Comparative assessment on heat transfer characteristics of a Truck Radiator using variousnano-additives

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Abstract

The thermal performance of tractor radiator is compared for various nanofluids of Cu/water (metal form)and with Al_2O_3/water,CuO/water (metal Oxide form)nanofluids as workings fluid. The maximum thermal management of nanofluid is identified and improved performance of tractor in its application gives a significant strength in improving the farm equipment development.Heat transfer in automobile is accomplished by means ofradiators. Throughout thisanalysis, an experimental analysison the enhanced heat transfer properties of a radiator by employing Cu/water and Al_2O_3/water,CuO/water nanofluids for 0.025, 0.05 and 0.075% volume fraction is carried out with entry temperature of 50°C - 60°C through the turbulent flow region. The experimental outcomes using Cu metal particles of nanofluid arerelated with Oxide and the theoretical values which displays arise in heat transfer coefficient. The metal form of nanofluids exhibitedsuperior heat transfer performance as an innovative substitute coolant for the radiators.

Keywords: Heat Transfer, Nanofluids, CuO/water and Cu/water, Tractor Radiator

1. Introduction

The decline of energy usage can be increased by increasing the efficiency of heat exchange systems and by incorporating several techniques for improving heat transfer. During the mid-1950s, several attempts were made to modify the configuration of the heat exchanger system using various fin forms or different tube extensions or rough surfaces [1-3].Several researchers have focused on the application of electrical or magnetic field techniques or vibration methods [4-6]. More improvement in heat transfer is continuously required, as the efficiency of these systems is based on the degree of cooling. New technologies and progressive liquid shaving superior prospective to enhance flow and thermal properties are two ways for increasing the rate of heat transfer and the latter options are dealt with in this article.Emerging progresses in nanotechnology have facilitated the creation of a new group of liquids called nanofluids. Such liquids are fluid suspensions comprisingelements that are slightly lesser than 100 nm and have a higher thermal conductivity of bulk solids than conventional fluids [7].Nanofluids are produced by the suspension of metallic or non-metallic oxide nano-additives in conventional heat transfer liquids[8]. Several authors have confirmed that these nano-additives can improve the performance of heat transfer.Researchers Pak and Cho[9] performed atest analysis on the convective turbulent heat transfer performances of 1-3 volt water nanofluid. It's percent. The number of Nusselt nanofluids increased with arise in the fraction of nanofluid volume and the number of Reynolds.Nguyenet al. [10] have conducted experiments with a heat exchanger type radiator and a 6. It's 8 vol. percent of Al_2O_3 in water produced a 40% increase in the coefficient of heat transfer.Forced convection heat transfer coefficients for water and water with Cu and CuO nano-powder blends are recorded in this paper under entirely turbulent environments. The experimentunit consists of a standard farm machinery tractor radiator and analyzes the effect of the functioningenvironments on its heat transfer efficiency.

The tractor engine radiator cooling is enhanced by nanofluid mechanism of heat transfer for its improved performance in agricultural work. If the tractor engine cooling is enhanced then using this farm equipment more agricultural field can be ploughed which can be utilized for cultivation within a short period of time.The research papers related to cooling of the tractor radiators using nanofluids are very less only. Therefore, this is an attempt to bring out the research interests on the cooling of tractor radiator using nanofluids.

2. Nano fluids Preparation

Production of nanofluids is a primary phase in laboratory testing. The basic criteria for nanofluids are, uniformly, stable suspension, sufficient stability, negligible agglomeration of particulate matter, no chemical variation of particulate matter or liquids, etc. Nano fluids areproduced by dissolvingnm sized solid elements into conventional liquids such as water, EG, oil, etc. In the process of nano fluids preparation, agglomeration is a critical issue. One-step or two-step methods are applied to prepare nano fluids.

2.1 Two-step method

Nano-additives were first developed in this process and then distributed in conventionalliquids. Particle dispersal is carried out by ultrasonic apparatus and also decreases the accumulation of particles. The nanofluid preparation and equilibrium process is asignificantmovement as it requires the extraction of the advantages of nanoparticles in the heat cycle.

