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Fabrication and Analysis of Power Generation from Waste Heat in Industries Using Thermoelectric Generator

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ABSTRACT

The increasingly worldwide problem regarding rapid economic development and a relative shortage of energy, the internal combustion engine exhaust waste heat and environmental pollution has been emphasized more heavily recently. 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, resulting in an entropy rise and serious environmental pollution, so it is required to utilize waste heat into useful work. As waste heat recovery techniques, such as a thermoelectric generator (TEG), are developed, they have become a promising alternative green technology due to distinct benefits of thermoelectric generators.

1. INTRODUCTION

In recent years, an increasing concern of environmental issues of emissions, in particular global warming and the limitations of energy resources, has resulted in extensive research into novel technologies of generating electrical power.

Thermoelectric power generators have emerged as a promising alternative green technology due to their distinct advantages. Out of the total heat supplied to the machines 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, resulting in an entropy rise and serious environmental pollution, so it is required to utilize waste heat into useful work.

In this project, the conversion of the Heat energy into electrical energy. By using this energy fan, it operates and the energy is stored in a battery. The control mechanism carries the A.C ripples neutralizer, unidirectional current controller, and 12V, from this battery supply, which will pass to the inverter, and it is used to drive AC/DC loads. The battery is connected to the inverter. This inverter is used to convert the 12 Volt D.C to the 230 Volt A.C. This 230 Volt A.C voltage is used to activate the loads. We are using a conventional battery charging unit, also for giving supply to the circuitry. In this project, we are using TEP Transducer. Transducer is a device that converts one form of energy into another form of energy. This includes electrical, mechanical, light, and heat energy, also. While the term transducer commonly implies the use of sensors/detectors, any device that converts energy is considered a Transducer.

A. Objectives

The current research is focusing on a technology, which is able to convert the thermal energy contained in the exhaust gas directly into electric power. In this project concept, it is an exhaust gas-based thermoelectric power generator for an industry application.

In this invention, the exhaust gas gases in the pipe provide the heat source to the thermoelectric power generator. So, this project proposes and implements a thermoelectric waste heat energy recovery system from the exhaust heat from running machinery.

The key is to directly convert the heat energy from automotive waste heat to electrical energy using a thermoelectric generator. While the electric power generation by such a system is still relatively small at a maximum of 10 W from a single TEG module, rapid progress in materials research can make the ambitious objective of generating higher watts by all means of feasible proposition.

2. Literature Review

This invention relates to the Internal Combustion Engine. Among all research directions, waste heat recovery (WHR) is most concerned, due to the widespread existence and high accessibility of suitable resources. According to India Bureau of Energy Efficiency, the benefits of WHR include reduction in the process consumption and costs, reduction in pollution and equipment sizes, and also reduction in auxiliary energy consumption. While there are several devices to fulfil WHR, thermoelectric generator (TEG) has been utilized in most automotive applications.

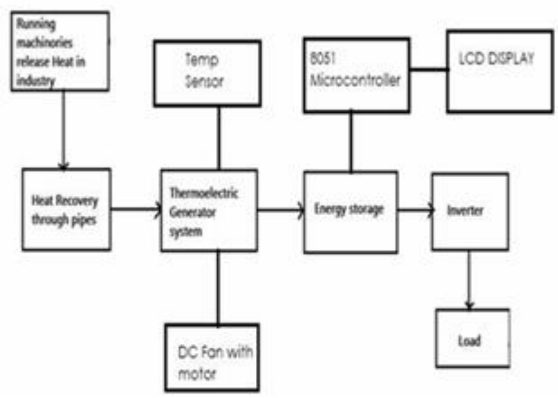
Jihad G. Haidar, Jamil I. Ghojel, "waste heat recovery from the exhaust of low- power Diesel engine using thermoelectric generators, 20TH international conference on thermoelectric (2001), p413-417 From literature survey 1 we studied how to recover waste heat and how to utilize waste heat from different industries.

K. Li, G. Garrison, and M. Moore, "Experimental study on the effects of flow rate and temperature on thermoelectric power generation," in Proc. 44th Workshop on Geothermal Reservoir Engineering, Stanford Univ., SGP-TR-214, Feb. 2019.

