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CROSS FLOW HEAT EXCHANGER USING HYBRID NANO FLUIDS EXPERIMENTALY FOR IMPROVEMENT OF HEAT TRANSFER

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Abstact

In this paper, forced convective heat transfer in a water based nanofluid has experimentally been compared to that of pure water in an automobile radiator. Three different concentrations of nanofluids 0.1%, 0.2%, 0.3% of volume has been prepared by adding of TiO_2Nano particles into the water. The test liquid flow through the radiator consisted of 34 vertical tubes with an elliptical cross section and air makes across flow inside the tube bank with constant speed. Liquid flow rate has been changed in the range of 100-600 LPH to have the fully turbulent regime.

Additionally, the effect of fluid inlet temperature to the radiator on heat transfer coefficient has also been analyzed by varying the temperature in the range of 55°C-75°C. Results demonstrate that increasing the fluid circulating rate can improve the heat transfer performance while the fluid inlet temperature to the radiator has trivial effects. Meanwhile, application of nanofluid with low concentrations can enhance heat transfer efficiency up to 35% in comparison with pure water.

The higher heat transfer coefficients obtained by using nanofluid instead of water allow the working fluid in the automobile radiator to be cooler. The addition of nanoparticles to the water has the potential to improve automotive and heavy-duty engine cooling rates or equally causes to remove the engine heat with are reduced size coolant system. Smaller coolant systems result in smaller and lighter radiators, which in turn benefit almost every aspect of car and truck performance and lead to increased fuel economy.

Keywords: Automotive Radiator, Nanofluid, TiO_2, Heat transfer enhancement.

1. Introduction

Recent automotive engines generate a large amount of heat. This heat is generated when the air mixture and gasoline is ignited in the combustion chamber. This explosion leads the piston to be pushed down inside the engine, levering the connecting rods, and turning the crankshaft, generating power. Metal temperatures of the combustion chamber could be exceed 1000° F. Because to prevent the overheating of the engine oil, pistons, valves, cylinder walls and other components by these extreme temperatures, it is required to effectively dispose of the heat. Recently automotive engines have mainlydiscarded the Air Cooled System for the more efficient Liquid Cooled System to grip the job. In a liquid cooled system, heat is passed away by the use of a heat absorbing coolant that circulates throughout the engine, particularly around the combustion chamber in the cylinder head area of the engine block. The coolant is pumped throughout the engine, then after absorbing the heat of combustion is circulated to the radiator where the heat is passed to the atmosphere. The cooled liquid is then passed back into the engine to repeat the process. Extreme cooling system capacity can also be harmful, and may influence engine life and performance. You must understand that coolant temperatures also it

Affects on oil temperatures and more engine wear occurs when the engine oil is below 190°F. An effective cooling system control the engine temperature within a specific range so that the engine stays within peak performance.

1.1 Cooling system functions

Temperatures in the combustion chamber of the engine can reach 250°C, so cooling the area around the cylinders is dangerous. Areas around the exhaust valves are particularly crucial, and almost all of the space inside the cylinder head around the valves that is not required for structure is filled with coolant. If the engine runs without cooling, the metal got hot sufficient for the piston to weld itself to the cylinder. This generally means the complete damage of the engine. The cooling system removes sufficient heat to keep the engine at a secure temperature for best performance.

1.2 Fluids

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Cars operate in a wide range of temperatures, from well below freezing to well over 38°C. So whatever fluid is used to cool the engine is having low freezing point, a high boiling point, and it has to have the capacity to hold a lot of heat. Water is one of the effective fluids for hold heat, but water freezes at too high a temperature to be used in car engines.

Table No. 1. Conventional working fluid in radiator

Properties	Pure Water	50/50 $C_2H_6O_2$/Water	70/30 $C_2H_6O_2$/Water
Freezing Point	0°C	-37°C	-55°C
Boiling Point	100°C	106°C	113°C

1.3. Thermophysical properties of nanofluid

Cooling System Liquid heats Resistively Crucible the thermal conductivity measurement of nanofluids was the main center in the nanofluid research. Considering the application of heat transfer fluids, heat transfer coefficients of nanofluids in flow condition is also very important. The important properties other than thermal conductivity that affect the heat transfer coefficients are heat capacity,density and viscosity of dispersions. Since the nanoparticle concentration in nanofluids generally are very low, the particle effect on the density and heat capacity of the dispersions is not significant.

