Use of exhaust heat energy of two wheelers to generate power by seebeck effect

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ABSTRACT:

In internal combustion engines the thermal efficiency is around 30 %, roughly 30% of the fuel energy is wasted in exhaust gases, and 30% in cooling water and 10% are unaccountable losses. Efforts are made to catch this 30 % energy of exhaust gases. If this waste heat energy is trapped and converted into usable energy, the overall efficiency of an engine can be improved. Thermoelectric modules which are solid state devices that are used to convert thermal energy to electrical energy from a temperature gradient and it work on principle of Seebeck effect. The process plan includes using a Thermo-Electric Generator (TEG) to produce electricity using the temperature difference between the exhaust gas temperature and coolant flowing over the system. Heat exchangers are used on both sides of the modules to supply this heating and cooling.

Keywords: Seebeck effect, Thermo-electric generator, Heat exchanger, Thermo-electric materials, Battery

INTRODUCTION:

The **Seebeck effect** is a phenomenon in which a temperature difference between two dissimilar electrical conductors or semiconductors produces a voltage difference between the two substances. A Thermoelectric generator or TEG (also called a Seebeck generator) is a solid state device that converts heat (temperature differences) directly into electrical energy through a phenomenon called the Seebeck effect. Thermoelectric generators could be used to convert waste heat into additional electrical power and in automobiles as automotive thermoelectric generators (ATGs) to increase fuel efficiency. Thermoelectric power generators consist of three major components: thermoelectric materials, thermoelectric modules and thermoelectric systems that interface with the heat source.

Thermoelectric materials generate power directly from heat by converting temperature differences into electric voltage. These materials must have both high electrical conductivity (σ) and low thermal conductivity (κ) to be good thermoelectric materials. Having low thermal conductivity ensures that when one side is made hot, the other side stays cold, which helps to generate a large voltage. A thermoelectric module is a circuit containing thermoelectric materials that generate electricity from heat directly. Substantial thermal energy is available from the exhaust gas in modern automotive engines. Two-thirds of the energy from combustion in a vehicle is lost as waste heat, of which 40% is in the form of hot exhaust gas. The power from vehicle exhaust is used to generate the electricity which can be stored in battery for the later consumption.

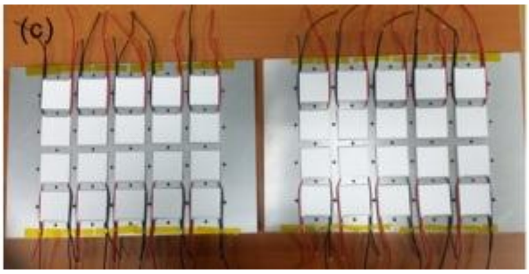
LITERATURE REVIEW

Jing-Hui Meng, Xiao-Dong Wang, and Wei-Hsin Chen performed investigation and design optimization of the thermoelectric generator (TEG) which is applied in automobile exhaust waste heat recovery [1]. Their work develops a multiphysics thermoelectric generator model for automobile exhaust waste heat recovery, in which the exhaust heat source and water-cooling heat sink are actually modelled.

Gregory P. Meisner has developed a Thermoelectric Generator for automotive waste heat recovery [2]. It includes the study of thermoelectric materials for development of TEG's. This model is capable of computing the overall heat transferred, the electrical power output, and the associated pressure drop for given inlet conditions of the exhaust gas and the available TEG volume.

S.Pratheebha has worked on usage of exhaust from any engine to generate power using thermoelectric generators [3]. She placed a turbine in the path of exhaust in the silencer. The turbine is connected to a dynamo, which is used to generate power. Depending upon the airflow the turbine will start rotating, and then the dynamo will also start to rotate. A dynamo is a device which is used to convert the kinetic energy into electrical energy. The generated power is stored to the battery.

