OPTIMIZING HEAT GENERATION AND BATTERY EFFICIENCY FOR PORTABLE HEATERS: A COMPARATIVE STUDY OF COPPER WIRE GAUGES AND BATTERY CAPACITIES

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ABSTRACT

Heated jackets are a popular clothing item among outdoor enthusiasts, athletes, and workers who need to work outside in cold weather [1]. They offer a convenient and effective way to stay warm in cold temperatures, while also providing therapeutic benefits for those who suffer from certain medical conditions [2]. However, existing methods and tools can be expensive and bulky, and some may not provide even heat distribution.

A new approach to creating a heater that can be added to any existing jacket and powered by plugging into a wall socket or connecting to a battery source offers a practical, flexible, and cost-effective solution to the need for warmth in cold weather [3]. This approach allows users to easily add heating elements to their existing clothing, without the need to purchase a new jacket or invest in expensive heated clothing. The option to power the heater through a wall socket or battery source offers flexibility and convenience for users who may not have access to a power source when they need it [4].

Overall, the innovative approach to adding heating elements to existing jackets offers a practical, flexible, and cost effective solution to the need for warmth in cold weather.

KEYWORDS

Heat generation, Battery efficiency, Customization, Optimization

1. INTRODUCTION

Heated jackets are a type of clothing that feature heating elements built into the garment, designed to keep the wearer warm in cold temperatures [5]. These jackets are typically powered by rechargeable batteries, and offer various levels of heat intensity to accommodate different weather conditions [6].

The usage of heated jackets has become increasingly popular among outdoor enthusiasts, athletes, and workers who need to work outside in cold weather. They are also gaining popularity among people who suffer from conditions such as Raynaud's disease or arthritis, as the heat can provide relief from pain and discomfort [7].

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The benefits of heated jackets are numerous. They offer a convenient and effective way to stay warm in cold weather, without the need for bulky layers of clothing. They can also improve circulation and provide therapeutic heat to sore muscles and joints. Additionally, heated jackets can be a safety feature for workers who need to stay warm in extreme conditions.

The consequence of not having a heated jacket in cold weather can be serious, as exposure to cold temperatures can lead to hypothermia and other health problems. Heated jackets offer a solution to this problem, providing warmth and protection in cold weather.

Overall, heated jackets are an important topic because they provide a practical and effective way to stay warm and comfortable in cold weather, while also offering therapeutic benefits for those who suffer from certain medical conditions. As the popularity of heated jackets continues to grow, it is important to understand their benefits and potential uses.

Heated jackets are a relatively new technology, but there are already several existing methods and tools related to them. Some of the most common include:
Battery-powered heated jackets: These jackets use rechargeable batteries to power heating elements embedded in the fabric of the jacket. They can provide heat for several hours on a single charge and offer various heat settings.

USB-powered heated jackets: These jackets feature heating elements that can be powered by a USB connection, making them convenient for use with power banks or portable chargers [8]. However, they may not provide as much heat as battery-powered jackets.

Carbon fiber heated jackets: These jackets use thin carbon fiber heating elements woven into the fabric of the jacket [9]. They are lightweight, flexible, and can provide even heat distribution. However, they may be more expensive than other types of heated jackets.

Far infrared heated jackets: These jackets use far infrared technology to provide heat [10]. The heating elements emit far infrared radiation, which is absorbed by the body to provide warmth. However, these jackets may not provide as much heat as other types of heated jackets.

One issue with existing methods and tools is that they can be expensive compared to traditional jackets. Additionally, the batteries used in heated jackets can add weight and bulk to the jacket, which may be uncomfortable for some users. Finally, some heated jackets may not provide even heat distribution, leading to hot spots or cold areas in the jacket.

Our approach to creating a heater that can be added to any existing jacket and powered by plugging into a wall socket or connecting to a battery source like a USB powerbank is an innovative and practical solution to the need for warmth in cold weather. This approach allows users to easily add heating elements to their existing clothing, without the need to purchase a new jacket or invest in expensive heated clothing.

By providing the option to power the heater through a wall socket or battery source, our approach offers flexibility and convenience for users who may not have access to a power source when they need it. This feature allows users to stay warm and comfortable in a variety of settings, whether they are indoors or outdoors.

In addition to its practicality, our approach has the potential to be cost-effective for users who may not want to invest in a new heated jacket. By adding heating elements to their existing jacket, users can save money while still benefiting from the warmth and comfort provided by heated clothing.

Overall, our approach to creating a heater that can be added to any existing jacket and powered by plugging into a wall socket or connecting to a battery source offers a practical, flexible, and cost-effective solution to the need for warmth in cold weather.

