Design and Development of Air Preheater to Improve Engine Efficiency: A Review

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Abstract— The focus of the study is to review the modern changes and technologies on waste heat recovery of exhaust gas from internal combustion engine. These include the thermoelectric generator, turbocharger, exhaust gas through I.C engine. Due to the total heat supplied to the engine in the form of fuel around 30-40%, heat is converting in to the use full mechanical work and residual parts of the wastage heat 60-70% as friction, exhaust gas and engine cooling system. Waste heat release in the form of fumes in environment through I.C engine, which also includes the exhaust gases. The side effects are global warming, greenhouse effects and entropy increases etc. Therefore, it is required to use the waste heat in to useful work. The recovery of waste heat not only conserves fossil fuel but also control the environment pollution. Therefore, main objective of this paper is to evaluate (waste heat recovery system) technology based on the total waste heat converted into the useful mechanical work and possible methods to recovery of the waste heat from I.C engine. As a result, waste heat recovery from the I.C engines and utilization shall be remain best technique in future automobile application save the fuel and protect the environment.

Keywords: Waste heat recovery system, efficiency improve, Thermoelectricity, temperature

I. Introduction

engine is a device that uses fossil fuel (Chemical energy), extensive research and technology converts into the heat energy, and then finally converts in the use full mechanical work. Ruddolf Diesel invented diesel engine in 19th century. Generally, there are two main methods to improve efficiency, power output .One is through the optimization of combustion process, and the other one is to recover waste heat of the engine. Almost of the scientists research suggest in the field of waste heat recover system. The paper report the research and explanation by converting waste heat in to the electrical energy and then these energy in to the useful mechanical applications. Conclusion of waste heat recover technology is reducing fuel cost, increases the engine output. The recovery and utilization of waste heat conserves fuel, usually fossil fuel, and reduces the amount of waste heat. Given the importance of increasing energy conversion efficiency for reducing both the fuel consumption and emissions of engine, scientists and engineers have done lots of successful research aimed to improve engine thermal efficiency with supercharge, lean mixture combustion, and many more. From all the energy saving technologies studied. Exhaust Gas Heat Recovery System for I.C [1]. As one of the most widely used source of primary power for machinery critical to the transportation, construction and agricultural sectors, engine has consumed more than 60% of fossil oil. On the other hand, legislation of exhaust emission levels has focused on carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides(NOx), and particulate matter (PM). Energy conservation on engine is one of best ways to deal with these problems since it can improve the energy utilization efficiency of engine and reduces emissions [2].

A. Availability of Waste heat from I.C engines

Waste heat produced by fuel combustion or chemical reaction, and then "dumped" into the environment even though it may still be reused for some useful and economic purpose.

Output energy from I.C engine is about 30 to 40% of the total heat and residual parts of the heat waste in the form of cooling, friction in bearing & exhaust gas of the engine. Waste heat losses from equipment in the form of efficiencies reduction and from thermodynamics limitations on equipment and process. It means about 60 to 70% energy losses as a waste heat through the engine, 30 to 40% in the form of exhaust gas, 30 to 40% waste energy in the form of cooling system [3]. Temperature of exhaust gases immediately leaving the engine may have temperature in the range of 450-600^{0}C. This temperature is low through recovery of exhaust gas and change into useful work and low temperature of exhaust gas in the environment. The literature is available on the Adsorption cooling with the exhaust gas heat of the engine. Consequently, these exhaust gases have high heat content, carrying away as exhaust emission. Efforts can be made to design more energy efficient through engine with better heat transfer and lower exhaust temperatures; however, the laws of thermodynamics place a lower limit on the temperature of exhaust gases leads to reduction in the flue gas produced [5].

– Reduction of exhaust gases and protects the environment and controls the global warming, ozone depletion layer etc.

