International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 3, Issue 12 (July 2014) PP: 29-33

Single-Phase Heat Transfer and Pressure Drop In the Micro-Fin Tube with Coiled Wire Insert

R. S. Lavate[1], A. M. Patil[2], N. V. Deshpande[3]
[1]*Student, IV Semester M. E (Heat Power Engineering)*
[2]*Assistant Professor and Vice-Principal, Mechanical Engg. Dept., P.V.P.I.T College of Engineering, Budhgaon, Dist.-Sangli 416416 (India)*
[3]*Assistant Professor, K.I.T. Kolhapur*

Abstract: *The heat transfer duty or thermal performance of heat exchangers can be improved by heat transfer enhancement techniques. Coiled wire insert has been used as one of the passive heat transfer enhancement techniques and are the most widely used tubes in several heat transfer applications, for example, heat recovery processes, air conditioning and refrigeration systems, chemical reactors, food and dairy processes, Thermal Power plants, radiators for space vehicles, automobiles etc. These techniques broadly are of three types viz. passive, active and compound techniques. The present paper is a review of the passive augmentation techniques used in the recent past.*

Keywords: *coiled wire insert, Heat transfer augmentation technique, Micro fin tube, Passive methods,*

I. Introduction

Heat exchangers have several industrial and engineering applications. The design procedure of heat exchangers is quite complicated, as it needs exact analysis of heat transfer rate and pressure drop estimations apart from issues such as long-term performance and the economic aspect of the equipment. Whenever inserts are used for the heat transfer enhancement, along with the increase in the heat transfer rate, the pressure drop also increases. Therefore any augmentation device should optimize between the benefits due to the increased heat transfer coefficient and the higher cost involved because of the increased frictional losses. The present paper includes various heat transfer augmentation techniques. A literature review of heat transfer augmentation using passive techniques has been included. Experimental work on heat transfer augmentation using coiled wire inserts and a new kind of insert is carried out. Inserts when placed in the path of the flow of the liquid, create a high degree of turbulence resulting in an increase in the heat transfer rate and the pressure drop.

II. Need Of Argumentation

In Tube in tube heat exchanger design the tube side often represents poor performance when handling viscous liquids in laminar flow. This is because near the tube wall, there is thermally inefficient boundary layer with very little mixing. Since heat transfer is controlled principally by the thickness of the boundary layer and its thermal conductivity. A very poor heat transfer coefficient results, so it is required.

III. What Inserts Do

These inserts continually remove low velocity fluid from the tube wall and replace it with fluid from the centre of the tube. By braking up the boundary layer at the wall and promoting radial mixing of the tube side fluid, these inserts increases the heat transfer coefficient dramatically for a given pressure drop. These increases could be as large as 20 times for flow at very low Reynolds numbers.

IV. How Inserts Are Useful

- Reduce the first cost of a heat exchanger.
- Saving pumping power.
- Reduce the number of shells.
- Revamp application.

V. Classification Of Various Heat Transfer Enhancement Techniques-

They are broadly classified into three different categories:

