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Experimental Study of Heat Transfer Parameters using internal threaded pipe fitted with inserts of different materials

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Abstract

Many heat transfer enhanced techniques have simultaneously been developed for the improvement of energy consumption, material saving, size reduction and pumping power reduction. Screw tape inserts in tubes are a typical technique that offers a higher heat transfer increase and, at the same time, only a mild pressure drop penalty. This study investigates the heat transfer characteristics of a horizontal tube-in-tube heat exchanger having internal threaded pipe with Screw tape inserts of different materials i.e. Mild steel screw tape and Aluminum screw tape inserted in the inner tube. Heat transfer, flow friction characteristics in a threaded tube fitted with screw tape, using oil as working fluid are investigated experimentally. Influences of the changing material i.e M.S screw tape and Aluminum screw tape arrangements are also described. The experiments are conducted using the tapes with same twist ratios and pitch over a Reynolds number range less than 2,000 in a heat exchanger.

Introduction

Laminar flow is encountered in many industrial applications. Flow of solar thermal mass of viscous oil in a parabolic trough solar collector in solar electric thermal power plant is an example. In Such case of laminar flow, there is major thermal resistance in the bulk flow in addition to the dominant thermal resistance in the thin boundary layer adjacent to the flow. Twisted-tape inserts are, therefore, used to mix the gross flow effectively in laminar flow to reduce the thermal resistance in the core flow through the helical screw inserts also turbulators. Use of heat transfer enhancement techniques lead to increase in heat transfer coefficient at the cost of increase in pressure drop, while designing a heat exchanger using any of these techniques, analysis of heat transfer rate, and to perform experimental work on considered arrangement to develop characteristics equation for predicting thermo hydraulic performance of heat exchanger. Apart from this issues like long term performance and detailed economic analysis of heat exchanger has to be studied. To achieve high heat transfer rate in an existing or new heat exchanger several techniques have been proposed in recent works and are discussed in chapter 3.Screw tapes a type of passive heat transfer have shown good results in past studies. For experimental work different types of screw tapes of different materials of same dimensions(pitch 9mm ,depth 2.5mm, thickness of tape t= 1mm) combined with internal threaded copper pipe (ID= 13mm OD= 19mm, W= 8 mm, d= 3mm L=550 mm) have been studied.

Date et al. [1] has integrated correlation for friction factor that reflects the influences of secondary flows and wall shear by extracting relationships for relevant parameters from previous numerical predictions of laminar flow in a tube containing a full length twisted tape, the axial momentum equation for flow in a tube containing regularly spaced twisted tape elements **Dewan et al. [2]** has shown that heat transfer augmentation techniques (passive, active or a combination of passive and active methods) are commonly used in areas such as process industries, heating and cooling in evaporators, thermal power plants, air-conditioning equipment, refrigerators, radiators for space vehicles, automobiles, etc. **Sivashanmugam et al. [3]** presented Experimental investigation on heat transfer and friction factor characteristics of circular tube fitted with right-left helical screw inserts of equal length, and unequal length of different twist ratio have been presented. **Yadav et al. [4]** investigated influences of the half length twisted tape insertion on heat transfer and pressure drop characteristics in a U-bend double pipe heat exchanger have been studied experimentally. In the experiments, the swirling flow was introduced by using half-length twisted tape placed inside the inner test tube of the heat exchanger. **Jiangfeng et al. [5]** presented the simulation results are analyzed from the viewpoint of field synergy principle, it is found that the principle could explain well the mechanism of heat transfer enhancement of the helical twist inserts. **Nagarajan et al. [6]** investigated that 3Experimental investigation of heat transfer and friction factor characteristics of circular tube fitted with 300 right-left helical screw inserts with 100 mm spacer of different twist ratio has been presented for laminar and turbulent flow. **Naphon et al. [7]** studied the heat transfer characteristics and the pressure drop of the horizontal concentric tube with twisted wires brush inserts are investigated. The inner diameters of the inner and outer tubes are 15.78and 25.40 mm, respectively.