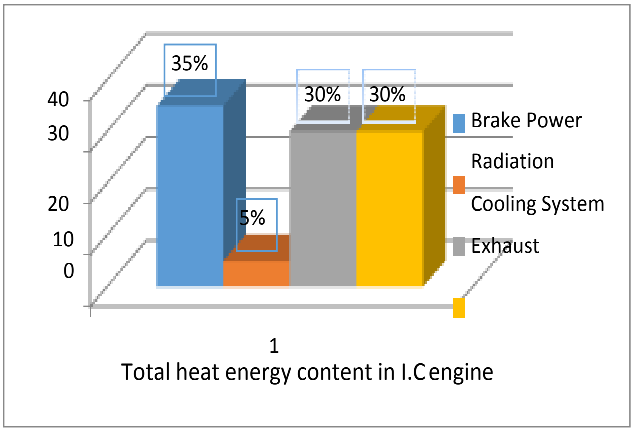


Fig. 1: show total energy distributions from internal combustion engine.

B. Benefits of Waste Heat in I.C engine

In automobile engines significant amount of heat is released to the environment. For example, As much as 35% of the thermal energy generated from combustion in an automotive engine is lost to the environment through exhaust gas and other losses. The amount of such loss, recoverable at least partly or greatly depends on the engine load [3]. Among various advanced concepts, Exhaust Energy Recovery for Internal Combustion (IC) engines has been proved to not just bring measurable advantages for improving fuel consumption but also increase engine power output (power density) or downsizing, further reducing CO2 and other harmful exhaust emissions correspondingly [4]. Which was predicted that if [5] of the heat contained in the exhaust gases were converted to electric power, 10% reduction of fuel consumption can be achieved [6].

- Reduction in secondary energy consumption and equipment sizes gives additional benefits in the form of reduction.
- Reduction in equipment sizes: Waste heat recovery reduces the fuel consumption, which

C. Possibility of waste heat from I.C engine

Modern days are totally depending on the automobile engine. I.C Engines, Such as (SI) spark ignition or compression ignition engines (CI). Diesel engine is widely used in the heavy load and low rpm. Such as- tractors, Truck, bus and locomotive train. Petrol engine is use in light load and high rpm. Thermal efficiency of diesel engine is much better "than" C.I engine [7].

In I.C engine heavy power engines up to 35KW output and heavy load upto 150KW output is used. Earth moving machinery used engines with an output up to 520 KW or even higher up to 740KW.Truck and all kind of road engine usually use high- speed diesel engine with 220 KW output. Diesel engine are used in small electrical power generating units. [8].

D. Various Engines and their Output

S.No.	Type of Engines	Output Power in KW	Waste heat
1	Small air cooled diesel engine	35	30-40 % of Energy Waste loss from I.C. Engine
2	Small agriculture tractors and construction machines	150	
3	Water air cooled engine	35-150	
4	Earth moving machineries	520-720	
5	Marine application	150-220	
6	Trucks and road engines	220	

Diesel engines have an efficiency of about 35% and thus the rest of the input energy wasted. In water-cooled engine of about 35 KW, 30-40% of the input energy wasted in the coolant and exhaust gas respectively. Johnson [9] found that engines have maximum output power (115KW), but waste heat dissipates in the range from 20KW to as much as 400KW in the atmosphere. Average heating power available from waste heat is about 23KW compare to 0.8 to 3.9 KW of cooling capacity .Provided by typical passenger car [10]. These technical possibilities are now under investigation by research institute and manufacturers of I.C Engine.

E. System Availability of waste heat recovery

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

$$Q^{\cdot}=m^{\cdot}xcpxdt$$

Where, (Q) is the heat loss (kJ/min);
(m) Is the exhaust gas mass flow rate (kg/min);
Specific heat of exhaust gas (kJ/kg°K); and
(dT) 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 [8]

S.No.	Engine	Temperature in ^{0}C
1	Single Cylinder four Stroke Diesel Engine	456
2	Four stoke Diesel Engine(Tata Indica)	448
3	Six Cylinder Four stoke Diesel Engine (Tata Truck)	336
4	Four Cylinder Four stoke Diesel Engine (Mahindra arjun 605DI)	310
5	Genest (Kirloskar) at power198hp	383
6	Genest (Cummims) at power200hp	396

Table 2: Temperature Range from Diesel Engine

Survey of exhaust gases are measurement of exhaust temperature from internal combustion engine of automotive vehicles and stationary engine.

