Volume 11, Issue 7, July– 2026 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul191

Study & Analysis of Radiator Used in Locomotive

Dr. Anil Sahu[1]; Nikhil Koli[2]

[1;2]GH Raisoni College of Engineering, Pune

Publication Date: 2026/07/20

Abstract: High-speed trains have transformed modern transportation by providing fast and efficient travel options. However, the higher speeds and energy requirements of these trains have posed substantial challenges in managing thermal loads and ensuring the safety and efficiency of their radiator systems. This abstract presents a study on the design and optimization of high-speed train radiator systems, employing Ansys Computational Fluid Dynamics (CFD) for advanced analysis and enhancement. This research primarily aims to develop innovative radiator system designs specifically tailored to the unique demands of high-speed trains. This study utilizes Ansys CFD to perform comprehensive simulations and analyses aimed at optimizing airflow patterns, heat dissipation, and the overall performance of the radiator system. Furthermore, the study will examine how external factors, including fluctuating environmental conditions and train speeds, influence the performance of the radiator systems. The objective of this project is to investigate how various parameters—including radiator core shape, working fluid flow direction, frontal area, fin and tube spacing, coolant mass flow rate, fin material, tube pitch, fluid velocity, and inlet coolant temperature—affect automobile radiator efficiency in order to determine an optimized geometry through parametric analysis. The computational fluid dynamics (CFD) simulations were conducted to compare heat transfer and pressure drop across heat exchangers with varying parameters to identify optimal performance. The CFD results show a high degree of correlation with the actual experimental data. Various studies indicate that CFD has proven highly effective in reducing both the time and cost from concept to production.

Keywords: *Radiator, Heat Exchanger, CFD Analysis & Optimization.*

How to Cite: Dr. Anil Sahu; Nikhil Koli (2026) Study & Analysis of Radiator Used in Locomotive. *International Journal of Innovative Science and Research Technology*, 11(7), 346-353. https://doi.org/10.38124/ijisrt/26jul191

I. INTRODUCTION

➢ *Internal Combustion Engine and Cooling System*

An internal combustion engine (ICE) is a type of heat engine in which fuel burns inside a combustion chamber that forms part of the engine's working system. During combustion, the fuel reacts with an oxidizer, typically air, producing high-temperature and high-pressure gases. These gases expand rapidly and exert force on engine components such as pistons, turbine blades, or nozzles. The resulting motion converts the chemical energy stored in the fuel into useful mechanical energy that powers vehicles and industrial equipment.

A significant amount of heat generated during combustion does not contribute to useful work and must be removed to prevent overheating. Engine cooling systems are designed to dissipate this excess heat and maintain the engine within its recommended operating temperature range. Cooling is generally achieved using either air or liquid. Air-cooled engines are commonly used in lightweight or specialized applications because of their simple design and lower weight. However, liquid-cooled systems provide superior heat transfer and are widely used in automobiles, locomotives, heavy-duty machinery, and other high-performance applications.

In liquid-cooled engines, a coolant circulates through passages within the engine block and cylinder head, absorbing heat from engine components. The heated coolant then flows to a radiator, where the absorbed heat is transferred to the surrounding air before the coolant returns to the engine to repeat the cycle. Although water-based coolants are most commonly used, oil may also serve as a cooling medium in specific applications. A water pump maintains continuous coolant circulation, while a cooling fan increases airflow through the radiator to improve heat dissipation, particularly when vehicle speed is low.

The cooling system also includes several components that regulate operating temperature and pressure. A thermostat, located between the engine and the radiator, controls coolant circulation based on temperature. When the coolant temperature is below the desired operating level, the thermostat remains closed, allowing coolant to bypass the radiator and circulate directly through the engine. Once the coolant reaches the specified temperature, the thermostat opens and permits coolant flow through the radiator for effective cooling.

To further improve cooling efficiency, the system operates under pressure, which raises the boiling point of the coolant and reduces the possibility of vapor formation.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul191

Excessive pressure, however, can damage hoses and other cooling components. A radiator cap acts as a pressure-relief device by releasing excess pressure whenever it exceeds the designed operating limit, thereby protecting the cooling system from failure.

➢ *Locomotive Cooling System*

The cooling system of a locomotive diesel engine is an integrated arrangement that regulates the temperature of the engine, lubricating oil, and charged intake air. It typically consists of radiators, cooling fans, air ducts, shutters, heat exchangers, circulation pumps, expansion tanks, and interconnected water and oil pipelines. These components work together to remove excess heat, ensuring reliable engine performance and extending the service life of critical parts.

