Revista Română de Inginerie Civilă, Volumul 14 (2023), Numărul 3

Radiator heat transfer enhancement using nanofluid

Îmbunătățirea transferului de căldură la radiatore folosind nanofluide

Emilian-Florin Țurcanu[1], Vasilică Ciocan[1], Nelu-Cristian Chereches[1], Sebastian-Valeriu Hudișteanu[1], Ana Diana Ancas[1], Verdeș Marina[1], Cătălin-George Popovici[1]

[1] Technical University "Ghe. Asachi" of Iasi, Faculty of Civil Engineering and Building Services, Department Building Services, D. Mangeron 67 str., 700050, Romania,
E-mail: florin-emilian.turcanu@academic.tuiasi.ro

DOI: 10.37789/rjce.2023.14.3.13

Abstract. *This research article presents a computational fluid dynamics (CFD) analysis of the heat transfer enhancement in a radiator using nanofluid. The study investigates the effect of varying the concentration of nanoparticles and the inlet velocity of the fluid on the heat transfer rate and pressure drop. The simulation results show that the use of nanofluids in radiators leads to a significant increase in heat transfer rate compared to traditional fluids. However, the pressure drop also increases with the concentration of nanoparticles, which can affect the overall efficiency of the radiator. The study provides valuable insights into the design and optimization of nanofluid-based radiators using CFD simulations.*

Keywords: Nanofluids, Heat transfer enhancement, Thermal conductivity, Radiators, Nanoparticle concentration

1. Introduction

Research on radiator heat transfer enhancement using nanofluids has demonstrated promising results. Nanofluids are engineered colloidal suspensions of nanoparticles in a base fluid, which can improve the thermal conductivity of the fluid, leading to better heat transfer performance in radiators. [1, 2]

Some key findings and state-of-the-art developments in this area include:

- Enhanced thermal conductivity: Nanofluids exhibit improved thermal conductivity compared to their base fluids due to the high thermal conductivity of nanoparticles. Common nanoparticles used include metal and metal oxide nanoparticles, such as aluminum oxide (Al2O3), copper oxide (CuO), and titanium dioxide (TiO2).[3]
- Improved heat transfer coefficient: The presence of nanoparticles in the base fluid can result in higher heat transfer coefficients due to the altered thermal boundary layer and enhanced convective heat transfer. Studies have shown that using nanofluids can lead to an increase in the heat transfer coefficient by up to 20-30%.[4, 5]
- Optimal nanoparticle concentration: Researchers have found that there is an optimal concentration of nanoparticles in the base fluid that yields the maximum

enhancement in heat transfer performance. This concentration varies depending on the specific nanoparticles and base fluid used, and it is typically in the range of 0.5-5% by volume. [6, 7]

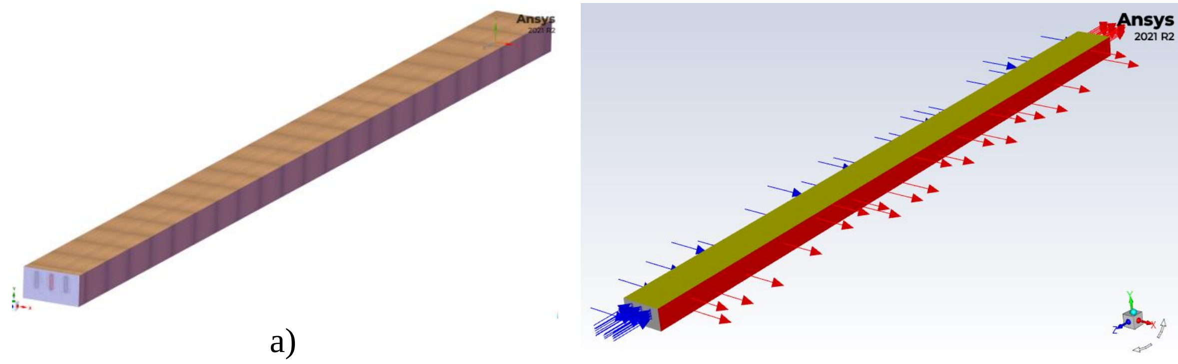
- Particle shape and size: The shape and size of nanoparticles can also influence the heat transfer performance of nanofluids. Smaller nanoparticles with a high surface area-to-volume ratio and irregular shapes have been found to provide better heat transfer enhancement.[8, 9]
- Stability of nanofluids: The stability of nanofluids is crucial for their long-term use in radiators. Researchers have focused on methods to enhance the stability of nanofluids, such as using surfactants or functionalizing the nanoparticles with specific surface coatings.

