The Conversion of Waste Heat From Motorcycle Into Small Power Plant

Lia Kamelia [a] , Adam Faroqi [b] , Ahmad Ariz Muajianisan [c]

[a, b, c] Department of Electrical Engineering,
Sunan Gunung Djati State Islamic University of Bandung, Indonesia
[a] Corresponding E-mail: liafandi79@gmail.com,

OIDA International Journal of Sustainable Development, Ontario International Development Agency, Canada
ISSN 1923-6654 (print) ISSN 1923-6662 (online)
Available at http://www.ssrn.com/link/OIDA-Intl-Journal-Sustainable-Dev.html

Abstract: The law of conservation of energy states that energy can be transformed from one form to another but can not be created nor destroyed. Since energy is also gone every time it transferred between organisms, that missing heat must go someplace. That missing energy becomes waste heat in the atmosphere. The heat which generated from the motorcycle is able to reach 579.8^{o}C. To utilize this thermal energy we propose to design power plants from thermoelectric. Thermoelectric is a device that can transform heat energy (temperature difference) into electrical energy directly. The research concludes that the use of Peltier modules that are mounted on two-wheel motorcycle exhaust can generate the maximum voltage at 2.89 volts with a surface temperature of the heat side of Peltier modules is 579.8^{o}C and low temperatures on the surface of the cold side of Peltier modules is 18.9^{o}C (ΔT = 560.9^{o}C) , after tested for 60 minutes. After being processed by the LM2952 voltage regulator, voltage will rise to 12.8 volts at charging batteries for motorcycles.

Keywords*: Charging, Peltier module power plant, thermoelectric, waste heat,.*

Introduction

Nowadays, electricity is one of the primary energy needs of the human being. To meet the increasing demand for electricity, power producers, especially in Indonesia, PLN needs a lot of fuel to generate electricity, which mostly use coal fuel. To generate electricity is usually performed by burning coal to turn turbines which is then converted into electricity using a generator. In this process, as much as 2/3 of the energy is lost into heat energy, which is called waste heat.

Waste heat sources include all kinds of human activities, natural systems, and all organisms Waste heat produced by the machine that does the work and other processes that use energy, for example, in heating or combustion engines that release heat to the environment. The needs of the system to reject heat as a byproduct of its operations are the concept of the thermodynamics laws. Waste heat has higher entropy than the original energy source.

Rather than "wasted" freely into the surrounding environment, sometimes the waste heat can be utilized as another process, or partially wasted heat should be reused by the same process if the make-up of heat added to the system. To generate electricity from the heat of the motor vehicle, Thermoelectric Generators can be an option, its relatively small size allows it to be installed in all kinds of fields, and also able to survive in a very long period of time is approximately 50 thousand hours. By using thermoelectric generators, waste heat generated from the heat of the motor vehicle can be recycled into electrical energy, which can then be reused, such as for the supply of Air Conditioner, lights, or to recharge the battery Accu.

Automobiles are an example of high energy usage with inferior effectiveness. Approximately 75% of the energy produced during combustion will lost in the exhaust or engine coolant in the form of heat. By utilizing a fraction of the lost thermal energy to charge the battery instead of using an alternator the overall fuel economy can be increased by about 10%

It has been recognized that there are great potentials of energy savings through the use of waste heat recovery technologies. Waste heat recovery defines capturing and reusing the waste heat from internal ignition engine for heating, generating mechanical or electrical effort and refrigeration method. It would also help to distinguish the development in performance and emissions of the engine. If these technologies were adopted by the automotive manufacturers then it will be respond in efficient engine performance and low emission.

Waste heat is heat which is generated in a path by way of energy ignition or substance reaction, and then discarded into the atmosphere even though it might still be reused for some valuable and profitable function. The important value of heat is not the quantity but rather its value. The approach of how to improve this heat depends in part on the temperature of the waste heat gases and the economics implicated.
Large capacity of hot pipe gases is generated from boilers, ovens and furnaces. If some of this waste heat may possibly be improved, a considerable amount of primary fuel could be saved. The energy lost in waste gases cannot be completely recovered.

Thermoelectric devices can replace temperature differences into electric power, or cold materials by passing currents. The main principle of thermoelectric is based on the Seebeck effect which states: If the two pieces of different metals are connected in one point, then given a different temperature on the connection, there will be differences in voltage on one point to the other point. Seebeck's discovery inspired the Jean Charles Peltier to see the reverse of the phenomenon. He conduct electricity on two pieces of metal that embedded in a circuit. When electric current is applied, heat absorption occurs at the junction of the two metals and disposition heat on the other connection. The release and absorption of this heat will be turn around when the current direction is reversed. The discovery occurred in 1934 was later known as the Peltier effect. Seebeck and Peltier effects became the beginning of the development of thermoelectric technology.