Young Kim, Assmelash A. Negash, Gyubaek Cho experimentally investigated the waste heat recovery performance of a thermoelectric generator (TEG). Customized thermoelectric modules (TEMs) were installed on the upper and lower sides of a rectangular exhaust gas channel. Water at an ambient temperature of 293 K was supplied from a cooling tower and was used to create a temperature difference across each TEM [4].The diesel engine was operated under various conditions for maximizing the TEG power output observed that the power output of the TEG increases with the engine load or speed. The maximum power output was approximately 119W at 2000 rpm with a BMEP of 0.6 MPa; the maximum energy conversion efficiency was approximately 2.8%. The pressure drop across the TEG was experimentally found to be 0.45–1.46 kPa under all engine operation conditions.

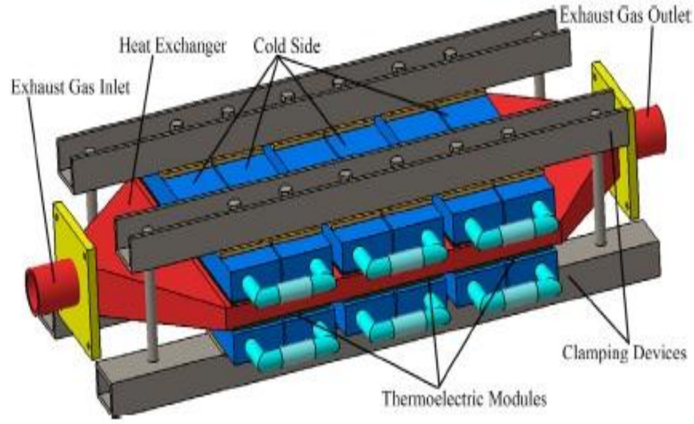


TEM arrays attached to the surfaces of the coolers

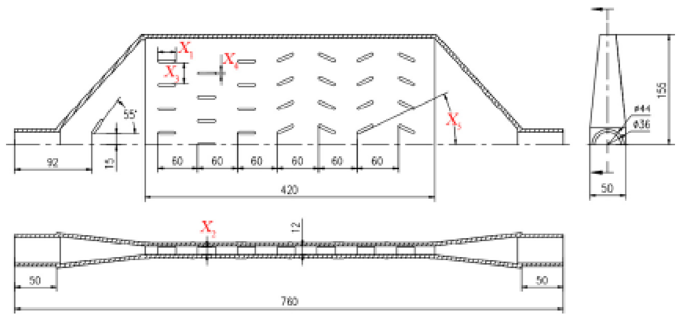
TEG installed in the middle of the tail pipe of the diesel engine.

Kranthi Kumar Guduru and Yakoob Kol ipak demonstrated a concept of generating power in a stationary single cylinder diesel engine by the usage of turbines [5]. The turbine is connected to a dynamo, which is used to generate power, similar to the work done by S.Pratheebha.

C. Liu, Y.D. Deng, X.Y. Wang, X. Liu, Y.P. Wang, and C.Q. Su designed a heat exchanger for an automotive exhaust thermoelectric generator [6]. They also evaluated the thermal properties and pressure losses of a heat exchanger. The horizontal temperature difference after optimization is reduced; the average temperature is improved from 222.46 degree Celsius to 226.4 degree Celsius, whereas the longitudinal temperature difference is decreased from 29.36 degree Celsius to 28.9 degree Celsius. Moreover, the pressure drop is decreased by approximately 20%, which may be significant for the global improvement of a thermoelectric generator system.

