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Effect of Water and Ethanol as Coolant on the Performance of Peltier Module for Cold Storage

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Abstract*: The steep rise in earth temperature also tends to rise in energy consumption for the sake of which demand for cooling also increases. Various cooling equipment's are available within the market within different working principle, in which vapour compression system being the most common. But due to its design it is not easy to make it portable in which use of Peltier comes in place. Peltier being solid state in nature also has a benefit of being small in size as well it runs completely on Direct current. But due to lower efficiency of Peltier module the use is limited to some specific purpose. The heat dissipation of Peltier is higher than that of the absorption which intends require continuous removal of heat. For which liquid cooling outperform all in coefficient of performance. There are various coolants that can be incorporated within the system, in which water being the most common. So as per this research, water is compared to that of ethanol which being less common in terms of coolant. The study majorly concerned into various analytical part used for the calculation of COP of Peltier module in both the cases. Since our system doesn't concern about overall system performance at present it is only concerned with the module efficiency so system COP was omitted in case of calculation and comparison. In the study it was obtained that for water and ethanol subjected to both natural and fan assisted radiator cooling a COP of 0.402, 0.413, 0.409 and 0.412 was obtained respectively for both coolant and cooling methods. Water was found the most suitable medium of cooling in regard to ethanol as due to tendency of heating up.

Index Terms*: Bi-Te, COP, Direct Current, Ethanol, Heat sink, Peltier.

I. INTRODUCTION

In the brief period of required cooling equipment which requires in today's world for the optimum cooling of various agricultural products. For this purpose, several equipment has been designed for specific purpose but majority lack on or other feature such portability or active cooling. Due to this requirement various techniques have been researched for the above problem in this regard semiconductor comes in play which has great stability and portability. Peltier module which is often referred as thermoelectric generator due to its ability to generate electricity in the presence of temperature gradient between its two surfaces. Peltier module can be used either as heat pump or it can also be used a cooling device. For the purpose of cooling device, the Peltier module needs DC current in symmetric polarity so as to that of Peltier. This in turns extracts the heat from the cold side surrounding and expels it from the other side.

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This function corresponds to the series connection of Bismuth-Tellurium block which acts as heat pump when current flow through it. Due to the fact that the heat is being pumped by the help of electricity not by pressure source as in contrast to vapour compression system there is always a negative side of resistance to it performance which eventually effects the efficiency. To release the heat by the mean of natural convection to the surrounding air the radiator required would be of several meter. In such system the heat transfer coefficient does not exceed 3-5 kCal/m2.h.deg. [1]. Due to this better heat removal system such as liquid heat removal system is employed. At the junction of hot thermopile side and liquid where the heat flux is maximum it is possible o trach a maximum heat transfer coefficient equal to 100-150 kCal/m2.h.deg [1]. As this is way higher than that of what air or natural convection can achieve almost 20-30 times. But due to the complication of application of liquid cooling within the system it is not applied at almost all of the scenario. But in advancement of technology and greater flexibility of material the liquid cooling system can be made more sophisticated and can be utilized for the same. There are various types of liquid cooling system that are available within the market majorly for the cooling of CPU these days. The same system can be employed in the Peltier cooling, but some modification within the system so as to tailor it designs as per the need of Peltier can be helpful. Most of the liquid cooling system mainly consists of reservoir which act as a key in the storing and continuous supply of the fluid without any interrupt. Now a day's various development in the coolant technology includes Nano-fluids that consists of nano particle of certain specific type of metal that may have higher thermal conductivity, further these nano-particle are dispersed within a suitable medium mainly water, glycol and ethanol. Several other techniques such as phase change material are also employed for the purpose of manufacturing heat sink due to the property of high thermal conductivity. The thermal conductivity of composite material can reach as high as 4.767 W/mK [2]. A part of thermal conductivity also depends upon the flow pattern of certain liquid as different flow combination can have drastic effect on the thermal conductivity of the material.

II. OVERVIEW OF EXPERIMENTAL SETUP

The test box designed for the experiment consists of several components assembled within. The major part consists of a test storage area made up of plywood lined by thermocol and aluminium within.