Continuing research in thermoelectric materials and manufacturing techniques, enables the technology to make an increasing contribution to deal with the rising necessity for low power energy sources typically used in energy harvesting and scavenging systems. Commercial thermoelectric modules can be used to produce a small amount of electrical power, typically in the mW or μW range.

Many applications use thermoelectric energy that is being developed today, such as the utilization of heat differences in seabed and land, or the utilization of geothermal energy. The biggest difficulty in the development of this energy is searching thermoelectric material that has high energy conversion efficiency. Thermoelectric material parameters consider from the value of the-figure-of-merit of a material. Ideally, the thermoelectric material has a high electrical conductivity and low thermal conductivities. But the reality is very difficult to get material like this, because commonly if the electrical conductivity of the material is high, thermal conductivity will be high.

In this paper we proposed the electricity generated from Thermoelectric Generator occur due to Seebeck effect, this effect happens due to the temperature difference between the heated side of the module and the cold side, by transferring heat quickly, So that electrical energy is generated. The greater the temperature difference (ΔT) between the hot side and the cool side, the greater the electrical power generated. In this research, topics raised the use of Thermoelectric Generator, using Thermoelectric Coolers that made from aluminum mounted on a motor vehicle for generating electrical energy. A Peltier modules with aluminum is generally intended for cooling, since the Seebeck coefficient required for cooling is adequate (3.5 mV/K). In this research, the use of A Peltier modules with aluminum is used as a power plant based on the the Seebeck effect. The purpose of this study is to realize an electric generator tool that can change the heat energy from the engine exhaust into electrical energy using Thermoelectric Cooler.

Materials And Methods

Tools and materials used at this stage is a Peltier module TEC1-12706 type, voltage regulators and Accumulator. In general, the design process is shown in Figure 1.

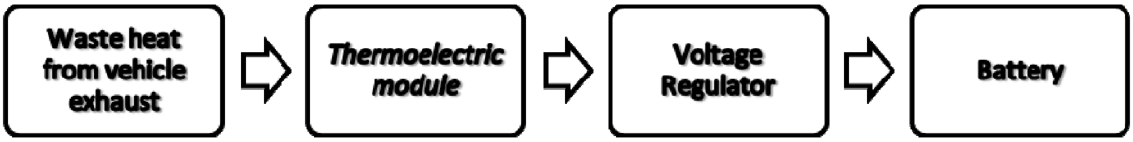

Figure 1: Diagram of Research Design.

The heat energy from engine exhaust routed to the heat sink using a thermoelectric device in direct contact. to obtain a suitable voltage to the charging voltage of the batteries, it takes a voltage of about 12-15 volts. Then, the output voltage from thermoelectric voltage regulator connected to in order to obtain the required voltage. After that, the output voltage is connected to the batteries.

In the design of voltage regulators, voltage regulator appliance requires an output of 12-15 volts. Therefore, the regulator IC LM2952 used as a step-up voltage regulator. The voltage regulator circuit is shown in Figure 2.

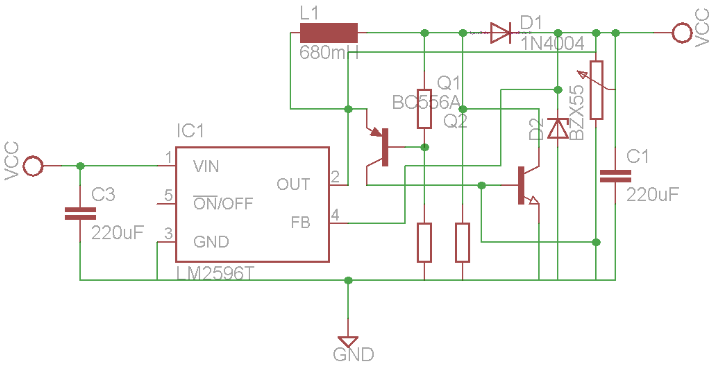

Figure 2: Scheme for Voltage Regulator circuit : LM 2952

The voltage circuit used IC LM2952 as a basis step-up voltage regulator, which aims to increase the output voltage of the Peltier modules. The incoming voltage from the input pin will increase by IC LM2952. Minimum incoming voltages that can be processed by a voltage regulator LM2952 are 2 volts. If the input voltage is below 2 volts, the voltage regulator will not process the input voltage. The voltage regulator will increase the input voltage when the input voltage has passed the minimum limit.

After designing and manufacturing a voltage regulator, the next stage is the assembly process for TEC1-12706 Peltier modules, 12V DC fan, heatsink and Accu.

