EXPERIMENTAL STUDY ON HEAT TRANSFER ENHANCEMENT IN A PLAIN TUBE HEAT EXCHANGER FITTED WITH TWISTED TAPE INSERT WITH DIFFERENT TWIST RATIO BY USING WATER-BASED AL_2O_3 NANOFLUID

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Abstract : In the present work, the heat transfer and friction characteristics were experimentally investigated, employing twisted tape insert with holes inserted in a plain tube heat exchanger. The experiment was conducted by using water-based Al_2O_3 nanofluid at 0.3% volume concentration. The twisted tape insert with holes was inserted into the tube to generate the turbulent flow which helped to increase the heat transfer rate of the tube. The flow rate of the tube was in a range of Reynolds number between 800 to 2400. The physical properties of water-based Al_2O_3 nanofluid needed to calculate the pressure drop and convective heat transfer coefficient have been measured. In this experiment the pitch length 4cm and 6cm twisted tape insert with holes was used. In the experiment, the water-based Al_2O_3 nanofluids used as a working fluid and the readings are taken down with and without twisted tape insert with holes. The experimental data obtained were compared with those from plain tubes of published data. Experimental results confirmed that the use of twisted tape insert with holes leads to a higher heat transfer rate over the plain tube of water-based Al_2O_3 nanofluid.

IndexTerms **- Enhancement heat transfer, Nusselt number, Reynolds number, Water-based Al_2O_3 nanofluid, twisted tape insert with holes, Friction factor.**

I. INTRODUCTION

A majority of heat exchangers used in thermal power plants, chemical processing plants, air conditioning equipment, refrigerators, petrochemical, biomedical and food processing plants serve to heat and cool different types of fluids. Both the mass and overall dimensions of heat exchangers employed are continuously increasing with the unit power and the volume of production. The need to optimize and conserve these expenditures has promoted the development of efficient heat exchangers. Different techniques are employed to enhance the heat transfer rates, which are generally referred to as heat transfer enhancement or heat transfer augmentation techniques. In this report, the augmentation of heat transfer with twisted tape insert with holes was developed and investigated experimentally. The twisted tape inserts are expected to induce a rapid mixing and a high turbulent flow resulting in an excellent rate of heat transfer in the tube.

II. EXPERIMENTAL SETUP

The schematic diagram of the experimental setup is shown in figure. It consists of a calming section, test section, pump, cooling unit, and a fluid reservoir. The test fluid is directed from the reservoir to the calming section and then to the test section using a pump. There is a valve and a bypass valve used to control the flow rate. The flow rate is shown by paddle wheel flow meter. The fluid after passing through the heated section flows through a riser section and then through the cooling unit and finally it is collected in the reservoir. The test section is heated uniformly by the electrical heating wire, attached to an auto-transformer, by which the heat flux can be varied by varying the voltage. Calibrated RTD sensors are used to measure the inlet, outlet and surface temperatures at five different locations.

