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PAPER

Development of Kennel Cage Cooling System Using Thermoelectric Cooler

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ABSTRACT

Animal welfare is one of society's top priorities nowadays; hence, pets have been considered part of every family's household. Pet safety and its condition are frequently monitored, and many innovative inventions are being created. A Peltier module, commonly known as a thermoelectric cooler, is widely used in cooling modules. A thermoelectric cooler is used to produce cold air to give comfort to their cages. Installing a cooling system with a control system creates cool air inside the cell with a fan. The temperature inside the cage can be manually controlled depending on the desired temperature, between 20 and 25 degrees Celsius. Using t-test analysis, the results show that the thermal reading of the developed device is accurate and the system is fully operational. However, outdoors may affect the task; the Peltier may produce less coldness and vary according to the kennel cage design and size.

KEYWORDS

Peltier Module, Thermoelectric cooler, Kennel cage

1 INTRODUCTION

Humans may stay cool and lower their body temperature by sweating when the temperature rises. However, animals such as dogs are very much unlucky. Dogs do not sweat. That is why they tend to pant to keep their body cool. Unlike humans, dogs do not sweat across their skin. Dogs cool themselves through their respiratory system. That is why dogs pant when they are hot [1]. Dogs are prone to heat exhaustion when placed in a kennel cage, especially during transportation and even in a stationary location, such as dog events away from home.

Animal welfare and pet safety are significant to society, especially to those who own one of them [2]. "Dogs are man's best friend" is a common phrase about domestic dogs, and various studies have proven the impact dogs have on human health and well-being [3]—many inventions are being created to improve the safety and comfort of their pets. Globally, plenty of devices are being made and developed due to the demand to comfort pets, and even they are being caged [4]. However, the temperature of the environment where domesticated dogs are housed can positively or negatively affect their well-being, especially in their behaviors [5]. The dog's average body temperature is not the same as that of people; it is 38.3-39.2 degrees Celsius for dogs. This means that dogs need to maintain a slightly higher temperature than us to feel comfortable. Dogs with a large, long-haired dog, such as a Husky or Samoyed, around 22 to 25 degrees Celsius may be best during the hot season, especially in tropical countries like the Philippines. If you have an elderly and short-haired pet, 25 degrees Celsius could be preferable [6].

It is usual for pets to be caged, especially for stationary places such as pet shows and dog events. Due to space limitations where the shows are held, kennels are primarily stored in proximity to areas with less than the ideal air temperature control. These environmental conditions may result in excessively high temperatures that may be hazardous to the pets. In the past decade, several apparatuses were claimed and created to promote ventilation and air-conditioning for pet cages, such as putting a cushion that includes a ventilation layer in an air-tight compartment cage [2]. Another study has claimed to use a 110 AC source to power a temperature-controlled cell, and it uses thermoelectric elements and a fan to produce calm and warm air into the cage [7]. Most recent studies use semiconductor refrigeration devices or Peltier modules to maximize their uses. In addition, a current invention in China uses this device and a fan to cool and warm a fixed Pet House [8]. At the end of the 1950s, a new DC source refrigeration technology was discovered. In recent years, semiconductor refrigeration technology, known as the thermoelectric cooler, has rapidly developed worldwide [9].

Furthermore, thermoelectric devices are solid-state devices that convert thermal energy into electrical energy [10]. While the conversion of temperature difference into electricity is due to the Seebeck effect, an inverse reciprocal effect that enables the transfer of heat when electrical energy is provided is known as the Peltier effect [11, 12]. Therefore, a thermoelectric cooling device (also known as a Peltier device) is a solid-state heat pump that transfers heat from one location to another in the presence of an electrical current [13]. The research also uses a fan-based cooling system. The Fan-based cooling systems have typically provided systems with low cost, relatively acceptable performance, and easy implementation [14, 15, 16, 17, 18]

Most cages with previously built cooling systems contribute to their cooling mechanism rather than the control system. In addition, some inventions that have a temperature-controlled cooling system are pet houses. Pet housing is neither transferable nor portable. It means the pet house is attached to a shelter in either the backyard or the indoor place. However, there is no development of a kennel cage with a control system for its temperature output inside the cell. At the same time, it can be used during transportation; hence, you could bring the device anytime if you are away from home.

