Differentiate between two comparative Nano fluids for enhancing the heat transfer coefficient inside the heat exchanger using inserts

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ABSTRACT. *Investigation was carried out within tube heat transfer enhancement, using copper oxide/water, Titanium oxide/water Nano fluids for turbulent flow in a copper circular tube inserted with perforated twisted strip insert. The copper tube of 15 mm outer diameter and 12 mm inner diameter and test length of 1000 mm was used. Reynolds number varied in the range of 10000 to 40000. The Size of circular hole in the twisted tape insert was taken as 8 mm. Volume concentration of Nano fluid was taken as 0.1%, 0.3% & 0.5%, Heat transfer coefficient & Nusselt number from Gnielinski correlation be compared with results of pure water & Theoretical heat transfer coefficient, Nano fluids by using both hole & without hole insert. Heat transfer coefficient enhancement as compared with the pure water is found to be for Reynolds number of 40000, volume concentration of 0.5% found to be 100.9% without insert, 199.7% with insert as compared with the base fluid i.e. pure water.*

RÉSUMÉ. *Le tube de cuivre de diamètre extérieur 15 mm et de diamètre intérieur 12 mm et de longueur d'essai de 1000 mm a été utilisé. Le nombre de Reynolds variait entre 10000 et 40000. La taille du trou circulaire dans l'insert de ruban torsadé était de 8 mm. La concentration en volume de nano-fluide a été prise comme 0,1%, 0,3% et 0,5%. Le coefficient de transfert thermique et le nombre de Nusselt de la corrélation de Gnielinski doivent être comparés aux résultats de l'eau pure et du coefficient de transfert thermique théorique, Nano fluides en utilisant à la fois un trou et un insert sans trou. On a constaté que l'amélioration du coefficient de transfert de chaleur par rapport à l'eau pure correspondait à un nombre de Reynolds de 40000, la concentration volumique de 0,5% était de 100,9% sans insert, 199,7% avec l'insert par rapport au fluide de base, à savoir de l'eau pure.*

KEYWORDS: *heat exchangers, titanium oxide & Copper Oxide nanoparticles, nanofluids, heat* *transfer enhancement, inserts.*

MOTS-CLÉS: *échangeurs de chaleur, nanoparticules d'oxyde de titane et d'oxyde de cuivre, nanofluides, amélioration du transfert thermique, inserts.*

