UTILIZATION OF WASTED STEAM OF I.C ENGINE IN POWER GENERATION

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***Abstract*: The increasingly worldwide problem regarding rapid economy development and a relative shortage of energy, the internal combustion engine exhaust waste heat and environmental pollution has been more emphasized heavily recently. Out of the total heat supplied to the engine in the form of fuel, approximately, 30 to 40% is converted into useful mechanical work; the remaining heat is expelled to the environment through exhaust gases and engine cooling systems, resulting in to entropy rise and serious environmental pollution, so it is required to utilized waste heat into useful work. The study shows the availability and possibility of waste heat from internal combustion engine, also describe loss of exhaust gas energy of an internal combustion engine. Possible methods to recover the waste heat from internal combustion engine and performance and emissions of the internal combustion engine. Waste heat recovery system is the best way to recover waste heat and saving the fuel.**

In six stroke I c engine we can recover heat from engine coolant and combustion exhaust gas so here we can recover heat from two sources so we can increase more waste heat and decrease the emission.

***Index Terms*: Power Generation, Wasted Heat Power Generation, Utilization of Power Generation.**

I. INTRODUCTION:

Almost 1.5 billion people worldwide do not have access to electricity. Most of these electricity deprived live in sub-Saharan Africa and south Asia. Usually, this population lives in remote areas far from the centralized electricity grid with very low income and extending the electricity is not seen as economically feasible for electricity companies which prefer to concentrate their activities in urban areas. On the other hand, existing conventional power plants use fossil fuels as inputs and are integrated in centralized systems. Derived consequences are power losses in transportation lines due to remoteness of the electricity infrastructure from the consumers and environmental pollution. Pollution released in the atmosphere are responsible of the ozone depletion, global warming, acid rains and contamination of land and seas. In this context, using renewable energies like solar energy, wind energy, biomass and geothermal heat as well as waste heat for electricity production becomes important.

Recent trend about the best ways of using the deployable sources of energy in to useful work in order to reduce the rate of consumption of fossil fuel as well as pollution. Out of all the available sources, the internal combustion engines are the major consumer of fossil fuel around the globe. Out of the total heat supplied to the engine in the form of fuel, approximately, 30 to 40% is converted into useful mechanical work. The remaining heat is expelled to the environment through exhaust gases and engine cooling systems, resulting in to entropy rise and serious environmental pollution, so it is required to utilized waste heat into useful work.

The recovery and utilization of waste heat not only conserves fuel, usually fossil fuel but also reduces the amount of waste heat and greenhouse gases damped to environment. It is imperative that serious and concrete effort should be launched for conserving this energy through exhaust heat recovery techniques. Such a waste heat recovery would ultimately reduce the overall energy requirement and also the impact on global warming. The Internal Combustion Engine has been a primary power source for automobiles and automotives over the past century. Presently, high fuel costs and concerns about foreign oil dependence have resulted in increasingly complex engine designs to decrease fuel consumption.

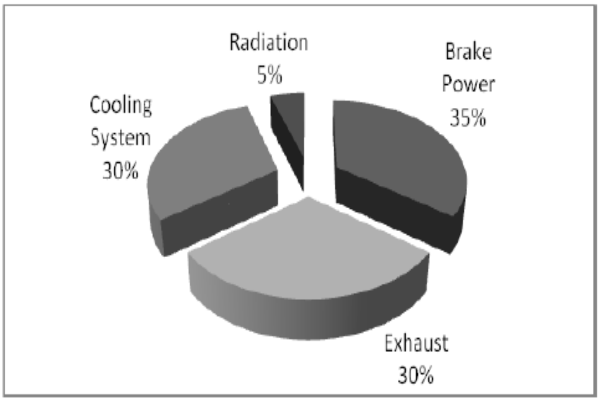

Fig. 1 Total Fuel Energy Content in I.C Engine

II. ALTERNATIVE METHODOLOGY:

(A) Availability of heat From I.C. Engine:

Waste heat is heat, which is generated in a process by way of fuel combustion or chemical reaction, and then "dumped" into the environment even though it could still be reused for some useful and economic purpose. This heat depends in part on the temperature of the waste heat gases and mass flow rate of exhaust gas. Waste heat losses arise both from equipment inefficiencies and from thermodynamic limitations on equipment and processes. For example, consider internal combustion engine approximately 30 to 40% is converted into useful mechanical work. The remaining heat is expelled to the environment through exhaust gases and engine cooling systems. It means approximately 60 to 70% energy losses. as a waste heat through exhaust (30% as engine cooling system and 30 to 40% as environment through exhaust gas). Exhaust gases immediately leaving the engine can have temperatures as high as 842-1112°F [450-600°C]. Consequently, these gases have high heat content, carrying away as exhaust emission. Efforts can be made to design more energy efficient reversible engine with better heat transfer and lower exhaust temperatures; however, the laws of thermodynamics place a lower limit on the temperature of exhaust gases.

