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Heat Transfer Enhancement of Pure Distilled Water and Al2O3 Nanofluid in Circular Pipe with Twisted Tape Insert

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***Abstract*--The convective heat transfer behaviour of pure distilled water and Al2O3 nanofluid in a circular tube with different twist ratios of twisted tape inserts are studied experimentally. The experiment was conducted with pure distilled water and nanofluids with inserts and without inserts. heat transfer coefficient data at various volume concentrations for flow in a plain tube and with twisted tape insert is determined. Particle volume concentration of $0 < \varphi < 0.5\%$ and twisted tape with twist ratio in the range of $0 < H/D < 10$. The result indicates that the increase heat transfer coefficient is found with decrease in twist ratio and with higher nanofluids volume concentration.**

Key words: Heat Transfer Enhancement, Nanofluid, Inserts, Twist Ratio, Passive Technique

I. INTRODUCTION

Heat transfer enhancement with nanofluids and twisted tape inserts has gained significant attention over the past few years. As the technique of heat transfer is widely used to prevent the overheating and improvement of heat transfer rate. For the better improvement of the heat transfer rate in heat exchangers namely two methods are used one is active and another one is passive. Apart from nanofluids conventional fluids such as ethylene glycol, water are unable to meet increasing demand for cooling in high energy applications this all due to, conventional fluids are having low thermal conductivity property. Heat transfer enhancement refers to different methods used to increase rate of heat transfer without affecting much to the overall performance. Uses of twisted tape inserts with nanofluids have been widely used for enhancing the convective heat transfer in various applications which is possible due to their effectiveness and low cost.

II. EXPERIMENTAL SET UP AND PROCEDURE

An experimental set up is fabricated to study the convective heat transfer feature in a tube with twisted tape inserts and with without inserts, the working fluid used over here was pure distilled water and Al2O3 nanofluid. As shown schematically in Fig. 1, The set up consists of test section of 0.8 meter length of copper tube of 0.014m inner diameter. The storage tank of 6 l capacity was used in the experimental set up, The thermocouples are located at regular interval within the test section in order to measure the temperatures at the various locations within the test section, five PT 100 type thermocouples are used within the test section and two PT 100 type thermocouples are used at the inlet and exit of the test section.

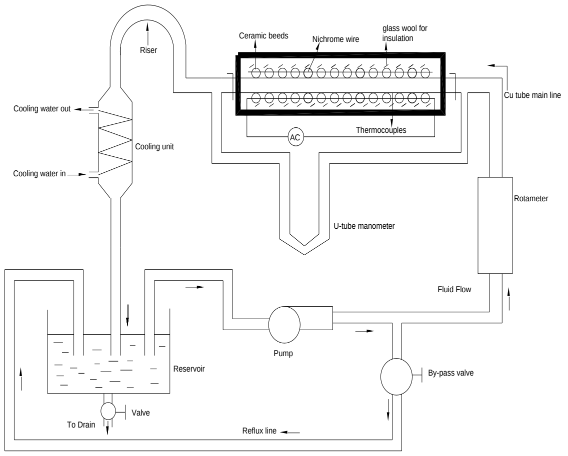

Fig. 1 Experimental Set up

The experiments were conducted with pure distilled water and later by the nanofluid i.e. Al2O3 , with the different loading by volume and at various flow rate within the test section without inserts and with twisted tape inserts with three different twist ratios i.e. 2.5, 5, 10. The temperature at the various locations as well as at inlet and at the exit of the test section is measured for the distilled water and for nanofluid. After the experimental set up is assembled, the storage tank is filled with the working fluid. Experiments are conducted with water and nanofluid to determine the heat transfer coefficients for a flow in a tube. Nanofluid of different volume concentrations of 0.1%, 0.3%, 0.5%, was used in conducting experiments. Al2O3 nanoparticles of size < 50 nm (less than 50 nm) are supplied by Sigma–Aldrich Chemicals Ltd., Germany, and distilled water is used to prepare the nanofluids.

TABLE I. Properties of Al2O3 nanopowder

Properties	Al2O3
Diameter (nm)	Size < 50nm
Density (kg/ m3)	3700
Specific Heat (J/kg-K)	880
Thermal Conductivity (W/m-K)	46

The twisted tapes are made from 3 mm thick and 0.012 m width of aluminum strip and dimensions of twisted tape inserts is shown in Table II. The two ends of a strip were inserted into the lathe, one at the headstock end and the other at the tail stock end. The strip was then subjected to twist by turning the chuck manually. Three twist ratios of TR = 2.5, 5, and 10 were made.

