A Review on Heat Enhancement Techniques

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Abstract

Heat transfer is the phenomena, of transfer energy (thermal energy) in between the systems or system and surroundings. And heat exchanger is the main device which is used for transfer of heat (thermal energy) in many industries like food industries, chemical industries, thermal power plant, air conditioning equipment etc. So because of heat exchanger importance, many heat enhancement techniques are adopted to improve the performance of heat exchanger. In the previous years, many research on passive techniques have been studied. This paper is the review of such techniques used in heat exchanger to improve the effectiveness. Twisted tapes, wire coils, ribs fins etc. are commonly used heat augmentation tools.
Keywords: Friction Factor, Heat Exchanger, Pressure Drop, Twisted Tape Insert, Wire Coils

I. Introduction

Heat transfer techniques are used to achieve high transfer rate with less power and to increase the efficiency of the system. There are mainly three types of techniques which are used for heat transfer enhancement:

A. Active Techniques:
In active techniques, external power input are required for enhancement of heat transfer. These techniques are complicated as point of usage and implement in actual applications and are not economically feasible. Active techniques may include chemical or fluid additives, mechanical rotation, scraping and wiping of heated surface, gas injection etc.

B. Passive techniques:
In passive techniques, no external power input are used for heat enhancement. Passive techniques make use of some form of surface treatment or special structural geometry to improve heat transfer. Some examples are coated surfaces, rough surfaces, swirl flow devices, etc.

C. 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.

II. Terminology Used

A. Thermo Hydraulic Performance
For a particular Reynolds number, the thermo hydraulic performance of an insert is said to be good if the heat transfer coefficient increases significantly with a minimum increase in friction factor. Thermo hydraulic performance estimation is generally used to compare the performance of different inserts under a particular fluid flow condition.

B. Overall Enhancement Ratio
The overall enhancement ratio is defined as the ratio of the heat transfer enhancement ratio to the friction factor ratio. This parameter is used to compare different passive techniques and enables a comparison of two different methods for the same pressure drop.

C. Nusselt Number
The Nusselt number is a measure of the convective heat transfer occurring at the surface and is defined as hd/k, where h is the convective heat transfer coefficient, d is the diameter of the tube and k is the thermal conductivity.

D. Prandtl Number

The Prandtl number is defined as the ratio of the molecular diffusivity of momentum to the molecular diffusivity of heat, ν/α.

E. Pitch

Pitch is defined as the distance between two points that are on the same plane, measured parallel to axis of a twisted tape.

F. Twist Ratio, y

The twist ratio is defined as the ratio of pitch to inside diameter of the tube **y = H/di**, where **H** is the twist pitch length and **di** is the inside diameter of the tube.

III. REVIEW OF WORK CARRIED OUT

The present paper give an overview of work carried out on heat enhancement techniques.

M.M.K. Bhuiya et al [1] 2013 performed experiment to investigate Nusselt number, friction factor and thermal performance factor in a circular tube with perforated twisted tape with four different porosities of 1.6, 4.5, 8.9, and 14.7%. The experiment was carried out in flow regime. It was found that Nusselt number, friction factor and thermal performance factor was 110 -340, 110 -360 and 28 – 59% was more than plane tube values. And results with porosity 4.5% was better than other porosity results.

Paisarn Naphon [2] 2006 performed experiment to predict heat transfer and pressure drop in double pipe heat exchanger equipped with twisted tape. The twisted tape was of aluminum with thickness 1mm and length 2000mm. The results attained with twisted tape are compared with plain tube without twisted tape. From the results, it was found that twisted tape has major effect on heat enhancement. Both heat transfer and pressure drop increased.

P. Bhardwaj et al [3] 2009 performed experiment to determine heat transfer characteristics of water in a spirally groove tube with twisted tape insert with twist ratio y = 10.15, 7.95 and 3.4. And results was compared with plane tube results. From the data, it was found that heat transfer enhancement was 400% in the laminar regime, 140% in the turbulent regime and reduction in heat transfer in the regime $2500 < Re < 9000$ in tube without twisted tape. And with twisted tape, 600% in laminar regime and 140% in turbulent regime. With y = 10.14, there was reduction in heat transfer for regime $6000 < Re < 13000$. Heat transfer routine of twisted tape with twist ratio y = 7.95 was found better among three twist ratio.

CUI Young – zhang [4] 2010 performed experiment and simulation to predict heat transfer and pressure drop of air in circular tube with Edge fold twisted tape(ETT) and with Spiral twisted tape(STT). To simulate pressure drop and heat transfer characteristics, RNG turbulence model and pressure velocity method was used. Heat transfer with ETT inserts was found greater than STT insert. The factors which affect heat transfer was twist angle and gap between tube and inserts. Twist ratio from 5.4 to 11.4 and Re from 2500 to 9500 was used. Nusselt number and friction factor with ETT inserts was 3.9%-9.2% and 8.7%-74% higher than STT inserts in tube.

Bodius Salam et al [5] 2013 conceded experiment to determine heat transfer coefficient, friction factor and heat transfer efficiency of water in tube fitted with rectangular cut twisted tape insert. Twisted tape was of stainless steel and twist ratio 5.25. Nusselt numbers were increased by 2.3 to 3.9 with rectangular cut twisted insert in tube than plain tube without insert. And friction factor were enhanced 1.4 to 1.8 times with twist tape as compared to plane tube. Heat transfer efficiencies were in range of 1.9 to 2.3 and increased with Reynolds Number.

