CFD Analysis of using Deionized Water in Radiator to Enhance the Efficiency for Sustainable Growth

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Abstract-: Conventional liquid coolant used in automotive radiators is often used as an engine coolant. Heating systems in automotive air chambers are commonly used to cool circulating fluids, usually water or an aqueous combination of antifreeze agents such as ethylene glycol (EG). This study examines the benefits and issues of the usage of deionized water in all radiators. Deionized (DI) water has received attention as a possible alternative to chemical coolants generally used in automobile air conditioners. Automotive engineers are addressing the demanding situations of intense freezing by developing special garage systems to optimize engine overall performance and limit environmental impact. Compared to conventional refrigerants, the usage of deionized water has lesser environmental consequences, consisting of decreased corrosion and mineral production, which extends radiator lifestyles and improves cooling efficiency. Moreover, DI-water poses several challenges, which include the capability to freeze and compatibility with some radiator materials. Ultimately, this study investigates using deionized water as a refrigerant while used in radiators inside the inlet water. Additionally, it explores the impact of deionized water on engine performance, durability, heat transfer overall performance, corrosion resistance, and potential overheating, at the same time as additionally addressing environmental problems.

Keyword-: Automobiles, enhanced cooling systems, engines, deionized water, heat exchange systems.

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1 Introduction

The use of DI-water in radiators shows a remarkable improvement in automotive cooling systems [1]. By removing mineral ions, DI-water reduces the risk of scale buildup and damage, resulting in better radiator performance and longer life [2,3]. This cleaning also provides heat dissipation the body is improved, facilitating better heat transfer. While the use of deionized water is often limited by additives, the introduction reflects the automotive industry's commitment to innovation and efficiency, ensuring that the vehicles operate reliably and efficiently. The study assesses the multi-walled graphite nanotube' (the MWCNTs') [4-5] thermal performance in distilled water in an automobile radiator. The particles were diluted in water at quantities between 0.05 and 0.16 weight percent using high-pressure homogenization. Up to a 5% fall in the amount of heat transferred was seen in the experiment; the rate similarly fell when the amount of particles rose [6-8]. It looked at how tiny fluids affected a small heat pipe radiator's ability to conduct heat. The utilization of SiO2/water tiny fluids enhanced heat performance by lowering wall temperature variations, according to the results [9]. When measured against deionized fluid, the coefficient of thermal conductivity dropped by 23% to 40%. Compared to charge SiO2/water nanofluids, the fin heat dissipation increased 1.17 times [10-14]. This letter describes the underwater breakdown mechanism of microsecond pulsed discharges in deionized water and shows that the breakdown channel topology is asymmetrical negative. Significant variances in parameters are seen throughout different regions of the channel, and an enhanced two-stage analytical approach is developed to assess parameter variations. Field and ionization impact handles account for the positive charge channel's or the negative channel's fast growth at the needle's tip or ground electrodes [15] The application of tiny fluids in heat exchange systems, such as radiators in cars and other sectors, is investigated in [16-19]. The water-based tiny fluids ZrO2 and staggered conical strip inserts with various twist ratios were examined for their thermally hydraulic performance. The use of staggered conical strip inserts increased heat transfer rates by up to 145.03% in the backwards configuration and 130.5% in the inward configuration at the 0.5% volume concentration of ZrO2 tiny fluids, according to the results [20]. Additionally, because of their increased efficient temperature conductivity, bigger concentration tiny fluids facilitate higher heat transfer. Additionally, correlations between the frictional parameter or the Nussle value were generated in the investigation [21]. The heat transmission properties of DI water and the ethylene glycol tiny fluids in vehicle radiators are investigated in this work. A mixture of DI water, ethylene glycol, temperature four levels of tiny fluids was prepared, with coolant and airspeed varied. Findings indicated that EG tiny fluids have an additional substantial heating factor and a lower thermal conductivity compared DI water. As concentration rose and heat decreased the nanofluid's fluidity changed accordingly [22-25]. The study examined the laminar forced convective heat transfer behavior of a water-based tiny fluids ionized with multiwall nanotubes of carbon utilizing the response surface methodology (RSM). MWCNT was dissolved in the deionized water solution using surfactants. In a 1:1 ratio, the best sample was chosen. The flow rates, concentrations, and magnetic fields were varied in 15 trials. Reliability and validity of the RSM tackle were confirmed when the highest possible heat transfer efficiency was attained at an amount of 0.09wt%wt [26-29] The performance of ZnO/water and Al2O3/water nanofluids in an automobile radiator test rig is compared in this study. Findings indicate that Al2O3 nanoparticles work better at keeping the engine from overheating and failing. To ensure precise findings, the vehicle radiator test apparatus was adjusted [30]. The need for material to lighten vehicles is growing in the auto industry. One way that scientists are pursuing efficiency would be to find new methods. To enable the transmission of heat through a radiator, they tried silicon carbide nanofluids. The study's results proved that bigger particles performed worse than smaller ones, demonstrating stronger heat transfer characteristics at 24 nm. Hence, this would mean either reducing the surface area of radiators or enhancing conduction by mixing tiny nanoparticles with their base fluids [31-33]. Various liquids including Cu-EGW, Al2O3-EGW and Fe3O4-EGW were used by researchers in this experiment which investigate heat transfer properties of electrical heaters. It was observed that as mass concentration of particles increases so does heating efficiency in the case Cu-EGW nanofluid which shows most improvement over Al2O3-EGW and Fe3O4-EGW nanofluids when it comes to transmitting heat [34]. Heat transmission in screen mesh wick heat pipes is greatly impacted by tilt angle and hybrid nanofluid, according to experimental research on heat pipe alignment as well as fluid type [35]. For 75% CuO–25% ZnO/DI water, heat pipes with a 60° angle had the optimum heat transmission characteristics. However, their thermal characteristics were hindered by the growth of heat fluxes in the 60-160 W range.