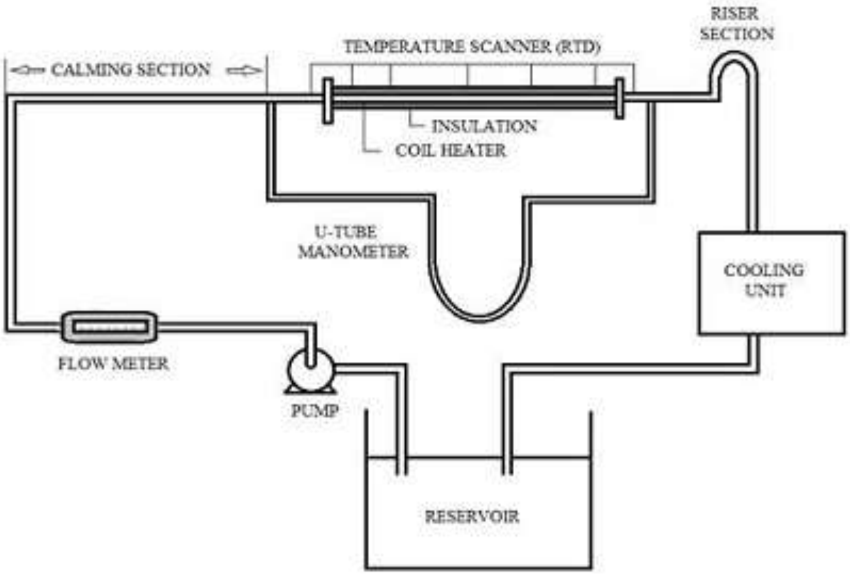

Fig 1: Schematic diagram of experimental setup

A differential U-tube manometer is fitted across the test section to measure the pressure drop. An ordinary type of fan is provided for the effective cooling of the fluid.

III. PROPERTIES OF NANOFLUID

In this experiment 0.3% volume concentration of water-based Al_2O_3 nanofluid was used. The physical properties of water-based Al_2O_3 nanofluid are very important for convective heat transfer and pressure drop calculations. There are some standard equations are available to calculate the properties of water-based Al_2O_3 nanofluid.

Density of nanofluid

$$\rho_{nf} = \Phi\rho_n + (1-\Phi)\ \rho_{bf}$$

heat capacity of nanofluid

$$Cp_{nf} = \Phi\ Cp_n + (1-\Phi)\ Cp_{bf}$$

Thermal conductivity of nanofluid

$$K_{nf} = (1+8.733\ \Phi) * K_{bf}$$

Viscosity of nanofluid

$$\mu_{nf} = \mu\ (1+K_1\ \Phi)$$

IV. DATA REDUCTION

The total heat generated by the electrical winding is calculated as

$$Q_1 = VI$$

Heat absorbed by the fluid is calculated as

$$Q_2 = \dot{m}\ C_p\ (T_{out} - T_{in})$$

Where, V is applied voltage, I current, ṁ mass flow rate of water, Cp specific heat of water, $T_{in\ and}$ $T_{out\ inlet}$ and outlet temperatures of water.

The average heat transfer is

$$Q = Q_1 + Q_2 / 2$$

The measured local wall temperature and heat flux are used to calculate the local heat transfer coefficient defined by the following formula,

$$h = Q / A\ \mathbf{\Delta T}$$

The average Nusselt number is calculated as,

$$Nu = \frac{hD}{k}$$

The pressure drop (Δp) measured across the test section under isothermal condition is used to determine the friction factor (f) using the following relation,

$$f = \frac{\Delta p}{\frac{1}{2}\rho v^2}\frac{D}{L}$$

4.1 Validation of experimental setup

To validate the experimental setup, experiments were conducted with pure water in plain tube with Reynolds numbers in the range 800-2400 for laminar flow. The experimental data for laminar flow can be solved by Shah Equation, given by, $Nu = 1.90\ (Re*Pr*D/ L)^{0.333}$

