A Review on Performance Characteristics of Heat Exchanger with Twisted Tape Inserts and Nano Fluids

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Abstract--- Heat transfer enhancement techniques are widely used in various applications such as air conditioning, chemical reactors and refrigeration systems. Therefore several techniques have been promoted to enhance heat transfer rate and to decrease the size and cost of equipment especially the heat exchangers. One of the main tools used in passive heat transfer to create turbulence flow is with the help of twisted tape inserts. The current paper investigates about the different types of twisted tape inserts used in shell and tube heat exchanger in the recent years are studied at the turbulent zone and also about the overall enhancement ratio.

Keywords--- Twist Ratio, Heat Transfer Coefficient, Nano-fluids and Particles.

I. INTRODUCTION

Heat exchangers are used in various applications for the effective transfer of heat from one material to another material. The widely used heat exchanger is Shell and tube type which is generally employed in field of heat transfer technology. Baffles are commonly used in shell and tube heat exchanger. But it has its own drawbacks such as fouling resistance, pressure drop and vibration failure caused by turbulent flow. The pumping power is the main parameter which decides the enhancement ratio. Hence one has a wide chance of selecting the best twisted tape which has a good overall enhancement ratio.

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II. TT INSERTS

Among the swirl flow devices, twisted tape inserts are the best one to create a swirl because of their good thermal performance. It has its wide range of application like boilers etc because it is easy to manufacture and implement them. To study the about the characteristics of TTs, we have to study about some important parameters. They are:

- Reynolds number (Re).
- Pitch (H).
- Twist ratio (Y).
- Number of revolutions (Ne).

TTs are widely used to transfer heat at a faster rate by swirling the flow, which makes the fluid mixing, helically twisting around the tube and increase in velocity. The flow creates a turbulence by mixing all the stream flow lines which leads to heat convection and more tangential velocity near at the tube walls. This simple swirl flow is created at lesser reynolds number or at a big twist ratio or the inverse. The fin effect also increases the heat transfer by heat conduction at tapes body. The materials used for TT are:

- Carbon steel.
- Aluminium.
- Stainless steel.
- Copper.

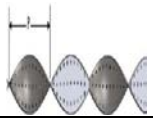
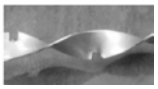
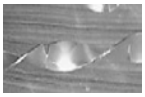
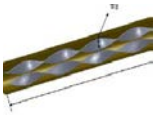
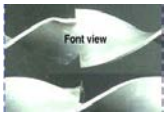
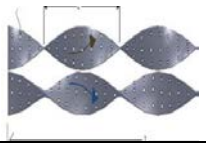
The method of installing TT is quite simple by passing it inside the tube gently without any damage. The clearance between the wall of the tube and the TT

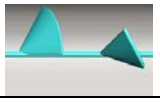
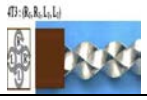
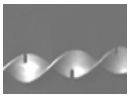
should be in the range of 0.3 to 0.5mm. The industrial application TT has 10 to 20mm width and 0.5 to 1.5mm thick. TT can be made in many ways. One such way is by holding one side of the tape in a fixed fixture and the other side is holded by a rotating device. When the device rotates at a very low rpm, the sheet turns into a twisted tape. The sheet is turned until the required twist ratio is achieved.

III. THE HEAT TRANSFER ENHANCEMENT

One of the important definition parameters usually used in heat transfer augmentation is the overall heat transfer enhancement ratio to estimate the performance the different configurations of heat exchangers. This parameter involves the Nusselt number as heat transfer coefficient and the friction factor as pumping power or pressure drop as a parameter. For a particular fluid flow, with the help of a TT, if the heat exchanger can give good heat transfer coefficient, the enhancement ratio of this heat exchanger is estimated as a good one. For definition of this parameter it is mandatory to define about some pre equations. Also the comparison between swirl flow in the tube with TT and straight flow is usually made by comparing heat transfer coefficients at identical pumping power, since this is relevant to the operation cost.