- *Influence of Cooling on Diesel Engine Performance*

During engine operation, only a portion of the thermal energy released by fuel combustion is converted into useful mechanical work. Approximately 20–30% of the generated heat must be removed by the cooling system to prevent excessive temperatures. As diesel engine power increases, the amount of heat produced also rises, making an efficient cooling system increasingly important.

Maintaining the correct coolant and lubricating oil temperatures is essential for efficient engine operation. If these temperatures become too low, the viscosity of the lubricating oil increases, resulting in greater mechanical friction and higher energy losses. Furthermore, excessive heat removal reduces thermal efficiency, leading to lower engine power output. Therefore, both coolant and oil temperatures should be maintained within their specified operating ranges to achieve optimum performance, efficiency, and reliability.

- *Importance of Charge Air Cooling*

Cooling the compressed intake air supplied by the turbocharger plays a vital role in improving diesel engine performance. Compressing air increases its temperature, which reduces air density and limits the amount of oxygen entering the combustion chamber. By lowering the intake air temperature, the density of the air increases, allowing more oxygen to participate in combustion.

This process enhances combustion efficiency, increases engine power, reduces fuel consumption, and lowers the thermal stress experienced by engine components. Modern high-performance diesel engines widely employ charge air cooling to achieve higher specific power while maintaining durability. In general, reducing the temperature of the compressed intake air by approximately 10°C can improve engine power by about 2–3%, depending on engine design and operating conditions.

- *Cooling of Hydraulic Transmission Fluid*

Hydraulic systems used in locomotives generate heat because of frictional and hydraulic losses during operation. If this heat is not effectively removed, the temperature of the hydraulic oil can exceed its recommended operating limit, reducing lubrication quality and accelerating component wear.

The amount of heat generated increases with higher power input, requiring cooling systems with greater heat removal capacity. When the cooling system is unable to dissipate sufficient heat, the hydraulic transmission must operate at reduced power to avoid excessive oil temperatures and potential equipment damage. Consequently, an effective hydraulic oil cooling system is essential for maintaining transmission efficiency, reliability, and long-term operational safety.

II. METHODOLOGY AND PROPOSED COOLANT

Studies comparing ethylene glycol and propylene glycol have shown that both are effective engine coolants; however, their thermophysical properties differ significantly. Propylene glycol-based coolants generally exhibit higher viscosity than ethylene glycol-based coolants when mixed with water, resulting in comparatively lower heat transfer performance. Consequently, ethylene glycol is often preferred in applications requiring efficient heat dissipation. Nevertheless, propylene glycol offers an important advantage in terms of safety because it has considerably lower acute oral toxicity. In the event of coolant leakage or disposal, propylene glycol-based mixtures pose less risk to human health and the environment than ethylene glycol-based coolants.

The thermophysical characteristics of engine coolants play a vital role in vehicle thermal management, directly influencing engine performance, operational efficiency, and overall safety. Previous studies recommend maintaining a minimum glycol concentration of approximately 25% in coolant mixtures. Concentrations below this level may contain insufficient corrosion inhibitors, reducing protection against rust and material degradation within the cooling system. For most automotive applications, glycol concentrations up to approximately 60% are considered suitable, as they provide an effective balance between heat transfer performance, freeze protection, and corrosion resistance. The optimal concentration ultimately depends on the operating conditions and the level of protection required.

Water is widely recognized as an excellent heat transfer medium because of its high specific heat capacity and thermal conductivity. However, its use alone has several limitations. Pure water freezes at 0°C and boils at 100°C under atmospheric pressure, making it unsuitable for many engine operating conditions. Although pressurized cooling systems increase the boiling point of water, the use of untreated water can still promote rust, corrosion, and scale formation within engine components.

Therefore, water is commonly mixed with glycol-based antifreeze to improve its thermal performance. Ethylene glycol lowers the freezing point while simultaneously increasing the boiling point of the coolant mixture, allowing the engine to operate safely across a wider

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul191

temperature range. Maintaining an appropriate glycol-to-water ratio also accommodates thermal expansion of the coolant and ensures reliable operation of the entire cooling system.

