

Experimental Analysis of Heat Exchanger for Enhancement of Heat Transfer with Different Concentrations of TiO₂ Nano Fluid

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ABSTRACT: The heat transfer rate in engine by using the conventional coolants like water is poor. In automotive industry, it is desirable to have coolant with good thermo physical properties as compared to water. This paper presents effect of adding titanium oxide Nano particles in water on heat transfer rate in heat exchanger. Different concentrations of titanium oxide Nano particles are added in water and are tested for heat transfer rate in heat exchanger. It was found that specific heat of Nano fluid increases as concentration of titanium oxide Nano particles in Nano fluid increases. The effect of Nano fluid on density, viscosity, thermal conductivity is also studied. It is found that the heat transfer rate increases by 16% in 0.1% concentration titanium oxide Nano fluid and increases by 24% in 0.3% concentration titanium oxide Nano fluid.

KEYWORDS: TiO₂, Specific heat, Heat transfer, Effectiveness, Nano fluid.

I. INTRODUCTION

The heat exchanger is a device that uses for transfer of thermal energy from one fluid over another or one surface with fluid by making the thermal contact between them. The heat exchangers can be used for recovering or rejecting heat to the fluid. Many heat exchangers can be separated by heat transfer surfaces since they do not mix with each other or leak. The conventional fluid used as coolant in heat exchanger is water. The water is having more negative impacts of temperature on its thermal properties like, in cold weather water may be freeze & made clogging in pipes of heat exchanger which cannot be afforded as that reduces the effectiveness of the system or sometime may stop the system. To avoid that the ethylene glycol is introduced with water. These types of conventional fluids are having low thermal characteristics. So it is mandatory to implement new techniques for increase the heat transfer rate & effectiveness of heat exchanger. In early days the various techniques used for improving the heat transfer rate are like, inserting tube inserts, by changing the shape geometry or by introducing rough surfaces. The compactness and effectiveness of heat exchanger implies new technique like addition of additives may implement. Further improvement in enhancement technique is always in demand since the operation speed of the device is dependent on cooling rates. The cooling technology in engine is most important parameter for improving the efficiency of engine. The Nano technology is the new technique can be used for heat transfer improvement. Suspending the metallic or non-metallic particles having size ≥ 100 nm in base fluid such as conventional fluids like water, ethylene glycol is known as Nano fluid. The Nano fluids are having good thermal characteristics as compare to water because the thermal conductivity of

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Nano particles is more as compare with base fluids. For experimentation in this paper TiO_2 Nano fluids are made by dispersing the TiO_2 Nano particles of 15 nm with base fluid as water.

R.J. Bhatt et al.[1] gave the detail description about Nano fluid. They described different types of Nano fluids with base fluids. They also found the various useful relations for finding the thermo physical properties of Nano Fluid.

M.Gajendiran et al. [2] stated the effect of Cu particles with base fluid as transformer oil. They made calculations for 0.1-0.3% of Cu particles concentration with base fluid transformer oil. They compared the results for water with transformer oil by varying the flow rates and rpm of engine. They found that more than 15% of heat transfer rate is increased as compare to water and more than 66% heat transfer rate is increased as compare to transformer oil with different concentrations.

S.M. Peyghambarzadeh et al.[3] Studied two types of Nano particles viz. CuO and Fe_2O_3 . They used 0.15-0.65% concentration of particles with stability analysis of particles by pH method. They found the heat transfer rate followed by overall heat transfer coefficient. They found that Fe_2O_3 with water has better heat transfer rate as compared with CuO with water.

Hemant M Patel et al.[4] experimented on exhaust gas calorimeter with two different constructions like spiral tube heat exchanger and modified shell and tube type heat exchanger. They found that the shell and tube type heat exchanger having 0.63% reduction in weight & 1.64% reduction in error as compare to the spiral tube type heat exchanger. The shell and tube type heat exchanger is having more brake power with less fuel consumption as compared to spiral tube type heat exchanger.

