Heat Transfer Augmentation Using Twisted Tape Inserts in Heat Exchanger: A Review

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Abstract- Heat transfer enhancement techniques are popularly used in various engineering applications such as heat exchanger, air conditioning, chemical reactors and refrigeration systems. Twisted tape is one of the most important passive techniques, which has been proved to disturb the flow fluid in tube and then strengthen the heat transfer efficiency. This paper conducted comprehensive and comparative review on experimental and numerical works taken by researchers. It is found that both heat transfer coefficient and friction factor increase with the decreasing of twisted ratio. The twisted tapes combined with different modified techniques are the new development directions of heat transfer enhancement. The appropriate twisted tape modification is necessary for heat transfer enhancement with pressure loss penalty at a reasonable level.

Index terms- Twisted Tap, Nusselt Number, Heat transfer, Pressure Drop

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 into 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 can be classified into three broad categories: active, passive and compound methods. The active method involves some external power input for the enhancement of heat transfer. On the contrary, the passive method can enhance the heat transfer by using modified surfaces or geometries such as rough surfaces, extended surfaces, tube inserts, etc. As the name implies, the compound method combines the passive method with the active method. To achieve an optimal heat transfer rate at an economic pumping power, the passive method is popularly used. As one of the passive method techniques, tube inserts technology has been widely used in the heat exchanger such as twisted tape, helical spring, ribs, conical nozzle, and conical ring etc. The tube inserts can be divided into two broad categories: stationary and self-rotating. The stationary inserts have the relatively fixed position in plain tube. The self-rotating inserts are defined as such inserts which can automatically rotate while the fluid flows through the tube. The self-rotating inserts can strengthen the heat transfer efficiency and achieve the on-line anti-scaling and descaling effect.

II. LITERATURE REVIEW ON RIB TURBULATORS FOR HEAT TRANSFER ENHANCEMENT

In several engineering application systems, such as vortex combustor, internal duct cooling of the gas turbine blades, thermal regenerators, electronic cooling devices, and solar water heaters, heat exchangers play an important role in such a system. However, to reduce the energy consumption and to increase economic benefit, traditional heat exchangers with plain tube are always not competent
enough due to low heat transfer coefficients as well as poor thermo-hydraulic performance. The requirement of a high-performance thermal system leads to the development of various techniques for enhancing the heat transfer rate with a view to reducing the overall heat exchanger sizes and increasing its efficiency.

Fig. 1. Different types of twisted tape
Those techniques included various roughen surfaces or inserted devices such as ribs [1–3], baffles [4–6], coiled wires [7,8], twisted tapes [9–12], conical rings [13,14], vortex rod/conical strip vortex generators [15–17], V-shaped rings [18], and winglet vortex generators [19–21], have been widely reported in the literature and employed to produce the longitudinal vortex/swirl flows which can help convey the core fluid into the near-wall regime and vice versa.

