Group 114

SΔT power cell

STEM 6th October for boys - G10 2021-2022

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key words: Heat - Seebeck - Electricity - Thermoelectricity - Alternative energy

Abstract

The lack of alternative energy utilization is one of the most progress-hindering grand challenges in Egypt. It results in many other problems; one is the increase in atmospheric pollution due to the reliance on fossil fuel combustion. This in turn affects the population's public health. The second problem is that there is a huge amount of waste heat emitted from lots of fields such as industrial processes, electrical generators, and building envelopes. Furthermore, alternative energy resources must be developed as fossil fuels are finite resources that are bound to deplete in the near future. This study's purpose was that heat could be exploited in electricity generation as it is one of the most efficient means of alternative energy generation. The main design requirements were chosen to develop the solution: power efficiency, and cost-efficiency. The major findings of the study were marvelous as the prototype achieved the desired results.

Introduction

Energy use is rising in Egypt by 6.5% per year, but the boundless reliance on finite resources has placed the future of energy sustainability in danger. Furthermore, the ordinary combustion of fossil fuels for energy contributes to producing a significant amount of greenhouse gas emissions, increasing the pollution level dramatically. as shown in figure (1) using of fossil fuels in Egypt is in increase. Accordingly, the importance of generating energy from the alternative energy source is discerned as a critical challenge that encourages Egypt to investigate this field. Waste heat energy is emitted every day from many fields such as industrial processes, electrical generators, and building envelopes. Therefore, if this huge-amount of wasted heat energy is exploited in electricity generation as it is one of the most efficient means of alternative energy generation, it will solve the energy problem.

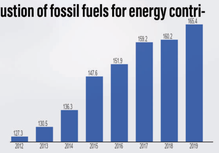


Figure 1 increasing of using fossil fuels

A previous solution to this problem was the "Heat Pipe Heat Recovery System". This project was made to collect the maximum amount of waste heat from flue gas. This recovery system can be used to recover waste heat from flue gas generated in oil/gas/coal powered DGs. The advantage of this project is its low cost and its high energy generation. However, the main weakness is that the Heat recovery systems cannot provide sufficient outside air for cooling overheated rooms. Another solution was Internal combustion engines. The project converts waste heat emitted from the engine to electric energy to be stored in the battery. The idea of the project depends on the thermally regenerative electrochemical cycle (TREC) which uses the thermobalance effect. the TREC is made up of four processes heating, charging, cooling, and discharging. The project's strength is that it will make the battery's life period longer. unfortunately, it pollutes the environment by emitting gases.

Certain design requirements were determined to develop a solution that was efficient power generation and cost-efficient distribution. The chosen solution is to convert waste heat energy to electricity by using the prototype that depends on the Seebeck effect which is cooling one part and making the other part face the waste heat source. The prototype was made of two parts, the two rods that convert the heat energy into electricity and an evaporative cooling system that higher the efficiency.

The project has achieved the design requirements well. The next sections inaugurate the materials and methods used in order to meet the design requirements and the testable plan used to help ensure the meeting of the solution with the design requirements

Materials & Method

Materials

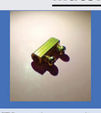
image					
name	Iron sheet	Electric terminal connector	Copper wire	Graphite	Copper
quantity	2 pieces 20*20	45 pieces	1.5 m 0.5 mm	11 pieces 2 mm	11 pieces 3 mm
description	Fixing connections on it	Connect copper wire with graphite and copper	Connect graphite with copper	Using as a N site	Using as a P site

table showing materials

Methods

1- The graphite and copper rods were cut into small equal pieces.
2- The graphite and copper pieces were connected together by a copper wire and electric terminal connector as shown in figure(2) until the connections become as long as needed.
3- The iron sheet was cut into two square pieces whose side length is 20 cm.
4- The connections were suspended between the two iron sheets as shown in figure (3).

Figure 2 graphite and copper connected together

Figure 3 connections fixed on the iron sheet

Test plan:

In order to determine the success of the prototype, a test plan was prepared beforehand. The test plan demonstrated in figure (4) aimed to test whether the prototype meets the design requirements. It consisted of the following steps:

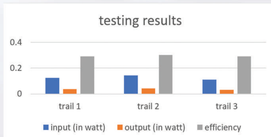
Figure 4 way of test plan

- In order to measure the input power, the prototype was put on the heat source for six minutes. The energy absorbed by the prototype after these six minutes was measured. The value of the energy absorbed was divided by the time taken to absorb this energy to get the input power in.
- The output voltage was measured by a voltammeter by connecting the circuit and the output current intensity was measured by the same circuit but with an ammeter.
- The output values of voltage and current were multiplied together to get the output power and then multiplied by the number of connections. In order to test the efficiency of the energy generated by the water current, the output wattage was divided by the input wattage.