Figure 3 is the circuit of power plants based on thermoelectric, its used Peltier module as a converter from heat energy into electricity. The output voltage from Peltier module step-up used LM2952 voltage regulator circuit, than the result voltage supplied to the battery.

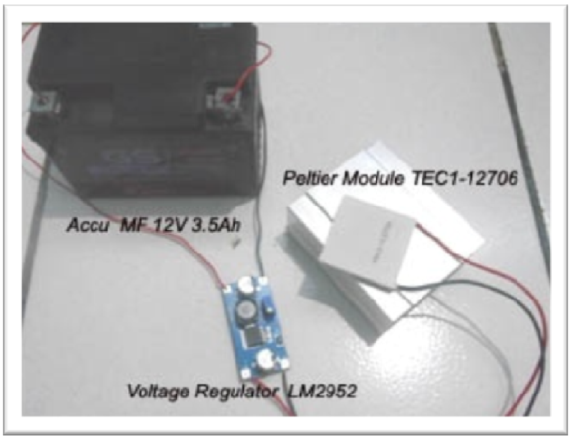

Figure 3 : The circuit of Power Plant from thermoelectric

Results and discussion

After the implementation of the circuit, next stage is examination the circuit. The first test is performed to determine whether the voltage generator can generate DC voltage, 12 volts, that produced by the motorcycle exhaust heat which is connected to the battery for charging. The testing was done by measure the output voltage Peltier modules and testing the voltage charging of batteries.

The test results of Peltier module output voltage shown in Table 1.

Table 1: Testing Results for Output Voltage by Peltier Module

Time (Minutes)	Output Voltage (Volts)	Temperature on Hot Side of Peltier Module (^{o}C)	Temperature on Cold Side of Peltier Module (^{o}C)	Description
5	1.21	90.2	16.1	Failed
10	1.50	178.7	16.5	Failed
15	1.62	224.9	16.5	Failed
20	2.08	348.3	16.6	Succeed
25	2.22	385.1	16.8	Succeed
30	2.35	426.2	17.0	Succeed
35	2.44	454.6	17.1	Succeed
40	2.53	472.1	17.4	Succeed
45	2.66	509.2	18.2	Succeed
50	2.71	522.5	18.5	Succeed
55	2.79	548.7	18.7	Succeed
60	2.89	579.8	18.9	Succeed

Table 1 shows the results that at the 5th minute until 10th, the test results failed because of the voltage generated by Peltier modules did not reach the minimum limit voltage required by the LM2952 voltage regulator, which is 2 volts. While the 20th minute until 60th, the results of testing is successful because of the voltage generated of Peltier modules already passed the limit required voltage LM2952 voltage regulator, which is 2 volts.

Based on the output voltage testing for Peltier modules, after testing for 60 minutes, the voltage can be produced by Peltier modules have 1:21 volt minimum voltage and a maximum voltage of 2.89 volts.

Factors that led to Peltier modules can not generate a higher voltage are the material used and the temperature difference. The material used for these Peltier modules is aluminum with a Seebeck coefficient of 3.5 mV / K, and therefore the level energy change efficiency less well due to the small coefficient.

Peltier modules used in this research are capable of producing a maximum voltage of 2.89 volts at ΔT of 560.9^{o}C. Rate of change in of energy that can be changed depend to level of ΔT, the higher the ΔT, the higher the voltage generated by Peltier modules.

In comparison with the calculation results, the test results showed a voltage of 2.89 volts as the result of the calculation is 2.91 volts, there is a difference 0:02 volts. This may occur due to several factors, including the temperature of the surrounding environment, areas of Peltier module attached that is not proper at the motor exhaust, and the level absorption efficiency Peltier modules themselves. The test results for batteries charging shown in Table 3.

Table 3: Test results for batteries charging

Time after…minutes	***Accu voltage (V)***	**Current (Ampere)**	**Description**
5	8.22	0.04	Failed
10	8.22	0.06	Failed
15	8.22	0.07	Failed
20	8.55	0.12	Succeed
25	8.87	0.15	Succeed
30	9.02	0.18	Succeed
35	9.10	0.20	Succeed
40	9.13	0.20	Succeed
45	9.17	0.21	Succeed
50	9.24	0.22	Succeed
55	9.30	0.22	Succeed
60	9.34	0.22	Succeed

Table 2 shows the test results for batteries charging. It shows that in the 5th minute to the 15th, the test results failed because the voltage that comes out of the Peltier modules has not reached the limit voltage required by the voltage regulator LM2952 at 2 volts, so the voltage regulator LM2952 does not process the input voltage from the Peltier modules. This causes the voltage of the batteries do not run batteries charging. Whereas in the 20th minute to 60th, the test results declared successful because the voltage coming out from the Peltier modules have reached the limit voltage required by the regulator, the battery charging process can be done as indicated by the increase in voltage Accu.

