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Review Paper On Heat Transfer Augmentation By Using Swirl Generating Devices In Tubes Of heat exchangers

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2.1 Abstract

A lot of work has been done in the field of heat transfer augmentation. Many researchers have conducted experiments to find out effect of various passive heat transfer augmentation elements like twisted tapes, springs, conical tube elements etc. Effect of these elements on important parameters like heat transfer co-efficient, friction factor and surface temperature has been investigated. Some of them are described here.

2.2 Review of literature

Subhashis Ray et al.[1]

The possibility of using wire-loop structures on the active plate of a parallel plate channel for efficient heat transfer augmentation was explored. For this purpose, numerical simulations werecarried out for periodically fully-developed turbulent flow in typical repeating modules using the realizable-ε model. Experiments were also conducted in order to validate some of the results obtainedfrom numerical simulations. For both studies, the Reynolds number was varied from 2000 to 20,000. Theeffect of three different loop-densities on fluid flow and heat transfer characteristics were investigatedwhen wire-loops were placed perpendicular to the main flow direction, whereas the effect of looporientationson these parameters were studied for a fixed loop density of 2270 loops/m^2. While for allinvestigated cases, substantial heat transfer augmentation was observed with wire-loop structures as compared to the empty parallel plate channel under the condition of identical pressure gradient, the thermal-hydraulic performance improved significantaly with the increase in loop-density. The maximum attainable loop-density, however, was found to strongly depend on the loop-orientation owing mainly to the geometric as well as manufacturing constraints. It was also observed that loops, oriented diagonally to the main flow direction offer the best performance.

Jian Guo et al. [2]

Laminar forced convective heat transfer was studied for the purpose of getting the best heat transfer performance with the least flow resistance increase. The variation calculus method is employed to establish the equations describing the optimized fluid velocity field and temperature field. Numerical solutions of the equations for a convective heat transfer process in a section-cut of a square duct indicate the optimized flow should have a transverse secondary swirl flow pattern consisting of multiple vortexes with identical swirl direction in the junction region of any two neighboring vortexes. We then propose the convective heat transfer enhancement method relying on excitation of transverse secondary swirl flow. To validate this method, we numerically study the heat transfer and flow resistance characteristics of laminar flows in tubes with four-reverse-vortex-generator (FRVG) inserts, four-homodromous-vortex-generator (FHVG) inserts, or a twisted tape insert. The calculated transverse secondary flow in the tube with the FRVG inserts approximately follows the optimized flow pattern and the tube is thus found to have the best thermo-hydraulic performance, validating the proposed convective heat transfer enhancement method.

Convective heat transfer for laminar flows has been studied theoretically for the purpose of achieving maximum heat transfer enhancement effect at the constraint of constant pump work consumption. The objective function for heat transfer enhancement and the constraint function for external pump work consumption were derived, and the optimization equations for flow and temperature fields were established via the variation calculus method. The numerical solutions of the optimization equations showed that the optimized velocity field takes on a transverse secondary flow pattern of multiple vortexes with identical swirl direction at the junction of any two neighboring vortexes. Enlightened by these theoretical results, a novel convective heat transfer enhancement method for laminar flows was proposed, which relies on the excitation of transverse swirl flow. This secondary swirl flow consists of multiple vortexes and for a pair of neighboring vortexes the flow swirl directions are identical in the junction region. Numerical results corroborated that the tube with FRVG inserts has superior overall heat transfer performance over the tubes with FHVG inserts or a twisted tape insert in laminar flow regime.

Wen-Chieh Huang et al. [3]

Heat transfer enhancement of repeated ring-type ribs in circular tubes was experimentally investigated. Air, water and ethylene glycol–water solution (33.3% EG by vol.) were used as the working fluids. The rib height-to-tube inner diameter ratio (e/d) and rib pitch-to-tube inner diameter ratio (p/d) were arranged in the range of 0.025–0.069 and 0.29–5.8 respectively. The Reynolds number (Re) was in the range of 3601–26025 and the Prandtl number (Pr) was in the range of 0.7–15.6. The Nu value increases with the e/d value and it decreases with an increase of the p/d value. In addition, the Nu value increases with the Re value and it is proportional to the 0.45 power of the Pr value. The Nu enhancement index and mechanical energy consumption index were used to compare the heat transfer enhancing tubes to a smooth tube. At e/d 60.043, for achieving an effective heat transfer enhancement, the p/d value needs to be smaller than 4.35; at e/d P0.069, for avoiding a large pressure drop, the p/d value should be larger than 1.45.