Due to the small particle size, the nanoparticle affects on the viscosity of the dispersions might be significant, especially for nanotube or other high or low aspect ratio nanoparticle dispersions. Some of the properties of base fluids and nanoparticles are listed in Table 2 useful for assessing the nanofluid properties.

Table No.2. Thermo physical Properties of Tio_2Nanoparticles

Nano-particle	Particle Size (nm)	Density (kg/m^3)	Sp. Heat (J/Kg.K)	Thermal Conductivity (W/m^2K)	Specific Surface area (m^2/g)
TiO_2	40	4250	686.2	8.95	30.7

2. Literature Review

The following is a brief description of the work and research completed by some prominent researchers in the field of nanofluids, specifically related to this work. This review illustrates the current schools of thought on the factors involved in influencing the properties of nanofluids.

Author performed research on the thermal conductivity of two-component systems because of develop an understanding of the basis of many current modeling equations for nanofluid thermal conductivity. This research dealparticularly with identifying how the shape of the components of a system affected the thermal properties of that system.This experiment provided data supporting the shape effect of metal particles on conductivity,(Hamilton et al, 1962).Performed research specifically on nanofluids with oxide particles at Argonne National Laboratory. This experiment examined Al_2O_3 and CuO nanoparticles isolated in both demonized water and ethylene glycol and their related thermal conductivities as calculated by the transient hot-wire method. A strong dependence on particle size and an almost linear augment of conductivity with volume fraction of the particles were found. CuO nanoparticles were found to have a better heat transfer effect than Al_2O_3 particles, which was suggested to be due to the CuO particles being smaller (Lee et al, 2007). The thermal conductivity of Al2O3 and CuO nanoparticles dispersed in various base fluids, including ethylene glycol,water, engine oil and vacuum pump fluid. Thermal conductivity was measured by the use of the steady-state parallel,one-dimensional plate method. This experiment resulted in data that suggests a feasible relation between thermal conductivity and the size of the Nano particles, as well as the method of dispersion used (Wang et al, 1999).

The effect of nanoparticles on convective heat transfer under a laminar flow regime. This research entailed experiments in a piping system of disc shaped graphite nanoparticles dispersions in two different base fluids. The goal was to test the theory of increased heat transfer capabilities without a significant change in flow characteristics such as viscosity. The experiments resulted in data that supports this idea as well as suggesting a number of factors that play a role in the convective heat transfer capabilities of these fluids. However, the correlations used to predict the results were not accurate. Therefore, it has been suggested that further research is needed (Yang et al,2005).Performed research involving a theoretical explanation of the possible reasons for the departure of experimental results from predicted results of thermal conductivities of nanofluids. The authors explain the macroscopic theory of heat transport in composites which is based on the diffusive nature of heat transport and note the mechanisms of enhanced heat conduction such as Brownian motion. There is also a description of the ballistic nature of heat transport which is suggested will better explain the experimental evidence. Research was supported by atomic-level molecular dynamics simulations (Keblinski et al,2005). Conducted research on the convective heat transfer properties of nanofluids and the factors affecting these properties. The purpose of this research was to test the

theory that the effects on heat transfer that are not explained by the thermal conductivity characteristics are attributed to the turbulence induced by the motion of the nanoparticles and the dispersion methods. (Buongiorno, 2006)Studied the single phase flow heat transfer performance of nanofluids in turbulent flow regimes. The nanofluid used was Cu particles dispersed in water. Substantial increases in the convective heat transfer rates were noted while also noting that the flow characteristics closely resemble those of the base fluid, which suggests that there will be no adverse pumping power requirements associated with the use of nanofluids (Xuan et al,2007).Conducted experiments to determine the temperature dependence of thermal conductivity of nanofluids. It was found that the thermal conductivity increased with temperature from 21 °C to 51^{0}C, which suggests a possible use as a cooling mechanism in devices with high energy densities (Das et al, 2003).