The quantity of waste heat contained in a exhaust gas is a function of both the temperature and the mass flow rate of the exhaust gas,

$$Q = m \times C_p\,(t_{2-}\,t_1) \qquad (1)$$

Where, is the heat loss (kJ/min); is the exhaust gas mass flow rate (kg/min); is the specific heat of exhaust gas (kJ/kg°K); and is temperature gradient in °K. In order to enable heat transfer and recovery, it is necessary that the waste heat source temperature is higher than the heat sink temperature. Moreover, the magnitude of the temperature difference between the heat source and sink is an important determinant of waste heats utility or "quality". The source and sink temperature difference influences the rate at which heat is transferred per unit surface area of recovery system, and the maximum theoretical efficiency of converting thermal from the heat source to another form of energy (i.e., mechanical or electrical).

Finally, the temperature range has important function for the selection of waste heat recovery system designs.

(B) Possible way of using heat recovery system:

The increasing fuel costs and diminishing petroleum supplies are forcing governments and industries to increase the power efficiency of engines. A cursory look at the internal combustion engine heat balance indicates that the input energy is divided into roughly three equal parts:

1. Energy converted to useful work,
2. Energy transferred to coolant and
3. Energy lost with the exhaust gases.

There are several technologies for recovering this energy on an internal combustion engine, where as the dominating ones are:

Waste heat can utilize for;

- heating purpose,
- power generation purpose,
- refrigeration purpose

Power generation further classified by;

- Direct method

- Thermoelectric generation,
- Pizeo electric generation,
- Thermo photovoltaic generation

➢ Indirect method
- Rankine cycle,
- Stirling cycle

DIRECT METHOD,

Thermo electric generator:

The exhaust pipe contains a block with thermo electric materials that generates a direct current, thus providing for at least some of the electric power requirements. In which two different semiconductors are subjected to a heat source and heat sink. A voltage is created between two conductors. It is based on the see back effect. The Cooling and Heating is done by applying electricity. It is low efficiency approximately (2 to 5%) and high cost. Thermo Electric Generator is used to convert thermal energy from different temperature gradients existing between hot and cold ends of a semiconductor into electric energy this phenomenon was discovered by Thomas Johann See back in 1821and called the See back effect. The device offers the conversion of thermal energy into electric current in a simple and reliable way. Advantages of Thermo Electric Generator include free maintenance, silent operation, high reliability and involving no moving and complex mechanical parts. Recycling and reusing waste exhaust gas can not only enhance fuel energy use efficiency, but also reduce air pollution. Thermal power technology such as the Thermo Electric Generator arises, therefore, significant attention worldwide. Thermo Electric Generator is a technology for directly converting thermal energy into electrical energy. It has no moving parts, is compact, quiet, highly reliable and environmentally friendly. Because of these merits, it is presently becoming a noticeable research direction. The mathematical model of a Thermoelectric Generator device using the exhaust gas of vehicles as heat source, and preliminary analysis of the impact of relevant factors on the output power and efficiency of Thermo Electric Generator .Analysis of model simulates the impact of relevant factors, including vehicles exhaust mass flow rate, temperature and mass flow rate of different types of cooling fluid, convection heat transfer coefficient, height of PN couple, the ratio of external resistance to internal resistance of the circuit on the output power and efficiency. Analysis of thermoelectric generator for power generation from internal combustion engine shows results as 20% of energy releasing for the waste heat from engine. It is able to 30-40% of the energy supplied by fuel depending on engine load [1].