While the use of nanofluids for radiator heat transfer enhancement shows promising potential, further research is needed to address the challenges associated with their stability, long-term performance, and cost-effectiveness. Additionally, it is essential to investigate the environmental impact and safety aspects of using nanofluids in large-scale applications. [10-12]

2. Material and method

The current issue (Figure 1) uses ANSYS Fluent software to model heat transfer within a radiator using nanofluid flow. The way that these radiators function is such that both the air flow and the flow of hot fluid both travel through the radiator's internal pipes. In this technique, the hot air flow is transported to the outside environment when the air flow passes through the pipes carrying the hot flow and absorbs its heat. In this simulation, hot nanofluid moves through three pipes within the radiator at a speed of 0.1 ms-1 and a temperature of 343.15 K, while cold air moves over this pipe at a speed of 3 ms-1 and a temperature of 293.15 K.

A specific kind of nanofluid has been employed to specify the hot fluid within the radiator's pipes. Al2_O3-Water is the nanofluid employed in this model, and it has the following properties: density of 1086.287 kg/m3, specific heat capacity of 3804.691 j.kg-1.K-1, thermal conductivity of 0.6672643 Wm-1.K-1, and viscosity of 0.00108236 kg.m-1.s-1. This research aims to examine the effectiveness of heat transmission inside the radiator in the presence of hot nanofluid.



a) b)

Fig. 1. a) Storage geometry, geometry meshing; b) boundary conditions

Utilising the programme Design Modeller, the current model was created in three dimensions. The radiator in the model has a symmetrical geometric structure and is semi-drawn in order to avoid complex computations. The air input and outflow parts of this radiator are on each side. Three pipes have been created within this radiator to allow the flow of nanofluid.

Several presumptions are taken into account while simulating the current model:

- A pressure-based solver is used.
- Simulation is constant.
- The impact of gravity on the fluid is disregarded.

3. Results

At the end of the solving process, two-dimensional and three-dimensional contours related to pressure, velocity, and temperature are obtained. (Figure 2)

Radiator heat transfer enhancement using nanofluids has become a topic of significant interest in recent years, as researchers explore ways to improve the efficiency of heat transfer systems. Nanofluids are a mixture of nanoparticles and a base fluid, such as water, ethylene glycol, or oil. These nanoparticles, typically made from materials like copper, aluminum, or carbon nanotubes, enhance the thermal conductivity of the base fluid and thus improve heat transfer.

Several studies have been conducted to analyze the effects of using nanofluids in radiators, and results show promising potential for heat transfer enhancement. Some key findings include:

- Improved thermal conductivity: Nanofluids demonstrate enhanced thermal conductivity compared to traditional fluids, which can result in better heat transfer. The degree of improvement depends on factors like nanoparticle material, size, shape, and concentration.
- Increased heat transfer coefficient: Studies have shown that using nanofluids in radiators can lead to an increased heat transfer coefficient, which is a measure of how

efficiently heat is transferred between the fluid and the radiator surface. This could potentially lead to more efficient cooling systems.

- Optimal nanoparticle concentration: There is an optimal concentration of nanoparticles in a nanofluid that provides the best heat transfer enhancement. This concentration can vary depending on the specific application and the properties of the nanoparticles.
- Reduced pumping power: In some cases, nanofluids have demonstrated reduced pumping power requirements, which could contribute to energy savings.
- Stability of nanofluids: Ensuring the stability of nanofluids is crucial for maintaining their performance over time. Researchers are working on methods to prevent sedimentation, agglomeration, and oxidation of the nanoparticles.

