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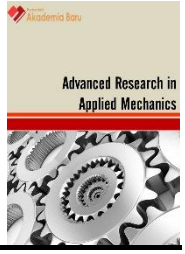

Experimental study of Peltier-Based Thermoelectric Cooling Box System

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ABSTRACT

Thermoelectricity especially the Peltier concept can be one of the useful alternatives for the refrigeration system. The refrigeration systems nowadays which are based on vapour compression cycles are less environmentally friendly. This paper presents a Peltier-based thermoelectric cooling box and its functionality as a cooling mechanism. The activities involved in developing this system are designing the product using CAD applications, producing electrical circuits, and experimental analysis to evaluate the system's performance. The material used is the Peltier module, CPU fan, polystyrene box and, some other materials in producing a mini thermoelectric cooling box. The experimental data showed proved the system's cooling capabilities to function as a cooling box over a specific duration when tested with and without a canned beverage to simulate as products to be cooled. Overall, the temperature drops faster when there are no beverages in it with an average temperature difference of 4.86 °C after 90 minutes for both conditions. In addition, some improvements can be done to the product in many aspects especially on its cooling capabilities. The Peltier can be added for maybe one or two more in parallel connections which can improve its cooling capabilities.

Keywords:
Thermoelectric; Peltier Module; Cooling; Environmentally Friendly

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1. Introduction

This research focuses on designing a Peltier-based thermoelectric cooling box system and testing the cooling box functionality. To test the cooling box functionality, an experiment was conducted on time taken for the designated cooling box to cool down. However, the use of the Peltier module for this project has some cons where a single Peltier module cannot generate a high amount of power which means that the cooling effect is not at optimum state. To counter back this problem, the Peltier module should be used more while connected in a parallel circuit.

This research focuses primarily on thermoelectric studies and the use of a CAD application for the design of a technical drawing. Internet was used widely in this project on finding information for this project and the on shape CAD application was used as the design drawing medium. In terms of the

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Peltier module applications, it has been used widely in the industrial, scientific, and medical fields [1]. This project will benefit some groups of people which are mainly travelers and cold food and beverages sellers. It is because it can be used in the vehicle which has the built-in USB port that can be the cooling box power source. Also, this project will be a good reference for studies of thermoelectric design in the future for the students or even for some academic staff.

1.1 Related Work

Peltier Effect stated that potential differences in thermocouples happen due to temperature differences of either high or low temperatures between different material intersections in thermocouples [2]. There was also another concept which is the Seebeck Effect that also applies the concept of thermoelectric but is different from the Peltier Effect which is then classified as also true by the founder of the Peltier Effect [3]. From the Peltier Effect research, a cooling method named thermoelectric cooling was created. Thermoelectric cooling was found very unique and useful because it can cool down an object without any moving pieces or other complex machinery that separates the cooler from its ambient surroundings [4]. Moreover, the device that was created to take place for this type of method is the Peltier elements or thermoelectric coolers which also known as TECs [5]. The Peltier elements are just a basic module of thermoelectric cooling but they can be constructed into a far more complicated Peltier module device. These Peltier elements are connected to semiconductor materials [6]. As a result, the semiconductor materials are often used in the thermocouple of thermoelectric coolers such as the combination of Bismuth and Telluride [7]. These materials were constructed to come into contact with the radiator hot and cold side of the Peltier element. The cubes then were named the P and N-type semiconductors based on the free electrons in the cube [8]. The cubes with extra free electrons and which means mainly carry the negative charge elements were named the N-type semiconductors [9]. This Peltier element is compulsory for the project as the designated Cooling Box is using this component as the main cooling source. As of today, the applications of thermoelectric cooler or Peltier elements are quite big. All of these TEC modules are being used in military, medical, industrial, scientific, and laboratory, as well as telecommunications organizations [10].

