ISSN 2395-1621

Experimental Investigation on Enhancement of Heat Transfer Using Spiral Tapes

#1Ramesh Swami, #2 M. G. Bhong, #3H. V. Darokar

[1]ramesh_swami47@yahoo.co.in
[2]mahesh.bhong@indiraicem.ac.in

#1Department of Mechanical Engineering, Indira College of Engineering & Management, Savitribai Phule Pune University, Parandwadi, Pune India 410506

#23 Department of Mechanical Engineering, Indira College of Engineering & Management, Savitribai Phule Pune University, Parandwadi, Pune India 410506

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ABSTRACT

Techniques have been developed on enhancement of heat transfer rate and decrease of the size and cost of the equipments used in heat exchangers. One of the techniques comprises the use of Spiral tapes inserted in the tubes wherein the swirling motion of fluid is generated to increase the heat transfer rate. The rate of heat transfer from a tube depends on various parameters like the material, size and thickness of tube, mass flow rate and initial temperature of fluid, the contact surface area of the fluid, etc. This work aims to focus on the tubes with such spiral tapes in a heat exchanger considering the variation in the parameters stated above while ensuring minimal pressure drop in the system. Experimentation is conducted over a physical setup representing the elements of Heat exchanger. Feasibility of development of this physical experimentation is assessed during work. The tube in tube type heat exchanger is used in which inner tube which carries cold water is of MS material of 21.3 mm diameter and of 1 m length and outer tube which carries hot water is of PVC material of 42.2 mm diameter. Three different spiral tapes of different pitch 50 mm, 100 mm & 150 mm and of 1 m length are employed for achieving the optimum solution of heat transfer enhancement at different Reynolds number. The performance of heat exchanger is improved due to increased temperature difference of working fluid by using spiral tapes.

***Keywords*— a**

ARTICLE INFO

Article History

Received :18th November 2015

Received in revised form :

19th November 2015

Accepted : 21st November , 2015

Published online :

22nd November 2015

I. INTRODUCTION

Effective utilization of available energy becomes need of hour today. This obviously requires effective devising. When it concerns heat energy the devices are heat exchangers. Heat exchangers are used in variety of applications. Heat exchangers are commonly used in automotive, air conditioning, oil refineries and other large-scale chemical processes. Increase in Heat exchanger performance can lead to more economical design of heat exchanger which can help to make energy, material & cost savings related to a heat exchange process.

Several design parameters and operating conditions influence the optimal performance of a heat exchanger. Past studies have shown that the flow in the heat exchanger is strongly dependent on geometrical parameters. By manipulating the geometrical parameters of the chamber, we can obtain a heat exchanger with maximum heat transfer coefficient within allowable design limit. The goal of enhanced heat transfer is to encourage or accommodate high heat fluxes. The need to increase the thermal performance of heat exchangers, thereby effecting energy, material and cost savings have led to development and use of many techniques termed as heat transfer augmentation. These techniques are also referred as Heat Transfer Enhancement or Intensification. Augmentation techniques increase convective heat transfer by reducing the thermal resistance in a heat exchangers.

A. *Heat Transfer Augmentation Techniques*

"Heat transfer Augmentation" means Increase in Heat exchanger's performance with the Help of augmentation techniques, this can lead to more economical design of heat exchanger. These augmentation techniques in general are classified into Passive, Active and Compound techniques.

1) *Active techniques:* This method involves some external power input for the enhancement of heat transfer. Some examples of active methods include induced pulsation by cams and reciprocating plungers, the use of a magnetic field to disturb the seeded light particles in a flowing stream, mechanical aid, surface vibration, fluid vibration, electro static fields, suction or injection and jet impingement requires an external activator/power supply to bring about the enhancement. It finds limited application because of the need of external power in many practical applications.

2) *Passive techniques:* This method generally uses surface or geometrical modifications to the flow channel by incorporating inserts or additional devices. For example, inserts, swirl flow devices, treated surface, rough surfaces, extended surfaces, displaced enhancement devices, coiled tubes, surface tension devices and additives for fluids.

3) *Compound techniques:* A compound augmentation technique is the one where more than one of the above mentioned techniques is used in combination with the purpose of further improving the thermo-hydraulic performance of a heat exchanger.

B. Review of Spiral tapes

Spiral tapes are the metallic strips twisted with some suitable techniques with desired shape and dimension and are inserted in the flow domain.

II. OBJECTIVE

Heat exchanger is an important device in automotive and air conditioning applications, therefore having an effective heat exchanger will enhance the performance of the whole system. The stringent design requirement force designers to fit the layout of exchanger in limited space so as to save the space and cost required to build the exchanger. Spiral channel exchanger shall be a proposed solution to this problem.