Smita Agrawal et al.[4]

Agitation of air flow was produced inside a high-aspect-ratio rectangular channel by means of a transnational oscillating plate. So that the test simulates channel flow between fins of a heat sink for cooling of electronics, the channel was opened at one end, allowing oscillatory inflow and outflow at that end. At the other end where the roots of the fins that constitute the heat sink channel walls reside, there was a gap between the moving agitator plate and the channel base. Local heat transfer rates and velocity measurements were made within different regions of the channel. Heat transfer measurements were made on a channel wall augmented with cylindrical pin fins. They compared with equivalent measurement results taken on a smooth wall channel. An increase of 4–7%, based on total wetted area was found in the heat transfer coefficient, generally, when the pin fins are introduced. The change varies according to location within the channel, however. For instance, the heat transfer coefficient in the region near the base of the fins actually decreased 4–5% (again, based on total wetted area) when the pin fins were added. In this region, the flow passing through a tip gap between the agitator tip and the channel base wall, creates strong vorticity and high near-wall shear. These features of the flow were partially blocked by the pin fins, decreasing the effectiveness of the vorticity.

It was observed that:

- An increase of about 6–7% is found in the entry region based on the total wetted area when the heat transfer coefficient is compared with that of the plain wall case.
- An increase of about 3–4% in heat transfer coefficient is found in the central region in the presence of pin fins when the total wetted area is taken into account. This is attributed to greater mean velocity in the presence of pin fins in the central region.
- A decrease in heat transfer coefficient based on wetted area of about 5% is found in the base region (the region nearest the base of the channel) when pin fins are added.

Mohsen Sheikholeslami et al. [5]

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. Extensive literature review of various turbulators (coiled tubes, extended surfaces (fin, louvered strip, winglet), rough surfaces (Corrugated tube, Rib) and swirl flow devices such as twisted tape, conical ring, snail entry turbulators, vortex rings,coiled wire)for enhancing heat transfer in heat exchangers was carried out.

It was concluded that:

- 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.

- Delta winglets generate the vortexes which increase the heat transfer without much increase in friction factor in solar air heater or heat exchangers. Curved trapezoidal winglet delta winglet had the best thermo-hydraulic performance in fully turbulent flow region.
- Full length twisted tape increases the pressure drop comparing to an empty tube. Twisted tape in turbulent flow insert is not very effective.
- The helical ribs have a significant effect on the heat transfer and pressure drop augmentations. The pressure drop across the tube with helical rib is produced by drag forces, flow blockage, turbulence augmentation and rotational flow produced by the helical rib.
- Thermal performance factor increases with increasing number of perforated whole in conical ring.
- Wire coil gives better overall performance if the pressure drop penalty is considered. 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.
- Twisted tape inserts perform better in laminar flow. The other several passive techniques to enhance the heat transfer in a flow, such as ribs, conical nozzle, are generally more efficient in the turbulent flow than in the laminar flow.

Tabish Alam et al. [6]

In order to enhance the heat transfer rate to flowing air in the duct of solar air heater and heat exchangers various turbulence generators viz. ribs, baffles and delta winglets are considered as an effective technique. Investigators reported on various turbulators in literature for studying heat transfer and friction characteristics in a duct of solar air heaters and heat exchangers. An attempt has been made in this paper to carry out an extensive literature review of various turbulators investigated for enhancing heat transfer and friction in solar air heaters and heat exchangers. The correlations developed for heat transfer and friction factor in solar air heaters and heat exchangers by various investigators have been presented and reviewed.