F. Heat Loss through the exhaust in Internal Combustion Engine

Engine specification is given in the table III. Heat loss through the exhaust gas internal combustion is calculated as follows. Assuming,
Volumetric efficiency (η_v) is 0.8 to 0.9
Density diesel fuel is .084 to0.85 gm. /cc
Calorific value of diesel is 42 to 45 MJ/kg
Density air fuel is 1.176 kg/m^3
Specific heat of exhaust gas is 1.1-1.25 KJ/kg^{0}k

Manufacturing	Kirloskar oil engine Ltd. Pune
engine	Single cylinder 4-stoke,vertical stationary C.I Engine
bore	87.5 mm
stroke	110 mm
Comp. ratio	17.5
Power	8 hp(5.9KW)
Sp.Fuel combustion	220gms/kw-hr
RPM	1800rpm
BHP@1800 rpm	5.9 KW
Cooling system	Water cooled

Table 3: Specification of engine

Therefore, the total energy loss by diesel engine is %.Hence the loss of heat energy through the exhaust gas exhausted from I.C engine in to the environment 29.21% energy.

1) Possible way of using z system

Increasing of fuel costs and diminishing petroleum supplies are focusing governments and industries to increase the power efficiency of engines. There are several technologies for recovery this energy from C.I engine, where as a controlling ones are: Waste heat can be used for heating purpose, power generation purpose, refrigeration purpose etc.

2) Heating purpose

Waste heat can be used for purpose of space heating, preheating intake air and fuel, drier etc. Anyone has design waste heat recovery for preheating intake air, and made-up and its effect has been tested on diesel engine and diesel exhaust emissions. Heat energy is recovery from the exhaust gases that causes lower heat addition, thus improving thermal efficiencies. Low-grade fuel such as kerosene may be used in diesel by blending with conventional diesel fuels. Using the pre heating system and 10% kerosene blend as fuel, the thermal efficiency is improved and exhausts emissions (Nox and CO) are reduced about heat diesel fuel without preheating air system. Though studied use of alternative fuel in internal combustion engines and leads to some problems such as poor fuel atomization and low volatility mainly originating from their high viscosity, high molecular weight and density. It is reported that these problems may cause important engines failures such as piston ring sticking injector coking, formation of carbon deposits and rapid deterioration of lubricating oil after the use of alternative fuel for a long period [9].

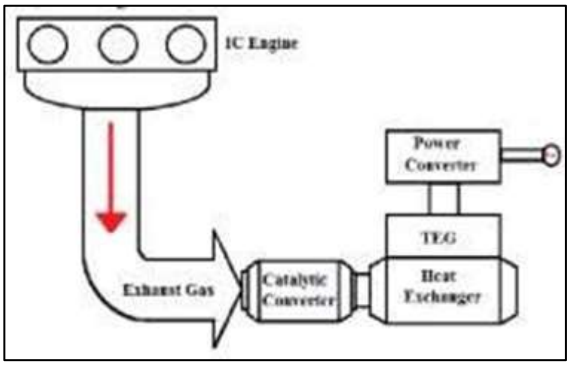
II. Power Generation Purpose

A. *Direct Method*

Generating power from waste heat normally involves waste heat use from internal combustion engine to generate mechanical energy that drives an electric generator. Efficiency of power generation is heavily depended on the temperature of the waste heat gas and mass flow rate of exhaust gas[10].