The nano-additivesapplied in this analysis were copper and copper oxide, aluminum oxide nanoparticles about 40nm in diameter and 95%, and 99% purity. Characteristics of nanoparticles are revealed in Table.1, trials of 0.025, 0.05 and 0.075%, fluids without surfactants and following ultrasonic process for 2 h isdepicted in Fig.1.The samples demonstrated to be extremelysuitable in terms of homogeneous dispersal and long-standing stability of nanofluid residues for 3-4 hours (Fig. 2). A detailed characteristic of nanofluids prepared with base fluids are summarized in Table 2. Fig.3. shows the SEM images of the nanofluids. Particles are homogeneously distributed in the base fluid in an appropriate manner.


Ultrasonicator


Al_2O_3 nanofluid


CuO nanofluid


Cu nanofluid

Fig. 1Photographic view of Nanoparticle suspended in 5% EG + 95% as a base fluid

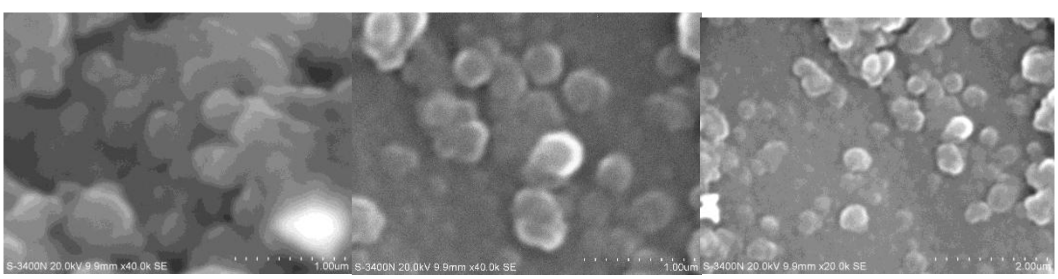
Fig.2Prepared Nanofluids samples

Table 1Characteristics of nanoparticle

Material	Grain size	Appearance	Purity	Density (Kg/m^3)	Specific heat (J/kgK)	Thermal conductivity (W/mK)
Al_2O_3	40nm	White powder	98%	3960	773	40
CuO	40nm	Black powder	95%	6500	535	76.5
Cu	40nm	Black powder	95%	8933	385	401

Table 2Characteristics of nanofluid and base fluid

Fluid	Density (Kg/m^3)	Specific heat (J/kgK)	Thermal conductivity (W/mK)	Viscocity (Kg/m^2s)
Water	997	4180	0.62	0.00065
Air	1.614	1005	0.024	0.0000184
Aluminium Oxide	1219	3353	0.754	0.00191
Copper oxide	1402	2935	0.77	0.00191
Copper	1592	2587	0.79	0.00191



(a) (b) (c)

Fig 3 SEM image of (a) CuO/water and (b) Cu/water (c) Al_2O_3/water

2. Experimental Setup

The experimental setup was depicted in Fig. 4 and Actual systemwas revealed in Fig.5. This investigationalarrangementconsists of a steel tank, an electric heat supply unit, a centrifugal pump, a flow meter, tubes, regulators, a fan, a DC energysource, 10 J-type temperature measurement thermocouples, and a heat exchanger (radiator). Inside the steel storage tank, an electric heater (1500W) was employed to reflect the engine and heat the fluid. The voltage regulatorwas attachedto control the temperature in the radiator. The specifications of the used tractor radiator are given in the Table 3.

