International Journal of Scientific & Engineering Research, Volume 8, Issue 4, April-2017
ISSN 2229-5518

Experimental Investigation of grooved tube in tube heat exchanger with and without Nano-fluid

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Abstract— This paper presents experimental investigation of tube in tube heat exchanger in which four different heat exchanger test sections[1] are compared for different thermal characteristics. Tubes of heat exchanger test section are made up with single start internal/external and combined grooves. Overall heat transfer coefficient is compared with increase in inlet temperature by keeping flow rate constant. Variation of Reynolds number with Nusselt number and friction factor are checked by varying flow rate. Water, Al_2O_3 Nanofluid of 0.25%, 0.50%, 0.75% has been studied. The results are compared with Open Literature. It has been observed that overall heat transfer coefficient increases with increase in concentration of nano-fluid. Increase in surface irregularities leads to increase in pressure drop. For plain pipe heat exchanger 48% increase in overall heat transfer coefficient is observed for 0.75% concentrated Al_2O_3 nanofluid as compared to distilled water. Same was 27%, 25% and 16% for section 2, 3 and 4 respectively. Nusselt number varies as 10.25, 11.89, 4.75, 7.5% respectively for test section 1,2,3,4 respectively. Pressure drop of 37% is observed in grooved tubes as compared to plain tubes.

Index Terms— [1]- Test section1- tube in tube heat exchanger both tubes plain, Test section 2- tube in tube heat exchanger inner tube internally grooved outer tube plain, Test section 3- tube in tube heat exchanger inner tube grooved on either sides outer tube plain, Test section 4- tube in tube heat exchanger inner tube grooved on either side outer tube grooved internally, $\dot{Q}_h$ - Heat loss by hot water, $\dot{Q}_c$ - Heat gain by cold water, h- Convective heat transfer coefficient, f- Friction factor, A-surface area,, Re- Reynolds number, Nu- Nusselt number, Pr- Prandtl number, Cp- Specific heat, ΔP- pressure drop, Thi –hot air inlet temperature, Tho –hot water outlet temperature, Tci –cold water inlet temperature, Tco –cold water outlet temperature, $\dot{m}$ -flow rate

1 INTRODUCTION

Various techniques have been used to increase the performance of heat exchanger like, fins, wire insert, twisted tape inserts, electrohydrodynamic technique, nano-fluids, turbulence, etc. Mainly three points has to be considered while designing a heat exchanger viz fluid properties, material roperties and flow pattern. Internal grooves in a heat exchanger pipe increases internal surface area as well as turbulence to the flow, Nano fluid has more thermal conductivity as compared to water which increases heat transfer rate.

P. Bharadwaj et.al [10] have analysed grooved tube with and without twisted tape inserts with heating coil wound. They have found that heat transfer increases considerably in laminar and moderately in turbulent range of Reynolds numbers. Paisarn Naphon et al [1] investigated the heat transfer characteristics of the horizontal double pipes with and without coiled wire inserts. They found that the coiled wire insert has a significant effect on the enhancement of heat transfer. The pressure drop is found maximum with the coiled wire inserts. Ebru Kavak Akpinar [12] evaluated heat transfer and exergy loss in a concentric double pipe exchanger equipped with helical wires. Inner fluid is used as air and outer fluid is used as water.

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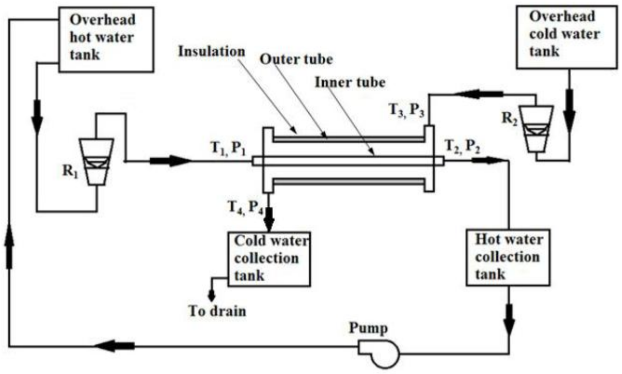
2 EXPERIMENTAL SETUP AND PROCEDURE

Experimental setup is manufactured at Government college of Engineering Karad. Inner tube is copper tube having internal diameter 12mm and outer diameter 15mm. Outer tube is MS tube having ID 20mm and OD 25 mm. Inner tubes are grooved internally by using tap tool with welded handle. Outer grooves are made on lathe. Inner tube is placed at centre of outer tube by using MS T drilled at centre. First section has both inner and outer tube plain(case 1). Second section has inner tube internally grooved and outer tube plain(case 2). Third section has inner tube grooved on either side and outer tube plain (case 3). Fourth section has inner tube grooved on either side and outer tube grooved internally. All the four sections are inspected under same setup as shown in the fig. 1.

