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Design and Development of a Portable Beverage Cooling System Using a Heatsink and Wind Tunnel Fan Based on the Peltier Effect

Muhammad Adinda Hadinur[1], Komarudin[2]
[1]Universitas Dian Nusantara, Jakarta, Indonesia, hadi.mohmd90@gmail.com
[2]Universitas Dian Nusantara, Jakarta, Indonesia

Corresponding Author: hadi.mohmd90@gmail.com[1]

Abstract: Development system cooler portable become important along increasing need cooling practical without use refrigerant and compressor . System cooler based The Peltier effect offers solution friendly environment and size compact , but performance is greatly influenced by ability disposal hot on the side hot module . Research This aim design and build system cooler drink portable based Peltier module with optimization mechanics using a heatsink and wind tunnel fan. Research methods covering design mechanics , manufacturing prototype , as well as testing performance thermal through measurement temperature side hot , side cold , temperature drinks and consumption Power electricity . The test results show that the system is able to achieve a minimum cold side temperature of 12 °C, a cooling chamber temperature of 16 °C, and reduce the beverage temperature by up to 5 °C within a 30-minute test duration. The use of *a heatsink* combined with *a wind tunnel fan* has been shown to increase the effectiveness of heat dissipation, thereby maintaining the stability of the Peltier module's performance. This system has the potential to be developed as an alternative small-scale portable cooler with low power consumption.

Keywords: system cooler portable , Peltier effect , heatsink , wind tunnel fan , displacement hot

INTRODUCTION

The demand for practical, compact, and environmentally friendly portable cooling systems continues to increase along with higher outdoor mobility. Conventional vapor compression cooling systems offer high thermal performance; however, their large size, heavy weight, and high power consumption make them unsuitable for portable applications. Therefore, this study aims to design and develop a portable beverage cooling system based on the Peltier effect, with a focus on optimizing heat dissipation using a combination of a heatsink and a wind tunnel fan. The research methodology includes mechanical design, prototype fabrication, and thermal performance testing through measurements of hot-side temperature, cold-side temperature, cooling chamber temperature, beverage temperature, and electrical power consumption. Experimental results show that the system achieves a minimum cold-side temperature of approximately 12 °C, a cooling chamber temperature in the range of 16–18 °C, and a beverage temperature reduction of up to ±9 °C within 30 minutes of operation. The integration of a heatsink with a wind tunnel fan significantly enhances heat rejection on the hot side of the Peltier module, allowing stable cooling performance to be maintained. This system demonstrates potential for further development as a small-scale portable beverage cooler with relatively low power consumption.

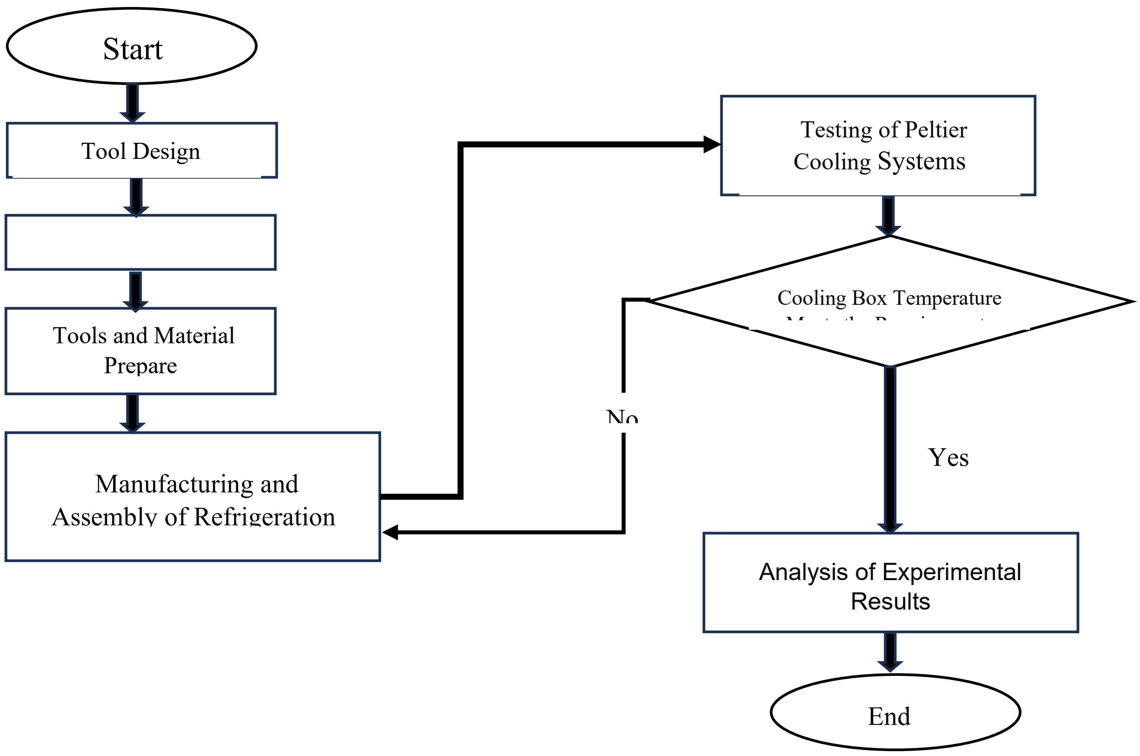
However , the weakness main The Peltier system is based on the accumulation of hot on the side hot module that causes decline performance cooling (Rowe, 2018). Because that , the system disposal effective heat become factor key success cooling . Heatsink and *wind tunnel fan* can utilized For increase rate displacement hot convective through optimization wide surface and distribution flow air (Bhowmik & Dutta, 2022).