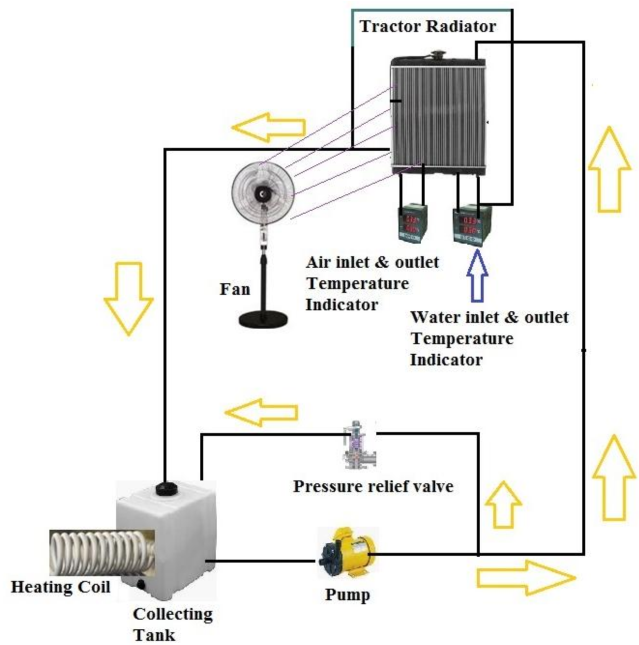


Fig 4Schematic arrangement of theinvestigationalsystem

In order to calculate and monitor the flow rate, a flow meter and dualcontrollers were used. The fluid flow was determined usingflexiblepipes with a centrifugal pump from the storage tank to the radiator systemwith a volume flow rate of 1–15 LPM. In all experimental phases, the flowingliquidwas maintained as same amount. Two J-type thermocouples are attached to the circuitlink to measure the entry and exit temperatures of the liquid. The tractor radiator had louvered fins and fortyhorizontalperpendicular aluminum tubes having a horizontal cross-section area. The space between the tube rows was packed with small, vertical aluminum fins. For the air side, an axial force fan was mounted along the radiator axis wall.

Fig 5.Photographic view of Radiatorsystem

Table 3Specifications of tractor radiator

Details	
Fin type	Ruffled
Fin thickness (cm)	0.01
Hydraulic diameter D_h (cm)	0.54
Frontal air sized dimension(m)	0.45x0.40
Number of tubes	80
External total area (m^2)	4.3
Internal tube area (m^2)	0.610

4. Nanofluid Thermo physicalcharacteristics

The governing correlationsassociatedfor thermal performance are determined by the below mentioned equations [11-14]

$$\rho_{nf} = \emptyset.\rho_p + (1-\emptyset).\rho_w \quad (1)$$

$$(\rho C_p)_{nf} = \emptyset(\rho C_p)_p + (1-\emptyset)(\rho C_p)_w \quad (2)$$

$$\mu_{nf} = \mu_w(123\emptyset^2 + 7.3\emptyset + 1)(3)$$

$$k_{nf} = \frac{k_p + (n-1)k_w - \emptyset(n-1)(k_w - k_p)}{k_p + (n-1)k_w + \emptyset(k_w - k_p)}(4)$$

5. Data Reduction

Calculation of heat transfer coefficient

In this analysis, the air-side and the tube-side heat transfer rates aremeasured by the following equations:

$$Q_a = m_a C_{p,a}(T_{a,o} - T_{a,i})(5)$$

$$Q_{nf} = m_{nf}C_{p,nf}(T_{nf,i} - T_{nf,o})(6)$$

The mathematics average of the heat transfer rate is given by:

$$Q_{ave} = 0.5(Q_a + Q_{nf}) \quad (7)$$

The performance of the heat exchangers is examined by ε-NTU method and the effectiveness, ε, is expressed by the following relation:

$$\epsilon = \frac{Q_{ave}}{(mC_p)_{min}(T_{nf,i} - T_{a,i})}(8)$$

The correlation of the effectiveness, NTU, and the minimum heat capacity flow rate at the air side are given by [15]:

$$\epsilon = \frac{1}{C^*}[1 - e^{-(1-e^{-NTU})}](9)$$

$$NTU = \frac{UA}{(mC_p)_{min}}(10)$$

$$C^* = \frac{(mC_p)_{min}}{(mC_p)_{max}}(11)$$

From theEqs. (9) and (10), the experimental overall heat transfer coefficient, UA, can be determined.

The overall heat transfer coefficient is calculated by the below mentioned overall resistances [16] by theactual values:

$$\frac{1}{UA} = \frac{1}{\eta_o h_o A_o} + \frac{\delta}{k_t A_t} + \frac{1}{h_i A_i}(12)$$

The tube-side heat transfer coefficient is found out using Dittus Boelter [17] relationship for the turbulentmovement

$$Nu = 0.0236Re^{0.8}Pr^{0.3}(13)$$

The air-side heat transfer coefficient is determined by usingrelationshipsuggested for the radiator as [15]:

$$Nu_a = [10.145 \times Ln(Re_a - 46.081)] \times Pr_a^{0.33}(14)$$

6. Result and Discussion

6.1 Effectof nanofluid on the overall heat transfer rate

Fig. 6 reveals the relation between total heat transfer rate for Cu / Water nanofluid for various nanofluid flow rate at different fan speeds. From the figure, it is noted that the average rate of nanofluid heat transfer increased dramatically with arise in temperature. It is due to the non-uniform fraction of the particle in the pipeline [18]. Ding and Wen [19] examined elementsrelocation by shear rate gradient, viscosity gradient, and Brownian movement, that induces particle concentration non-uniformity. In addition, the addition of nanoparticles has resulted in a higher thermal conductivity of the fluid and hence increased the rate of heat transfer [20-21].