1. Passive Techniques
2. Active Techniques
3. Compound Techniques.

5.1. Passive Techniques

1. Treated surfaces are heat transfer surfaces that have a fine-scale alteration to their finish or coating. The alteration could be continuous or discontinuous, where the roughness is much smaller than what affects single-phase heat transfer, and they are used primarily for boiling and condensing duties.
2. Rough surfaces are generally surface modifications that promote turbulence in the flow field, primarily in single-phase flows, and do not increase the heat transfer surface area. Their geometric features range from random sand-grain roughness to discrete three-dimensional surface protuberances.
3. Extended surfaces more commonly referred to as finned surfaces, provide an effective heat transfer surface area enlargement. Plain fins have been used routinely in many heat exchangers. The newer developments, however, have led to modified finned surfaces that also tend to improve the heat transfer coefficients by disturbing the flow field in addition to increasing the surface area.
4. Displaced enhancement devices are inserts that are used primarily in confined forced convection, and they improve energy transport indirectly at the heat exchange surface by "displacing" the fluid from the heated or cooled surface of the duct with bulk fluid from the core flow.
5. Swirl flow devices produce and superimpose swirl or secondary recirculation on the axial flow in a channel. They include helical strip or cored screw-type tube inserts, twisted ducts, and various forms of altered (tangential to axial direction) flow arrangements, and they can be used for single-phase as well as two-phase flows.
6. Coiled tubes are what the name suggests, and they lead to relatively more compact heat exchangers. The tube curvature due to coiling produces secondary flows or Dean vortices, which promote higher heat transfer coefficients in single-phase flows as well as in most regions of boiling.
7. Surface tension devices consist of wicking or grooved surfaces, which direct and improve the flow of liquid to boiling surfaces and from condensing surfaces.
8. Additives for liquids include the addition of solid particles, soluble trace additives, and gas bubbles in single-phase flows, and trace additives, which usually depress the surface tension of the liquid, for boiling systems.
9. Additives for gases include liquid droplets or solid particles, which are introduced in single-phase gas flows in either dilute phase (gas–solid suspensions) or dense phase (fluidized beds).

5.2. Active Techniques

In these cases, external power is used to facilitate the desired flow modification and the concomitant improvement in the rate of heat transfer. Augmentation of heat transfer by this method can be achieved by

(i) Mechanical Aids: Such instruments stir the fluid by mechanical means or by rotating the surface. These include rotating tube heat exchangers and scrapped surface heat and mass exchangers.
(ii) Surface vibration: They have been applied in single phase flows to obtain higher heat transfer coefficients.
(iii) Fluid vibration: These are primarily used in single phase flows and are considered to be perhaps the most practical type of vibration enhancement technique.
(iv) Electrostatic fields: It can be in the form of electric or magnetic fields or a combination of the two from dc or ac sources, which can be applied in heat exchange systems involving dielectric fluids. Depending on the application, it can also produce greater bulk mixing and induce forced convection or electromagnetic pumping to enhance heat transfer.
(v) Injection: Such a technique is used in single phase flow and pertains to the method of injecting the same or a different fluid into the main bulk fluid either through a porous heat transfer interface or upstream of the heat transfer section.
(vi) Suction: It involves either vapour removal through a porous heated surface in nucleate or film boiling, or fluid withdrawal through a porous heated surface in single-phase flow.
(vii) Jet impingement: It involves the direction of heating or cooling fluid perpendicularly or obliquely to the heat transfer surface.

5.3. Compound Techniques: When any two or more of these techniques are employed simultaneously to obtain enhancement in heat transfer that is greater than that produced by either of them when used individually, is termed as compound enhancement. This technique involves complex design and hence has limited applications.

VI. Literature Review

Jacqueline Biancon Copetti, Mario Henrique Macagnan, Daiana de Souza, Rejane De Ce´saro Oliveski *et al.*-[1] experimentally investigated heat transfer and friction characteristics for water single-phase flow in micro-fin tubes. The analysis of thermal and hydraulic behaviour from a laminar to a turbulent flow was carried out in an experimental setup with a 9.52 mm diameter micro-fin tube. The tube was wrapped up with an electrical resistance tape to supply a constant heat flux to its surface. Different operational conditions were considered in the heating tests. The inlet and outlet temperatures, differential wall temperatures along the tube, pressure drop and flow rate were measured. The relationships of heat flux and flow rate with heat transfer coefficient and pressure drop were analyzed. Under the same conditions, comparative experiments with an internally smooth tube were conducted. The micro-fin tube provides higher heat transfer performance than the smooth tube (in turbulent flow hmicro-fin / hsmooth = 2.9). In spite of the increase in pressure drop (Δpmicro-fin / Δpsmooth = 1.7) the heat transfer results were significantly higher (about 80%). He found that, the micro-fin tube tested allowed a significant increase in the heat transfer compared to the smooth tube. Increments of up to 190% in the heat transfer coefficient at turbulent flow were observed. In laminar flow this increment was only about 20%, which does not justify its application considering its higher costs compared to smooth tubes. The increase on pressure drop was also verified, but the efficiency index showed that the heat transfer increase is always superior. In a turbulent flow, this relation is of about 80%. Empirical correlations for heat transfer were formulated for micro-fin tube and compared with experimental data achieving a good agreement.