Calibrated instruments are used to take the readings. Readings are taken for counter flow case as results for counterflow heat exchanger are better than parallel flow. Water and Nanofluids of 0.25, 0.5 and 0.75 concentration are used as working fluid in inner tube and water for outer tube. Heater with regulator is used to control the temperature of water flowing through inner tube. First the inner tube fluid is heated to certain temperature and then it is allowed to flow through inner tube then cold water is allowed to flow through outer tube. Once the flow is fully developed readings are taken. As the experimentation of P. Bharadwaj showed that grooves gives better effects in laminar flow region so by keeping flow rate of 0.01 kg/s constant, Readings are taken by varying *Thi*. Then to cheque the effect of Re on Nu flow rate is varied and temperature is kept constant.



R_1, R_2 – Rotameter, T_1, T_2, T_3, T_4- Temperature indicators, P_1, P_2, P_3, P_4 - Pressure indicators

Fig. 2.1 Experimental Setup

3 MATHEMATICAL ANALYSIS

For the first type of readings on four cases flow rate of 0.01 kg/s corresponding to Re 2000 is kept constant. The readings are taken by varying inlet temperature of hot water. Each time the flow is allowed to develop fully and readings are taken.
The heat given out by hot water Q_h is obtained by,

$$Qh = \dot{m}h \times Cp \times (Thi - Tho)$$

Where 'ṁ' is the flow rate, *Cp is the specific heat of water obtained from the property chart, Tho and Thi* are outlet and inlet temperatures of hot water respectively which are obtained by thermocouples mounted at inlet and outlet of inner tube. Heat gain by cold water ($Q\dot{c}$) is obtained by,

$$Qc = \dot{m}c \times Cp \times (Tco - Tci)$$

Then the Log Mean Temperature is obtained by,

$$LMTD = \ln\frac{\Delta T1}{\Delta T2}$$

where, $\Delta T_1 = Thi - Tco$
$\Delta T_2 = Tho - Tci$

The overall heat transfer coefficient is calculated as,

$$U = \frac{Qh}{Ai \times LMTD}$$

Second type of readings has been taken by varying flow rate 0.01 to 0.13 ltr/sec at constant temperature of 65^{0}C. Reynolds number is calculated by,

$$Re = \frac{Vm}{\nu}$$

Nusselt number is calculated by,

$$Nu = 0.023 \times Re^{0.8} Pr^{0.4}$$

Friction factor is calculated by,

$$f = \frac{\Delta p \times 0.012}{2 \times 980 \times Vm^2}$$

Various properties for water and nano-fluid are obtained from Heat transfer Data Book.

4 RESULT AND DISCUSSION

4.1 Inlet temperature Vs Overall heat transfer coefficient:
Tests were conducted for different heat exchanger sections. Inlet temperature is varied by using dimmerstat. Working fluid is varied as water, 0.25%, 0.50% and 0.75% nano-fluid. Results for different working fluids are plotted for test section 1, 2, 3 &4 as shown in fig4.1.1, fig4.1.2, fig4.1.3 and fig4.1.4 respectively.

It is observed that for every test section overall heat transfer coefficient increases as increase in inlet temperature. For test section 1, average 48% hike in overall heat transfer coefficient is observed for 0.75% nano-fluid as compared to water. For test section2, 3 and 4 this hike is around 27%, 25% and 16% respectively.