Experimental set up

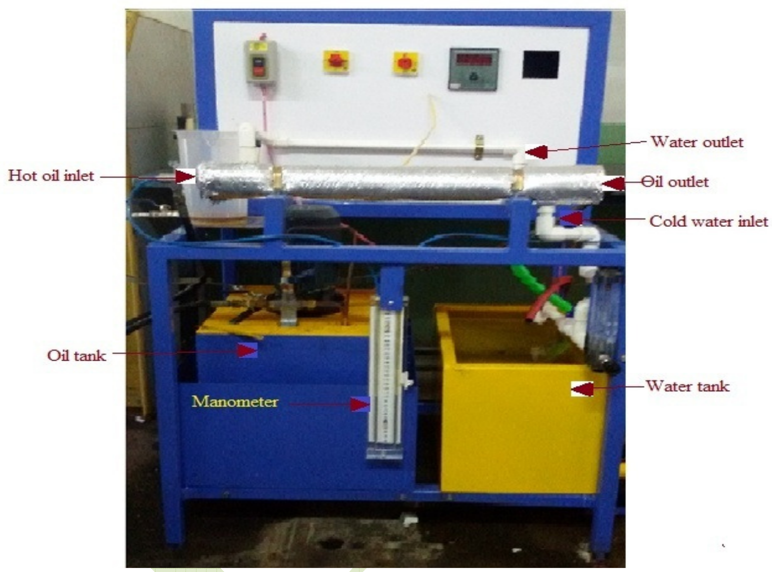

Fig.1 Experimental Setup

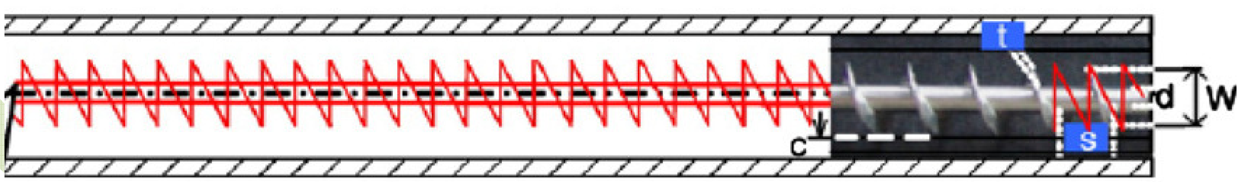

Fig. 2 Section of Screw tape insert with internal threaded pipe

Photo 3 MS screw tape insert (W= 8mm,d=3mm,Pitch=9mm,)