M.M.K. Bhuiya et al [6] 2013 conducted experiment to predict the effect of triple twisted tape inserts with twist ratio y = 1.92, 2.88, 4.81 and 6.79. In tube on heat transfer rate, friction factor and thermal enhancement efficiency. The Nusselt number, friction factor and thermal enhancement efficiencies gained with triple twisted tape insert was 1.73 to 3.85 , 1.91 to 4.2 and 1.10 to 1.44 times respectively greater than plain tube values.

P.Murugesan et al[7] 2011 performed experiment to predict heat transfer and friction factor of circular tube equipped with plain twisted tape(PTT) and U – cut twisted tape(UTT) with twist ratio y = 2.0, 4.4 and 6.0 in turbulent region of $2000 < Re < 12000$. Experimental results obtained from UTT were compared with results that obtained from plain tube and tube with PTT. Nusselt number and friction factor for UTT was greater than those of plain tube and PTT. UTT give better heat transfer augmentation than plain tube and PTT.

Chinaruk Thianpong et al.[8] 2009 performed experiment to predict effect of pitch and twist ratio on heat transfer coefficient and pressure drop using two dimple tube(PR = 0.7, 1) and three twisted tapes with twist ratio y = 3, 5, 7 respectively. Results obtained from plain tube and dimple tube was used for comparison. Heat transfer and friction factor in dimpled tube with twist tape was 1.66 to 3.03 and 5 to 6.31 respectively higher than plain tube.

P.Eiamsa – ard et al [9] performed experiment to predict heat transfer augmentation and friction factor in the tube equipped with rectangular – winged twisted tape (TT- RWs). In the experiment, wing depth ratio was varied from 0.1 to 0.3 while twist ratio remain unchanged. Water was working fluid and Re number varied from 5500 to 20200. Tubes with TT-RWs gave better performance as compared to TT, TA and plain tube. TT-RWs with $\frac{d}{w} = 0.3$ gave greater nusselt number and thermal performance of 1.86.

Somsak Pethkool et al [10] 2006 performed experiment to calculate the effect of louvered strips in double pipe heat exchanger on friction factor and heat transfer performance. Strips was made of brass and of thickness 0.5mm and width 9mm. The experiment performed at Re from 6000 to 65000. The results revealed that Nusselt number enhanced up to 246% and friction enhanced 167% as compared to plain tube.

S. Eiamsa-ard et al [11] 2005 performed experiment to predict the effect of nozzle turbulator on pressure drop and heat transfer characteristics. The nozzle turbulators produced more turbulence flow as compared to plain tube. Heat transfer rate in the tube equipped with nozzle turbulators was 300% for pitch ratio y = 1.0 as compared to plain tube.

D.G. Kumbhar et al [12] 2010 performed experiment to predict heat transfer, friction factor and thermal performance characteristics in a horizontal circular tube fitted with conical wire coil inserts (CWCI). In this work two shapes of wire coil inserts (WCI) were applied, one being CWCI and other being full length WCI were located in a test tube, through which a working fluid air was allowed to pass. The CWCI of 6mm, 9mm and 12mm spring pitches are introduced in each run. In addition, the CWCI of PR 2.5mm and 3.5mm are also tested within $2000\leq Re\leq 10000$. The experimental results reveal that the tube fitted with the CWCI and full length WCI provides values of around $5\% \leq Nu \leq 12\%$ and $0.78\leq\eta\leq 0.98$ vis-à-vis plain tube.

M.KANNAN et al [13] 2012 performed experiment to compare different types heat enhancement techniques with the help of simulation. From the data, it was found that annular method gave better heat transfer than other methods.

V. Kongkaitpaiboon et al [14] 2010 performed experiment to determine the effect of perforated conical rings (PCR) on Nusselt number, friction factor and thermal performance factor characteristic. In the experiment, PCR was used as tabulators with three different pitch ratio y = 4, 6, 12 and three different perforated holes 4, 6, and 8 respectively. The experiment was carried in the range of Re from 4000 to 20000. It was found that the PCR reduces the development of thermal boundary layer, leading to the heat transfer rate up to 137% vis-à-vis in plain tube. PCRs enhanced the heat transfer more efficiently than the typical CR on the basis of thermal performance factor of around 0.92 at the same pumping power.

A. Mehta Kushal K et al [15] performed experiment to determine the effect of insert and delta winglet in tube in tube heat exchanger. Heat transfer in terms of Nusselt number depend upon the different length of inserts and delta winglet. The range of Re number was from 1400 to 6500. From the results, it was found that Nusselt number for 50 cm insert was enhanced by 53%, for 20 cm was enhanced by 27% in comparison to plain tube.

Pongjet Promvonge et al [16] 2010 performed experiment to predict the combined effect of ribs and winglet type vortex gernerators (WVGs) on heat enhancement and friction factor for turbulent air flow. Cross section of ribs was of isosceles triangle shape. WVGs with attack angles (α) of 60, 45 and 30 degree respectively established on duct entrance. Nusselt number and friction factor was more in case of both ribs and WVGs as compared to alone ribs and winglet.

Oliver and Shoji [17] performed experiments by inserting wire coils in a tube using a non- Newtonian fluid and found that heat transfer is enhanced by a factor of 4 and the relative pressure drop caused by the wire coil is by factor of 5.

IV. CONCLUSION

In this review paper, an overview of passive techniques is given about various heat enhancement techniques which have been used in various fields. The main factor which are considered for investigations are heat transfer, friction factor and thermal performance factor.

In passive techniques, some kind of insert are placed in flow passage to augment the heat transfer. These inserts block the passage, due to this pressure drop will increase and viscous effect dominate because of reduced area. Secondary flow due to increase in flow velocity provides a better contact between the surface and fluid. And due to proper mixing, temperature gradient will increase.

These deduction will be very useful for applications of heat transfer augmentation in heat exchanger.

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