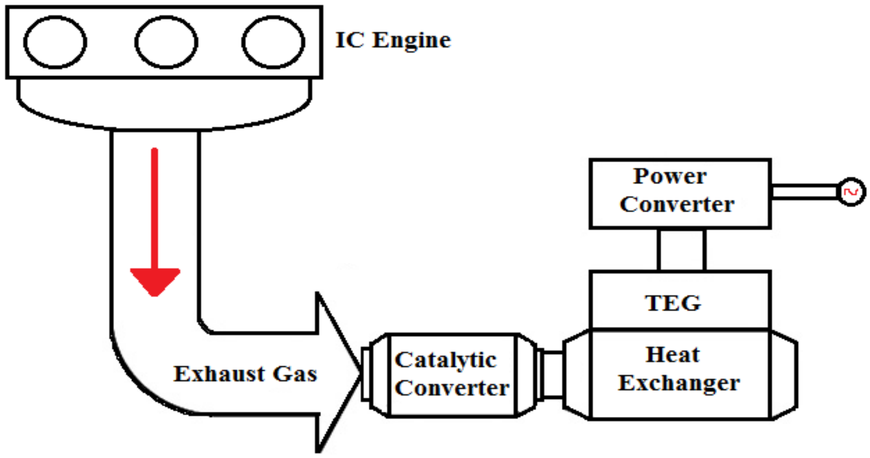

Fig. 2 Thermo electrical generator

Piezoelectric Generation:

It is used for low temperature range of 100 to 150. Piezoelectric devices convert mechanical energy in the form of ambient vibration to electric energy. This is thin film membrane can take advantage of oscillatory gas expansion to create a voltage output.

Thermionic Generation:

It is thermoelectric device operate on thermionic emission. In this system a temperature difference drives the flow of electron through vacuum from metal to metal oxide surface at 1000°C

In direct method,

Rankine Cycle:

The system is based on the steam generation in a secondary circuit using the exhaust gas thermal energy to produce additional power by means of a steam expander. A special case of low temperature energy generation systems uses certain organic fluids instead of water in so-called Organic Rankine Cycle (ORC). This technique has the advantage compared with turbo-compounding that does not have so an important impact on the engine pumping losses and with respect to thermoelectric materials that provides higher efficiency in the use of the residual thermal energy sources. Waste heat recovery from rankine cycle operated at low temperature difference using unconventional fluids (refrigerants, CO2, binary mixtures). At very low heat source temperature the trans-critical CO2 cycle produces highest net power output [2]. Rankine bottoming cycle techniques maximize energy efficiency; reduce fuel consumption and green house gas emissions.

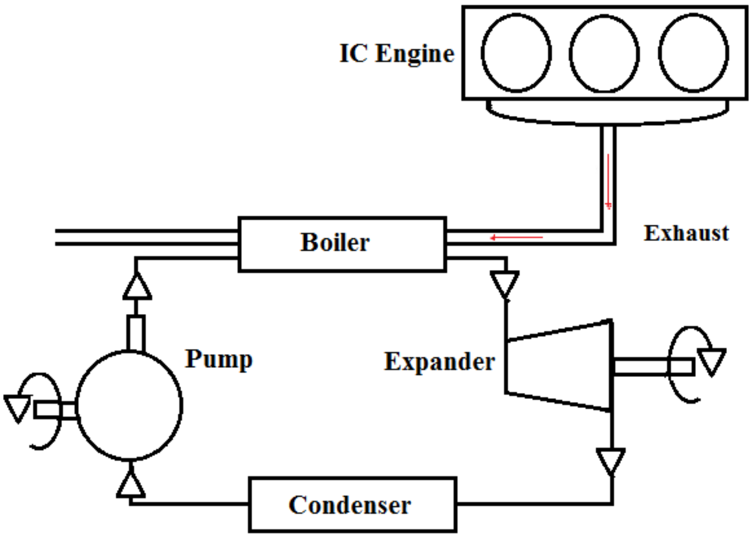

Fig. 3 Rankine cycle

Stirling Cycle:

Linearly reciprocating internal combustion engine offers many advantages over the conventional crank-slider engine. Benefits include improved efficiency, higher power-to-weight ratio and multiple fuel capability. A Stirling engine is a heat engine operating by cyclic compression and expansion of air or other gas, the working fluid, at different temperature levels such that there is a net conversion of heat energy to mechanical work.

