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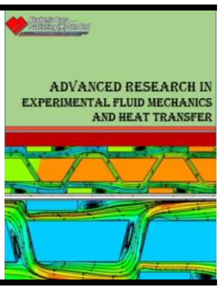

Study on The Application of Thermoelectric Coolers Inside Unmanned Surface Vehicles

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ABSTRACT

The development of unmanned surface vehicles for military and commercial needs is increasing as the development of autonomous control systems. The farther the operation range of unmanned surface vehicles makes the propulsion motor generated heat and decreased the performance of the vehicle. The aim of this study is to analyse the application of a thermoelectric cooler to control the room temperature of unmanned surface vehicles to keep stable. The research was carried out by prototyping the thermoelectric cooler 12V and tested at unmanned surface vehicles 1.5 meters. The results showed the thermoelectric cooler effective to reduce the room temperature of the unmanned surface vehicles up to 19.5 C. The results of this study contributed to the development of reliable unmanned surface vehicles.

Keywords:
Unmanned surface vehicle;
thermoelectric cooler; cooling system

1. Introduction

The world demand for unmanned surface vehicles (USV) is expected to see the fastest development in the defense and industrial sector. USV can be described as an unmanned vehicle, performing tasks without human interference in a variety of messy environments, and basically showing a very nonlinear dynamic [1]. It is expected that further development of USV would deliver extraordinary benefits such as lower production and operating costs, wider operational range (reliability) and accuracy, greater autonomy and enhanced versatility in a sophisticated environment [2-3]. USV may be built in cost-effective ways for a range of possible applications, such as scientific research [4], environmental missions [5], military use [6] and transportation uses [7]. The future success of USVs depends on the advancement of complete autonomy, efficient communication systems and adequate performance in hull design [8]. Among the several USV studies most researchers focus solely on the autonomous vehicle, work on the hull 's performance seems to be lacking.

The performance of a ship's hull is influenced by many factors such as the shape of the hull itself [9], and efficient propulsion system [10] as well as additional technologies such as hydrofoil [11-12] or air bubble lubricant [13]. In terms of the propulsion system on USV, overall, the development of

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this vehicle agreed to use motor propulsion that uses battery power. The electric marine propulsion system provides many advantages, namely not providing a mechanical drive system, giving operators direct control with an appropriate increase in maneuver response and freedom of installation arrangement that is not possible in a mechanical system that requires an in-line layout between the prime mover and the propeller [14-15]. However, the use of an electric propulsion system with a driving motor will generate heat during operation [16]. The increase in temperature due to the rotation of the brushless direct current motor can reach 60 degrees Celsius [17]. To prevent overheating, a cooling system can be made in the propulsion motor, there are two types of cooling systems namely the air or liquid systems [18].

As heat demand increases in electronic uses, the cooling technique has a significant effect on increasing its performance. Thermoelectric cooling techniques are one of a variety of cooling techniques that have been developed continuously to accomplish different applications. Research which considers the effects for electronic devices of heating heat loads and input currents on thermoelectric air conditioning modules [19]. Other research studies new thermoelectric self-cooling concepts which can be introduced as cooling and temperature control devices using thermoelectric technology without the consumption of electricity [20]. The application of nanofluids as a working fluid in a hot pipe liquid block combined with thermoelectric cooling [21]. Investigation of a thermoelectric generator model combined with a drain and a cooler for exhaust gas based cooling systems [22]. Many experimental and numerical studies have investigated fluid flow and heat transfer in cooling mini-rectangular fins for cooling the Central processing unit [23-25]. Of the many applications of thermoelectric coolers, very few have conducted research on propulsion systems with electric motors, especially in unmanned surface vehicle propulsion systems, so far this study has not been found. From this research application gap, this paper aims to conduct an experimental study of the application of thermoelectric coolers to propulsion systems in unmanned surface vehicles. The contribution of the results of this study will be twofold, namely knowing the effectiveness of the application of thermoelectric coolers to decreasing the temperature of electric motors and providing an overview of the application of thermoelectric coolers on unmanned surface vehicles.