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1. Introduction

We know that the modern heat transfer instruments are very highly equipped as per thermal considerations and as per the environment. In the earlier period research efforts was focus on the development of advanced methods for heat transfer equipment. Nilesh C. Kanojiya, Dr. V. M. Kriplani Experimental study was did on convective heat transfer in a horizontal tube using insert using Nano fluids. They concluded that the heat transfer coefficient, heat transfer enhancement, friction factor of Copper oxide and aluminium oxide Nano fluids in a copper circular tube with perforated twisted tape insert for the given Reynolds number range i.e. 10,000 – 35,000for the Volume concentration varied from 0.05% to 0.3% was more as compared to the heat transfer rate of using aluminium oxide for same Nano fluid volume concentration. Nilesh C. Kanojiya, Dr. V. M. Kriplani (Nilesh *et al*., 2014) Heat Transfer Enhancement in Heat Exchangers with Inserts: A Review. This paper was studied on how the heat transfer should be increased by using various inserts and importance in heat exchanger devices. Nilesh C. Kanojiya, Dr. V. M. Kriplani (Nilesh *et al*., 2015) Review on Enhancement of heat transfer in Heat Exchangers with Inserts and Nano fluid This paper was studied & focus on how the heat transfer should be increased by using various Nano fluids especially oxides and importance in heat exchanger devices for the heat transfer enhancement. Sarit Kumar Das, Stephen U. S. Choi & Hrishikesh E. Patel Heat Transfer in Nano fluids—A Review. The paper was about to study (Theoretically) on role of the contact resistance in the thermal transport of Nano fluids, the various idea about nanotubes, about thermal conductivity and other various properties of Nano fluids. Dongsheng Wen and Yulong Ding (Wen and Ding, 2005) “Experimental investigation into the pool boiling heat transfer of aqueous based c-alumina Nano fluids “They concluded that the heat transfer enhancement increases when increasing particle concentration, reaches up to40% at loading of 1.25%.Results was suggests that the thermal performance of Nano fluids, the nucleate pool boiling conditions with the properties, reactions of the boiling surface Nano fluids’. Parvin, K.F.U. Ahmed, M.A. Alim and N.F. Hossain (Parvin *et al*., 2012), “Heat Transfer Enhancement by Nano fluid In a Cavity Containing a Heated Obstacle”. They investigate the case on the basis of numerical calculations and concluded the result of heat transfer enhancement. Hafiz Muhammad Ali, Muhammad Usman Sajid, Adeel Arshad (Yu and Xie, 2012), “Heat Transfer Applications of titanium oxide Nano fluids”. After getting overview of titanium oxide Nano fluids application at different heat transfer systems, they concluded that because of the high thermal conductivity of Nano fluids comparing with the simple water and other fluids, titanium oxide Nano fluids was executed as more efficiently. Wei Yu and Huaqing XieA (Wen and Ding, 2015) “Reviewed on Nano fluids Preparation, Stability Mechanisms, & its Applications”. They studied the various Nano fluid used for heat transfer enhancement application and also about the stability mechanism of different Nano fluids. Dongsheng Wen & Yulong Ding (Meganathan *et al.*, 2016), this investigation was about the pool boiling heat transfer using Nano fluids, they concluded that the enhancement goes higher while increasing the nanoparticle concentration and pool boiling heat transfer and its effective performance. Meganathan M.E, Guru Prasanth. G, (Ramteke and Ate, 2014) they studied on how the Thermal Conductivity of a Heat Exchanger will increase by Using two Nano Fluids i.e. Copper Oxide & Ethylene Glycol. The result of investigation was shows that overall heat transfer rate rises when it was subjected to Nano Fluids as compared to the water. The ethylene glycol fluid which they had used with copper oxide Nano fluid result in fouling in the resistance. .

1.1. Objective of work

The main objective of work was to investigation the heat transfer enhancement in copper tube using Comparison of two Nano fluids i.e. copper oxide & titanium oxide was selected, because of conform higher thermal conductivity than metallic oxides on the basis of studying various research papers and result of higher heat transfer enhancement. Base fluid was pure water. As per the literature gap was studied by referring many research articles is found that the investigation on TiO_2 and CuO Nano fluids with twisted tape inserts using three concentration was not studied in any previous researcher.

2. Experimentation and discussion

The schematic of experimentation used for to investigate the convective heat transfer enhancement by using Nano fluids in copper tube heated with consistently. It includes heater, pump, reservoir tank, flow meter, duct, thermocouples, cooling unit etc. The Test section was horizontal copper tube i.e. Internal Diameter of 12 mm, Outer Diameter of 15 mm, length 1000 mm, insulated with heating coil uniformly wound along the length of the tube. Experimental investigation was conducted first with pure water, Titanium Oxide and Copper Oxide nanoparticles, with changing mass flow rates 6, 8, 10, 12, and 14 litters/min, with Titanium/water Nano fluid, volume concentrations 0.1%, 0.3% and 0.5%. For the same the procedure was repeated with squire perforated tape insert had same volume concentrations.

3. Discussion on nanofluid properties

As per the many research's, the nanoparticles are used in many heat transfer equipment's for enhancing the output of the system as per the requirement of the researcher, in this investigation we used two comparative Nano particles which is now a day's very useful for heat transfer enhancement process especially in heat exchanger devices. For taking into considerations we used copper oxides and Titanium oxide for the investigations. Before using the Nano oxides we find the suitable thermal properties of Nano oxides. For that we decided to check whether it was suitable for the temperature up to 90 0 C or not, and we concluded after taking references of many papers related to Nano oxides and we started our investigation.