2 Methodology

Radiators are heat exchangers used to transfer thermal energy from one medium to another for the purpose of cooling and heating. A radiator is always a source of heat to its environment, although this may be for either the purpose of heating this environment, or for cooling the fluid or coolant supplied to it, as for automotive engine cooling. Most radiators transfer the bulk of their heat via convection instead of thermal radiation. The use of deionized water in radiator systems presents an attractive method of improving cooling efficiency and reducing potential maintenance problems Water free of ionic impurities provides hydration clean and inoperative for heat exchanger. Free ions reduce the risk of mineral build up and corrosion in the radiator system, which can prolong its life. This makes it especially attractive in applications where precise temperature control and durable equipment are paramount. Automotive applications may favour deionized water in high-performance vehicles or in harsh operating conditions, where optimum engine temperature is required for performance and longevity However, although water with ions does not provide these advantages but it is necessary to consider costs, as investment in initial ionization equipment and the cost of ongoing purchases reduced maintenance, improved efficiency And there may be more to it than savings, but, where sanitation , and services and facilities where efficiency is paramount, the use of deionized water in radiators in remains an interesting avenue that requires much research and investigation. There are several steps that are important in setting up computational fluid dynamics (CFD) as shown in Fig.1, analysis to study the use of deionized water in a radiator for efficiency. Initially, the objectives for thermal performance are defined well and fluid behavior analysis clearly. Then, the geometry of the radiator is modeled and a mesh is constructed to divide this model into discrete cells, which is necessary for detailed analysis. The material-fluid properties of the radiator and deionized water, such as thermal conductivity and viscosity, are then entered into the CFD software. Appropriate boundary conditions are established to define the flow characteristics and environmental conditions. The simulation is performed using the Navier-Stokes and the solution of the energy equation to determine the flow and heat transfer characteristics of the deionized water in the radiator Postprocessing follows where the results are analyzed to control temperature distribution, flow dynamics and efficiency. The evaluation may include recommendations for efficiency and validation against experimental data to ensure accuracy, culminating in a comprehensive report describing findings and recommendations for the potential of deionized water work properly for the efficiency of the radiator

