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A Review of heat transfer augmentation technique for combined coiled insert and dimple tube approach.

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***Abstract* — In today there is great need of energy conservation. In every aspect of social and industrial applications. In process industry the heat phenomenon is used to carry out the functions. The heat either may be used to add or reject from the system. There are many types of heat losses observed in these processes researchers are working hard to minimize these losses and enhance the heat transfer rate in either directions. This paper made an attempt to review the some of the passive techniques and revel the possibilities of the combined approach of this technique.**

***Keywords*—coiled wire insert, dimple tube, heat transfer enhancement, passive technique.**

I. INTRODUCTION

Heat exchangers are popular used in industrial and engineering applications. The design procedure of heat exchangers is quite complicated, as it needs exact analysis of heat transfer rate, efficiency and pressure drop apart from issues such as long term performance and the economic aspect of the equipment. Whenever inserts technologies are used for the heat transfer enhancement, along with the improvement in the heat transfer rate, the pressure drop also increases, which induces the higher pumping cost. Therefore any augmentation device or methods utilized in to the heat exchanger should be optimized between the benefits of heat transfer coefficient and the higher pumping cost owing to the increased frictional losses. In general heat transfer augmentation methods are classified in to three broad categories:

Active Method

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, mechanicals aids, surface vibration, fluid vibration, electrostatic fields, suction or injection and jet impingement requires an external activate or power supply to bring about the enhancement. [1]

Passive Method

This method generally uses surface or geometrical modifications to the flow channel by incorporating inserts or additional devices. For example, inserts extra component, swirl flow devices, treated surface, rough surfaces, extended surfaces, displaced enhancement devices, coiled tubes, surface tension devices and additives for fluids.[1]

Compound Method

Combination of the above two methods, such as rough surface with a twisted tape swirl flow device rough surface with fluid vibration, rough surface with twisted tapes. This paper focuses on review in the passive methods in pipe heat exchanger. The passive heat transfer augmentation methods as stated earlier do not need any external power in put. For the convective heat transfer, one of the ways to enhance heat transfer rate is to increase the effective surface area and residence time of the heat transfer fluids. The passive methods are based on this principle, by employing several techniques to generate the swirl in the bulk of the fluid sand disturb the actual boundary layers as to increase effective surface.

Although there are so many passive methods employ to enhance the heat transfer rate, following are the most commonly used methods are discussed here;

a. Treated Surfaces: They 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.
b. Rough surfaces: They 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 and grain roughness to discrete three dimensional surface protuberances.
c. Extended surfaces: They provide effective heat transfer enlargement. The newer developments have led to modified fin surfaces that also tend to improve the heat transfer coefficients by disturbing the flow field in addition to increasing the surface area.
d. Displaced enhancement devices: These are the insert techniques that are used primarily in confined fe devices improve the energy transfer in directly at the heat exchange surface by displacing the fluid from the duct pipe with bulk fluid to the core flow.
e. Swirl flow devices: They produce and superimpose swirl flow or secondary recirculation on the axial

flow in a channel. These devices include helical strip or cored screw type tube inserts, twisted tapes. They can be used for single phase or two-phase flows heat exchanger.

f. Coiled tubes: These techniques are suitable for relatively more compact heat exchangers. Coiled tube produce secondary flows and vortices which promote higher heat transfer coefficient in single phase flow as well as in most boiling regions.
g. Surface tension devices: These consist of wicking or grooved surfaces, which directly improve the boiling and condensing surface. These devices are most used for heat exchanger occurring phase transformation.
h. Additives for liquids: These include the addition of solid particles, soluble trace additives and gas bubbles into single phase flows and trace additives which usually depress the surface tension of the liquid for boiling systems.
i. Additives for gases: These include liquid droplets or solid particles, which are introduced in single phase gas flows either as dilute phase (gas–solid suspensions) or as dense phase (fluidized beds). [1]

