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Experimental Investigation on Enhancement of Heat Transfer Rate in Heat Exchangers using Plain and Punched Twisted Tape Inserts and Nanofluid Employing Al_2O_3 Particles

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Abstract

Enhancement of heat transfer rate is one of the crucial factors to be considered in design of heat exchangers. In the present work, experimental investigation is carried in out to achieve the enhancement of heat transfer in the heat exchangers using plain tube, tube with twisted tape inserts and also using the tube with regularly punched twisted tapes. The tape insert with a twisting ratio of 2.37 has been used in the flow passage at flow rates maintained at 4, 6, 8 LPM. The heat transfer rate, friction factor and pressure drop have been calculated for each test case with and without inserts, whereas the range of Reynolds number is 2000<Re<10000, Comparative studies have been carried out for the above mentioned cases using water as well as Nanofluids. While using Nanofluids, the performance of the heat exchangers in terms of the heat transfer and pressure drop are found to be much superior to the performance using distilled water for the same geometric configurations. The rate of heat transfer is found to increase by using inserts and hence modifying the geometry of the flow passage in the duct of the heat exchangers.

Keywords: Heat Exchanger, Heat Transfer Enhancement, Nanofluid, Plain Cut and Punched Twisted Tape Inserts, Twist Ratio, Al_2O_3

1. Introduction

Now a days there are so many techniques are developed to increase the rate of heat transfer in a heat exchanger tubes, these heat transfer techniques are widely used in areas such as boilers, chemical reactors, refrigeration system and air conditioning systems[1]. The efficiency of heat transfer rate can be improved by disturbing the motion of fluid in the heat exchanger but by doing this there extra work on pumping the fluid[2]. In general the heat transfer techniques are divided in three groups one is passive, active and compound techniques, among all the twisted tape insertion technique is the most promising techniques in heat transfer augmentation which improves fluid mixing by generating the swirl effect of fluid. In passive technique insertion of twisted tapes in a tube created swirl into the bulk flow by disturbing the boundary layer at the tube surface due to repeated changes in its surface geometry which helps to enhance convective heat transfer in a heat exchanger[3]. There are so many research works carried on finding the better rate of heat transfer with less frictional losses, the rate of heat transfer in a twisted type inserts are depends on the twist ratio and pitch, the enhancement of heat transfer can further increased by making a changes or by modifying the geometry design of the twisted tapes such as twisted tapes with punch, twisted tapes with V cut[4]. The passive type of heat transfer techniques are most widely used in heat transfer in circular type of heat exchangers. The active techniques are involves the addition of nano sized, metallic powder and high thermal conductivity to maximize rate of heat transfer in the heat exchanger.

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2. Literature Survey

P. Murugesan et al.[5]: In his research exhibit an impact of V-cut bended tape is inserted in round tube of heat exchanger to find the heat transfer rate, friction factor and thermal performance aspect attributes with three twist ratios (y=2.0, 4.4 and 6.0). From test outcomes it found that the V-cut abrasion tape offered a higher heat transfer rate, friction factor and also thermal performance factor compared with the horizontal bended tape.

Sarang S. Hole et al.[6]: In this article author was focused on improvement of the rate of heat transfer using modified bended tape. In this case of bended tape with changed dimensions are used, during the fluid swirl that time it creates more turbulence and gives the high heat transfer rate comparing with the plain and altered twisted tape. This modified bended tape gives more heat transfer rate and less friction factor for both laminar and turbulent flow.

Prashant Tikke et al.[7]: Author studied experimental analysis of heat transfer, friction factor and thermal characteristics of turbulent flow in channel with bended tape as the swirl generates under the condition of constant wall heat flux. From test outcomes they conclude that Nusselt number increases with increasing the Reynolds number and bended tape will have constant pumping power.

Kundan Lal Rana et al.[8]: They conducted test on finding thermal properties of nanofluid like viscosity, thermal conductivity, heat transfer coefficient and thermal diffusivity using Al_2O_3 nano-particles of 0.1% to 0.9% volume concentration with base fluid like (water). From test results they concluded that use of Al_2O_3 nano-particles with water the thermal properties such as thermal conductivity, heat transfer coefficient of nanofluid found to be increased.

