A REVIEW ON METHODS FOR HEAT TRANSFER ENHANCEMENT IN HEAT EXCHANGER

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ABSTRACT

This paper present a broad review of the various heat transfer enhancement techniques caused due to various specification rotors and swirl flow. Swirl flow has various applications in the area related to engineering field such as chemical industry, electric power, metallurgical industry, lighting industry, mixing and separation devices, turbo machinery, chemical reactors, combustion chambers. To enhance the heat and mass transfer, there is a need of the better utilization of swirl flow and selection of proper specification of rotors. The swirl flow can be generated by various techniques either by active or passive. It includes literature survey which provides various enhancement techniques in heat transfer using swirl flow and by inserting the rotor inside the tube.

***Keyword:* Enhanced Heat Transfer, Rotors, Heat Exchanger and Critical Velocity.**

I INTRODUCTION

The heat transfer enhancement plays a key role in improving energy efficiency and reducing heat exchanger size. For that purpose it is needed to increase the turbulence level. So more is the turbulence, more will be the heat diffusion causing augmentation in heat transfer rate. Heat transfer enhancement at heat exchangers may be achieved by numerous techniques, and these techniques can be classified into three groups: passive, active and compound techniques.

In the active techniques, heat transfer is improved by giving additional flow energy into the fluid. In the passive techniques, however, this improvement is acquired without giving any extra flow energy. In the compound techniques, two or more of the active or passive techniques may be utilized simultaneously to produce an enhancement that is much higher than the techniques operating separately. This paper contains literature survey which provides various enhancement techniques in heat transfer using swirl flow and tube inserted with rotors.

II.HEAT TRANSFER ENHANCEMENT TECHNIQUES

2.1 By Swirl Flow Methods

Ebru Kavak Akpinar et al [1], has studied the effect of heat transfer rates, friction factor and energy loss by applying the holes on the swirl generators. Various numbers of holes having different diameters were used. Hot air and cold water were passed through the inner pipe and annulus, respectively. Experiments were carried out for both parallel and counter flow models of the fluids at Reynolds numbers between 8500–17 500. Heat transfer, friction factor and energy analyses were made by comparing with and without swirl generators conditions. By giving rotation to the air with the help of swirl elements Nusslet number was increased upto130% at a value of about 2.9 times increase in the friction factor. With Swirl generators energy was found to be increased by 1.25 times as compared with that for inner pipe without swirl generators. After performing the experiment for both counter and parallel flow mode, results were compared to those obtained from the empty tube and Dittus–Boelter correlation *Nu* = 0.023*Re0.8Pr0.4* (describes non-swirling flow in the smooth-tube). The highest Nusselt number was achieved with the heat exchanger operated in a counter-flow mode and equipped by a swirl generator having 20 circular holes with 3 mm diameter. While the increase in the Nusselt number was 113% at swirl generator having 20 circular holes with 6 mm diameter, the increase was 109% at 9 mm diameter.

Betul Ayhan Sarac et al [2], had investigated heat transfer and pressure drop characteristics of a decaying swirl flow in a horizontal pipe. The decaying swirl flow was produced by the insertion of vortex generators with propeller-type geometry (fig1). The author for each position, effects of the vane angle about the core of the insert device and the number of the vanes attached circumferentially to the device on heat transfer and pressure drop were studied. Experiments were conducted at Reynolds numbers ranging from 5000 to 30,000. Depending on the Reynolds number, the position of the vortex generator, the angle and the number of the vanes, the Nusselt numbers were found to increase, which ranges from 18.1% to 163%. From the experimental results, it can be concluded as follows:

1. For the decaying swirl flow, the heat transfer and pressure drop decreases with the axial distance.
2. The inserts with six vanes resulted in more heat transfer values than those with four vanes.
3. The position of the insert in the axial direction had a considerable effect both on heat transfer and pressure drop.
4. Increasing the vane angle resulted in lower heat transfer and pressure drop results. This was attributed to the fact that an increase in the vane angle would increase the swirl period.

Fig1:The Propeller-Type Swirl Generator.

Gülşah Çakmak et al [3], the experiment was carried out by placing various injectors with various diameters on the entry of heat exchanger at different Reynold number .As shown in Fig 2 swirl element having diameter 6mm and 20 number of injector are placed with an angle 60° then heat transfer enhancement is increases.

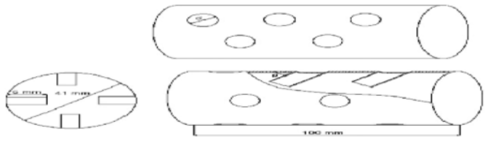

Fig 2: The Swirl Element with Triangle Arranged and 60° Angle.