Results

After testing the prototype, it was apparent that it successfully met the design requirements. Although the first test did not bear great results, a solution was crafted in order to counteract the problems which made the results much better than they previously were.

When the prototype was initially tested, the wattage and the efficiency were too low. This problem was studied well, and it found the reason for this problem is that the surface area facing the heat was too small. The problem was solved quickly by making the surface area much bigger by adding a flat ceramic to collect heat. The prototype met the design requirements and was able to achieve an average efficiency of 29% from three trials (as shown in graph(1) and table (1) which was calculated by dividing the output electric power by the input heat power.



graph 1 thre trails results

Figure 5 voltage and Ampere result

	Input power (In watt)	Output power (In watt)	Efficiency (%)
Trail 1	0.125 watt ±2%	0.0363 watt ±2%	29% ±2%
Trail 2	0.142 watt ±2%	0.0426 watt ±2%	30% ±2%
Trail 3	0.109 watt ±2%	0.0316 watt ±2%	29% ±2%
average	0.1253 watt ±2%	0.03683 watt ±2%	29.3% ±2%

table1 three trails results

Analysis

First of all, the main function of the project is to solve the wasted heat energy and find a clean alternative energy source by converting the wasted heat energy into electricity. The project finally achieved standard results and met the design requirements according to a strong scientific base which is represented in detail through this section.

The Seebeck effect in the prototype: (as in the figure 6)

It is a phenomenon in which the variance in the temperature between two semiconductors or electrical conductors produces a difference in the voltage between the two substances. When the heat is applied, on one of the two prototype's faces, heated electrons flow toward the cooler face, then the electric current can flow if an electric circuit is connected. The semiconductors are used between the two faces of the prototype because the semiconductors have some properties (as in L04 in Chemistry) as heir electrical conductivity depends on the temperature only, their electrical conductivity is between the conductors and insulators. The prototype consists of two types of semiconductors which are the p and n types, the p-type is usually boron which has 3 electrons in their outermost energy level, then they have positive particles which are called holes that exist when the electron is absent from its place. The n-type is usually phosphorus which has 5 electrons in their outermost energy level, so they have free electrons that carry a negative charge. The negative electrons and positive holes transfer from the hotter face to the cooler once, so they can make an electric current. The electric field can be calculated by the following equation: $E = S\Delta T$ as E is the electricity, S is the Seebeck coefficient and ΔT is the difference in the temperature. The ability of the prototype materials to convert heat energy into electricity (Z) is determined by the equation $Z = S2\ \rho k$ as S, p, and k are Seebeck coefficient, electrical resistance, and thermal conductivity.

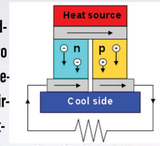


Figure 6 The Seebeck effect

Material analysis

In the prototype, copper and graphite is used as materials to construct the prototype. Copper is a metallic element with high thermoelectric conductivity and thermal conductivity. The element copper is used because of its availability and its relativity cheap price. However, the main reason is because of its seebeck coefficient of 9.8μ-V/K and thermal conductivity of 397W/M.K at 20 C degrees. The mineral graphite is a crystalline form of carbon. It is made up of hexagonal layers of graphene that are weakly bonded together. Graphite is the most stable form of carbon that occurs naturally. It is used because it is cheap and available almost everywhere. The graphite has a seebeck coefficient that ranges between 25 μV/K at 380 K. the thermal conductivity of graphite is high as it ranges between 25 W/M.K to 470 W/M.K.

Calculating the voltage

In order to calculate the output voltage that the prototype is going to generate a few mathematical and physical points will be followed in order to calculate the voltage. The amount of the voltage depends heavily on the material that is used in the making of the prototype. As the way to generate voltage is through the seebeck effect. Which depends on the seebeck coefficient of the material. The law is ΔV= -S ΔT. ΔV is the voltage difference and -S is the seebeck coefficient and ΔT is the temperature difference between the two sides of the prototype. The seebeck coefficient is physical property of a material and changes according to the temperature it is also the measure of magnitude of an induced thermoelectric voltage in respond to a change in the temperate across that material.

Efficiency measurement:

The input of heat also has to be calculated for the efficiency calculations in Watt. A plate of aluminum is used to transfer the heat from the source to the prototype to generate electricity. And in the process of the transfer of the heat that the aluminum plate had absorbed to transfer it to the prototype, it will lose some of the heat and that depends on the thickness of the plate and the thermal conductivity of aluminum. So firstly in order to calculate the heat energy that the aluminum absorbed the following equation was used: Q = MCΔT(as mentioned in L.O. 13 in chemistry). After it absorbs the heat, it transfers this heat to the prototype. Therefore, it would lose some heat while transferring it and that lost heat is calculated by k = (Q×L) ÷ (A×ΔT). K is thermal conductivity, Q is the heat in joule per second, L is the distance or the thickness, A is the Area and ΔT is the temperature difference. the temperature difference is the only unknown value and it is the input of the heat. After the heat energy that was absorbed by the prototype in the six minutes was measured. The value of the heat energy absorbed was divided by the time taken to absorb this value which is six minutes.