C. Steps of work

1. Study the current application and replicate using a simplified representation of the working conditions
2. Develop a physical prototype representing the application
3. Run a trial to benchmark the performance of the current application
4. Deploy mathematical modeling for arriving at the solution
5. Validate using data for comparison secured from the two differing methodologies employed
6. Suggest alternative arrangements in the path of the duct by introducing spiral shaped tape or insert to improve surface area
7. Record pressure drop as well as any heat enhancement by virtue of the change
8. Recommend improved alternative to the existing application.

III. FLOW CHART FOR METHODOLOGY

a For this thesis work, the baseline physical model would be tested before performance and the same would be compared with CFD/ FEA Analysis results for reinforcing the validation. A good match for the results would be precursor for evaluating the alternatives (Variants) using key methodology as computational simulation (CFD Software). The final results obtained using the Analytical/ Computational method would be considered valid while extrapolating the baseline (existing) results.

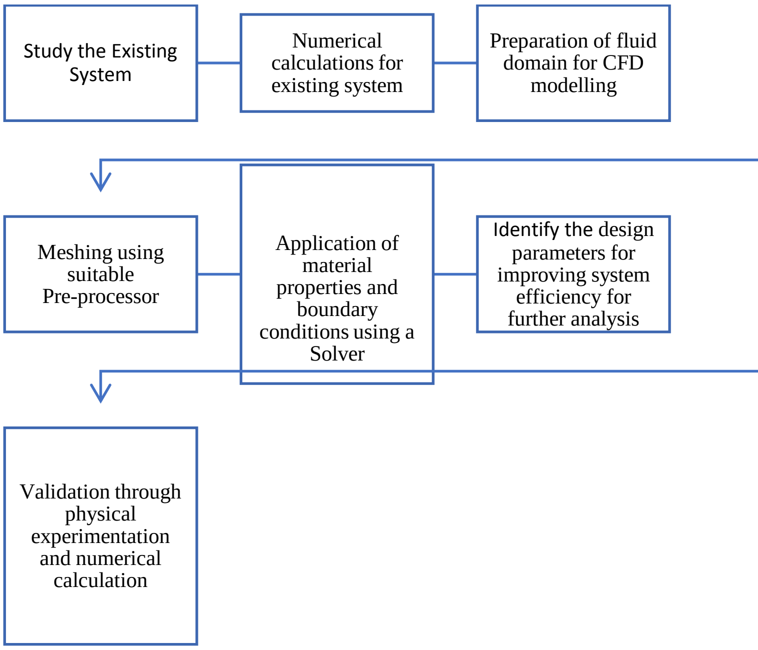

Figure 1: Flow chart for methodology

IV. VARIOUS APPROCHES

For achieving our objective, we are going to perform the methodology in three approaches, viz., Experimental, Analytical & simulation tool.