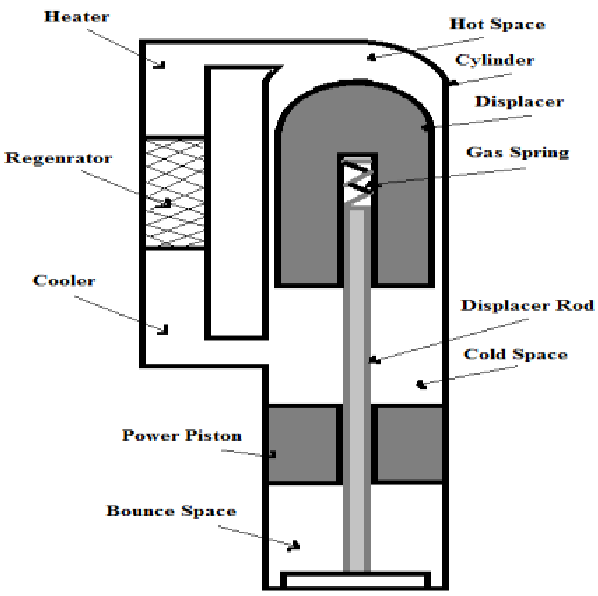

Fig. 4 Free Piston Stirling Cycle

Waste heat recovery from internal combustion engine analyzed with two different fluids by using organic rankine cycle. The best performance was obtained when R-123 was applied as the working fluid. They have Observe reduction of fuel consumption was also studied.

A set of free piston Stirling engine with output power, hot and cold space temperatures and operation frequency designed by coupling structural dynamics analysis and thermodynamics calculation. Fin structure was selected for Heater and cooler to increase heat exchange area and improve heat transfer performance. Size of gap used for clearance seal is designed and completed by precision machining processing, which is a key step of whole engine manufacturing. Design free-piston Stirling engine, which works at relatively low differential temperature. The free piston Stirling engine is a beta type configuration. The free piston Stirling engine couples with a pneumatic cylinder And results by simulation shows the Output power from numerical simulation was higher than that of experiment according to theoretical assumptions [3]. Gamma type Stirling engine was design and developed for application of waste heat recovery system. The performance of low temperature difference Stirling engine was investigated.

Mechanical Turbo-compounding:

A compressor and turbine on a single shaft, It is used to boost the inlet air (or mixture) density. Energy available in the engine exhaust gas is used to drive the turbocharger turbine which drives the turbocharger compressor which raises the inlet fluid density prior to entry to each engine cylinder. The fig shows a turbocharged and turbo-compounded internal combustion engine is shows in fig. 5. The turbo demonstrates a method that is presently utilized widely to convert waste energy to improve the efficiency and power output of the internal combustion engine. The problem with current turbochargers is that they do not extract all the possible energy available. The concept of using a turbine to recover energy comes from the turbocharger. The turbocharger is a mechanism that increases the power output of the engine using a turbine. Rather than using the turbine to power a compressor, the turbine could be connected to a generator. Alternatively, a series of turbines could be connected to a series of generators. If an efficient design was implemented the alternator could be removed from the car to improve the efficiency of the engine by lowering the load on it and by decreasing the weight of the car itself. A turbine of this nature would have to be situated after the catalytic converter.

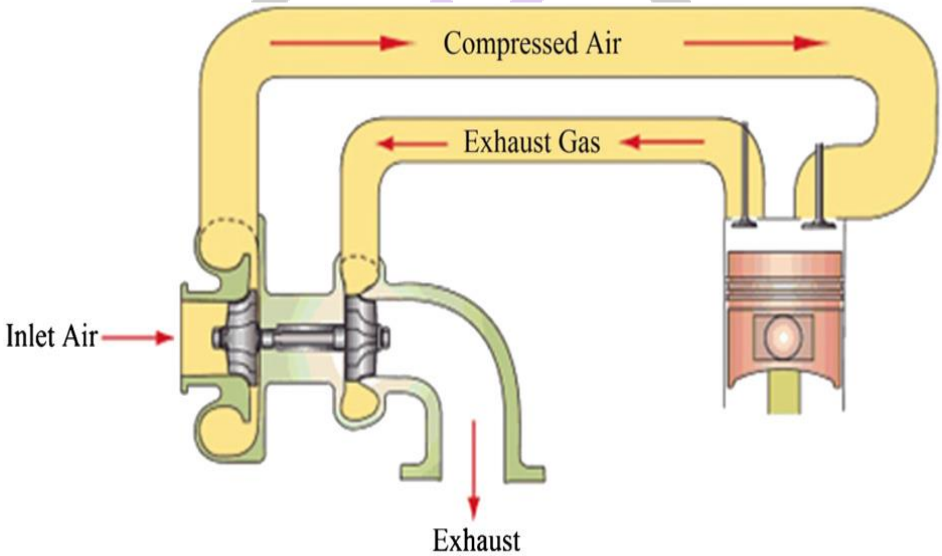

Fig. 5 Typical turbocharger with compressor wheel and turbine

Refrigeration:

Heat recovery from automotive engines has been predominantly for turbo-charging or for cabin heating with application of absorption chillers. The experiments conducted on the system, prove that the concept is feasible, and could significantly enhance system performance depending on part-load of the engine. Also the concept could be used for refrigeration and air conditioning of transportation vehicles [4].