Alpesh Mehta et al. [5] have done study of mini heat exchanger with Al_2O_3 Nano fluid. They developed the lattice Boltzmann model for heat transfer in Nano particles and suggested that the heat transfer rate of heat exchanger is increased as increase in Nano fluid concentrations.

The Table-1 gives description of different properties for Nano particles with base fluids as water & ethylene glycol. The specific heat of Nano particles is less but with base fluid it increases specific heat of Nano fluid. The density of Nano particles is more than base fluids but it decreases density of Nano fluid because Nano particles occupies the space of base fluid molecules. The thermal conductivity of Nano particles is more which ultimately increases the specific heat of Nano fluid and thus increases the heat transfer characteristics of base fluid.

Table-1 Thermo physical properties of Nano fluids with base fluids.

Property	Water	Ethylene glycol	Cu	Al_2O_3	CuO	TiO_2
C(J/Kg k)	4179	2415	385	765	535.5	686.2
ρ (Kg/m ³)	997.1	1111	8933	3970	6500	4250
K(w/mk)	0.605	0.252	400	40	20	8.9538
α (m ² /s)	1.47	93	1163	1317	57.43	30.7

Praveen K Namburu et al.[6] carried out the study of CuO , TiO_2 , SiO_2 Nano fluid in ethylene glycol and water mixture. They found the effect of Nano particles on heat characteristics as viscosity of Nano fluid is increased as increase the diameter of Nano particles. At fixed Reynolds number of 20000, the Nusselt number of CuO is increased by 1.35 times with base fluids. Also the heat transfer rate is increased upto 1.75 times over base fluid for constant Reynolds number 20000. They also found the Gnielinski correlation for heat transfer in Nano fluids.

M. Naraki et al.[7] carried out the study of CuO with water as Nano fluid. They used Taguchi method for statistical analysis. They found that the heat transfer coefficient decreases with increasing the inlet temperature of Nano fluid. More than 8% heat transfer coefficient is increases with compared to water.

Adnan M. Hussein et al.[8] studied TiO_2 , SiO_2 Nano particles with base fluid as water. They found the correlation for Nusselt number by regression analysis. The Nusselt number is increased up to 22.5 % and 11% for SiO_2 and TiO_2 Nano fluids respectively as compared with water.

Adnan M. Hussein et al.[9] studied SiO_2 Nano particles dispersed in water. They found that Nusselt number is increased by more than 40% as compare to water. They validated the results obtained by CFD software.

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II. NANO FLUID PREPARATION& PROPERTIES

The Nano fluid is prepared by dispersing 15 nm TiO₂ Nano particles in concentration up to 0.1& 0.3 % in base fluid as water. The TiO₂ Nano particles are obtained from Sigma Aldrich, India Ltd. To remove agglomeration high speed stirrer technique is used for 1 hour. It is observed that the TiO₂ Nano particle fluid stable for more than 12 hours. The Table-2 gives the composition present in TiO₂ Nano particles used for experimentation. It contains iron about 50 mg/kg, lead about 20 mg/kg and antimony about 50 mg/kg.

Table-2 Composition present in TiO₂ Nano particles

Contents	Fe	Pb	Sb
Values	≤50 mg/kg	≤20 mg/kg	≤50 mg/kg

The Figure-1 shows the Scanning Electron Microscopy (SEM) images for TiO₂ Nano particles. The SEM is a technique for finding the morphology of particles by magnifying them up to 30000X. The Figure-1 shows the TiO₂ Nano particles in pure form.

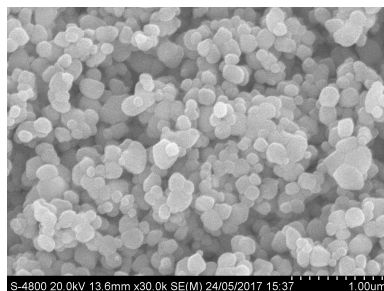


Figure-1 SEM images for TiO₂ Nano particles.