Table 1: Experimental Analysis of Heat Exchanger with Twisted Tape Inserts

Author & Inserts Name	Twisted Tape	Re Number	Nusselt Number	Friction Factor	Thermal Performance Factor
M.M.K.Bhuiya [1] Perforated		7200-49800	110 -340% >Plain tube	110 - 360% >Plain tube	28-59 % >Plain tube
A. Hasanpour [2] U cut & V cut		5000-13000	1.2	0.8	-
		5000-15000	1.4	1.3	-
M.M.K.Bhuiya [4] Double counter		6950-50050	60 – 240% >Plain tube	91 – 286% >Plain tube	34 % >Plain tube
M. Farhadi [5] Delta wing		3000- 27000	1.6	1.5	1.1
M.S.U. Chowdhury [6] Triple tapes		7200-50200	3.85 times >Plain tube	4.2 times>Plain tube	1.44
A.K. Azad [7] Perforated double counter		7200-50000	80 – 290%> Plain tube	111 –335% >Plain tube	1.08 – 1.44
M.Kh.Abdolbaqi [9] Twin twisted		7200-32400	-15 to 15%	-10 to 10%	61% >Plain tube

Smith Eiamsa-Ard [10] Counter clockwise		3000- 27000	9 – 11 %	23 – 26 %	1.4
Mahdi Pourramezan [11] Conical strip		-	3.5 times>Plain tube	25 times>Plain tube	-
Pongjet Promvonge [12] Quadruple Vfinned		4000- 30000	1.86 – 2.26	3.44 – 3.51	1.75
Murugesan [13] Square cut		2000- 12000	2.3 – 2.9	1.25	1.06
Eiamsa-ard [14] Central wing and alternate axis		5200- 22000	17.7% to wing	1.31	1.4

IV. NANO FLUIDS

Nano fluids are the one which contains nano particles, which are in the size of a nanometer. It was first discovered by Sir Stephan Choi in 1995. The nano particles are mixed or colloided in a base fluid to obtain the nano fluid. The common base fluids used are water, ethylene glycol and oil. These nano fluids have various engineering applications such as coolant in automobiles, fuel cells, pharmaceutical process, heat exchanger, domestic refrigerator, grinding machine. In the recent years, many researchers have been done on nano fluids in the domain of heat exchanger. They use the nano fluids as a fluid to make the heat transfer process quicker. The nano fluids exhibit excellent thermal conductivity and good convective heat transfer coefficient compared with the base fluid and so they replace the conventional base fluids. The heat transfer is increased by increasing the concentration of the nano particles in the base fluid. The common used nano fluids are Al_2O_3, CuO, Fe_3O_4, Fe_2O_3, SiO_2, TiO_2, Ag, Cu, ZnO, SiC, nano-diamond, graphite, and carbon nano tubes.

V. PREPARATION OF NANO FLUID

The nano particles can be synthesized in many ways:

- Direct evaporation
- Gas condensation/dispersion
- Chemical vapour condensation

The commonly used method is the direct dispersion of nano particle in the base fluid. The average size of the particle is decided (approx.20-25nm) and they are broken by using the ultrasonic vibrator for 6-8 hours to make stabilization of particles. Then the chemical compositions are checked for the proper mixture. Each time a nano fluid is used, its density and nano particle dispersion is checked using TEM and SEM. Several researchers use different type of nano particle which exhibits various properties that helps in the enhancement of heat transfer. All the experiments use water as the base fluid in which they are dispersed. Also, the modern papers show that hybrid varieties of nano fluids are prepared by mixing two or more nano particle in a calculated proportion.

Table 2: Properties of Nano-fluids Used

Nano fluid name	Nano particle size (nm)	Density (kg/m3)	Specific heat (J/Kg K)	Thermal conductivity (W/mK)
Al_2O_3[15]	>50	3970	525	17.65
Fe_2O_3[17]	40	4845.4	4179	0.631
SiO_2[19]	30	2220	745	1.4
TiO_2[19]	50	4175	692	8.4
CuO [20]	30-50	89.33	385	400
ZnO[21]	>100	5610	-	50
Ethylene glycol[22]	150	1030	3.90	0.512