2. Methodology

2.1 Design of Unmanned Surface Vehicle

Unmanned surface vehicles used in this study use monohull type and are designed for search and rescue vehicles. The designed USV has the main dimension, which is an overall length of 1.5 meters, a width of 0.4 meters, a height of 0.3 meters, and draft 0.06 meters. The prototype of USV in this study is shown in Figure 1. The propulsion system used on USV is using a water jet system with an electric motor drive that uses battery power. General description of the electronic system design on this USV is the controller using NodeMcu and ArduinoProMicro, IoT protocol using Streaming Cloud through Firestore, Power of 12v-10ah, Brushless DC Motor 3674-KV2075, battery capacity of 6200 mAh. The general plan of the propulsion system, the electronic system and the cooling system on this USV is shown in Figure 2.

Fig. 1. The prototype of the unmanned surface vehicle

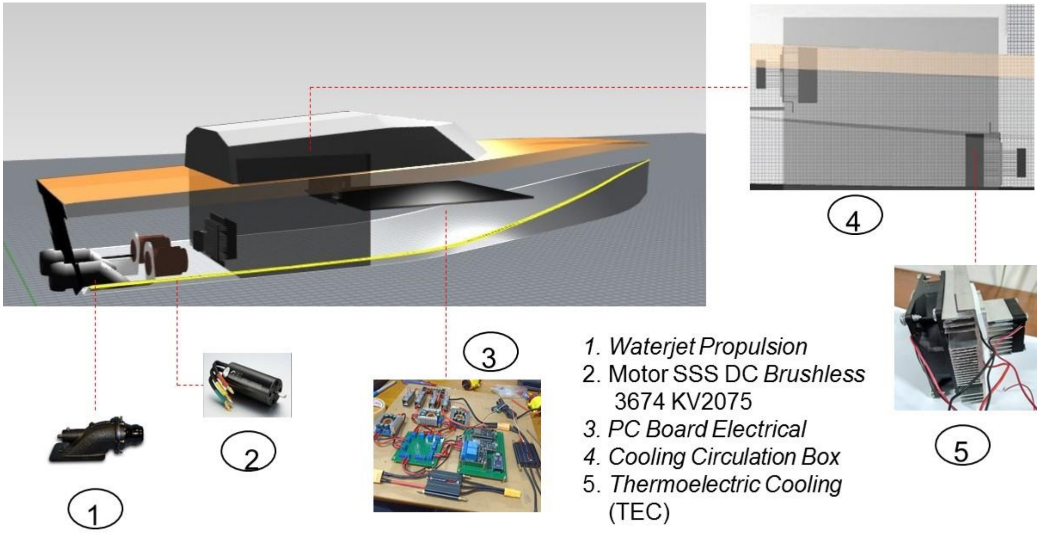

Fig. 2. General arrangement of electronic and cooling system of the designed USV

2.2 Design of Thermoelectric Cooler

In this study the dimensions of the cooling circulation box installed with thermoelectric cooler to circulate cold air to the electric motor are 0.3 meters long, 0.2 meters wide and 0.2 meters high. The cooling circulation box that is designed has the function of flowing hot air out of the room. The equipment components contained in the cooling circulation box are two heatsinks, two exhaust fans, a water-cooling hose, and two water block units. While the cold side is faced with an electric motor that is used as a water jet propulsion system, the components of the cold side are 12V TEC-12706 Peltier units, two heatsink units, and two exhaust fan units. In designing this thermoelectric cooling system, specification requirements must be considered to ensure the cooling system that is made will meet the cooling criteria in the ship. Based on preliminary analysis and data obtained, some of the requirements specifications that must be met are:

I. The heat inside the Cooling Circulation Box must be able to be discharged back out of the ship,
II. Able to cool ship space especially in electrical and mechanical components in the range of 10 ˚C - 30 ˚C,
III. The use of small electric power,
IV. Construction of a cooling device that is simple and easily repaired,
V. Laying the cooling device facing electrical and mechanical components so that cooling can be spread evenly,

VI. Using raw materials that are easily available on the market.

After considering the existing limitations, the thermoelectric cooler design that is used is to use a cooled-water system that is flowed to an electric motor. The designed thermoelectric cooler is shown in Figure 3. After the thermoelectric cooler design has been assembled, the experimental test was carried out with the experiment scheme shown in Figure 4. The experimental test is conducted to obtain the thermoelectric cooler device performance data to determine the cooling performance and heat dissipation effectiveness of the Cooling Circulation Box. Data collection includes data collection with variations in fan power and data collection with variations in use only with water cooling, only fan, and combining water cooling with fans. The greater the fan's power, the bigger the air discharge will be. On the cold side, the greater the power of the cooling air fan will be more and more at the same time. The variation of fan power is based on variations in fan voltage which are 4V, 8V, and 12V.