3. Development of experimental Set up

As shown in Fig. 1, the experimental system used in this research includes flow lines, a storage tank, a heater, a centrifugal pump, a flow meter (Rotameter), a forced draft fan and a cross flow heat exchanger (an automobile radiator). The pump gives a flow rate of 2800 LPH; the flow rate to the test section is regulated by appropriate adjusting of a globe valve on the recycle line as shown in Fig.1. The working fluid fills 70% of the storage tank whose total volume is (45cm×45cm×45cm). The total volume of the circulating liquid is constant in all the experiments. The CPVC tubes (18 mm diameter) have been used as connecting lines. A flow meter (Rotameter) was used to control and manipulate the flow rate with the precision of 10 LPH. For heating the working fluid, a three phase electrical heater and a controller were used to maintain the temperature between 55°C and 75°C. Two RTDs (PT-100, Rod end type) were implemented on the flow line to record radiator fluid outlet and inlet temperatures. Five RTDs (PT-100, Bare type) were used for radiator wall temperature measurement.

These thermocouples were installed at the Different locations on the radiator wall. The locations of the surface thermocouples have been selected so that they give the average wall temperature. For this purpose, 5 RTDs were connected by silicon paste to various positions of the external walls on each side of the radiator.

When the experiment started, the location of the thermocouple accessible the average value of the readings was selected as a point of average wall temperature. It would be remarkable that these two locations on each side of the radiator did not exactly correspond.

Due to very small thickness and very large thermal conductivity of the tubes, it is reasonable to equate the inside temperature of the tube with the outside one. The temperatures from the RTDs were measured by two digital meters, one is showing continuously inlet and outlet temperature of fluid entering and leaving the radiator.

Table No. 3 The radiator side important dimensions.

Dimension	Notation	Value
Radiator length	Lrad.	0.370m
Radiator height	Hrad.	0.420m
Radiator width	Wrad.	0.040m
Tube length	Lt	0.015m
Tube height	Ht	0.315m
Tube width	Wt	0.002m
Tube thickness	dt	0.00008m
Number of tubes	-	33
Tube hydraulic diameter	dh	0.003530m

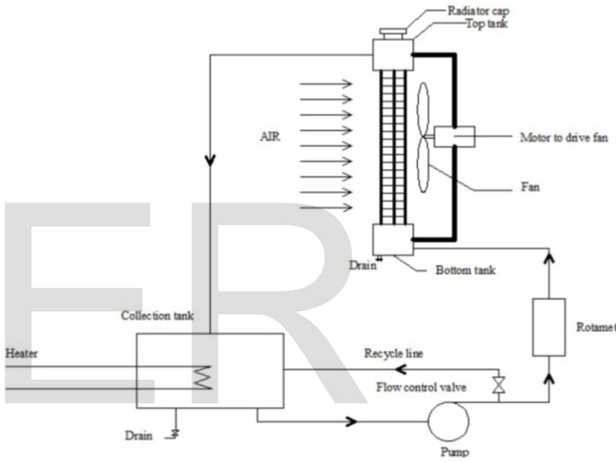

Fig. 1. Schematic of Experimental setup

3.1 Test Methodology

The radiator heat enhancement is tested with the pure water as a working fluid. The test procedure is conducted at different flow rate of water having range100 LPH to 600 LPH and temp range is 55° to 75°. The temperature of water of water in the tank is controlled with controller up to 55°C for distillation cycle of testing procedure. The 55° C hot water passes through pump and Rotameter at variable discharge. The discharge is set to the 100 LPH. The inlet &outlet temperature of the water in radiator is measured with a channel temperature indicator. At the same time the wall temperature of radiator at different points is measured with 6 channel temperature indicator and the water is discharged to the tank.

After completion of first cycle of test the temperature is kept constant at 55°C and the flow rate is set to the 200 LPH with flow control valve. The Tin and Tout measured are indicated on 2 channelindicator. At same time the wall temperature are noted down from the 6 channel indicator and water isdischarged to the tank to complete the cycle. Again the temperature is kept constant at 55°C and the flow rate is varied at 300LPH, 400LPH, 500LPH, 600LPH. For taking readings from two channel temperature indicators Tin and Tout respectively. The Twis measured from six channel temperature indicator and procedure is continued. After completing the readings for 55°C, the temperature is set to 60°C, 65°C, 70°C& 75°C respectively. And the temperature readings are taken from respective temperature indicators.

The pure water is changed with Nano fluid with 0.1% Nano powder. 40gm Nano powder $TiO_2$is mixed in to pure water and the readings are taken same as pure water. The 0.2% & 0.3% concentration of Nano fluid is made with same as procedure of 0.1% mixture procedure and readings are taken same as water readings.