TABLE II. DIMENSIONS OF TWISTED TAPE INSERTS

S. No.	Parameters	Twist Ratio, TR= W/H (m)		
		2.5	5	10
1	W (width)	0.03	0.06	0.12
2	H (height)	0.012	0.012	0.012

III. EFFECTIVE PROPERTIES OF NANOFLUID AT VARIOUS VOLUME CONCENTRATION LOADING: FOR 0.1% LOADING BY VOLUME

- Density of nanofluid,

$$\rho nf = \varphi.\rho s + (1- \varphi).\rho w$$
$$= 0.001x\ 3700 + (1-0.001)\ x\ 997$$
$$= 999.70\ kg/m3$$

- Viscosity of nanofluid,

$$\mu nf = \mu w\ .\ (1+2.5\ \varphi)$$
$$= 6.54x10\text{-}4.\ (1+2.5x0.001)$$
$$= 6.56x10\text{-}4\ N\text{-}s/m2$$

- Specific heat of nanofluid,

$$Cpnf = \frac{\varphi(cps\,.\rho s)+(1-\varphi)(cpw\,.\rho w)}{\rho nf}$$
$$= 4175\ J/kg\text{-}K$$

- Thermal conductivity of nanofluid,

$$Knf=[\frac{Ks+2Kw+2(Ks-Kw)(1+\beta)3.\varphi}{Ks+2Kw-(Ks-Kw)(1+\beta)3.\varphi}]\ xKw\ = 0.63\ W/mK$$

IV. RESULT AND DISCUSSION

A. *Heat transfer coefficient of pure distilled water and nanofluid without inserts*

The balance between the heat supplied by heating and absorbed by the flowing liquid is given by using Eqs. (1) and (2) for every set of data and the experimental heat transfer coefficient is given by Eq. (3)

$$Q=VxI \quad (1)$$
$$Q=(\rho UA)xCpx(To\text{-}Ti) \quad (2)$$
$$hEexp = \frac{(\rho\ U\ A)\ \ Cp\ \ (To\text{-}Ti)}{(\pi\ d\ L)\ [(Tw - \frac{To+Ti}{2})]} \quad (3)$$

$$And\ Nuexp = \frac{hwexp\ \ x\ d}{kw} \quad (4)$$

The experimental result is compared with the theoretical co-relation,`

Saider – Tate is valid for the low loading and laminar region.

$$Nutheo = 1.86(Re.Pr.d/L)0.33\frac{\mu nf}{\mu wnf} \quad (5)$$

The values of Nusselt number of Al_2O_3 and pure distilled water estimated from Eq. (4) in a plain tube it indicated that the convective heat transfer coefficient of nanofluids increases with volume concentration as compare to the pure distilled water. Heat transfer enhancement at 0.3% loading of Al_2O_3 by volume is more as compare to other volume concentration and pure distilled water at the same Reynolds Number. The result for the rate of the heat transfer enhancement is shown in Fig. 2

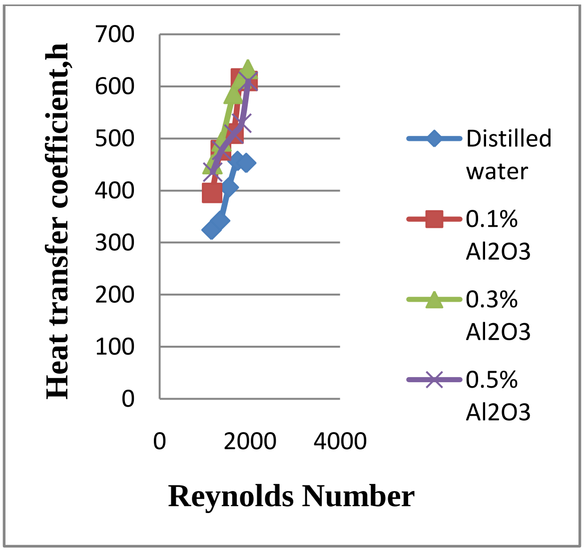

Fig. 2 Heat transfer coefficient (W/m2K) Vs Reynolds Number for pure distilled water and various loading of Al2O3 in distilled water for without inserts

B. Heat transfer coefficient of pure distilled water and nanofluid with inserts.

Experiments with twisted tape inserts are further conducted to estimate the heat transfer coefficient twisted tape inserts with nanofluid Al2O3 flowing in a tube, because that is the main objective of this present work. The procedure is repeated with tapes of different twist ratios of 2.5, 5, 10. The value of Nusselt number is estimated from Eq. (14) for both the fluid and the compared with the theoretical values obtained from Eq. (5) from the obtained result the rate of heat transfer is more with twist ratio 2.5 at 0.3% loading of Al2O3 by volume and as the flow rate increases the rate of heat transfer also increases. The result for the enhancement rate as shown in Fig. 3, Fig. 4, Fig. 5 respectively.