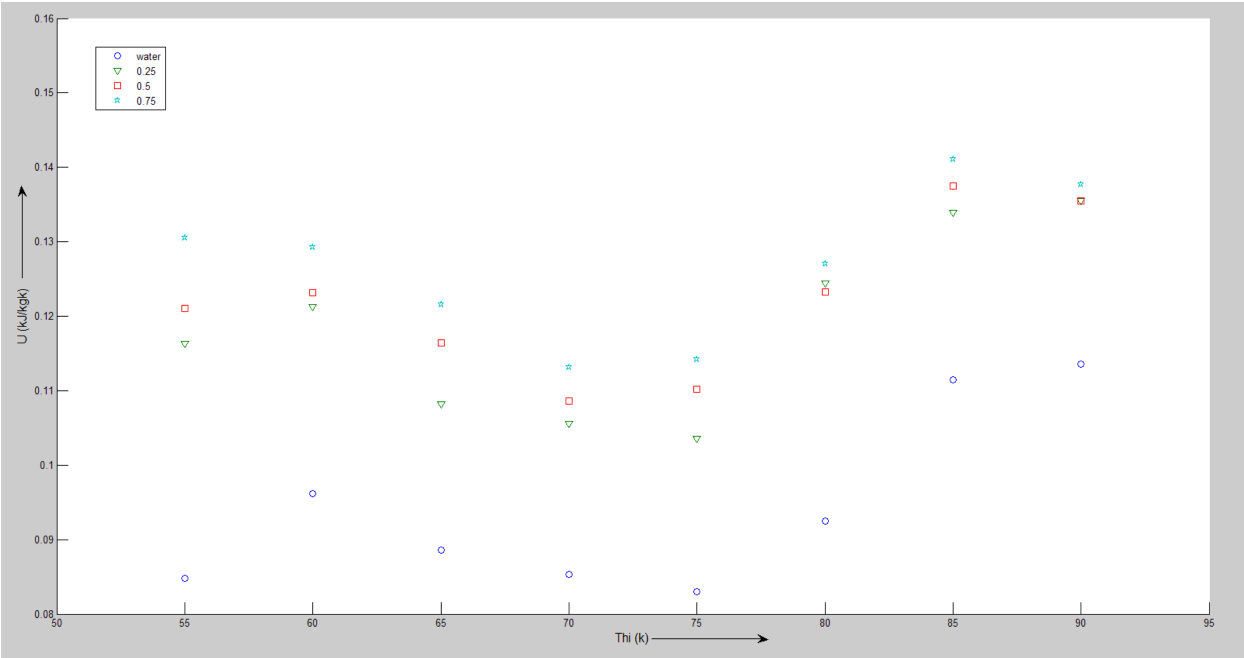


Fig.4.1.1 Thi Vs U for test section1

Fig.4.1.1 Thi Vs U for test section2

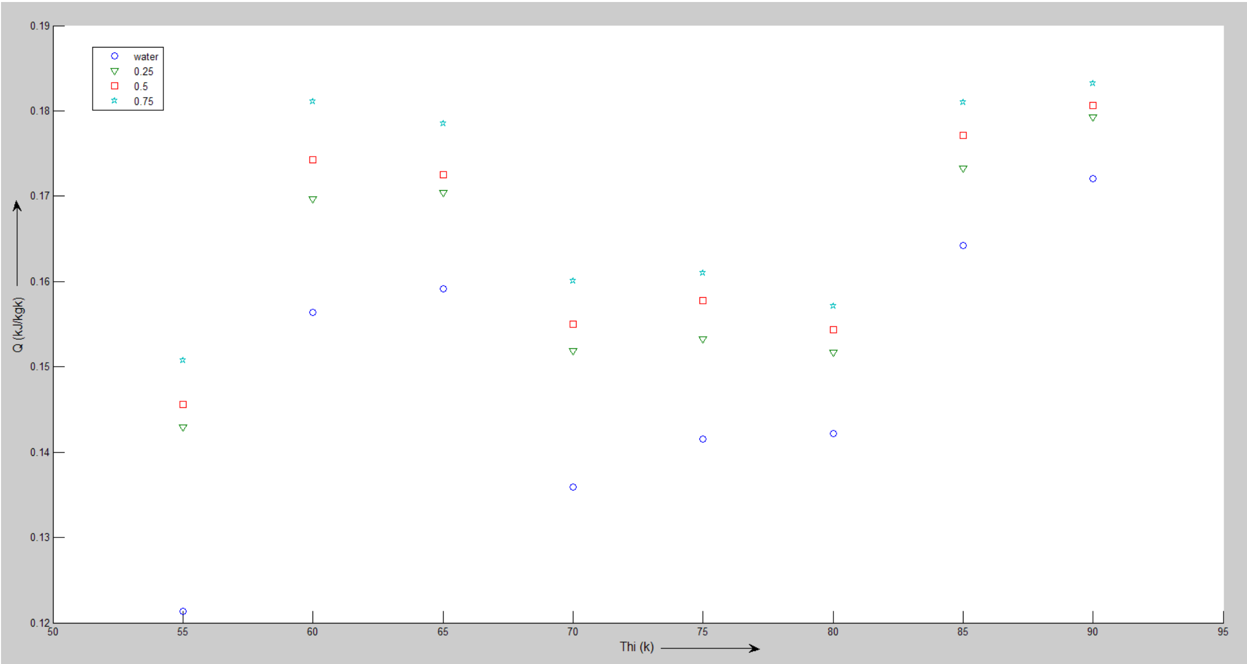


Fig.4.1.1 Thi Vs U for test section3

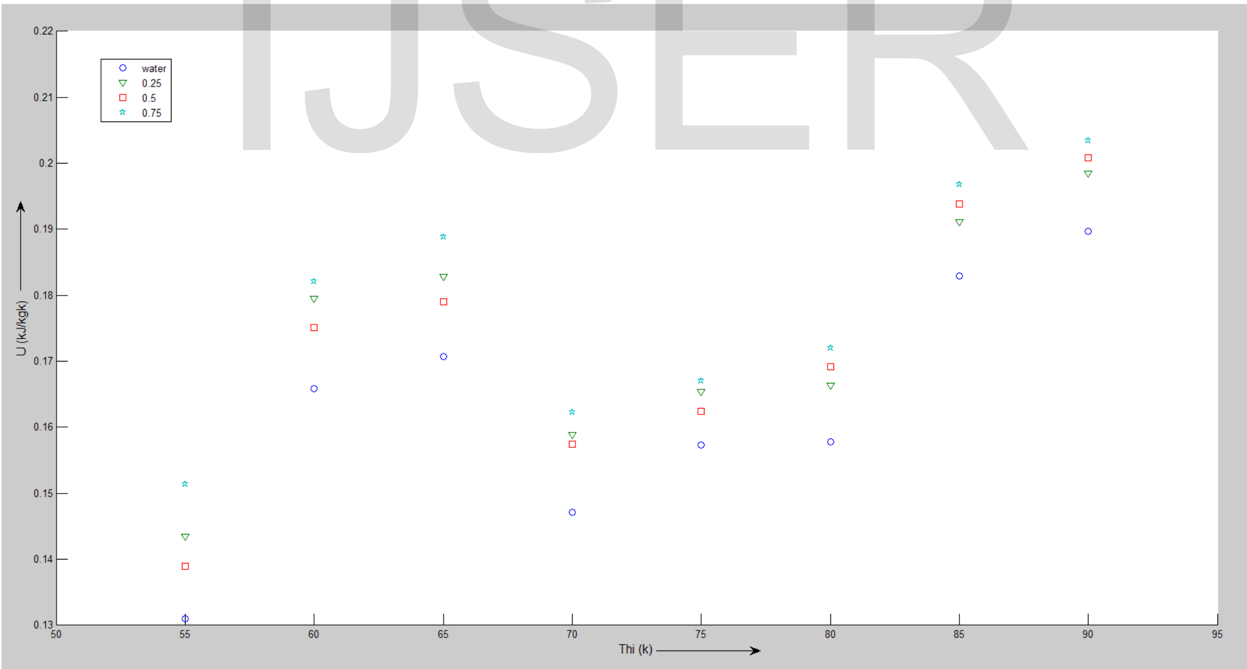


Fig.4.1.1 Thi Vs U for test section4

4.2 Variation of Re Vs Nu:

Tests were carried by varying flow rate at constatnt temperature of 65^{0}C. flow rate is varied from laminar to turbulant flow. Reynold number and nusslt number are calculated and plot as shown in figures 4.2.1, 4.2.2, 4.2.3, 4.2.4. It has been observed that in laminar region effect of threads has considerably large impact on nusselt number as compared to plain tube. In turbulent region the results of plain and grooved tube are moderately different. For laminar region Nusselt number varies as 10.25%, 11.89%, 4.75%, 7.5% for test section1,2,3 &4 respectively for 0.75% nanofluid as compared to water.