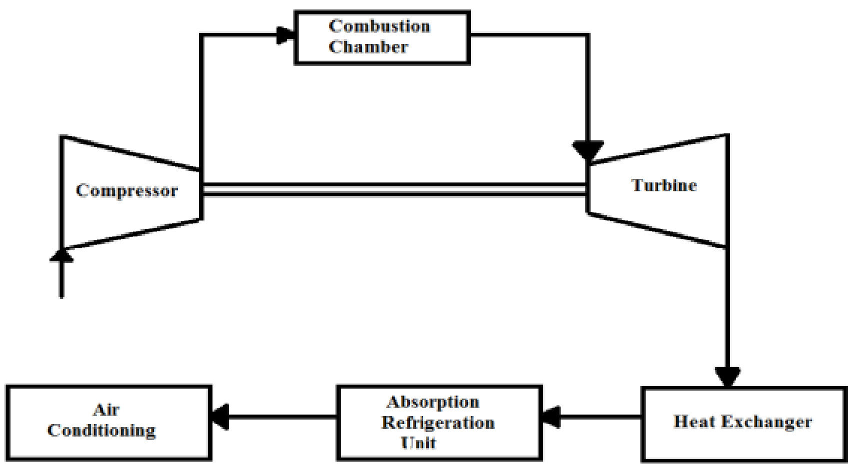

Fig. 6 Vapour absorption machine

III. POWER GENERATION FROM SIX STROKE I.C ENGINE:

Internal combustion engines efficiency is less than 40%. Most of the energy generated by burning the fuel in the combustion chamber is lost in water cooling and exhaust [5]. During every cycle in a typical four stroke engine, piston moves up and down twice in the chamber, resulting in four total strokes and one of which is the power stroke that provides the torque to move the vehicle. But in a six stroke engine there are six strokes and out of these, there are two power strokes. The automotive industry may soon be revolutionized by a new six-stroke design which adds a second power stroke, resulting in much more efficiency with less amount of pollution.
According to Crower's design, during the operation of a six stroke engine, water is injected only after the exhaust stoke is completely finished. In order to recover the waste heat, a second method has been adopted in this paper.

Table 1:Engine specification

Engine type	4-stroke single cylinder OHC
Displacement	97.2 CC
Maximum power	4.7 KW@5000RPM
Maximum torque	0.77KGM@6000RPM
Bore *stroke	50*49.5MM
Compression ratio	8:8:1
Idel speed	1400 RPM
Ignition	CDI Capacitor discharge ignition
Break drum diameter	0.4mm
Chain diameter	0.02mm

CALCULATION:

Number of Power Stroke per minute = 5000/2 =2500 rpm
=2500 × 60 rph
= 150000 rph

Calorific Value of petrol = 44000 KJ/Kg

Specific heat capacity of 1 Kg water, Cw = 4.18 KJ/Kg

Fuel Consumption =195g/KW/h

Input Power (water), (lw) = Cw × Ww
= 4.18 × 1995
= 8.33 KW

Input Power (Fuel), (lf) = 44000 × 0.195
= 8.58 KW

Total Input, (Pi) = 8.33+8.58
= 16.91 KW

Frictional Power, FP Therefore for six stroke = 1.6 for 4 stroke
= 1.6+1.6/2
= 2.24 KW

% FP = (2.4/ 16.95) × 100
= 14.15 %

Where,
Heat Lost Through Cooling Air/Water
Mw = Mass of cooling water
Tw1 = temperature of outlet water
Tw2 = temperature of inlet water

H w = Mw C w (Tw1- Tw2) / 1000 KW
= 172.24 × 4.18 (36-29)/ 1000 KW#
= 5.039 KW

% Hw = Hw / Pi
= (5.039/16.96)/1000
= 29.71%

Where,
Heat Lost Through Exhaust Air
Ma = mass of air Ta1 = temperature of outlet air
Ta2 = temperature of inlet air

