Study On Waste Heat Recovery In An Internal Combustion Engine

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Abstract

Usually Internal Combustion engine an extensive heat is passed away by exhaust gases. To recover the waste heat, a variety of methods are being adopted. Turbo charging is the one of the best method to recover the waste heat. Throughout this task an attempt has been made to look at the various possibilities of waste heat (energy) recovery methods in conventional commercial two wheeler and four wheelers. In this circumstance, a new theory of hybrid engine has also been discussed. Different methodologies were implemented to recover the waste heat from IC engines. Basically, by introducing a supplementary combustion chamber and injecting an additional proper fuel and then allowing it to increase in a turbine which forms the part of turbo charger unit. Thus the waste heat energy is utilized to burn an additional amount of fuel. The subsequent stage contains a thermoelectric generator which produces electrical energy by utilizing the high heat of exhaust gases. The final stage energy recovery is done by combination of compressor and an alternator. Both being coupled to the turbine shaft, produces electrical energy and compressed air which can be accumulate and used effectively for running any auto auxiliaries. Thus the principle of electro turbo generation has been adopted for waste heat recovery. In order to use the abovementioned combination of waste heat recovery systems a matrix has also been suggested.

Keywords: *waste heat recovery, spark ignition, internal combustion engine, engine exhaust*

1. Introduction

National energy security, rising energy prices, increasingly aggressive global markets, and stringent regulations for environmental emissions are the primary driving forces in the search for sustainable and economically viable technologies that incorporate efficient and clean approaches to energy conversion and utilization. Internal combustion (IC) engines are the prime movers of choice when high power densities and efficiencies are desirable. Because of relatively cheap fuel prices in the last few decades, IC engines had been optimized for high power densities and low emissions. However, in recent years, with escalating fuel prices and concerns about sustainability, engine efficiency has assumed greater importance. Since the oil resources are depleting day by day with a rapid increase demand for energy, research is in progress to identify an alternative source. At the same time the present day equipments are being developed to give maximum output to conserve resources till an alternative is developed. Reciprocating internal combustion engines being the most widely preferred prime movers gives a maximum efficiency range of 27% to 29%. Rotary engines, even though having higher efficiencies up to 45% are restricted to aircrafts due to their very high speeds of 45000 rpm to 90000 rpm. Cogeneration is the method of simultaneous production of heat and other form of energy in a process. Many cogeneration techniques have been employed in IC engines to recover the waste heat. Turbo charging is also a kind of waste heat recovery technique in which the exhaust gases leaving the engine are utilized to run a turbine to produce power.

Reciprocating engines remain the dominant power plant for both vehicles and power generation up to a few MW. Yet, circa 30% of the energy in the fuel is lost through the exhaust system. In today's market, it has become essential to attempt to recover some of this “wasted energy” and put it to good use. Exhaust Heat Recovery (EHR) systems are playing an increasingly important role in the Emissions and Fuel Consumption challenges facing today's Heavy Commercial Vehicle (HCV), Off-Highway and Power Gen markets globally. Exhaust heat recovery using electro turbo generators by Patterson, A., Tett, R., and McGuire, J. puts forward an argument in favor of Electro-Turbo compounding as a system that is technically mature enough to benefit the above markets today.

Only a part of the energy released from the fuel during combustion is converted to useful work in an engine. The remaining energy is wasted and the exhaust stream is a dominant source of the overall wasted energy. There is renewed interest in the conversion of this energy to increase the fuel efficiency of vehicles. There are several ways this can be accomplished. This work involves the utilization thermoelectric (TE) materials which have the capability to convert heat directly into electricity. A new model was developed to study the feasibility of the impression.

Waste energy recovery identification is newly developed from design of Experiment was performed to improve the design on the basis of higher power generation and less TE mass, backpressure, and response time. Results suggest that it is possible to construct a realistic device that can convert part of the wasted exhaust energy into electricity thereby improving the fuel economy of a gas electric hybrid vehicle. Thus the Various possible exhaust heat recovery methods have been discussed by Husain, Q., Brigham, D., and Maranville,C in Thermoelectric Exhaust Heat Recovery for Hybrid Vehicles. Considering heavy truck engines up to 40% of the total fuel energy is lost in the exhaust. Because of increasing petroleum costs there is growing interest in techniques that can utilize this waste heat to improve overall system efficiency. Leising, C., Purohit, G., DeGrey, S., and Finegold, J., examines and compares improvement in fuel economy for a broad spectrum of truck engines and waste heat utilization concepts.