Praveen et al.[9]: Considered the heat transfer improvement - Al_2O_3 water Nano fluid. The rate of heat transfer is estimated with various temperatures (250-800K), different concentrations (0.01-0.5%) and various Reynolds number (2500-5000). They finally conclude that the rate of Heat transfer is increases with increasing Reynolds number and volume concentration of Nanofluid but decreased when increasing initial temperature of Nano fluid.

Jaafar Albadr et al.[10]: Author Studied experimental convective of heat transfer and flow characteristics of Al_2O_3 nanofluid by using water and different volume concentration flowing horizontal in shell and tube heat exchanger counter flow under turbulent condition. They come up with a results convective heat transfer coefficient of nanofluid are slightly higher than the base liquid at same mass flow rate at same inlet temperature. The heat transfer coefficient of nanofluid increases with an increasing mass flow rate and volume concentration of Al_2O_3 nanofluid.

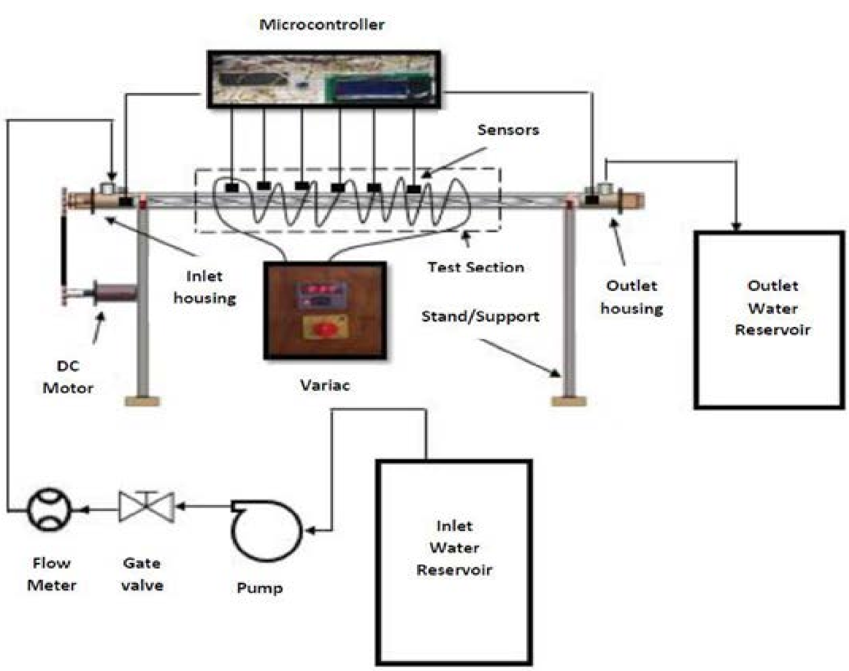


Figure 1. Block diagram of experimental setup.

3. Methodology

The photographic view of the experimental setup is shown below the figure. It consist of test section where water or fluid is allowed to pass through it from inlet to outlet at constant flow rate 4, 6, 8 liter per minute, the power supply is adjusted using dimmer stat at const rate of heat supply. The experimentation was conducted to estimate the rate of heat transfer, pressure drop and friction factor. The same procedure is followed by three different cases, in first case the experiment were conducted using without twisted tape inserts in tube of heat exchanger with twist ratio of 2.37, twist angle 180˚ and twist length of 50mm shown in Figure 2a.

The purpose of using twisted tapes is to create the turbulence of the fluid flow by disturbing the motion of the fluid, as results decreases in the thickness of boundary layer which enhance maximum heat transfer. The water and Al_2O_3 nanofluid is passed through the test section separately at flow rate of 4, 6, 8 LPM the thermal properties of both fluids are noted. In second phase same experiment using plain twisted tape inserts in the tube of heat exchanger and same geometry of heat exchanger shown in Figure 2b. The water and Al_2O_3 nanofluid passed into the test section separately at 4, 6, 8 LPM flow rate the obtained values are compared without twisted tape inserts. Finally, Third phase there is a little modification is done on the geometry shape of the twisted tape i.e. a small hole is drawn on the twist tape with 4 mm inside diameter which is shown below Figure 2c, this is made to analyze the effect of difference in heat transfer rate of plain twisted tape compared to punched (Zero cut) twisted tape of heat exchanger, the water and Al_2O_3 nanofluid passed into test section at various flow rate 4, 6, 8 LPM. The pressure drop heat transfer rate and frictional factors across punched twisted tapes are compared with plain twisted tapes.

Figure 2a. Fabricated Experimental Setup.