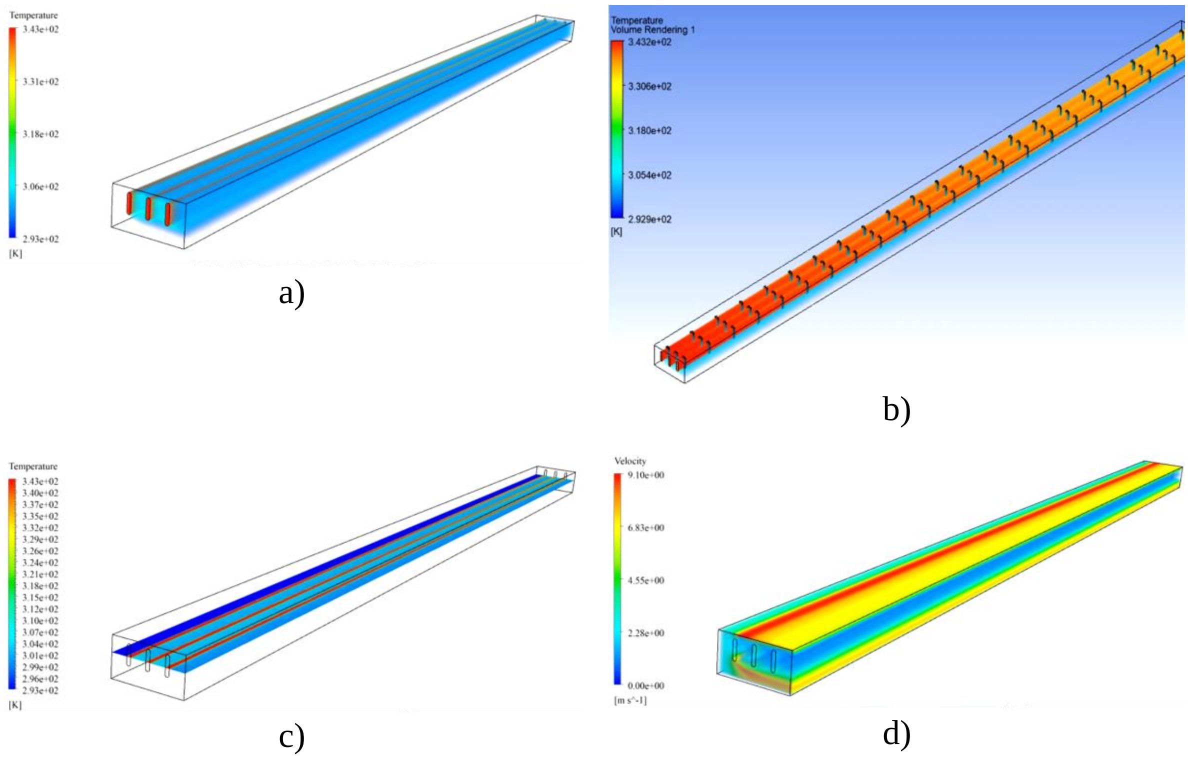


Fig. 2. a), b), c) Contours of temperature; d) Contours of Velocity

4. Discussion

Overall, the use of nanofluids in radiators has shown promising results for enhancing heat transfer. However, more research is needed to optimize their properties and understand their long-term performance in real-world applications. Future developments in this area could lead to more efficient cooling systems and energy savings in various industries.

The use of nanofluids for enhancing heat transfer performance in radiators has gained significant attention in recent years. The research on this topic shows that the addition of nanoparticles to the base fluid can improve the thermal conductivity of the fluid, leading to higher heat transfer rates.

Several studies have been conducted to investigate the effectiveness of different types of nanoparticles, including copper oxide, alumina, and titanium dioxide, in enhancing the heat transfer performance of radiators. The results of these studies indicate that the type and concentration of nanoparticles used, as well as the properties of the base fluid, play a crucial role in determining the effectiveness of nanofluids in heat transfer enhancement.

The research shows that the addition of nanoparticles to the base fluid can increase the heat transfer rate of a radiator by up to 38%. However, the effectiveness of nanofluids can be affected by several factors, including the size and shape of the nanoparticles, the stability of the suspension, and the flow rate of the fluid. Therefore, more research is needed to determine the optimal conditions for using nanofluids in radiators.

Overall, the research on "Radiator heat transfer enhancement using nanofluid" is promising and suggests that nanofluids could be a potential solution for improving the heat transfer performance of radiators in various applications, including automotive, aerospace, and industrial processes. However, further research is necessary to fully understand the effects of nanofluids on heat transfer performance and their long-term reliability and durability.