B. *Thermoelectric Generation*

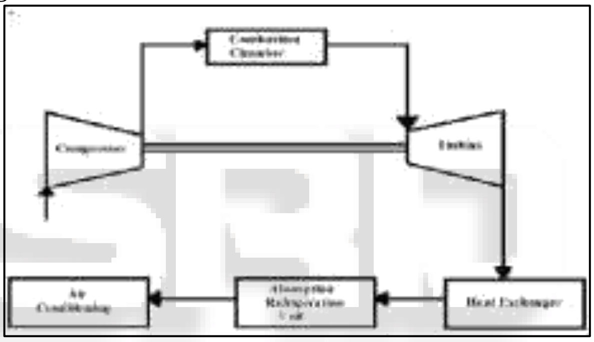
The exhaust pipe has a block with thermo electric materials that generates a direct current, thus providing for at least some of the electric power requirements. In which two different semiconductors are subjected to a heat source and heat sink. A voltage is created between two conductors. It is based on the see back effect. The Cooling and Heating is done by applying electricity. Study on waste heat recovery system by using thermoelectric generator from internal combustion engine reviews the main aspects of thermal design of exhaust-based thermoelectric generators (ETEG) systems [11]. 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 recover 30-40% of the energy supplied by fuel depending on engine load [12].



Thermoelectric generator[12]

C. *Refrigeration*

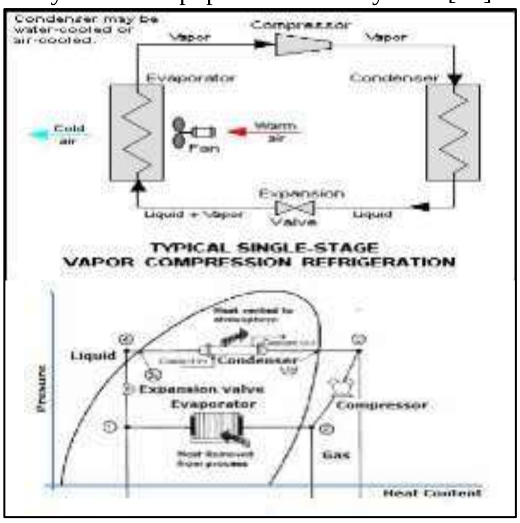
Heat recovery from automotive engines has been mainly used for turbo-charging or for cabin heating with application of absorption chillies. The experiments conducted on the system, prove that the concept is possible, and may significantly improve system performance depending on part-load of the engine [13]. Also the concept may be (used for (refrigeration and air conditioning of transportation vehicles [6].Systematic view of Vapour Absorption Cycle shown in Figure:-



refrigeration cycle [13]

D. *Vapor Absorption Cycle*

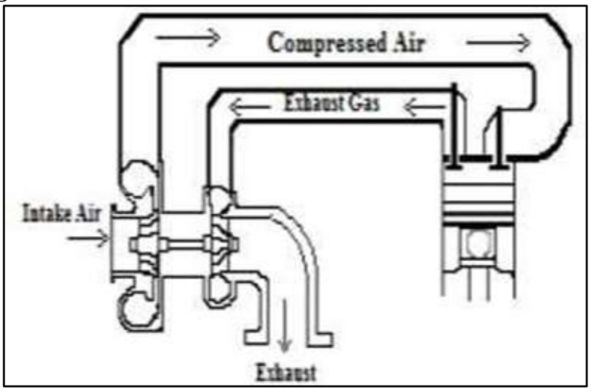
An absorption refrigerator is a refrigerator that uses a heat source (e.g., solar, kerosene-fuelled flame, waste heat from factories or district heating systems) to give the energy needed to drive the cooling system. In the early years of the twentieth century, the vapour absorption cycle using water-ammonia systems was popular and widely used [14]



A vapour absorbtion cycle[14]

III. Mechanical Turbo Compounding

A compressor and turbine on single shaft, it is" used" to boost the inlet air (mixture) density. Energy available in the engines exhaust gas is" use" to drive the turbo charger turbine, that drives the turbo charger compressor which increases the inlet fluid density prior to entry to each engine cylinder. Fig. shows a turbo charged and turbo compounded internal combustion engines is shows in fig.The turbo determines a method that a now utilised widely to convert in to energy to improve the efficiency and power output of internal combustion engine[15].