Fig.4.2.1 Variation of Nusslt number Vs Reynolds number for test section1

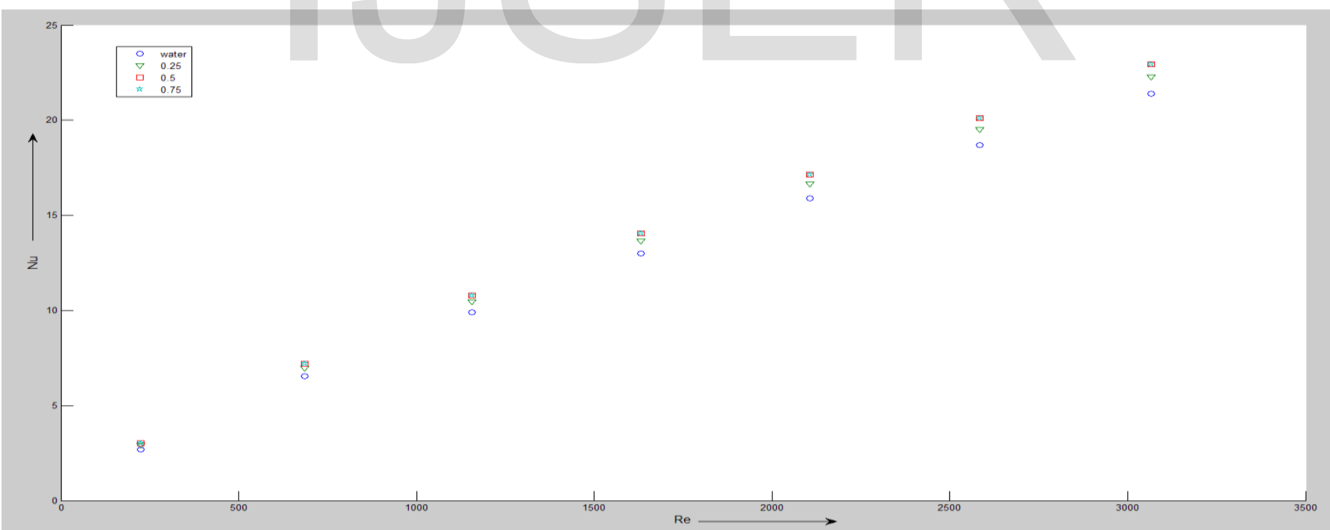


Fig.4.2.2 Variation of Nusslt number Vs Reynolds number for test section2

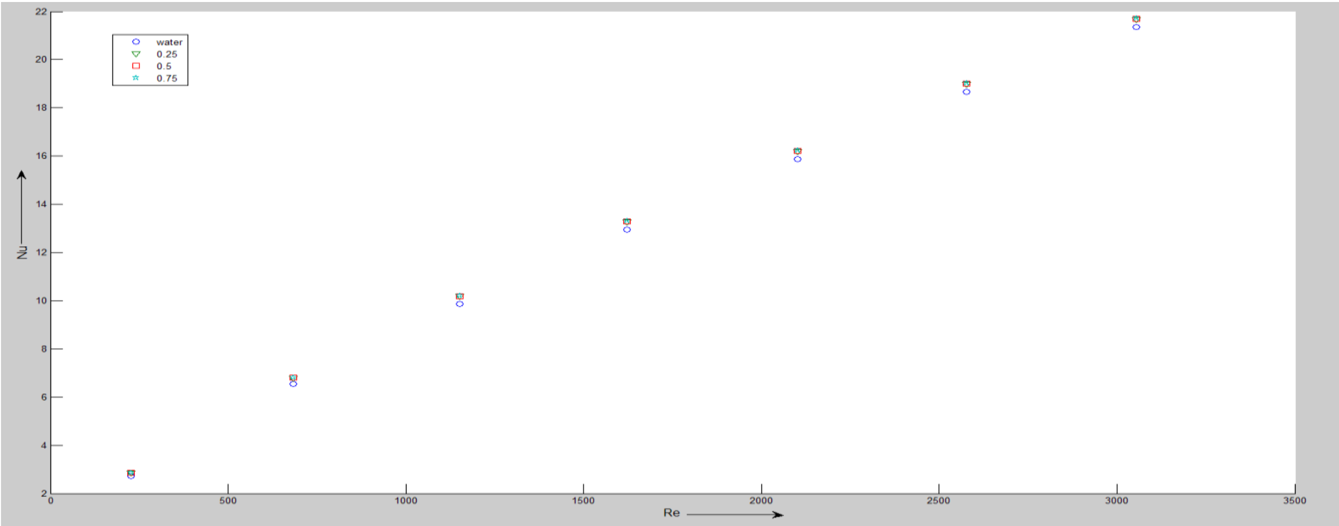


Fig.4.2.3 Variation of Nusslt number Vs Reynolds number for test section3

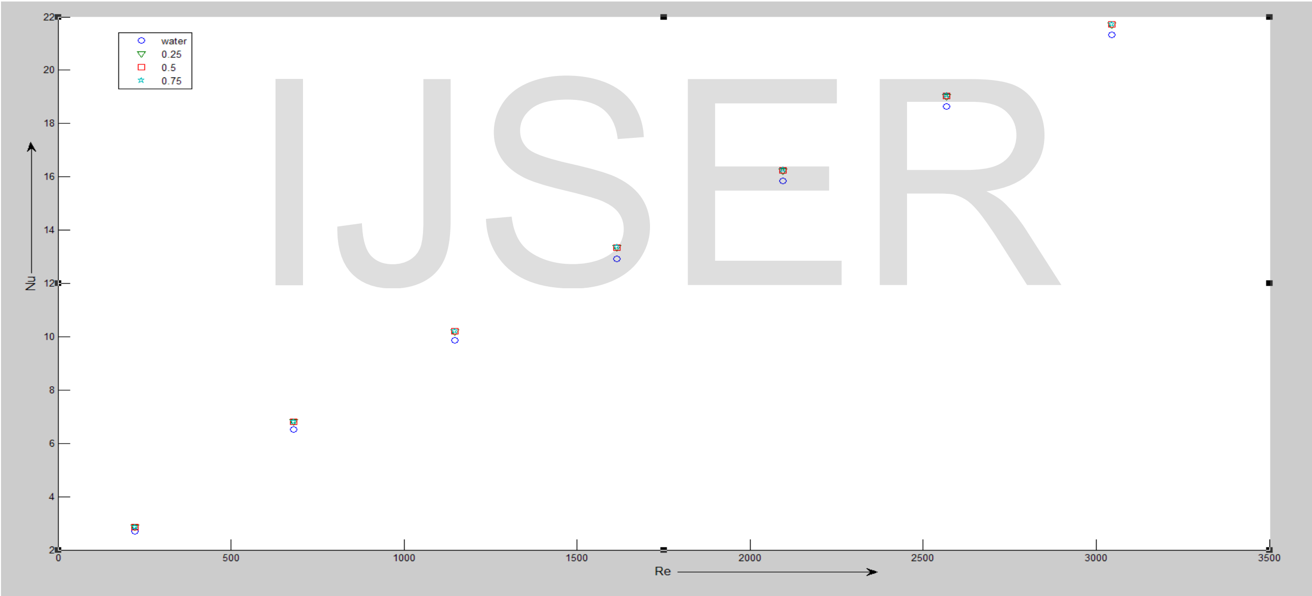


Fig.4.2.4 Variation of Nusslt number Vs Reynolds number for test section4

4.3 Tests for Re Vs U