3.2 Data Reduction:

The heat input, effectiveness of heat exchanger is calculated by the following equations.

$Q = h \times A \times \Delta T$---------------------------------(Equation no.1)

$Nu = \frac{h \times Dhyd}{kw}$---------------------------------(Equation no.2)

$Q = Ap \times Vf$-----------------------------------(Equation no.3)

$Re = \frac{(\rho np \times Vf \times dp)}{\mu nf}$--------------------------(Equation no.4)

4 Results and Discussion

4.1.:-Plots of flow rate VS outlet temperature

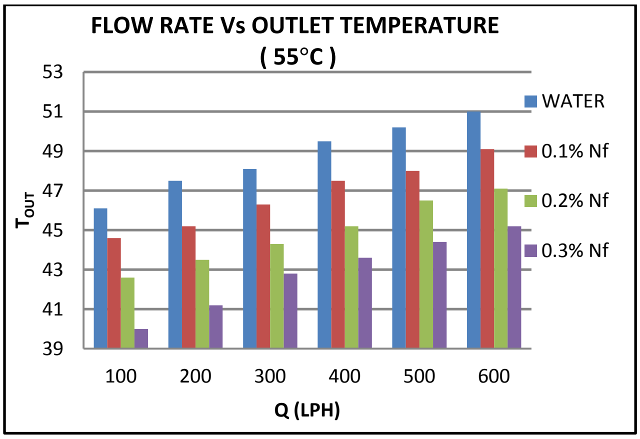

Fig. 2 Plot of Flow rate Vs outlet temperature (55°C)

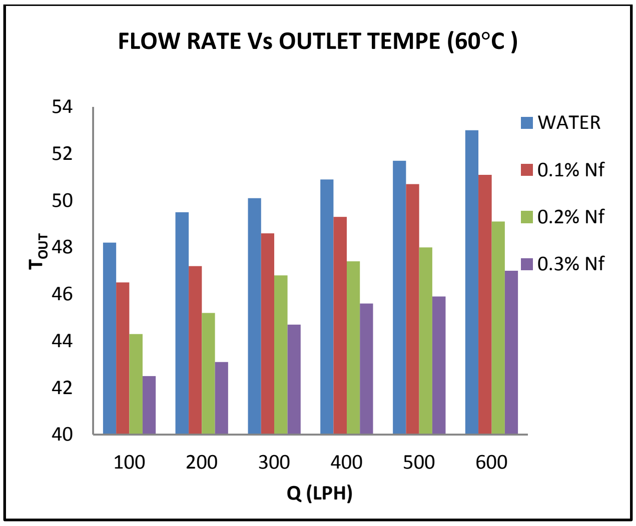

Fig. 3 Plot of Flow rate Vs outlet temperature (60°C)

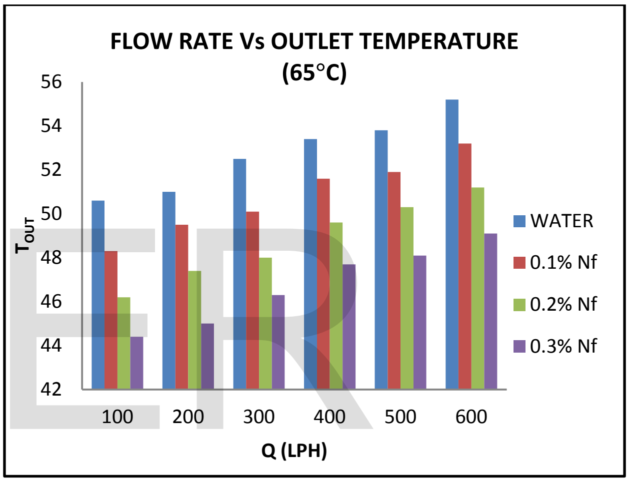

Fig. 4 Plot of Flow rate Vs outlet temperature (65°C)

