

Heat Transfer Enhancement in Louvered Fin Flat Tube Radiator Using Hybrid Nanofluids [†]

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Abstract: This research explores the potential of hybrid nanofluids to improve the thermal efficiency of a car's louvered fin flat-tube radiator. Hybrid nanofluids were prepared by combining distilled water with a 0.1% vol. concentration of SiO₂ and MWCNT nanoparticles, using different ratios of nanoparticles: 80:20, 50:50, and 20:80. The experimental analysis focused on examining the heat-transfer performance of the radiator. The results clearly demonstrated a significant improvement in the radiator's thermal performance when using hybrid nanofluids. These nanofluids effectively enhanced the rate and coefficient of heat transfer. Notably, an increase of 15.6% in the Nusselt number was observed with the SiO₂–MWCNT 20:80 water containing a 0.1% volumetric concentration of nanoparticles. Overall, the findings highlight the promising application of hybrid nanofluids in boosting the thermal efficacy of car radiators.

Keywords: hybrid nanofluids; flat tube radiator; CFD; thermal performance; heat-transfer coefficient



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1. Introduction

The development of efficient cooling systems is crucial for optimizing the performance and longevity of automotive engines. The effectiveness of traditional coolants, such as water or ethylene glycol, is limited. However, recent advancements in nanotechnology have led to the emergence of hybrid nanofluids as promising alternatives for car radiator systems [1]. Hybrid nanofluids, consisting of a base fluid and nanoscale additives, offer improved thermal properties and enhanced heat-transfer capabilities [2]. Hybrid nanofluids exhibit significantly enhanced heat-transfer properties compared to conventional coolants [3].

This research presents an innovative method to improve car radiator efficiency using a mix of SiO₂ and MWCNT nanoparticles. The findings have important implications for making cars and other cooling systems work better, saving energy and being more eco-friendly.

2. Experimental Setup and Procedure

SiO₂ and MWCNT nanoparticles were dispersed in distilled water to create hybrid nanofluids. In this experiment, nanoparticle concentrations were set at 0.1 vol% with varying nanoparticle ratios of 80:20, 50:50, and 20:80. The formulation process involved magnetic stirring to achieve a uniform dispersion, followed by sonication to further enhance dispersion and break down agglomerates. Sodium carbonate was added as a surfactant to enhance stability. The resulting nanofluid exhibited improved stability and reduced agglomeration. In the experimental setup, a Suzuki Mehran car radiator made of aluminum was used. The setup included a pump for coolant circulation, a hot fluid reservoir with a heater, a flow meter, and valves for flow control. A total of five K-type thermocouples were placed at the radiator's inlet, outlet, and various points on its wall to measure the radiator's temperature. A data-acquisition system and laptop were utilized for real-time temperature

monitoring and analysis. A constant 65 °C coolant temperature was maintained while the ambient temperature was 27 °C. We analyzed the performance of the radiator under different fluid flow rates to assess its efficiency. Figure 1 represents the experimental arrangement.

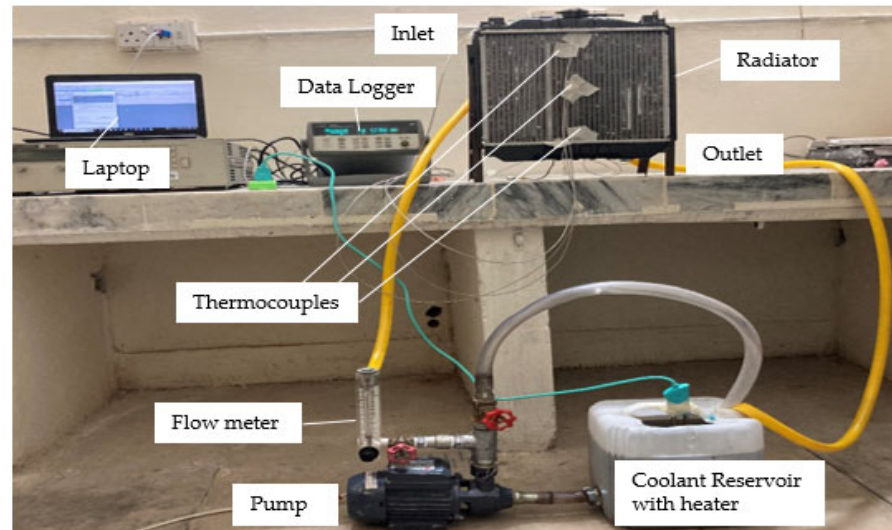


Figure 1. View of experimental arrangement.