Tests are carried for different flow ratefrom laminar to turbulant region. Results are plotted reynold number Vs overall heat transfer coeffiecient for different test sections. Fig. 4.3.1 shows the variation for water as working fluid. Similarlly Fig. 4.3.2, 4.3.3 & 4.3.4 gives the variation for Nanofluid of concentration 0.25%, 0.50% and 0.75% respectively

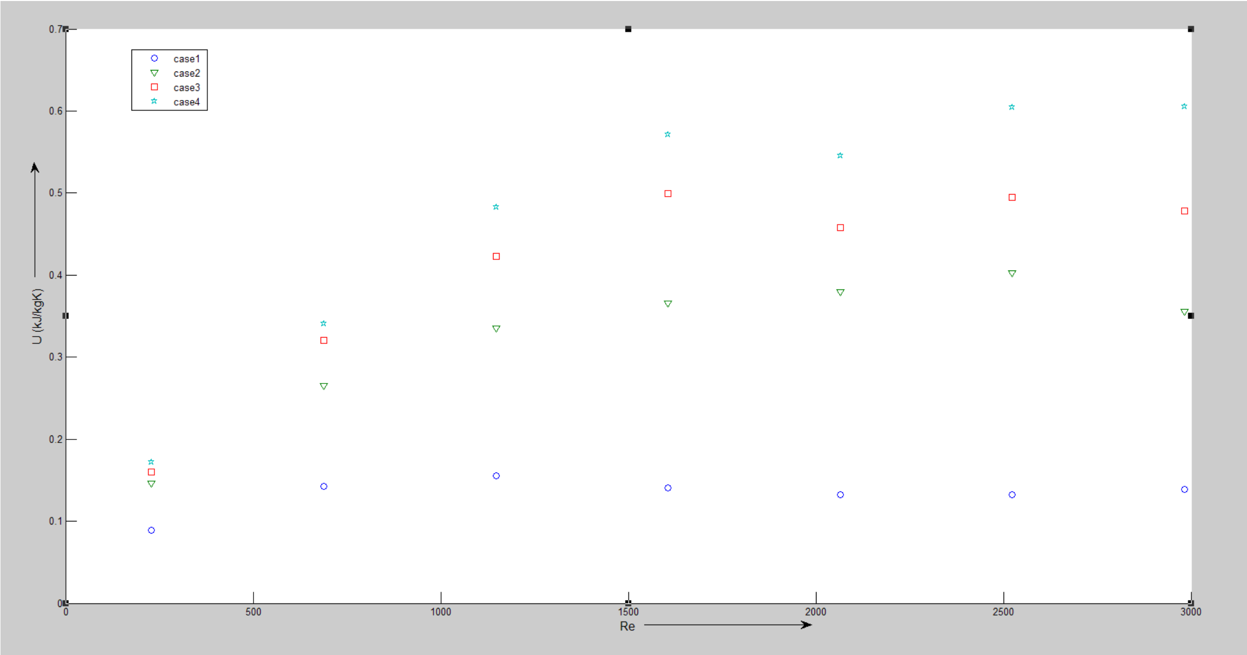


Fig.4.3.1 Variation of Reynolds number Vs Nusslt number for Water as working fluid