2. Methodology

The primary goals are to create a Peltier-based thermoelectric cooling box and test its functionality as a cooling mechanism. To complete this research product, several materials and procedures were used. First, the materials used for this project will be briefly explained. There will be an explanation to rationalize why all of the materials had been chosen as the main components for this research on Peltier-based thermoelectric cooling box. Then, the method or process included from the first step on creating the cooling box till the product is finally finished installed will be explained. All explanations on every process of creating this product will be assisted with some figures to shows more clearly how the cooling box is been done.

2.1 Materials

Peltier modules are exceptionally compulsory for this project which produce the cool thermal energy from electrical energy and cool down space in the polystyrene box. Two Peltier modules connected in parallel are being used to increase the product cooling capability. Then, the heatsink works as a heat transfer medium from the Peltier module to avoid the elements in the Peltier module meltdown because of the heat generated. Four heatsinks which consist of two small and two big heatsinks were used to transfer heat from the Peltier module inside and outside from both sides of the cooling box. Next, a polystyrene box is used as the main space to store the object that needs to be cool down as it is efficient to prevent the cool air heat loss from going outside of the cooling box. Then, the power supply is used as the main source of power or electrical energy to operate the product, which converts from DC to AC, and lastly producing AC for the product power source. There were four CPU fans used for this project. Same as the heatsinks, there were two small and two big CPU fans used as the heat dissipater to prevent any overheating of the component and spreading the cool air widely in the polystyrene box. The big CPU fans act outside the cooling box while the small CPU fans work vice versa. Then, the thermal paste is used as the adhesive medium to attach the Peltier module, heatsinks, and CPU fans while also can transfer the heat through all the components. Lastly, connecting wire is used as the connector for the loop of the electric circuit which connects the Peltier cooling elements to the power supply and the power supply to the electrical energy source through a plug.

2.2 Methods

The product's method or its assembly processes started with preparing all the main components used for the Peltier module assembly process as the **Figure 2(a)**. Then, the next process is by placing or sticking the Peltier module hot side on the big heatsink using the thermal paste as the adhesive material while sticking the small heatsink on the cold side of the Peltier module using the screws and nuts as the **Figure 2(b)**.

Figure 2(a): Power Supply, Heatsinks, Peltier Module and CPU Fans Preparation

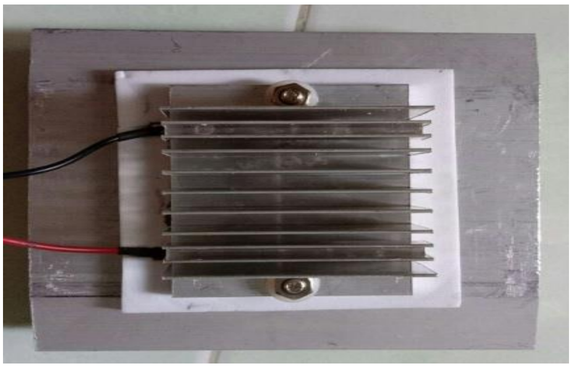

Figure 2(b): Fastening Process for the Peltier Module between Small and Big Heatsink

The wiring and fastening process is primarily used in making this project's end product out of all the methods for producing the product. All of the wirings must be perfectly connected for the product to function properly and to avoid an electrical accident such as an electric shock. Then, the fastening process must be done well and on-point for all the components fastening position because sometimes a wrong arrangement of position for the components can affect the product's effectiveness and safety.

3. Results

As for the outcomes, a physical product was produced which is the Peltier-based thermoelectric cooling box as the **Figure 3(a)** and **Figure 3(b)**. Then, the functionality of the Peltier-based cooling box being tested by experimenting with it under some conditions and the data recorded will be discussed.