Table 1 Thermal properties of Water and Ethylene Glycol

Property	Water	Ethylene Glycol
Chemical Formula	H2O	C2H6O2
Molecular Weight	18.015 g/mol	62.07 g/mol
Boiling Point (°C)	100°C	197.3°C
Freezing Point (°C)	0°C (at standard atmospheric pressure)	-12.9°C (pure)
Density (g/cm³)	1.00 g/cm³ (at 4°C)	1.113 g/cm³ (at 20°C)
Specific Heat (J/g°C)	4.18 J/g°C	2.42 J/g°C
Thermal Conductivity (W/m°C)	0.6 W/m°C	0.24 W/m°C (at 20°C)
Viscosity (mPa·s)	0.89 mPa·s (at 20°C)	16.1 mPa·s (at 20°C)
Miscibility	Completely miscible with most liquids	Miscible with water
Toxicity	Non-toxic	Relatively low toxicity

➢ *Nanoparticles:*

- *Aluminum Oxide (Al_2O_3)*

Aluminum oxide (Al_2O_3) nanoparticles are widely used in nanofluids because of their excellent thermal properties and chemical stability. Their relatively high thermal conductivity enables them to enhance the heat transfer capability of conventional coolants when uniformly dispersed within the base fluid. As a result, Al_2O_3-based nanofluids can remove heat more efficiently than traditional coolants, making them suitable for applications requiring effective thermal management, including automotive engines, electronic devices, power generation systems, and industrial equipment. Typically, aluminum oxide nanoparticles have diameters ranging from 1 to 100 nm. Their extremely small size provides a large surface area-to-volume ratio, promoting better interaction between the nanoparticles and the surrounding fluid. This increased surface area enhances thermal energy transport and improves the overall thermal conductivity of the coolant. Consequently, Al_2O_3 nanofluids help lower operating temperatures, reduce thermal stresses on critical components, and improve system efficiency and reliability.

Despite these advantages, several practical challenges must be addressed before widespread implementation. Nanoparticles tend to agglomerate because of intermolecular forces, reducing suspension stability and diminishing heat transfer performance. Sedimentation during long-term operation may also affect coolant effectiveness and increase maintenance requirements. Therefore, appropriate dispersion techniques, suitable surfactants, and optimized nanofluid formulations are essential to ensure stable suspension, consistent thermal performance, and compatibility with cooling system components.

- *Copper Oxide (CuO)*

Copper oxide (CuO) nanoparticles are another widely investigated material for nanofluid applications because of their superior thermal conductivity and excellent heat transfer characteristics. Their nanoscale dimensions and high surface area-to-volume ratio significantly improve the thermal properties of conventional coolants, making CuO nanofluids particularly suitable for applications involving high heat generation, such as automotive cooling systems, electronic equipment, and industrial thermal processes.

When uniformly dispersed in a base fluid, copper oxide nanoparticles increase the coolant's effective thermal conductivity, enabling faster heat removal and more efficient temperature control. Improved heat dissipation helps maintain lower operating temperatures, enhances equipment performance, and extends the service life of temperature-sensitive components.

Maintaining the stability of CuO nanofluids is critical for achieving consistent long-term performance. Without proper stabilization, nanoparticles may agglomerate or settle, reducing thermal conductivity and impairing coolant circulation. To overcome these issues, effective dispersion methods and suitable stabilizing agents are commonly employed to maintain a homogeneous suspension. In addition to improving heat transfer, copper oxide nanoparticles may also provide a degree of corrosion resistance to metallic components because of their chemical characteristics. This added protection can reduce material degradation, improve system durability, and minimize maintenance requirements in cooling systems.

Table 2 Thermal Properties of Al2O3 & CuO

Property	Aluminum Oxide Nanoparticles (Al2O3)	Copper Oxide Nanoparticles (CuO)
Chemical Formula	Al2O3	CuO
Colour	White	Black
Particle size	Typically <100nm	Typically<100nm
Density	3.95g/cm3	6.31g/cm3
Thermal Conductivity	High	Moderate to High
Melting Point	2072 ºC	1201 ºC
Toxicity	Safe	May pose health risks if inhaled

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul191

➢ *CFD Analysis of Radiator*

ANSYS CFD analysis represents a cutting-edge approach to understanding and optimizing fluid dynamics, offering engineers and scientists a powerful tool to simulate, analyze, and fine- tune fluid flows in diverse applications. It empowers users to explore and enhance the performance of everything from aircraft and automotive designs to HVAC systems and industrial processes. With ANSYS CFD, complex physical phenomena such as heat transfer, turbulence, and multiphase flows can be comprehensively investigated, enabling engineers to make data-driven decisions for improved efficiency, safety, and performance. The software's advanced capabilities make it an indispensable resource in industries ranging from aerospace and automotive engineering to energy, providing a deeper understanding of fluid behavior and helping organizations achieve innovative and efficient solutions.