An attempt was made to report heat transfer and friction characteristics of artificially roughened duct. The correlations for the heat transfer coefficient and the friction factor developed by various investigators for different geometries were reviewed and presented in the paper.

It was concluded that:

- It has been found that small element roughness geometries have been used in different arrangements by various investigators. Different arrangements include fixing of wires (transverse, angled, V-shape, multi V-shape, W-shape and discrete etc.), groove formation by machining process, expanded metal mesh ribs, metal grits and creating dimple shaped geometries.
- Transverse rib at different angle further enhances the heat transfer due to movement of vortices along the rib and formation of a secondary flow cell which results in high heat flow region near the leading end.
- It is found in the literature that perforated blocks/baffles are thermo-hydraulically better in comparison to solid blocks/baffles because perforation in blocks/baffles enhances the Nusselt number due to elimination of hot spot just behind the ribs.
- Delta winglets generate the vortexes which increase the heat transfer without much increase in friction factor in solar air heater or heat exchangers. Thus there is tremendous scope.

Tu Wenbin et al. [7]

Heat transfer performance and pressure drop tests were performed on a circular tube with small pipe inserts. These inserts with different spacer lengths (S = 100, 142.9 and 200 mm) and arc radii (R = 5, 10 and 15 mm) were tested at Reynolds numbers between 4000 and 18,000. Tap water was used as working fluid. The use of pipe inserts allowed for a high heat transfer coefficient with relatively low flow resistance. The Nusselt number and friction factor increase with the decrease in spacer length. Optimal results were obtained for S = 100 mm (R = 10 mm). Heat transfer rates and friction factors were enhanced by 2.09–2.67 and 1.59–1.85 times, respectively, to those in the plain tube. Performance evaluation criterion (PEC) values were approximately 1.79–2.17. The Nusselt number and friction factor increase with the decrease in arc radius. Small pipe inserts with R = 5 mm and S = 100 mm show maximal heat transfer rates of 2.61 –3.33 and friction factors of 1.6–1.8 times those of the empty tube. The PEC values were 2.23–2.7. Compared with other inserts, pipe inserts can transfer more heat for the same pumping power for their unique structure.

M.M.K. Bhuiya et al. [8]

The study explored the effects of the double counter twisted tapes on heat transfer and fluid friction characteristics in air flow in a heat exchanger tube. The double counter twisted tapes were used as counter-swirl flow generators in the test section. The experiments were performed with double counter twisted tapes of four different twist ratios (y = 1.95, 3.85, 5.92 and 7.75) using air as the testing fluid in a circular tube turbulent flow regime where the Reynolds number was varied from6950 to 50,050.