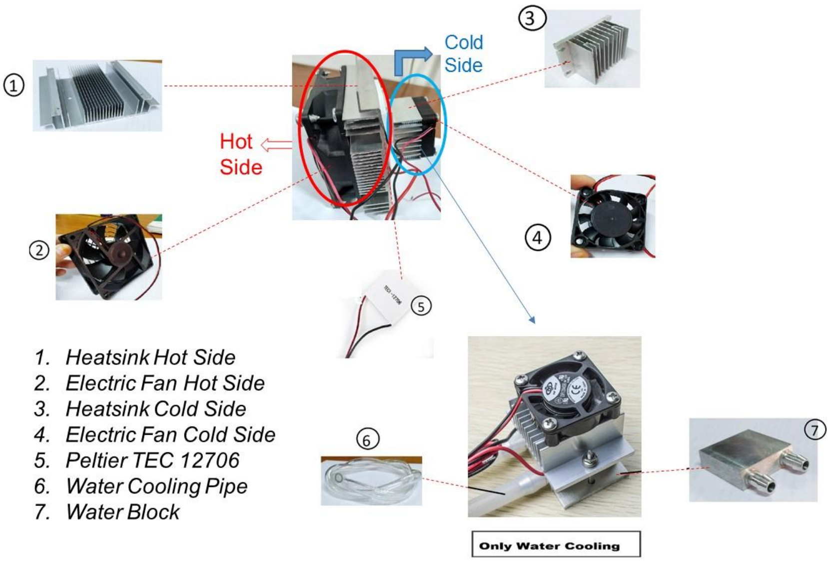

Fig. 3. Design of mini thermoelectric cooler

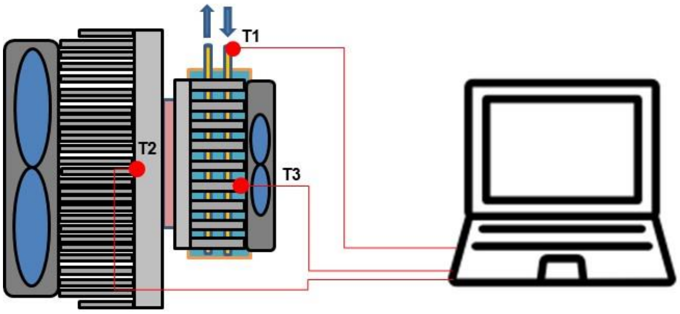

Fig. 4. Design of experimentation of thermoelectric cooler

3. Results and Discussion

3.1 Initial Temperature Inside USV

The experiment was carried out in the experimental basin by placing a temperature sensor inside the USV near the electrical circuit. Experiments carried out in calm water conditions for 30 minutes continuously. From the environmental data, it is known that ambient temperature is 36 ˚C.

Temperature data is recorded continuously and shown in Figure 5. From the results it is seen with a continuous operational pattern for 30 minutes, the room temperature in USV reaches 39 ˚C, this indicates the influence of rotation electric motors that cause heat inside the USV. From the recorded of the room temperature inside the USV, the increased temperature used as reference data for the performance of the thermoelectric cooler, the target of room temperature decreases minimal 3 ˚C.