The main objective of this invention is to develop a kennel cage cooling system. Specifically, improve the design by adding a temperature control system and a portable and transferable cooling system device. AC power is used to create a stable electric current.

This study aims to produce a complete control system design that enables pet owners to control the desired temperature for their pets to be comfortable inside the cage. Moreover, this invention is also an electrical and mechanical investigation into discovering possible outcomes with the different design approaches. In addition, the pet's welfare and safety are this invention's top priority.

The study concentrates on developing and improving the design of the cooling system device to be attached to a kennel cage. By installing a control system, it is easy to manipulate the desired output temperature as the veterinarian prescribes, depending on the pet breed type. The device used an AC source that provides stability in the current since the control system is based on the current; a DC source is not an efficient option. The cage in this experiment is enclosed as much as possible to retain the temperature produced by the device. Hence, the temperature may vary depending on the kennel cage used.

2 MATERIALS AND METHODS

2.1 Hardware and Power System Design

As shown in Fig. 1, the hardware design of the system uses a foam board and steel plate casing, which serves as housing for the different components of the device. The primary materials used are Arduino UNO, a board based on ATmega328P, an operating voltage of 5v, and a flash memory of 32KB. It serves as the brain of the device control system and will give instructions to the Peltier and temperature sensor. Peltier Module TEC-12076 is the device cooling system with a working current and 5 A and 12V voltage. The proponents utilized two Peltier Modules enough to provide the cooling requirement of the system. DHT22 is the device temperature sensor suitable for -40 to 80° C and has an accuracy of ±0.5°C and is used to monitor and regulate the appropriate temperature inside the cage. SC-300T DC 12V ultra-quiet Water Pump has a 150ml water tank and a flow rate of 300L/h and is used to cool the hot side of the Peltier Module. The cage used has a dimension of 60x40 cm, is ideal for small dogs, and is attached at the end of the device.

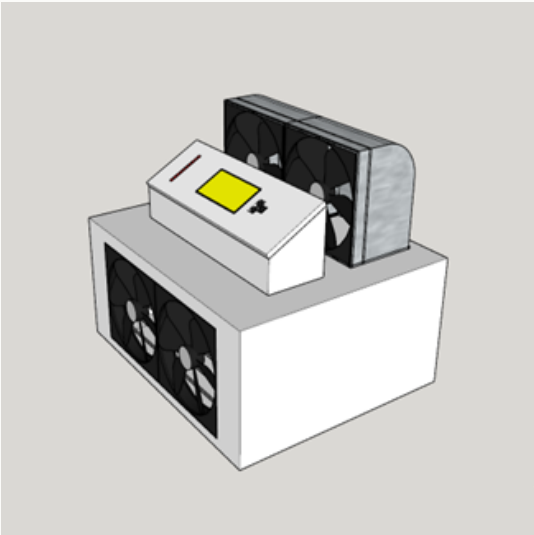

Fig. 1 Hardware Design

The application of this device is to provide a cooling system convenient for dogs. Shown in Fig. 2 is the block diagram of the system. The temperature sensor is the device's input. It sends data to the microcontroller, enabling the Peltier to run the desired temperature. At the same time, the water pump circulates the water in the radiator to cool the hot side of the Peltier Module. A heatsink and fans are attached to the cold side, dissipating the cool air throughout the cage. The proponents used an AC power source to have a stable flow of current in the Peltier module, making it efficient since Peltier cools air based on the current from the power source. Unlike the DC source, as it provides an unstable current.

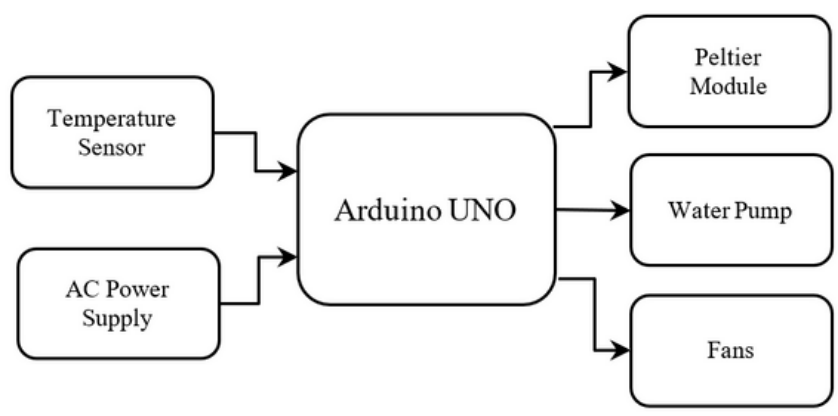

Fig. 2 Block Diagram of the System

The development of this research will also focus on how the researchers will use a thermoelectric device to produce cool air inside the kennel cage. Fig. 3 shows how a thermoelectric device works.