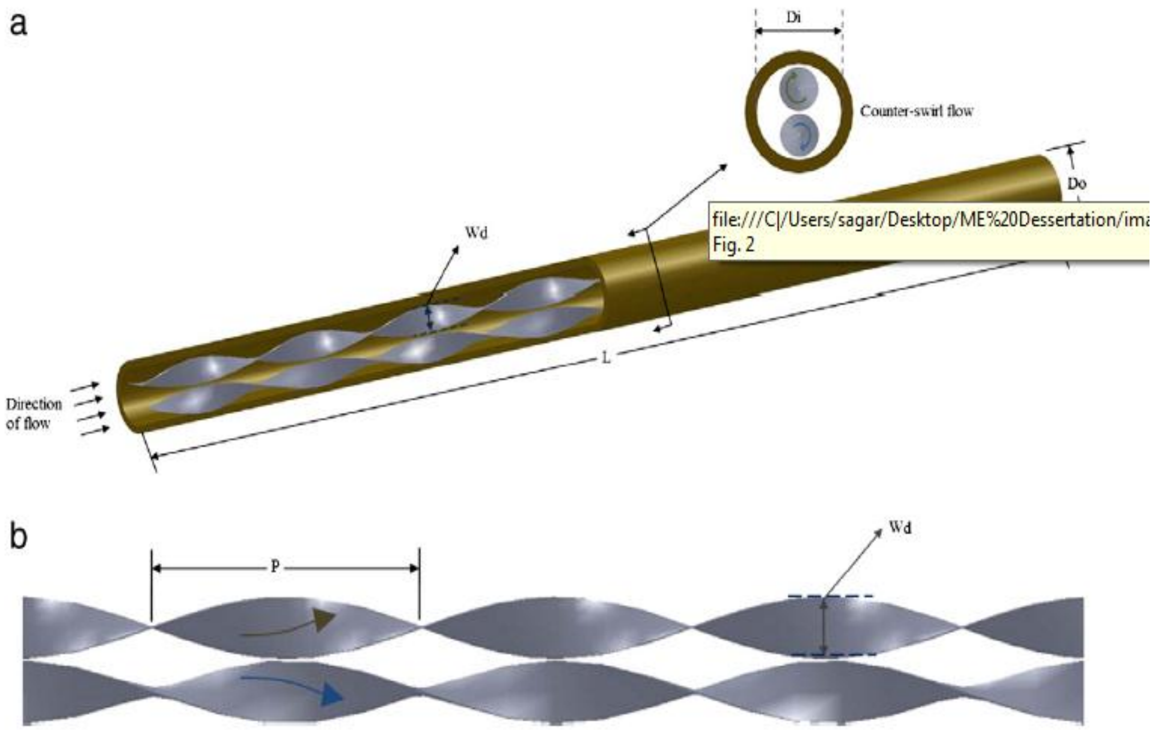

Fig.2.1[8]

a) Geometry of test section with double counter twisted tape insert

b) Geometric parameters of double counter twisted tape insert

The experimental results demonstrated that the Nusselt number, friction factor and thermal enhancement efficiency were increased with decreasing twist ratio. The results also revealed that the heat transfer rate in the tube fitted with double counter twisted tape was significantly increased with corresponding increase in pressure drop.

Based on the experimental results, the key findings of this study could be summarized as follows:

- The double counter twisted tape offered a significant enhancement of heat transfer, friction factor as well as thermal enhancement efficiency compared with the plain tube values.
- In general observations, it was found that the heat transfer, friction factor and thermal enhancement efficiency increased with decreasing twist ratio. Furthermore, the Nusselt number increased with the increasing Reynolds number while the opposite trends were found for the case of friction factor and thermal enhancement efficiency.
- The thermal enhancement efficiency for all the cases was more than one, which indicated that the effect of heat transfer enhancement due to the enhancing tool was more dominant than the effect of the rising friction factor and vice versa.
- The Nusselt number and friction factor for the tube with double counter twisted tape inserts obtained were 60 to 240% and 91 to 286% higher than those of the plain tube values at the comparable Reynolds number, respectively.
- The thermal enhancement efficiency in the tubes equipped with double counter twisted tapes at constant blower power was achieved to be around 1.01 to 1.34.

  Conclusions:

- [1] Wire - loop structures leads to substantial heat transfer augmentation. Thermal-hydraulic performance improves significant ally with increase in loop density.
- [2] Laminar forced convective heat transfer was studid with four reverse vortex generator(FRVG) Inserts and four -homogeneous-vortex-generator(FRVG) inserts. FRVG inserts have superior overall heat transfer performance over the tubes with FHVG inserts.
- [3]Repeated ring-type ribs in circular tubes can be used for heat transfer enhancement. The Nu valve increases with e/d valve and it decreases with increse in p/d valve
- [4] A transnational oscillating plate can be used to enhance heat transfer for air flow inside high- aspect- ratio rectangular channel.
- [5]Heat transfer co-efficient of coiled tubes with larger pitches are less than those of ones with smaller pitches; and the effect of pitch on Nusselt number is more visible in high temperature
- [6] Heat transfer rate in the duct of solar air heater can be increased by various trubulance generator Vi2. ribs, baffles, delta wing lets and wire loops.
- [7] Small pipe inserts can transfer more heat for the same pumping power for their unique structure.
- [9] Double counter twisted tape offere significant enhancement of heat transfer, friction factor as well as thermal enhancement efficiency compared with plain tube valves.

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