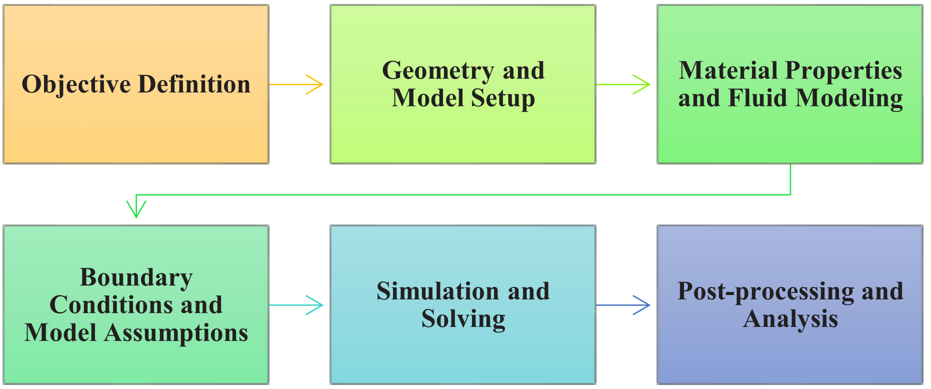

Fig.1: Flow chart of CAD Analysis

Aside from its purity, deionized water possesses several vital properties that are crucial for a number of applications. At a density of 1000 kg/m³, it exhibits a relatively high specific heat of 4184 J/kg K, making it effective for thermal buffering in processes requiring temperature stability. With a low thermal conductivity of 0.22 W/mK, it serves as an insulator in many thermal applications. Its dynamic viscosity, measured at 0.00314 Ns/m², indicates its resistance to flow, influencing fluid behaviour in hydraulic systems and heat exchangers. The Prandtl number, a dimensionless parameter describing fluid flow and heat transfer, is approximately 7 for deionized water, revealing its behavior in different flow regimes and boundary layers.

3 Result and Discussion

The main objective of the present work to investigate the heat transfer performance of the radiator at different flow rate of the heat transfer fluid by using various coolants such as deionized water, mixture of ethylene glycol and water (60:40) mixed with Al2O3 nanofluid. Mass flow inlet of heat transfer fluid ranging from 180 LPH, 240 PH, 300 LPH, 360 LPH and 420 LPH has been used.

3.1 Temperature analysis

Table 1: Temperature analysis based on different flow rates

Flow Rate (LPH)	Inlet Temperature (°C)	Outlet Temperature (°C)	Temperature Difference (°C)
180	90	74.28	15.72
240	90	77.49	12.51
300	90	77.63	12.37
360	90	78.05	11.95
420	90	78.42	11.58

According to Computational Fluid Dynamics (CFD) analysis, the radiator's cooling performance by using deionized water at various flow rates, maintained at 90°C, is summarized in the table 1. It illustrates how the outlet temperature of the coolant increases from 74.28°C to 78.42°C as the flow rate is escalated from 180 LPH to 420 LPH, indicating a higher overall heat absorption with increasing flow. A simultaneous decrease in temperature difference between the inlet and outlet, which represents the radiator's efficiency in cooling the fluid, is observed. While the exit coolant is warmer at higher flow rates, the cooling efficiency per unit actually goes down slightly—most likely because the radiator coolant is exposed for shorter times and the total volume of the liquid is greater; hence, it would facilitate greater heat transfer. To be able to optimize radiator designs and operating parameters in order to achieve desired cooling efficiencies under a variety of operational conditions, capturing data of this nature is vital.

Table 2: Velocity analysis depending on different flow rates

Flow Rate (LPH)	Max Velocity (m/sec)	Outlet Velocity (m/sec)
180	15.28	12.01
240	21.45	16.86
300	24.53	19.28
360	30.76	24.09
420	36.79	28.74

Data from a Computational Fluid Dynamics (CFD) analysis is displayed in the table 2, which illustrates the velocity characteristics of a radiator using deionized water at various flow rates. At the lowest flow rate, the maximum and outlet velocities of the coolant were 15.28 meters per second (m/sec), and at the highest flow rate, 36.79 m/sec. As the flow rate increases from 180 to 420 liters per hour (LPH), the velocities also increase. Specifically, the outlet velocity increases from 12.01 m/sec to 28.74 m/sec over the same range. By increasing the flow rate of coolant through the radiator, the speed at which it travels through the system is not only improved, but also the dynamic behavior within it is altered, which is crucial in optimizing radiator performance and ensuring efficient cooling under various conditions.