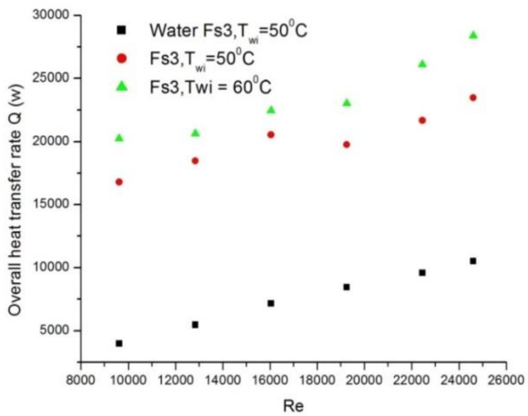


Fig 6 Overall heat transfer rate Vs Reynolds number for 0.025 % vol fraction

6.2 Comparison of heat transfer coefficient of nanofluidsfor different air flow rate

In Fig.7(a) (b) (c) the overall heat transfer coefficient increased for various fan speeds (Fs1, Fs2, Fs3).The investigationaloutcomes showed that, as the fan speed increased, the average coefficient of heat transfer increased with a fixed volume fraction of 0.025%. The average coefficient of heat transfer of Cu / water nanofluid indicates an increased coefficient of heat transfer thanother nanofluids.

Cu/Water

- Decreases with the rising inlet temperature of the nanofluid and decreases with the introduction of base fluid nanoparticles.
- The coefficient of heat transfer is increased by 9% from concentration of 0.025% to 0.05% and from concentration of 0.05% to 0.075% by 19%.
- The coefficient of heat transfer increases by 21.68% from a minimum concentration of 0.025% to a maximum concentration of 0.075%.

CuO/Water

- The heat transfer coefficient increased by 7.4% from 0.025% to 0.05% concentration and by 16% increase from 0.05% to 0.075% concentration.

- The coefficient of heat transfer increased by 23% from a lower fraction of 0.025% to a higher fraction of 0.075%.

Al_2O_3/water

- The heat transfer coefficient increased by 5% from 0.025% to 0.05% concentration and by 10.2% increased from 0.05% to 0.075% concentration.
- The coefficient of heat transfer increased by 14.5% from lower fractions of 0.025% to a higherfraction of 0.075%.
- The average coefficient of heat transfer increased substantially in nanofluid relative to pure water.

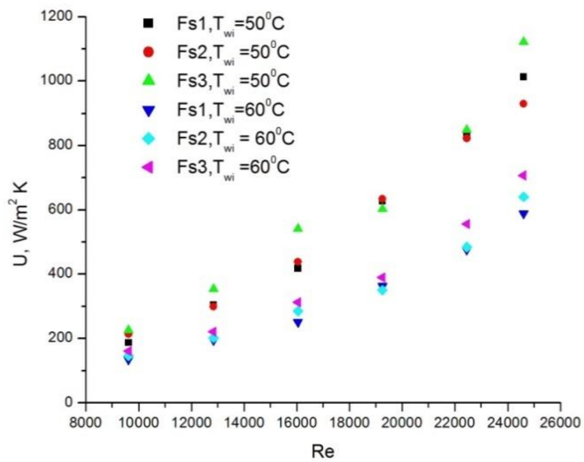
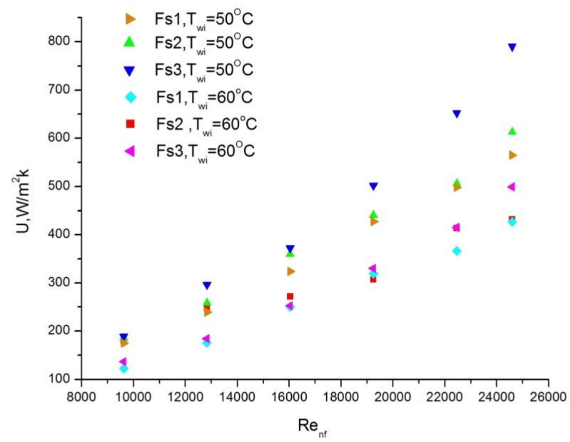


