Review on Electric Power Generation by use of IC Engine Exhaust Thermal Energy Utilization in Thermoelectric Module

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Abstract: *The current worldwide trend of increasing transportation is responsible for increasing the use of internal combustion engines. The internal combustion engine does not efficiently convert chemical energy into mechanical energy. 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. Over two-thirds energy of fuel consumed by an automobile is discharged to the surroundings as waste heat. Promising technology that were found to be useful for this purpose were thermoelectric generators. Thermoelectric Module converts this waste heat into useful work done as electric energy. The system converts the waste heat from the exhaust manifold into electrical energy using a thermoelectric generator. The experimental results demonstrate that the proposed system recovers considerable amount of waste heat which can be used to power some auxiliary automobile devices.*

***Key Words*:** **IC engine, exhaust gas, heat energy recovery, heat transfer, thermoelectric generator, silencer**

1. INTRODUCTION:

The automobile industry is one of the world's most important economical sectors. Automobiles use IC engines, which have huge amount of energy loss up to 70% in the form of heat. In the recent times, scientists have tried and refined the automobile technology appreciably, but could not control the loss in IC engine in the form of waste heat. . 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, the internal combustion engine (ICE) drives vehicles with only 30% of the total heat generated by the gasoline used. During this process, the other 40% of the heat is lost through waste gas exhaust and 30% by the coolant, so it is required to utilized waste heat into useful work. This focuses its attention not to control the waste heat in IC engine, rather it focuses on trapping the waste heat to generate electricity by using a suitable device called thermoelectric generator. Thermoelectric generator is a device which converts thermal energy directly into electrical energy, using seebeck effect. The Seebeck Effect is the conversion of temperature differences directly into electricity. Thermoelectric module has a cold side and a hot side. By using the modules in reverse, where a temperature differential is applied across the faces of the module, it is possible to generate electrical power. Some of the properties of thermoelectric generators are, environmentally friendly, utilizes waste heat, scalability, reliable power source, low noise operation, can be used as a cooler/heater, no moving elements.

2. WORKING PRINCIPLE OF THERMOELECTRIC GENERATOR:

The EMF cause by temperature gradient across the junctions of two dissimilar conductors, which form a close loop is seebeck effect shown in figure

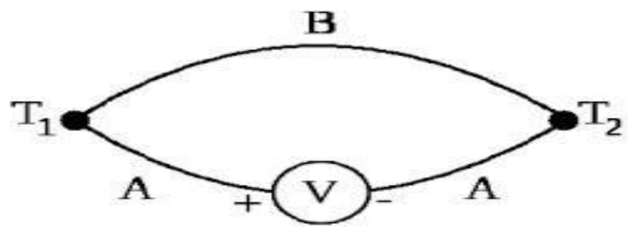

Figure 1: Seebeck effect

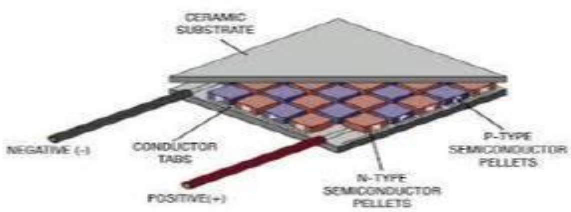

Figure 2: thermoelectric generator

A single thermoelectric couple is constructed from two "pellets" of semiconductor material usually made from Bismuth Telluride (Bi_2Te_3). One of these pellets is doped with acceptor impurity to create a P-type pellet; the other is doped with donor impurity to produce an N-type pellet. The two pellets are physically linked together on one side, usually with a small strip of copper, and mounted between two ceramic outer plates that provide electrical isolation and structural in thermoelectric generator. For thermoelectric power generation semiconductor material

A and B joint together show in figure.1, if a temperature difference is maintained between two sides of the thermoelectric couple (T1 and T2), thermal energy will move through the device with this heat and an electrical voltage, called the Seebeck voltage, will be created. If a resistive load is connected across the thermoelectric couple's output terminals, electrical current will flow in the load and a voltage (V) will be generated at the load. Practical thermoelectric modules are constructed with several of these thermoelectric couples connected electrically in series and thermally in parallel.