At minute 5th to 15th, there is no process of charging the batteries. While at the 20th minute to 60th, the test results stated successful because the voltage comes out from Peltier modules have reached the limit voltage required by the regulator, and therefore the battery charging process can be done as indicated by the increase of voltage Accu.

Conclusions

After the design, assembly and implementation, we already implemented a power generation device using thermoelectric cooler. From the testing, we concluded that:

1. The maximum voltage from the Peltier module is equal to 2.89 volts
2. The output voltage of the voltage regulator for charging batteries is 12.8 volts
3. Minimum ΔT needed for Peltier modules may produce the minimum threshold voltage is 367.7oC.
4. Charging the accu can be done by increasing the voltage of 1:12 volts.

References

[1] W. H. Ahmed and B. I. Ismail, "Thermoelectric Power Generation Using Waste- Heat Energy as an Alternative Green Technology Thermoelectric Power Generation Using Waste-Heat Energy as an Alternative Green Technology," *Recent Patents Electr. Eng.*, vol. 2, no. October, pp. 27–39, 20010.

[2] P. Ajit, K. Senapati, S. P. Dash, and P. Rakesh, "Thermo-Electric Generator in Turbocharged Diesel Engine - A Review," *Int. J. Innov. Sci. Eng. Technol.*, vol. 1, no. 3, pp. 276–280, 2014.

[3] L. E. Bell, "Review Cooling, Heating, Generating Power, and Recovering Waste Heat with Thermoelectric Systems," vol. 321, no. September, pp. 1457–1462, 2008.

[4] S. Boskovic and M. Tabatabaian, “Thermoelectric power generation from waste heat,” 2011.
[5] B. Dziegielewski and T. Bik, “Water Use Benchmarks for Thermoelectric Power Generation,” 2006.
[6] M. Gupta, “Review on Heat Recovery Unit with Thermoelectric Generators,” vol. 4, no. 4, pp. 128–131, 2014.
[7] T. T. Heikkila, “References 1.,” *SCIENCE*, vol. 342, no. November, pp. 703–705, 2013.
[8] J. S. Jadhao, D. G. Thombare, P. G. Student, and D. Sangali, “Review on Exhaust Gas Heat Recovery for I . C . Engine,” *Int. J. Eng. Innov. Technol.*, vol. 2, no. 12, pp. 93–100, 2013.
[9] P. F. K. Wojciechowski, J. Merkisz and M. S. , P. Lijewski, “Study of Recovery of Waste Heat From the Exhaust of Automotive Engine.”
[10]H. Kaibe, T. Kajihara, S. Fujimoto, K. Makino, and H. Hachiuma, “Recovery of Plant Waste Heat by a Thermoelectric Generating System Thermo,” 2011.
[11]C. R. Kumar, A. Sonthalia, and R. Goel, “Experimental Study On Waste Heat Recovery From An Internal Combustion Engine Using Thermoelectric Technology,” *Therm. Sci.*, vol. 15, no. 4, pp. 1011–1022, 2011.
[12]S. Kumar, S. D. Heister, X. Xu, J. R. Salvador, and G. P. Meisner, “Thermoelectric Generators for Automotive Waste Heat Recovery Systems Part II : Parametric Evaluation and Topological Studies,” *J. Electron. Mater.*, 2013.
[13]S. Leblanc, “Sustainable Materials and Technologies Thermoelectric generators : Linking material properties and systems engineering for waste heat recovery applications,” *Sustain. Mater. Technol.*, vol. 1–2, pp. 26–35, 2014.
[14]G. P. Meisner, “Thermoelectric Conversion of Exhaust Gas Waste Heat into Usable Electricity,” 2011.
[15]A. Moreira, R. Freitas, J. Sepúlveda, and J. S. Esteves, “Miniature Thermoelectric Power Plant,” *Int. J. Hands-on Sci.*, vol. 3, no. 1, pp. 32–36, 2010.
[16]K. Smith and M. Thornton, “Feasibility of Thermoelectrics for Waste Heat Recovery in Conventional Vehicles,” Colorado, 2009.
[17]J. Vázquez, M. A. Sanz-bobi, R. Palacios, and A. Arenas, “State of the Art of Thermoelectric Generators Based on Heat Recovered from the Exhaust Gases of Automobiles,” in *Proceedings of the 7th European Workshop on Thermoelectrics*, 2002.

About the authors:

Name: Lia Kamelia
Lecturer of Electrical Engineering Department, Sunan Gunung Djati State Islamic University Bandung
Mailing address: Jl. A.H.Nasution 105 Bandung Indonesia
Tel:62-858-6158-4158
E-mail: liafandi79@gmail.com