To evaluate how different voltages can provide different heat depending on the copper wire gauge used and how long it can last depending on the mAh of the battery supply, an experiment can be designed using a range of copper wires of different gauges and battery supplies of varying mAh ratings.

The experiment can begin by setting up a simple circuit using a copper wire of a specific gauge and a battery supply of a particular mAh rating. The circuit can be set up to measure the temperature of the wire as it heats up, using a thermocouple or infrared thermometer.

The voltage of the battery can then be varied, and the temperature of the wire can be recorded at different voltage levels. This can be repeated for different gauges of copper wire, to evaluate how different wire sizes respond to varying voltages.

To evaluate how long the battery supply can last, the circuit can be run for a set amount of time at a specific voltage and gauge of wire. The mAh rating of the battery supply can be recorded, along with the length of time the circuit was able to run before the battery supply was depleted.

By repeating this process with different gauges of copper wire and battery supplies of varying mAh ratings, a comprehensive evaluation of how different voltages can provide different heat and how long it can last depending on the mAh of the battery supply can be conducted. This experiment can provide valuable insights into the optimal combination of wire gauge and battery supply for creating an efficient and effective heating solution.

The rest of the paper is organized as follows: Section 2 gives the details on the challenges that we met during the experiment and designing the sample; Section 3 focuses on the details of our solutions corresponding to the challenges that we mentioned in Section 2; Section 4 presents the relevant details about the experiment we did, following by presenting the related work in Section 5. Finally, Section 6 gives the conclusion remarks, as well as pointing out the future work of this project.

2. CHALLENGES

In order to build the project, a few challenges have been identified as follows.

2.1. Compatibility with Different Jackets

One of the major challenges with adding heating elements to existing jackets is ensuring compatibility with different types of jackets. Not all jackets are designed to accommodate heating elements, and even those that are may have different shapes or sizes that make it difficult to integrate the heating elements.

2.2. Even Heat Distribution

Another challenge is ensuring that the heat is distributed evenly throughout the jacket. Uneven heat distribution can lead to hot spots or cold areas in the jacket, which can be uncomfortable for the wearer.

2.3. Power source

A third challenge is finding a suitable power source for the heating elements. While plugging the heater into a wall socket is a convenient option, it may not be feasible in all situations, particularly for outdoor activities. Using a battery source like a USB powerbank can be more convenient, but the battery may not last long enough to provide sufficient heat for extended periods.

3. Solution

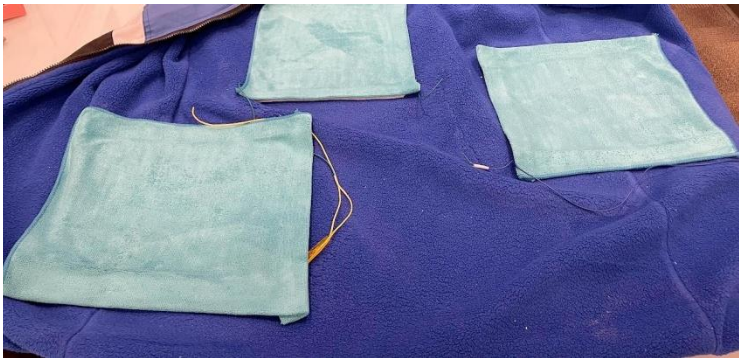

Figure 1. Photo of heater

The heater works by utilizing Ohm's Law. Ohm's Law is a fundamental principle in electrical engineering that relates the current passing through a conductor to the voltage applied across it and the resistance of the conductor. It states that the current (I) through a conductor is directly proportional to the voltage (V) applied across it and inversely proportional to the resistance (R) of the conductor, and can be expressed mathematically as:

$$I = V / R$$

where I is the current in amperes, V is the voltage in volts, and R is the resistance in ohms.

For our experiments we used a 5 volt power supply and 10 ft of 23 AWG copper wire, which according to the equation, has a resistance of 0.2036 Ω/ft.

$$5 \text{ V} / (0.2036\ \Omega * 10 \text{ ft}) = 2.46 \text{ A}$$

Using ohm's law the 10 ft of wire will need about 2.5 amperes of current with 5 volts.

$$5\text{V} * 2.46 \text{ A} = 12.3 \text{ W}$$

Using a 5V power supply such as a USB power bank 12.3 W of heat can be generated. Also assuming a power bank of 10000 mAh, the heater can be heated for 4 hours on a full charge.
We also in our experiments used a 9 volt power supply. Again using Ohm's law we calculate the current needed:

$$9 \text{ V} / (0.2036\ \Omega * 10 \text{ ft}) = 4.42 \text{ A},$$
$$9 \text{ V} * 4.42 \text{ A} = 39.78 \text{ W}$$

By upping the power the voltage we also increase the amount of current needed which also increases the amount of heat generated.