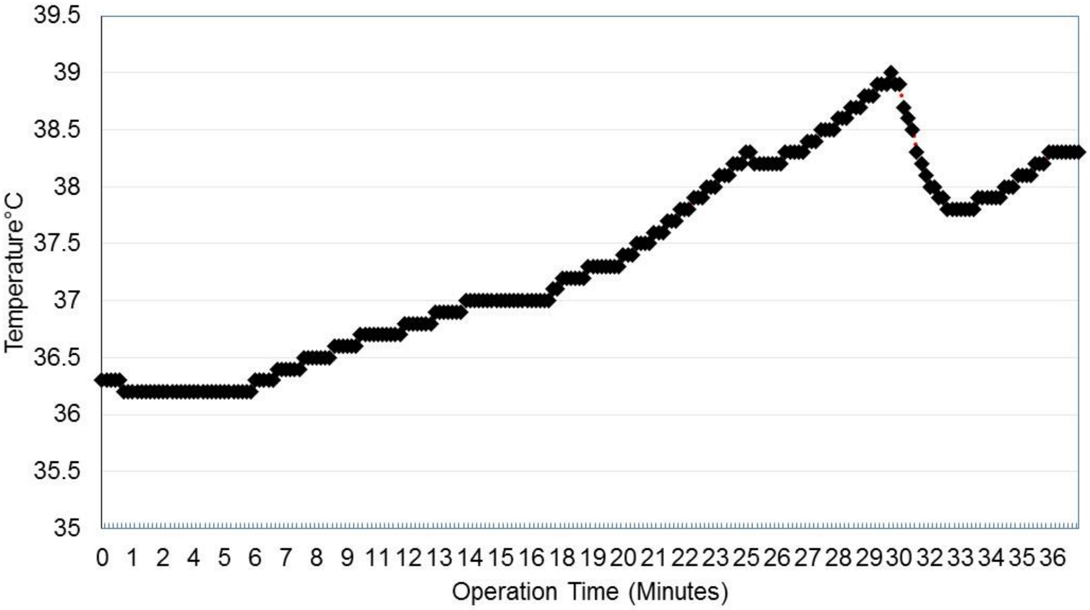

Fig. 5. Initial temperature inside USV during operation

3.2 Performance of Thermoelectric Cooler

After obtaining preliminary data on the temperature inside USV, this section will discuss the basic performance of thermoelectric coolers that have not been installed into USV. In this experiment it was measured only on the hot and cold sides of the thermoelectric cooler with a time of about 30 minutes, the measurement results shown in Figure 6. From the performance measurements of thermoelectric cooler show that this tool is functioning properly, a significant temperature difference starts after the 5th minute, the temperature on the cold side begins to fall from room temperature 28 ˚C down to 13 ˚C. On the hot side temperature increases tend not significant, after 5 minutes the temperature starts to rise from 30˚ ˚C to 33 ˚C, after which the temperature tends to be constant. After the 10th minute, both the hot side and cold side temperatures begin to stabilize at 31 ˚C and 12 ˚C, it can be seen that the temperature difference of the cold side and hot side is around 19 ˚C, this certainly exceeds the target of the expected temperature reduction. After obtaining this result, the thermoelectric cooler was set into the inside of USV, this experiment carried out to show the effectivity of the cooling performance inside the USV. Experiments carried out are transferring heat from the electric motor to the cold side of the thermoelectric cooler. Heat transfer occurs through water media connected with the heat pipe around the electric motor, which is considered as a source of heat, then the heat pipe is connected to the cold side of the thermoelectric cooler. Measurements were made at three points: T1 is in the heat pipe of the electric motor, T2 is on the hot side of the thermoelectric cooler, and T3 is on the cold side of the thermoelectric cooler. The results of the measurements can be seen in Figure 7. From this result, the temperature at each point starts to be constant after the 10th minute, after this time the thermoelectric cooler is stable runs.