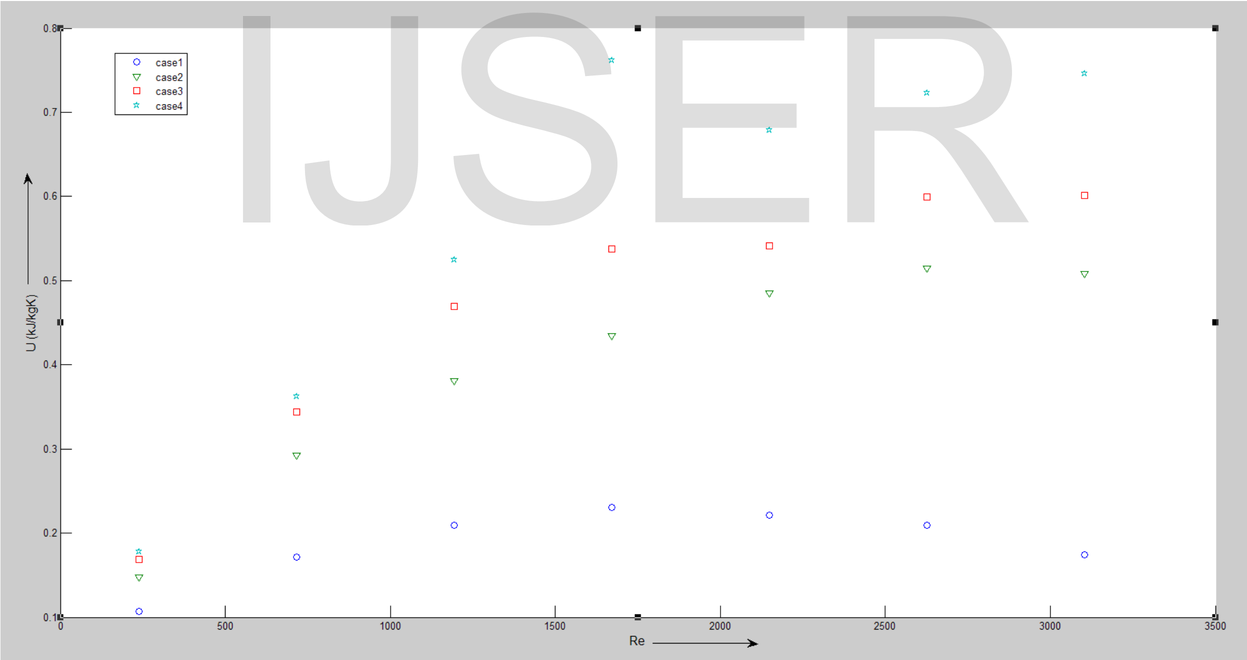


Fig.4.3.2 Variation of Reynolds number Vs Nusslt number for 0.25% nano-fluid as working fluid

