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Design and Analysis of Quality Improvement for Radiator Manufacturing Industry

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Abstract

This study investigates the design and analysis of quality control measures for the radiator manufacturing industry through the utilization of various nanofluids. Both experimental techniques and computational fluid dynamics (CFD) simulations using ANSYS software are employed to assess the performance of different nanofluids in enhancing the efficiency and reliability of radiators. The experimental aspect involves testing the heat transfer characteristics and thermal conductivity of nanofluids, while CFD simulations provide insights into fluid flow behaviors within radiator systems. By combining these approaches, a comprehensive understanding of the impact of nanofluids on radiator performance is achieved, facilitating the development of effective quality control strategies. The findings from this research contribute to advancing the utilization of nanofluids in radiator manufacturing processes, potentially leading to a more efficient and durable radiator system.

Keywords: Radiator, nanofluids, ANSYS, CFD

INTRODUCTION

By integrating experimental techniques with computational fluid dynamics (CFD) simulations, researchers are delving into the realm of nanofluids to optimize radiator performance. Nanofluids, which are engineered by suspending nanoparticles in traditional fluids, have shown promising heat transfer properties owing to their enhanced thermal conductivity. The experimental aspect, which involves assessing the heat transfer characteristics and thermal conductivity of nanofluids, provides tangible data for analyzing their effectiveness. Meanwhile, utilizing CFD simulations using ANSYS software offers a virtual platform to understand fluid flow behaviors within radiator systems, enabling researchers to visualize and analyze complex phenomena that are difficult to observe directly. The synergy between these two approaches allows for a comprehensive evaluation of the impact of nanofluids on the radiator performance. By gaining insight into the behavior of different nanofluids under various conditions, researchers can develop robust quality control measures tailored to enhance the efficiency and reliability of radiator manufacturing processes. The implications of this research are significant as they could potentially revolutionize radiator design and production, leading to more efficient and durable radiator systems. Moreover, advancements in nanofluid utilization could have broader implications beyond radiators, influencing various industries in which heat transfer plays a critical role [1].

PROPOSED METHOD

Choose nanoparticles with high thermal conductivity and compatibility with radiator materials [2]. Develop techniques to uniformly disperse nanoparticles within radiator materials to prevent agglomeration and ensure effective heat transfer. Evaluation of the compatibility of nanoparticle-infused radiator materials with coolant fluids and operating conditions. Rigorous testing is

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conducted to assess the thermal conductivity, heat dissipation efficiency, and durability of nanoparticle-enhanced radiators compared to traditional radiators. Iterate the process to optimize the nanoparticle concentration, dispersion techniques, and manufacturing parameters for scalable production [3].

EXPERIMENTAL SETUP

An experimental setup for testing the fluid rate and heat exchange of a single-panel radiator used in a Maruti 800 consists of several components. The radiator was made of aluminum and contained 33 tubes. A thermostat heater ensured a continuous temperature of 90°C for the fluid to pass through the radiator. The heater operated on an AC power supply, while the thermostat was powered by a DC supply, maintaining the temperature consistently. To circulate the fluid, a 0.5 centrifugal water pump operates at single-phase powers of 0.5 kW, 220 V, and 0.5 HP. The fluid was placed in a steel tank with a capacity of 10 liters. This comprehensive setup allows for precise testing and analysis of the radiator's performance in exchanging heat efficiently (Figure 1).

Calculation for Different Flow Rate Using Theoretical Method

The Hagen-Poiseuille formula for laminar flow in a cylindrical pipe is (Tables 1 and 2)

$$Q = \frac{\pi r^4 \Delta P}{8 \mu L}$$

Where, Q is the flow rate (volume per unit time), rr is the radius of the tubes, ΔP is the pressure difference, μ is the dynamic viscosity of the fluid, and LL is the length of the radiator.

Substituting values as r=0.01 m, ΔP= 1000 pa, μ=0.001 pas, L=1 m, we get Q=0.0157 m^3/s. The flow rate of nanoparticles through a pipe can be estimated using the Kozeny–Carman equation, which relates the pressure drop to permeability and dynamic viscosity.

$$Q = kA/L\ \mu$$

Where, μ is the dynamic viscosity of the fluid is the flow rate, k is the permeability of the medium, and L is the length of the pipe. Where $k=1 \times 10^{-12}$ m^2 for aluminum nanoparticles and $k=5 \times 10^{-14}$ m^2 for diamond nanoparticles and other values are the same pipe dimensions as water.