Fig.7(a) The Overall heat transfer coefficient Cu/water at the concentration of 0.025 vol%



(a) CuO/water

Fig.7(b) The Overall heat transfer coefficientCuO/water at the concentration of 0.025 vol%

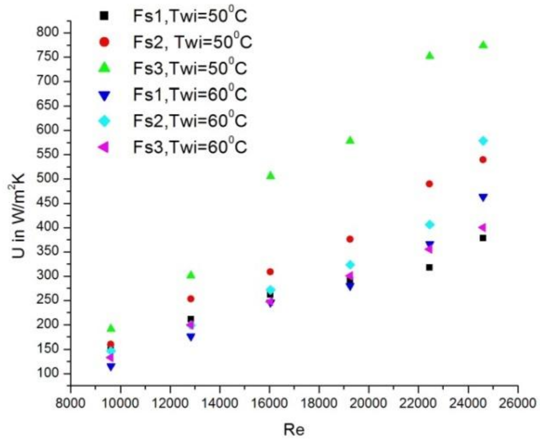


Fig 7. (c) The Overall heat transfer coefficient Al_2O_3/water at the various concentrations

Fig. 8displays the experimental data and the theoretical coefficient of heat transfer. It reveals that Nuincreased with higher Re, the fraction of volume and the air flow rate as revealed in Fig.9. The average values for the Nu are 620 for the Cu / water nanofluid, respectively. It shows that the Cu / water nanofluid is stronger than the conventional liquid for heat transfer change relative to pure water.Animprovedblending of nanoparticles was witnessed during a higher flow rate of nanofluids which enhanced thermal transport characteristics resulting in a higher heat transfer rate [22].Reasons for increased number Nusselt are due to increased thermal conductivity, Brownian movement of nano-additives and movement of nanoparticles related to greater volume fractions of nano-additives. The higher Nucould also be due to the improvement of the thermo-physical characteristics of nanofluids and the improved consequence of liquid radiation on the inner surface of tubes [23-25].

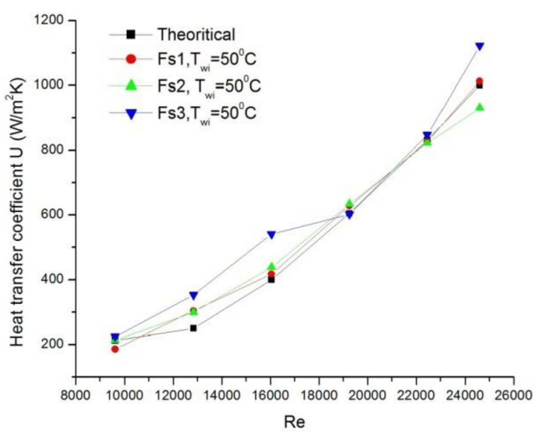


Fig.8Theoretical and experimental heat transfer coefficient for different Reynolds number