3. LITERATURE REVIEW:

1) M G Jadhav, J S Sidh u

Types of thermoelectric generator:- thermoelectric generator materials and there temperatures range is as follows. There are number of materials known till date but few are identified as thermoelectric materials. This project aims to find a possible way to recover the waste heat from the exhaust of I.C. engine as well as to design and fabricate one such system to serve the aim. Experimentally it is found that when two thermoelectric generators are connected in series. This generated power either directly used to run some auxiliary devices of an automobile or may be stored in the battery and used later. The engine performance is unaffected by the designed system because the exhaust manifold which does not affected the working of engine.

Table 1: Types of thermoelectric generator

Sr no.	Thermoelectric generator Materials	Temperature range
1.	Material based on Si-Ge alloys	Higher temperature upto1300K
2.	Materials based on alloys of Lead (Pb)	Intermediate temperature up to 850K
3.	Alloys based on Bismuth (Bi) in combinations with Antimony(An), Tellurium (Te) or Selenium (Se)	Low temperature up to 450K

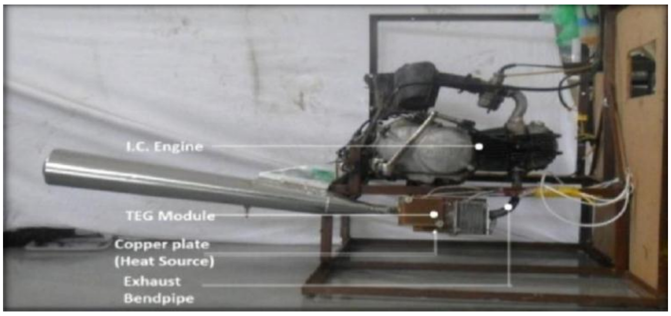

Figure 3 Experimental setup of present study

To the bend exhaust pipe of the IC engine specified above, a copper plate 6 mm thick is welded to form the junction of the thermo electric generator. Two thermoelectric generators connected in series, are placed on the hot copper plate acting hot junction, on the other side of the thermoelectric generator, the cold sink of aluminium is connected. In between hot and cold junction thermoelectric generator's are fitted by nuts and bolts shown in figure. The hot and cold side temperature of thermoelectric generator is continuously monitored using digital thermometers. The heat paste is applied at the junction to ensure proper contact between surfaces and conduction of heat.

(2)B. Orr a, A. Akbarzadeh, M. Mochizuki, R. Singh Both thermoelectric generators and heat pipes are solid state, passive, silent, scalable and durable. Heat pipes can reduce the thermal resistance between the thermoelectric generator and gases. Heat pipe can reduce the pressure losses in the gas stream due to reduced fin surface area. Heat pipes can be used for temperature regulation of the thermoelectric generator. Thermoelectric generator have limitations such as relatively low efficiency and maximum surface temperatures.

(3)Y.Y Hsiao, W.C. Chang, S.L. Chen The simulation result of mathematical model have been verified with experimental data and showing consistence. Under designed working condition, a maximum power of 0.43 W was generated at 0.35 a current. Maximum power density was 511.3 W/m^2The output voltage, according to the seebeck effect, also increased as the temperature difference increase.

(4) K. Zeb, S.M. Ali, B. Khan, C.A. Mehmood, N. Tareen, W. Din, U. Farid, A. Haidera

Although thermoelectric generator has high capital cost but its operational cost makes it feasible for implementation on large scale. Recently, thermoelectric generator is extensively commercializing in various areas, i.e. domestic and industrial electric power generation, refrigeration, biomedical, aerospace, military, automobiles, watches, and remote applications. The thermoelectric generator series and parallel arrangement increases voltage and current capability as well as wattage of module respectively.