Coiled Wire Inserts

The helical inserts are new addition to the family of inserts for enhancement of heat transfer. For the helical taps, the swirl moves in one direction along the helical and induce swirl in the flow, which increase their tension time of the flow and consequently provide better heat transfer performance over twisted tape insets. The high heat transfer with helical inserts is also accompanied by a higher pressure drop across the flow, but at low Reynolds number, helical tapes are used in solar water heating applications to drive heat transfer benefit. However inserts of different configuration are being used to meet the need so for higher heat dissipation rates. Re oil inserts are currently used in the applications such as oil cooling devices, preheated or fire boilers. They show several advantages in relation to other enhancement techniques:

i. Simple manufacturing process with low cost.
ii. Easy installation and removal.
iii. Preservation of original plain tube mechanical strength.
iv. Possibility of installation in an existing smooth tube heat exchanger.
v. Fouling mitigation (in refineries chemical industries and marine application).

Dimple Tube

Many techniques to reduce the tube side boundary layer resistance have been tried including various styles of tube inserts which make the form of complex wire shapes or flat twisted strips fitted inside the tube and various style of tube deformation most have advantages of increasing the resistance to fluid flow the pressure loss at rate which increases more rapidly than the decrease in boundary layer resistance.

One technique which does not have these advantages however is that of deforming the tube with either continuous spiral indentation or an intermittent spot indentation. Research was shown that by choosing the depth, angle and width of the indentation carefully. The rate of decrease in boundary layer resistance can exceed the rate of increase in pressure loss.

They show several advantages in relation to other enhancement techniques:

a. Reduction in heat exchanger size.
b. Reduction in product hold up volume.
c. Reduction in processing time.
d. Reduction in fouling potential.
e. Increased cleaning potential.
f. More efficient processing of viscous fluid.

II. PRESENT RESEARCH WORK

In this section a review of research work in the area of coiled inserts an dimple tube is carried out and based on this review certain observation were made

Gars' etal. [2] and Yakut and Sahin [3]. The vortex characteristics of tabulators, heat transfer rate and friction characteristics were considered as the criterions to evaluate the enhancement performance of coiled i.e. Garcı´aetal. Experimentally studied the helical wire coils fitted inside around tube in order to characterize their thermo hydraulic behaviour in laminar, transition and turbulent flows. Results have shown that

i. In laminar flow, wire coils behave as a smooth tube but accelerate transition to critical Reynolds numbers down to 700.
ii. At the low Reynolds numbers about Re 700, transition from laminar to turbulent flow occurs in a gradual way.
iii. Within the transition region, heat transfer rate can be increased up to 200% when kept the pumping power constant.
iv. Wire coils have a predictable behaviour within the transition region since they show continuous curves of friction factor and Nusselt number, which involves a considerable advantage over other enhancement techniques.
v. In turbulent flow, wire coils cause a high pressure drop which depends mainly on the pitch to wire diameter ratio (p/e).

In turbulent flow, the pressure drop and heat transfer are both increased by up to nine times and four times respectively, compared to the empty smooth tube. Therefore, it can be concluded that the wire coil do not cause obvious pressure drop and heat transfer rate increase, but induces the flow transition at a critical low Reynolds numbers at about 700. For pure turbulent flow, it can be stated that Prandtl number does not exert an influence on heat transfer augmentation. On the contrary, when working with high Prandtl number fluids within the transition region, wire coils produce the highest heat transfer increase. Mean while, the wired coils offer their best performance with in the transition region where they present a considerable advantage over other enhancement techniques. Following the pervious researches,

Promvong e etal.[4,5,6], experimentally studied the effects of wires coils with different square cross sections; coiled wires in conjunction with a snail type swirl generator mounted at the tube entrance; wire coils in conjunction with twisted tapes used as a tabulator; and combined devices of the twisted tape (TT) and constant periodically varying wire coil pitch ratio. For the wires with square cross section, the Nusselt number augmentation tends to decrease rapidly with the rise of Reynolds number. If wire coils are compared with a smooth tube at a constant pumping power, an increase in heat transfer is obtained, especially at low Reynolds number. Although fairly large differences have been observed among the analysed coil wires, their evaluated performances are quite similar under the condition of Re=5000, heat transfer enhancement efficiency (11.3) and Re=25,000, (1.11.15). Therefore, the coiled square wire should be applied to obtain a higher thermo hydraulic performance, but it will lead more compact heat exchanger construction. The use of the coiled wires in conjunction with a snail type swirls generator results in a high increase of the pressure drop but provides considerable heat transfer augmentations. The heat transfer enhancement ratio is from 3.4 to 3.9, and the Nusselt number augmentation tends to decrease with the rise of Reynolds number. The best operating regime for combined tabulators is at lower Reynolds number and the lowest values of the coil spring pitch and Twist ratio .Similar with the coiled wires used in reference, the Nusselt number augmentation tends to decrease with the rise of Reynolds number. Comparing the combined tabulators consisted of wire coil and twisted tape with a smooth tube at a constant pumping power, a double increase in heat transfer performance is obtained specially at low Reynolds number.

