Advancements in Heat Transfer Efficiency Nanofluids Implementation in Radiators

[1]Amit Kumar, [2]Shamir Daniel, [3]Jeetendra Mishra

[1]M. E Scholar, Department of Mechanical Engineering, Truba Institute of Engineering & Information Technology, Bhopal, MP, India.

[2]Assistant Professor, Department of Mechanical Engineering, Truba Institute of Engineering & Information Technology, Bhopal, MP, India.

[3]Assistant Professor, Department of Mechanical Engineering, Truba Institute of Engineering & Information Technology, Bhopal, MP, India.

Email [1]amitmechanical27@gmail.com, [2]shamirdaniel3004@gmail.com. [3]jeetendra.mishra@trubainstitute.ac.in

* Corresponding Author: Amit Kumar

Abstract: *The radiators include heat exchangers that transfer heat from a single material to another for cooling and heating purposes. To examine the thermal performance of the radiator at various heat transfer fluid flow rates while using different coolants, such as deionized water, a blend of ethylene glycol and water (60:40) mixed with Al2O3 nanofluids, a combination of ethylene, which is glycol and water (50:50) mixed with ZnO Nanofluids, and a combination of ethylene glycol and water (60:40) mixed with graphene oxide, computational and computational fluid dynamic analysis has been To do this, a three-dimensional CAD radiator model was made using the design module of the ANSYS workbench, and a steady state pressure-based absolute velocity version analysis was defined, using the Energy equation for thermal analysis and the K-epsilon RNG viscous simulation using a standard wall function for turbulent flow. Heat transfer fluid mass flow inlets with a range of 180 LPH, 240 PH, 300 LPH, 360 LPH, and 420 LPH have been employed. The heat transfer coefficient increases by 7.9 times at 180 LPH, the Nusselt number increases by 1.77 times at 180 LPH, and the temperature difference increases by 1.67 times at 300 LPH when using a ZnO Nanofluids mixture of ethylene glycol & water (50:50) as opposed to deionized water, according to the results.*

Keywords: *Radiators, heat exchangers, CFD analysis, nanofluid,,*

I. INTRODUCTION

Radiators are a type of heat exchanger that transfers heat energy from one medium to another, specifically for the purposes of cooling and heating. The radiator serves as the primary cooling system for internal combustion engines [1]. Very high temperatures are produced by the combustion process, particularly when an engine is running at full power. The temperatures of these hot gases range from 2300 to 2500 OC. These temperatures may cause damage to the engine cylinder walls. Therefore, it is imperative to lower the temperature. The engine block and its components would not be able to withstand the generated extraordinarily high thermal stress and would quickly fail if they were not adequately cooled. In order for the engine to operate properly, heat must be removed from it. The radiator is a significant heat exchanger that is crucial to preserving the engine's operating temperature. The goal of the cooling system is to maintain the engine's optimal operating temperature. In order to remove heat from the engine by conduction, convection, and radiation, the current cooling system uses water and an anti-freezing chemical as the coolant for the radiator. [2] A radiator will have a large number of fins arranged in a similar pattern that come into contact with the tube carrying liquid pumped into the radiator tube. This is known as convection, and it refers to devices or substances where the source of heat is not directly exposed to or released from the substance. Heat energy is transferred through the mechanism of conduction when nearby atoms or molecules collide. Solids and liquids both facilitate conduction more easily. When there is a significant temperature differential between the substances that are in contact, the rate of energy transfer by conduction is increased.

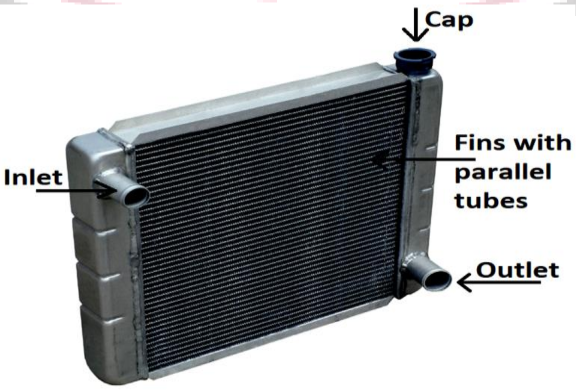

Figure 1.1: Radiator

On the other hand, there are many uses for heat exchangers outside of automotive systems. They are used in many different industries, such as oil refineries, HVAC (heating, ventilation, and air conditioning), refrigeration, and power generating. In order to transmit heat between the hot fluid and the cold fluid without allowing them to mix, heat exchangers are used.