Turbocharger [16]

IV. Conclusion

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 through thermoelectric generator. Thermoelectric generator is very low efficiency. But It is helped by waste heat increasing the thermal efficiency and reduction in emission. The biggest advantage is to improve cabin warm up performance. Thermo-Electric and Rankin cycle system "only" deliver minor fuel economy benefit over the NEDC (New European Drive Cycle) test.

References

[1] Diego A. Arias, Timothy A. Shedd, Ryan K. Jester, "Theoretical analysis of waste heat recovery from an internal combustion engine in a hybrid vehicle," SAE paper 2006-01- 1605.

[2] Schwarze. H., Brouwer, L., Knall,G., Schlerege, F., Miiller- Frank, U.Kopnarski. M., Emrich, S., "Olalterung and Verschlei. Im Ottomator: MTZ, 2008-10 (Germany)

[3] K. Nantha Gopal, Rayapati Subbarao, V. Pandiyarajan, R. Velraj, "Thermodynamic analysis of a diesel engine integrated with a PCM based energy storage system," International Journal of Thermodynamics 13 (1) (2010) 15-21

[4] Will.F. "A Novel Exhausts Heat Recovery System To Reduce Fuel Consumption" F2012A073, FISTIA conference Budapest Hungry 2010.

[5] J.S Jadhao, DG. Thombare, "Review on Exhaust Gas Heat Recovery for I.C. Engine, "International Journal of Engineering and Innovation Technology (IJEIT) Volume 2, issue 12June 2013.

[6] H. Teng, G. Regner, C. Cowland, "Waste Heat Recovery of Heavy-Duty Diesel Engines by Organic Rankine Cycle Part I: Hybrid Energy System of Diesel and Rankine Engines," SAE Int. Publication 2007-01-0537 (2007).

[7] Colbourne, D., Ritter, T.J., 2000. Compatibility of Non-Metallic Materials with Hydrocarbon Refrigerant and Lubricant Mixtures. IIF-IIR- Commission B1, B2, E1 and E2 – Purdue University, USA

[8] Hakan Özcan, M.S. Söylemez, "Thermal Balance Of A LPG Fuelled, Four Stroke SI Engine With Water Addition," Energy Conversion and Management 47 (5) (2006) 570-581

[9] Diego A. Arias, Timothy A. Shedd, Ryan K. Jester, "Theoretical analysis of waste heat recovery from an internal combustion engine in a hybrid vehicle," SAE paper 2006-01- 1605.

[10] J. Vazaquez, M.A. Zanz-Bobi, R. Palacios, A. Arenas, "State of the art of thermoelectric generators based on heat recovered from the exhaust gases of automobiles," Proceedings of 7th European workshop on thermoelectric, 2002.S.

[11] N. Hossain And S Bari, "Effect Of Design- Parameters Of Heat Exchanger On Recovering Heat From Exhaust Of Diesel Engine Using Organic Rankine Cycle," Proceedings of the International Conference on Mechanical Engineering 2011 (ICME2011) 18-20 December 2011, Dhaka, Bangladesh

[12] V. Johnson, "Heat-generated cooling opportunities in vehicles," SAE Technical Papers, No. 2002, 2002-01-1969.

[13] John B. Heywood, "Internal Combustion Engine Fundamental," Tata McGraw Hill Education Private Limited, Edition 2011, pp 249-250.

[14] J.S Jadhao, DG. Thombare, " Review on Exhaust Gas Heat Recovery for I.C. Engin ," International Journal of Engineering and Innovation Technology (IJEIT) Volume 2, issue 23 June 2013

[15] M. Hatazawa, "Performance of a thermo acoustic sound wave generator driven with waste heat of automobile gasoline engine," Transactions of the Japan Society of Mechanical Engineers 70 (689) (2004) 292–299. Part B.

[16] Pandiyarajan, M. Chinna Pandian, E. Malan, R. Velraj, R.V. Seeniraj, "Experimental investigation on heat recovery from diesel engine exhaust using finned shell and tube heat exchanger and thermal storage system," Applied Energy 88 (2011), pp 77–87.