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Experimental Investigation of Portable Refrigerator through Thermo Electric System

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ABSTRACT: An experimental performance analysis of thermoelectric refrigerator in this study is presented. The cooling system of refrigerator is consists of one thermoelectric module. The experiments carried out for deferent system different refrigerant load. The results show that the cooler temperature of system is about 15°C for 10L flow rate for 60minutes. COP value of thermoelectric refrigerator is 0.23 in the flow rate 10 L/hr while COP is 0.24 in the flow rate 10 L/hr at the end of 60 min cooling times. This study concludes that the performance of thermo electrical module used in this study has as well as water cooled systems used to absorb heat from thermoelectric modules hot side.

I.INTRODUCTION

Refrigeration is an important process for many applications, ranging from fresh keeping the perishable food products to the wide variety of the temperature controllers used in electronics and other industrial fields. In conventional domestic refrigerators are used the vapor-compression technology. The refrigerators based on vapor compression have a high coefficient of performance (COP) but the refrigerants used in such systems have detrimental effects on the global environmental. Thermoelectric refrigeration based on the Peltier effect has important advantages compared to conventional vapor technology in spite of the fact that its COP is not as high a vapor compression technology. Some of these can be listed: free of refrigerant, the using of electrons as refrigerant, more compact system state, lower noise and vibrations, high quality temperature control and less maintenance requirements. In addition, they possess advantage it can be powered by direct current (DC) electric sources as photovoltaic cells.

Nowadays, the application areas of thermoelectric cooling include thermoelectric refrigeration, electronic and automobile cooling, thermoelectric air-conditioning, photovoltaic-thermoelectric hybrid system, active building envelope system and fresh water production etc. . In the design of thermoelectric cooling systems, the cooling power and COP are two important performance indicators, and the COP of overall system effects significantly from the COP of the thermoelectric module used in the applications. There are several methods foremost the enhancements of thermoelectric cooling system performance. It can be classified as thermoelectric module design (thermoelement length, number of thermocouples etc.), thermal design (heat sink geometry, allocation of heat transfer area, and more effective heat sinks etc.) and the refining of operational conditions of thermoelectric cooling system (heat sink coolant, mass flow rate of coolant etc.). In the past years, various articles and reports have been presented on evaluating the performance of thermoelectric refrigerators. Min and Row conducted experimental evaluation of prototype thermoelectric refrigerators and evaluated their cooling performances by considering COP values, cooling down rates. The COP was found around 0.3–0.5 for typical operating temperature at 5 °C with ambient at 25 °C. Results also show that its COP is possibly after enhancements in module contact resistances, thermal interfaces and effectiveness of heat exchangers. Astrain et al., developed a computational model for thermoelectric refrigerator based on Peltiers eff ect and its application to a refrigerator with an inner volume of 0.055 m3 analyzed. They found that the accuracy of the model was acceptable and a maximum error for COP was ± 7% and maximum discrepancy for thermal drop 1.2 K. Dai et al. conducted an experimental study for thermoelectric refrigerator driven by photovoltaic module with battery storage. Their results revealed that the refrigerator can maintain the temperature at 5–10 °C, and have a COP about 0.3. Abdul-Wahab et al.designed a portable solar thermoelectric refrigerator for using rural areas. This refrigerator was experimentally tested for various operating parameters. They reported that the inner temperature of the refrigeration area was reduced form 27–5 °C in approximately 44 min. In their study, COP was calculated as about 0.16. Vián and Astrain developed a thermoelectric refrigerator whose cooling system consisted of two thermoelectric modules and two-phase thermosiphons and capillary lift with a single compartment of 0.225 m3 for food preservation at 5 °C. Their results indicated that by using two phase- devices into the refrigerator was increased the COP by 66% compared with finned heat dissipater. Jugsujinda et. al. analyzed performance of thermoelectric refrigerator with an inner volume of 0.022 m3 by considering time, current, temperature and COP. Results indicated that the cold side temperature of