Paisarn Naphon, Parkpoom Sriromruln *et al.*-[2] experimentally investigate the heat transfer characteristics and the pressure drop of the horizontal double pipes with and without coiled wire insert. The inner and outer diameters of the micro-fin tube are 8.92 and 9.52 mm, respectively. The coiled wire is fabricated by bending a 1-mm-diameter iron wire into the coil wire with coil diameter of 7.80 mm. Cold and hot water are used as working fluids in shell side and tube side, respectively. The test runs are performed at the cold and hot water mass flow rates ranging Between 0.01 and 0.07 kg/s and between 0.04 and 0.08 kg/s, respectively. The inlet cold and hot water temperatures are between 15º and 20º C and between 40º and 45º C, respectively. The results obtained from the micro-fin tube with coiled insert are compared with those from the smooth tube and micro-fin tube without coiled wire insert. The effects of the inlet conditions of the working fluids flowing through the test sections are discussed. We found that the coiled wire insert has a significant effect on the enhancement of heat transfer. However, the friction factor of the tube with the coiled wire insert also increases.

Jin Min Cho, Min Soo Kim *et al.*-[3] Experimental studies on Carbon dioxide among natural refrigerants has gained a considerable attention as an alternative refrigerant due to its excellent thermo physical properties. In-tube evaporation heat transfer characteristics of carbon dioxide were experimentally investigated and analyzed as a function of evaporating temperature, mass flux, heat flux and tube geometry. Heat transfer coefficient data during evaporation process of carbon dioxide were measured for 5 m long smooth and micro-fin tubes with outer diameters of 5 and 9.52 mm. The tests were conducted at mass fluxes of from 212 to 656 kg m^{-2} s^{-1}, saturation temperatures of from 0º to 20º C and heat fluxes of from 6 to 20 kWm^{-2}. The difference of heat transfer characteristics between smooth and micro-fin tubes and the effect of mass flux, heat flux, and evaporation temperature on enhancement factor (EF) and penalty factor (PF) were presented. Average evaporation heat transfer coefficients for a micro-fin tube were approximately 150-200% for 9.52 mm OD tube and 170-210% for 5 mm OD tube higher than those for the smooth tube at the same test conditions. The effect of pressure drop expressed by measured penalty factor of 1.2-1.35 was smaller than that of heat transfer enhancement. Thus heat exchanger with 5 mm micro-fin tubes will be promising for the compact system with carbon dioxide as a refrigerant.

Pongjet Promvonge *et al.*-[4] experimentally studies on Thermal performance in circular tube fitted with coiled square wires. The effects of wires with square cross section forming a coil used as a turbulator on the heat transfer and turbulent flow friction characteristics in a uniform heat flux, circular tube are experimentally investigated. The experiments are performed for flows with Reynolds numbers ranging from 5000 to 25,000. Two different spring coiled wire pitches are introduced. The results are also compared with those obtained from using a typical coiled circular wire, apart from the smooth tube. The experimental results reveal that the use of coiled square wire turbulators leads to a considerable increase in heat transfer and friction loss over those of a smooth wall tube. The Nusselt number increases with the rise of Reynolds number and the reduction of pitch for both circular and square wire coils. The coiled square wire provides higher heat transfer than the circular one under the same conditions.

