Exhaust Waste Heat Recovery using Rankine Cycle by Tesla Turbine

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Abstract- *Now a days the escalating price of conventional fuel are affecting the road and ship transport. Increase in demand for fuel is also affecting the environment greatly. Although new regulations are trying to limit this pollution but almost every time it is done by compensating power output and increasing the system cost. At present, efficiency of an IC engine lies between 20%-30%. Almost 30-40% of total energy is wasted through the exhaust. There are several ways to recover this heat but if we look at today's power need except Rankin cycle all other ways are still in need of tremendous research to increase their cycle efficiency. In this paper we are aimed to design a compact Rankine cycle with lower maintenance which will be useful for food and pharmaceutical transport which requires cooling. In this paper we will have reading of a prototype which can be improved greatly by using advance engineering. Its cost can be minimized by mass production. We are not only aiming to study the working of the system but also to make this system feasible and affordable.*

I. INTRODUCTION

Now a days the IC engine is the key part of any type of transport because of its power to weight ratio. Transport through electric vehicles or hydrogen engines (fuel cell) are still under research to make them more affordable and feasible. Also they cannot replace current system instantly. But power need of transport cannot be stopped for it. Also issues of greenhouse gases are becoming more critical day by day .On an average 30%-40% of total energy is wasted through exhaust gases and there is hardly anything is left to do inside engine cylinder to increase efficiency. Thus to recover the waste heat is the best option. In this project we are using 98 cc engine which have 7.5 BHP at 7000 rpm. A shell tube heat exchanger is used instead of silencer and generated steam is expanded into the Tesla turbine. Easy manufacturing and less maintenance cost are the main factor to choose tesla turbine over other conventional turbines. Also Tesla turbines are smooth in operation which does not generate noise like other turbines. The shaft output is utilized by two method

1. To convert shaft power in to electricity and then use it to charge batteries on which refrigerator will work.
2. Another way is to connect shaft to reciprocating compressor of cooling system by means of reciprocating mechanism.

II. LITERATURE REVIEW

1. Exhaust Gas Heat Recovery for C.I Engine-A Review by Baleshwar Kumar Singh, Dr. Nitin Shrivastava.[24] An IJESRT paper gave the idea about the Waste Heat Recovery (WHR) and the methods to recover the energy. By using waste heat recovery concept we can save the fuel and utilized the waste heat also .There are the large amount of energy- saving through waste heat .Through above paper waste heat recovery are utilized in the form of heat generating, mechanical and electrical and refrigeration system in I.C engine. Mainly waste heat recovery from exhaust gas and converted in to mechanical work and then convert into electrical power

2. United States Patent 4393656, "WASTE HEAT RECOVERY SYSTEM FOR AN INTERNAL COMBUSTION ENGINE", by Forest L. Anderson, Dr. Denver Colo [25] Used Tesla turbine to generate the power output by Rankine cycle. A method primarily intended for recovering andutilizing waste heat from the exhaust and coolant of an internal combustion engine by using a single working fluid, said method comprising the steps of:
   a) pumping liquefied working fluid to a first location along a first path,
   b) vaporizing said working fluid at said first location along said first path to a high side temperature and pressure by applying waste heat from said exhaust,
   c) expanding said vaporized working fluid in said first path to produce work,
   d) condensing said expanded working fluid to a liquid state by removing heat there from,
   e) repeating steps (a)—(d) while simultaneously,
   f) pumping said liquefied working fluid along a second path having at least two portions thereof in parallel,

g) vaporizing said working fluid of step (f) in said parallel portions of said second path to high side temperatures and pressures less than the high side temperature and pressure of said first path by respectively applying waste heat in parallel from said coolant and the removed heat of step (d), (h) expanding said vaporized working fluid in said second path to produce work, (i) condensing said expanded working fluid of step (h) to a liquid state, and (j) repeating steps (f)-(i).

