A REVIEW ON PERFORMANCE CHARACTERISTICS OF HEAT EXCHANGER WITH CORRUGATED TYPE TUBE AND NANO FLUIDS

B. Senthil Kumar#1, R.Gokulprasath#2, N.Jenu Rooban#3 and R.Kavin Krishna#4

#1 Associate Professor, Sri Ramakrishna Engineering College,
#2, #3, #4 Sri Ramakrishna Engineering College,

ABSTRACT
Heat transfer enhancement techniques are widely used in the applications of air conditioning, refrigeration, Power stations, Radiators and chemical reactors. Therefore several techniques have been used to enhance the heat transfer rate in order to increase the efficiency of the heat exchanger. One of the main tools used in heat exchanger to create turbulence flow with the help of corrugated tubes. The current paper investigates about the different arrangements of corrugated tubes used in tube heat exchangers in the recent years are studied at the turbulence zone and also the overall enhancement ratio.

KEYWORDS: Heat transfer, Corrugated tube, Nano fluids, Nusselt number, Friction Factor, Reynolds number.

Corresponding author: B. Senthilkumar

1. INTRODUCTION
In thermal engineering systems heat exchangers plays a major role to transfer heat from solid body to fluid or between fluids. The applications such as chemical processing industries, thermal power plants, radiators, air conditioning systems, etc… are widely depends upon the heat exchangers to have a better efficiency. Traditional heat exchanger coolants have poor properties of heat transfer coefficient and also low thermal conductivity. This heat transfer mainly depends upon the (1).the types of tube used (2).the types of fluid used (3).the material of tube used. In another words, the thermal conductivity is also depends upon the turbulence level of the flowing fluid so that corrugated tubes can be used to increase the turbulence level of the flowing fluid as a result in increase in convective heat transfer coefficient. Polymer based corrugated heat exchanger over metallic based corrugated tube heat exchanger can be used to enhance the property of anticorrosion and life. And also polymers are good insulators and has more chemical resistance and more durable. The major disadvantage is low thermal conductivity of 0.3 to 0.5 W/mk while the other materials stainless steel has 16W/mk and aluminium has 205W/mk [1]. By adding carbon nanotubes (CNT), and reducing the wall thickness we can increase the thermal conductivity. Some researches have reported that addition of CNT increases the thermal conductivity upto 14-53 W/mk [2]. Usage of Nano fluids as coolant fluid can also increases the convective heat transfer coefficient.

2. CORRUGATED TUBES
Among the turbulent flow devices, the corrugated tubes are the best one to create turbulent flow because of their geometrical arrangements. It has its wide applications in heat regenerators. To study the characteristics of corrugated tubes, the following parameters are should be known,
- Reynolds number (Re)
- Corrugation angle (θ)
- Corrugation height (H)
- Pitch (P)

Corrugated tubes are widely used to transfer heat at a faster rate by turbulent flow, which makes the fluid mixing. 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. The higher Reynolds number is created to produce more turbulent flow. The corrugation height effect also increases the heat transfer by heat conduction. The materials used for Corrugated tubes are
- Mild steel
- Aluminium[3]
- Stainless steel
- Copper

This includes the implementation in double pipe heat exchangers with counter flow applications. This paper investigates, in double pipe heat exchangers the inner pipe be as corrugated tube or outer pipe as corrugated tube or both the pipes are corrugated tubes. The thickness of the pipe may varies from 0.1mm to 10mm. The required corrugated geometry can be achieved by special machines.

2.1 THE HEAT TRANSFER ENHANCEMENT

Heat transfer enhancing is the important techniques to increase the effectiveness of the heat exchanger. The following methods can be used to enhance the heat transfer,

- Use of secondary heat surface area.
- Promoting boundary layer separation
- Introducing secondary flows (swirl flow)
- Increasing the turbulence level of the fluid
- Promoting counter flow in heat exchangers
- Increasing the effective length of heat exchangers
- Optimizing the friction factor[4]
- More pressure drop causes high heat transfer rate.
- Using nano fluids as working fluid[5]

3. 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 researches 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 Al₂O₃, CuO, Fe₃O₄, Fe₂O₃, SiO₂, TiO₂, Ag, Cu, ZnO, SiC, nano-diamond, graphite, and carbon nano tubes.
3.1 PREPARATION OF NANO FLUID

Preparing of Nano-fluids is the most important part in analysis of heat transfer setup. Nano-fluids is prepared by any of these two ways,

(i) one step method
(ii) two step method.

There are two techniques to prepare Nano fluids (two steps and single step[6]). Those techniques have been implemented by using different types of physical(PVD) and chemical(CVD) methods to ensure that the mixture remains in stability. The two steps of method have been conducted by synthesizing Nano powders, and then dispersed to liquid.

In single step method, the nanoparticles are prepared and suspended to the basefluids [7]. Modern nanofabrication technologies give great opportunities to produce materials at nanometre scale (nanoparticles). Generally, nanoparticles are available in the powder form with higher thermal conductivities than conventional fluids. Nanoparticles materials usually used in the preparation of Nano fluids are made of metals, oxides or carbides Das et al. [8]. Nano fluids are prepared by dispersing nanoparticles with average sizes less than 100 nm in base fluids such as water, ethylene glycol or oil. Nano fluids must be stable suspensions with no particles agglomeration and no chemical reaction. Nano fluids can be prepared by using two-step or single-step method Wang and Mujumdar[9]. In two-step method, nanoparticles (nanopowder) are produced then nanoparticles are dispersed in the basefluids using ultrasonic equipment Wang and Mujumdar [10]. The limitations of this technique are the clustering and sedimentations of nanoparticles in a base fluid. The single-step method combines the fabrication of nanoparticles and the preparation of nanofluids into one step. A direct evaporation single-step method is one of the common techniques. In this technique, the nanofluid is prepared by condensing nanoparticles vapor in a low-vapor-pressure-base fluids Eastman et al. [11]. The advantages of single-step method are to minimize the agglomeration of nanoparticles and prevent oxidation of nanoparticles. However, two-step method is preferred due to its low cost, therefore, it is appropriate for large-scale Nano fluids production. The two-step method is used to prepare Nano fluids in most of previous experimental studies. Nano fluids are prepared by suspended TiO2 nanoparticles in water by using ultrasonically equipment based on the two-step method by a number of investigators [12–16].

