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" COMPREHENSIVE ANALYSIS OF THERMOELECTRIC AUTOMOTIVE COOLING SYSTEM"

Ajay Raj Sharma [1], Ranjeet Singh [2], Dr. Gaurav Saxena [3], Praveen Kumar [4], Balram Kakoriya [5]

[1,2,3,4,5] *Department of Automobile Engineering, RJIT, BSF Academy Tekanpur, Madhya Pradesh, India*

ajayrajsharma90@gmail.com

praveenk.lunayach@gmail.com

ABSTRACT

This research investigates the Peltier thermoelectric cell was sandwiched between an external and internal heat sinks that acted to remove heat from the water block. When the Peltier thermoelectric cell connected to an external power source, the Peltier effect caused the heat from the refrigerator internal space to be conducted and removed to the ambient. The present research focuses on the application of ethylene glycol as a coolant, exploring the thermal parameters, temperature drop, and heat transfer rates of the hybrid cooling system. A literature review highlights the significance of heat transfer enhancement techniques, emphasizing the need for energy-efficient methods in the automotive industry. The research methodology involves experimental work, analytical calculations, and the preparation of coolant samples to evaluate thermo-physical parameters. The results demonstrate the temperature drop, Heat transfer for different flow rates, Bulk Mean Temperature difference. The result showed that presence of ethylene glycol in water enhances the desirable temperature drop of the heat transfer fluid. The heat transfer rate is increased by 58% for EG-100 sample as compared to pure water.

Key Words: *Thermoelectric Cooling, Peltier Effect, Heat Transfer, Ethylene Glycol, Thermal Parameters.*

I. INTRODUCTION

In 1834, thermoelectric based on Peltier Effect was discovered by Jean Peltier, in which the direct current applied across two dissimilar materials causes a temperature difference. It is found that when current flows across the intersection between two different wires, heat must be consistently added or subtracted to maintain the temperature. Peltier Effect in one of three effects that categorized in the thermoelectric system, where are See beck Effect and Thomson Effect. Ethylene glycol has been widely used as antifreeze in automobile radiators for many years because of its compatibility with metals and better heat transfer characteristics. Mixtures of ethylene glycol (EG) and water (W) are used in cooling the engines in automotive applications. This study explores the heat transfer performance of an EV cooling system using a hybrid Peltier approach, with a focus on the application of ethylene glycol as a coolant. Heat transfer has been involved in almost every sector of the engineering field. Heat transfer is classified into three categories: conduction, convection, and radiation. Peltier modules operate on the principle of the Peltier effect. This effect brings up a temperature difference by transferring heat through two junctions. Muhammad Fairuz Remeli et al. [1] experimented on mini thermoelectric Peltier cooler, sandwiched between external and internal heat sinks. The Peltier effect removed heat from the cooler box, lowering it to the ambient. The cooler produced a higher coefficient of performance (COP) than previous studies and reduced the cooler box temperature to 18.5°C. The validated model could be used to estimate design parameters. Weishen Chu et al. [2] focused on Peltier effect-dimensional thermoelectric Finite Element Analysis to validate the cooling performance of a thermoelectric micro cooler for localized hotspot

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cooling. The model shows successful heat flux change and optimal micro cooler size and activation current effects. A. S. Tijani et al. [3] examines the thermal characteristics of Nano fluid coolants in automotive radiators. The coolant, made of Alumina Oxide (Al2O3) based Ethylene Glycol, was analysed using ANSYS fluent software. The results showed an increase in heat transfer performance with an increase in Nano fluid concentration. The study found that the Nusselt number and heat transfer coefficient increased with Nano fluid concentration, with the highest heat transfer rate at 0.09%. N. S. Naveen and P. S. Kishore [4] compared forced convective heat transfer of a Water-EG coolant with a Water-EG-based Nano coolant in a radiator. Graphene nanoparticles were added in different proportions, and heat transfer parameters like rate, coefficient, Nusselt number, Reynolds number, and friction factor were evaluated experimentally.