This research aims to design, realize, and analyze the performance of a portable beverage cooling system based on the Peltier effect with an emphasis on the mechanical design aspects of the heatsink and wind tunnel fan. The main focus of the research is directed at increasing the effectiveness of heat dissipation on the hot side of the Peltier module so that the temperature difference between the sides can be maintained optimally during the cooling process. In addition, this research also evaluates the characteristics of the beverage temperature drop, the temperature stability of the cooling chamber, and the overall power consumption of the system.

METHOD

Work Flowchart

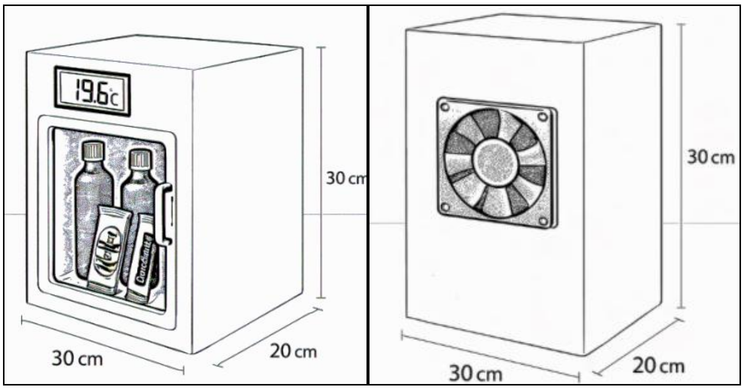
The research method used was an experimental one, beginning with the design of a cooling system, prototype construction, and thermal performance testing. This study is complemented by a flowchart as a systematic guideline for conducting the research from the initial process to the final stage, as shown in the following diagram.



Picture 2. Research workflow flowchart

Tool Design

Tool design aim describe configuration physical , placement component main , and dimensions from system cooler drink portable designed , namely with size length 30 cm, width 20 cm, and height 30 cm. Device This consists of on One internal fan , one fan external , and one Peltier element . Third component the mounted on the part behind room cooler , while system supply Power placed on the side outside rear of the cooler box . The size and placement of the components are depicted through a 2D model, as shown in Figure 3.



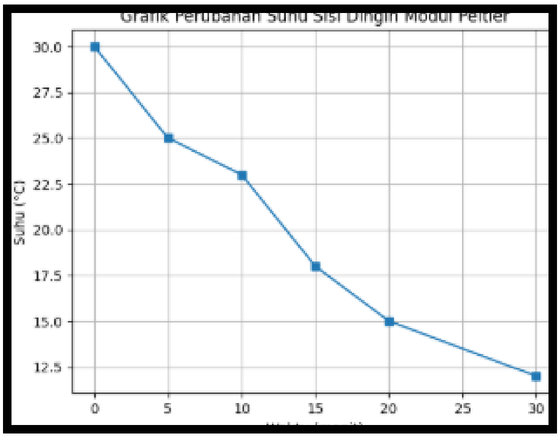
Picture 3. Mechanical design of the portable beverage cooling system

RESULTS AND DISCUSSION

Based on the research method used, the planned design was then realized into a real product as follows.

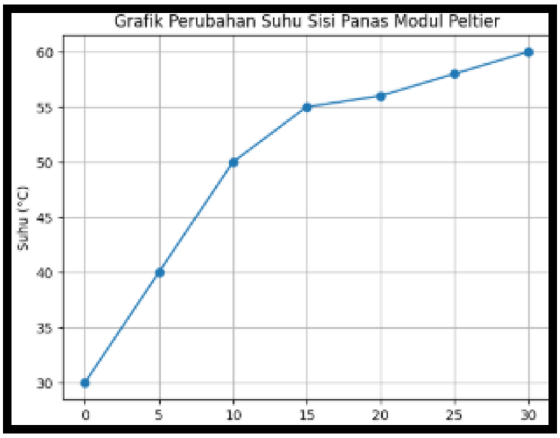
Picture 4. Front, side, and rear views of the fabricated portable cooling system

Figure 4 shows the component layout tailored to the system's function. The *cooler box* is lined with aluminum sheeting as an insulating layer to maintain the desired low temperature. Testing and measurement results using a K-type digital *thermocouple* are displayed graphically in Figure 11, which shows the temperature of the portable cooler.