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cooling unit in refrigerator was decreased from 30 °C to −4.2 °C for 1 h and the COP of refrigerator was calculated as 0.65. An experimental and simulation studies on development of a hybrid refrigerator with three compartments (refrigerator at 5 °C, super-conservation at 0 °C, and freezer at −20 °C) that combined thermoelectric and vapor compression technologies were performed by Vián and Astrain . Thermoelectric system was used for the super-conservation compartment. They concluded that the temperature of super-conservation compartment was kept constant at 0 °C, even if the ambient temperature rises to 30 °C. Martínez et al. investigated experimentally the effect of the described temperature control systems on both the electrical energy consumption and COP of a thermoelectric refrigerator. Their result proved that the controlling with idling voltage reduced the electricity consumption of the refrigerator by 32% and increased the COP by 64%. Ohara et al. designed a portable thermoelectric vaccine refrigeration system of 0.083 L inner volume for using developing communities. For the designed system, their results show that the chamber of refrigerator was reached a minimum temperature of 3.4 °C at an ambient temperature of 21 °C after 70 min of operation. As mentioned above, the numerous papers presented on design of thermoelectric refrigerators by considering different aspects. Thermoelectric modules used in thermoelectric refrigeration devices are contacted with cold and hot side heat received systems. Thus, design or selection of a heat sink for each side of thermoelectric module is crucial to the overall operation of a thermoelectric system . Various heat transfer techniques, including air-cooled and liquid-cooled heat sinks and systems involving heat pipe, two phase thermosiphons and phase change materials have been used in the thermoelectric cooling systems. On the other hand, mini-channel heat sinks can be used in a wide variety of applications, including previous passive cooling applications. Integration of the high efficient heat sinks such as mini-channel heat sinks to the heat side of the thermoelectric modules could be an alternative for enhancing the performance of the cooling system.

II.DESCRIPTION OF THE EXPERIMENTAL SYSTEM

The experimental setup used in the present study is schematically presented in Fig. 1. The main components of the setup are a refrigerator, thermoelectric modules, and the cold side heat dissipater for thermoelectric module, coolant storage tank, pump, power supply, and coolant circulating pump.

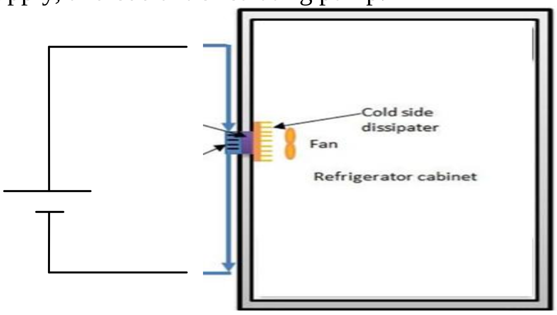

Fig.1: Schematic layout of Experimentation

The heat dissipater in the cold side of thermoelectric module is made of aluminium alloy. The dimension of heat dissipater used in the cold side of thermoelectric modules was 40 mm×40 mm×5 mm with 7fins.

High thermal conductance paste was used to reduce the contact thermal resistance in each surface of thermoelectric module. The type number of the thermoelectric module used in the present study is TEC1-12706.

For heat transfer between the cold side heat dissipater and its surroundings inside refrigerator cabinet was used a brushless fan (3 W). The measured parameters in the experiment are voltage of thermoelectric refrigerator, temperature of the cold side heat dissipater, ambient temperature, and inner volume temperature.

The temperatures in the experimental setup were measured by K type thermocouples with an uncertainty of ± 0.5°C. A data acquisition system, Infrared Temp Data Acquisition device from Measurement Computing Inc., is used to collect the related signals periodically. The cooling water in system is circulated using a brushless DC pump (12 V-2.5 A). The flow rate of water was controlled by the input voltage of pump and it was measured using a simple “catch and time” method. Water exiting in the system was passed through a fan-cooled radiator (12 V-3 A) in order to dump the heat gained in the heat sink and maintain a constant temperature reservoir. A DC power supply was used to provide the required power for system.

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III.METHODOLOGY OF THE EXPERIMENTAL ANALYSIS

The main goal of the water cooled-thermoelectric refrigerator study was to investigate cooling performance. Inner temperatures and COP (coeffcient-of-performance) for refrigerator are adopted as two performance indices. For evaluating of the cooling performance of refrigerator, effects of flow rate of water used to absorb the heat taken place on thermoelectric module hot side are investigated. The coeffcient of performance (COP) is the ratio between the refrigeration load and electrical power consumption. The COP calculation of the refrigerator was based on the following expression.

$$COP=\frac{Q_T}{W_e}$$

where $Q_{\dot{T}}$(the refrigeration load) is the total rate of heat gain of a refrigerated space, and in this study it was based on the following expression.

$$Q_T=Q_C+Q_P+W_{fan}$$

where $\dot{Q}_c$ is the heat flow entering the cabinet of refrigerator, $Q_{\dot{p}}$ is product load, which is the heat removed from the products in the cabinet of refrigerator , Ẇfan is the heat generated by the fan in the thermoelectric module cold side . The heat generation of the fan , Ẇfan, was calculated using its rated electrical power consumption. The power consumed by experimental system (thermoelectric modules and auxiliary equipment such as pumps, fans) can be calculated as below:

$$W_e=V\times I$$

The heat flow entering the cabinet of refrigerator can be calculated as

$$Q=AUdT$$

Where dT is the variation of water temperature in cooler and A is the area of cooler