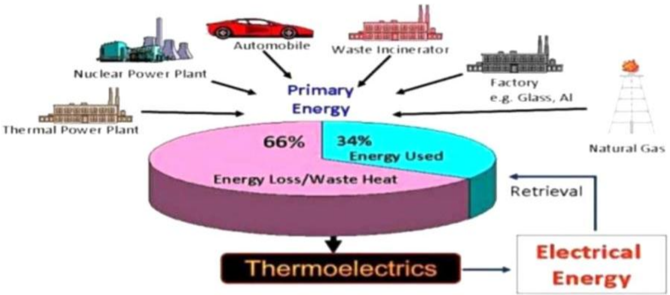

Figure 4: Energy Statistics: Thermoelectric Generators

(5)Hsiao-kang Ma, Ching-Po Lin, How-Ping Wu, Chun-hao Peng, Chai-Cheng Hsu

The operating temperature difference for a thermoelectric generator system is in the range of 150-505 K, and it can be obtained with a maximum open voltage pf 59 V. The surface temperature of the gasifier id approximately 473-633 K which is used for waste heat recovery shows the maximum power output is approximately 6.1 W. It has a power density is approximately 193.1 W/m^2 The aim of this study is to examine the use of waste heat that is recovered from a biomass gasifier. Also, the low heating value of biomass can be transferred to the high heating value of the combustible gaseous fuel during the gasification process. The experimental results show that the temperature of the gasifier outlet is about 623-773 K. To further improve the use of waste heat, the thermoelectric generators system (TEG) is attached to the surface of a catalytic reactor, which is used for cleaning the thermoelectric generators system is attached to the surface of a catalytic reactor, which is used for cleaning.

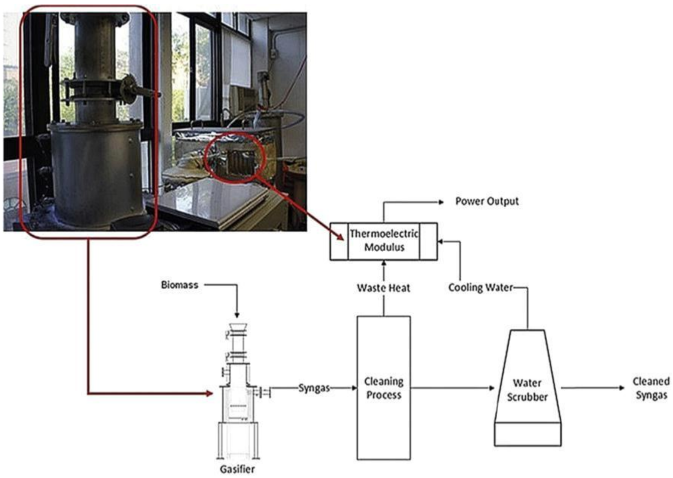

Figure 5: Schematic diagram of the waste heat recovery system

(6)M.A. Karri, E.F. Thacher, B.T. Helenbrook

The potential of the application of Quantum-well (QW) and Bismuth-Telluride (Bi_2 Te_3) based thermoelectric power generation from the sports utility vehicle and CNG engine power generator were examined. Under both these application the quantum-well (QW) based thermoelectric generator generated more power relative to Bismuth-Telluride (Bi_2 Te_3) based thermoelectric generator. The relative fuel savings for the sports utility vehicle averaged around 0.2% using Bi2Te3 and 1.25% using QW generators. For the CNG case the fuel savings was around 0.4% using Bi2Te3 and around 3% using QW generators.

7) Mohiuddin A K M, Muhammad Yazid Ameer, Ataur Rahman, Ahsan Ali Khan

As the temperature difference increases, the power output also increases. The result of the experiments shows that rectangular fin heat sink is more efficient in heat transfer compared to circular tube fin heat sink due to its geometry and properties. For the application of thermoelectric generator in the exhaust system, the selection of material must be suitable as it will affect the performance of the thermoelectric generator.

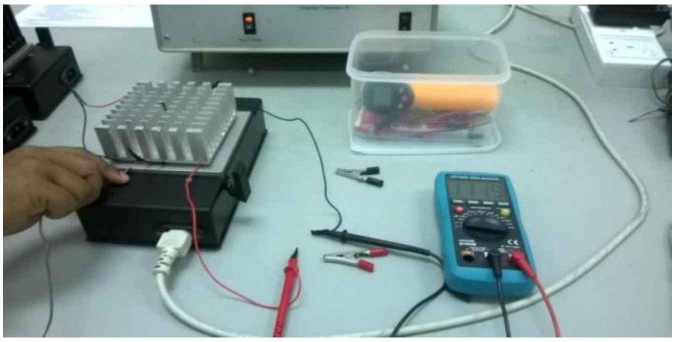

Figure 6: Experiment of heat sink with thermoelectric generator

(8) P. Mohamed Shameer, D. Christopher

To recover the surface exhaust heat to avoid the accidents (Burn-outs) caused by the overheated silencers, and to convert the recovered heat to useful electric energy. The output could be increased by connecting a number of thermoelectric generators in series, so that the voltage gets added up leading to increased power. The energy produced from this system could be used to power any auxiliary devices in an automobile directly or it could be stored in a battery and then used later.