Density of Nano fluids should be predicted by mixing theory as:

$$knf \;/\; kbf \;= \frac{knp + \;2kbf \;\; + 2(knp \text{ -} kbf)(1+\;\beta)3\varnothing}{knp \, + \, 2kbf \;\text{ -} \;(knp \text{ -} kbf)(1+\;\beta)3\varnothing} \tag{1}$$

$$\rho nf \;= (1-\varnothing)\rho bf + \varnothing\rho np \tag{2}$$

$$\mu nf = \mu bf\,(1 + 2.5\varnothing) \tag{3}$$

$$(Cpnf \;\; .\rho nf\,) = \varnothing(Cpnp.\rho np) \;\; + \;\; (1-\varnothing) \;\; (Cpbf\,.\,\rho bf \;\;) \tag{4}$$

Where,

“nf”, “np”, “bf” refer for the Nano fluid, Nano particle and fluid respectively.

$\emptyset$ = volume fraction of the nano particles

β =Nano layer thickness

It was taken as 0.1 for finding the Nano fluid actual thermal conductivity.

4. Observations

We performed the experimentation investigation by taking the steady state conditions. First we investigate how the transfer rate of heat will fluctuate when only pure water was used as heat transfer medium and after that for Titanium Oxide/water and Copper Oxide/water Nano Fluids was used to perform the investigation with volume concentrations 0.1%, 0.3% & 0.5% respectively.

For calculating the various parameters related to the heat transfer we used Newton’s law of cooling, statement i.e.

Heat Transfer (1)

Where mean bulk temperature is given by

Tbase = (Tinlet+Toutlet)/2

Heat transfer rate,Q=mass Cpnf(Tout–Tinlet)(1)

Heat Transfer Coefficient

hexpA (Tw – Tb) = m Cpnf (Tout–Tin)

hexp=[mass Cpnf(Tout–Tin)]/[A(Tw-Tb)] (5)

Nu = (hexperiment D) / k

As from the reference no.07 the researcher used the formulas for calculation are,

Nu = (f/8) (Re-1000)Pr

$$1 + 12.7 (f/8)0.3 (Pr2/3 -1) \quad (6)$$

The physical properties were estimated at bulk mean temperatures Tbase, of the base fluid.

5. Result and discussion

Investigation results was comparing with Dittus Boelter (1) and Gnielinsky (1) correlations,

$$Nu=0.023Re0.8Pr0.4 \quad (7)$$

$$Nu= [(f/8) (Re – 1000) Pr]/ [1+12.7 (f/8)0.5 (Pr2/3 – 1)] \quad (8)$$

$3000 \leq Re \leq 5 x 106$ and $0.5 \leq Pr \leq 2000$

From Petukhov, 1970, friction factor, was calculated as

$$f = (0.79 ln Re – 1.69)-2 \quad (9)$$

From Figure 1 & 2, it shows that the heat transfer coefficient is goes on increasing when we used Nano fluid as compared to pure water as a heat transfer cooling medium. And also the value of theoretical investigation of heat transfer coefficient shows that the Nano fluid can be the best suited heat transfer medium for any heat exchanging devices. It shows the theoretical value from the investigation value is very high due to the human error during the investigation. From figure 3 & 4 it shows that while increasing the volume concentration of Nano fluids simultaneously there is an increasing the value of heat transfer coefficient and its effects will shows on plotted graphs. If we increases the value of turbulence i.e. Reynolds no. from 10000 to 40000, due to more creation of turbulence in the flowing Nano fluids the hat transfer rate is goes on increasing while performing the experimentation and inserts are used for much more heat transfer results and its application will automatically increases the heat transfer rate.

