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Experimental water to air thermoelectric cooling application in automobile

Nattadon Pannucharoenwong[1, 2)], Somnuk Theerakulpisut[2], Athiwit Rakngam[1)],
Chatchai Benjapiyaporn*[2)], Julaporn Benjapiyaporn[2)] and Polkit Promteerawong[1)]

[1)]Faculty of Engineering, Thammasat University, Pathumthani 12120, Thailand.
[2)]Faculty of Engineering, Khon Kaen University, Khon Kaen 40002, Thailand.

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Abstract

In the present, HVAC in automotive application is a compulsory feature. It is to cool or heat a compartment or space for the comfort of users or preserving items. This will rely on a compressor driven system using compressed refrigerants. The system is however, requiring maintenance, space consuming, and drawing out a significant amount of valuable power from the engine in order to supply the system in case of automobiles. This research provides the feasibility test of a thermoelectric air conditioner in order to avoid the demerits of a HVAC system. Peltier effect was selected as the operating principle in the heat transfer process instead of the HVAC system. The benefit of a Peltier cooler is the compactness of the packaging as well as being maintenance free while offering reasonable cooling performance. Thermoelectric plates are connected with a water box then connected outside with a heat exchanger and radiator and fans. The module will be tested against the factory installed climate control system. The system could provide cooling effect by adjusting the electrical current path. This research will focus on the ambient temperature before and after the thermoelectric plates were switched on. The outcomes were that the system could not immediately cool the vehicle as good as the factory air conditioner due to poor ventilation system as well as the stability of the power supply that could be improved. The results proved that the thermoelectric principle itself could work and be used in applications, only it requires more optimization on the system.

Keywords: Thermoelectric, Cooling, Automotive, Heat exchanger, Peltier effect

1. Introduction

Air Conditioning is currently now a required element in daily life. It is found everywhere from buildings and automobiles to cool the space to a comfortable zone. Currently almost all automobiles are equipped with a compressor driven air conditioning system especially in tropical areas like Thailand. The system is however, quite space consuming and use refrigerants that are not environmentally friendly as well as drawing power from the engine. From the demerits of a HVAC system, there were effort on developing the actual application of thermoelectric cooling and heating in the last 40 years as it is environmentally friendly and almost maintenance free with compact packaging.

In 1823 Thomas Seebeck founded that electric current that flows along a closed circuit with different material to have their junctions to maintain at different temperature. The thermoelectric cooling effect started in 1834 where Jean Charles Athanese Peltier had discovered a phenomenon of heating and cooling using an electrified junction of two different conductor [1]. This had led to the possibility to generate a heat transfer between systems using only electricity. Later in 1979, Jon Henderson of Solar Energy Research Institute had made a release on the analysis of heat exchanger thermoelectric generator system to determine heat transfer properties and heat flow [2]. Recently, effort had been made towards making a thermoelectric cooling device as in 2012, Todd Bahnhart Et. Al. had investigated in a system for automobile climate control using thermoelectric plate with various system configuration using pressure and flow analysis [3]. In the same year, Manoj S. Raut had actually applied the method of cooling to a vehicle. The results were acceptable within the indoor conditions but it could not still cool the vehicle in harsher conditions [4].

From the efforts made above, there are still not so many serious research into making a practical application of automotive thermoelectric air conditioner that could match the standards of a factory provided air conditioner system. In this research, we optimize using principle of heat transfer by improving the hot side ventilation as well as improving the cooling performance by using higher output thermoelectric plates. The results are taken into comparison with the stock air conditioner then develop a conclusion towards the feasibility of applying the method into automobile [5-6].

2. Materials and methodology

2.1 Materials used and system schematics

*Corresponding author. Tel.: +6697 247 3423
Email address: chaben@kku.ac.th
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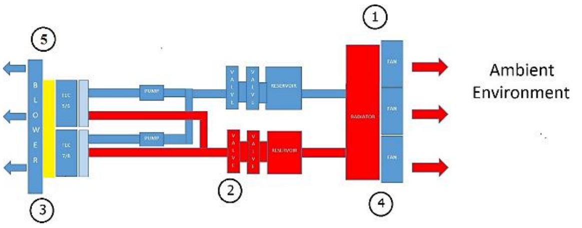

Figure 1 Schematic Diagram of Thermoelectric Cooling System

Figure 1 show the schematic of the operating system with the following points.

At point 1, an automobile was used in the prototype to dissipate the heat as in this experiment, no permanent modification had been made to the sample vehicle

At point 2, the valves are made for portability of the system in case of error and movement.

At point 3, a selection of thermoelectric plate are connected to electricity and mounted with the heatsink and blower.