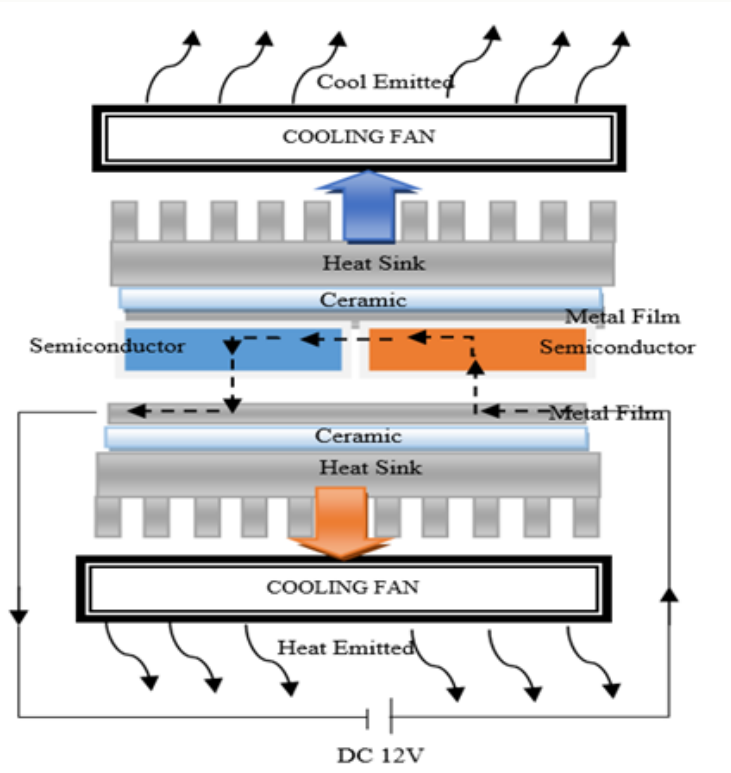

Fig. 3 Thermoelectric Device

The kennel cage cooling system's proposed design will install two thermoelectric devices. In addition, a temperature control knob will be installed outside the device. The knob will serve as the control for the switching of the thermoelectric device. The temperature will vary depending on the current input applied to it. A temperature sensor inside the cage and a display screen outside for the temperature reading will be installed.

2.2 Function Test and Testing Standards

The function test was conducted to verify whether the device met the study's objective. This section will observe the temperature output, a fail-over medium indicator if the temperature indicator is not accurate, and data analysis of the accuracy of the data gathered during the testing of the device. The proponent uses a t-test to calculate the accuracy of the device.

To confirm the functionality of the device and the overall system, the proponents follow various testing standards. The IEEE 119-1974 Recommended Practice for General Principles of Temperature Measurement as Applied to Electrical Apparatus highlights guidelines for applying temperature-measurement techniques in measuring the operating temperature and temperature rise of electrical machines, instruments, and apparatus in everyday use [19]. The IEEE 2700-2017 Standard for Sensor Performance Parameter Definitions provides a common framework for sensor performance specification terminology, units, conditions, and limits [20]. This standard presents a standard methodology for defining sensor performance parameters to ease the system integration burden and accelerate time to market (TTM).

3 RESULTS AND DISCUSSIONS

3.1 Ergonomic Design of the Kennel Cage Cooling System

The device was fabricated using economical materials readily available in the market. The design was made for it to be movable and user-friendly. The device mainly uses a thermoelectric cooler and fan as the primary material to produce cool air inside the cage.

