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Review of heat transfer enhancement techniques

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ABSTRACT

Heat transfer is very important process used in the industries, especially in process industries where raw material is subjected to various processes so as to convert it into finished products.To achieve better heat transfer efficiency of heat exchanger, maximum heat transfer should be take place within the operating temperature range of the fluids in the heat exchanger. Researcher have made an effort to improve the heat transfer rate between two fluids. They have been developed various heat transfer enhancement techniques to improve the heat transfer rate by considering various factors which affects the heat transfer rate such as temperature, velocity of fluid, turbulence, surface area subjected to heat transfer, etc. These techniques can be classified as an active techniques and passive techniques.Active techniques are those who requires power supply for the operation while passive techniques are those who does not require any external power supply for the operation.This paper presents a review of various heat transfer enhancement techniques so that they can be chosen into the industry as per the requirement and according to their relative merits.

Keywords— *Heat transfer enhancement techniques, Active Techniques, Passive Techniques, Turbulence*

1. INTRODUCTION

In today's era industries are widely growing specially process industries such as sugar mills, dairies, pharmaceutical industries, food industries, etc. and other industries which are related to manufacturing and power generation. In all these mentioned industries heat is major form of energy used for energy conversion and recovery. In all the process industries, raw material must go through the heat transfer process so as to take the required product form. Optimum utilization of the cost and other available resources is one of the important aspects of industrial strategy. So, to achieve this optimization with respect to heat transfer process in the industries, the concept of Heat transfer technique turns into the reality. This refers to the achievement of maximum possible heat exchanger efficiency from the heat exchanger designed is of low cost and small size. From last few decades, a lot of research gets done on this concept and yet it is continuing now.

Basically, enhancement of heat transfer through heat exchanger between two fluids is done by increasing effective heat transfer area, residence time and decreasing thermal resistance to the heat transfer. Thermal resistance generates because of formation of laminar layer region due to fluid layers when fluid is moving through heat exchanger. This laminar layer region can be destroyed by creating swirl or turbulence inside the fluid flow. Researchers have been developed various heat transfer enhancement techniques by considering above factors along with other factors which affects the heat transfer process such as fluid velocity, temperature difference, pressure drop, etc. These techniques are classified as Active techniques, Passive techniques and Compound techniques respectively.

1.1 Active Techniques

Active techniques are those who require external power supply as a process input. Heat transfer enhancement by surface or fluid vibration, electrostatic fields or mechanical stirrers is referred as Active technique. Although the Active techniques sought massive attention in research, their practical applications have been very limited.

1.2 Passive Techniques

Passive techniques do not require any external power supply for the process. These techniques work within the heat exchanger. In passive techniques, heat transfer enhancement is achieved by extended surfaces such as fins so as to achieve the more heat transfer area, by providing rough surfaces and using tube inserts such as twisted tape and wire coil in order to create turbulence inside fluid flow. Swirl generation by winglets is also option here.

1.3 Compound Techniques

Compound technique uses combination of both active and passive techniques so as to obtain better effect than the individual one.

2. TWISTED TAPE AS A TUBE INSERTS

H. V. Chavan et al. (2017) carried out the experiment for simple tube heat exchanger and different twisted tapes of twist ratio 3.78, 3.89 and 4.22 respectively. Air is used as a fluid. Reynolds no. of air flow is varied from 5000 – 25000.Results shown that the maximum heat transfer is achieved for the twist ratio 3.78. Trends in the result also shown that both Nusselt number (Nu) and Friction factor (f) are increased with decrease in specified twist ratios. Nusselt number get increased with increase in Reynolds no.(Re) while friction factor gets decreased with increase in Re for all mentioned twist ratios (Fig 1 and 2). Both Nusselt no and friction factor increased as compared to plain tube heat exchanger.

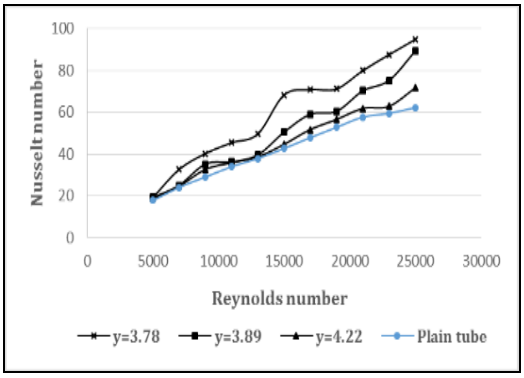

Fig. 1: Comparison Between Reynolds Number and Nusselt Number

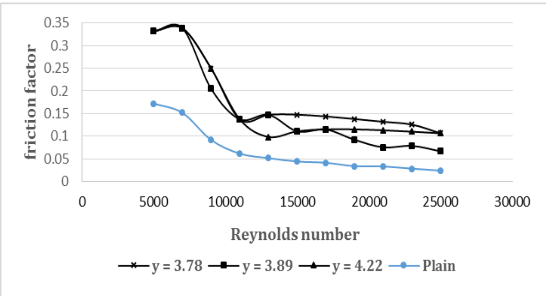

Fig. 2: Comparison Between Reynolds Number and Friction Factor

An experimental investigation was carried out by Bodius Salam et al. (2013) for a circular tube heat exchanger fitted with rectangular twisted tape insert (Fig. 3). Fluid used is a water and twisted tape of twist ratio 5.25 is used. Reynolds number varied from 10000 – 19000 and heat flux is varied from 14 – 22 KW/m^2 for plain tube and 23 -40 KW/m^2 for the tube fitted with twisted tape insert. Results shown that the Nusselt numbers for the tube fitted with rectangular twisted tape were enhanced by 2.3 to 2.9 times as compared to plain tube. At the same time, friction factor also increased by 1.4 to 1.8 times of plain tube. Heat transfer enhancement efficiency also increased with increase in Reynolds number.