After that, the output power is measured which is the electric power of the electric circuit. The power (P) of any electric circuit can be measured by the following equation:

$$P = V \times I$$

Here, V is the voltage of the current in volt, and I is the flowing current intensity in ampere. The voltage and the current intensity of one connection were measured and then they were multiplied by the number of the connections to get the voltage and the current intensity of the whole prototype. To measure the efficiency of the prototype the output power was divided by the input power and multiply it by 100%.

Conclusion

The project's main purpose is to use the waste heat in Egypt as a source of alternative energy. After constructing the prototype, it was tested according to some design requirements to ensure its success, and it has successfully achieved the design requirements. As shown from the results, the prototype has achieved an efficiency of 29% of the input power. This result is relatively high compared to the other solutions. The cost of the prototype is only 100 pounds which makes the prototype cost-efficient and can be used in large scales. In conclusion, the prototype showed its efficiency and ability to overcome the waste heat problem in Egypt.

Recomendation

Any solution can always be modified to be more efficient. The prototype could be used at the iron-nickel factory which emits a huge amount of heat energy. Therefore, there are some recommendations for both the design and the location of the project for being more effective when using it in real life.

Real life application:

In real life application it is recommended to use the prototype in steel and iron factory like the Helwan steel factory in Cairo, Egypt. The prototype will be used in the steel furnace as it will use the waste heat generated by the furnace to generate electricity. The furnace consists of different levels according to their temperature. The temperature range between 200 Celsius degrees to 1900 Celsius degrees (as shown in figure(7)) . The prototype will be used in the range where the temperature range between 200 and 1000 Celsius degrees. The average steel and iron furnace ranges between 20 to 110 meter in height and from 5 to 15 in diameter. The prototype will also be increased in the number of connections and the surface area would be increased to about 10 m2 so it can suit any steel furnace in the world .

Materials:

It is recommended to use Bismuth Telluride (Bi2Te3) shown in fig (7), Lead Telluride (PbTe), or Silicon Germanium (SiGe) as materials. Bismuth Telluride (Bi2Te3) has a high Seebeck coefficient of (voltage per unit temperature difference) of −287 μV/K at 54 °C. Also, Bismuth Telluride has a high electric conductivity of 1.1×105 S·m/m2 and a very low thermal conductivity of 1.20 W/(m·K). while the Lead Telluride is a semi-conductor it has a see beck coefficient of -174μV/K. If Bismuth Telluride and Lead Telluride were used, they would generate an electric current of 5kW.

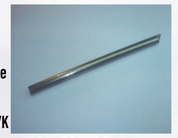


Figure 7 Bismuth Telluride

Figure 8 AC ammeter

Alternating Current (AC) source:

Using alternating current (AC) instead of the direct current (DC) has some advantages. The most essential benefit gained is that it is much more efficient when transmitting through long distances as fewer power is lost. Moreover, the alternating current can easily be converted into a direct current. The device that measures the AC current called AC ammeter as shown in fig (8).

Increasing the surface area:

The prototype design is made to collect the heat energy and convert it to electric energy. Furthermore, the surface area of the prototype is very important for our project as it will help the prototype collect more amount of heat and faster and produce more electric energy and faster too. In conclusion, the efficiency of the prototype is directly proportional to the surface area. Therefore, it is recommended to increase the surface area of the prototype as large as possible.

Thermal energy battery:

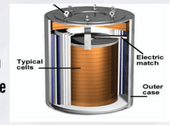


Figure 9 thermal energy battery

While the prototype faces the heat energy emitted from the factory it is a common problem that the heat energy will be distributed in the environment. Therefore, the problem addressed is that there is a huge amount of heat energy wasted. So, it is needed to collect the highest amount of heat energy to produce the highest amount of electric energy. It is recommended to use the thermal energy battery (shown in fig (9)) which acts like the traditional battery that stores the electric energy, but it stores heat energy. The purpose of the thermal energy battery is to store the heat energy for a long time and then release it when the order is made. The thermal energy battery will help a lot in reducing the wasted heat energy emitting and increase the electric energy produced by the prototype much more.

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Acknowledgement

First of all, and before anyone, we must thank God for guiding and helping us throughout the project from scratch we would like to give the humble thanks for the incredible effort those people had made to aid us in our work and those people are: Mr. Hesham Abdel-Razek (capstone supervisor in STEM unit), Mrs. Phoebe barsoom (Capstone leader of STEM 6th of October school),Mrs. Hanan Mahdy (chemistry teacher), Mr. Salah Abdel-Sattar (physics teacher).