Fig. 4 shows the actual design of the Kennel Cage Cooling System using a Thermoelectric Cooler. It was fabricated following the proponents' constraints and tested concerning various standards. The proponents were able to manufacture an economical device and reliable control system. Compared with existing studies, the proponents could use economical materials at a low cost. It includes the cooling and control system of the device. In testing the device's functionality, the proponents conducted multiple trials by setting the control system to the desired temperature. After a few minutes, the Peltier starts to cool its cold side, and the fan also starts to exert cool air inside the cage until it reaches its set temperature using the control knob attached outside the device. The proponents use an external thermal scanner to check the accuracy and real-time temperature inside the cage. When the set temperature is reached, the Peltier will stop cooling. It will start to cool once the temperature inside the cage increases.

Fig. 4 Actual Design

3.2 Data Analysis

The proponent conducted several tests by setting the desired temperature in the device. The device will produce cool air inside the kennel cage as the temperature is set. The cool air comes from the thermoelectric cooler, and a fan will bring the cool air inside the cage. A thermometer is placed inside the kennel cage to check if the temperature inside is the same as the set temperature in the setting.

Table 1 shows the summary of the data analysis results for the temperature setting and temperature readings. The significance level is 5%, most used with a degree of freedom (df) of 38. For the temperature t-test, since the absolute value of the computed t-value, t = 0.43475, is less than the tabular value, t = 1.96, we can accept the null hypothesis by rejecting the alternative hypothesis. It means that the mean temperature setting of the device is comparable to the mean temperature reading of the tester. Fig. 5 shows the equivalent graph between the set temperature and the actual Peltier reading. The test was conducted from 8:00 am to 5:30 pm with an interval of thirty minutes, totaling 20 trials. The graph shows that the highest temperature was 25.5 °C at 12:30 pm while the lowest was 20.0 °C at 5:30 pm.

Table 1. T-table for the Device Temperature Setting and the Peltier Temperature Reading

	No. of reading	Mean Temperature (°C)	t computed	t tabular	Decision
Set Temp.	20	22.75	0.43475	1.96	Comparable
Peltier Reading	20	22.535			

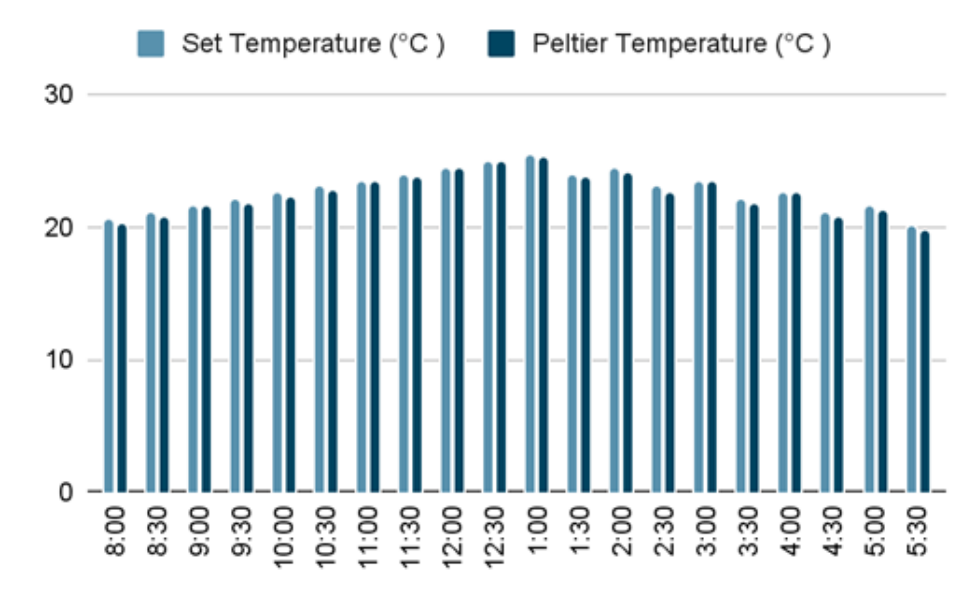

Fig. 5 Equivalent Graph for the Device Temperature Setting and Peltier Temperature Reading