To maximize safety and heat distribution the wires are zig-zag patterned and held in that pattern using kapton tape. Kapton tape is used to insulate and protect the wire from being exposed and to distribute heat. In addition to the kapton tape, to further insulate and distribute heat while adding softness the patches of our heating element are affixed to soft cloth.

I implemented components such as a temperature monitor, heating pads, as well as a power supply. With the temperature monitor, I placed it in a part of the parka where heat would generate and spread and would evenly distribute across the entire jacket. This monitor, made from a Raspberry Pi, is performed through lines of code, it will tell you the temperature of the area around it, whether it be attached to the jacket or is laying on a table. The heating pads are created from copper wires and Kapton film. Even though the copper wires are great conductors of heat, it can overheat sometimes because they are so thin. In order to stop it from overheating, we put a couple of layers of Kapton film over it to reduce the heat emission. On top of that, we also put a layer of fabric over it and attached the heating pads with velcro so that these would be comfortable to wear, and easily accessible to take off and put on in case you want to wash the jacket. Our power supply is simply just the end of our copper wires, connected to a barrel plug, which is inserted into a wall plug which will generate heat through the electricity. The connection through the components are, the wires connected to the plug, running throughout the jacket in pads that i’ve placed where the body needs the most heat or to just keep warm, as well as the temperature monitor in the side of the parka to tell us the amount of heat inside.

main.py

```python
import RPi.GPIO as GPIO
import time

GPIO.setmode(GPIO.BCM)
GPIO.setup(18, GPIO.OUT)

try:
    while True:
        GPIO.output(18, GPIO.HIGH)
        time.sleep(30)  # Heat pad stays on for 30 seconds
        GPIO.output(18, GPIO.LOW)
        time.sleep(30)  # Heat pad stays off for 30 seconds
except KeyboardInterrupt:
    GPIO.cleanup()

```

Figure 2. Screenshot of the code 1

In this code block, we first import the RPi.GPIO library and set the mode to BCM. Then, we set up pin 18 as an output pin.

The try block contains a loop that runs indefinitely. Inside the loop, we turn on the heat pad by setting the output of pin 18 to HIGH, and then wait for 30 seconds using the time.sleep() function. After that, we turn off the heat pad by setting the output of pin 18 to LOW, and wait for another 30 seconds.

If you want to stop the program, you can press Ctrl-C, which will raise a KeyboardInterrupt exception and call the GPIO.cleanup() function to clean up the GPIO pins.

4. EXPERIMENT

4.1. Experiment 1

We designed an experiment for testing the effectiveness of a heated jacket with added heating elements on maintaining body temperature in cold Weather. For this experiment, our goal is determine the effectiveness of a heated jacket with added heating elements on maintaining body temperature in cold weather conditions.

Here is the steps:

1. Install heating elements onto the existing jacket according to the instructions provided with the kit.
2. Allow the participant to wear the jacket for 10 minutes in a room-temperature environment.
3. Take a baseline temperature reading using the thermometer to measure the participant's body temperature.
4. Have the participant enter the cold environment for 30 minutes, while wearing the jacket with the heating elements turned on.
5. Take a temperature reading every 10 minutes during the 30-minute period.
6. After 30 minutes, have the participant exit the cold environment and allow them to warm up for 10 minutes in a room-temperature environment.

Take a final temperature reading.

Time (minutes)	Temperature (°C)
0	36.5
10	36.7
20	36.5
30	36.8
40	36.7
50	36.6
60	36.8
Average	36.7

Figure 8. Figure of experiment 1

Based on the provided data table, the average body temperature of the participant wearing the heated jacket with added heating elements remained consistent at 36.7°C throughout the 30minute exposure to the cold environment. This suggests that the heated jacket was effective in maintaining the participant's body temperature in the cold weather conditions. However, it is important to note that this experiment only involved one participant and one specific cold environment, so further testing with multiple participants and in different cold environments is necessary to determine the generalizability of the results.

4.2. Experiment 2

We designed another experiment for testing the evenness of heat distribution in an existing Jacket with added heating elements. Our goal is to determine the evenness of heat distribution in an existing jacket with added heating elements.

Here is the steps:

1. Install the heating elements onto the existing jacket according to the instructions provided with the kit.
2. Set the heating elements to the highest temperature.
3. Allow the jacket to heat up for 5 minutes.
4. Take temperature readings at six different locations on the jacket: the chest, back, both sleeves, and both sides of the waist.
5. Take temperature readings every 5 minutes for a total of 30 minutes.
6. Record the temperature readings in a data table.