For 0.3%vol. (From Figure 1 & 2) At Reynolds number 40000 with Copper Oxide/water Nano fluid, the heat transfer coefficient enhancement as on water is 98.1%, 115.5% with twisted tape inserts and 134.2% with perforated twisted tape inserts. For the case of Titanium Oxide/water Nano fluid, the enhancements are 102.1%, 121.1% and 153.5% respectively.

For 0.5vol % (From Figure 3 & 4) and Reynolds number 40000, with Copper Oxide/water Nano fluid, the heat transfer coefficient enhancement as on water is 102.2%, 128.5% with twisted tape inserts, and 169.2% with perforation twisted tape inserts. For the case of Titanium Oxide/water Nano fluid, the enhancements goes up to 118.9%, 149.1% and 199.7% respectively.

For 0.1%vol. (From Figure 5 and 6) At Reynolds number 40000 with Copper Oxide/water Nano fluid, the heat transfer coefficient enhancement as on water is 42.1%, 85.5% with twisted tape inserts and 108.2% with perforated twisted tape inserts. For the case of Titanium Oxide/water Nano fluid, the enhancements are 65.8%, 91.2% and 115.2% respectively.

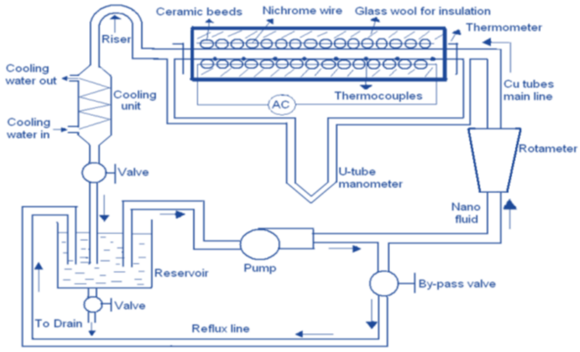

Figure 1. Shows the experimental set up

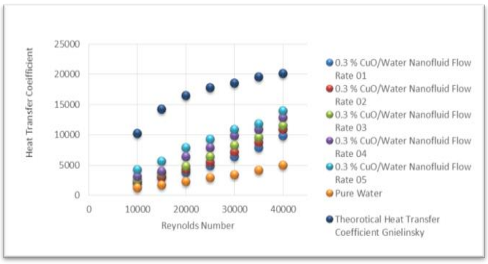

Figure 2. Heat transfer coefficient vs reynolds number for 0.3% copper oxide /water nano fluid & inserts

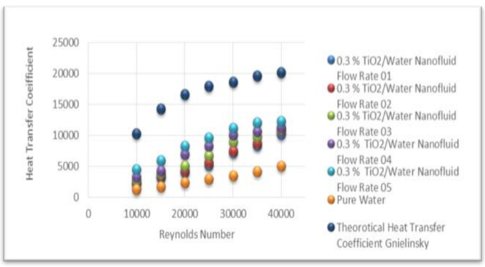

Figure 3. Heat transfer coefficient vs reynolds number for 0.3% titanium oxide /water nano fluid & inserts

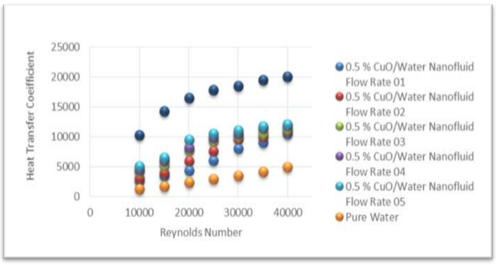

Figure 4. Heat transfer coefficient vs reynolds number for 0.5% copper oxide /water nano fluid & inserts

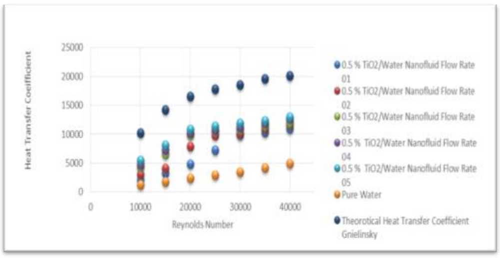

Figure 5. Heat transfer coefficient vs reynolds number for 0.5% titanium oxide /water nano fluid & inserts