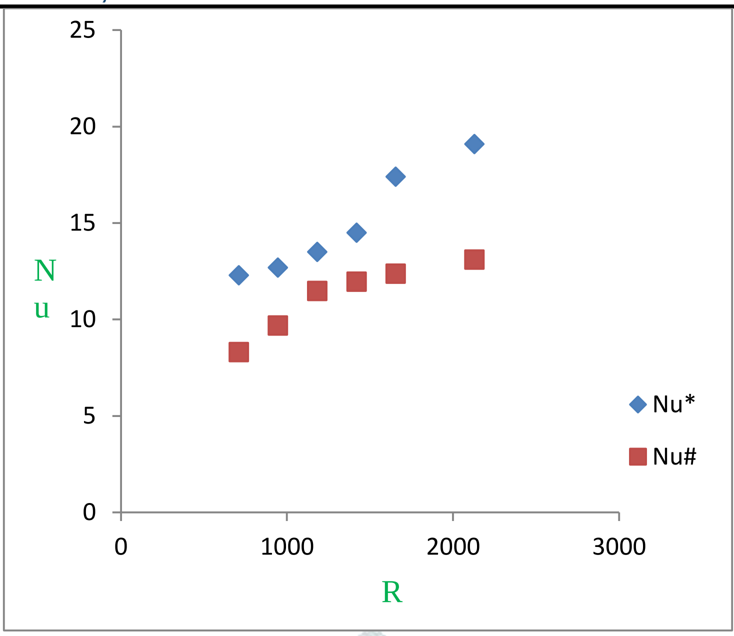

Fig 2: Verification of Nusselt number of plain tube

Where,

Nu*- Experimentally calculated

Nu#- Shah Equation

4.2 Validation of friction factor

The validation of experimental setup was done under constant heat flux conditions. The experimental friction factor data for laminar flow can be solved by Hagen-Poiseuille equation, given by

f = 64 / Re

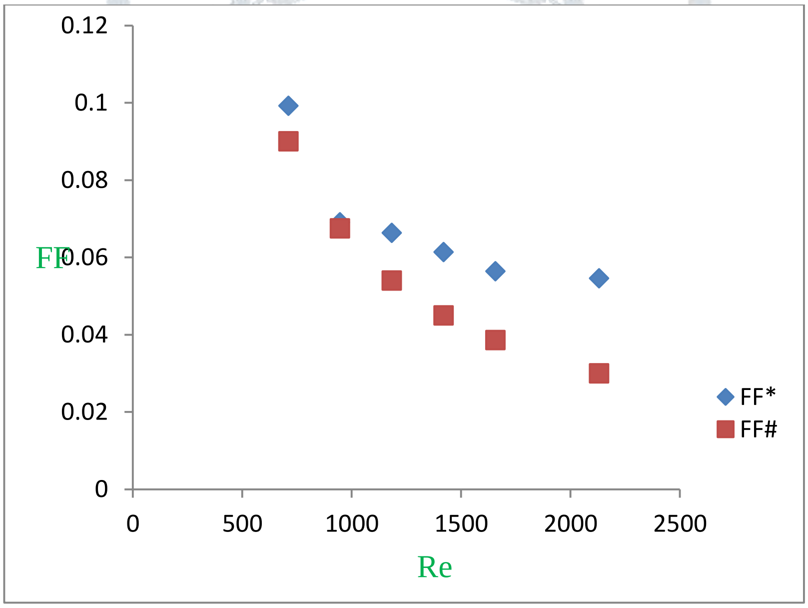

Fig 3: Verification of friction factor of plain tube

The Nusselt number determined from these experimental data was compared with the values obtained from the correlations of Shah Equation and the friction factor data was compared with Hagen-Poiseuille equation

V. RESULTS AND DISCUSSION

The experiments were conducted in a plain tube heat exchanger fitted with twisted tape insert using water- based Al_2O_3 nanofluid. In this experiment 4cm and 6 cm pitch length twisted tape insert with holes was used to generate the swirl flow of the flowing fluid in the test section.