Thermo physical Properties of TiO₂ Nano Fluid

The Table-3 gives the different thermo physical properties of TiO₂ Nano particles. The density is 4260 kg/m³, Thermal conductivity is 13 J/kg °C, specific heat is 544.28 J/kg °C & thermal expansion coefficient is $9.2 \times 10^{-6} \text{ 1/}^\circ\text{C}$

Table-3 Thermo Physical Properties of TiO₂ Nano particles.

Sr. No.	Property Name	Values
1	Density	4.26 g/ml
2	Thermal Conductivity	13 J/kg °C
3	Specific Heat	0.13 cal/g °C
4	Thermal Expansion	$9.2 \times 10^{-6} \text{ 1/}^\circ\text{C}$

The thermo physical properties of TiO₂ Nano fluid such as density, dynamic viscosity, Specific heat, Thermal conductivity is calculated as follows,

Density

The density of Nano fluid is measured from specific gravity bottle experiment.

Dynamic Viscosity

The dynamic viscosity of Nano fluid is measured from Ostwald's Viscometer.

Specific Heat

The specific heat is calculated from equation-1

$$(\rho C_p)_{nf} = \phi(\rho C_p)_p + (1-\phi)(\rho C_p)_w \text{----- (1)}$$

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Where suffix p, w, nf stands for particle, water, Nano fluid respectively and ϕ for % concentration of Nano particles. for respective temperatures Specific heat of particles is putted in equation -1 for finding Specific heat of Nano fluid.

III. EXPERIMENTATION

The experimental setup is shown in Figure-2 consists of single cylinder four stroke diesel engine of 5 BHP, 1500 rpm single cylinder four stroke engine. The tank of capacity 25 litres is attached to recirculate the Nano fluid from the engine with pump arrangement.

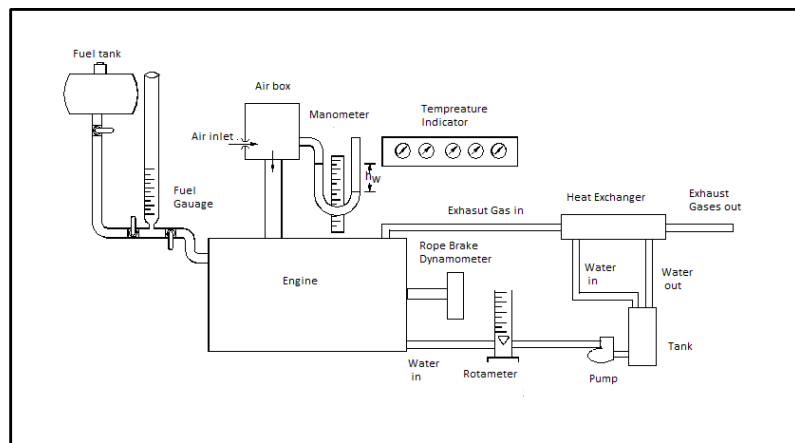


Figure-2 Experimental setup .

The Figure-3 shows cut section model of exhaust gas calorimeter having dimensions as outside shell diameter of 165 mm, diameter of tubes as 20mm, tube length as 800 mm & number of tubes are 31.

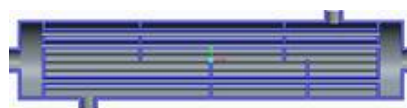


Figure-3 Cut section model of exhaust gas calorimeter.

T_1 = Inlet temperature of coolant to calorimeter.

T_2 = Outlet Temperature of coolant from calorimeter.

T_3 = Inlet temperature of exhaust gases to calorimeter.

T_4 = Outlet Temperature of exhaust gases from calorimeter.