(9) Alvin P Koshy, Bijoy K Jose, Jeffin Easo Johnson, K Navaneeth Krishnan, Bijeesh P

This is a novel mechanism which improves the performance of the engine. The power of the engine increases from 80 kW at 4000 RPM to 81.91895 kW. The thermal efficiency increases from 37.3% to 38.19%. There is a decrease in the bsfc by 5.28 g/kWhr.

(10) J. S. Jadhao, D.G. Thombare

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.

Table 2 Various Engine and There Output

Sr. No.	Engine type	Power output 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 applications	150-220	
6	Trucks and road engines	220	

(11) M.V. Harsha Vardhan, Prashanth. K.P, Venkatesha B K The heat being wasted was converted using a thermoelectric generator and then boosted using a booster circuit. This conversion of electricity doesn't involve any moving parts or any chemicals being used and conversion is environment friendly. With the help of two or more thermoelectric generators connected in series if higher amount of voltage needs to be extracted without using booster circuit.

(12) Z.B. TANG,Y.D. DENG, C.Q. SU, W.W.SHUAI, C.J. XIE The experimental results show that the power loss of the modules in series connection is significant, 11% less than the theoretical maximum power, due to the temperature mismatch condition. This situation is improved with thermal insulation on the modules and the power loss due to the inconsistent temperature distributions reduces to 2.3% at the same working condition.

(13) X. Liu, Y.D. Deng, Z. Li, C.Q. Su Because of the increasing emphasis on environmental protection, applications of thermoelectric technology are being extensively studied. How to transfer the waste heat from exhaust automotive thermoelectric generator system was constructed and large output power of 944 W obtained. To further improve the power generation, the exhaust pipe needs to be improved to decrease the effect of thermal contact and increase the hot-side temperature. Moreover, the connection method could also be optimized. To concern the optimization design, energy conversion efficiency and system power capacity that would be very important for prototype vehicle in next generation.

(14) Eid S. Mohamed the TEG system was mounted to the exhaust pipe of a light diesel vehicle in order to supply heat. The airflow around TEG has been simulated in the cold side to reject heat. The exhaust gas temperatures increase as a function of engine speed. It can be found that maximum temperatures of input and outlet are 340 °C and 300 °C at 3750 rpm respectively. The TEG output power is proportional to the vehicle engine speed; the maximum TEG output power is approximately 214W at 3750 rpm. The experimental results shown indicate that a reduction of exhaust gas emissions with actuation thermoelectric generator system.

(15) Alexander S. Rattner, Tyler J. Meehan Design considerations were discussed that led to a model system configuration for low production-volume waste heat recovery systems: a streamwise-aligned array of discrete thermoelectric generator modules, with heat transfer via conductive heat spreaders to extended surfaces in co-current heating and cooling streams. The proposed model was applied to evaluate and improve a representative vehicle waste heat recovery system design. This example showed how the model can be applied to design a waste heat recovery system by identifying the optimal number of thermoelectric generator modules and revealing the main parameters limiting power generation.

(16) Ding Luo, Ruochen Wang, Wei Yu, Zeyu Sun, Xiangpeng Meng In this study, the engine power and relative power caused by the application of thermoelectric generator system for traditional cars were modeled. Besides, an energy efficiency gain factor has been developed to investigate the energy recovery potential of thermoelectric generator system for three types conventional vehicles, which are light-duty, midsize and heavy-duty cars, respectively. Base on the results of theoretical model, the following conclusions are reached: (1) Power produced by thermoelectric generator is highly affected by temperature and mass flow rate of exhaust (2) The blow-down loss should be considered carefully if applying a thermoelectric generator system into a heavy-duty vehicle, and the thermoelectric generator weigh should be as low as possible for a light-duty automobile (3) In this work, it is most suitable to apply this thermoelectric generator to a heavy-duty car, if the vehicle run at a speed lower than 100km/h in most of time.