4 Comparative Results

The comparative analysis of temperature difference and heat transfer rate for deionized water is provided herein, highlighting key findings depicted in Fig. 2 to 5. Those figures illustrate the outlet temperature in Fig. 2, heat transfer rate in Fig. 3, heat transfer coefficient in Fig. 4, and Nusselt number of deionized water in Fig. 5, offering insights into the thermal performance characteristics. Through examination of Reynolds number, Nusselt number, and heat transfer coefficient, this study targets to elucidate the dynamics of heat transfer in deionized water, providing valuable insights for various industrial and scientific applications.

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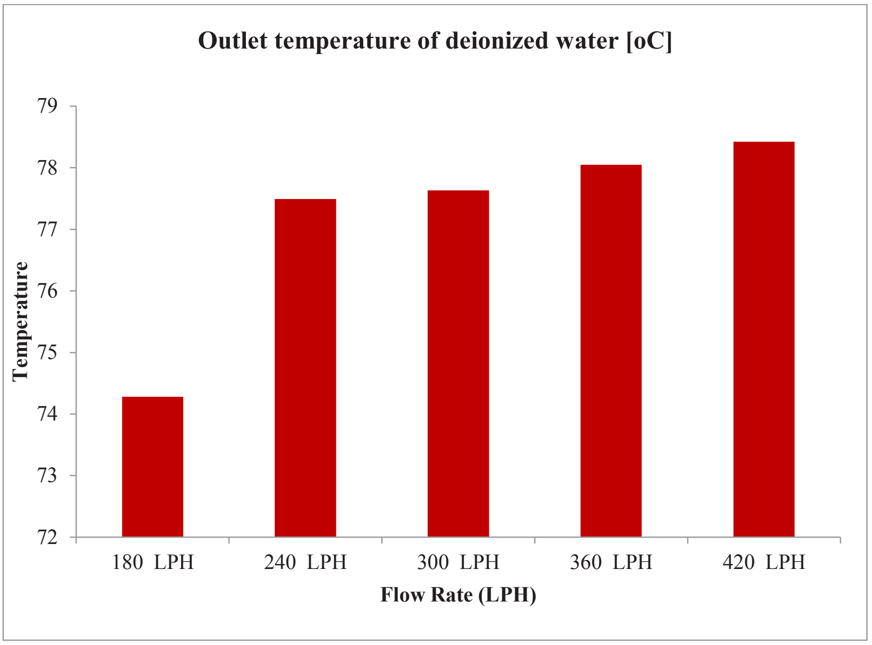

Fig. 2: Outlet temperature of deionized water

The flow rate of deionized water measured in Liters Per Hour (LPH), Fig. 2 shows the outlet temperature of deionized water measured in degrees Celsius. There are four flow rates to consider: 180 LPH, 240 LPH, 300 LPH, 360 LPH, and 420 LPH. A positive relationship between flow rate and temperature seems to exist between 180 LPH and 420 LPH, since the temperature of the deionized water also increases. The lowest temperature observed is around 74°C at 180 LPH, and the highest is close to 79°C at 420 LPH.