D. Experimental Approach

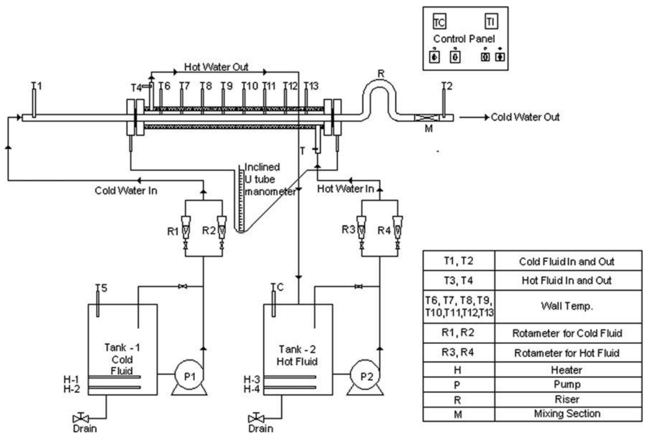

Figure 2: Experimental Setup for Tube in tube heat exchanger

Figure 3: Full length twisted tape insert inside a tube

4) *System description*

- Concentric tube Heat exchanger: It consists of two concentric tubes in which hot water flows through the inner tube (Mild steel tube, di = 21.3 mm, t = 3.73 mm, L = 1000 mm) and cold water flows in counter flow through annulus (U PVC pipe, di = 54.5 mm).
- Geyser (Water Heater): This is used as hot water generator. Electrical capacity 3 KW. Geyser consists of thermostat as safety device.
- Sensor: PT 100 type thermocouple for measurement of the temperature of hot & cold water at the inlet & outlet, Four thermocouples used for the measurement of temperature of hot & cold water at the inlet & outlet T1,T2,T3,T4.
- Rotameter: Two rotameters provided in the system to measure the mass flow rate of cold & water separately. Range: 60 to 600 LPH
- Spiral tapes: three twisted tapes each of 10 mm width, 1 m length, Aluminium material but different twist pitch of 50 mm. 100 mm & 150 mm
- Centrifugal Pump: Centrifugal pump is used to draw
  the water from the supply reservoir & supply it to the system. Two centrifugal pumps provided, one to supply the water from reservoir to the Geyser further inner tube & other to supply from reservoir to the Manifold further to the injectors.
  Power = 0.37 Kw / 0.5 H.P.
  Head = 15 – 30 M
  Discharge= 1020 LPH
- Base stand: This is made up of stainless steel square tubes & Euro bound sheets. Stand is powder coated. All equipments are mounted on base stand.
- Nozzles: Six convergent type of PVC nozzles are fitted to the outer pipe of the Tube in Tube heat exchanger such a way that the cold water enters the tube tangentially generating intense swirl. Flow rate of the cold water is changed & controlled by the ball valve.
- U-tube Manometer: U-tube manometer is connected at the ends of the inner tube to measure the pressure drop in tube.
- Pipe Fittings & Valves: Water sumps, Pump, manifold, Rotameter & Heat exchanger are connected in closed circuit with help of flexible pipes & valves.
- Temperature Indicator: Temperature indicator with 6 point selection switch provided to get the temperature of water at different points.
- Energy Meter: Energy meter is to measure the quantity of electrical energy supplied to heat the water in water heater.
  Type – SM 101, 1-Phase, 2 wire, 240 V, 50 Hz AC
  Energy meter constant- 3200 imp/ kWh.

5) *Experimental Procedure*

- The test fluid will be flowing through the inner tube and the hot water as the heat transfer medium passes at a very high flow rate in a countercurrent flow, through an annular channel formed between inner tube and outer tube to attain nearly uniform wall temperature conditions.
- Two RTD sensors one just before the test section and other after the mixing section will be placed to measure the inlet and outlet temperature of the test fluid.
- The hot water tank with the built-in controller and heaters will be provided to supply hot water at a constant temperature. Two more temperature sensors will be placed, one at inlet and other at the outlet of an annular channel to measure the hot water temperature.
- The mixing section will be initially with plain inner tube and later with Spiral inserts, to ensure efficient mixing at the outlet. The two pressure tapes one just before the test section and another just after test section will be provided for measurement of pressure drop. The isothermal pressure drop across the test section was measured by using an inclined U-tube manometer.
- Two Rotameters will be provided to indicate the flow rate of the test fluid and hot water respectively. Test fluid and hot water at a constant temperature will be taken from the tank inlets through centrifugal pumps and bypass valves were provided in the flow line to regulate the flow.

6) *Experimental readings for plain tube*

- The connections of the fluid flow fittings and instruments are made as per the required setup. The cold water flow is varied from 100 LPH to 400 LPH at an interval of 50 LPH, at a constant hot water flow of 200 LPH through geyser. Accordingly the temperature at inlet & outlet and pressure drops are noted down at each step with the help of above said instruments and tubulised as shown below.

TABLE I: EXPERIMENT READINGS USING THE PLAIN INNER TUBE

Cold water Mass flow rate	Cold water Inlet temp	Cold water outlet temp	Manometer Differential Height
(LPH)	(Deg.C)	(Deg.C)	(mm)
100	29	32.5	15
150	29	32	30
200	29	31.2	55
250	29	31	80
300	29	30.8	115

350	29	30.6	140
400	29	30.5	180

- After the plain tube experiment, the same procedure was conducted for the different cold water flow rate at a constant hot water flow rate of 200 LPH, but this time inserting a spiral tape of 50 mm pitch inside the inner tube over its complete length. The readings now were taken for inlet & outlet temperatures of cold water and pressure drop readings across the tube.

TABLE II: EXPERIMENT READINGS USING THE 50 MM PITCH SPIRAL TAPE

Mass flow rate	Cold water Inlet temp	Cold water outlet temp	Manometer Differential Height
LPH	Deg.C	Deg.C	mm
100	29	35	20
150	29	33.8	35
200	29	32.8	65
250	29	32	100
300	29	31.8	140
350	29	31.5	180
400	29	31	230

E. Analytical Approach

For heat exchanger selection, it is convenience to have a methodology in order to estimate the overall heat transfer coefficient or the size according to given temperature range and flow specifications.