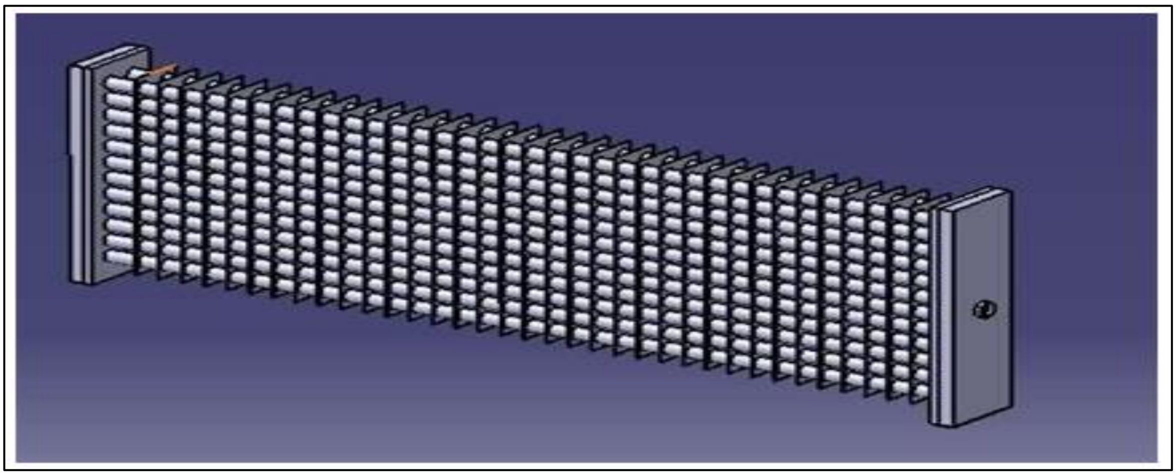
Fig 1 CAD Model of Radiator

➢ *Iteration 1: Air-Water*

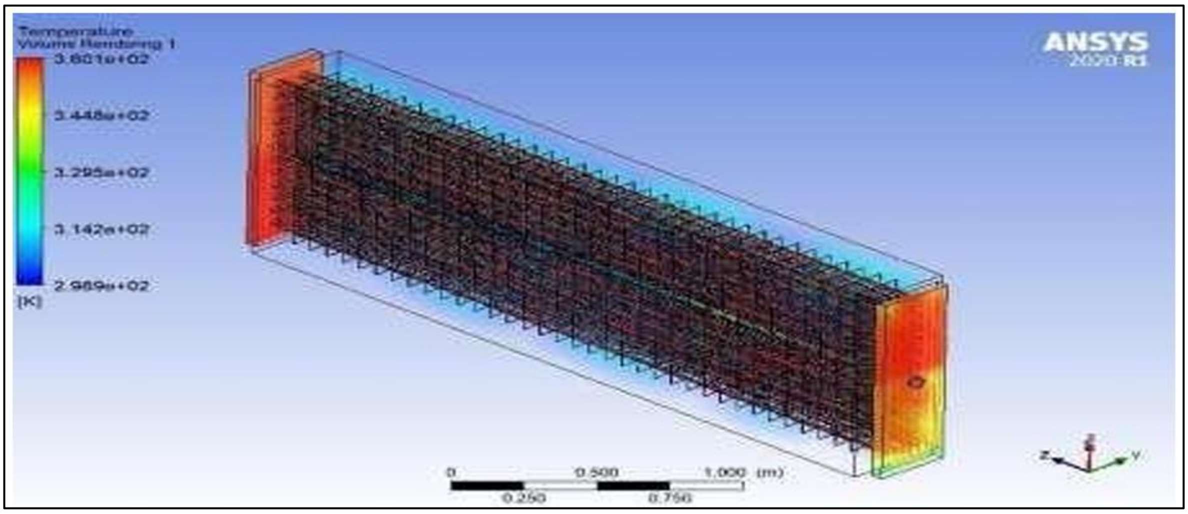

Fig 2 Temperature Contour of Water

Area-Weighted Average Static Temperature	(c)
inlet_1	86.999994
inlet_2	25.999994
outlet_1	83.49386
outlet_2	41.208617
Net	33.643399

Fig 3 Temperature Result of Only Water

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul191

➢ *Iteration 2: Air-Ethylene Glycol*

To increases the Heat transfer rate in radiator, change of working medium is implemented to know the highest rate of temperature reduction.