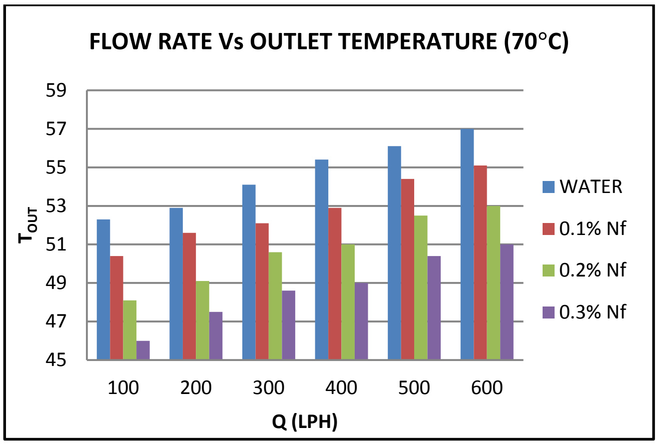

Fig. 5 Plot of Flow rate Vs outlet temperature (70°C)

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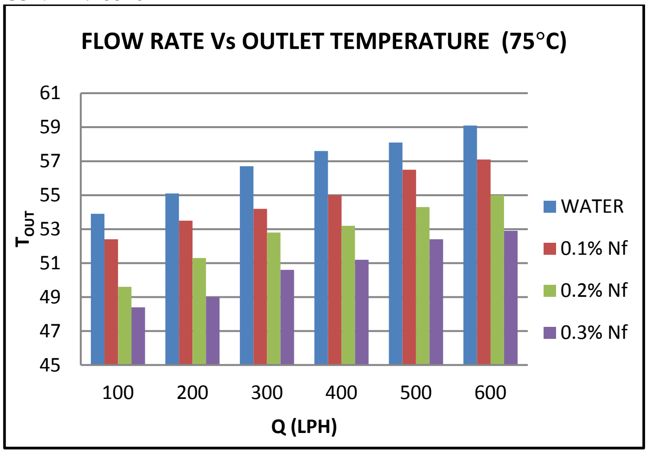

Fig. 6 Plot of Flow rate Vs outlet temperature (75°C)

Fig. 03 to 06 shows the radiator outlet temperature, Tout, as a function of fluid volume flow rate circulating in the radiator. Three series of data shown in this figure belong to pure water and also three different concentrations of nanofluids. It should be noted that all the data in Fig. obtained when the fluid inlet temperature to the radiator was 55°C, 60°C, 65°C, 70°C, 75°C. One can clearly observe that fluid outlet temperature has decreased with the augmentation of nanoparticle volume concentration.

4.2 Plots of flow rate VS Nusselt number

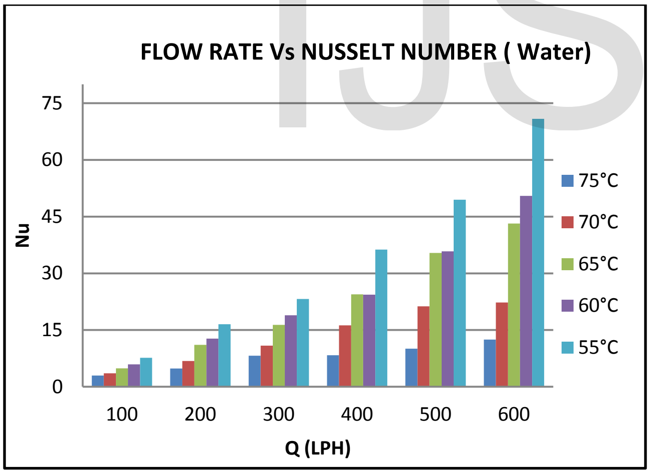

Fig.7 Plot of Flow rate Vs Nusselt number (Water)

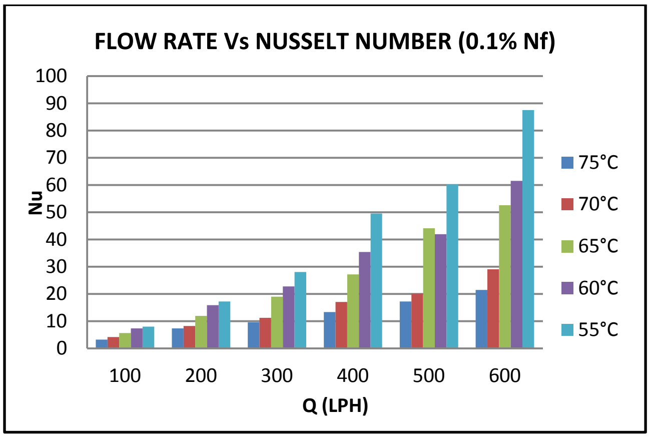

Fig. 8 Plot of Flow rate Vs Nusselt number (0.1% NF)