M. Ahmadvand et al. [4] , had investigated the effects of axial vane swirler on heat transfer augmentation and fluid flow. Decaying swirling pipe flow was obtained by swirl generator which was installed at the inlet of the annular duct. Fig. 3 shows different blade angels of 30°, 45° and 60°. Reynolds numbers ranging from 10000 to 30000 when rate flow is to be adjusted . Experiment has been done when air was used as working fluid. Higher results were obtained by using vane swirler than the plane tube. Nusselt was found to be increase from 50% to 110% depending upon the blade angle. Simultaneously friction factor increased by the range of 90-500%.Thermal Performance was evaluated for test section and test section together with swirled. In both cases, dependency of thermal performance on vane angle and Re number was observed and it was seen that, thermal performance was increased as vane angle is increased and decreased by growth of *Re* number. When increasing the blade angle, higher decay rate has been observed for local Nusselt number. As compare to axial pipe flow, heat transfer coefficients were improved by using this swirler. It was found that, heat transfer enhancement was dependent on blade angle (or inlet swirl intensity) and *Re* has no significant influence. Heat transfer was enhancement between 50–110% depending on vane angle, while friction factor enhancement was between 90–500 . By raising the vane angle, heat transfer performance was increased for a particular Reynold number. Evaluated performances for test section, based on blade angle, have been obtained to be between 1.26–1.34, whereas for swirler in conjunction with test section it ranges from 0.95 to 1.02 at *Re* =10000. Results show enhanced local *Nu* decays along the pipe in such a way that higher decay rate is specified to larger blade angles.

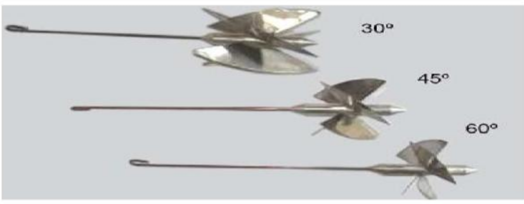

Fig3: Axial Guide Vane Swirler

A.E.Zohir et al. [5] aimed at studying the heat transfer characteristics and pressure drop for turbulent airflow in a sudden expansion pipe equipped with propeller type swirl generator or spiral spring with several pitch ratios. Fig 4 shows the spiral spring with different pitches and propeller. During experimentation Reynolds number was kept ranging from 7500 to 18,500 under a uniform heat flux. The experiments are also undertaken for three locations for the propeller fan (N = 15 blades and blade angle of 65_) and three pitch ratios for the spiral spring (P/D = 10, 15 and 20). The influences of using the propeller rotating freely and inserted spiral spring on heat transfer enhancement and pressure drop are reported. In the experiments, the swirl generator and spiral spring are used to create a swirl in the tube flow. Mean and relative mean Nusselt numbers are determined and compared with those obtained from other similar cases. The experimental results shows that,

The tube with the propeller inserts provides considerable improvement of the heat transfer rate over the plain tube. While for the tube with the spiral spring inserts, an improvement of the heat transfer rate over the plain tube around 1.37 times greater. Thus, because of the propeller location and the spiral spring pitch become increases the heat transfer enhancement. The pressure drop increases using the propeller and is found to be times and for spiral spring 1.5 times over the plain tube.

Fig 4: Spiral Spring with Different Pitches and Propeller Photos.

Clayton and Morsi [6], had investigated between two concentric stationary cylinders annulus formed. For measuring the time-mean parameters hot wire anemometry was used and turbulence components of the velocity components. Perspex bell-mouth was used to transport the vortex flow into a settling chamber in the swirling flow with as little disturbance as possible.

Algifri et al. [7] investigated the heat transfer in heated pipe for decaying swirl flow generated by radial blade cascade. The result is compaire with an expression proposed for predicting the heat transfer coefficient in swirling flow. The theoretical prediction is in good agreement with the experimental data, with average and maximum deviation of 7 and 11 percent respectively. The application of the theoretical approach to the experimental result obtained by other investigator for the heat transfer in decaying swirl flow generated by short –twisted tapes and tangential slots at inlet also give rise to encouraging agreement.

Kitoh [8] had investigated to obtain data about swirling flow through a pipe. A bellshaped cone at the centre of the swirler and radial swirl generator to deflect smoothly the radial flow into the axial direction

Yilmaz et al. [9] investigated the enhancement of heat transfer by turbulent decaying swirl flow generated by a radial guide vane swirler with conical deflecting element. The investigations in which radial swirl generators are used have been scant and have usually dealt with the flow characteristics, such as velocity, turbulence, shear stress, etc., and generally, a conical inserted centre body (deflecting element) has been used to deflect smoothly the radial flow into the axial direction in these investigations. An experimental setup was designed accordingly to investigate the effects of the geometry of the deflecting element in radial guide vane swirl generators on the heat transfer and friction characteristics in decaying swirl pipe flow. The swirl generators with conical deflecting element, with spherical deflecting element and with no deflecting element are three types of swirl generators that were used in the system.