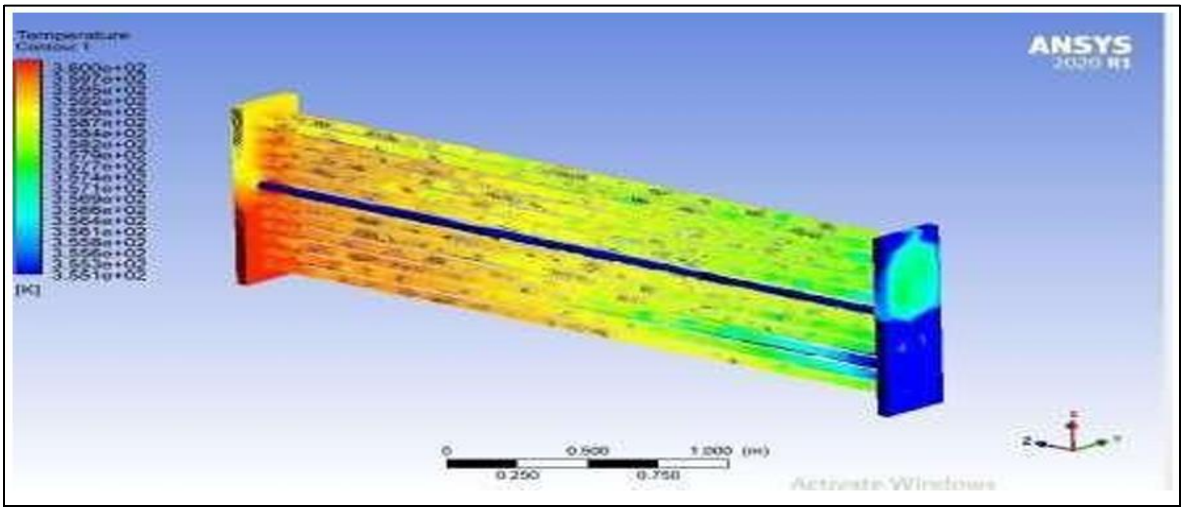

Fig 4 Temperature Contour for Fluid Medium at Inlet and Outlet

Area-Weighted Average Static Temperature	(c)
inlet_1	86.999994
inlet_2	25.999994
outlet_1	81.914423
outlet_2	35.678173
Net	30.879673

Fig 5 Temperature Results

➢ *Iteration 3: Influence of Aluminum Nano Particles in Ethylene Glycol*

The integration of nanoparticles into glycol-based radiator fluids introduces significant enhancements to cooling efficiency and thermal conductivity. By dispersing nanoparticles, such as graphene or aluminum oxide, within the glycol solution, the overall heat transfer capability of the coolant increases due to the augmented thermal conductivity and convective heat transfer coefficients. These nanoparticles create a stable suspension within the fluid, effectively improving heat dissipation from the radiator surface to the surrounding air.

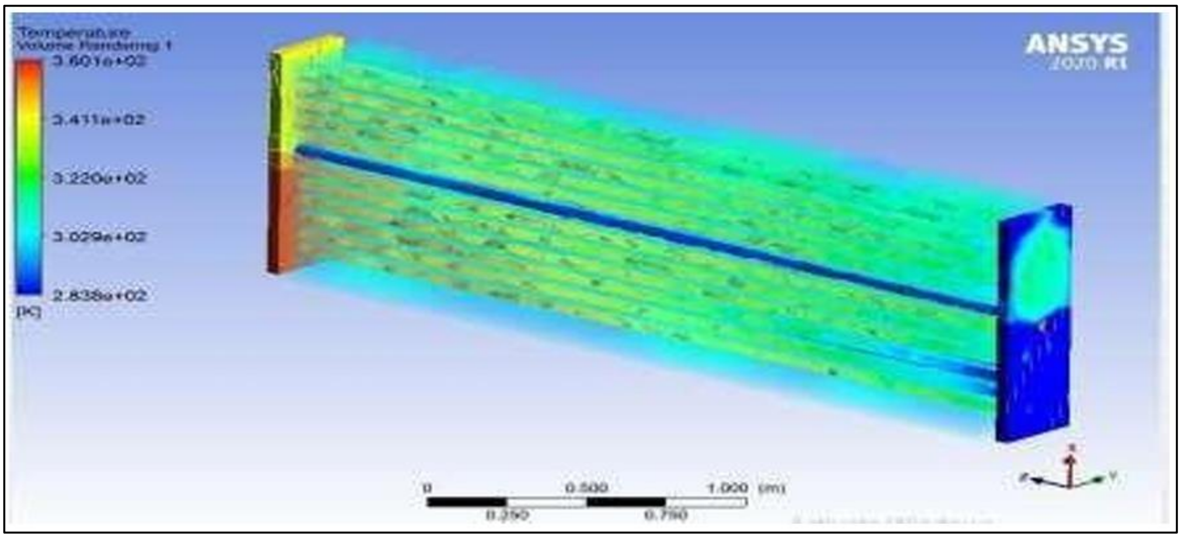

Fig 6 Temperature Contour Results

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul191

Area-Weighted Average Static Temperature	(c)
inlet_1	86.999994
inlet_2	25.999994
outlet_1	78.54046
outlet_2	37.610984
Net	31.844069

Fig 7 Temperature Results

➢ *Iteration 4: Influence of Copper NanoParticles in Ethylene glycol*

Copper and aluminum oxide nanoparticles exhibit distinct properties and are utilized in various applications due to their unique characteristics. Copper nanoparticles are known for their excellent thermal and electrical conductivity, making them ideal for applications such as thermal interface materials, conductive inks, and electronic devices. Additionally, copper nanoparticles possess antimicrobial properties, making them suitable for use in healthcare and antimicrobial coatings.