Fig. 2. Different types of twisted tape
The application of ribs/baffles/winglets mounted on the cooling/ heating channel walls is one of the commonly employed techniques in enhancing the heat transfer rate in a single-phase internal flow because ribs/baffles/winglets placed repeatedly on the channel wall not only interrupt the development of hydrodynamic and thermal boundary layers but also provide stronger turbulence flow mixing of fluid. Han et al. [22,23] experimentally studied on thermal and flow resistance behaviors in a square channel with various angled ribs at $P/e=10$ and $e/D=0.0625$ and suggested that the use of $60^\circ$ broken inclined V-ribs leads to higher heat transfer augmentation than the continuous V-ribs at a given operating condition. An investigation using a large eddy simulation on
thermal characteristics in a square duct with various ribs at e/D=0.1, P/e=10 and attack angle of 60° was conducted by Murata and Mochizuki [24] who proposed that the impingement/reattachment flow at the midpoint between the ribs gives rise to a great enhancement of the local convection heat transfer. A comprehensive review on thermal-performance augmentation using ribs mounted periodically on the surface of a solar air heater duct by numerical and experimental work was put forward by Hans et al. [25]. Tamna et al. [26] experimentally and numerically examined the turbulent flow and thermal behaviors in a channel mounted with 45° V-baffle vortex generators (BVG) and found that the BVG placed on a single wall with PR=0.5 offered the optimal thermal–hydraulic performance. Skullong et al. [27] investigated the flow friction and thermal characteristics in a rectangular duct with combined winglet-groove and indicated that the application of combined wavy-groove and trapezoidal-winglet provided the maximum thermal performance around 2.12 or about 43% higher than that of the single groove alone. Zhou and Ye [28] explored the flow resistance and thermal behaviors of a pair of curved trapezoidal winglet-type vortex generators placed on a solar air heater duct wall and suggested that the curved trapezoidal winglet yielded the peak thermal performance owing to streamlined shape and then lower friction loss. Skullong et al. [29] experimentally and numerically examined heat transfer characteristics in a solar air heater duct with two-typed perforated-winglets included rectangular and trapezoidal winglets. They found that the trapezoidal winglet provided the highest thermohydraulic performance around 1.84. For a tubular heat exchanger, many attempts have been made to investigate the vortex-generator application in enhancing the rate of heat transfer in the inserted heating/cooling tubes. Promvonge [30] examined the flow resistance and thermal behaviors in a circular tube with a uniform surface heat flux by insertion of coiled wires with square and round cross-sections. The effect of insertion of regularly spaced twisted tape elements on flow friction and thermal behaviors in a circular tube was also studied by Eiamsa-ard et al. [31]. Promvonge and Eiamsa-ard [32] reported the heat transfer behaviors in a round tube with conical nozzle inserts in common with a snail-type vortex generator placed at the entry to produce the vortex flow. The effect of the conical ring together with twisted tape on thermal characteristics was again explored by Promvonge and Eiamsa-ard [33]. Kongkaiptaiboones et al. [34] conducted an experiment to investigate the influence of holed conical-rings on behaviors of heat transfer in a heat exchanger tube. Promvonge et al. [35] experimentally studied the performance augmentation in a round tube with inclined rings and proposed that the angled ring insert yielded the considerable increase in TEF above the twisted-tape, wire coil and 90° typical ring acting alone. Liu et al. [36] put forward the heat transfer enhancement in a circular tube with multiple conical strips inserts. Akansu [37] performed a numerical investigation to explore the effect of PR of porous rings on the performance augmentation in a heat exchanger tube and pointed that the decline of PR resulted in the rise of heat transfer and pressure loss. Skullong et al. [38] reported thermal characteristics and turbulent flow structure in a tube with delta-wing inserts and found that the deltawing at α=30° and p/D=1.0 yielded the excellent thermal-hydraulic performance. The effect of staggered-winglet perforated-tape on the heat transfer enhancement in a tubular heat exchanger was also proposed by Skullong et al. [39] who suggested that the peak of thermal performance lies in a range of 1.23–1.71 for the tape at e/D=0.15, P/D=1.0. Xu et al. [40] examined thermal performance of a tube inserted with winglet vortex generator (WVG) and showed that the WVG with attack angle=0, BR=0.1 and PR=2.4 had the maximum TEF around 1.45. Zhai et al. [41] studied the flow resistance and thermal characteristics in a tube fitted with delta-winglet (DW) pairs using two different winglet arrangements to achieve the common-flow-up (CFU) and common-flow-down (CFD) vortices. They reported that the DW pair with CFD, BR=0.144, α=30°, s (spacing between leading edge of the DW pair)/D=0.29 and PR=9.6 yielded the maximum TEF around 1.44.

III. CONCLUSION

In the present paper an effort has been made to report useful passive methods which are used in order to enhance the heat transfer performance. Insertion of swirl flow devices enhance the convective heat transfer by making swirl into the bulk flow and disrupting the boundary layer at the tube surface due
to repeated changes in the surface geometry. That is to say such devices induce turbulence and superimposed vortex motion (swirl flow) which induces a thinner boundary layer and consequently results in a better heat transfer coefficient and higher Nusselt number due to the changes in the twisted tape geometry. However, the pressure drop inside the tube will be increased by introducing the twisted tape to insert. Based on the literature review following conclusions are drawn.

1. Compared with the stationary twisted tapes, the heat transfer enhancement and the function of online anti-scaling and descaling can be obtained with the self-rotating inserts in tube. Meanwhile, the tube with self-rotating twisted tapes gives the lower pressure drop in the researches.

2. The twisted tapes achieve remarkable and effective characterizes in laminar regions than in turbulent regions. Meanwhile, the twisted tapes have significant performance both in common fluid and nanofluid.

3. The Nusselt number and friction factor in the tube with cut twisted tape increase with decreasing twist ratios, width ratios and increasing depth ratios. The heat transfer and friction factor increases with decreasing the twist ratio and the width of twisted tape. The performance factors of all twisted tapes tend to decrease with increasing Reynolds number.

4. The novel twisted tapes can achieve an optimal comprehensive performance compared with the typical twisted tape, for the former can offer a stronger swirl flow to provide superior mixing and more efficient interruption of thermal boundary layer or have the access to prevent the formation of higher pressure drop.

5. The major criterion for selecting superior twisted tape configurations is the high value of thermal performance factor. All of these selected modified schemes have better thermal performance factor than typical twisted tape. The values of self-rotating twisted tape are higher than stationary twisted tapes.

6. The twisted tape, which is relevant to minimum pressure drop conjugate with the maximum heat transfer rate, is the optimal shape. At the same time, the method of twisted tape combined with other techniques is the new development direction of heat transfer enhancement.

7. The heat transfer coefficients of the coiled tubes with larger pitches are less than those of the ones with smaller pitches; and the effect of pitch on Nusselt number is more visible in high temperatures.

REFERENCES