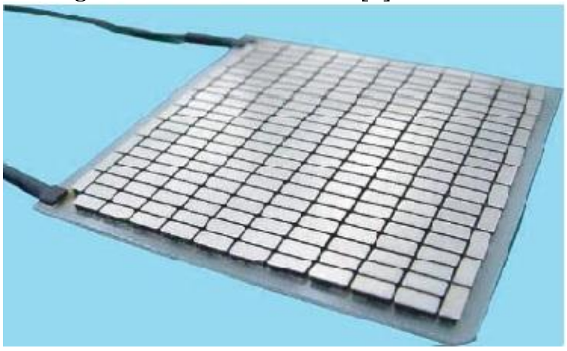


Structure of thermoelectric generator

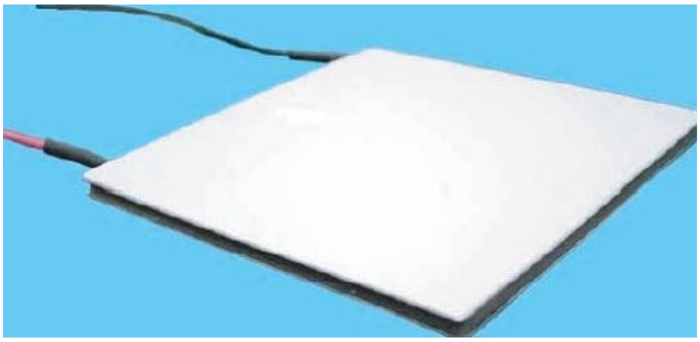


2-D structure of the plane-shaped heat exchanger (unit: mm).

Toshiki Sakamoto, Yasuhiro Suzuki and Takeshi Hirasawa developed a 70-mm-square Peltier module provided with superior stress resistance, which is aimed at solving the problem of the limited size of conventional modules and thereby responding to the needs for high-power, large-sized Peltier modules [7].



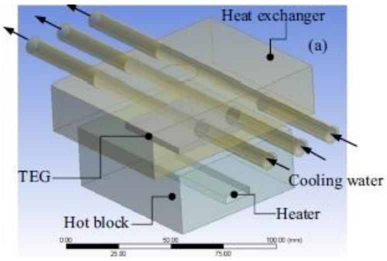
Structure of developed large-sized Peltier module



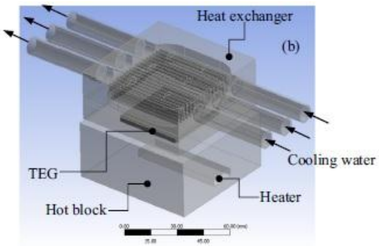
External view of standard shell

The module has been developed based on the skeleton structure where the semiconductor elements are held at the centre. The advantages of this module are that regardless of its large size it has sufficient durability against thermal strains as well as a high heat-absorption rate, which is unattainable for conventional structures. Durability test against thermal strains proved its highly stabilized performance.

W. Li, M.C.Paul, J.Siviter, AMontecucco, A.R.Knox, T.Sweetb, G.Min, H. Baig, T.K.Mallick, G.Han, D.H.Gregory, F.Azough and R.Freer studied the thermal and momentum transports in two different heat ex-changers, a tube type and a fin type, by means of a steady-state, 3D turbulent flow *k*-*ε* model with a heat conduction module under various flow rates[8]. In order to simulate the actual working conditions of the heat exchangers, a hot block with an electric heater is included in the model. The thermal parameters (heat transfer and fluid flow) were investigated and compared in both tube and fin heat exchangers. The fin heat exchanger is more compact and thus has a better thermal performance than the tube heat exchanger.



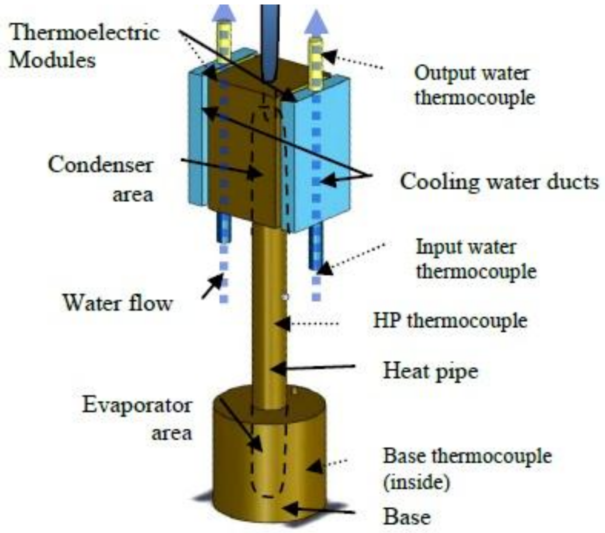
Design of Tube type heat exchanger for TEG