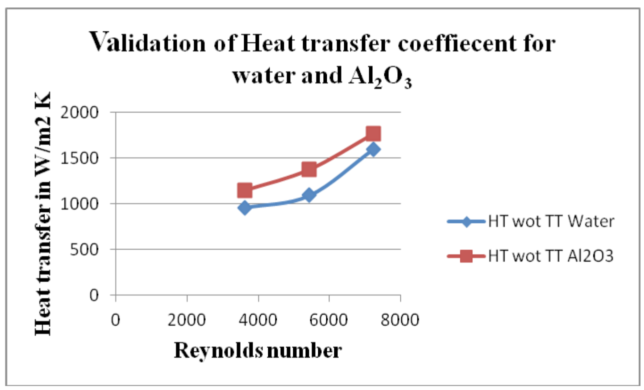
As soon as passing the nanofluid into the test section the steady state surface temperature (T1, T2, T3) are noted, and also there are two separate sensors are incorporated at inlet and outlet hoses to measure inlet outlet temperature (T4, T5) of water. The pressure gauges are placed at inlet and outlet of test section to measure the pressure (P1, P2). The pressure difference gives the maximum pressure drop in the test section for each fluid at every flow rate.

Figure 2b. Pictorial view of plain twisted tape.

Figure 2c. Pictorial view of punched twisted tape.

4. Results and Discussions

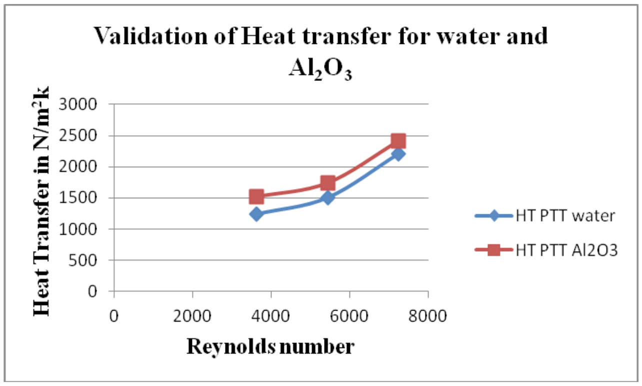
a) Validation of heat transfer coefficient without twisted tape for water and Al_2O_3 Nanofluid



From above graph the rate heat transfer coefficient variation with respect to water and Al_2O_3 nanofluid. The rate of heat transfer coefficient is higher for Al_2O_3 nanofluid compared with water for without twisted tape inserts at different mass flow rate; this is due to clustering and collision of nanoparticles. The heat transfer rate increases with increasing flow rate and at the same time

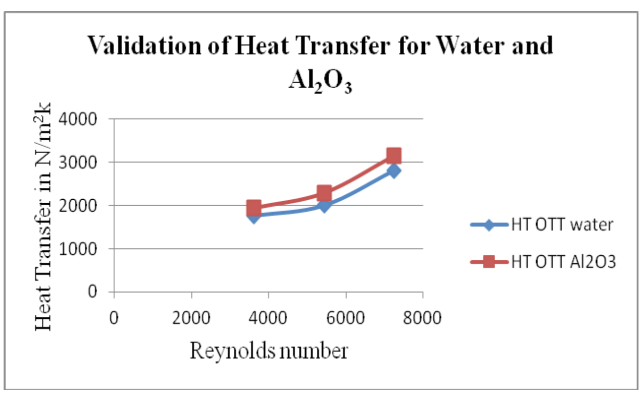
Reynolds number is also increases while comparison of water and Al_2O_3 nanofluid. However, with increase in concentration of nanoparticles the stability of fluid decreases and pressure drop will increases.

b) Validation of Heat transfer coefficient plain twisted tape for Water and Al_2O_3 Nanofluid