Picture 5. Cooling chamber temperature versus time

Based on picture 5, the test results show that in the 10th minute the temperature of the cooling chamber reached 23°C, while the ambient temperature was 29°C. In the 20th minute, the temperature of the cooling chamber decreased to 20°C. The test was continued gradually for 30 minutes and resulted in a cooling chamber temperature of 12.5°C, while the ambient temperature remained at 29°C. In addition to observations on the cold side, temperature measurements were also carried out on the hot side of the thermoelectric (Peltier) module. The test results data are presented in the form of graphs 2 of the Peltier hot side temperature against operating time.

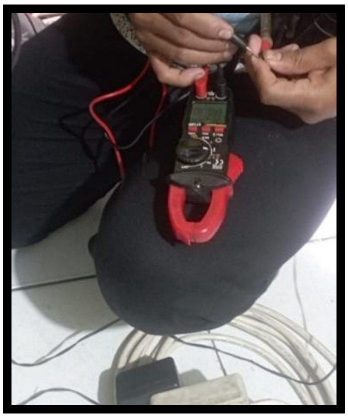


Picture 6. Hot-side temperature of the Peltier module versus time

Based on the picture 6, the temperature of the Peltier's hot side increases with operating time. At the beginning of the test, the increase was still small, around 10° C in 5 minutes, but as the work progressed, the heat buildup in *the heatsink* caused the temperature to continue to increase, until in the 30th minute, the temperature reached 60° C. This shows that the performance of heat dissipation through the fan and *heatsink fins* greatly affects the cooling effectiveness of the Peltier module.

Voltage Current and Power Results

The process of testing the current voltage and power is carried out with the help of a multitester which can be seen in Figure 5, with the voltage source from *the power supply* maintaining a constant input value at 12 V.



Picture 7. Voltage and current measurement using a multimeter

The beverage cooling system operated at a constant voltage of 12 V with an average current of 5.8 A during the test. A stable voltage indicates that *the power supply* is capable of providing a consistent power supply without significant drops. Then, for the calculation Power electricity done using the equation :

$$P = V \times IP = 12\,V \times 5{,}8\,A = 69{,}6\,W$$

From the results calculation obtained Power around 69–70 W. This value Still is at within safe and stable working limits , as well in accordance with specification Peltier module TEC1-12706 which has Power maximum about 72 W.

Transmission Cooling Load Analysis

Calculation burden cooler transmission done For know big incoming heat to in room cooler consequence displacement hot from environment through wall portable refrigerator . Cooling load transmission calculated using the equation :

$$Q = U \cdot A \cdot CLTD_{corr}$$

1) Wall Material Data
PVC thickness L_{pvc}= 3 mm = 0.003 m
Styrofoam thickness, L_{sty}= 20 mm = 0.02 m
Conductivity of PVC, k_{pvc}= 0.19 W/ m·K
Conductivity of Styrofoam, k_{sty}= 0.033 W/ m·K
2) Coefficient Data Convection
Coefficient convection in , h_i= 15 W/m²K
Coefficient convection outside , h_o= 25 W/m²K
3) Box Dimensions
Length = 0.3 m
Width = 0.2 m
Height = 0.3 m
4) Temperature Data
Temperature outside = 30 °C
Temperature in = 12 °C

Prisoner Total Thermal :

$$R_{total} = \frac{1}{h_i} + \frac{L_{pvc}}{k_{pvc}} + \frac{L_{sty}}{k_{sty}} + \frac{1}{h_o} R_{total} = \frac{1}{15} + \frac{0{,}003}{0{,}19} + \frac{0{,}02}{0{,}033} + \frac{1}{25} R_{total}$$
$$= 0{,}0667 + 0{,}0158 + 0{,}606 + 0{,}04 R_{total} = 0{,}7285\ m^2K/W$$

Coefficient Total Heat Transfer

$$U = \frac{1}{R_{total}} = \frac{1}{0,7285} U = 1,373\ W/m^2K$$

Box Surface Area

$$A = 2(pl + pt + lt)A = 2((0,3 \times 0,2) + (0,3 \times 0,3) + (0,2 \times 0,3))A$$
$$= 2(0,06 + 0,09 + 0,06)A = 0,42\ m^2$$

CLTDcorr

$$CLTD_{corr} = T_{luar} - T_{dalam} CLTD_{corr} = 30 - 12 = 18^{\circ}C$$

Cooling Load Transmission

$$Q = U \cdot A \cdot CLTD_{corr} Q = 1,373 \times 0,42 \times 18 Q = 10,38\ W$$

CONCLUSION

System cooler drink portable based Peltier module TEC1-12706 successful designed and realized with construction simple , light and easy moved . Use of PVC, aluminum plate and styrofoam capable support the cooling process as well as guard stability tool . Combination *heatsink* and *wind tunnel fan* effective throw away hot side Peltier heat so that system Work stable without *overheating* . Test results show temperature room *cooler* can lowered until around 18 °C, with temperature drink experience decrease of ±9 °C in 30 minutes . Consumption Power is in the range of 69–70 W at 12 V and still in accordance TEC1-12706 specifications . In overall , tool capable Work in accordance objective as cooler portable and friendly environment and decent For application scale small.

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