The thermophysical properties of nanofluids were determined using correlations proposed by different scientists [4–6]. These properties are calculated using Equations (1)–(4).

$$\rho_{hnf} = (\varphi_{nf1} * \rho_{nf1}) + (\varphi_{nf2} * \rho_{nf2}) + (1 - \varphi) * \rho_{bf} \quad (1)$$

$$C_{P_{hnf}} = \frac{\varphi_{nf1} \rho_{nf1} C_{P_{nf1}} + \varphi_{nf2} \rho_{nf2} C_{P_{nf2}} + (1 - \varphi) \rho_{bf} C_{P_{bf}}}{\rho_{hnf}} \quad (2)$$

$$\mu_{hnf} = (1 + 7.3\varphi + 123\varphi^2) \mu_{bf} \quad (3)$$

$$K_{hnf} = \frac{[(\varphi_{nf1} K_{nf1} + \varphi_{nf2} K_{nf2}) / (\varphi_{nf1} + \varphi_{nf2}) + 2K_{bf} + 2(\varphi_{nf1} K_{nf1} + \varphi_{nf2} K_{nf2}) - 2\varphi K_{bf}]}{[(\varphi_{nf1} K_{nf1} + \varphi_{nf2} K_{nf2}) / (\varphi_{nf1} + \varphi_{nf2}) + 2K_{bf} - 2(\varphi_{nf1} K_{nf1} + \varphi_{nf2} K_{nf2}) - 2\varphi K_{bf}]} K_{bf} \quad (4)$$

The rate and overall coefficient of heat transfer were determined using Equations (5) and (6):

$$Q = \dot{m} C_p (T_{in} - T_{out}) \quad (5)$$

$$U = \frac{Q}{n A_s (LMTD)} \quad (6)$$

In Equation (5), Q represents the rate of heat transfer, $\dot{m}$ represents the mass flow rate (kg/s), C_p represents the specific heat capacity (J/kg·K), and T_{in} and T_{out} represent the inlet and outlet temperatures (K). In Equation (6), U represents the overall heat transfer coefficient, n represents the tube count of the radiator, and A_s represents the radiator tube surface area. Equation (7) was used to calculate the logarithmic mean temperature difference (LMTD):

$$LMTD = \frac{T_{in} - T_{out}}{\ln \frac{T_{in}}{T_{out}}} \quad (7)$$

The Nusselt number, denoted as Nu , can be calculated using Equation (8):

$$Nu = \frac{h_{avg} D_h}{k} \quad (8)$$

In this equation, h_{avg} represents the average coefficient of heat transfer, D_h represents radiator's hydraulic diameter, and k represents coolant's thermal conductivity.

The average coefficient of heat transfer denoted as h_{avg} , was determined using Equation (9):

$$h_{avg} = \frac{Q}{nA_s(T_b - T_{wall})} \quad (9)$$

where, Q represents the rate of heat transfer, n represents the number of tubes of the radiator, A_s represents the surface area of the radiator, T_b represents the bulk temperature, which is mean of the inlet and outlet temperatures of the coolant, and T_{wall} is the radiator's wall temperature.

The Prandtl number, denoted as Pr , was determined using Equation (10):

$$Pr = \frac{\mu C_p}{k} \quad (10)$$

3. Result and Discussion

In this study, the Prandtl number decreased as the SiO_2 -MWCNT nanoparticles were added, with the lowest value observed in the 20:80 ratio nanofluid. The nanofluid with a 20:80 ratio of SiO_2 -MWCNT exhibited the most effective heat-dissipation capabilities. Hence, nanoparticles increased the thermal diffusivity of the nanofluid compared to its kinematic viscosity, enhancing its heat-transfer properties.

The graphs in Figure 2 compare the heat-transfer rates and coefficients for distilled water and the SiO_2 -MWCNT hybrid nanofluids flowing at various ratios. The results show that hybrid nanofluids outperformed distilled water in terms of heat-transfer rates and coefficients. Both the volume flow rate and hybrid nanofluids contributed to the increased heat transfer.