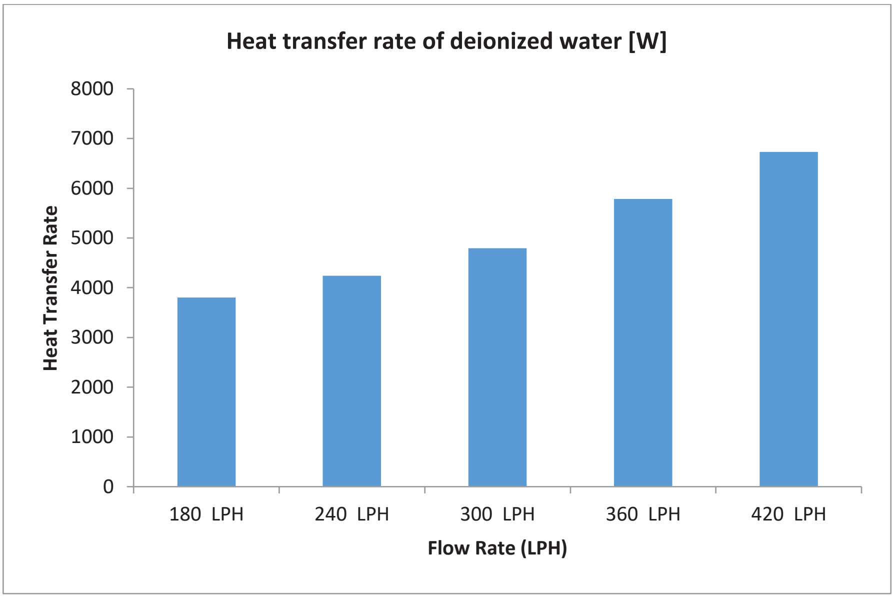

Fig. 3: Heat transfer rate of deionized water

Heat transfer rate of deionized water, measured in watts (W), is plotted against different flow rates in Fig. 3, measured in liters per hour (LPH). Flow rates of 180 LPH and 420 LPH result in the lowest heat transfer rate of around 3500 W and 7500 W, respectively, suggesting that higher flow rates offer greater heat transfer efficiency.

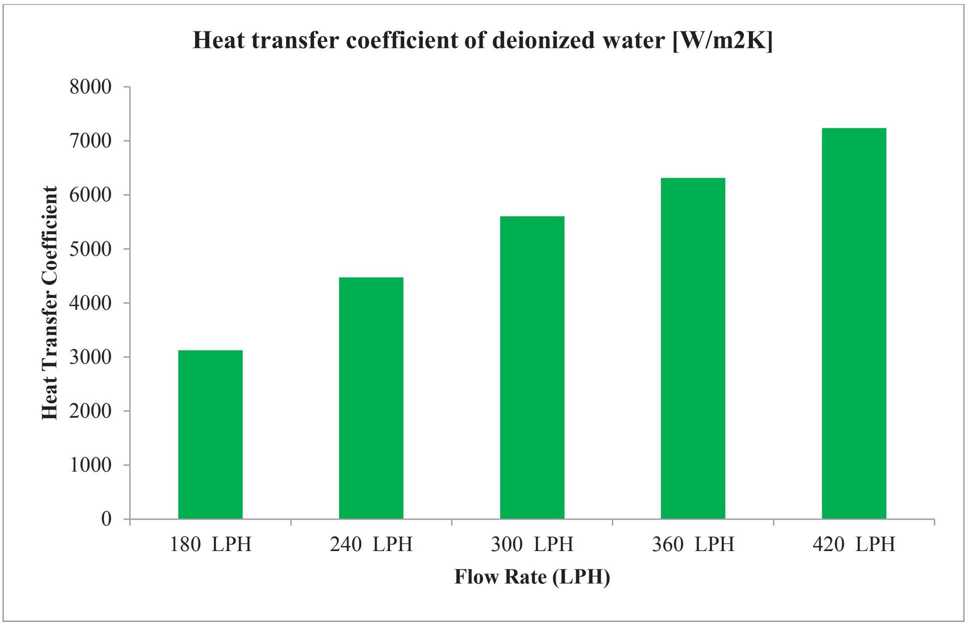

Fig. 4: Heat transfer coefficient of deionized water

Fig.4 shows that as the flow rate increases, the heat transfer coefficient tends to increase, indicating that the heat transfer has improved the flow rate The coefficient starts around 3000 W/m2k at 180 LPH, decreases slightly at 240 LPH, increases again at 300 LPH and 360 LPH, 420 LPH reaching a maximum of about 7000 W/m2K at This means that the flow rate increases in deionized water lack of internal structure facilitates this effective combustion