Ha = Ma Ca (Ta1-Ta2) /1000 KW
= 97.51 × 1.005 (70-30) / 1000 KW
= 3.91 KW

% Ha = Ha / Pi
= (3.91/ 16.96) × 100
= 23.05%

Output (Thermal Efficiency) = 100 – (Ha + H w+ FP)
= 100 – (23.05+29.71+ 14.15)
= 33.09%

Maximum Load BP = (2× 3.14 × N (D + d)/2 × 9.81v (w - s)) / 60000
= (2 × 3.14 × 5000 (0.4 + 0.2) / 2× 9.81 × (w - s)) / 60000 w-s
= 5.16 Kg (max load)

At No Load,

BP = (2 × 3.14 × 5000 (0.4 +0.02) / 2 × 9.81) / 60000
= 1.08 KW

Heat Lost through Cooling water (4 Stroke),

H w = Mw C w (Tw2- Tw1)/1000
= 75.75*4.18(32-29)/1000
= 0.9499 KW

%H w = 0.9499/16.91× 100
= 27.24%

Heat Lost through Exhaust Air (4 Stroke)

Ha = Ma Ca (Ta2- Ta1) /1000
= 6.74× 1.005(100-31) /1000
= 0.467 KW

% Ha = 0.467/16.91×100
= 13.53%

- **PERFORMANCE ANALYSIS**:

The heat that is evacuated during the cooling of a conventional engine's cylinder head is recovered in the six-stroke engine by the air-heating chamber surrounding the combustion chamber.

- After intake, air is compressed in the heating chamber and heated through 720 degrees of crankshaft angle, 360 degrees of which in closed chamber (external combustion).
- The transfer of heat from the very thin walls of the combustion chamber to the air heating chambers lowers the temperature and pressure of the gases on expansion and exhaust (internal combustion) .
- Better combustion and expansion of gases that take place over 540 degrees of crankshaft rotation, 360° of which is in closed combustion chamber, and 180° for expansion.
- The glowing combustion chamber allows the optimal burning of any fuel and calculates the residues.
- Distribution of the work: two expansions (power strokes) over six strokes, or a third more than that in a four-stroke engine.
- Better filling of the cylinder on the intake due to the lower temperature of the cylinder walls and the piston head.
- Elimination of the exhaust gases crossing with fresh air on intake. In the six stroke-engines, intake takes place on the first stroke and exhaust on the fourth stroke.
- Large reduction in cooling power. The water pump and fan outputs are reduced. Possibility to suppress the water cooler.
- Less inertia due to the lightness of the moving parts.

An ideal thermodynamics model of the exhaust gas compression, water injection at top centre, and expansion was used to investigate a modification to recover energy from two waste streams that effectively add two strokes to a common four-stroke internal combustion engine. The additional two strokes require substantial modifications to the exhaust valve operation as well as a manner to inject water directly into the combustion chamber because this injection water is heated by the engine coolant; this six-stroke concept presented here recovers energy from both the engine coolant and combustion exhaust gas. Thus, this concept recovers energy from two waste heat sources of current engine designs and converts heat normally discarded to useable power and work.

By the utilization of the waste heat, the performance of the internal combustion engine is considerably increased. With the utilization of the waste heat of internal combustion engine the world energy demand on the depleting fossil fuel reserves would be reduced. The fuel efficiency would be increased by the development of six stroke engine with the same amount of fuel the internal combustion engine would give more mileage and it would relief growing demand .

IV. CONCLUSION:

It has been identified that there are large potentials of energy savings through the use of waste heat recovery technologies.

Waste heat recovery defines capturing and reusing the waste heat from internal combustion engine for heating, generating mechanical or electrical work and refrigeration system.

The waste heat recovery from exhaust gas and conversion in to mechanical power is possible with the help of Rankine, Stirling and Brayton thermodynamic cycles, vapour absorption. For waste heat recovery thermoelectric generator is use low heat, which has low efficiency.

In six stroke I.C engine we can recover heat from engine coolant and combustion exhaust gas so here we can recover heat from two sources so we can increase more waste heat and decrease the emission.

The fuel efficiency would be increased by the development of six stroke engine with the same amount of fuel the internal combustion engine would give more mileage and it would relief growing demand.

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