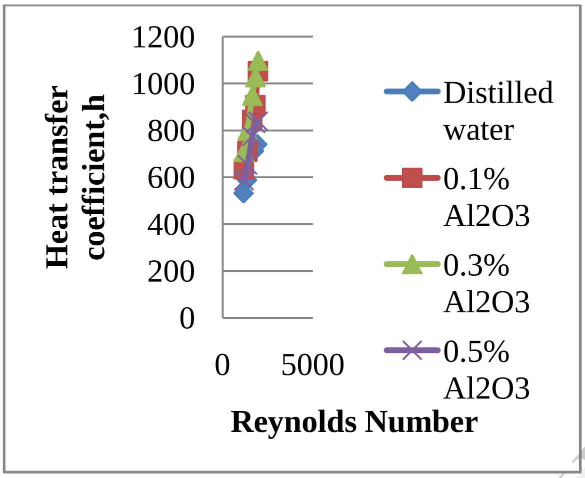

Fig. 3 Heat transfer coefficient (W/m2K) Vs Reynolds Number for pure distilled water and Various loading of Al2O3 in distilled water with insert, TR=2.5

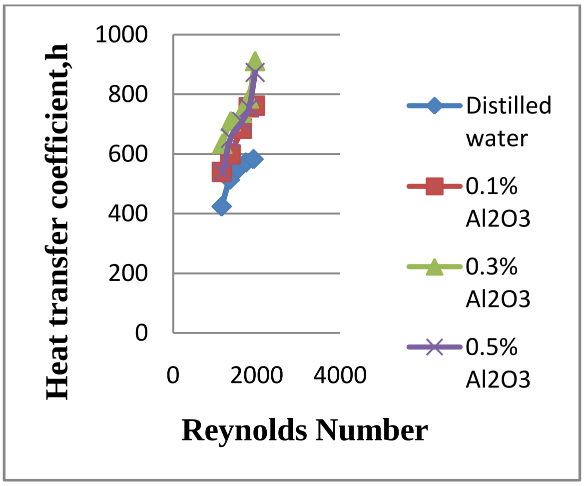

Fig. 4 Heat transfer coefficient (W/m2K) Vs Reynolds Number for pure distilled water and Various loading of Al2O3 in distilled water with insert, TR=5

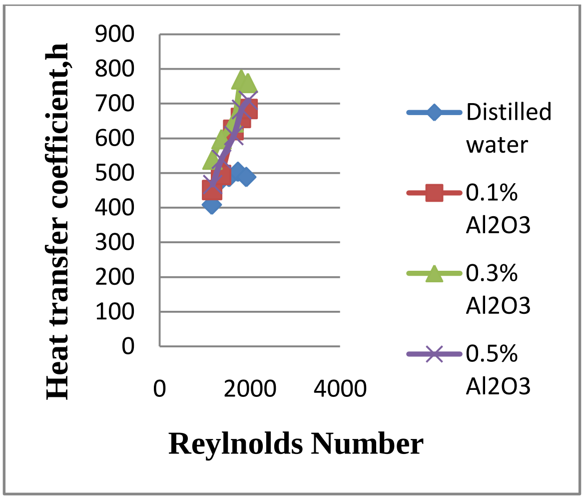

Fig. 5 Heat transfer coefficient (W/m2K) Vs Reynolds Number for pure distilled water and Various loading of Al2O3 in distilled water with insert, TR=10

V. CONCLUSION

- Heat transfer coefficient at Reynolds number in the range of 1000 – 2000 with nanofluids of 0.3% of volume concentration of nanofluid Al_2O_3 is higher when compared to the results obtained from pure distilled water and without inserts. The Nusselt number obtained here is 13.86.
- Heat transfer coefficient at Reynolds number in the range of 1000 – 2000 with TR=2.5 and nanofluid of 0.3% of volume concentration is higher when compared to the result obtained from without inserts for pure distilled water nanofluid of different volume concentration. The maximum Nusselt number obtained here is 23.97.
- Higher the concentration of nanofluid results into considerably high thermal performance. Proper handling of nanofluid is very much essential to reduce its oxidation.

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