Ahaad Hussein Alladeen, Shanshui Yang, Yazhu Liu, Feng Cao, Thermoelectric waste heat recovery with cooling system for low gradient temperature using power conditioning to supply 28V to a DC bus, 2017 IEEE Transportation Electrification Conference and Expo, Asia-Pacific (ITEC Asia-Pacific), 2017, From literature survey 3 we studied different types of cooling system and different types of coolant.

Arash Edvin Risseh, Electrical Power Conditioning System for Thermoelectric Waste Heat Recovery in Commercial Vehicles, IEEE Transactions on transportation electrification, 2018, p 2-16, From literature survey 4 we got an idea about how to recover the waste heat from automobile application.

3. Material And Methods



. Figure 1: Experimental block diagram

TEG consists of one hot side and one cold side. The hot side with higher temperature will drive electrons in the n-type leg toward the cold side with lower temperature, which cross the metallic

interconnect, and pass into the p-type leg, thus developing a current through the circuit.
If temperature difference is kept constant, then the diffusion of charge carriers will form a constant heat current, hence a constant electrical current.

Features Of Teg

- They are extremely reliable (typically exceed 100,000 hours of steady-state operation) and silent in operation, since they have no mechanical moving parts and require considerably less maintenance.
- They are simple, compact and safe.
- They have a very small size and virtually weightless.
- They are capable of operating at elevated temperatures.
- They are suited for small-scale and remote applications
- Typical of rural power supply, where there is limited or no electricity.
- They are environmentally friendly.
- They are not position-dependent.
- They are flexible power sources.

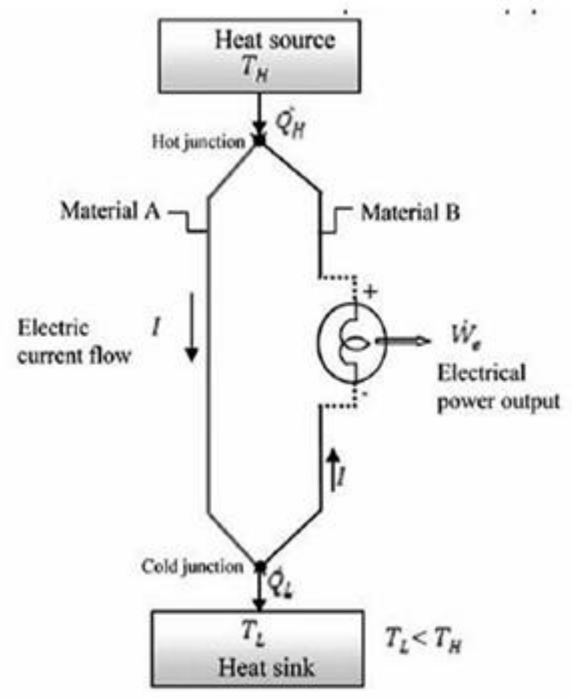


Figure 2: Schematic block diagram of TEG

In this project concept, it is an exhaust gas-based thermoelectric power generator for an industrial application.

In this invention, the exhaust gas gases in the pipe provide the heat source to the thermoelectric power generator. So, this project proposes and implements a thermoelectric waste heat energy recovery system from the exhaust heat from the running machinery in industries.

When we apply TEG with a Heat sink module to waste heat through a heat pipe, executed from the machine. Then at the same time TEG starts converting Heat energy into Electrical energy. We can measure this heat with the help of a temperature sensor attached to the system.

One DC fan is attached to the system to indicate the flow and conversion of heat energy into Electrical energy. As the temperature increases, the flow of the fan also increases.

Generated electrical energy is stored in the battery. This stored energy is supplied to the inverter to convert DC to AC.

At the output AC load is obtained. This AC load is utilized to run various loads in the same industry, like a fan, AC, light, etc. We also attached an 8051 microcontroller (AT89S52) with LCD display to measure the amount of voltage stored and remaining in the battery.