S. N. Sapali, Pradeep A. Patil *et al.*-[5] experimentally investigates the heat transfer coefficient (HTC) during condensation of HFC-134a and R-404A in a smooth (8.56 mm ID) and micro-fin tubes (8.96 mm ID). The present experiments are performed for various condensing temperatures, with superheating and sub cooling and using hermetically sealed compressor. The test runs are done at average saturated condensing temperatures ranging from 35º C to 60º C. The mass fluxes are between 90 and 800 kg m^{-2} s^{-1}. The experimental results indicate that the average HTC increases with mass flux but decreases with increasing condensing temperature for both smooth and micro-fin tubes. The average condensation HTCs of HFC-134a and R-404A for the micro-fin tubes was 1.5–2.5 and 1.3–2 times larger than that in smooth tube respectively. The condensation HTC increases with increasing mass flux and decreases with increasing condensing temperature for both smooth and micro-fin tubes. The condensation HTCs of HFC-134a are greater than that of R-404A at a similar mass flux and condensing temperature. The condensation HTCs in micro-fin tube are greater than their respective smooth tubes. The enhancement factors for HFC-134a and R-404A vary from 1.5–2.5 and 1.3–2.01 respectively. The new semi empirical correlations are developed for determination of condensation HTCs for smooth and micro-fin tubes using multiple linear regression technique and data gathered during experimentation of HFC-134a and R-404A with correlation coefficients 0.9687 for smooth tube and 0.9462 for micro-fin tube.

S. Eiamsa-ard, P. Nivesrangsan, S. Chokphoemphun, P. Promvonge *et al.*-[6] experimentally investigated heat transfer, friction factor and thermal performance behaviors in a tube equipped with the combined devices between the twisted tape (TT) and constant/periodically varying wire coil pitch ratio The periodically varying three coil pitch ratios were arranged into two different Forms- (1) D-coil (decreasing coil pitch ratio arrangement) and (2) DI-coil decreasing/increasing coil pitch ratio arrangement) while the twisted tapes were prepared with two different twist ratios. Each device alone is also tested and the results are subjected for comparison with those from the combined devices. The experiments were conducted in a turbulent flow regime with Reynolds numbers ranging from 4600 to 20,000 using air as the test fluid. Compared to each enhancement device, the heat transfer rate is further augmented by the compound devices. Over the range investigated, the highest thermal performance factor of around 1.25 is found by using DI-coil in common with the TT at lower Reynolds number. Also the empirical correlations of the heat transfer (Nu) and pressure drop (f) are also presented.

V.D. Hatamipour, M.A. Akhavan-Behabadi *et al.*-[7] experimentally studied Two-phase flow regimes and heat transfer coefficient of refrigerant R134a boiling in micro fin and smooth tube. Also Investigation of heat transfer during flow boiling of R-134a inside horizontal micro fin and smooth tube have been carried out experimentally The heat transfer coefficients for annular flow in the smooth tube is shown to agree well with Gungor and Winterton's correlation. All the flow patterns occurred in the test can be divided into three dominant regimes, i.e., stratified-wavy flow, wavy-annular flow and annular flow. Experimental data are plotted in two kinds of flow maps, i.e., Weber number for the vapor versus weber number for the liquid flow map and mass flux versus vapor quality flow map. At high vapor quality region annular flow is observed and in low vapor qualities stratified-wavy flow is captured. And in a small region between two previous regions wavy annular flow is observed. It was found micro fin tube have a noticeable effect on heat transfer coefficient. Horizontal micro fin tube increases the heat transfer coefficient by 0.65 percent in comparison to that for the horizontal smooth tube at high vapors quality region at the mass velocities of 100 and 150 kg/m^2.s. It was revealed heat transfer coefficient increases with the increase of flow mass velocity for smooth and micro fin tubes.

S. N. Sapali, Pradeep A. Patil *et al.*-[8] investigate the enhancement in condensation heat transfer coefficient and increase in pressure drop using micro-fin tube for different condensing temperatures and further develop an empirical correlation for heat transfer coefficient and pressure drop. They vary the different operating parameters such as condensing temperature, cooling water temperature, flow rate of refrigerant and cooling water etc. and study their effect on heat transfer coefficients and pressure drops in smooth and micro-fin tubes for various HFC refrigerants namely HFC-134a, R-404A, R-407C, R-507A. The condensation and pressure drop of HFC-134a in smooth and micro-fin tubes are measured and the values of condensation heat transfer coefficients for different mass flux and condensing temperatures are obtained using modified Wilson plot technique with correlation coefficient above 0.9. The condensation heat transfer coefficient and pressure drop increases with increasing mass flux and decreases with increasing condensing temperature for both smooth and micro-fin tubes. The heat transfer coefficients and pressure drops obtained for micro-fin tube are greater than that of smooth tube for all condensing temperatures and mass fluxes. The EFs obtained varies from 1.24 to 2.42, while PFs varies from 1 to 1.77.