Q_c = Heat carried by Coolant from calorimeter $= mc \times C_{pc} \times (T_2 - T_1)$

ϵ = Effectiveness of heat exchanger. $= \frac{m_h C_{ph} (T_3 - T_4)}{C_{min} (T_3 - T_1)}$

IV. EXPERIMENTAL RESULTS

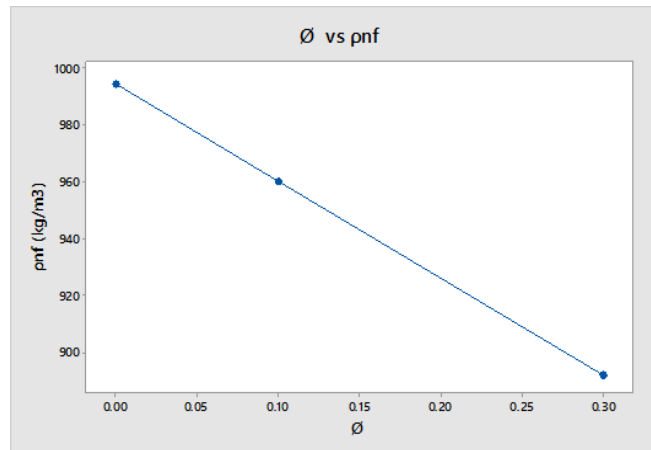
For the experimental test rig is shown in Figure-2, after taking all the readings T_1 to T_4 , the heat transfer rate & Effectiveness calculation was carried out followed by calculations of thermo physical properties. The Graph -1 shows the effect of TiO_2 Nano particle concentrations on density of Nano fluid. The density of Nano fluid is decreases as increasing the concentration (ϕ) of particles in fluid. The density of Nano fluid for 0% is 994 kg/m^3 is decreases upto 960 kg/m^3 for 0.1% and further addition of TiO_2 Nano particles results in density up to 891.8 kg/m^3 . since % addition in Concentration of TiO_2 Nano particles decreases density of Nano fluid.

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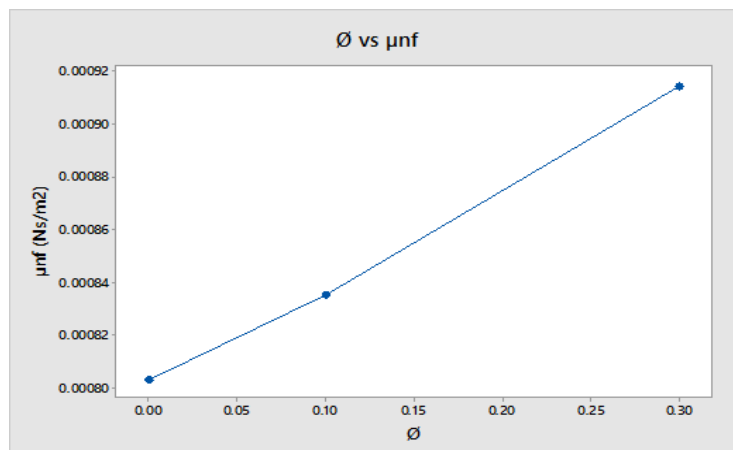
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Graph -1 ρ v/s Density of Nano fluid

The Graph -2 shows the effect of TiO_2 Nano particles concentrations on viscosity of Nano fluid. The viscosity of Nano fluid increases as increase in the concentration of TiO_2 Nano particles. The dynamic viscosity for 0% TiO_2 Nano concentration fluid is 0.000803 Ns/m^2 and for 0.1% it upto 0.000835 Ns/m^2 while for 0.3% it increases to 0.000914 Ns/m^2 . Since, the Dynamic viscosity of Nano fluid is increases as increase in concentration of TiO_2 Nano particles.



Graph -2 φ v/s Dynamic viscosity of Nano fluid.