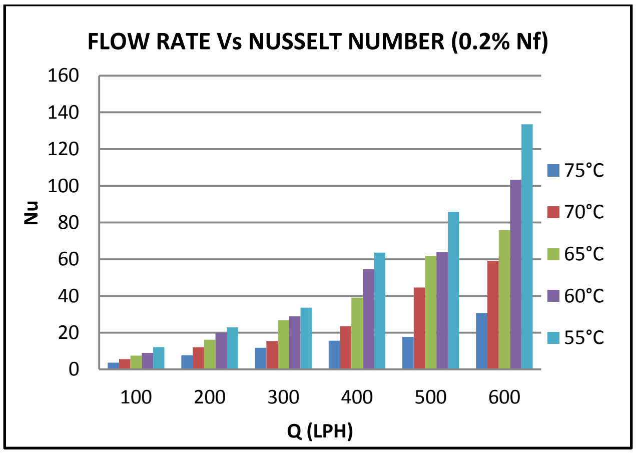

Fig.9 Plot of Flow rate Vs Nusselt number (0.2% NF)

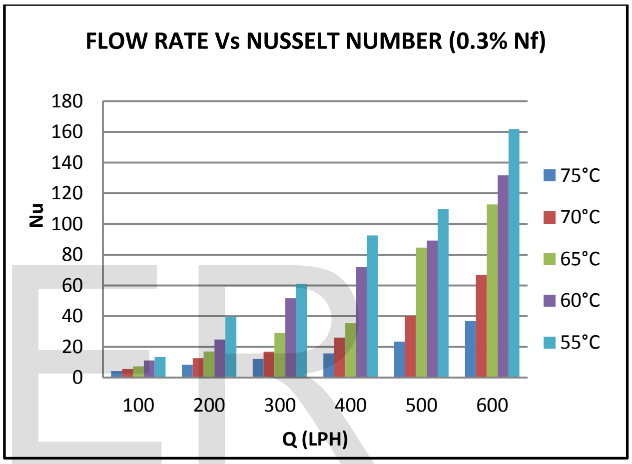

Fig.10 Plot of Flow rate Vs Nusselt number (0.3% NF)

As per Fig. 7 to 10 Nu number in all the concentrations has increased by increase in the flow rate of the fluid and consequently Re number. Additionally, the concentration of nanoparticle plays an important role in the heat transfer efficiency. It can be shown that when-ever the concentration becomes greater, heat transfer coefficient becomes larger. By the addition of only 0.1%, 0.2%, 0.3% vol. of TiO_2Nano particle into the pure water, an increase of about 10-15% in comparison with the pure water heat transfer coefficient was recorded. It should be mentioned that the trend of the curves at the other fluid inlet temperatures, i.e.55°C, 60°C, 65°C, 70°C, 75°C.

Conclusions

1. The presence of TiO_2 nanoparticle in water can enhance the heat transfer rate of the automobile radiator. The degree of the heat transfer enhancement depends on the amount of nanoparticle added to pure water. Ultimately, at the concentration of volume 0.1%, 0.2%, 0.3%, the heat transfer enhancement of 15%-20% compared to pure water was recorded.
2. Increasing the flow rate of working fluid enhances the heat transfer coefficient for both pure water and

nanofluid considerably while the variation of fluid inlet temperature to the radiator slightly changes the heat transfer performance.

3. It seems that the increase in the effective thermal conductivity and the variations of the other physical properties are not responsible for the large heat transfer enhancement. Brownian motion of nanoparticles maybe one of the factors in the enhancement of heat transfers. Although there are recent advances in the study of heat transfer with nanofluids, more experimental results and theoretical understanding of the mechanisms of the particle movements are needed to explain heat transfer behavior of nanofluids.
4. This new working fluid with higher heat transfer performance would promote the car engine performance and would reduce fuel consumption. Therefore, it can be followed by other investigators to eliminate the probable deficiencies for industrialization in the car industries. Some associated problems like stability and sedimentation should be studied with details.

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