Design of fin type heat exchanger for TEG

TEG technology was first tested in automotive waste heat recovery by Neild [9], followed by tests on modified cars/engines such as a Porsche 944, a 14 litre Cummins Turbo-diesel engine truck, a GM Sierra Pickup Truck and other, more recent works, but in most cases the potential for power recovery is just enough to meet the electric demands of the various electrical accessories. However, reputable studies indicate that, if the system is properly designed, it should be possible to recover a significantly higher amount of energy, when adding the combined potential of the cooling system, lubrication system and exhaust system. This paper by Neild focuses on a review of the main aspects of thermal design of ETEG systems through various investigations performed over the past twenty years. It shows the construction of a typical ETEG, the heat balance and efficiency of ETEG.

Jorge Martins, Francisco P Brito, L.M. Goncalves and Joaquim Antunes studied about reasons for the small thermal efficiency of TEG modules[10] which is due to the limitations in the maximum temperature that current modules are able to withstand (normally, up to 230ºC). Rather than the core materials of the module, it is normally the soldering between parts that are currently limiting their ability to work at higher temperatures. This is one of the main obstacles when trying to regenerate exhaust heat by using TEGs. They used heat pipes (HP) as a means of transferring energy from the hot exhaust gases to the TEG modules at a compatible temperature level while minimizing the loss of efficiency due to temperature downgrading. The type of heat pipe used in this study is called Variable Conductance Heat Pipe (VCHP), and its deployment has the advantage of inducing good temperature control.



Outline of Heat Pipe setup

Rohan Mathai Chandi and Rakesh Rajeev designed an Automobile Exhaust Thermoelectric System and analyzed for the waste heat recovery of an automobile engine [11]. The hot side was exhaust system and cold side was AC evaporator. The cold side heat exchanger analysis was done at a temperature of 269K. The hot side heat exchanger was analyzed at temperatures 600K, 750K, 900K, and 1200K. It was found that the voltage increase as temperature difference increases. According to the results, an aluminium fin type heat exchanger is selected to form the hot side. It can reduce the thermal resistance and obtain a relatively high surface temperature and uniform temperature distribution to improve the efficiency of the TEG. Results also show that voltage, current, power developed and efficiency of the system increase with the increase in engine speed. Hence the AETEG system traps the waste heat of exhaust gases from engine & generates useful power which can be used to charge the car battery, to power auxiliary systems and minor car electronics. As AETEG reduces the wastage of energy, it improves the overall efficiency of vehicle. TEG system can be profitable in the automobile industry.

METHODOLOGY

In this project we aim at utilizing the heat energy from exhaust gases to produce power using Seebeck Effect which can be further used to run an electric vehicle. The process plan includes using a Thermo-Electric Generator (TEG) to produce electricity using the temperature difference between the exhaust gas temperature and coolant flowing over the system. Our aim is to obtain a temperature difference as high as possible so as to generate a greater amount of electricity according to the specification of the TEG. The exhaust gases will pass over the thermoelectric generator which will in return convert the heat energy into electrical energy. The TEG is connected to a battery. The electrical energy produced will be utilized to charge the battery.

Using thermoelectric modules, a thermoelectric system generates power by taking in heat from a source such as a hot exhaust flue. In order to do that, the system needs a large temperature gradient. The cold side must be cooled by air or water. Heat exchangers are used on both sides of the modules to supply this heating and cooling. There are many challenges in designing a reliable TEG system that operates at high temperatures. Achieving high efficiency in the system requires extensive engineering design in order to balance between the heat flow through the modules and maximizing the temperature gradient across them. To do this, designing heat exchanger technologies in the system is one of the most important aspects of TEG engineering between the heating and cooling sources.