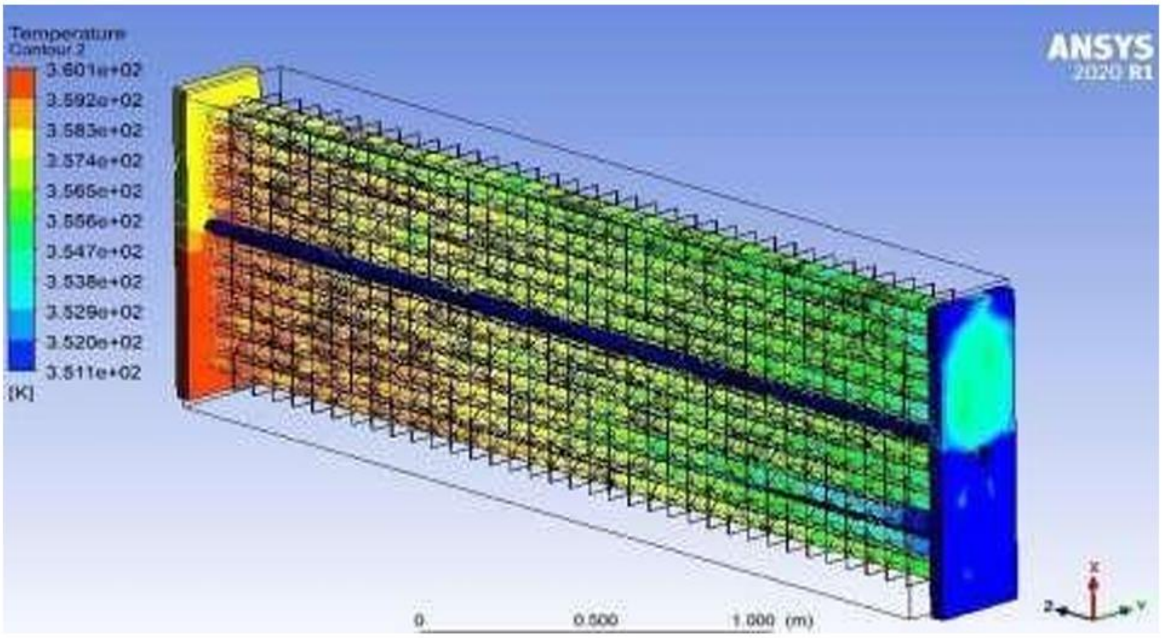

Fig 8 Temperature Contour Plots of Fluid

Area-Weighted Average Static Temperature	(c)
inlet_1	86.999994
inlet_2	25.999994
outlet_1	77.953882
outlet_2	34.378556
Net	30.228857

Fig 9 Temperature Results

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul191

➢ *Iteration 5: Optimization of Fins*

Optimize the Fin Design from flat plates to zigzag plates with Ethylene glycol & 5% Copper oxide Nano particle as working medium for better result procurement. Optimizing the fin design in a locomotive radiator from a parallel to a zigzag shape can significantly enhance airflow efficiency and heat dissipation. The transition to a zigzag configuration introduces turbulence, which disrupts the boundary layer and promotes more effective heat transfer between the radiator fins and the passing air. This alteration maximizes the contact area between the fins and the air flow, facilitating better cooling performance. Furthermore, the zigzag pattern reduces air resistance, allowing for smoother passage and increased air flow velocity through the radiator.