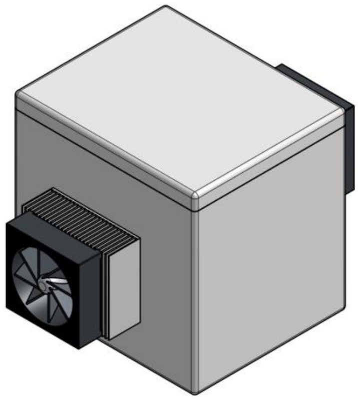

Figure 3(a): Peltier-Based Thermoelectric Cooling Box Final Technical Drawing Design

Figure 3(b): Peltier-Based Thermoelectric Cooling Box Final Product Result

Two conditions are set for the experiment to test the cooling box functionality where the first condition is there is nothing in the polystyrene box while there are six canned beverages in the polystyrene box for the second condition. For both conditions, the temperature was recorded in the polystyrene box every 15 minutes starting from the initial polystyrene box temperature until it finally reaches 90 minutes. For each condition, five tests were conducted to find the average temperature to ensure that the experimental data is accurate.

3.1 Discussions

As shown in **Figure 3(c)** and **Figure 3(d)**, the cooling performance of the conventional refrigerator is undoubtedly great as the compressor and the gases inside the refrigerator could easily drop and constantly kept the temperature of the refrigerator below 13 ^{o}C. Not to mention, the mini cooling box also had a good cooling performance mainly in the early minutes of the cooling process. But the lack of gas and compressor that has been used in conventional refrigerators makes the performance start to drop slowly as the temperature starts to maintain at 18 ^{o}C after 90 minutes of cooling compared to the conventional refrigerator which can drop to 13 ^{o}C. Next, the power generated by the conventional refrigerator is greater than the mini cooling box as the **Figure 3(c)** and **Figure 3(d)** shows that the refrigerator recorded a temperature of 17 ^{o}C after 90 minutes compared to the mini cooling box which was recorded just 18 ^{o}C after 90 minutes. The refrigerator might be the best choice to be the best storage for a long period but the mini cooling box can cool down the item stored inside of it quicker than the conventional refrigerator. This can be proved as the graph shows that the mini cooling box can drop about 10 ^{o}C in just 15 minutes of the cooling process. As for the similarity of data in both slopes in **Figure 3(c)**, both of the slope patterns on the graph look identical. For the first 15 minutes of the experiment, the temperature dropped much for approximately an average of 9 - 17 ^{o}C while the temperature drops every 15 minutes after the first 15 minutes till the end did not drop much with only approximately an average of 1 - 4 ^{o}C. This shows that at some point of the experiment where the temperature dropped slowly, the thermal equilibrium process happened. Thermal equilibrium seems more obvious when there are canned beverages in the cooling box.