The literature review emphasizes the growing importance of heat transfer enhancement in the automotive industry. Studies suggest that ethylene glycol, in conjunction with Peltier plates, can provide superior heat absorption compared to traditional coolants. Addressing these gaps and challenges through advanced thermal analysis, impact studies of different cooling systems, and the development of energy-efficient and environmentally friendly cooling technologies is essential for ensuring the reliable operation of electronic devices in the future. This study aims to investigate. A fully turbulent regime was achieved by varying the test fluid flow rate between 3 and 8 LPM. The obtained results show that heat transfer performance can be enhanced by increasing the fluid circulating rate. Applying a low-concentration nanofluid can increase heat transfer efficiency by 40–45% as compared to pure water.

II. EXPERIMENTAL SETUP

The experimental setup consists of a cross-flow compact heat exchanger with a single pass of multiples tubes with aluminium's fins. To study the effect of replacing the conventional heat transfer fluid with ethylene base fluid, firstly, the experiments were performed using pure EG and EG and water at a ratio of 90:10, 80:20, and 70:30. Heat transfer fluid experiments were performed by varying the inlet temperature of the hot fluid, the flow rate of the hot fluid, and the velocity of air passing over the heat exchanger. The flow rate of hot fluid was fixed at different values with the help of a valve provided at the bottom of the rotameter. Temperature sensors were placed at different locations of the heat exchanger to measure the temperature of hot and cold fluids. In this setup, the main components include a water block, Peltier, inlet and outlet fan, rotameter, radiator, water pump, Arduino UNO, temperature sensor, and flow sensor.

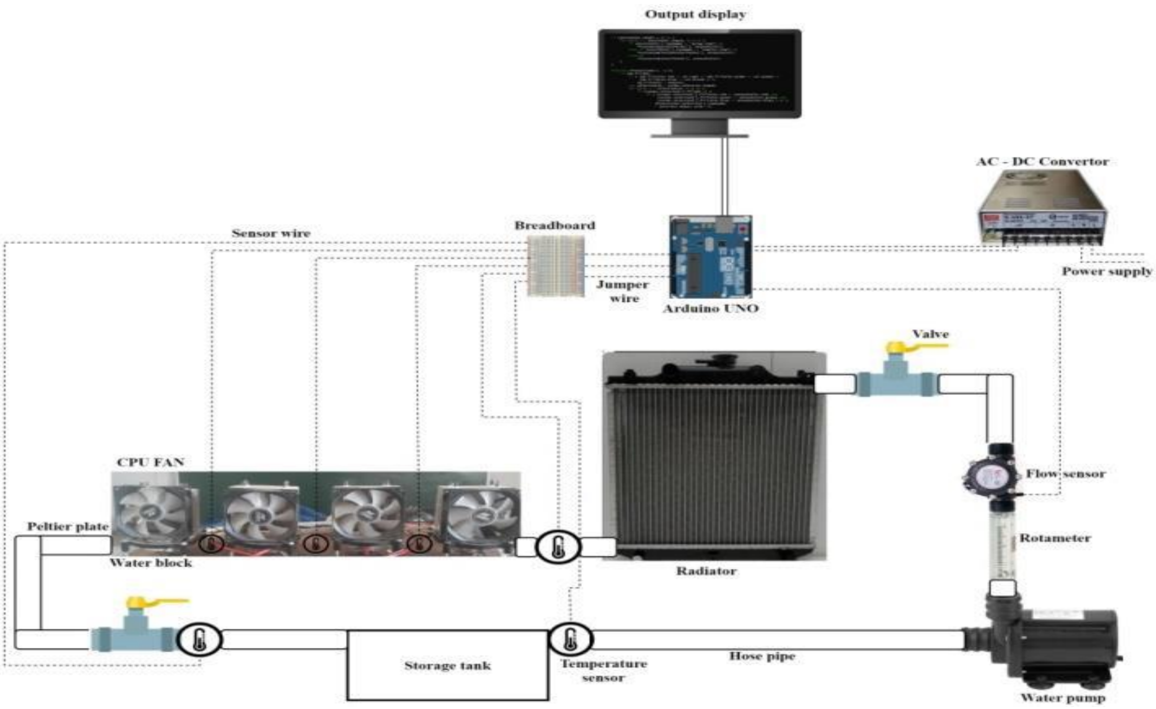

Fig. 1: Schematic Diagram of Experimental Setup

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Experimental work is performed with following considerations:

A. Ethylene glycol and water mixtures were taken as primary heat exchanger fluid in the system.
B. Inlet temperature of the hot fluid was kept at 60 °C in the storage tank.
C. Flow rate of the hot fluid is varied from 13 to 19 LPH with the help of a valve provided at its bottom and flow rate is measured with a digital rotameter.
D. While keeping the inlet temperature and flow rate of hot fluid constant, readings for temperature were taken at various locations of the heat exchanger.
E. Steps c) and d) were repeated for 4 numbers of samples constituting 16 experiments.
F. To record reading steady was maintained, all readings were recorded at a 10-minute time interval to achieve steady state.

III. Experimental Methodology

The research methodology involves a comprehensive approach of conducting experiments, collecting data, and performing analytical calculations for thermal parameters. The study employs a hybrid cooling system with ethylene glycol as the coolant, and the experimental setup involves the preparation of coolant samples through direct mixing using a magnetic stirrer.
The thermal parameters evaluated during experimentation work are discussed below:

- The heat transfer rate of overall section at hot fluid side is
  $\dot{Q} = \dot{m}Cp$ (T0−Ti)
- The heat transfer rate of all fluid. The higher the coefficient, the easier is to transfer heat.
  $\dot{Q}$=UA0θm
- The power consumptions for cooling system are evaluated. The voltage drops (V) and current consumed (I) is determined for the three setup and power consumption (V*I) is determined.
  $P=VI$

IV. Result

4.1 Temperature Drops

The temperature drops with respect to flow rate for ethylene glycol and water-based coolant at different proportions are shown in Fig. 2. The trend of the graph shows a negative slope due to the constant specific heat of the sample. At a fixed inlet temperature of 60 ˚C, the sample EG100 shows the highest temperature drop. The temperature drop remains equivalent to the coolant EG 100 up to 90:1 (EG90) proportional.

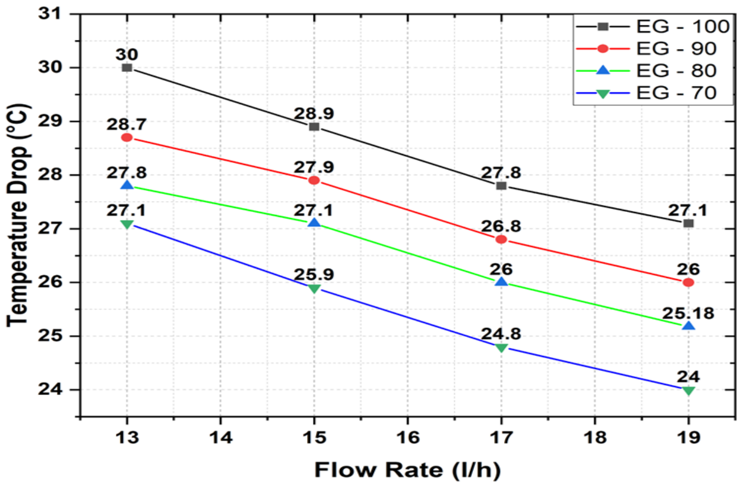

Fig. 2: Comparison of Temperature Drop with respect to flow rate

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4.2 Bulk Mean Temperature

Figure 3 shows the variation in bulk mean temperature of coolant with respect to an increase in flow rate. For the test run conducted on four samples of coolant, the results show there is an increase in bulk mean temperature with an increase in flow rate for all samples under consideration. This is due to a reduction in time for heat transfer. Further, the highest bulk mean temperature is obtained for the coolant sample EG-70, whereas the lowest bulk mean temperature is obtained for the sample BT-100.