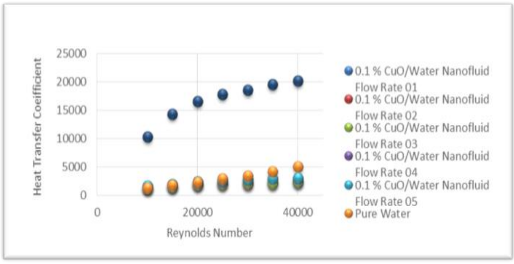

Figure 6. Heat transfer coefficient Vs Reynolds Number for 0.1% copper oxide /water nano fluid & inserts

For the error of investigation, theoretical heat transfer coefficient is compare with the investigated values of heat transfer coefficient.

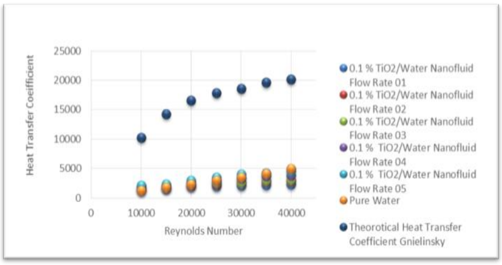

Figure 7. Heat transfer coefficient Vs Reynolds Number for 0.1% titanium oxide /water nano fluid & inserts

6. Discussion on concluding investigation

The investigation was performed for heat transfer coefficient, heat transfer enhancement, friction factor of Copper Oxide/water and Titanium Oxide/water Nano Fluids in a circular copper tube with perforated twisted tape insert. Reynolds number range was 10,000 to 40,000. Volume concentration varied from 0.1%, 0.3% and 0.5%. Conclusion of Investigation can be drawn as below:

The heat transfer coefficient increasers while increasing the flow rate of Nano fluid but if we increases the percentage Volume concentration in water of Nano oxides it results will goes on better way and heat transfer rate increases automatically.

The conclusion of the investigation is when we used both Nano fluids and inserts on same time the rate of heat transfer coefficient increases as compared to use of pure water then Nano fluids.

In case of 0.1% vol. concentration of both the Nano fluids the rate of heat transfer coefficient is increases constantly as compared with the percentage volume concentration of 0.3% and 0.5% respectively.

The flow rate of Nano fluids increases will increases in the heat transfer rate of the heat exchanging device.

Also concluded that the titanium oxide gives better result of heat transfer coefficient as compared with the base fluid and copper oxides Nano fluid.

The theoretical value of heat transfer coefficient is greater than the investigated value for both the Nano fluids it clarify that due to few human error while performing the experimentation.

If Reynolds no. increases the heat transfer rate increases automatically, for the Re. No. range from 20000 to 40000 the heat transfer enhancement results will increases and also the percentage value of heat transfer coefficient increases with more than 40 % as comparing with both the Nano fluids using perforated tape inserts.

The overall conclusion of the investigation is that the Nano fluids are the best suited heat transfer medium for enhancing the rate of heat and ultimately the heat transfer coefficient while flowing fluid is at higher value of Reynolds Number.

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Nomenclature

C_p specific heat of fluid (J/kg K)
d_{hyd} hydraulic dia. of test tube (m)
h heat transfer coefficient (W/m^{2}K)
k thermal conductivity (W/m K)
m mass flow rate of the fluid (kg/s)

Nu average Nusselt number = (hexpdhyd)/ k
P tube periphery (m)
Pr Prandtle number = µ Cp/k
Q heat transfer rate (W)
Re Reynolds number = ρ u dhyd/ µ
S cross sectional area of the test tube
T temperature (K)
U fluid velocity (m/s)

Greek letters
ρ density (kg/m^3)
µ Viscosity (kg/m s)
Ø Volume fraction