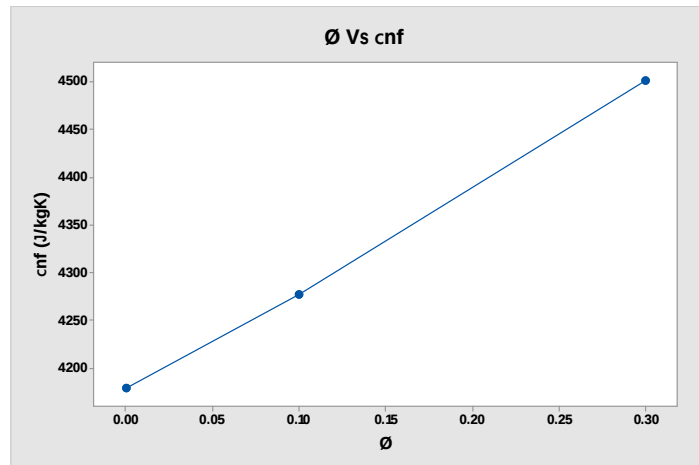
The Graph -3 shows the effect of the TiO_2 Nano particles concentration on specific heat of Nano fluid. The specific heat of TiO_2 Nano particles is increased as increasing the temperature. The specific heat for 0% TiO_2 Nano concentration fluid is $4179 \text{ (J/kg } ^\circ\text{C)}$ and for 0.1% it upto $4277.225 \text{ (J/kg } ^\circ\text{C)}$ while for 0.3% it increases to $4500.676 \text{ (J/kg } ^\circ\text{C)}$. Since, the specific heat of Nano fluid is increases as increase in concentration of TiO_2 Nano particles. Thus, the specific heat of Nano fluid increases as increase in concentrations of TiO_2 Nano particles in water as compare to pure water.

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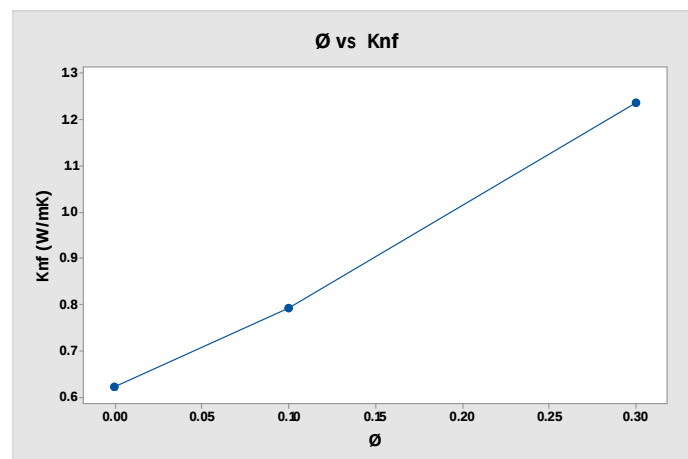
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Graph -3 Øv/s Specific Heat of Nano fluid

The Graph -4 shows the effect of TiO_2 Nano particle concentration on thermal conductivity of Nano fluid. The thermal conductivity for 0% TiO_2 Nano particle concentration fluid is 0.6221 ($\text{W/m}^\circ\text{C}$) and for 0.1% it increases up to 0.7906 ($\text{W/m}^\circ\text{C}$) while for 0.3% it increases to 1.2343 ($\text{W/m}^\circ\text{C}$). Since, the thermal conductivity of Nano fluid increases as concentration of TiO_2 Nano particles increases. The thermal conductivity of Nano fluid increases as increasing the concentrations of TiO_2 Nano particles in water as compared to pure water.



Graph -4 Øv/s Thermal conductivity of Nano fluid

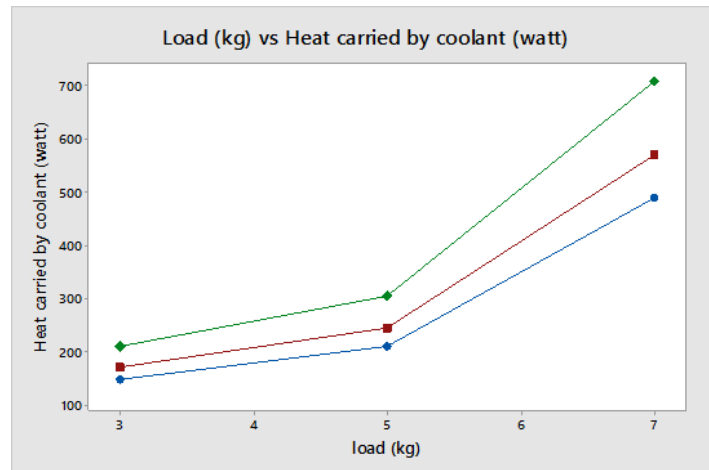
The Graph -5 shows the effect of increasing concentration of TiO_2 Nano particles in water on heat transfer rate. The blue line shows 0% TiO_2 concentration fluid, red line shows 0.1% TiO_2 concentration fluid & green shows 0.3% TiO_2 concentration Nano fluid.