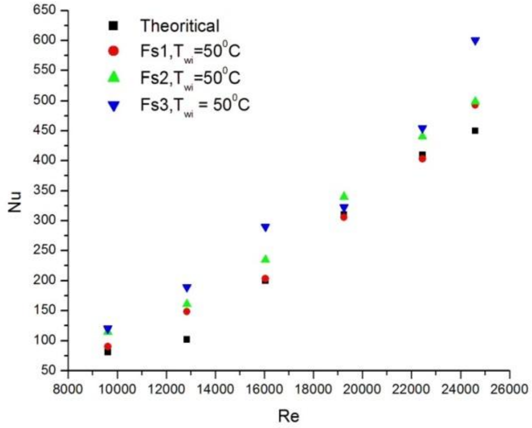


Fig.9Reynolds number vs Nusselt number

6.3 Effect of nanofluid concentrations

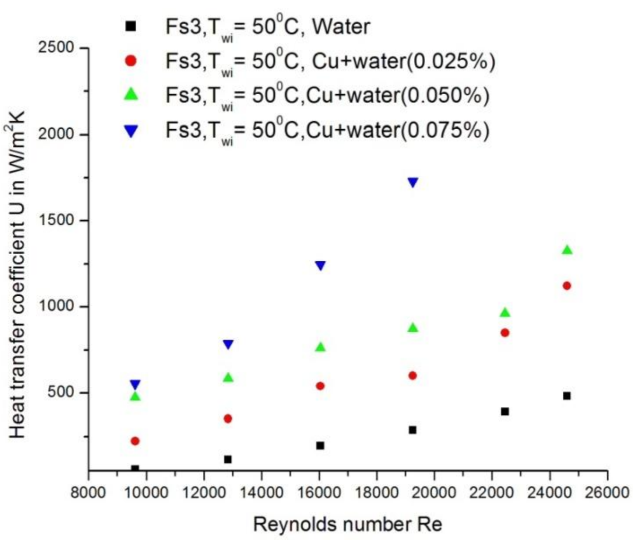


Fig.10 (a) Heat transfer coefficientVs concentration of nanofluid

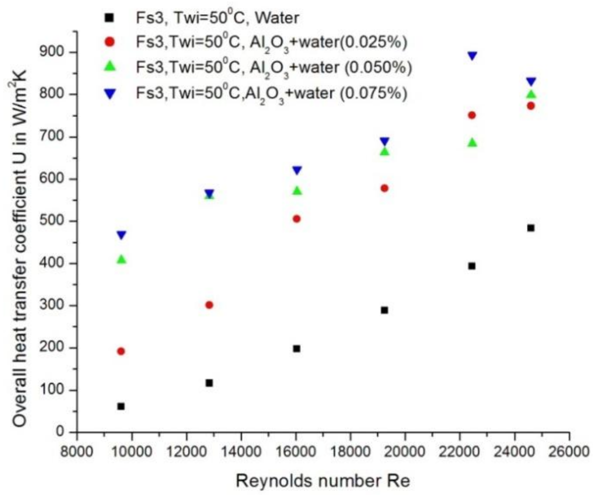


Fig.10(b) Heat transfer coefficient Vs concentration of nanofluid

From the Fig. 10 (a) & (b) the coefficient of heat transfer at three various volume fractions of 0,025%, 0,05% and 0,075% is compared with the base fluid water in the tractor radiator. On the other hand, the improvement of heat transfer is due to the presence of nanoparticles which reduce the thickness of the boundary layer and the clustering of particles. Nusselt number reduced with a rise in the fraction of nano-additives after reaching an optimum value. Beyond the optimum value of the nano-additive volume fraction, the Brownian motion of nanoparticles is hindered by a higher fluid viscosity that outcomes a lower thermal conductivity and therefore a lower heat transfer rate. On the other hand, because of the increased momentum transfer between the base fluid particles and nano-additives, the friction factor increased. The higher nanofluid concentrations may increase the fluid, which would decrease the heat transfer rate and increase the need for pumping power [26-27].

7. Conclusion

From theresearch work, the experimental heat transfer coefficient of a tractor radiator was determinedby employing Cu / water and Al_2O_3 / water, CuO / water nanofluid at various air and fluid volumetric flow rates. The mainoutcomesare summarized:

- The overall coefficient of heat transfer increased with lowerentry temperature of nanofluid and Cu / water nanofluid displayed improved heat transfer efficiency than to nanofluids.
- The overall coefficient of heat transfer is increased by the use of nano-additives to the base fluid. The heat transfer coefficient of Cu / water rises by 9% from 0.025% to 0.05%

volume fractions and from 0.05% to 0.075% concentration by 19% improvement. The coefficient of heat transfer increased by 21% from a lowerfraction of 0.025% to a higherfraction of 0.075%.

- The coefficient of heat transfer increases by 43% from base water to CuO / water nanofluid and 48% from base water to Cu / water and 35% from base water to Al_2O_3 / water When comparing the metal form of nanofluid Cu / water to the metal oxide form of nanofluid CuO / water, there are 11% increases and Al_2O_3 / water is 17.5%. The overall coefficient of heat transfer improvedconsiderablyusing nanofluidsthan water.
- The overall heat transfer coefficient exhibited for higher volume flow rate of nanofluids which increased with air flow rate.
- The thermal performance of nanoparticles increased through its thermo physical property. The dimensions of the radiator could be minimized by using nanofluids with superior thermophysical properties.

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