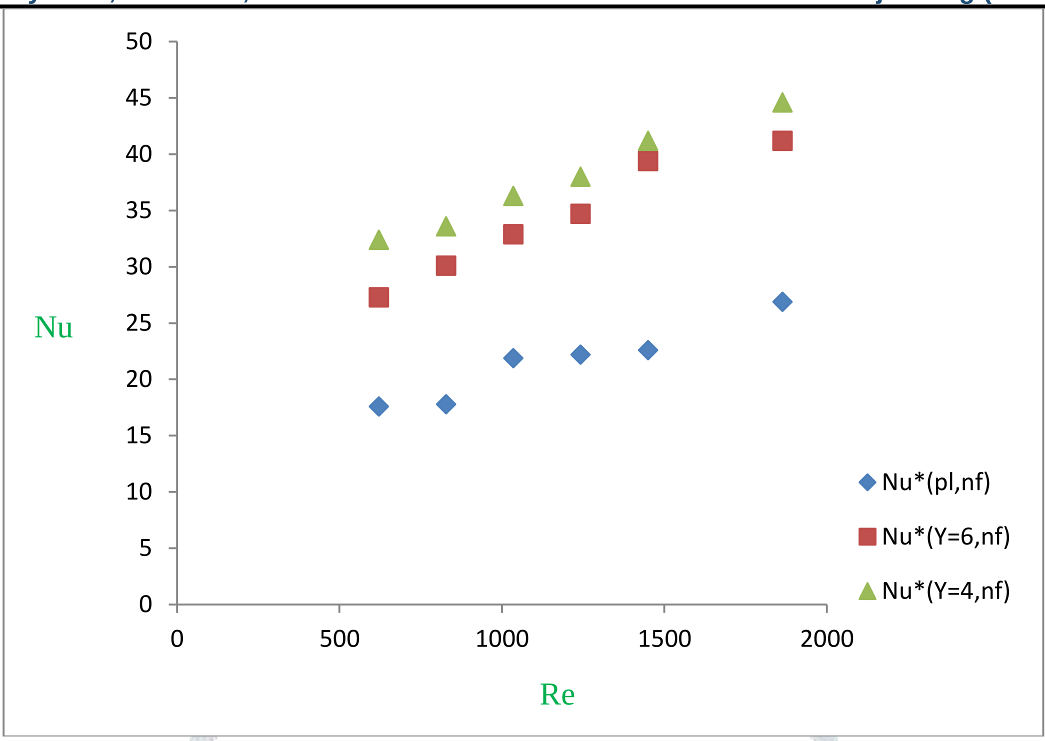

Fig 4: Nusselt number comparison for laminar flow

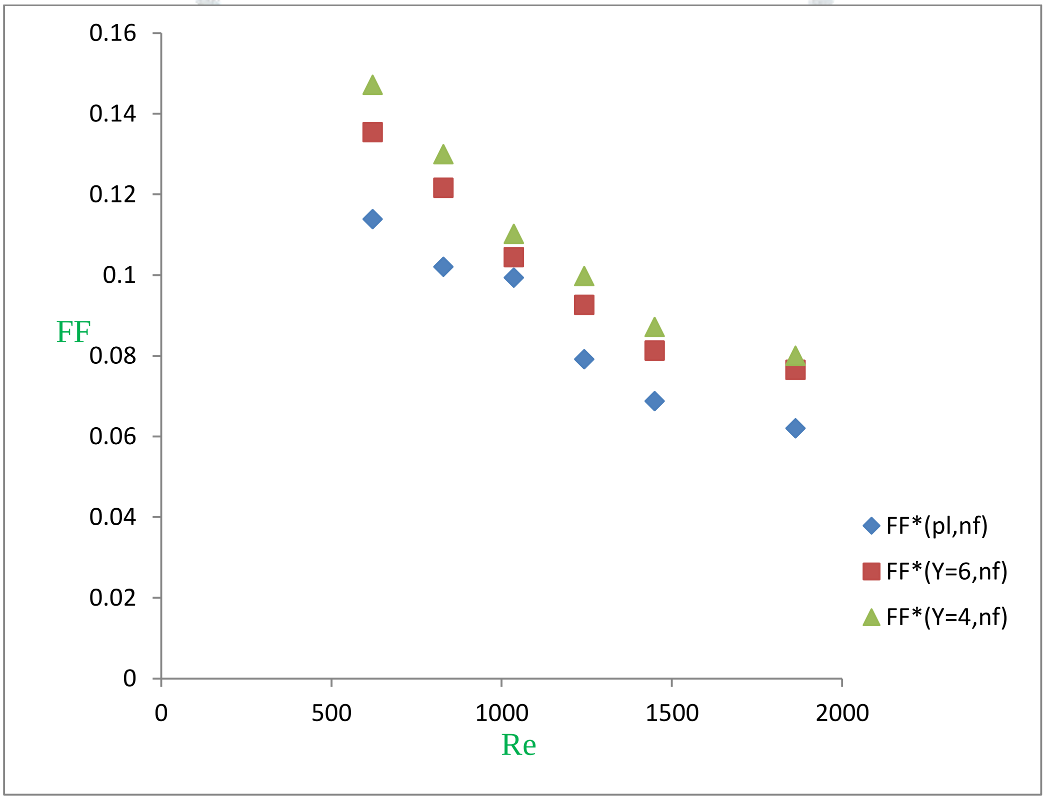

Fig. 5 Friction factor comparison for laminar flow

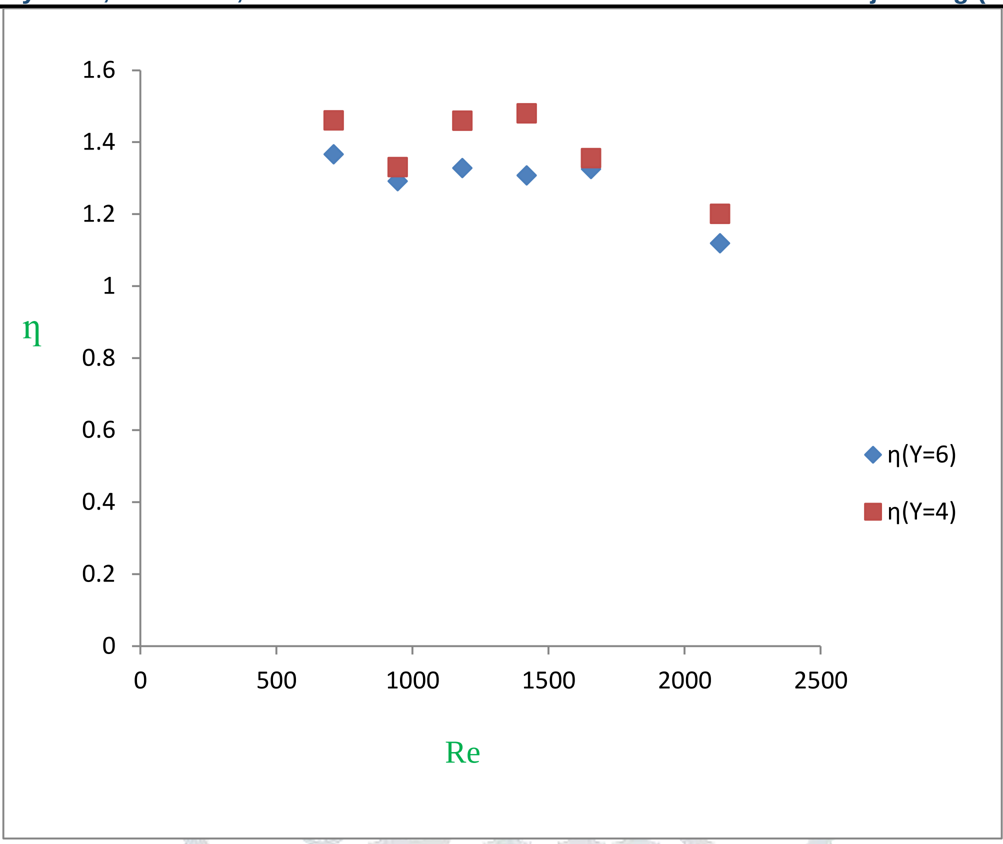

Fig. 6 Thermal performance comparison for laminar flow

From the above results the following conclusion were made,

- The convective heat transfer coefficient of the plain tube with inserts is always high as compared to the convective heat transfer coefficient of the plain tube without inserts.
- Enhancement of heat transfer in comparison to plain tube is highest for twisted tape insert with holes.
- As compared to twist ratio 6 insert, the convective heat transfer coefficient is high for twist ratio 4insert.
- Performance ratio increases with decreasing twist ratio with the maximum for the twist ratio 4 both laminar flow.

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