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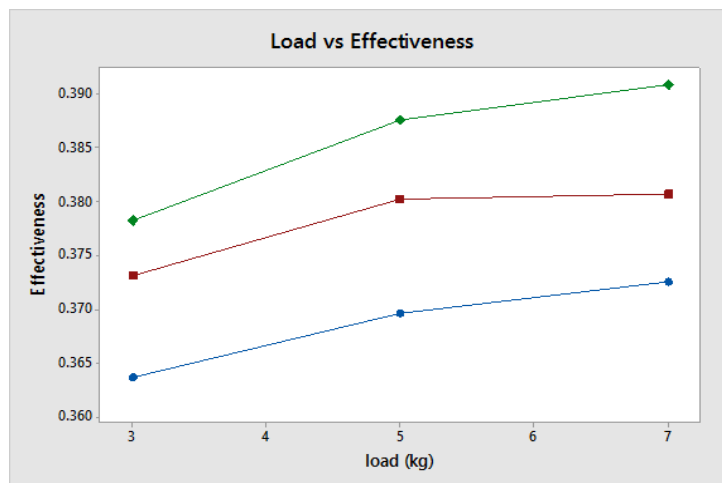
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Graph -5 Load v/s Heat carried by coolant

The Graph -6 shows effect of TiO_2 Nano particle concentrations on effectiveness of heat exchanger. The blue line shows for 0% concentration TiO_2 fluid, red line shows 0.1% concentration TiO_2 fluid and green shows 0.3% concentration TiO_2 fluid. The effectiveness of heat exchanger increases as increase in the concentration of TiO_2 in Nano fluid.



Graph -6 Load v/s Effectiveness.

V. CONCLUSIONS

The various experimental runs carried out using water and different concentrations of titanium oxide Nano fluid for change in heat transfer rate in heat exchanger shows that-

1. The TiO_2 Nano particles have good impact on thermo physical properties. The thermo physical property increases as increase in concentration of TiO_2 particles in water. The density of Nano fluid decreases, so results in pumping power reduction which increasing the efficiency of engine. Specific heat increased as increase in concentration of TiO_2 Nano particles in water. It results in increasing the heat transfer rate which also increases the efficiency of engine. The thermal conductivity of Nano fluid increases with increasing concentration of TiO_2 Nano particles in water. It increases the heat transfer rate and effectiveness of heat exchanger.

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2. The heat transfer rate is increased up to 16% in 0.1% concentration of TiO_2 particles whereas for 0.3% concentration it is increased up to 24%. Thus, increasing the concentration of TiO_2 Nano particles in base fluid increases the heat transfer rate of heat exchanger. This results in increase in efficiency of heat exchanger.
3. The effectiveness of heat exchanger is increased up to 1% for 0.3% Concentration of TiO_2 Nano Particles in water. It is seen that the efficiency of heat exchanger increased with increased concentration of TiO_2 Nano particles in base fluid.

FUTURE SCOPE

If Nano Composites are used by mixing the Carbon Nano Tubes (CNT) Nano particles with TiO_2 Nano particles in water, it may improve the heat transfer rate and effectiveness of heat exchanger. Because CNT have more specific heat and thermal conductivity than TiO_2 Nano particles. Some type of additives like CTAB, Pyrrole should be added in concentration for stability of Nano fluid.

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