In this way, the whole system works. Start from the wastage of heat dissipated in the industry through the production process. Then conversion of heat into electricity. Indication of conversion electricity through DC fan and motor. Storage of electricity in a battery. Conversion of DC voltage to AC voltage with the help of an inverter. Microcontroller attached to show the voltage present at the battery. And last AC load attached to the inverter.

If such a system were utilized in the automobile industry, the amount of wastage heat that we can utilize it. And also minimized the air pollution problem caused by vehicles.

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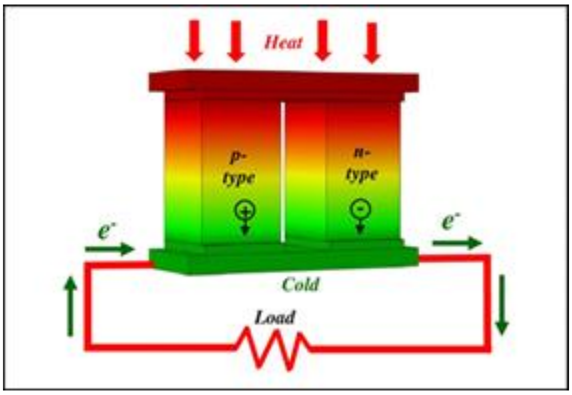

Figure 3: Schematic diagram showing components and arrangement of a typical single-stage thermoelectric power generator

Performance Of Thermoelectric Power Generators

The performance of thermoelectric materials can be expressed as

$$Z = \alpha 2/kR, \quad (1)$$

where Z is the thermoelectric material figure-of-merit, α the Seebeck coefficient given by

$$\alpha = -\Delta V/\Delta T \quad (2)$$

R is the electric resistivity (inverse of electric conductivity) and k is the total thermal conductivity. This figure-of-merit may be made dimensionless by multiplying by $\bar{T}$ (average absolute temperature of hot and cold plates of the thermoelectric module, K), i.e.,

$$ZT = \alpha 2T/kR \quad (3)$$

Components Used

- Thermoelectric plate
- Exhaust fan
- Aluminium heat sink
- Silencer
- Heat source (Engine considered device)
- DC motor with fan
- Battery
- Inverter module
- Temperature sensor
- Controller board
- LCD
- wiring
- switches
- LED bulb
- Metallic Frame
- connector circuit board
- Adapter

BENEFITS

TEGs are solid-state devices, which means that they have no moving parts during their operations. No moving parts, so maintenance required is less frequently, no chlorofluorocarbons. Temperature control to within fractions of a degree can be maintained, flexible shape, very small size.

- TEGs can be used in environments that are smaller or more severe than conventional refrigeration. TEG has a long life, and also it can be controllable by changing the input voltage/current.
- SCOPE:
- By using the thermoelectric generator to generate the power from waste heat in industries.
- TEG generates the power to charge the portable equipment like a laptop, mobile, etc.
- If TEG is installed in the vehicle above the radiator, the battery will charge itself.

ADVANTAGES

- Clean and noiseless
- Lower cost.
- Non-conventional system; no fuel required.
- Easy maintenance and portable.
- Promising technology for addressing power crises affordably.
- Simple in construction and free from pollution.
- Reduces transmission losses.
- Wide range of applications.
- Requires less space.
- Usable anytime when necessary.
- Fewer parts required.
- Can charge any electronic device.
- Electricity can be used for multiple purposes.
- Efficient and eliminates grid dependency.

DISADVANTAGES

- Improper variation of temperature gradient difference may damage the TEG, Complex design.
- Need proper maintenance every time.

APPLICATIONS

- It is used in industries to generate power from the various machines' exhaust.
- It can be installed in the vehicle's exhaust to produce electricity for the various applications.
- Charge the battery where waste heat is obtained.

CONCLUSION

Waste heat recovery entails capturing and reusing the waste heat from the machinery in industries and using it for generating electrical work. It would also help to recognize the improvement in performance and emissions of the machinery if these technologies were adopted by the production industries.

If this concept of the thermoelectric system is taken to the practical level, then there will be a large amount of electricity that can be generated, which will be used to run the industrial load itself. Also, a large amount of wastage heat for pollution is continuously used in this system. And such industries also somehow help to protect the environment from pollution.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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The author declare that they have no funding support for this study.

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