3. Brands MC, Werner JR, Hoehne JL, Kramers S. Vehicle testing of Cummins turbocompound diesel engine, SAE Paper No. 810073, 198 [27] Achieved WHR in a six cylinder, 14.5 L, Cummins NTC-400 diesel engine rated at 298 kW at 2100 RPM by turbo-compounding. This involved the use of a power turbine to recover energy from the exhaust gas. The authors demonstrated a 12.5% improvement in power and 14.8% net improvement in fuel economy due to WHR by Rankine cycle turbo-compounding.

4. Chen SK, Lin R. A review of engine advanced cycle and Rankine bottoming cycle and their loss evaluations, SAE Paper No. 830124, 1983 [26] Reviewed many methods incorporated by various investigators to improve engine efficiency. They came to the conclusion of a possible multi-stage Rankine cycle with the 1 st stage operating on water followed by a 2nd stage operating on R-11 (organic solvent) to recover high temperature exhaust heat and to enable low temperature exhaust WHR respectively. They also predicted a 15% improvement in efficiency through WHR. An ORC system operating on trifluoroethanol designed for use with a Class 8, long-haul vehicle diesel engine was tested for improvements in engine efficiency. A 12.5% increase in highway fuel economy was achieved with this system.

5. Vaja, A. Gambarotta, Internal combustion engine (ICE) bottoming with organic Rankine cycles (ORCs), Energy, 35 (2) (2010), pp. 1084–1093 [28] analyzed a supercritical ORC system of WHR from heavy duty diesel engines. The exhaust WHR was analysed from the perspectives of the first and second law of thermodynamics. They predicted up to a 20% improvement in engine power using a supercritical ORC.

III. DESIGN SPECIFICATIONS OF THE SYSTEM

Table 1. Specifications of the system

Component	material	dimensions
Heat exchanger(OD*ID *L)	Mild steel	94*90*500mm
Heat exchanger tubes(OD*ID*L)	Mild steel	12.5*8 *500mm
Tesla turbine Casing	Aluminium	100*115
Tesla discs	Mild steel	80*2.4 mm
Storage tank	Mild steel	2.5 litre

Figure 1.

Figure 2.

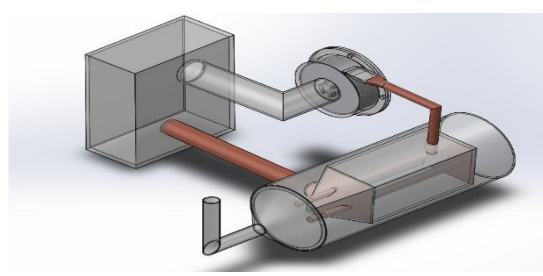

Figure 3.

Figure 4.

IV. OBSERVATION TABLE

T1= Temperature at inlet of heat exchanger, °C
T2= Temperature at outlet at heat exchanger, °C
T3=Temperature of water inlet, °C
T4= Temperature of steam, °C
T5 = Temperature at outlet of turbine, °C
P1= Pressure of steam, bar
P2= pressure at turbine outlet, bar

Table 2.

T_1	650
T_2	300
T_3	45
T_4	141
T_5	95
P_1	3.5
P_2	1.013

Mass flow rate of Exhaust= 21.1 Kg/Hr
Mass flow Rate of Steam= 16Kg/Hr
Enthalpy of steam = 2351.75 KJ/Kg
Efficiency of heat exchanger= 31.53%
Efficiency of turbine= 1.23%

V. CONCLUSION

1. Turbine have only 1.23% of efficiency which is due to lack of advance engineering and material technology available at college level.
2. Enthalpy drop in turbine is more than 800 watts .so in future using proper material and advance machinery we can have more shaft work by using more efficient turbine.
3. As engine is too small as compared to heavy transport vehicles engine the power output which we are getting is in the pulse format.
4. From above result we can conclude that this system can be used where a specific range of temperature is required like local transport of fish and vegetables
5. Power output is not constant because mass flow rate of exhaust gas varies with different factors like acceleration and load.

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