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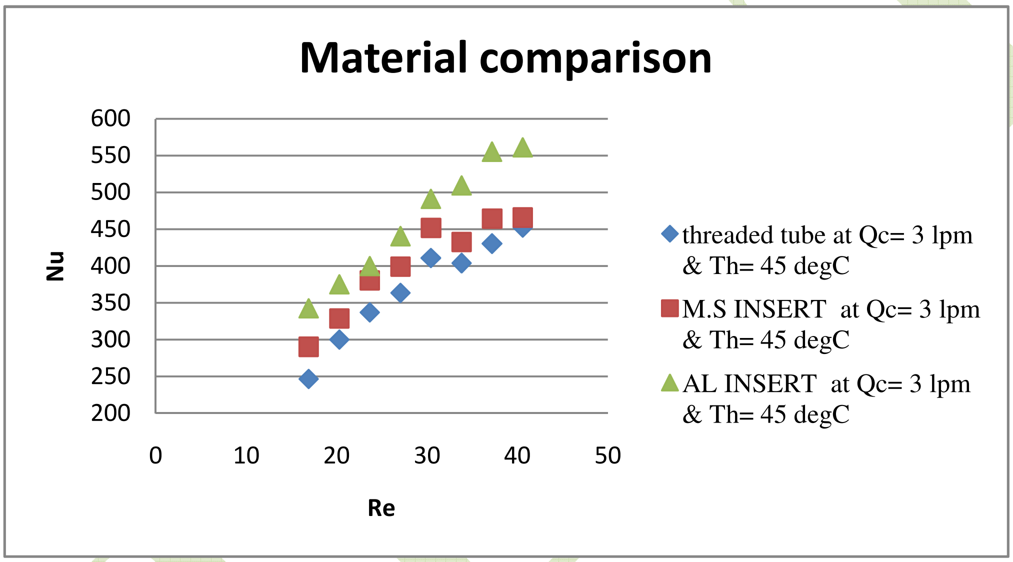
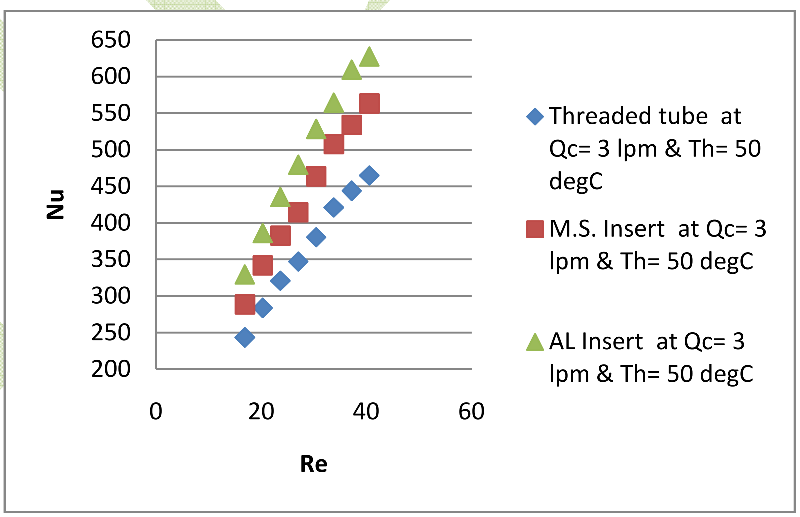
Photo 4 Aluminum screw tape insert (W= 8mm,d=3mm,Pitch=9mm)

Result and Discussions



Graph 1 Nusselt Number Vs Reynolds Number for threaded tube,MS insert and Al insert at Y=1.55,Th =45^0C& Qc= 3 LPM