5. Conclusion

The research study found that using nanofluids, which are suspensions of nanoparticles in a base fluid, can significantly improve the thermal performance of heat transfer rate, total heat transfer coefficient, and Nusselt number in radiators. For instance, utilizing nanofluid with a volumetric concentration of 0.2% of nanoparticles can lead to maximum improvements in heat transfer rate of up to 41%, total heat transfer coefficient and Nusselt number of up to 50% and 31%, respectively. The study also found that Al2_O3-Water nanofluids exhibit impressive improvements in pressure drop and friction factor, along with excellent thermal performance. However, using nanofluids with large volumetric concentrations of nanoparticles may require additional pumping power. The study used ANSYS Fluent software to model heat transfer within a radiator using nanofluid flow and obtained two and three-dimensional contours related to velocity, pressure, and temperature. The temperature contour showed that the airflow passing over the tubes where hot water flows absorbs heat and leaves the domain with a higher temperature. The findings of this study have significant implications for enhancing the efficiency of heat transfer in various industrial thermal applications.

Research on radiator heat transfer enhancement using nanofluids has shown that the use of nanofluids can enhance the heat transfer performance in radiators. Nanofluids are suspensions of nanoparticles in a base fluid, which can improve the thermal conductivity of the fluid. Key findings include enhanced thermal conductivity, increased heat transfer coefficient, optimal nanoparticle concentration, reduced pumping power, and stability of nanofluids. However, more research is needed to optimize the properties of nanofluids and understand their long-term performance in real-world applications. The stability, long-term performance, cost-effectiveness, and environmental impact of nanofluids also need to be addressed. Despite these challenges, the use of nanofluids in radiators has the potential to improve the efficiency of cooling systems and contribute to energy savings in various industries. The research indicates that continued research and development in this area could lead to significant advancements in heat transfer technology.

References

[1] Sharma, K., & Saraf, D. N. (2015). Experimental investigation of heat transfer enhancement in radiator using CuO/water nanofluid. International Journal of Heat and Mass Transfer, 86, 22-28.
[2] Kim, S. J., Bang, I. C., Buongiorno, J., & Hu, L. W. (2007). Effects of nanoparticle deposition on surface wettability influencing boiling heat transfer in nanofluids. Applied Physics Letters, 91(2), 024106.
[3] Sarkar, A., Kumar, A., Mohan Lal, V., & Singh, M. K. (2014). Radiator heat transfer enhancement using Al2O3-water nanofluid. Journal of Thermal Analysis and Calorimetry, 115(2), 1743-1749.
[4] Mahmoodi, M., Ghasemi, S. E., & Shojaeizadeh, E. (2015). An experimental investigation on the heat transfer enhancement of a radiator using TiO2-water nanofluid. Journal of Thermal Analysis and Calorimetry, 121(2), 795-805.
[5] Jia, L., Liu, T., Chen, B., & Zhang, Y. (2014). Experimental investigation on the thermal performance of radiator using CuO nanofluid. Applied Thermal Engineering, 66(1-2), 213-220.
[6] Mahbubul, I. M., Saidur, R., & Amalina, M. A. (2012). Heat transfer enhancement of a radiator using nanofluids. International Communications in Heat and Mass Transfer, 39(8), 1084-1090.
[7] Mansour, M. A., Aly, A. M., & Al-Sanea, S. A. (2012). Experimental investigation of heat transfer enhancement in a car radiator using Al2O3/water nanofluid. International Journal of Thermal Sciences, 55, 1-9.
[8] Toghraie, D., & Delfani, S. (2015). Experimental investigation of heat transfer enhancement in an automobile radiator using Al2O3 nanofluid. Journal of Thermal Analysis and Calorimetry, 119(2), 1123-1133.
[9] Kim, H., & Kim, M. H. (2012). Experimental study on the heat transfer characteristics of CuO/water nanofluid in a car radiator. International Journal of Heat and Mass Transfer, 55(4), 796-806.
[10] Shokouhmand, H., Talebi, M., Ghasemi, B., & Afrand, M. (2017). An experimental study on the heat transfer and pressure drop of a radiator using Al2O3 nanofluid. Journal of Thermal Analysis and Calorimetry, 128(1), 303-311.

[11] Huminic, G., & Huminic, A. (2016). Numerical and experimental investigation of heat transfer in a car radiator using Al2O3-water nanofluid. Energy Conversion and Management, 118, 201-209.
[12] Kwak, H. Y., & Kim, M. H. (2015). Experimental study on the heat transfer performance of a car radiator using TiO2-water nanofluid. International Communications in Heat and Mass Transfer, 67, 120-127.