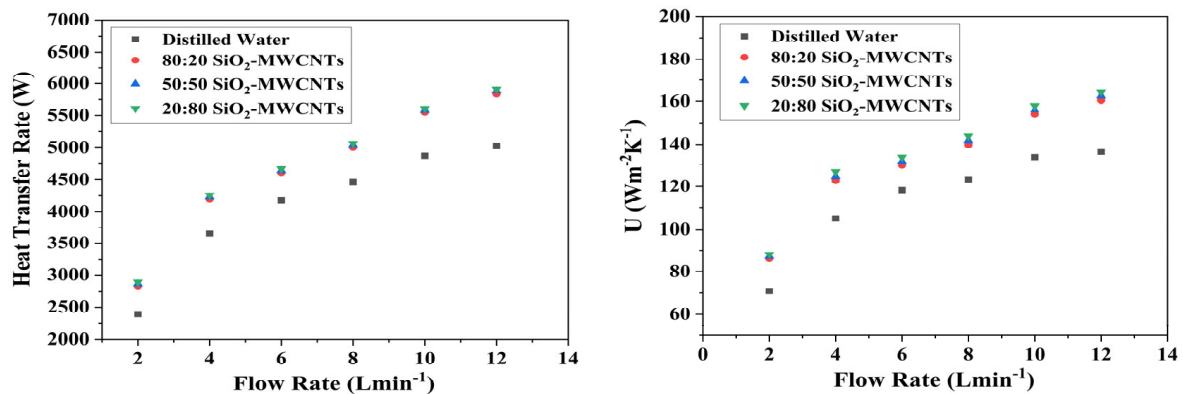


Figure 2. Rate and coefficient of heat transfer with varying flow rates of coolant.

In Figure 3, the graph compares the Nusselt number and Reynolds number for distilled water and the SiO_2 -MWCNT hybrid nanofluids with different ratios of nanoparticles. The outcomes demonstrated that for both the distilled water and nanofluids, raising the Reynolds number resulted in a rise in the Nusselt number. In comparison to distilled water, nanofluids consistently exhibited higher Nusselt numbers. Among the nanofluids, the SiO_2 -MWCNT 20:80 water nanofluid with a 0.1% concentration showed the highest enhancement in the Nusselt number, i.e., 15.63%.

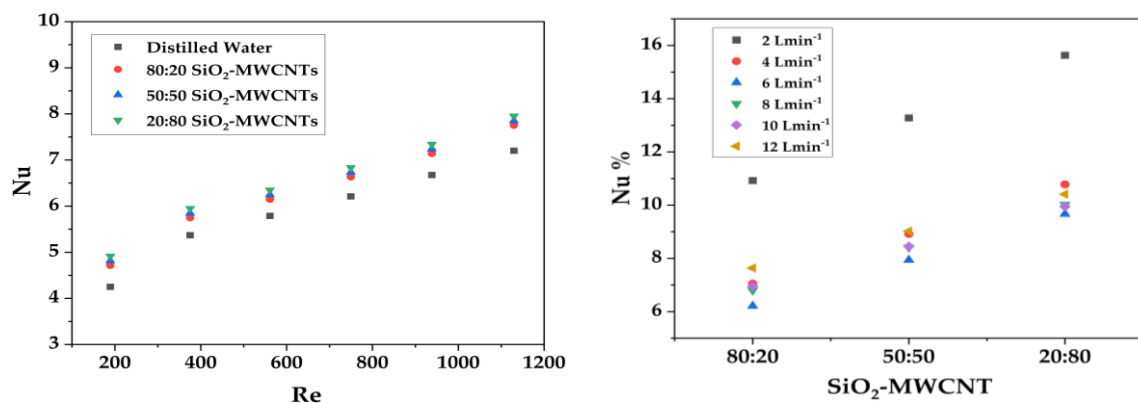


Figure 3. Relationship between Nusselt number and Reynold's number, and relationship between Nusselt number enhancement and different nanoparticle ratios.

4. Conclusions

This study examined the effectiveness of hybrid nanofluids in improving radiator thermal efficiency. Experimental analysis revealed that the combination of SiO₂ and MWCNT nanoparticles with distilled water enhanced its heat-transfer performance. Using the SiO₂-MWCNT 20:80 nanofluid, a 15.6% rise in Nusselt number was seen. These findings demonstrate the potential of hybrid nanofluids for optimizing cooling systems in automobiles and provide valuable insights for the design of efficient radiators. Overall, the study confirms the efficacy of hybrid nanofluids in enhancing thermal performance of car radiators.

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