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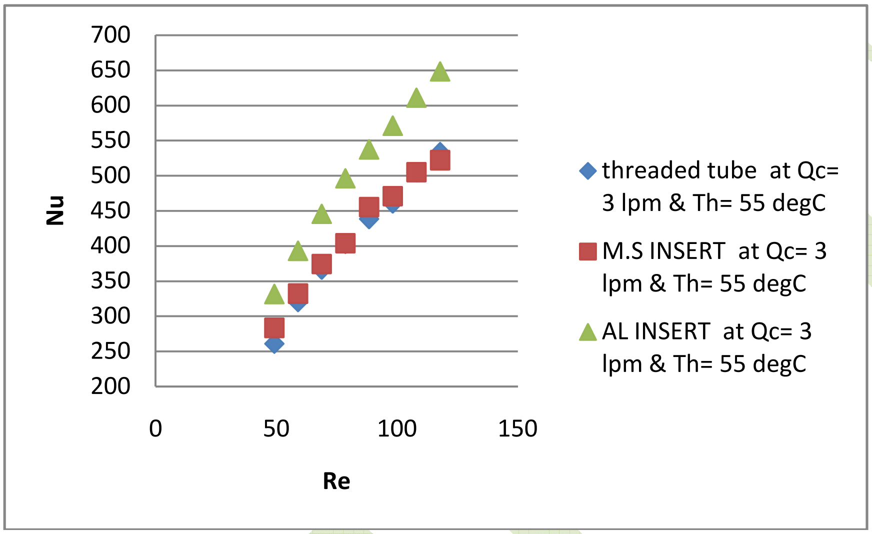
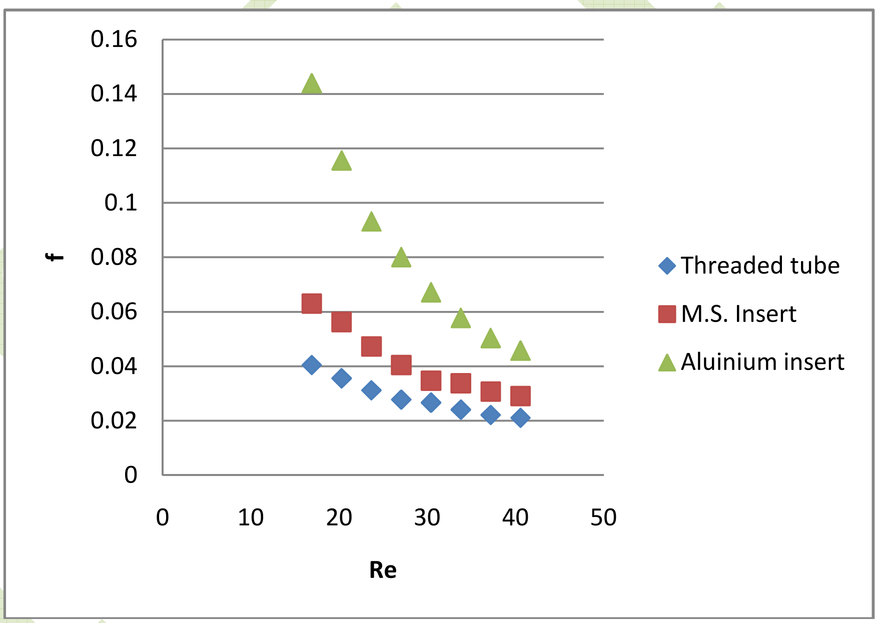
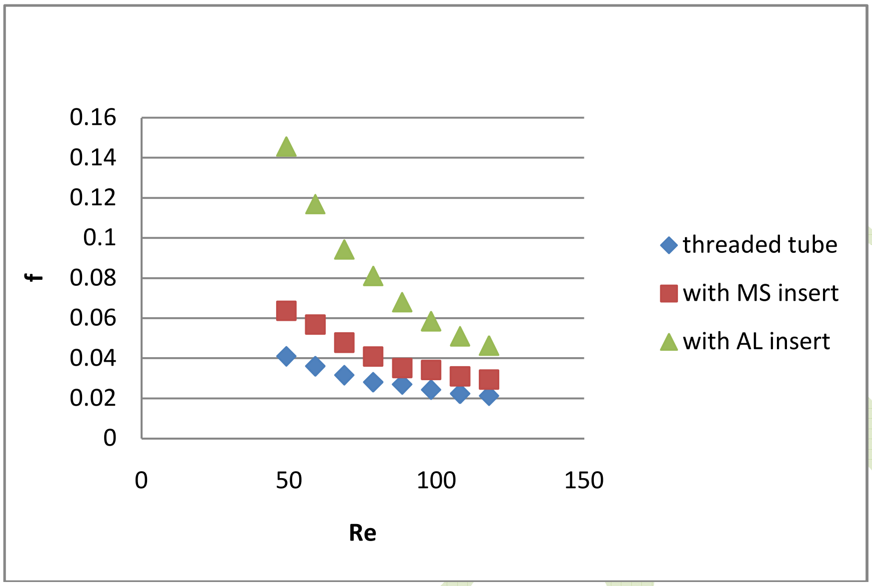
Graph 2 Nusselt Number Vs Reynolds Number for threaded tube, MS insert and Al insert at Y=1.55,Th =50^{0}C&Qc= 3 LPM In Graph2, it is observe that the Nusselt Number for MS Screw tape insert and Al Screw tape insert is increases 40-55%.This is due to increase of oil temperature from 45^{0}C to 50^{0}C. The increased value of temperature increases the thermal conductivity nearer to the surface of the tube and contributes to more heat transfer.