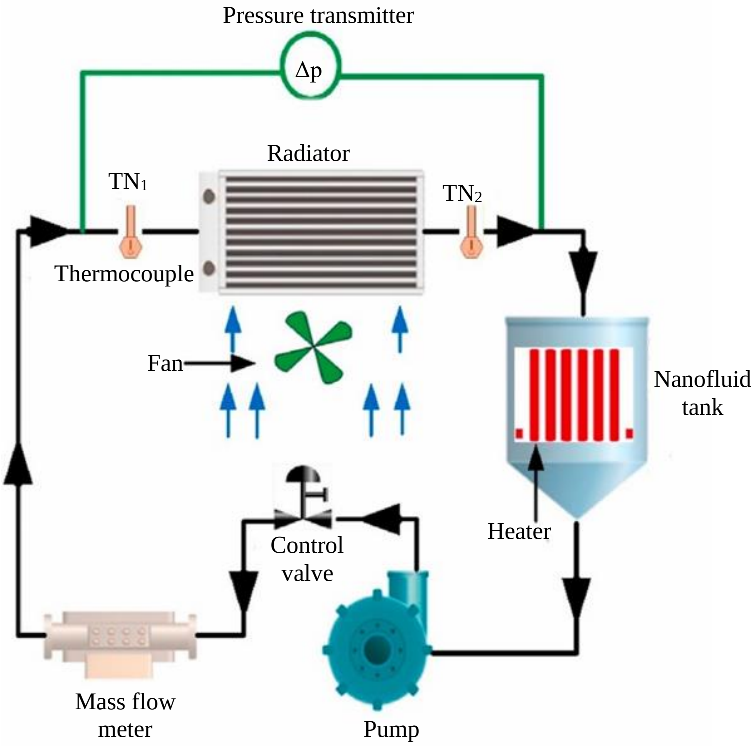

Figure 1. Experimental setup.

Table 1. Dimensions of radiator.

Radiator	Height (mm)	Length (mm)	Width (mm)
For Body	400	320	40
For Pipe	320	25	3

Table 2. Properties of fluids used.

Material	Density (kg/m³)	Specific heat (J/kg·K)	Thermal conductivity (W/m·K)
Water	998.2	4180	0.6
Aluminum oxide	3996	880	32
Diamond nano powder	3520	2380	2200

By substituting these values, the flow rate of the diamond nanoparticles was 4.02×10^{-12} m^3/s, and the flow rate of aluminum oxide nanoparticles was 8.04×10^{-11} m^3/s. In many cases, particularly in fluid dynamics, a reduced flow rate can indicate an improvement in quality depending on the context. In certain processes where precise control is essential, such as chemical reactions or material deposition, a reduced flow rate can mean that the substances are delivered more precisely and accurately. This can lead to improved quality of the final product [4]. Turbulence in the fluid flow can disrupt processes and cause uneven distribution or mixing. Lowering the flow rate can sometimes reduce turbulence, leading to smoother and more uniform processes, which may contribute to higher quality outcomes.

Some processes require sufficient time for interactions and reactions to occur. By reducing the flow rate, the retention time of substances within the system can be increased, allowing for more thorough mixing or reactions, which can enhance the quality of the final product. Lower flow rates can sometimes result in less waste or loss of material [5, 6]. This is particularly true in processes where excess material is undesirable, such as inexpensive or limited-supply substances. By reducing the flow rate to only what is necessary, waste can be minimized, and efficiency can be improved, indirectly contributing to higher quality. However, it is essential to consider the specific requirements of the process and desired outcomes. In some cases, higher flow rates may be necessary to meet the production demands or achieve certain process objectives. Therefore, although a reduced flow rate can often lead to improved quality, it may also have other consequences.

SIMULATION RESULTS

As per the physically measurable dimensions, a model is created in the design module of ANSYS FLUENT. The meshing of the radiator in the flow domain was calculated using the ANSYS Fluent meshing module. An unstructured tetrahedral mesh was used for meshing. ANSYS is used for governing equations. The governing equations are as follows: The solver setting is used for analysis in the 3D pressure-based solver with standard K–ω, and then the energy equation is activated. Here, we consider heat transfer. Therefore, the energy equation must start with the calculation of. Subsequently, the fluid properties and boundary conditions are applied to the solver. The algorithm for the coupling velocity was used. The higher-order upwind stream scheme was used for the pressure, momentum, turbulent kinetic energy, specific heat dissipation rate, and energy [7–10].

RESULTS AND DISCUSSION

Computational fluid dynamics simulations aimed at evaluating the efficacy of incorporating diamond and aluminum oxide nanoparticles to mitigate the flow rate and enhance the heat exchange rates have yielded promising results (Figures 1 and 2). By introducing these nanoparticles into the fluid, a noticeable reduction in the flow rate was observed, indicating their potential for flow-control applications. Moreover, the addition of nanoparticles led to a substantial increase in the heat exchange rates, suggesting their effectiveness in enhancing the thermal conductivity of the system. This outcome aligns with the objective of improving heat transfer efficiency in various engineering and industrial processes as shown in Figure 3. The CFD simulation provided valuable insights into the fluid dynamics and heat transfer mechanisms influenced by the presence of nanoparticles, providing a foundation for further exploration and optimization of nanoparticle-based additives for flow regulation and thermal management.

Figure 2. Geometry.