Promvongeetal.[7], investigated the combined devices consisted of the twisted tape (TT) and constant periodically varying pitch ratio of the wire coil. They found that, at low Reynolds number, the device combined with TT at twist ratio of 3.0 and the DI coil, provided the highest thermal performance which was around 6.3%, 13.7%, 2.4% and 3.7% higher than the wire coil alone, the TT alone, the TT with uniform wire coil, and the TT with D-coil, respectively.

Except the Promvonge's group, another two groups Gunesetal.[8] also investigated the thermo hydraulic behaviour of coiled wires in tube and pipe heat exchgers in 2010. Gunesetal. Experimentally investigated the coiled wire inserted in a tube for a turbulent flow regime. The coiled wire has equilateral triangular cross section and was inserted separately from the tube wall. They discovered that the Nusselt number rises with the increase of Reynolds number and wire thickness, and the decrease of pitch ratio; the best operating regime of all coiled wire inserts is detected at low Reynolds number, which leads to more compact heat exchanger; the pitch increases, the vortex shedding frequencies decrease and the maximum amplitude so pressure fluctuation of vortices produced by coiled wire tabulators occur with small pitches. Meanwhile,

Akhavan Behabadietal. [9] investigated seven coiled wires with pitches from 12mm to 69 mm, and wire diameters of 2.0 mm and 3.5 mm. These coiled wires are inserts inside a horizontal tube for heating the engine oil. The results show that the rise in fanning friction factor f due to the 2.0 mm thickness of the coiled wire insert for the Reynolds numbers less than 500. For Reynolds numbers higher than 500, the reduction in coil pitch causes an increase of the fanning friction factor.

Sibel Gunes [10] This study presents the determination of the optimum values of the design parameters in a tube with equilateral triangular cross-sectioned coiled wire inserts. The effects of the design parameters such as the ratio of the distance between the coiled wire and test tube wall to tube diameter (s/D), pitch ratio (P/D),ratio of the side length of equilateral triangle to tube diameter (a/D) and Reynolds number (Re) on heat transfer and pressure drop were investigated by using Taguchi method. The Nusselt number and friction factor were considered as performance parameters. An L9(34) orthogonal array was chosen as experimental plan. The goal of this study is to reach maximum heat transfer (i.e. Nusselt number) and minimum pressure drop (i.e. friction factor). First of all, each goal was optimized, separately. Then, all the goals were optimized together, considering the priority of the goals. Contribution ratios for each parameter on the heat transfer and pressure drop were determined. Consequently, the optimum results were found to be s/D =0.0357, P/D=1, a/D = 0.0714 and Re = 19800.

M. H. Mahmoud [11] An improved Metal Solar Wall with integrated thermal energy storage is presented in this research. The proposed Metal solar wall makes use of two, combined, enhanced heat transfer methods. One of the methods is characterized by filling the tested ducts with a commercially available copper Wired Inserts, while the other one uses dimpled or sinusoidal shaped duct walls instead of plane walls. Ducts having square or semi-circular cross sectional areas are tested in this work. A developed numerical model for simulating he transported thermal energy in MSW is solved by finite difference method. The model is described by system of three governing energy equations. An experimental test rig has been built and six new duct configurations have been fabricated and tested. Air is passed through the six ducts with Reynolds numbers from 1825 to 7300.Six, new, correlations for Nusselt number and friction factor are developed to assess the benefits that are gained from using the WI and the dimpled and sine-wave duct walls. It is found that higher heat transfer rates are achieved using the Dimpled, semi–circular duct with Wired Inserts. Also, it is found that Nusselt number and the pressure drop in the Dimpled, semi–circular duct with Wired Inserts are respectively (44.2% -100%) and (101.27% - 172.8%) greater than those of the flat duct with wire insert. The improvement in Nusselt number for flat duct with wire insert is found to be (1.4 – 2) times the values for flat duct with no wire insert. The results demonstrated that Dimpled, semi–circular duct with Wired Inserts provides enhance Metal Solar Wall enhancements efficiency value that is higher than those obtained from other types of ducts. The developed Metal Solar Wall ducts have added to local knowledge a better understanding of the compound heat transfer enhancement.