- Collect the Geometry information of setup like tube diameter, thickness, tube length.
- Select the material of construction for the tubes and get its thermal properties.
- Assume three known temperature and find the fourth one or four temperature values and find one of the shell or tube side flow rate.
- Use the heat duty equation $q = m_c cp_c (Tco - Tci) = m_h cp_h (Tho - Thi)$ where subscripts c and h refer to cold and hot streams.
- Based on the type of flow, calculate Log Mean Temperature Difference, LMTD.
  For counter current
  $$LMTD = \frac{(Thi - Tco) - (Tho - Tci)}{\ln \frac{(Thi - Tco)}{(Tho - Tci)}}$$
  For Co-current,
  $$LMTD = \frac{(Thi - Tci) - (Tho - Tco)}{\ln \frac{(Thi - Tci)}{(Tho - Tco)}}$$

Mean bulk temperature (Tb) was calculated as

$$Tb = \frac{Thi + Tco}{2}$$

Calculate the Reynolds number as below,

$$\mathrm{Re} = \frac{\rho v d}{\mu}$$

Calculate Prandtle number. $\mathrm{Pr} = \frac{\mu . Cp}{k}$

Obtain the inside heat transfer coefficient by Prandtl Corelation for turbulent flow

$Nu = 0.023\ Re^{0.8}\ Pr^{0.3}$ (Turbulent flow, Re > 2300)

And convective heat transfer coefficient is calculated by

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

Pressure drop in the tube side region

$$\Delta P = \frac{4 f . L . \rho . v^2}{2d}$$

F. Software tool Approach

Mathematical model shall be constructed for offering inputs that could lend a direction to the effort over engaging Analytical methodology for finding solution. ANSYS Fluent is being considered as a CFD solver for evaluating the alternatives in the form of variants of the type of fluid medium or the mass-flow rate of the fluid passing through the Spiral channel construction. Comparison shall be offered at the concluding stage of this work in favour of validation of the proposed solution.

V.RESULT & DISCUSSION

Calculations are performed analytically by following the above said mathematical modelling and results are presented in the table & chart format as shown below.

TABLE III: HEAT TRANSFER COEFFICIENT & PRESSURE DROP CALCULATIONS FOR PLAIN TUBE

Mass flow rate	Reynolds number	Prandtl number	Nusselt number	Heat transfer coefficient (h)	Pressure drop
LPH	Re	Pr	Nu	W/m^{2}k	Pa
100	3229.54	5.32	24.36	1088.28	24.39
150	4844.32	5.33	33.71	1503.56	54.88
200	6386.24	5.41	42.26	1875.57	97.54
250	7982.80	5.42	50.53	2240.85	152.41
300	9579.36	5.42	58.48	2591.26	219.47
350	11175.92	5.43	66.19	2928.02	298.72
400	12772.48	5.44	73.69	3254.41	390.17

Similar calculations are performed for tube with spiral tape only with a difference of increased friction factor due to additional obstruction of spiral tape and values are tubulised as below.

TABLE IV: HEAT TRANSFER COEFFICIENT & PRESSURE DROP CALCULATIONS FOR TUBE WITH 50 MM PITCH SPIRAL TAPE

Mass flow rate	Reynolds number	Prandtl number	Nusselt number	Heat transfer coefficient h	Pressure drop
LPH	Re	Pr	Nu	W/m^2k	Pa
100	3320.01	5.14	24.65	1108.39	26.84
150	4935.01	5.20	33.98	1522.72	60.38
200	6459.09	5.32	42.42	1894.80	107.32
250	8073.86	5.33	50.73	2262.56	167.69
300	9688.63	5.33	58.73	2614.89	241.47
350	11303.40	5.35	66.50	2951.38	328.67
400	12772.48	5.41	73.59	3265.79	429.32

1) Comparison of plain tube & spiral tape tube

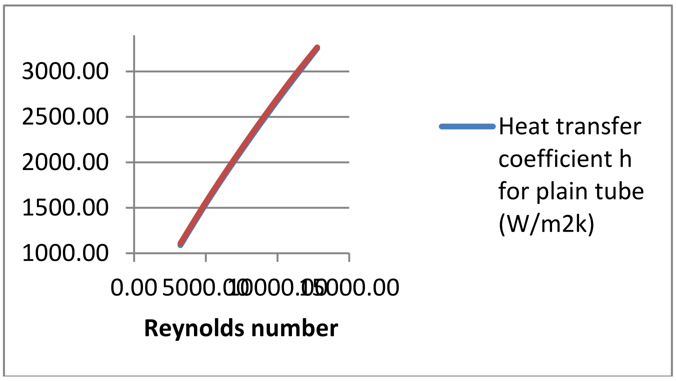

Figure 4: Graph for Reynolds number V/s heat transfer coefficient for plain tube & spiral tape tube