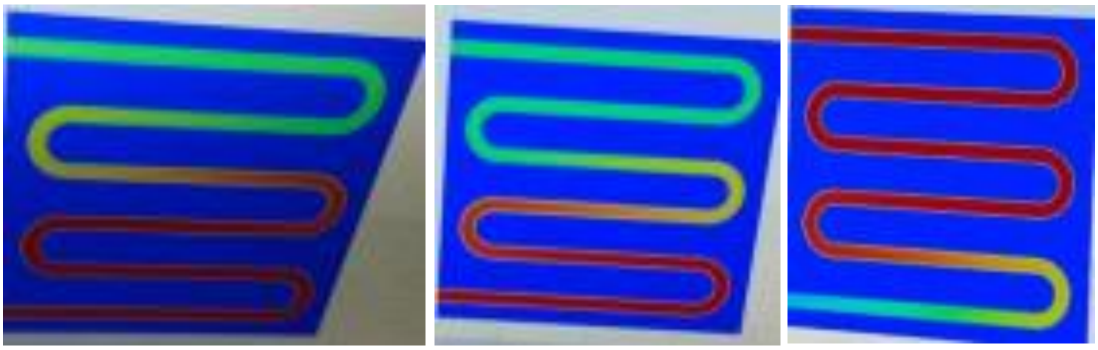

Figure 3. Temperature contour of diamond, aluminum oxide nanoparticles vs water.

These findings underscore the potential of nanoparticle-enhanced fluids in advancing heat transfer technologies, with implications for diverse fields ranging from energy systems to electronic cooling and beyond.

CONCLUSION

The CFD simulation results indicated that the inclusion of diamond and aluminum oxide nanoparticles in water as a coolant had a marginal effect on the flow rate within a radiator. While the addition of these nanoparticles slightly improved the fluid flow dynamics, the observed enhancement was not substantial enough to bring about a significant increase in the radiator's overall performance. Nanoparticles primarily influence the thermo-physical properties of the fluid, such as viscosity and density, which can have secondary effects on the flow behavior and heat transfer characteristics. However, the degree of impact was limited under the conditions analyzed in this study. These findings suggest that the choice of nanoparticle material and its concentration play a crucial role in determining the extent of performance enhancement. For instance, although diamond nanoparticles offer high thermal conductivity, their interaction with the base fluid and the operating conditions of the system may dilute their potential benefits. Similarly, aluminum oxide nanoparticles, although cost-effective and widely used, may not provide significant advantages in optimizing flow rates alone.

These results emphasize the need for further research to explore alternative nanoparticle materials or combinations that might yield more pronounced improvements. Factors such as particle shape, size, and surface treatments can be examined to optimize the nanoparticle-fluid interactions. Additionally, investigating higher concentrations of hybrid nanoparticles could uncover strategies for achieving better heat transfer efficiency and flow dynamics. Such studies could lead to the development of advanced coolant formulations that enhance the performance of radiators for automotive and industrial applications.

REFERENCES

1. Wong KV, De Leon O. Applications of nanofluids: Current and future. Adv Mech Eng. 2010;2:519659. DOI: 10.1155/2010/519659.
2. Nair AS. An overview of recent nanofluid research. Int Res J Pharm. 2014;5:73–7.
3. Li X, Zou C, Qi A. Experimental study on the thermo-physical properties of car engine coolant (water/ethylene glycol mixture type) based SiC nanofluids. Int Commun Heat Mass Transf. 2016;77:159–64. DOI: 10.1016/j.icheatmasstransfer.2016.08.009.
4. Leong KY, Saidur R, Kazi SN, Mamun AH. Performance investigation of an automotive car radiator operated with nanofluid-based coolants. Appl Therm Eng. 2010;30:2685–92. doi: 10.1016/j.applthermaleng.2010.07.019.
5. Elsebay M, Elbadawy I, Shedid MH, Fatouh M. Numerical resizing study of Al_2O_3 and CuO nanofluids in the flat tubes of a radiator. Appl Math Model. 2016;40:6437–50. doi: 10.1016/j.apm.2016.01.039.
6. Peyghambarzadeh SM, Hashemabadi SH, Hoseini SM, Seifi Jamnani MS. Experimental study of heat transfer enhancement using water/ethylene glycol-based nanofluids as a new coolant for car radiators. Int Commun Heat Mass Transf. 2011;38:1283–90. doi: 10.1016/j.icheatmasstransfer.2011.07.001.
7. Nagulkar NS, Lawankar SM. Improving the cooling performance of automobile radiator with ethylene glycol water-based ZrO2 nanofluid and comparison with Al_2O_3 nanofluid. Int Res J Eng Technol. 2017;4(7):1255–60.
8. Giwa SO, Adegoke KA, Sharifpur M, Meyer JP. Research trends in nanofluid and its applications: A bibliometric analysis. J Nanopart Res. 2022;24:63. DOI: 10.1007/s11051-022-05453-z.
9. Devendiran DK, Amirtham VA. A review on preparation, characterization, properties, and applications of nanofluids. Renew Sustain Energy Rev. 2016;60:21–40. doi: 10.1016/j.rser.2016.01.055.
10. Elias MM, Mahbubul IM, Saidur R, Sohel MR, Shahrul IM, Khaleduzzaman SS, et al. Experimental investigation on the thermo-physical properties of Al2O3 nanoparticles suspended in car radiator coolant. Int Commun Heat Mass Transf. 2014;54:48–53. DOI: 10.1016/j.icheatmasstransfer.2014.03.005.