A variety of engines should be considered, they are the Diesel, spark ignition, gas turbine, and Stirling. Principal importance is placed on the turbocharged four-stroke Diesel engine. Because of increased exhaust energy and a large potential improvement in performance, the still-to-be-developed "adiabatic" Diesel is also examined. The waste heat utilization concepts include preheating, regeneration, turbo charging, turbo compounding, and Rankine engine compounding. Predictions are based on fuel-air cycle analyses, computer simulation, and engine test data. All options are compared on the basis of maximum theoretical improvement. The Diesel and adiabatic Diesel are also evaluated in terms of maximum expected improvement and expected improvement over a driving cycle.

The various results indicate that Diesels should be turbocharged and after cooled to the maximum possible level. Based on current design practices fuel economy improvements of up to 6% might be possible. It is also revealed that Rankine engine compounding can provide about three times as much improvement in fuel economy as turbo compounding, but perhaps only the same improvement per dollar. By turbo charging, turbo compounding, and Rankine engine compounding, driving cycle performance could be increased by up to 20% for a Diesel and by up to 40% for an adiabatic Diesel. The study also indicates that Rankine engine compounding can provide significant fuel economy improvement for gas turbine and spark ignition engines and regeneration could significantly enhance the performance of spark ignition engines. Because of the low heat content in the exhaust of a Stirling engine it has only a small potential for further waste heat recovery.

2. Basic idea about Electro Turbo Generation

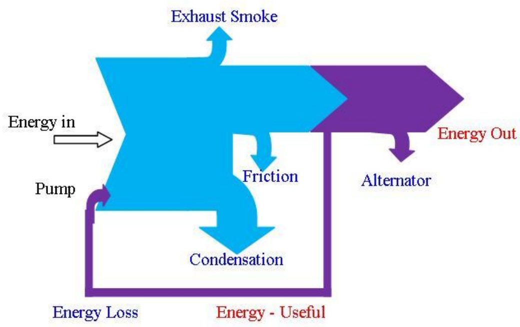

Figure. 1 Energy split in a diesel engine

Energy is lost in several forms. Figure. 1 shows the energy path of a diesel engine. The largest being the heat energy dissipated to the environment via exhaust gases. The EHR system is designed to recover heat energy in the exhaust gases and convert in to useful work for the vehicle. Existing system convert come of the exhaust heat energy in to mechanical energy that is fed back to crank shaft via hydraulic coupling and gear train.

The concept of electro turbo generation converts some exhaust heat energy in to electrical energy. The underlying technology is based on integrating compact high speed electrical machines (alternators) with high performance turbo machinery in various combinations.

3. Electro Turbocharged Hybrid Engine with Cogeneration

In connection of this project an effort has been taken to explore the possibilities of waste heat recovery in conventional IC Engines. The heat contained in the exhaust gases is recovered in two stages. The exhaust gases coming out of the engine is allowed to pass through an auxiliary combustion chamber. The temperature of exhaust gases in a petrol engine lies between 200^{o}C to 230^{o} C. At this high temperature fuel can be injected at comparatively low injection pressures and burnt. In this auxiliary combustion chamber, an injector injects a fuel and the fuel is burnt due to the high heat of exhaust gases. This results in a boost of pressure and temperature.

This high temperature gas is introduces into a turbine stage where it is expanded. The output of this turbine is given to an alternator to produce electrical energy. The electrical power thus produced is tapped into a battery to run a dc motor.

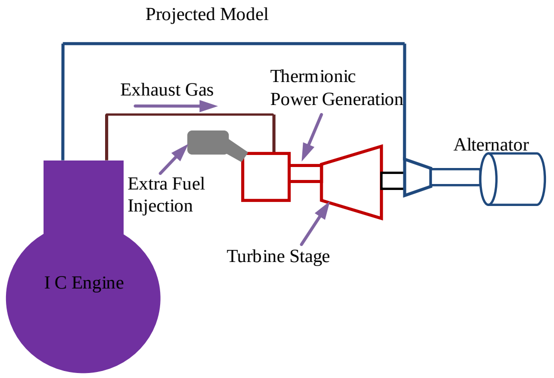

Fig.2. Planned model for waste heat recovery

The test rig is a two wheeler dynamometer used to measure the performance of a two wheeler. This effectively consists of a base and a clamp to fix the front wheel of the vehicle. The back wheel will be driving a drum provided at the base to measure the brake power and speed. The test rig is connected to a computer and the sensors mounted at various locations will send inputs (engine running parameters) to the computer.