The proponent uses an external temperature scanner to check if the thermometer reading inside the cage is accurate. Table 2 summarizes the data analysis results for the Peltier Device and the Scanner Temperature Readings. The level of significance use is 5%, with degrees of freedom (df) of 38. For the temperature t-test, since the absolute value of the computed t-value, t = 0.5101, is less than the tabular value, t = 1.96, we can also accept the null hypothesis by rejecting the alternative hypothesis. It also means that the mean temperature reading of the device is comparable to the mean temperature reading of an external scanner. Fig. 6 shows the equivalent graph between the Peltier temperature and scanner temperature readings. The test was conducted from 8:00 am to 5:30 pm with an interval of thirty minutes, totaling 20 trials. The graph shows that the highest temperature was 25.2 °C at 12:30 pm while the lowest temperature was 19.7 °C at 5:30 pm.

Table 2. T-table for the Peltier Device and the Scanner Temperature Reading

	No. of reading	Mean Temperature (°C)	t computed	t tabular	Decision
Peltier Reading	20	22.535	0.5101	1.96	Comparable
Scanner Reading`	20	22.795			

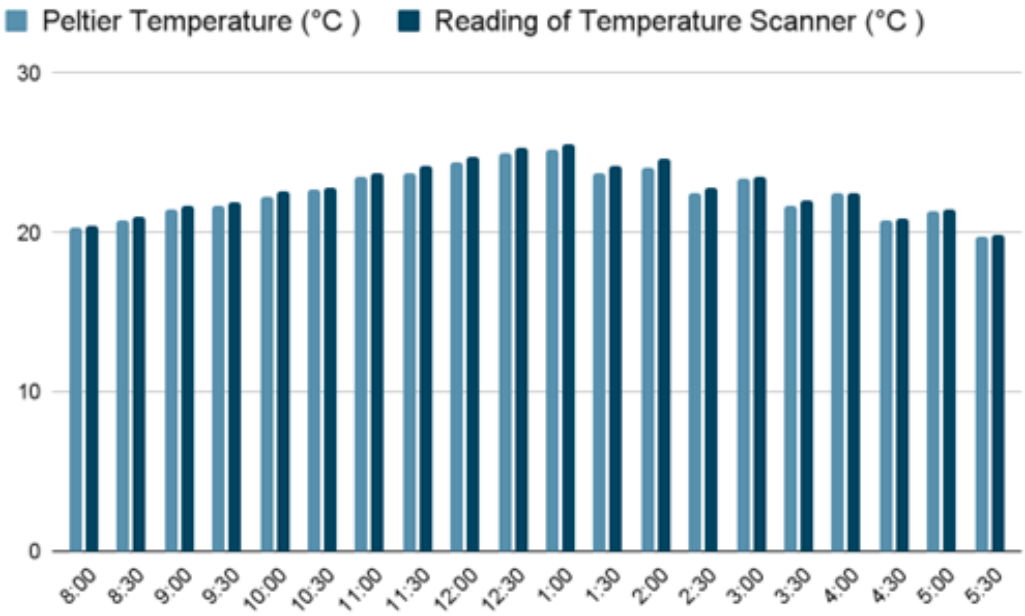

Fig. 6 Equivalent Graph for the Peltier Device and Scanner Temperature Reading

In addition to the study, the device is sufficient to produce cool air. The kennel cage should also be designed to contain the cool air the device makes to sustain the temperature inside the cage. The said results are the test conducted by the proponent by placing the temperature sensor inside the device.

4 CONCLUSIONS AND FUTURE WORKS

Pets are companions and family. That is why innovative research is a trend in this modern day and age to provide comfort and care for pets. In the old times, dogs were needed to give us a safeguarded environment; however, some wanted to give the best comfort they could share with their pets.

Most of the existing studies on thermoelectric devices are focused on energy innovation. However, it could be maximized and used efficiently. In that way, we could create something that gives comfort and relaxation. The researcher designed a cooling system for pets even if the owner and pet are away from home. Though the system has so much to improve regarding the design and structure, it still satisfies pet owners in ensuring the comfort of their pets. For future work, it is recommended to modify the structure of the kennel cage to improve the airflow. Also, it is best recommended that the pet owner control the system even if they are away from home, such as an application on mobile devices. It could be a great innovation in the future as it provides convenience not just for the pet but also for the owner. Overall, it is always essential that humans are kind to all living beings and be responsible if they are pet owners.

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