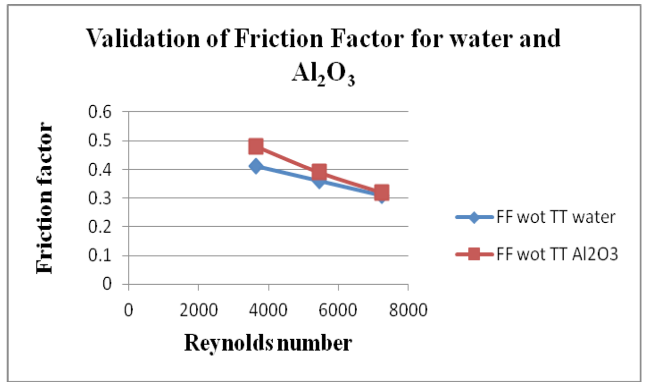
From above graph the rate heat transfer coefficient variation with respect to water and Al_2O_3 nanofluid. The rate of heat transfer coefficient is higher for Al_2O_3 nanofluid compared with water for plain twisted tape inserts at different mass flow rate; this is due to clustering and collision of nanoparticles. The heat transfer rate increases with increasing flow rate and at the same time Reynolds number is also increases while comparison of water and Al_2O_3 nanofluid. However, with increase in concentration of nanoparticles the stability of fluid decreases and pressure drop will increases.

c) Validation of Heat transfer coefficient punched twisted tape for Water and Al_2O_3 Nanofluid



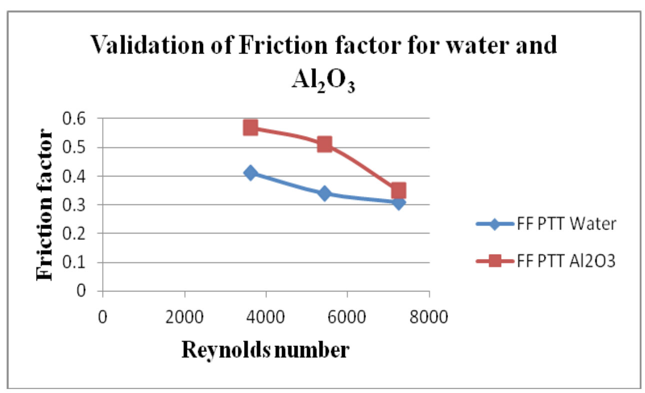
From above graph the rate heat transfer coefficient variation with respect to water and Al_2O_3 nanofluid. The rate of heat transfer coefficient is higher for Al_2O_3 nanofluid compared with water for punched twisted tape inserts at different mass flow rate; this is due to clustering and collision of nanoparticles. The heat transfer rate increases with increasing flow rate and at the same time Reynolds number is also increases while comparison of water and Al_2O_3 nanofluid.

d) Validation of Friction factor without twisted tape for Water and Al_2O_3 Nanofluid



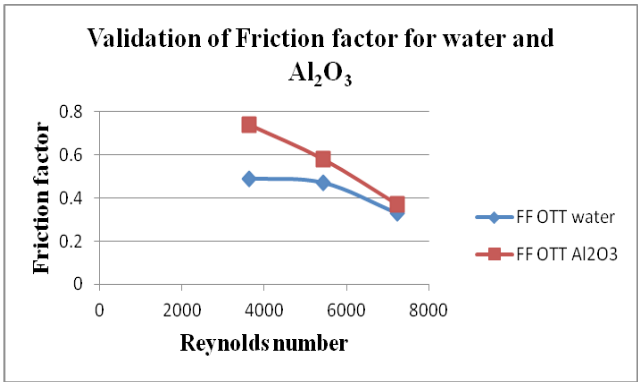
From above graph the friction factor variation with respect to water and Al_2O_3 nanofluid. The friction factor is higher for Al_2O_3 nanofluid compared with water for without twisted tape inserts at different mass flow rate; this is due to clustering and collision of nanoparticles. The friction factor decreases with increasing flow rate and at the same time Reynolds number is also increases while comparison of water and Al_2O_3 nanofluid.

e) Validation of Friction factor plain twisted tape for Water and Al_2O_3 Nanofluid



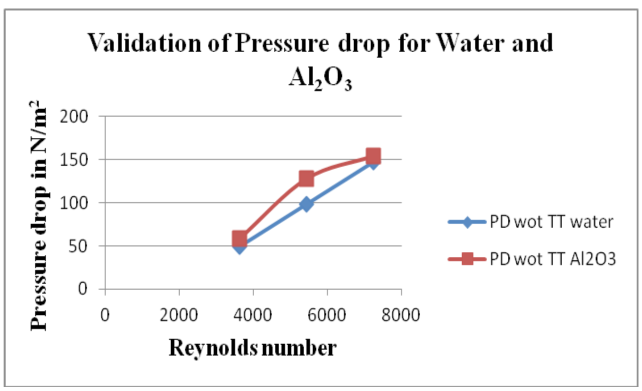
From above graph the friction factor variation with respect to water and Al_2O_3 nanofluid. The friction factor is higher for Al_2O_3 nanofluid compared with water for plain twisted tape inserts at different mass flow rate; this is due to clustering and collision of nanoparticles. The friction factor decreases with increasing flow rate and at the same time Reynolds number is also increases while comparison of water and Al_2O_3 nanofluid.