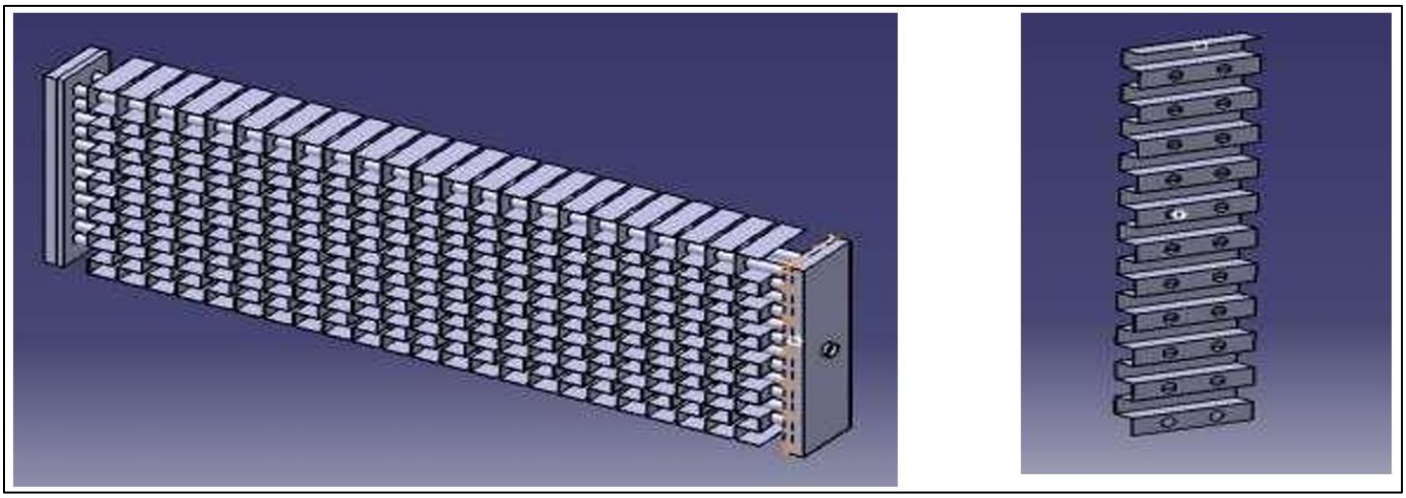

Fig 10 Zig-Zag Fin Plates for Optimization of Radiator

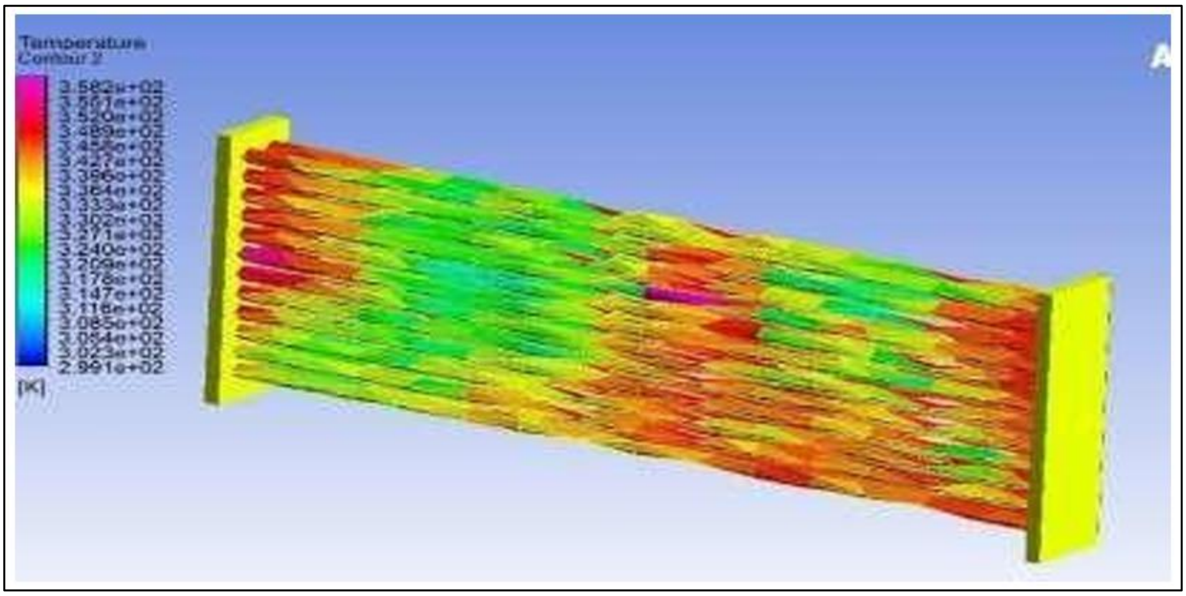

Fig 11 Temperature Counter

Area-Weighted Average Static Temperature	(c)
inlet_cold	26
inlet_hot	87
outlet_cold	75.419368
outlet_hot	35.281473
Net	30.667842