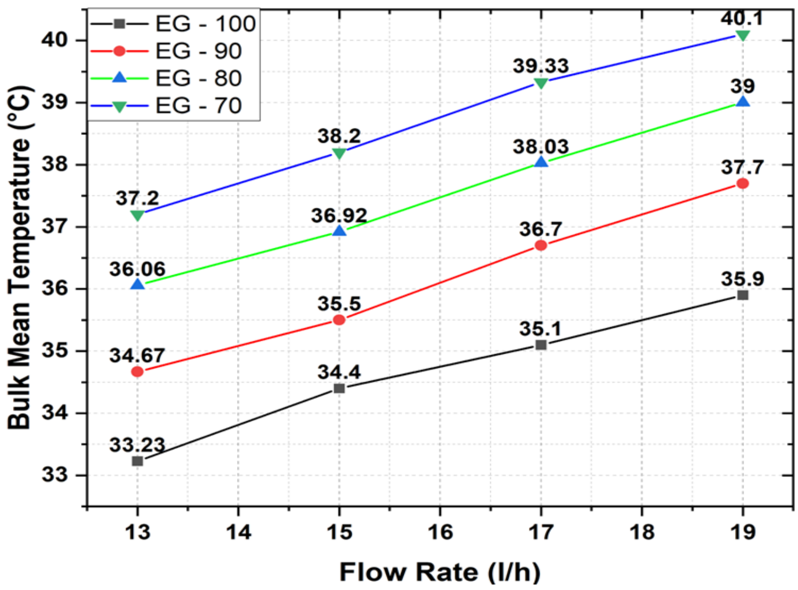

Fig. 2: Comparison of Bulk Mean Temperature with respect to flow rate

4.3 Heat Transfer Rate

Figure 3 shows the heat transfer rate with respect to flow rate for the test run conducted on four samples of coolant. The results show an increase in the heat transfer coefficient with respect to flow rate for all samples. This is due to consideration of heat transfer rate (w). Further, the highest heat transfer rate is obtained for coolant sample Q100.

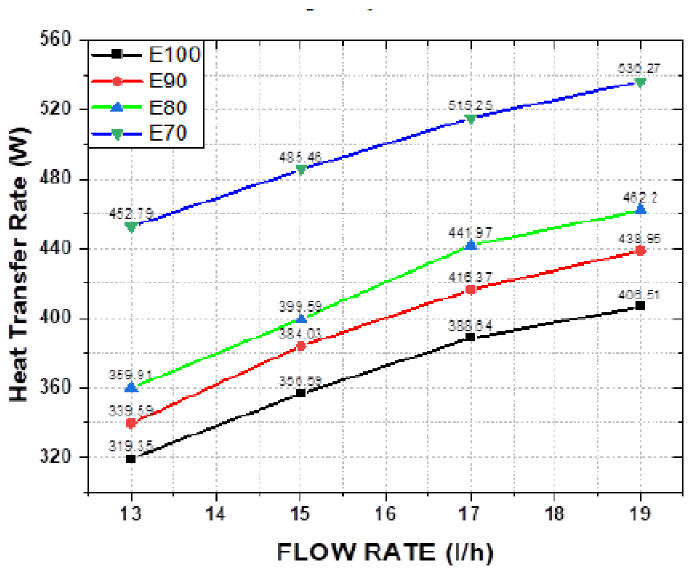

Fig. 3: Comparison of Heat Transfer Rate with respect to flow rate

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V. Conclusion

An innovative hybrid cooling system using thermoelectric systems in conjunction with conventional radiator-based cooling is designed and installed. Considerable augmentation in output factors against input variables was documented for processing the thermal parameters using mathematical relations.

- The presence of ethylene glycol in water enhances the desirable temperature drop of the heat transfer fluid (coolant). The increase in temperature drop depends on the amount of water added to ethylene glycol. The temperature drops for pure ethylene glycol get increased by 2.9 ºC by considering the 6 lpm variation in flow rate, which is higher than other samples.
- Results of experimental study showed, bulk mean temperature increased in comparison with the base fluid. heat transfer rate for ethylene glycol and water is 2.9 °C and 2.67 °C respectively.
- Heat transfer rate of pure ethylene glycol is higher than other samples.

VI. Acknowledgement

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