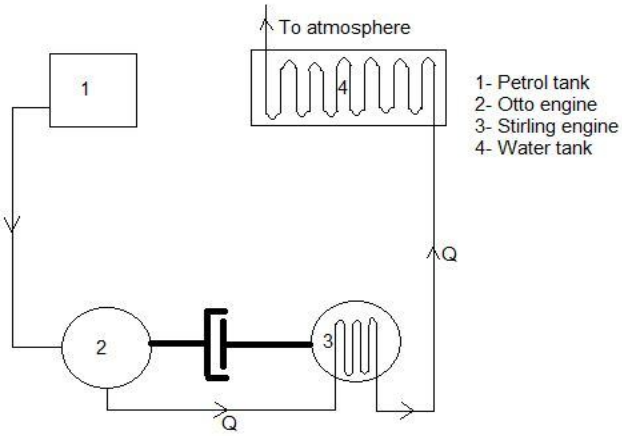

Fig. 7: Layout of Open Petrol Cycle

The petrol engine [1] used works on the 4-stroke mechanism: Suction, Compression, Power/ Combustion, and Exhaust. The combustion stroke provides the initial power.

Due to combustion, the exhaust gases escape out through the outlet valve and fed into the Stirling engine for heat addition. The addition of heat results in expansion of air inside the cylinder and thus the reciprocating movement of piston [3]. This causes the rotation of crankshaft. Initially both engines are coupled by the crankshafts with an auto-clutch [6] mechanism.

After heat addition to Stirling engine, surplus heat of the exhaust gases is used to pre-heat the water (Fig. 7). This results in an increase in the temperature of water before the start of water cycle. It is an open cycle because petrol burns to form gases that escape out in the atmosphere.

2. CLOSED WATER CYCLE

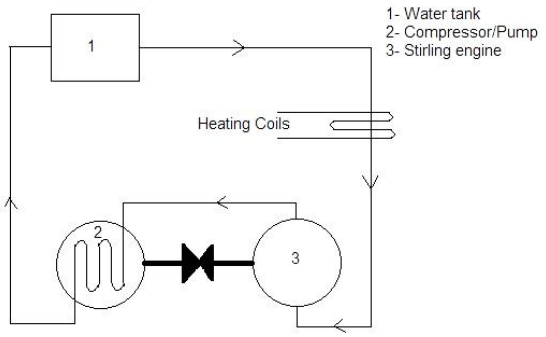

Fig. 8: Layout of Closed Water Cycle

The Stirling engine, working on Helium gas as working fluid [4], is also connected to the compressor/pump to which water is fed and high temperatures and pressures are reached from the water tank with the use of car battery powered heating coils, shown in fig. 8.

In this arrangement, heating coils are utilized to increase the temperature of pre-heated water for an efficient compression. After water is compressed, its temperature further increases to cause boiling and steam generation. The generated steam or boiled water is pumped out through the compressor/pump to the Stirling engine. As the action of this pump continues, water continues to circulate throughout the pipe channel. The generated steam or boiled water is utilized for the heat addition in the Stirling engine for air expansion. This heat addition results in a net increase in the rpm.

This way, closed water cycle continues till the temperature needed for the expansion of air in the Stirling engine is maintained. Hence ECO-TWINGINE continues to work with water as fuel till any reduction in power output and required operating temperature of the Stirling engine. This condition engages the auto-clutch [6] again with the help of thermal sensor [5] equipment and the action of petrol valves [2] and the open petrol cycle comes into role once again only for re-establishing the conditions for Stirling engine to work.

III. ANALYSIS

In T-S diagram, process 4_o-1_o is an isochoric process for Otto cycle and process 2_s-3_s for the Stirling cycle [1].

If the lower temperature of both cycles are equal 1_0-2_s and the higher temperature of the Stirling cycle is equal to the exhaust temperature of the Otto cycle 3_s-4_o, then the heat rejected in the Otto cycle [1] would be equal to the heat addition in the Stirling cycle. So, the process 4_o-1_s and 2_s-3_s together form a reversible process and hence it can be neglected or cancelled out of the cycle. In the p-V diagram of the combination also, the process 4_o-1_o and 2_s-3_s together form reversible process so it has been removed /discarded. T-S and p-V diagrams of Dual Cycle are shown in fig. 9 and fig. 10 respectively.