4. Experimental setup

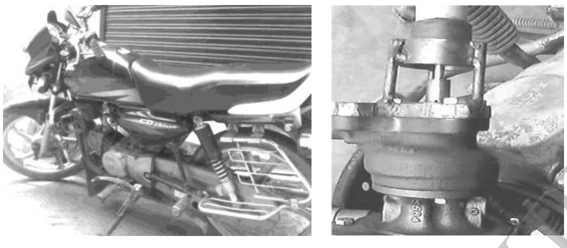

Fig.3. Turbo charger- made-up model (CD-Deluxe)

The experimental model used consists of a turbo charger (TATA Indica) attached to the exhaust manifold of a HERO HONDA CD Deluxe bike. The turbo charger shaft is coupled to a DC Generator of voltage rating of 6 V.

5. Results and Discussion

In order to find out the feasibility of running a DC dynamo by the turbo charger, the engine was allowed to run at different speeds .the output of the generator was also noted.

Table: 1. Experimental Data

Sl. No	*Engine Speed (rpm)*	*Alternator (Voltage)*
1.	*1250*	*-*
2.	*1750*	*-*
3.	*2250*	*8.5*
4.	*3250*	*10.8*
5.	*3750*	*-*

Power produced by the electrical machine

Power (P) = Voltage x Current

= 10.8 V x 0.48 A

= 5.184 Watts

Before mounting electro turbo generator:

Table: 2 Energy split data as applied to the test engine

Describtion	*Energy (%)*	*BHP (Watts)*
Total power given by fuel	*100*	*20480*
Useful power at crank shaft	*24*	*4915*
Frictional losses	*6*	*1229*
Cooling losses	*31*	*6349*
Exaust gases	*39*	*7987*

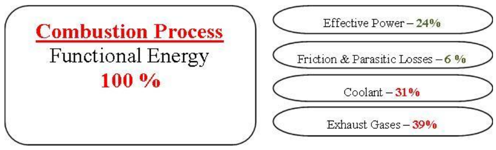

Figure 4. Classic Energy split in Internal Combustion Engines (SI)

After mounting electro turbo generator:

From the experiment, the power obtained by connecting the alternator to the turbo charger is 5.184 Watts which is 0.035% of the total power supplied by the fuel. Thus it is obvious that, out of the 39% exhaust losses 0.06% can be recovered by electro turbo charging in this engine.

Describtion	*Energy (%)*	*BHP (Watts)*
Total power given by fuel	*100*	*20480*
Useful power at crank shaft	*24*	*4915*
Frictional losses	*6*	*1229*
Cooling losses	*31*	*6349*
Exaust gases	*38.965*	*7980.03*
Power Recovered (After turbo generation)	*0.035*	*7.17*

Table: 3 Energy split data after mounting electro turbo generator

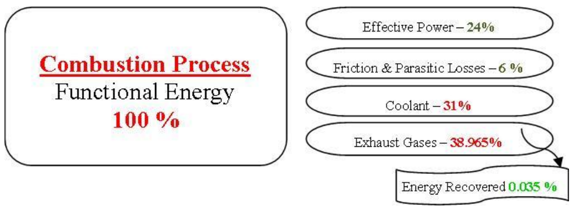

Figure: 5 Energy fracture in Gasoline Diesel Engine

6. Conclusion

In an attempt to explore the possibilities of waste heat recovery in an IC engine, the concept of Electro Turbo generator has been proved by running an alternator coupled to a turbocharger. By the introduction of electro turbo generation the useful work obtained from the engine has been increased from 24% to 24.035%. The above quantity is a very small quantity. As the electro turbo generation system used here is not a specially designed one for this engine. By designing an alternator for this engine conditions, the quantity of useful work recovered can be improved. In a small engine this quantity may be of less advantageous. But thinning in a global manner the energy conserved will be high. At present this idea is in initial stage and is to be analyzed by constructing the appropriate physical system. The following are the constraints which are to be overcome.

- ❖ Design of the alternator (due to frequency very high).
- ❖ Designing of auxiliary combustion chamber.
- ❖ Type of fuel to be used / selection of fuel for auxiliary Combustion Chamber.
- ❖ Overall efficiency, Torque and speed performance of the turbo charger to be studied

7. References

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