For the calculation of convective heat transfer coefficient, the correlation given by Parmelee and Huebscher for flat plate is used. This correlation is given as below

$$N_u=0.664Pr^{\frac{1}{3}}Re^{\frac{1}{2}}$$

The product load in the refrigerator cabinet can be calculated below:

$$Q = mCp(T_i - T_f)/\Delta t$$

Where m is the mass of the food product, Cp is the specific heat of the product, T_i and T_f are initial and final temperatures of product, respectively, Δt is time interval needed to cool a product from Ti to T_f. In this study, 10000 mL water was put into refrigerator as product material.

IV.RESULTS AND DISCUSSION

The present study was designed to evaluate the performance of thermoelectric refrigerator. In study, cooler temperatures and coefficient of performance (COP) for thermoelectric refrigerator are selected as two performance indices. Each condition of the experimental study was performed at the lab room temperature of 25–35 °C in the period time of 60 min for the steady state condition. The voltage value for module is maintained at a constant level whose value is 12.0 V.

Figure2 shows variation of cooler temperature with respect to time, within one hour cooler reaches the 15.2°C. The inner temperature of cooler was decreased rate of 0.48 °C/min in the time interval 0–25 min. A variation of refrigerator temperatures with respect to 10 L/hr flow rate for thermoelectric module hot side is shown in Figure2 As can be seen this figure. At the end of 60 min, the inner temperature of the cooler reaches about 15 °C. In this case, decrease rate of inner temperature is 0.64 °C/min.

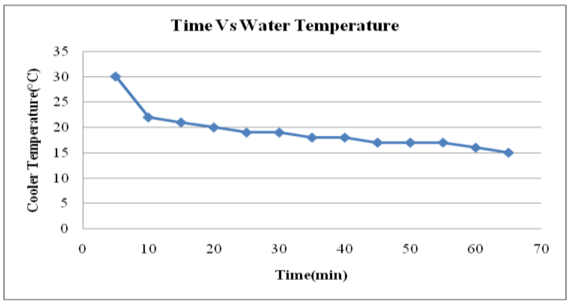

Fig.2: Variation of water cooler temperature with respect to time

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Figure3 shows variation of peltier surface temperature with respect to time, within one hour peltier module temperature reaches the 20°C. The inner temperature surface was decreased rate of 0.48 °C/min in the time interval 0–60 min.

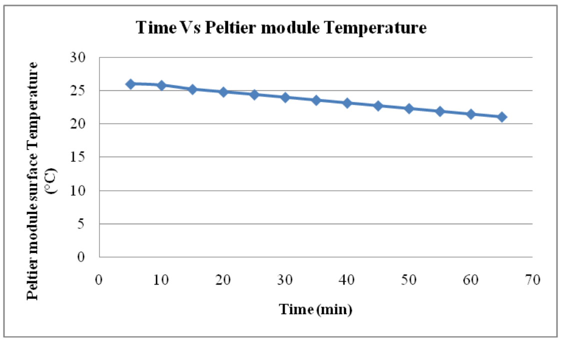

Fig.3: Variation of peltier surface temperature with respect to time

Figure4 shows variation of peltier surface temperature with respect to COP, when cooler temperature reaches to 15°C the system COP is achieved 0.001,the over all COP of system is 0.23

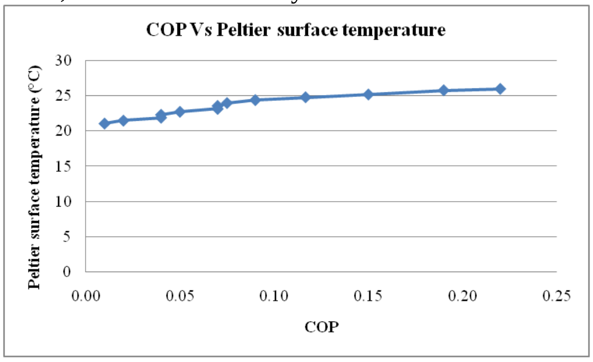

Fig.4: Variation of peltier surface temperature with respect to COP

V.CONCLUSION

- In this study, the eff ect of heat sink on the thermal performance of thermoelectric refrigerator was experimentally investigated.
- The fins was used to absorb heat from the hot side of thermoelectric module
- It given good cooling rate with low power consumption.
- It given COP 0.23 for 10literes of water flow rate

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