The temperature of the exhaust gases of a petrol engine is higher as compared to the diesel engines. In our project, the first stage includes measuring the temperature of the exhaust gases to estimate the amount of power that can be generated with that particular temperature. Further around 40 TE modules will be connected in series to form a TEG as a whole. The thermoelectric modules will be selected according to the temperature of exhaust and specifications as mentioned above. The TE modules will be mounted on the heat exchanger such as the hot plate is in contact with the hot exhaust gases and the cold plate is in contact with the cooling water or air. The heat exchanger will have an inlet and an exit manifold. The inlet is directly attached to the exhaust pipeline in order to prevent losses in temperature. Further the temperature difference created will develop a voltage difference between the two terminals of the TEG generating power which will be used to charge a battery.

We will be using Lithium-Polymer (Li-Po) battery due to its advantages such as light in weight and requires less time to charge as compared to traditionally used Lead-Acid batteries. Also a greater range of current rating can be obtained using the Li-Po battery. The battery further causes the ease in operating the vehicle as an electric bike for desirable distances.

CONCLUSION

Thus, it is possible to utilize the waste energy by using a thermoelectric generator and produce optimum amount of electrical energy to charge a battery. The main advantage of this project is that the consumption of fuel as well as the emissions will be reduced. The fuel used will be indirectly used to charge the battery which will operate the vehicle as an electric bike. The reduction in emissions is an important aspect with respect to environmental damage. As a whole, this project is a blend of energy conservation and security.

REFERENCES:

1] Jing-Hui Meng, Xiao-Dong Wang, and Wei-Hsin Chen, Performance investigation and design optimization of a thermoelectric generator applied in automobile exhaust waste heat recovery, State Key Laboratory of Alternate Electrical Power System with Renewable Energy Sources, North China Electric Power University, Beijing 102206, China.

2] Gregory P. Meisner, Thermoelectric Generator Development for Automotive Waste Heat Recovery, 16th Directions in Engine Efficiency and Emissions Research (DEER) Conference
Detroit, Michigan, September 29, 2010.

3] S.Pratheebha, Engine Battery Supercharging from Exhaust Gas, International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2763 Issue 04, Volume 3 (April 2016).

4] Young Kim, Assmelash A. Negash, Gyubaek Cho, Waste heat recovery of a diesel engine using a thermoelectric generator equipped with customized thermoelectric modules, Engine Research Laboratory, Korea Institute of Machinery & Materials, Daejeon 34103, Republic of Korea.

5] Kranthi Kumar Guduru and Yakoob Kol ipak, Power Generation by Exhaust Gases On Diesel Engine, International Journal of Research and Computational Technology, Vol.7 Issue.5 Page:06-13

6] C. Liu, Y.D. Deng, X.Y. Wang, X. Liu, Y.P. Wang, and C.Q. Su, Multi-objective optimization of heat exchanger in an automotive exhaust thermoelectric generator, Applied Thermal Engineering 108 (2016) 916–926

7] Toshiki Sakamoto, Yasuhiro Suzuki and Takeshi Hirasawa, Development of High-Power Large-Sized Peltier Module.

8] W. Li, M.C.Paul, J.Siviter, AMontecucco, A.R.Knox, T.Sweetb, G.Min, H. Baig, T.K.Mallick, G.Han, D.H.Gregory, F.Azough and R.Freer, Thermal performance of two heat exchangers for thermoelectric generators, Case Studies in Thermal Engineering 8 (2016) 164–175.

9] Neild Jr. A.B. "Portable thermoelectric generators", Society of Automotive Engineers, New York, SAE-645A

10] Jorge Martins, Francisco P Brito, L.M. Goncalves and Joaquim Antunes, Thermoelectric Exhaust Energy Recovery with Temperature Control through Heat Pipes, SAE International 2011.

11] Rohan Mathai Chandi and Rakesh Rajeev, Design and Analysis of Heat Exchanger for Automotive Exhaust based Thermoelectric Generator [TEG], International Journal for Innovative Research in Science & Technology| Volume 1 | Issue 11 | April 2015.