2.2 By Inserting Rotors inside the Tube

Lin Guang-yi et al [10] had studied the effect of heat transfer rates by inserting the 19-100(means rotor outer diameter is 19 mm, lead is 100mm) and 19-400(means rotor outer diameter is 19 mm, lead is 400mm) in the heat exchanger.

After performing the experiment for both specifications result were compared to 19-400 specification rotors better than 19-100 specification rotors. When the water flow velocity is greater than the critical velocity , the heat transfer performance of tube inserted with 19-100 specification rotors which exists a critical velocity is better than smooth-tube. The rotation of different specification of rotors in the water, it can be seen that first part of rotor rotate gradually when the water flow rate gradually increases up to certain value.

Fig5: Shape of Rotor

Zhen Zhang et al [11] had investigated the heat transfer, friction factor and thermal performance factor characteristics of the circular tube fitted with Left-Right helical blade rotors. The effect of assembled mode between Left helical blade rotors and Right helical blade rotors on heat transfer enhancement performance of helical blade rotors also studied. From experimental result it can be conclude as follows:

1. The heat transfer enhancement performance of helical blade rotors was effectively improved by assembling the Left- Right helical blade rotors. The Nusselt number of the tube inserted with Left-Right helical blade rotors increased with decreasing numbers of Right helical blade rotors. Meanwhile, the enhanced tube with ratio Left-Right helical blade rotors(S) is 1/3 generated the higher thermal performance factor followed by enhanced tube with S=1 and then the enhanced tube with S=0.
2. The friction factor of the enhanced tube with number of Right helical blade rotors (Nr) =1 was higher than that of the enhanced tube with Nr =0, while with the friction factor of the enhanced tube with Nr =4 and Nr =8 were all smaller than that of the enhanced tube with Nr =0.
3. The thermal performance factor of Left-Right helical blade rotors increased with decreasing number of the Right helical blade rotors; at the same time ,the enhanced tube with S= 1/3 generated the highest thermal performance factor followed by the enhanced tube with S=1 and then the enhanced tube with S = 0

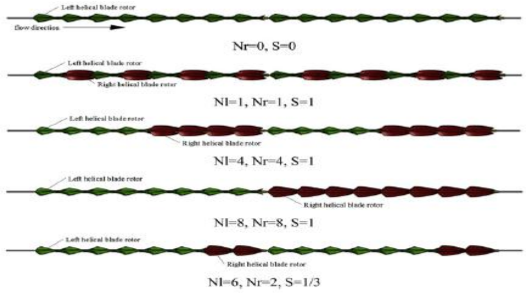

Fig6: Geometric Configuration and Assembled Mode of the Left Right Helical Blade Rotors

P.Sivashanmugam et al [12], had investigated heat transfer and friction factor characteristics of circular tube fitted with full-length helical screw inserts of different twist ratio, and increasing and decreasing order of twist set. The experimental data obtained were compared with those obtained from plain tube. The heat transfer coefficient and friction factor increases with twist ratio. There is no much change in magnitude of heat transfer coefficient enhancement with decreasing and increasing twist ratio. Fig 6 shows helical screw-tape with increasing twist ratio and decreasing twist ratio.

Fig 6(A): Helical Screw Insert Of Increasing Twist Ratio

Fig 6(B): Helical Screw Insert Of Decreasing Twist Ratio.

Zhen Zhang et al [13] has been conducted to study the heat transfer rate and friction factor characteristics of the tube fitted with rotors. Meanwhile, the rotor with ellipse section shape; for rotor with increasing rotor axis diameter and rotor with four blade numbers; generated higher Nusselt number, friction factor and thermal performance factor. The tangential velocity of the tube with helical blade rotors were significantly larger than plain tube, the tangential velocity of the tube inserted with rotors was significantly higher than radial velocity.

Li Feng –Xiang et al [14] had investigated heat transfer enhancement and flow friction in rotors-assembled strand inserted tube were measured using water as working fluids. The Prandal number of the working fluids varied from 5.64 to 5.80 and Reynolds number varied from 21,300 to 72,200.The tube inserted with rotors – assembled strand show remarkable improvement for heat transfer with Nusselt number increased by 9.764 to 11.87 % and overall heat transfer coefficient increased by 7.08 to 7.49 % within the range of Reynolds number from about 21,300 to 55,500.

Table 1: Shows A Various Result Of Swirl Flow In Heat Transfer Enhancement Techniques.