Fig. 3: Twisted Tape

3. WIRE MATRIX AS A TUBE INSERTS

J. M. Ritchie et al. (2007) used wire coil matrix as a tube insert so as to avoid adverse effect of fouling on heat transfer devices in the crude oil industries. This experimentation with wire coil matrix also lead to the better heat transfer enhancement. Wire coil matrix used in this experiment continually mixes the fluid in tube wall region with the bulk flow region. This cause destruction of laminar boundary layer near the tube wall surfaces and ultimately improves the heat transfer rate. As the laminar boundary layer is destructed, both biological and chemical fouling get reduced.

4. USING NANO FLUIDS

Shanmuga Sundaram et al. (2014) used Nano fluids for thermal enhancement. The reason behind for using Nano fluids was to develop new method to argument synthesis method. From this experiment they found that the size of Nano particles plays an important role to improve heat transfer properties. The dispersion behaviour of Nano Particles enhances, if the Nano particles can be prevented from agglomeration using appropriate surfactants. Dinda Anggara Firlianda et al. (2019) did research on the effect of adding MnFe2O4 nanoparticles to ethylene glycol base fluid. The results of the research can be summarized into several points such as

(a) The effect of increasing the concentration of MnFe2O4 nanoparticles on thermophysical properties of nanofluid has increased and
(b) The addition of a concentration of nanoparticles of 0.075% has the best thermophysical properties.

On the application of Nano fluid on a shell and tube type heat exchanger working system, heat transfer analysis is carried out by using the LMTD method. The calculation of heat transfer characteristics can increase in dimensionless numbers which include Prandtl, Reynolds, and Nusselt along with the addition of MnFe2O4 Nanoparticles. The results of heat transfer analysis by using the LMTD method, it indicates an increase in the heat transfer value that occurs in a heat exchanger. The greatest heat transfer is obtained by using Nanofluid with the addition of nanoparticle concentration MnFe2O4 of 0.075%

In calculating the type of heating value of the nanofluid at Fig. 5, the results are inversely proportional to the viscosity and density, where the occurrence of type of heat decreases along with the addition of nanoparticles. The largest type of heating value is at the concentration of 0.025%, which is equal to 2347.775 J/kg°C, while the smallest heating value is found at a concentration of 0.075%, which is equal to 2271,325 J/kg°C.

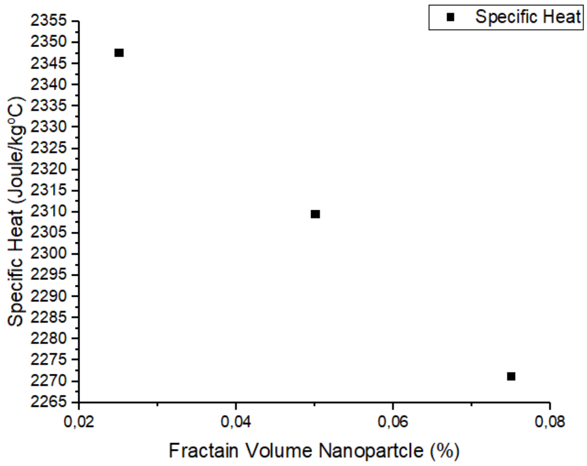

Fig. 4: Graph on the effect of adding nanoparticles on the heat of Nano fluid types

5. USING COILED WIRE INSERTS

Garcia et al. (2007) found that coiled wire inserts increase the disturbance of laminar boundary layer and redevelop the thermal and hydrodynamic boundary layers in the tube flow effectively. Also in helically coiled wire can be used to generate secondary flow which helps to enhance the heat transfer rate. Advantages of Coiled Wire Inserts:

- Easy manufacturing and installation
- Lower manufacturing cost

Better fluid mixing and disturbance of laminar boundary layer.

Fig. 5: Coiled Wire Insert

6. USING HELICAL SCREW INSERTS

Sivashanmugam and Suresh, 2007 used the full-length helical inserts with different twist ratios, with equal and unequal lengths with right and left turns. Their experiments showed that the helical tape insert improves the heat transfer compared to a plain tube and the TPF with right-left helical insert could be obtained and up to 3 for different configurations.

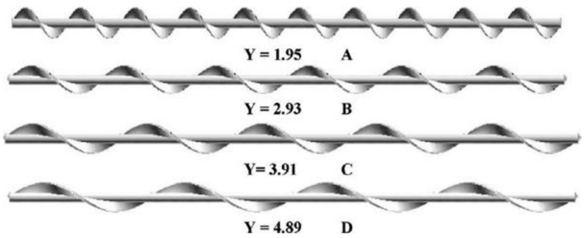

Fig. 6: Helical screw inserts of different twist ratio

7. CONCLUSION

This review consists of important investigations on the heat transfer enhance techniques like twisted tape, wire matrix, Nano Fluids, Coiled wire inserts, Helical Screw Inserts. In conclusion, the following statements can be generalized as a result of this review study:

- Twisted tape inserts generally show better performance in laminar flow region. Twisted tape inserts cause high-pressure drop penalty in turbulent region so they are not good at enhancing thermo-hydraulic performance.
- In Wire Matrix, due to brush like structure restriction of laminar boundary layer near the tube wall surfaces takes place and ultimately improves the heat transfer rate with fouling reduction.
- The heat transfer rate of the Nano fluid was approximately 14% greater than that of pure water. They also showed that the convective heat transfer coefficients of the Nano fluids and water increased with increasing of the mass flow rate
- Coiled wire shows better performance to create swirl flow inside the tube. Coiled wire inserts have the ability to destruct the laminar boundary layer.
- Helical tape insert also improves the heat transfer compared to a plain tube

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