The fundamental idea underlying heat exchangers is to maximize the amount of surface area available for heat transfer while designing a fluid flow pattern that is effective. The cold fluid normally enters the exchanger through a different set of tubes or channels than the hot fluid, which is carrying more heat. Heat can be transferred from the hot fluid to the cold fluid by the close closeness of these fluids, which are only separated by the tube walls or plates.

There are many different kinds of heat exchangers, and each has specific setup and design requirements. Shell-and-tube heat exchangers, plate heat exchangers, finned-tube heat exchangers, and compact heat exchangers are examples of common types. The kind of fluids, needed heat transfer rate, pressure drop restrictions, available space, and economic considerations all affect the heat exchanger selection.

Fluid flow patterns, tube geometry, surface area, and the thermal characteristics of the associated fluids are some of the parameters that affect efficient heat transmission in radiators and heat exchangers. To maximize the overall performance and energy efficiency of these systems, high heat transfer rates and low thermal resistance are essential [3].

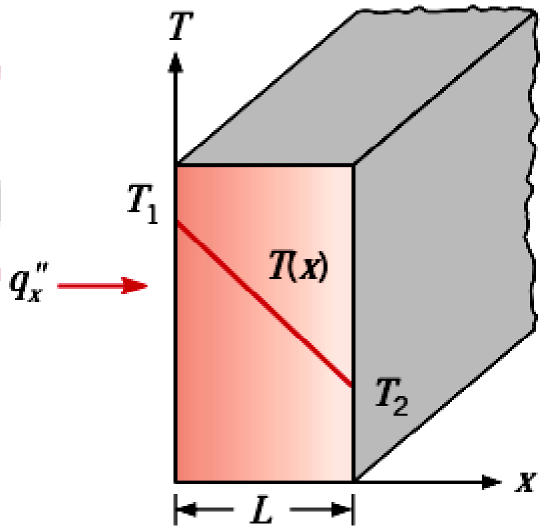

Figure 1.2: One-dimensional conduction heat transfers

Convection is a method of transferring heat from a solid surface to a nearby moving liquid or gas. It combines the effects of conduction with fluid motion. When a fluid is pushed to flow over a surface by an outside force, such as a fan, pump, or the wind, the process is referred to as forced convection. As opposed to this, convection is referred to as natural (or free) convection when the fluid motion is brought about by buoyant forces that are brought about by density changes brought about by temperature variations in the fluid.

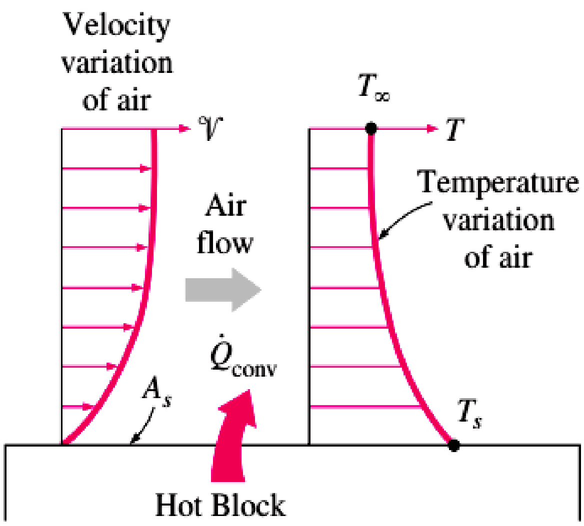

Figure: 1.3: Heat transfer from a hot surface to air by convection.

II. LITERATURE REVIEW

Elsaid et al. (2021) conducted a study using hybrid nanofluids on the efficiency and energy analysis of various perforated rib designs in a triple tube heat exchanger. The research used a variety of rib designs and hybrid nanofluid combinations to improve the heat transmission and energy efficiency of the heat exchanger. According to the study, hybrid nanofluids and various rib configurations have the potential to improve heat exchanger performance and energy efficiency.

Bahiraei and Monavari (2020) examined the thermohydraulic properties of a microplate heat exchanger used with nanofluids while taking diverse nanoparticle forms into consideration. The study's main objective was to examine how the morphologies of nanoparticles affected the microplate heat exchanger's pressure drop and heat transfer properties. The results highlighted the significance of choosing the right nanoparticle form for enhancing heat transfer and fluid flow in nanofluid-based heat exchangers.

Samiolo and Verdin (2022) offered a numerical modeling analysis of an electric vehicle application's finless heat exchanger arrangement. Through numerical simulations, the study sought to improve the finless heat exchanger design's heat transfer and fluid flow properties. The study highlighted the finless heat exchanger layout's appropriateness for cooling applications for electric vehicles and showed how it may enhance heat transfer performance.