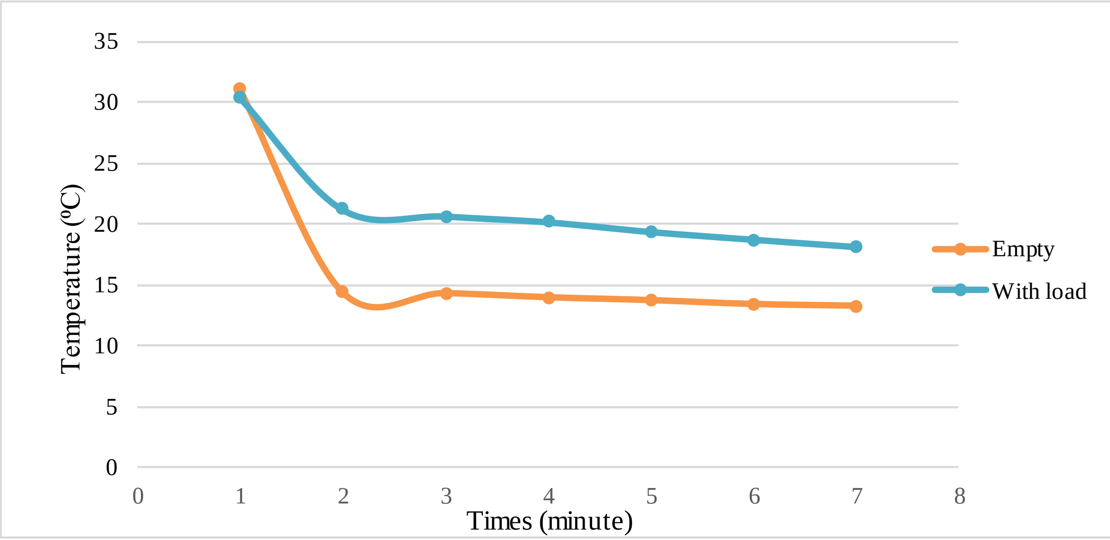

Figure 3(c): Graph of Temperature versus Time Taken for Both Experiment Data

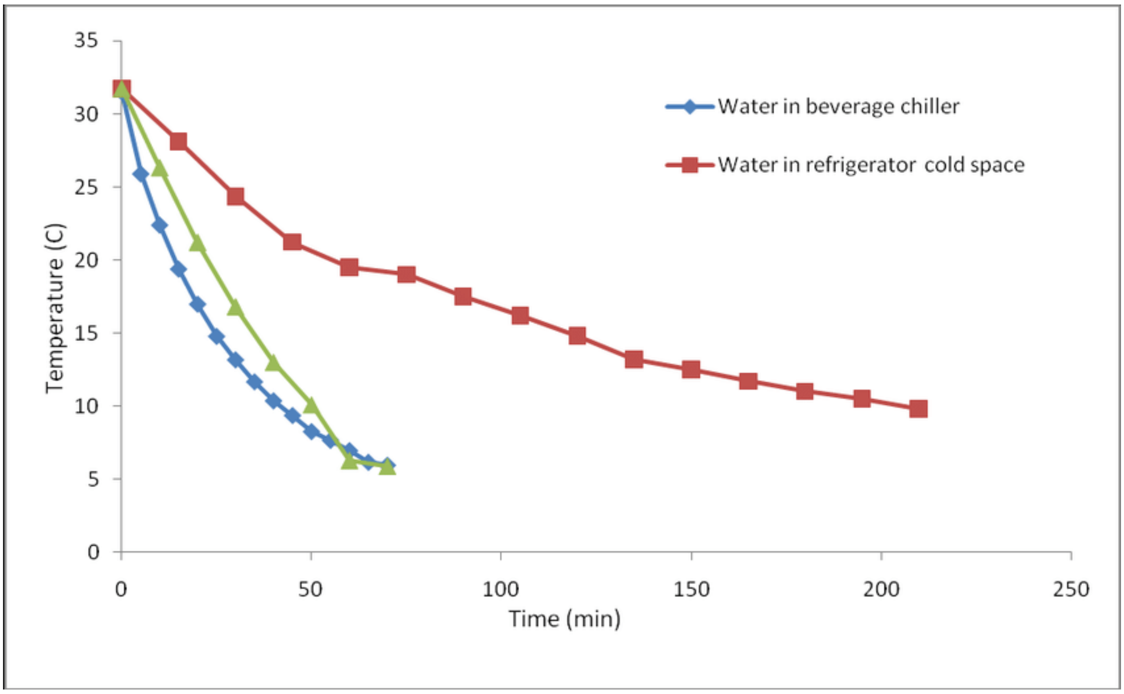

Figure 3(d): Graph of Temperature versus Time Taken for Water in a Refrigerator Cold Space. [5]

4. Conclusions

In conclusion, the designated Peltier-based thermoelectric cooling box works well and does achieve all the objectives for this project. As for the objective, the Peltier-based thermoelectric cooler was successfully designed while at once, implementing the thermoelectric studies on our designated project. Then, the cooling box functionality was tested where it functioned well based on our expected result. From this project, more about thermoelectricity especially the use of Peltier elements that supports our research and studies. Our soft skills in using CAD applications on producing a technical drawing of a design also improved. Then, experiments to find supportive findings for the project also become our main methods for this research. This research can be the perfect reference for the alternative cooling system to replace the compressor-based cooling system. Maybe in the future, the Peltier module can be developed better on efficiency and functionality where it can be used widely across the world. Even though there was a well-built product, there was always some room for improvements.

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