Ref Num.	Nusselt Number	Reynolds Number	Conclusion
1	Increases Up to 130%	8500 to 17,500	Heat transfer rate increases, when diameter of holes decreases and number of holes increases.
2	Increases Up to 163%	5000 to 30,000	Heat transfer rate increases, when vane angle decreases and number of vane increases.
3	Increases Up to 93%	10,000 to 21,000	Heat transfer rate increases when diameter and number of holes increases.
4	Increasing Up to 110%	10,000 to 30,000	Swirl intensity and thermal performance increases when angle increases
5	Increases up to 1.69	7500 to 18500	The heat transfer rate depend upon propeller location and spiral spring pitch

Table 2: Shows A Various Result Of Insertion Of Rotor Inside The Tube In Heat Transfer Enhancement Techniques.

Ref Num.	Types of Rotors	Conclusion
10	19-100 and 19-400 specification	Heat transfer rate of 19-400 better than 19-100 specification.
11	Left-Right helical blade rotors	Heat transfer rate and Nusselt number increases by decreasing number of right helical blade rotors.
12	Full-length helical screw of different twist	The transfer coefficient and friction factor increases with twist ratio.
13	Ellipse section rotors with increasing rotor axis diameter	Increases heat transfer rate and Nusselt number
14	Wire coil of different pitch	Prandal number varied from 5.64 to 5.80 and Reynolds number varied from 21,300 to 72,200.

III CONCLUSION

From this review, various ways of enhancing the heat transfer rate by generating the swirl flow and inserting the rotors inside the tube. It is seen that in most of the cases, enhancement in active method is more pronounced than passive method but simultaneously friction factor is also increased. A basic comparative study is provided above which gives an idea about the relation between the various governing parameters and heat transfer rate, friction factor and nusselt number.

Terminology:

N =Number of blades

P =Pitch of spiral spring

D =Diameter of spring

Nr =Number of right helical blade rotors

S = Ratio of Left-Right helical blade rotors number

REFERENCES

[1] Ebru Kavak Akpinar , Yasar Bicer (2004) "Investigation of heat transfer and energy loss in a concentric double pipe exchanger equipped with swirl generators". Int. J. Thermal Sciences 44 (2005) 598–607.

[2] Betul Ayhan Sarac, Tulin Bali (2007) "An experimental study on heat transfer and pressure drop characteristics of decaying swirl flow through a circular pipe with a vortex generator". Experimental Thermal and Fluid Science 32 (2007) 158–165.

[3] Gülşah Çakmak , Cengiz Yıldız (2007) "The influence of the injectors with flow generating on the heat transfer in the concentric heat exchanger". International Communications in Heat and Mass Transfer 34 (2007) 728–739.

[4] M. Ahmadvand A.F. Najafi · S. Shahidinejad, (2009) "An experimental study and CFD analysis towards heat transfer and fluid flow characteristics of decaying swirl pipe flow generated by axial vanes". Meccanica (2010) 45: 111– 129.

[5] A.E. Zohir a, A.A. Abdel Aziz b, M.A. Habib c, (2010) "Heat transfer characteristics in a sudden expansion pipe equipped with swirl generators". Int. J. Heat and Fluid Flow 32 (2011) 352–361.

[6] Clayton, B.R., Morsi, Y.S.M., 1984. "Determination of principal characteristics of turbulent swirling flow along annuli" . Int. J. Heat Fluid Flow 5 (4), 195–203.

[7] Algifri, A.H., Bhardwaj, R.K., Rao, Y.V.N., 1988. "Heat transfer in turbulent decaying swirl flow in a circular pipe". Int. J. Heat Mass Transfer 31 (8), 1563– 1568.

[8] Kito, O., 1984. "Axi-asymmetric character of turbulent swirling flow in a straight circular pipe" . Bull. JSME 27 (226), 683–690.

[9] Yilmaz, M., Çomakly´, O., Yapy´ cy´, S., 1999. "Enhancement of heat transfer by turbulent decaying swirl flow" .Energy Convers. Manage. 40, 1365–1376.

[10] Lin Guang-yi Zhang Xiao-hong Liu Ze Yang Wei-min, "Research on enhanced heat transfer characteristics in heat exchanger inserted with rotors",IEEE Shandong Provincial Key Laboratory Of Polymer Material Advanced Manufactorings Technology, 2011.

[11] Zheng Zhang et al, "Heat transfer enhancement in tube fitted with Left-Right helical blade rotors" Applied Thermal Engineering55 (2013)95-101.

[12] P.Sivashanmugam et al, "Experimental studies on heat transfer and friction factor characteristics of laminar flow through a circular tube fitted with helical screw-tape inserts", Applied Thermal Engineering26(2006)1990-1997.

[13]Zheng Zhang et al, "Numerical study on thermo- hydraulic charecteristic of turbulent flow in circular tube fitted with helical blade rotors" International Journal of Heat and Mass Transfer 60 (2013) 603-611.

[14]Li Feng-Xiang et al, "Laboratory investigation and commercial test for rotors-assembled strand applied in smooth tube" Experimental Thermal and Fluid Science 33(2008) 1-9.