Juin Chen Hans [12] Heat transfer enhancement was investigated in a coaxial-pipe heat exchanger using dimples as the heat transfer modification on the inner tube. Tube-side Reynolds numbers were in the range of 7:5 × 103±5.2 ×104 for water flow. A constant annular mass flow rate was chosen to obtain the highest possible Reynolds number of 1.1×104. Typically, the heating water inlet temperature was 68.1 × 0.1 C. All six variants with inward-facing, raised dimples on the inner tube increased the values of heat transfer coefficient significantly above those for the smooth tube. Heat transfer enhancement ranged from 25% to137% at constant Reynolds number, and from 15% to 84% at constant pumping power. At a constant Reynolds number, the relative J factor (ratio of heat transfer coefficient to friction factor, relative to smooth tube values), had values from 0.93 to 1.16, with four dimpled tube configurations having values larger than unity. Despite the extremely simple design, this outperforms almost all heat transfer enhancements recommended in the literature. A correlation based on the results of the present work appears to be sufficiently accurate for predicting heat transfer coefficients and friction factors for the design of dimpled-tube heat exchangers.

Chinaruk Thianpong , [13] Friction and compound heat transfer behaviours in a dimpled tube fitted with a twisted tape swirl generator are investigated experimentally using air as working fluid. The effects of the pitch and twist ratio on the average heat transfer coefficient and the pressure loss are determined in a circular tube with the fully developed flow for the Reynolds number in the range of 12,000 to 44,000. The experiments are performed using two dimpled tubes with different pitch ratios of dimpled surfaces (PR=0.7 and 1.0) and three twisted tapes with three different twist ratios(y/w=3, 5, and 7). Experiments using plain tube and dimpled tube acting alone are also carried out for comparison. The experimental results reveal that both heat transfer coefficient and friction factor in the dimpled tube fitted with the twisted tape, are higher than those in the dimple tube acting alone and plain tube. It is also found that the heat transfer coefficient and friction factor in the combined devices increase as the pitch ratio (PR) and twist ratio (y/w) decrease. In addition, an empirical correlation based on the experimental results of the present study is sufficiently accurate for prediction the heat transfer (Nu) and friction factor (f) behaviours.

S.W. Chang and K.F. Chiang [14] Measurements of detailed Nusselt number (Nu) distributions and pressure drop coefficients (f) for four hexagonal ducts with smooth and dimpled walls are performed to comparatively examine the thermal performances of three sets of dimpled walls with concave–concave, convex–convex and concave–convex configurations at Reynolds numbers (Re) in the range of 900–30,000. A set of selected experimental data illustrates the influences of dimple configuration and Re on the detailed Nu distributions, the area-averaged Nu over developed flow region (Nu) and the pressure drop coefficients. Relative enhancements of Nu and f from the smooth-walled references (Nu1 and f1) along with the thermal performance factor (g) defined as (Nu/Nu1)/(f/f1)1/3 are examined. Nu and f correlations are individually obtained for each tested hexagonal duct using Re as the controlling parameter.

III. CONCLUSIONS

In plain tube heat transfer enhancement is lower than passive heat transfer enhancement technique. Twisted tape in tube give higher heat transfer enhancement in laminar flow. Coiled wire gives higher heat transfer enhancement in turbulent flow. Dimple tube also gives higher heat transfer enhancement in turbulent flow along with dimple tube has long life than coiled wire. Experiments were conducted twisted tape with dimple tube and gives good result.

There is scope to further carry research for combined approach of coiled wire insert and dimple tube.

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