Ibrahim et al. (2021) evaluated the financial, thermal, and hydraulic capabilities of a non-Newtonian nanofluid-filled corrugated helical heat exchanger. The study analyzed the non-Newtonian nanofluid heat transfer and pressure drop properties in the corrugated helical heat exchanger. The results gave information about the helical heat exchanger design's thermal-hydraulic performance and economic viability while using non-Newtonian nanofluids.

Hojjat (2020) did a study to see how well shell and tube heat exchangers would work with nanofluids as coolants. Artificial neural network (ANN) modeling and multi-objective optimization were used in the study to identify the ideal heat transfer enhancement settings for the heat exchanger. The study showed how shell and tube heat exchangers could use nanofluids and optimization techniques to increase heat transfer efficiency.

Saffarian et al. (2020) studied the use of nanofluids with various flow path shapes to improve heat transfer in a flat plate solar collector. The study's goal was to enhance heat transfer efficiency by optimizing the flat plate solar collector's flow path geometry. The results showed how flow path design and the use of nanofluids could improve heat transfer efficiency in solar collectors.

Bretado-de los Rios et al. (2021) conducted a thorough analysis of the use of nanofluids in solar thermal applications and heat exchanger sustainability. The study gave a general overview of how nanofluids are used in heat exchangers and what that means for improving thermal systems' sustainability. It talked about how nanofluids might boost heat transfer effectiveness and lessen negative environmental effects. The evaluation highlighted the requirement for additional study to evaluate the long-term viability and financial viability of nanofluid-based heat exchangers in solar thermal applications.

Kushwah et al. reviewed the thermal analysis of car radiators and presented it. The study's main objective was to evaluate the radiators' thermal performance and effectiveness in vehicle cooling systems. It covered many aspects of radiator performance, including coolant flow rate, design specifications, and heat transfer properties. The investigation emphasized the value of thermal analysis in enhancing the layout and functionality of car radiators for effective heat dissipation.

Alshahrani et al. (2021) TiO_2 nanofluid was used to study the operation and interaction with the surroundings of a concentric heat exchanger. The purpose of the study was to assess the effectiveness of heat transmission and the environmental effects of employing nanofluids in concentric heat exchangers. It covered the impact of operating circumstances and nanofluid concentration on heat transfer effectiveness and environmental sustainability. The results highlighted the ability of TiO_2 nanofluid to enhance heat exchanger performance while taking into account environmental conditions.

Mustafa et al. (2022) did a combined simulation study using computational fluid dynamics and molecular dynamics to forecast the characteristics of a nanofluid moving inside a micro-heatsink with a radiator that has holes on its fins. The goal of the study was to look into the fluid flow and heat transfer properties of a micro-heatsink with nanofluid flow. The integrated modeling method shed light on the molecular behavior of nanofluids and how it affects heat transfer in micro-scale heat exchangers. The study demonstrated how the combined simulation technique may be used to enhance the functionality and design of nanofluid-based micro-heatsinks.

III. NANOFLUIDS: DEFINITION AND POTENTIAL BENEFITS

The early 1990s saw the invention of the term "nanofluids," which describes a class of manufactured fluids made up of a base fluid and suspended nanoparticles. The nanoparticles typically range in size from 1 to 100 nanometers and can be either metallic or non-metallic materials, with the base fluid being a traditional coolant like water or ethylene glycol.

In comparison to ordinary fluids, the base fluid's thermophysical properties are altered when nanoparticles are added, improving heat transfer performance. In order to optimize heat transfer capacities, the nanoparticles employed in nanofluids are carefully chosen for their distinctive properties, such as high thermal conductivity and large surface area[4].

The greatly improved thermal conductivity of nanofluids compared to the base fluid alone is one of their key benefits. The fluid's effective thermal conductivity is raised by the presence of nanoparticles, improving its capacity to conduct heat. This characteristic allows for greater heat dissipation and temperature control, which makes it very helpful in applications where high heat transfer rates are required.

The potential of nanofluids to enhance convective heat transfer is another advantage. As a result of the fluid's suspended nanoparticles, the convective heat transfer coefficient is improved, allowing for more effective heat transmission between the fluid and the heat transfer surface. As a result, thermal resistance is decreased and heat transfer efficiency is increased, which eventually improves system performance.

Additionally, by encouraging improved interaction between the fluid and the heat transfer surface, the small size and huge surface area of nanoparticles in nanofluids allow efficient heat transfer. This larger interfacial surface improves heat transmission, enabling a faster and more effective exchange of thermal energy.