4. LITERATURE REVIEW

Table 1: Experimental analysis of heat exchanger with corrugated tubes comparing to plain tubes

<table>
<thead>
<tr>
<th>AUTHOR &amp; CORRUGATED TYPE</th>
<th>CORRUGATED TUBES</th>
<th>Re NUMBER</th>
<th>NUSSELT NUMBER</th>
<th>FRICTION FACTOR</th>
<th>HEAT TRANSFER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hamedsadighidizaji[17] &amp; Concave and convex</td>
<td>3500 – 18,000</td>
<td>15 – 110%</td>
<td>150 – 250%</td>
<td>26 – 38%</td>
<td></td>
</tr>
<tr>
<td>H. Pehlivan[18] &amp; Corrugated Channel</td>
<td>4000 – 7400</td>
<td>-</td>
<td>-</td>
<td>16 – 22%</td>
<td></td>
</tr>
</tbody>
</table>
Table 2: Properties of nano-fluids used

<table>
<thead>
<tr>
<th>Nano fluid name</th>
<th>Nano particle size (nm)</th>
<th>Density (kg/m3)</th>
<th>Specific heat (J/Kg K)</th>
<th>Thermal conductivity (W/mK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al₂O₃[24]</td>
<td>&gt;50</td>
<td>3970</td>
<td>525</td>
<td>17.65</td>
</tr>
<tr>
<td>Fe₂O₃[25]</td>
<td>40</td>
<td>4845.4</td>
<td>4179</td>
<td>0.631</td>
</tr>
<tr>
<td>SiO₂[26]</td>
<td>30</td>
<td>2220</td>
<td>745</td>
<td>1.4</td>
</tr>
<tr>
<td>TiO₂[27]</td>
<td>50</td>
<td>4175</td>
<td>692</td>
<td>8.4</td>
</tr>
<tr>
<td>CuO [28]</td>
<td>30-50</td>
<td>89.33</td>
<td>385</td>
<td>400</td>
</tr>
<tr>
<td>ZnO[29]</td>
<td>&gt;100</td>
<td>5610</td>
<td>-</td>
<td>50</td>
</tr>
<tr>
<td>Ethylene glycol[30]</td>
<td>150</td>
<td>1030</td>
<td>3.90</td>
<td>0.512</td>
</tr>
</tbody>
</table>

4.1 PERFORMANCE ANALYSIS OF HEAT EXCHANGER USING NANO FLUIDS

The author P.V.Durga Prasad and K.Deepak used Al₂O₃ as 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[24]. 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$_2$O$_3$. It is found that the convective heat transfer is higher for the maximum thickness (2mm) and also for the higher volume concentration [25]. The authors Mohammad Hossein Aghabozorg, Alimorad Rashidi, Saber Mohammad used Fe$_2$O$_3$ as their nanofluid and showed a higher heat transfer of 27.69% at 0.1 volume concentration and 37.50% at 0.2 volume concentration comparing with the base fluid [26]. Another authors L. Syam Sundar, Antonio C.M. Sousa, Manoj K. Singh used Fe$_3$O$_4$ and gave the comparative results of friction factor increased by 50.99% at Re=22000 at 0.3% volume concentration [27]. 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 [28]. 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 with twist ratio 2.7 at Re = 6200 [29]. The author I.M. Shahrul, I.M. Mahbubul, R. Saidurmade, made a comparative study between Al$_2$O$_3$, SiO$_2$ and ZnO. The highest heat transfer rate was found with ZnO around 35% than the other fluids [30]. 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 of MWCNT [31]. 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 [32]. 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 [33]. The authors R. Dharmalingam, K.K. Sivagananprabhu and B. Senthilkumar experimented with Al$_2$O$_3$ and silver in the solar flat plate collectors to enhance the heat transfer rate and obtained a maximum efficiency of 78.6% with volume concentration of 0.04% [34] [35].

The above graph gives a graphical representation of heat transfer vs axial distance using Al$_2$O$_3$ as a nano fluid done by E. Esmaeilzadeh. It clearly shows that the heat transfer rate increases for nano fluid than normal water and also at higher volume concentrations.
5. RESULT

In this review paper we clearly found that the maximum heat transfer occurs when both tubes are corrugated made up of aluminium strip. Then heat transfer is increased by 65 – 90 % and nusselt number increased by 55 – 90 %[19]. And also when the nano fluids are used as a working fluid the heat transfer also gets increasing , When ethylene glycol is used as a working fluid the heat transfer is increased by 160% in heat transfer coefficient for 0.45% volume concentration[31].

6. CONCLUSION

Thus the corrugated tube 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 corrugated and different nano fluids available. The researcher is free to choose any kind of nano fluid based on their need, cost, applications. With the use of corrugated 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

7. REFERENCES