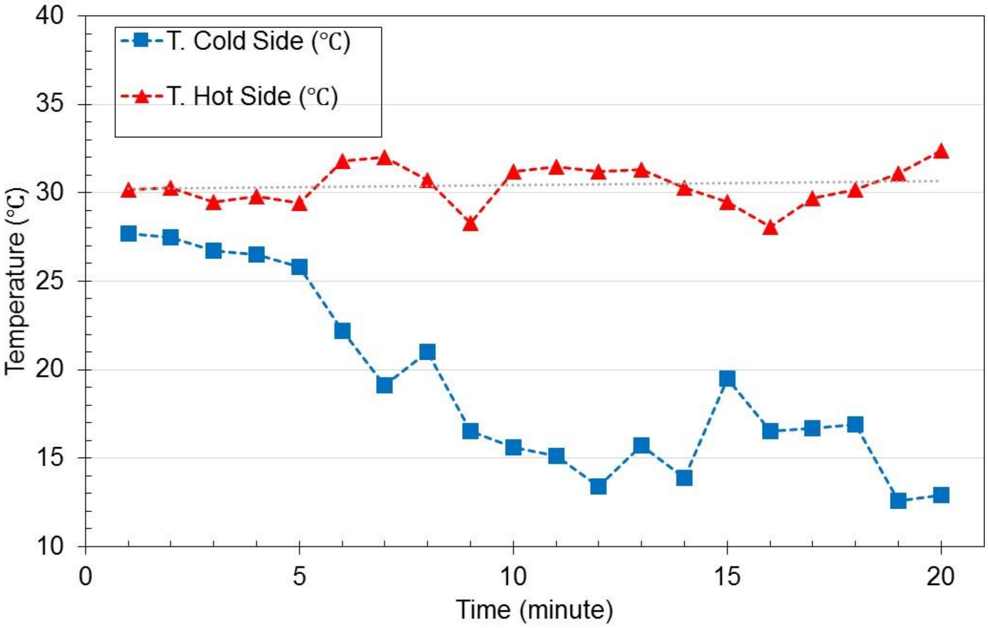

Fig. 6. Temperature on the hot side and cold side of thermoelectric cooler

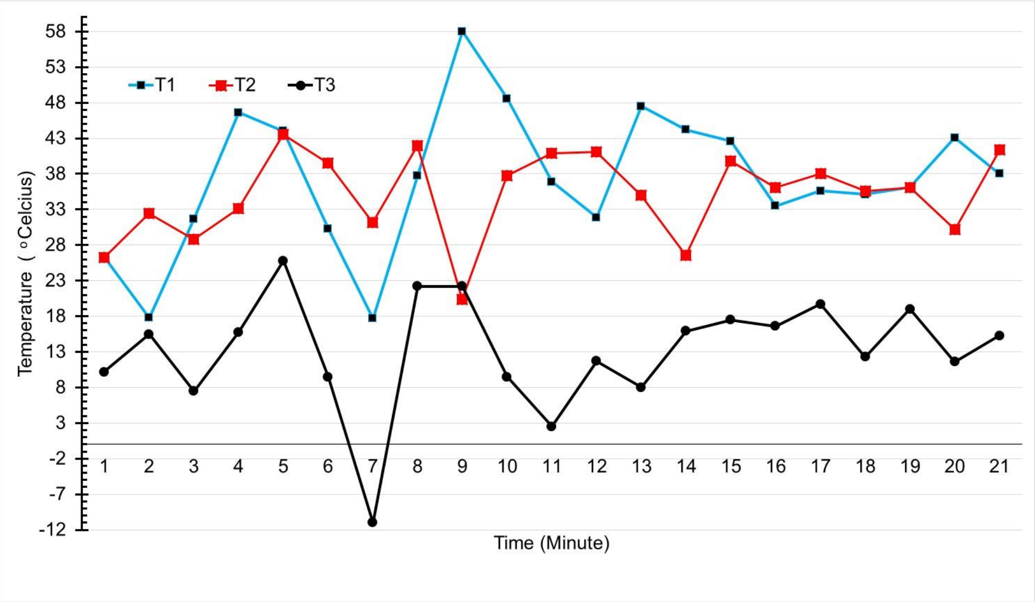

Fig. 7. Temperature on thermoelectric cooler with water cooled system

FThe average temperature at this point is T1 is 38˚C, T2 40 ˚C, and T3 14 ˚C. The temperature difference on the hot side and the cold side reaches 28 ˚C. These results show that due to the heat from the electric motor, causing the temperature on the hot side to rise. As is known from the results of the performance of the thermoelectric cooler, the temperature difference between the hot side and the cold side without a heat source is 19 ˚C. Thus it can be explained that the heat from the electric motors causes a temperature increase up to 9 ˚C, so that the cooling load becomes greater, which means the power needed by the thermoelectric cooler is also getting bigger.

4. Conclusions

An experimental study of the application of thermoelectric coolers in the unmanned surface vehicle (USV) has been performed to reduce the electric motor propulsion system. An assembled thermoelectric cooler using 12V TEC-12706 Peltier units was installed inside the USV. Experimental set up has been performed in two-stage i.e. first experiment to know the performance of the thermoelectric cooler, second experiment is the application of thermoelectric cooler into the USV. The results show that the temperature difference on the hot side and cold of the assembled thermoelectric cooler reaches 19 ˚C. After the thermoelectric cooler is applied inside the USV, the temperature difference reaches 28 ˚C. This result can be concluded that heat from the electric motors causes a temperature increase up to 9 ˚C, so that the cooling load becomes greater, which means the power needed by the thermoelectric cooler is also getting bigger. From this study provides research direction to optimize the design of low energy consumption thermoelectric coolers.

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