VI. PERFORMANCE ANALYSIS OF HEAT EXCHANGER USING NANO FLUIDS

The author P.V. Durga Prasad and K. Deepak used Al_2O_3as a nano fluid in their experiment and observed that 34.24% increase in nusselt number and 1.29 times increase in friction factor at 0.03% volume concentration when compared with water[15]. Another authors E.Esmaeilzadeh, H. Almohammadi, A. Nokhosteen, A. Motezaker, A.N. Omrani made a comparative study on the heat transfer enhancement by varying the thickness of the twisted plates using Al_2O_3. It is found thatthe convective heat transfer ishigher for the maximum thickness (2mm) and also for the higher volume concentration [16]. The authors Mohammad Hossein Aghabozorg, Alimorad Rashidi, Saber Mohammad used Fe_2O_3as their nanofluid and showed a higher heat transfer of 27.69% at 0.1 volume concentrations and 37.50% at 0.2 volume concentration comparing with the base fluid [17]. Another authors L. SyamSundar, Antonio C.M. Sousa, Manoj K. Singh used Fe_3O_4 and gave the comparative results of friction factor increased by 50.99% at Re=22000at 0.3% volume concentration [18]. The authors W.H.Azmi, K.V.Sharma, Rizalman Mamat used two nano fluids. SiO_2 gave 27.9% higher heat transfer coefficient at 3% volume concentration compared with water while TiO_2 gave 11.4% higher heat transfer coefficient at 3% concentration compared with water [19]. The authors Khwanchit Wongcharee and Smith Eiamsa-ard used CuO where he found increased heat transfer rate 2.67 times and friction factor 5.76 times than the normal tube at 0.7% volume concentration withtwist ratio 2.7 at Re = 6200 [20]. The author I.M. Shahrul, I.M. Mahbubul, R. Saidurmade, madea comparative study between Al_2O_3, SiO_2 and ZnO. The highest heat transfer rate was found with ZnO around 35% than the other fluids [21]. V. Kumaresan, R. Velraj and Sarit K. Das used ethylene glycol and showed a increase of maximum 160% in heat transfer coefficient for 0.45% volume concentration MWCNT [22]. A special type of nano fluid named nitrogen-doped, graphene based nano fluid was used by Marjan Goodarzi, Masoud Afrand, Emad Sadeghinezhad, Somchai Wongwises, M. Dahari. The NDG was made in a aqueous solution of 0.025 wt,% Triton X100 as a surfactant. They showed 15.86% increase in convective heat transfer coefficient than water at 0.06% weight concentration [23]. A hybrid variety of nano-fluid was proposed by H.R. Allahyar, F. Hormozi, B. Zare Nezhad. It contains 97.5% alumina and 2.5% Ag. The maximum heat transfer is obtained 31.58% higher than the distilled water at 0.4% volume concentration [24].The authors R. Dharmalingam, K.K. Sivagnana prabhu and B. Senthil kumar experimented with Al_2O_3 and silver in the solar flat plate collectors to enhance the heat transfer rate and obtained a maximum efficieny of 78.6% with volume concentration of 0.04% [25] [26].

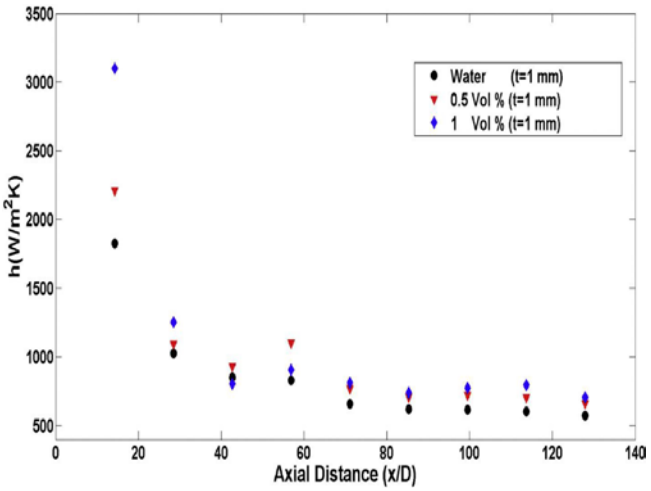


Fig 1: Graphical Representation Axial Distance (vs) Heat Transfer Coefficient

The above graph gives a graphical representation of heat transfer vs axial distance using Al_2O_3as a nano fluid done by E. Esmaeilzadeh [14]. It clearly shows that the heat transfer rate increases for nano fluid than normal water and also at higher volume concentrations.

VII. RESULTS

Thus the twisted tape inserts and nano-fluids plays a important role in heat exchanger for the effective transfer of heat from one fluid to other one with the aid of different

structures of twisted tapes inserts and different nano fluids available. The researcher is free to choose any kind of nano fluid based on their need, cost, and applications. With the use of twisted tape inserts and nano fluids in a normal heat exchanger, we can:

- Enhance the convective heat transfer coefficient, h.
- Increase the friction factor, f.
- Increase the Nusselt number, Nu.
- Reduction in pressure drop, P.

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