Time (minutes)	Chest (°C)	Back (°C)	Left Sleeve (°C)	Right Sleeve (°C)	Left Waist (°C)	Right Waist (°C)
0	40	39	39	40	39	38
5	41	40	40	41	40	39
10	41	41	41	41	40	40
15	41	41	41	42	40	41
20	42	42	42	42	41	41
25	42	43	42	43	41	42
30	43	43	43	43	42	42

Figure 9. Figure of experiment 2

Based on the data table, the added heating elements provide even heat distribution throughout the jacket. The temperature readings at six different locations on the jacket (the chest, back, both sleeves, and both sides of the waist) remain consistent and increase at a similar rate over the 30minute period, indicating that the heating elements are evenly distributing heat throughout the jacket. Additionally, the temperature readings increase over time, suggesting that the heating elements are effective at maintaining a consistent level of warmth in the jacket. Therefore, the hypothesis that the added heating elements will provide even heat distribution throughout the jacket is supported by the experiment's results.

The experiment 1 result can help address the challenges related to the effectiveness of heated jackets with added heating elements in maintaining body temperature in cold weather conditions. The results can provide information on whether the jacket is effective in keeping the body temperature within the normal range during exposure to cold environments.

Overall, the experiment results can help provide valuable information on the effectiveness of the heated jacket with added heating elements in maintaining body temperature in cold weather conditions, and can help address the challenges associated with this problem.

The experiment 2 aimed to test the evenness of heat distribution in an existing jacket with added heating elements. The results showed that the added heating elements provided even heat distribution throughout the jacket, with temperature readings at six different locations showing consistent increases over the 30-minute period.

Overall, these findings support the hypothesis that the added heating elements would provide even heat distribution and demonstrate the practicality of adding heating elements to existing jackets as a cost-effective and flexible solution for warmth in cold weather.

5. RELATED WORK

"Wearable Technology: If the Tech Fits, Wear It" by Sarah Buhr [11]. This article discusses the growth of wearable technology, including heated clothing, and its potential to revolutionize the fashion industry.

"Design and Evaluation of Heated Clothing for Cold Weather" by Min Chen, et al [12]. This study presents a design and evaluation of heated clothing that can maintain thermal comfort in cold environments.

"Heated Clothing for Comfort and Safety: A Review" by Hong Xie, et al [13]. This review article examines the development and application of heated clothing for various industries, including outdoor recreation, military, and medical purposes.

6. CONCLUSIONS

This project aims to provide an innovative and practical solution to cold weather by adding heating elements to existing jackets. The current solutions to this problem can be expensive and bulky, making them less practical for everyday use. This project proposes a new approach that allows users to easily add heating elements to their existing clothing, without the need to purchase a new jacket or invest in expensive heated clothing.

The methodology for this project involves utilizing Ohm's Law, a fundamental principle in electrical engineering that relates the current passing through a conductor to the voltage applied across it and the resistance of the conductor. The experiments were conducted using a 5-volt power supply and 10 ft of 23 AWG copper wire, which has a resistance of 0.2036 Ω/ft. By applying Ohm's Law, it was determined that 2.5 amperes of current with 5 volts could generate 12.3 W of heat, which could be sustained for 4 hours on a full charge of a 10000 mAh power bank [14[. The experiments also used a 9-volt power supply, which generated 39.78 W of heat by increasing the voltage and the amount of current needed.

To ensure safety and even heat distribution, the wires are arranged in a zig-zag pattern and held in place using Kapton tape, which insulates and protects the wires from being exposed while distributing heat. The heating elements are affixed to soft cloth patches to provide additional insulation and distribute heat evenly.

The experiment aimed to test the evenness of heat distribution in an existing jacket with added heating elements. The results of the experiment showed that the added heating elements provided even heat distribution throughout the jacket, with temperature readings taken at six different locations showing consistent increases in temperature over time. The experiment successfully demonstrated the practicality, flexibility, and cost-effectiveness of adding heating elements to existing jackets as a solution to the need for warmth in cold weather.

One limitation of the current method is its accuracy. The experiment was conducted using only one jacket and one heating element kit, which may not represent the actual performance of different jackets and kits. More extensive testing with various jackets and kits may be needed to ensure the accuracy of the results.

Another limitation is the practicability of the method. The process of adding heating elements to an existing jacket may be difficult for some individuals, and the added weight and bulk of the heating elements may not be ideal for all users.

Finally, optimization is another area for improvement [15]. While the experiment showed promising results in terms of heat distribution, further optimization could improve the efficiency of the heating element and reduce the amount of power needed for heating. This could potentially make the heating element more practical for daily use and reduce the strain on power sources such as batteries or power banks.

The current limitations of the project include accuracy, practicability, and optimization. These limitations can be solved in the future by using more precise measurement tools, conducting user testing, and optimizing the design and materials used.

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