(17) B.V.K. Reddy, Matthew Barry, John Li, Minking K. Chyu A thermoelectric element made of *p*- and *n*-type semiconductor plates bonded onto a highly thermal and electrical conducting inter-connector material with an integrated flow can be treated as an integrated thermoelectric device. The performance of an integrated thermoelectric device with multiple elements connected electrically in series and thermally in parallel has been investigated using numerical simulations.

(18) Ataur Rahman, Fadhilah Razzak, Ra fia Afroz, Mohiuddin AKM, MNA Hawlader This study presents an innovative approach on power generation from waste of IC engine based on coolant and exhaust. The waste energy harvesting system of coolant is used to supply hot air at temperatures in the range of 60–70 °C directly

into the engine cylinder, which would be useful to vaporize the fuel into the cylinder. The waste energy harvesting system of exhaust system the waste energy harvesting system has been developed with integrating fuzzy intelligent controlled Micro-Faucet emission gas recirculation and thermoelectric generator. Engine combustion chamber's fuel atomization and vaporization and heat transfer needs to control more accurately in order to get more engines brake main effective pressure and reduce emission.

(19)Lauri K�ta , John Millar, Antti Karttunen, Matti Lehtonen, Maarit Karppinen This review aims to present a summary of the current state of art in applications incorporating thermoelectric generator units. Description of components critical to thermoelectric generator system analysis will be provided. Especially practical results available from testing of the experimental systems will be addressed. The review is split in 2 parts, with first part covering thermoelectric generator fundamental operating principles and materials, the power electronic converters of the thermoelectric generator loading system, with applications of domestic boilers and biomass stoves. Second part of the review will provide overview of the solar energy harvesting thermoelectric generation application. Thermoelectric generator is the component where the conversion from heat to electric power occurs.

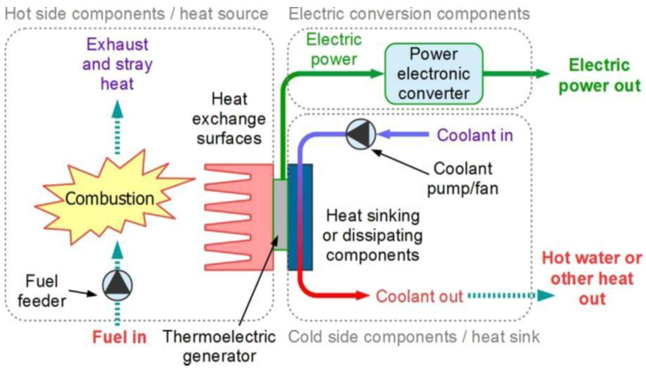

Figure 7: Layout of a combustion-based thermoelectric conversion

(20) Norbert Stuban, Adam Torok the authors investigated the usage of Peltier element because of the easier additivity to the exhaust system. The authors have found linear function between resistance [Ω] and voltage [V] according to the international literature. Not only the Seebeck related voltage but the maximal allowable power generated by the Peltier element is important. Due to the author's calculation a thermocouple with 50 W nominal power with 87 �C temperature difference can generate 1.2 W.

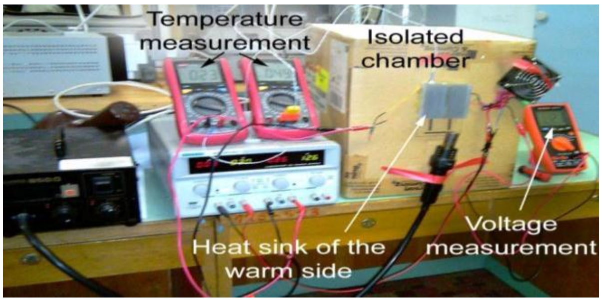

Figure 8: Measurement setup of measuring the voltage of the Peltier element by different temperature

4. CONCLUSION:

With a view to develop a new way for electricity generation we have studied and simulation a thermoelectric module. It is done with a structure designed and a considerable voltage is obtained. Thermoelectric module can be used to generate a small amount of electrical power, typically in the range, if a temperature difference is maintained between two terminals of a thermoelectric module. The maximum voltage generated occurred at a maximum temperature difference.

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