Paisarn Naphon *et al.*-[9] investigated the heat transfer characteristics and the pressure drop of the horizontal double pipe with coil-wire insert. The inner and outer diameters of the inner tube are 8.92 and 9.52 mm. The coiled wire is fabricated by bending a 1 mm diameter of the iron wire into a coil with a coil diameter of 7.80 mm. Cold and hot water are used as working fluids in the shell side and tube side The test runs are performed at the cold and hot water mass flow rates ranging between 0.01 and 0.07 kg/s, and between 0.04 and 0.08 kg/s, respectively. The inlet cold and hot water temperatures are between 15 and 20 °C, and between 40 and 45 °C, respectively. He considered effect of the coil pitch and relevant parameters on heat transfer characteristics and pressure drop. Coil-wire insert has significant effect on the enhancement of heat transfer especially on laminar flow region. Non-isothermal correlations for the heat transfer coefficient and friction factor are proposed. It can be seen that the heat transfer rate and heat transfer coefficient depend directly on the mass flow rates of hot and cold water. Effect of coil-wire insert on the enhancement of heat transfer tends to decrease as Reynolds number increases.

VII. Conclusion

The coiled wire insert has a significant effect on the enhancement of heat transfer. The friction factor of the tube with the coiled wire insert also increases. The micro-fin tube with coiled wire insert allowed a significant increase in the heat transfer compared to the smooth tube. When making a comparison between smooth and microfin tubes on the same condition of the condensation tube length and the total heat transfer rate, the total pressure drop and the overall heat transfer coefficient in microfin tube are higher than those in smooth tube.

REFERENCES

[1.] Jacqueline Biancon Copetti, Mario Henrique Macagnan, Daiana de Souza, Rejane De Ce´saro Oliveski, Experiments with micro-fin tube in single phase, International Journal of Refrigeration 27 (2004) 876–883

[2.] Paisarn Naphon, Parkpoom Sriromruln, Single-phase heat transfer and pressure drop in the micro-fin tubes with coiled wire insert

[3.] Jin Min Cho, Min Soo Kim, Experimental studies on the evaporative heat transfer and pressure drop of CO2 in smooth and micro-fin tubes of the diameters of 5 and 9.52 mm, International Journal of Refrigeration 30 (2007) 986-994

[4.] Pongjet Promvonge, Thermal performance in circular tube fitted with coiled square wires, 26 November 2007

[5.] S. N. Sapali, Pradeep A. Patil, Heat transfer during condensation of HFC-134a and R-404A inside of a horizontal smooth and micro-fin tube, Experimental Thermal and Fluid Science 34 (2010) 1133–1141

[6.] S. Eiamsa-ard, P. Nivesrangsan, S. Chokphoemphun, P. Promvonge, Influence of combined non-uniform wire coil and twisted tape inserts on thermal performance characteristics, International Communications in Heat and Mass Transfer 37 (2010) 850–856.

[7.] V.D. Hatamipour, M.A. Akhavan-Behabadi, Visual Study on Flow Patterns and Heat Transfer during Convective Boiling Inside Horizontal Smooth and Microfin Tubes, World Academy of Science, Engineering and Technology 69- 2010

[8.] S. N. Sapali, Pradeep A. Patil, A new experimental technique to determine heat transfer coefficient and pressure drop in smooth and micro-fin tube, Journal of Mechanical Engineering Research Vol. 2(4), pp. 71-84, September 2010

[9.] Paisarn Naphon, Effect of coil-wire insert on heat transfer enhancement and pressure drop of the horizontal concentric tubes