From Otto cycle: Compression ratio $r_{ko} = V_{1o}/ V_{2o}$
From Stirling cycle: Compression ratio $r_{ks} = V_{1s}/ V_{2s}$

Therefore, Efficiency of dual cycle

$$\eta_d = 1 - (T_2/T_3) = 1 - (T_1/T_3)$$

Also, $T_2/T_3 = T_1/T_3 = (V_3/V_1)^{\gamma-1}$ (i)

From (i); Efficiency of dual cycle,

$$\eta_d = 1 - (V_3/V_1)^{\gamma-1} = 1 - [1/(V_1/V_3)^{\gamma-1}] = 1 - [1/r_{kd}^{\gamma-1}]$$

Where compression ratio of dual cycle, $r_{kd} = r_{ko} + r_{ks}$

(*Note that subscripts o and s stand for Otto and Stirling respectively.*)

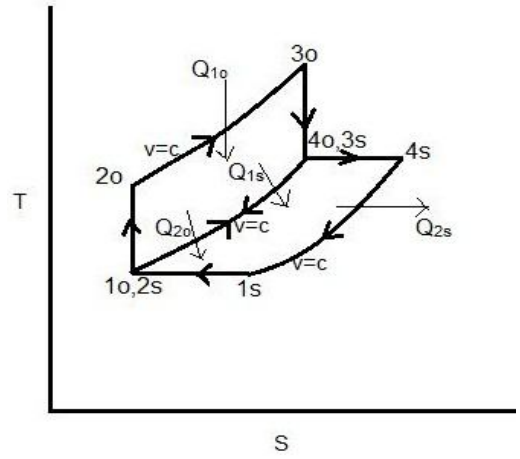

Fig. 9: T-S diagram of Dual Cycle

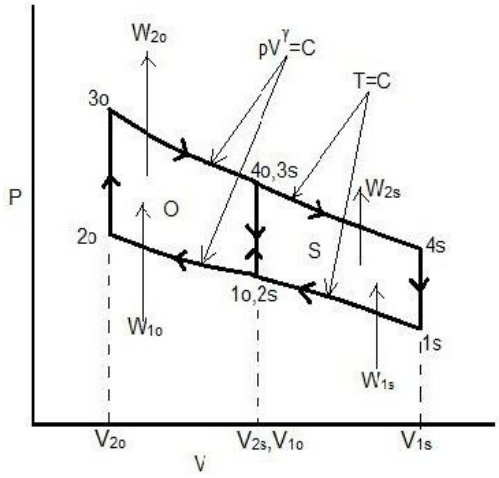

Fig. 10: p-V diagram of Dual Cycle

CALCULATIONS:

Heat generated inside Stirling engine, $H = mC_v dt$

Where m = mass of helium gas in *kg*,

C_v = heat capacity [4] of helium = 3.117 *kJ/kg K*,

dt = difference in temperature of helium and exhaust gases from petrol engine in *K*.

Let mass of Helium gas used be 1 kg and temperature maintained inside the Stirling engine be 40 °C, i.e. 313 K.

Also, under normal driving conditions, exhaust gas temperature remains around 500 °C, i.e. 773 K.

Therefore, $H = 1\ kg \times 3.117\ kJ/kg\ K \times (773\ K - 313\ K) = 1433.82\ kJ$

Let we assume that heat generated is completely converted into work done by the piston.

Hence, Work done by the piston = 1433.82 *kJ*,
and Indicated power = 1433.82 *kJ/s* or *kW*

Since the Stirling engine is known for its high mechanical efficiency [9], we consider it to be 80 %.

Therefore,
Brake Horse Power = $0.80 \times 1433.82\ kW = 1147.05\ kW$

Hence for a required size of Stirling engine, the mass of helium gas can be varied for obtaining desired output power.

Since expansion temperature of helium is low [4], therefore water may be utilized under its boiling temperature for the operation of Stirling engine. However for increasing the power output, water may be heated up at a greater temperature with the help of heating coils.

CONCLUSION:

Now, if the individual cycles of Otto and Stirling engine are combined to form a dual cycle then the compression ratio becomes

$$r_{kd} = V_{1s} / V_{2o}$$ (see fig. 10)

Therefore compression ratio of overall dual cycle increases. This in turn increases the efficiency of the petrol cycle.

If the relation for efficiency of petrol engine and compression ratio is taken into consideration, then there is an increase in efficiency of the petrol engine with an increase in the compression ratio. Hence ECO-TWINGINE working on a dual hybrid cycle results in an overall increase in efficiency and lesser consumption of gasoline/petrol, consequently leading to a greener environment.

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APPLICATIONS

- Implementation in automobile sector.
- Utilization for power generation.
- Implementation in aircrafts.
- Realization in marine engines.
- Application in agricultural practices.

FURTHER SCOPE OF RESEARCH

Elementary calculations have shown that such the concept is possible. Practical feasibility of this concept needs to be proved. Another horizon of this research could be a combination to implement and work on other types of engines, for example integrating Stirling engine with diesel engine. Another possibility would be of having the Stirling engine to work on different fuels other than water. The alternatives can be air, bio-gas etc.

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