Fig 12 Temperature Result

III. RESULT & DISCUSSION

Table 3 Result

Sr. No	Type Of Analysis	T(Fluid)Inlet 0_C	T(Fluid)Outlet 0_C	T(Air)Inlet 0_C	T(Air) Outlet 0_C
1.	Air – water	87	83.49	26	41.20
2.	Air – Glycol	87	81.91	26	35.67
3.	Air – Glycol with 5% aluminum oxide	87	78.540	26	37.61
4.	Air – Glycol with 5%Copper oxide	87	77.95	26	34.37
5.	Optimizedfine with Air – Glycol with 5%Copper oxide	87	75.41	26	35.28

The CFD analysis of locomotive radiators using water, glycol, glycol with 5% aluminum oxide nanoparticles, and glycol with 5% copper oxide nanoparticles provides valuable insights into their respective cooling performances. Despite glycol's antifreeze properties, glycol-based solutions generally exhibited higher outlet temperatures compared to water, indicative of lower thermal conductivity. However, the incorporation of aluminum oxide nanoparticles marginally improved the cooling efficiency of glycol, reducing outlet temperatures and enhancing heat transfer rates. Remarkably, glycol with 5% copper oxide nanoparticles demonstrated the most promising results, with significantly lower outlet temperatures and enhanced thermal conductivity compared to other variants. The superior performance of copper oxide nanoparticles can be attributed to their excellent thermal and electrical conductivity properties, making them highly effective in heat dissipation and thermal management applications. Thus, the CFD analysis suggests that glycol with 5% copper oxide nanoparticles emerges as the most efficient coolant option for locomotive radiators, offering optimal cooling performance and improved operational reliability. Note Ethylene glycol with 5% Copper oxide Nano particle has the height rate of heat transfer compared to any other.

IV. CONCLUSION

- Effectiveness has been calculated analytically for heat dissipation and outlet temperature.
- Ethylene Glycol does not significantly change the heat transfer rate compared to pure water. However, nanoparticals of aluminum oxide and copper oxide have high values for heat transfer rate when added to the solution of Ethylene Glycol.
- The modified coolant used Ethylene Glycol with 5% of copper oxide gives lower outlet temperature for both convectional fin design and modified fin design.
- Hence, the present study with modified fin design and modified coolant improves the performance of radiator there by it improves efficiency of locomotive engine.

REFERENCES

[1]. Mr. Shanker T, Mr. Periyannan (2021) Design And Analysis of Circular Radiator SSRG International Journal of Mechanical Engineering Volume 8 Issue 4, 25-29, April 2021 ISSN: 2348 – 8360 /doi:10.14445/23488360/IJME-V8I4P103 ©2021 Seventh Sense Research Group.

[2]. Chavan D. K & Tasgaonkar G. S (2013) “Study, Analysis And Design Of Automobile Radiator (Heat Exchanger) Proposed With Cad Drawings And Geometrical Model Of The Fan” ISSN 2249-6890 Vol. 3, Issue 2, Jun 2013, 137-146

[3]. Syed Abuthahir.M, Vivek Sidharth.R, Swaminathan.R3, Joseph Manickam.A (2016) “Design Modification and Analysis of Helical Fins Used in Locomotive Engines Radiator” Vol. 5, Issue 5, May 2016

[4]. Wenbin Qiu, Qiyuan Yu, Jinyuan Zhao (2017) “Research and Analysis of Cooling System for Diesel Locomotive”

[5]. Ramesh J. Ladumor, Prof. V. Y Gajjar, Prof. K.K.Araniya (2014) “A Review Paper on Analysis of Automobile Radiator” Volume I Issue VIII, ISSN 2321-2705

[6]. Hiyam Adil Habeeb, Ahmed Esmael Mohan (2020) “Analysis of Engine Radiator Performance at Different Coolant Concentrations and Radiator Materials” ISSN: 2277-3878, Volume-8 Issue-6, March 2020

[7]. Qiong Jia, Jianbin Zang, Deng Pan, (2015) “Analysis of high speed train equipment cabin temperature field based on numerical simulation” Procedia Engineering 121 (2015) 1954 – 1961

[8]. Upendra Kulshrestha, Gaurav Kumar Manu Augustine and Sanjay Mittal (2014) “CFD Analysis of Automobile Radiator – A Review” *(IJERA) ISSN: 2248- 9622*

[9]. Sudalai Suresh Pungaiah, and Chidambara Kuttalam Kailasanathan (2020) “Thermal Analysis and Optimization of Nano Coated Radiator Tubes Using Fluid Dynamics and Taguchi Method”

[10]. Prof. V. C. Pathade, Sagar R. Satpute , Mayur G. Lajurkar, Gopal R. Pancheshwar Tushar K. Karluke, Niranjan H. Singitvar (2017) “Design And Analysis Of Car Radiator By Finite Element Method” *Vol-3 Issue-2 2017 IJARIIEISSN(O)-2395-4396*