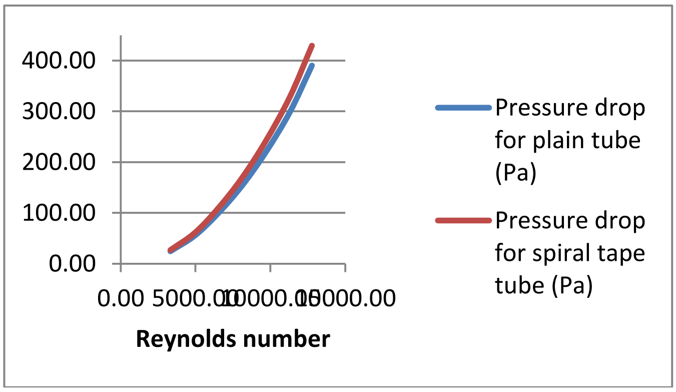

Figure 5: Graph for Reynolds number V/s Pressure drop for plain tube & spiral tape tube

VI.CONCLUSION

a As seen from the above graphs, it is clear that the use of spiral tapes gives a reasonable rise to the heat transfer coefficient of the test fluid from 1088 W/m^2k to 1109 W/m^2k within the same set up while at the cost of a considerable rise in pressure drop from 24.39 Pa to 26.8 Pa for a range of Reynolds number from 3000 to 13000. Hence optimum solution can be generalized for the particular instantaneous experiment setup. Further the use of different spiral tapes can be analysed in the same way of the current procedure & the results will be furnished soon in the form of comparison.

Future scope may include the use of CFD analysis for the one of the variant of the readings which can be taken as the benchmark for the rest of the readings so as to get the optimum solution.

REFERENCES

[1] D.R.Waghole, R.M.Warkhedkar, V.S. kulkarni, N. K.Sane, *A Review on Heat Transfer Augmentation using Twisted Tape inserts inAbsorber/Receiver of PTC*. Department of Mechanical Engineering, Government College of Engineering, Pune, India: IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE).

[2] S. Naga Sarada, A.V. Sita Rama Raju, K. Kalyani Radha, L. Shyam Sunder, *Enhancement of heat transfer using varying width twisted tape inserts*. Department of Mechanical Engineering, JNTUH College of Engineering, Hyderabad, A.P, INDIA: International Journal of Engineering, Science and Technology, 2010.

[3] A.Rahul kumar, P.N.S Srinivas, *Experimental Analysis of Heat Transfer Augmentation by Using Twisted Tapes of Different Twist Ratio as Flow Arrangement inside the Tubes*.: International Journal of Modern Engineering Research (IJMER), 2013.

[4] A. Klaczak, *Heat transfer by laminar flow in a vertical and horizontal pipe with twisted tape inserts*.: Springer-Verlag, 2001.

[5] M. A. Habib, S. A. M. Said, A. A. Al-Farayedhi, S. A. Al-Dini, A. Asghar, S. A. Gbadebo, *Heat transfer characteristics of pulsated turbulent pipe flow*.: Springer-Verlag, 1999.

[6] A.V.Gawandare, M.M.Dange, D.B.Nalawade, *Heat Transfers Enhancement with Different Square Jagged Twisted Tapes*. Department of Mechanical Engineering, GenbaSopanraoMoze College of Engineering, Pune,India: Int. Journal of Engineering Research and Applications, 2014.

[7] Yu. A. Kuzma-Kichta, P. A. Savel'ev, *Studying of Heat-Transfer Enhancement in Tubes with Screw Knurling*. Moscow, 111250 Russia: ISSN 0040-6015, Thermal Engineering, 2007.

[8] M.-Y. Wen, K.-J. Jang, C.-C. Yang, *Augmented heat transfer and pressure drop of strip-type inserts in the*

small tubes.: Heat and Mass Transfer 40 (2003) 133–141, 2003.

[9] S.K.Routa, D. N. Thatoia, A.K. Acharyaa, D. P. Mishraa, *CFD supported performance estimation of an internally finned tube heat exchanger under mixed convection flow*. Odisha, India.: www.sciencedirect.com.

[10] R. Tiruselvam, W. M. Chin, Vijay R. Raghavan, *Double tube heat exchanger with novel enhancement:part 3—convective condensation*.: Springer-Verlag, 2012.

[11] M.Premkumar, S.Ramachandran, *CFD Analysis for Heat Transfer Between Copper Encapsulated Phase Change Material and Heat Tranfer Fluid*. Research scholar, Sathyabama University: International Journal of Engineering Science and Technology.