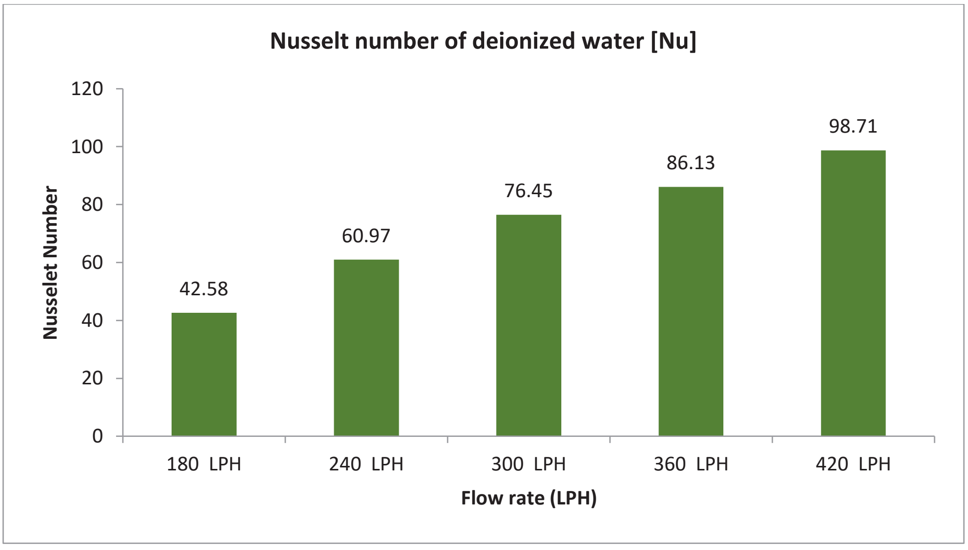

Fig. 5: Nusselt number of deionized water

Based on Fig. 5, when the flow rate goes up, the Nusselt number goes up too. It starts at 42.58 at 180 LPH and goes up to 98.71 at 420 LPH. This shows that as the flow rate of pure water goes up, the heat transfer efficiency also gets a lot better. Every bar in the graph has the Nusselt number written on it. This gives exact points to check how well the heat gets transferred at each flow rate.

5 Conclusion

In the present work mathematical and computational fluid dynamic analysis have been performed for radiator in order to investigate the thermal performance of the radiator at different flow rate of the heat transfer fluid by using various coolants such as mixture of ethylene glycol and water (60:40) mixed with Al2O3nanofluid For that three dimensional CAD model of radiator has been created in design modular of ANSYS workbench and perform CFD analysis by defining the Steady state pressure based absolute velocity formulation analysis where Energy equation is used for thermal analysis, K-epsilon RNG viscous model with standard wall function has been used for turbulent flow. Mass flow inlet of heat transfer fluid ranging from 180 LPH to 420 LPH has been used. There are following conclusion having been observed from the above analysis.

Conclusion for radiator using deionized water at different flow rate:

- At 180 LPH, observing an outlet temperature of 74.28 ºC, a maximum velocity of 15.28 m/sec near the bending section, and a Nusselt number of 42.58.
- At 240 LPH, observing an outlet temperature of 77.49 ºC, maximum velocity of 21.45 m/sec near the bending section, and a Nusselt number of 60.97.
- At 300 LPH revealed a maximum velocity of 24.53 m/sec near the bending section and an outlet velocity of 19.28 m/sec, with a heat transfer rate of 4792.2 W.
- At 360 LPH, observing a temperature distribution of 90°C, outlet temperature of 78.05°C, maximum velocity of 30.76 m/sec, and Nusselt number of 86.13.
- At 420 LPH, observing a temperature distribution of 90°C, outlet temperature of 78.42°C, maximum velocity of 36.79 m/sec near the bending section, and a heat transfer rate of 6792.22 W, 7238.71 W/m2K, and 98.71 Nusselt number.

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