The aluminium heat sink was placed onto the cold junction of thermopile whereas another aluminium water reservoir heatsink was placed at heated side. Water circulation was fulfilled by a DC centrifugal pump with a maximum power consumption of 8W. Plastic reservoir of capacity of 1.5 L maintained the continuous supply coolant within the system without interruption as well as it also eases the replenishment of same. Coolant flow through a radiator made up of copper tubes which is facilitated by 2 DC axial fan for the purpose of forced convection. The whole setup was eventually monitored by digital temperature sensor.

III. Thermal Analysis

A comparative study of two different fluids on two different cooling methods has been performed so as to calculate the corresponding COP. In a closed test environment two COPs are present- Overall System COP and Peltier Module COP. Overall System COP can be described as the COP of the test box in which the experiment has been undertaken. Whereas Peltier Module COP can be described as the COP of the peltier module working specific in that environment. In the above scenario following parameters needs to be resolved as per the COP that needs to be calculated. The heat rejected by the peltier module within the system in addition with the heat generated by itself due to resistance is denoted by Q_H. Whereas the heat absorbed by the peltier module within the system is denoted by Q_L. Q_L is the heat load onto the peltier which includes the heat of the material within the test box in addition to heat influx from the walls and insulation. The temperature of the fluid reservoir is the hot side temperature within the system which is denoted as T_H. Whereas the temperature of the heat sink attached to the cold side of the peltier module is denoted by T_C [4]. Following formulas were used to calculate the COP of the peltier module-

Heat load on peltier module within the system is given by-

$$Q_L = -[SIT_C - \frac{1}{2} I^2 R - k(T_H - T_C)] \qquad \text{...Eq 1}$$

(-sign for heat rejection)

While heat transfer through heat sink from the hot side is-

$$Q_H = SIT_H + \frac{1}{2} I^2 R - k(T_H - T_C) \qquad \text{...Eq 2}$$

The thermoelectric peltier module is made up of BiSn. The properties of 127 BiSn thermocouple 6A module TEC-12706 are

- Seebeck Coefficient (S) = 0.01229 V/K
- Module Thermal Resistance (K) = 0.1815 W/K
- Module Resistance (R) = 5.4 Ω

To calculate COP for the peltier module following formula will be used-

$$COP = \frac{Q_L}{W} \qquad \text{...Eq 3}$$

Energy supplied for the overall system.

$$W = Q_H - Q_L \qquad \text{...Eq 4}$$

Energy supplied specific to the Peltier module

$$W = SI(T_H - T_C) + I^2 R \qquad \text{...Eq 5}$$

The following equation was applied in the subsequent stage so as to obtain the desired result [3].

IV. Analysis of COP

Various parameter was obtained with the help of various measuring devices, as the voltage and current for the specific design was obtained using multimeter which was almost same for both the liquid subject to same fluid flow cooling methods i.e., *5.53 and 5.57 A* for natural radiator cooling and forced fan cooling respectively and the voltage was approximately constant at *10.6 V*, further different temperature reading was obtained mainly at the cold and hot end of the peltier which was further tabulated in *table-1*. COP was calculated with the help of formulae stated in thermal analysis further heat load and heat transfer was calculated using *Eq 1* and *Eq 2* respectively, the total energy supplied to the setup was calculated using *Eq 4*, which in turn provided COP for the required system using *Eq 3*, and also another energy can be calculated when comparing the COP of overall system is required or when the peltier setup has been placed within the system for a closed space cooling in which various other parameter may be required for consideration but as per consideration only peltier arrangement was there for COP calculation. The calculation showed almost same result as when both are compared for a small-time frame, as due to fact of surrounding environment but as for the longer run the ethanol reservoir temperature spiked significantly thus lowering the thermal exchange between the coolant as well as peltier hot side. The COP of peltier was in range of 0.409 to 0.413