Graph 6.3 Nusselt Number Vs Reynolds Number for threaded tube, MS insert and Al insert at Y=1.55,Th =55^{0}C&Qc= 3 LPM



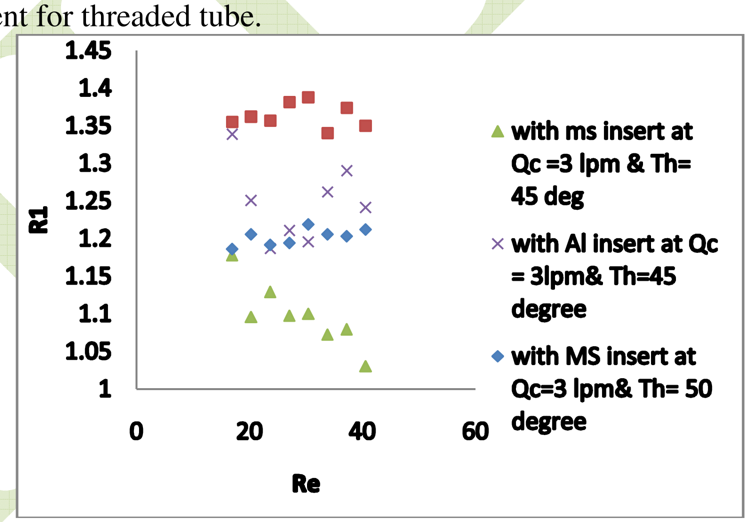
Graph 6.4 friction factor Vs Reynolds Number for Threaded tube, with MS insert, Al insert at Qc = 3LPM &Th= 45^{0}C



Graph 6.5 friction factor Vs Reynolds Number for Threaded tube, with MS insert, Al insert at Qc = 3LPM Th= 55^{0}C

Performance Evaluation Criteria (R1)

Bergles have suggested several criteria for the performance evaluation of heat transfer enhancement devices. The performance of the heat transfer enhancement device evaluated on the basis of constant mass flow rate.
R1=ha/ho
Where ha= Heat transfer coefficient for tube with Inserts,
ho= Heat transfer coefficient for threaded tube.



Graph.6.19- Performance Evaluation Criteria (R1) Vs Reynolds Number for MS & Al insert at constant Qc=3LPM

In Graph.6.19, a plot between performance evaluation criteria R1 Vs. Reynolds no. for MS screw tape insert and Al insert at constant cold fluid flow is shown. Maximum value of R1 is observed wit Aluminum insert Qc =

3LPM &Th=50^{0}C. From this we can conclude that this is the best arrangement out of all arrangements tested for this experiment.

Conclusions

The effects of the materials on the heat transfer enhancement and friction factor behaviors in laminar flow regimes (Re < 2,000) are described. The Screw tapes of MS and Aluminum insert with same dimensions (W= 8mm,d=3mm,H=9mm) at different temperatures and different cold fluid flow rates are tested using the oil as the hot working fluid and other is water. The conclusions are drawn as follows:

1. With Al screw tape insert, Nusselt's Number increases and also at the same time pressure drop increases.
2. Using M.S. screw tape insert Nusselt number is 15-20 % increases as compared with threaded tube.
3. From the experimental results we find out Aluminum insert gives better heat transfer as compared to M.S insert.
4. In a heat exchanger, while the inserts can be used to enhance the heat transfer rate, they also bring in an increase in the pressure drop. When the pressure drop increases, the pumping power cost also increases, thereby increasing the operating cost. So depending on the requirement, one of the above mentioned inserts can be used for heat transfer augmentation.
5. On the basis of performance evaluation criteria R1, we can say that the Aluminum screw Tape gives the highest R1 range with the maximum value of Heat transfer coefficient around 1.48 times of the value for the threaded tube.
6. On the basis of performance evaluation criterion R1, Aluminum screw tape with Y=1.55, W= 8mm, d= 3mm & H=9mm were found to be the best tape for heat transfer augmentation at (Qc= 8LPM &Th= 45^{0}C).

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