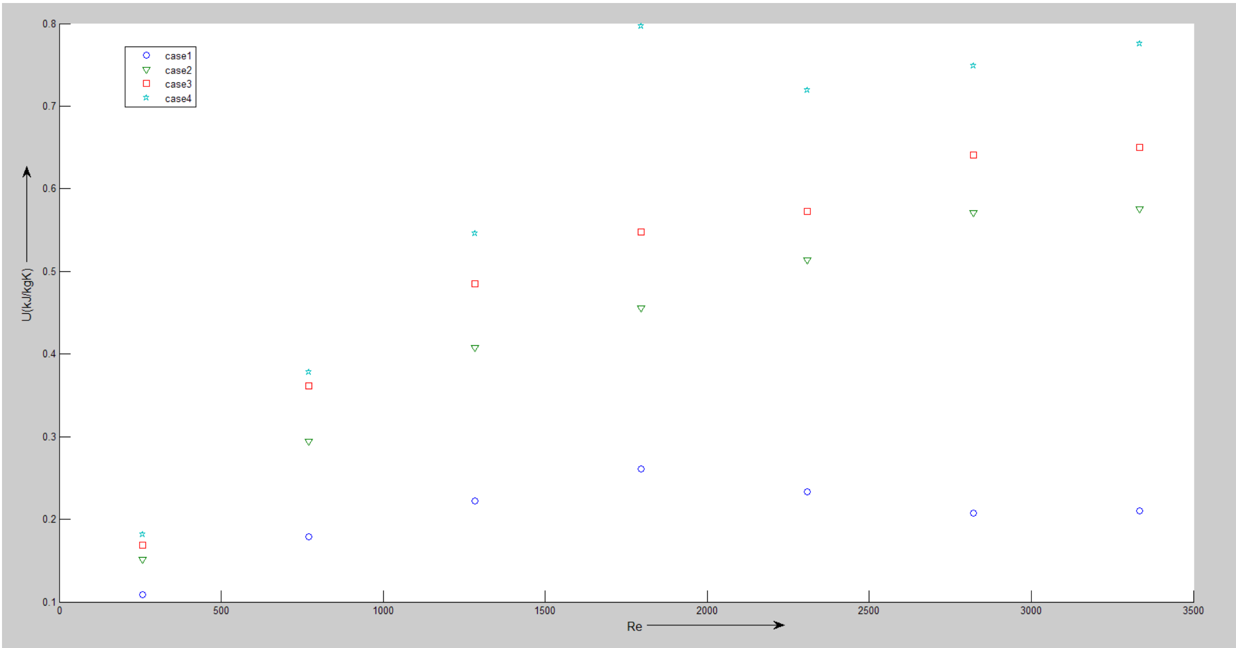


Fig.4.3.3 Variation of Reynolds number Vs Nusslt number for 0.50% nano-fluid as working fluid

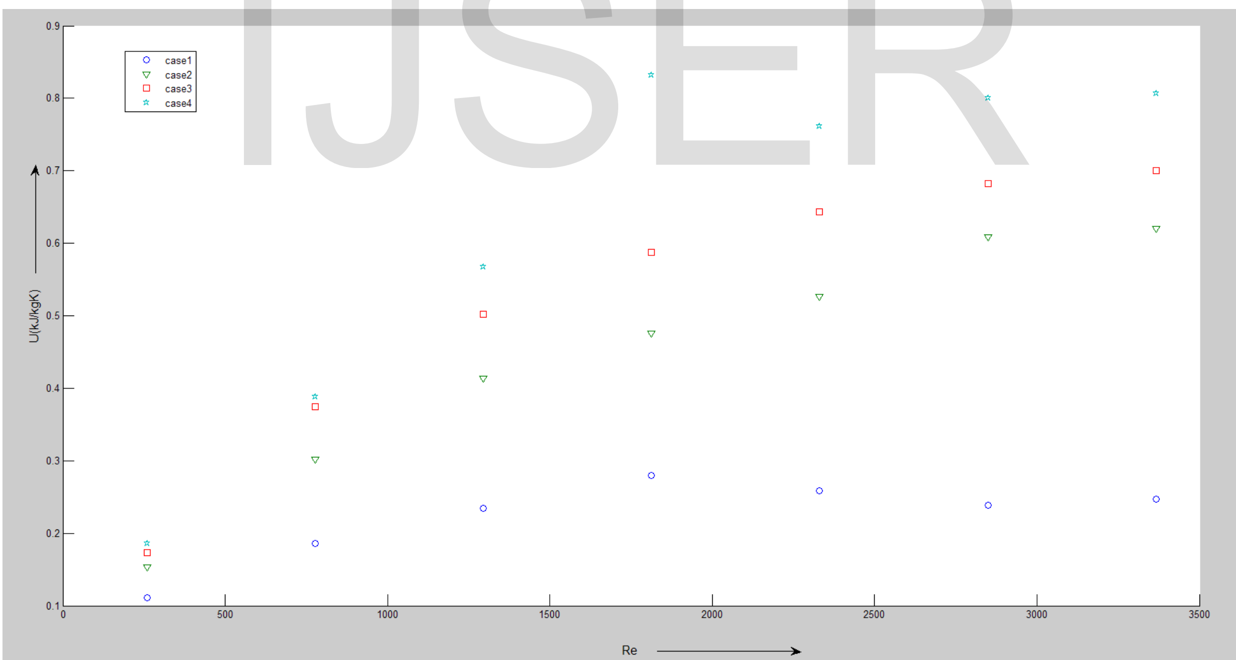


Fig.4.3.4 Variation of Reynolds number Vs Nusslt number for 0.75% nano-fluid as working fluid

5 Conclusion

Following conclusions can be drawn from the study,

A) It has been observed that overall heat transfer coefficient increases with increase in concentration of nano-fluid.

B) Increase in surface irregularities leads to increase in pressure drop.

C) For plain pipe heat exchanger 48% increase in overall heat transfer coefficient is observed for 0.75% concentration Al_2O_3 nanofluid as compared to distilled water. Same was 27%, 25% and 16% for section 2, 3 and 4 respectively.
D) Nusselt number varies as 10.25%, 11.89%, 4.75% and 7.5% respectively for test section 1, 2, 3 and 4 respectively.
E) Pressure drop of 37% is observed in grooved tubes as compared to plain tubes.
F) Experimentations can be done by adding twisted tape inserts as this will lead to more turbulence and results can compared.

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