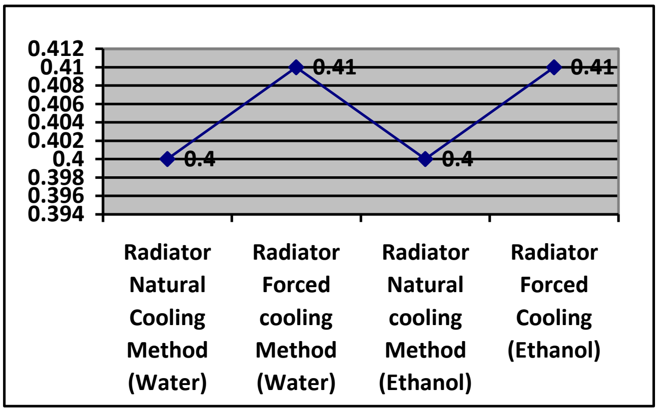

Fig. 1: COP vs Cooling Method

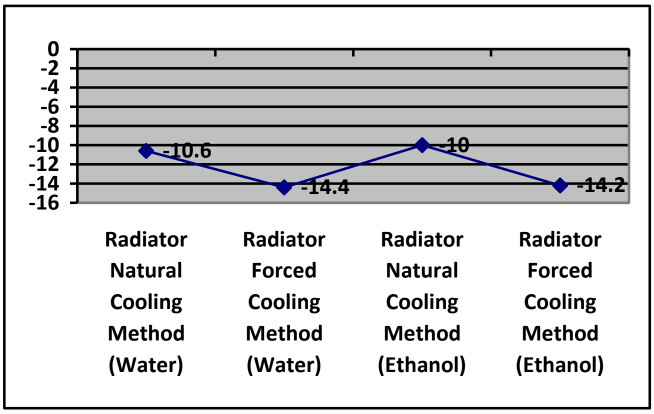

Fig. 2 : Temperature vs Cooling Method

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Table 1 : Thermal and electrical observation

Fluid	Fluid Flow	T_C (°C)	T_H (°C)	Current (I)	Voltage (V)	Heat Removed (Q_L)	Work Done (W)	COP of Peltier Module
Water	Radiator Natural Cooling Method	-10.6	39.8	5.53	10.06	45.255	110.57	0.409
	Fan Cooling Method	-14.4	37.7	5.72	10.08	48.836	118.261	0.413
Ethanol	Radiator Natural Cooling Method	-10	39.8	5.53	10.06	45.23	110.567	0.409
	Fan Cooling Method	-14.2	37.7	5.72	10.08	48.710	118.226	0.412

I. CONCLUSION

Present paper showed the emphasis of using liquid cooling in the efficient removal of heat form the heated side of the Peltier module. In the present study water and ethanol was taken as coolant for the system, several other coolants are already in place such as glycol, nano fluids etc., the study was conducted in department of food process engineering, SHUATS, which detailed about the practicality of the coolant to be used. The study showed that water having highest specific heat showed the best possible heat removal capacity due to larger amount of heat that can be absorbed with respect to the rise in temperature, whereas ethanol despite having lower heat capacity showed better result as compared to that of water but due to faster circulation of coolant throughout the system as well the pressure of circulation being constant, ethanol temperature rose which eventually leaded to lower thermal gradient thus limiting the heat transfer from the system. We know that the heat capacity of water is 4.186 J/g°C and that of ethanol is 2.46 J/g°C. As stated, the heat capacity of water is almost double than that of ethanol, so when both fluids are tested in the test box with the same quantity and similar flow rate then water performed same as that of ethanol but due to higher heat capacity the heat absorption of water is more as compared to ethanol and so it can absorb more heat from the heat dissipating surface of the peltier module. The ethanol temperature spiked quickly within the reservoir which in turns reduced the temperature gradient between coolant and that of hot side of the peltier which lowers the heat transfer rate and thus reducing performance. From the study it could be understood that ethanol which reached a temperature of 14.2°C and a COP of 0.41 in forced cooling system could be used in place where there is sufficient amount of travel length so heat could be dissipated from the coolant thus lowering the temperature, another problem associated with use of ethanol was its volatility which posses concern in regard such as flammability and also decrease in volume which needed to be refilled every time it volume decreases or else a complete closed system needs to be designed so as avoid loss which again incur cost.

Whereas in case of water which achieved a temperature of -14.6°C in forced cooling system and COP of 0.41 these associated problem doesn't occur which adds benefit for the use of water in system as well water being easily available can be replenished whenever wanted and less secure system needs to be designed which lowers the further cost of the project. So, this study concluded that water being more suitable option as coolant with better performance matrix than ethanol in smaller system where cost and design constrain are in place, whereas for larger system both can be used with almost negligible difference in performance but with higher cost.

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