f) Validation of Friction factor punched twisted tape for Water and Al_2O_3 Nanofluid



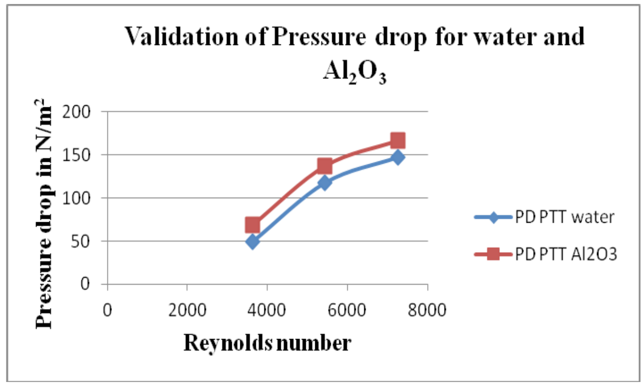
From above graph the friction factor variation with respect to water and Al_2O_3 nanofluid. The friction factor is higher for Al_2O_3 nanofluid compared with water for punched twisted tape inserts at different mass flow rate; this is due to clustering and collision of nanoparticles. The friction factor decreases with increasing flow rate and at the same time Reynolds number is also increases while comparison of water and Al_2O_3 nanofluid.

g) Validation of Pressure drop without twisted tape for water and Al_2O_3 Nanofluids



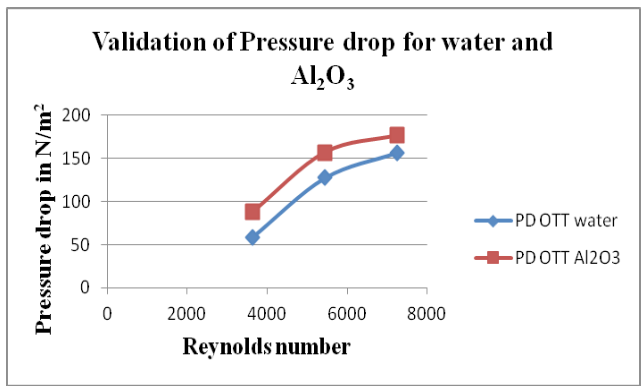
From above graph the pressure drop variation with respect to water and Al_2O_3 nanofluid. The pressure drop is higher for Al_2O_3 nanofluid compared with water for without twisted tape inserts at different mass flow rate; this is due to clustering and collision of nanoparticles. The pressure drop increases with increasing flow rate and at the same time Reynolds number is also increases while comparison of water and Al_2O_3 nanofluid.

h) Validation of Pressure drop plain twisted tape for water and Al_2O_3 Nanofluids



From above graph the pressure drop variation with respect to water and Al_2O_3 nanofluid. The pressure drop is higher for Al_2O_3 nanofluid compared with water for plain twisted tape inserts at different mass flow rate; this is due to clustering and collision of nanoparticles. The pressure drop increases with increasing flow rate and at the same time Reynolds number is also increases while comparison of water and Al_2O_3 nanofluid.

i) Validation of Pressure drop punched twisted tape for water and AL_2O_3 Nanofluid



From above graph the pressure drop variation with respect to water and Al_2O_3 nanofluid. The pressure drop is higher for Al_2O_3 nanofluid compared with water for punched twisted tape inserts at different mass flow rate; this is due to clustering and collision of nanoparticles. The pressure drop increases with increasing flow rate and at the same time Reynolds number is also increases while comparison of water and Al_2O_3 nanofluid.

5. Conclusion

From the test results we found the rise of heat transfer coefficient in plain twisted tape was 30% higher than without insert TT tube and rise of heat transfer in punched twisted tape was 56% higher than plain tube of heat exchanger. Also the friction factor in plain twisted tape inserts was 33% lower than without inserts twisted tape in tube, and for punched twisted tape inserts 38% lower than plain tube without inserts. This rise was observed due to turbulence created by the change in the geometry shape of twisted tape inserts on the plain tube of heat exchanger.

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