At point 4, fan are installed to blow out heated water to the environment.

At point 5, water box are shown in light blue and heatsink is shown in yellow.

Figure 2 Rear Trunk Latch (Left), Test Vehicle (Right)

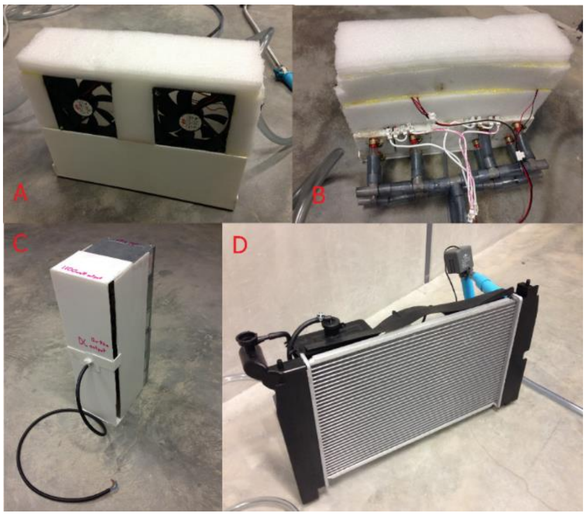

Figure 3 Power Supply and Test Apparatus

Figure 3 shows the module that would be supplied using a parallel connection of 12 PC power supplies due to the requirement of high current shown in point C. The module would be mounted inside the trunk with internal ventilation being connected through an access latch within the back seat. The module front and back side is shown in point A and B respectively. The radiator is shown in point D of figure above. In this experiment, the air conditioner would be externally powered and connected into the test vehicle shown in Figure 2.

2.2 Equations and theories involved

The theories behind the calculation of power supply specification are as following

Joule's Law

$$P = I V \quad (1)$$

Where "P" is the power in Watt, "I" is the current in Ampere, and "V" is the Voltage in Volts.
The theories behind the thermoelectric cooler module are as following

Energy Balance Equation

$$Q_{hot}=Q_{cold}+Q_{in} \quad (2)$$

Where Q stands for heat, and hot and cold stands for the hot and cold module side respectively.

2.3 Methodology and experimental condition

Table 1 Initial Parameter

Parameter	Value
Environment Ambient Temperature	29.5 ◦C
Vehicle Interior Temperature	32.5 ◦C
Initial Coolant Temperature	30.8◦C
Power Supply Specification	12V 1,100 W / 96A MAX
Effective Thermoelectric Output	1,000 W Combined
Vehicle Compartment Volume	Approximately 3000 Liters
Infrared Gun Tolerance	+- 2%

The data shown in Table 1 is the basic set of data related to the testing condition which is done in an area with no wind to remove any other effect that is not required within the experiment. The experiment had been carried out in two rounds. The first round would be testing the stock air conditioner being switched on at 24.0 ◦C with fan speed at low. The second test would be done with the thermoelectric cooling system. Both test would be recorded at one minute interval for 10 minutes shown in Figure 4. . Temperature measurement had been done using an infrared gun pointing onto the console surface.

3. Results and discussion

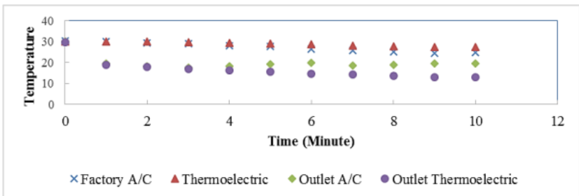

Figure 4 Interior Ambient Temperature of Factory A/C against Thermoelectric Module

The feasibility of applying the method in automobile is possible from the experiment conducted. It is clearly shown that the issue of air distribution is still a question that would lead to the practicality of the method as the module itself is able to cool the surrounding areas efficiently. This is due to the temperature measurement being scanned 100 cm from the module towards the front console. Since only 4 thermoelectric modules are used, it may not sufficient to cool down the car with the current configuration and will not be able to withstand extreme heat. The module had been quieter than the original air conditioner system. The experiment showed that the thermoelectric cooling device could slightly cool down the car with passengers feeling comfortably when the fan is directed at, only that it could not do the task in a timely manner due to small surface area and poor ventilation. The data on the outlet temperature had proved the thermoelectric plate's capability to be matching with the original HVAC system.

4. Conclusion

The results proved that the thermoelectric cooling has the capability of cooling a vehicle. However, it would require better ventilation as well as more surface area in order to make it practical. The results of the factory installed system and the thermoelectric module had resembled in the beginning, but starts to diverge afterwards. This research could be a model for other future research on this field of study.

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