In comparison to conventional suspensions, nanofluids also have better stability and suspension characteristics. The nanoparticles stay suspended in the base fluid for extended durations without experiencing considerable settling or agglomeration because of the surface changes and stabilizing chemicals utilized throughout the nanofluid manufacturing process[5]. Over time, this stability guarantees dependable and consistent heat transfer performance.

Nanofluids also provide flexibility in terms of their composition and characteristics. By choosing several base fluids and nanoparticles, scientists can customize the nanofluid formulation for certain uses. This adaptability makes it possible to tailor the properties of nanofluids to the needs of various heat transfer systems, improving overall efficiency.

Significant interest has been generated by the potential advantages of nanofluids in enhancing heat transfer efficiency in a number of industries, including automotive cooling, electronics cooling, thermal management in power plants, and renewable energy systems. To be widely used in industry, however, issues including nanoparticle sedimentation, stability, and cost-effectiveness must be resolved despite the many benefits.

A. Advantages and Disadvantages of Nano-Fluid:

Table 1.1 Advantages and Disadvantages of Nano-Fluid

Advantages	Disadvantages
• Enhanced thermal conductivity, mostly from laminar flow, which results in an increased heat transfer coefficient.	• The expensive suspension of nanoparticles, especially ones that need stabilizers like surfactants to be added.
• Because of the enhanced heat transfer, tiny devices are now practicable.	• Corrosive damage to subsided parts owing to flow and the deposition of particles when the fluid is in a state of stagnation for an extended period of time.

V. CONCLUSION

Collectively, the investigations discussed in this paper show the possibility of using nanofluids to improve the effectiveness of heat transfer in radiators and heat exchangers. Nanofluids, which are composed of nanoparticles dispersed in conventional heat transfer fluids, present intriguing potential for enhancing the efficiency of heat exchange systems overall and the performance of heat transfer processes.

The base fluid's thermal conductivity and convective heat transfer coefficients are improved by adding nanoparticles. Radiators and heat exchangers are ultimately more efficient as a result of faster heat transfer rates and less thermal resistance. The type of nanoparticles used, their concentration, and the dispersion method all have a significant impact on the performance gains made.

The investigations examine the effects of a variety of nanoparticles on heat transfer efficiency, including alumina, copper oxide, and titanium dioxide. Effective dispersion of nanoparticles in the fluid has been achieved using a variety of techniques, including direct mixing, the two-step method, and surface modification. These investigations have repeatedly demonstrated appreciable increases in heat transfer rates, demonstrating the viability of using nanofluids in heat exchange systems.

REFERENCES

[1] Khoshvaght-Aliabadi, M., Tatari, M., & Salami, M. (2018). Analysis on Al2O3/water nanofluid flow in a channel by inserting corrugated/perforated fins for solar heating heat exchangers. Renewable Energy, 115, 1099-1108.

[2] Anitha, S., &Pichumani, M. (2022). Numerical analysis on heat transfer performance of industrial double-tube heat exchanger using CNT: Newtonian/non-Newtonian hybrid nanofluids. Journal of Thermal Analysis and Calorimetry, 147(17), 9603-9624.

[3] Sheikholeslami, M., Farshad, S. A., & Said, Z. (2021). Analyzing entropy and thermal behavior of nanomaterial through solar collector involving new tapes. International Communications in Heat and Mass Transfer, 123, 105190.

[4] Siavashi, M., & Miri Joibary, S. M. (2019). Numerical performance analysis of a counter-flow double-pipe heat exchanger with using nanofluid and both sides partly filled with porous media. Journal of Thermal Analysis and Calorimetry, 135, 1595-1610.

[5] Maisuria, M. B., Sonar, D. M., &Rathod, M. K. (2021). Nanofluid selection used for coolant in heat exchanger by multiple attribute decision-making method. Journal of Mechanical Science and Technology, 35, 689-695.

[6] Elsaid, A. M., El-Said, E. M., Abdelaziz, G. B., Sharshir, S. W., El-Tahan, H. R., &AbdRaboo, M. F. (2021). Performance and exergy analysis of different perforated rib designs of triple tubes heat exchanger employing hybrid nanofluids. International Journal of Thermal Sciences, 168, 107006.

[7] Bahiraei, M., &Monavari, A. (2020). Thermohydraulic characteristics of a micro plate heat exchanger operated with nanofluid considering different nanoparticle shapes. Applied Thermal Engineering, 179, 115621.

[8] Samiolo, M., &Verdin, P. G. (2022). Numerical modelling of a finless heat exchanger layout for electric vehicle application. Applied Thermal Engineering, 211, 118506.