



# Performance Evaluation of Double Pipe Heat Exchanger Having Different Shape Grooves on Inner Tube Cross Section with Al<sub>2</sub>O<sub>3</sub>/Water Nano Fluid

<sup>1</sup>Pratik Tiwari, <sup>2</sup>R. C Gupta,

<sup>1</sup>Research Scholar, Department of Mechanical Engineering, JEC Jabalpur,

<sup>2</sup>Professor, Department of Mechanical Engineering, JEC Jabalpur,

## **Abstract:**

The growing need to create and improve the performance of heat exchangers has given rise to number of studies aimed at enhancing heat transfer rate while reducing the size and cost of industrial equipment. The double pipe heat exchanger is one of the many equipment utilised in various industries. Because of its simplicity and wide range of applications, this form of heat exchanger has gotten a lot of attention. Several precise and useful investigations in twin pipe heat exchangers have been conducted in recent years. The development process for this type of heat exchanger has been thoroughly examined in this review, as well as the heat transfer improvement methods used in the aforementioned heat exchangers. Furthermore, several studies involving the use of nanofluids in double pipe heat exchangers have been thoroughly reviewed.

## **Introduction:**

Nowadays, heat exchangers are widely used in industrial and engineering applications. It is believed that coming up with design of an efficient heat exchanger is quite complicated for engineers. The reason towards that is not only an accurate assessment of the long-term performance and the regarding financial costs is needed, but a comprehensive investigation of heat transfer, pressure drop and the effectiveness which cannot be neglect which require a lot of work. Upon using heat transfer enhancement methods, pressure drop will also be increased which results in a higher pumping power. So, it is firmly stated that some of these heat transfer enhancement methods may just adversely affect the need to an optimum case containing the heat transfer rate and pressure drop. As a result, choosing the methods wisely is of great importance. It is also believed that having a high and appropriate heat transfer rate in devices such as computers, electric power systems, automobile engines and other numerous examples .

One of the most simple and applicable heat exchangers is double pipe heat exchanger (DPHE) (Fig. 1). This kind of heat exchanger is widely used in chemical, food, oil and gas industries. Upon having a relatively small diameter, many precise researches have also held firmly the belief that this type of heat exchanger is used in high-pressure applications. They are also of great importance where a wide range of temperature is needed. It is also well documented that this kind of heat exchanger makes a significant contribution to pasteurizing, reheating, preheating, digester heating and effluent heating processes. Many of small industries also use DPHEs due to their low cost of design and maintenance.

In double pipe heat exchangers, hot and cold fluids flow mostly in concentric pipes in different configurations which are parallel and counter flows. In the first case, both fluids flow in the same direction. While the other is one in which fluids flow in an opposite direction.

In previous years, an excess of researches has been carried out which fall into various categories. In some cases, just the working fluids characteristics and their modifications were studied, some investigated active methods, passive methods, compound methods, geometry change and the other heat enhancement methods.

### *Previous research on Geometry change*

In an experimental work, Yang and Chiang et al the heat transfer in a DPHE containing a periodic varying-curvature inner tube with water as the working fluid. Effects of Dean, Prandtl and Reynolds numbers and also the curvature ratio on heat transfer rate and pressure drop coefficient were widely studied and it was concluded that the Nusselt number and friction coefficient, in comparison with smooth tube, increased 100 and 40 percent, respectively.

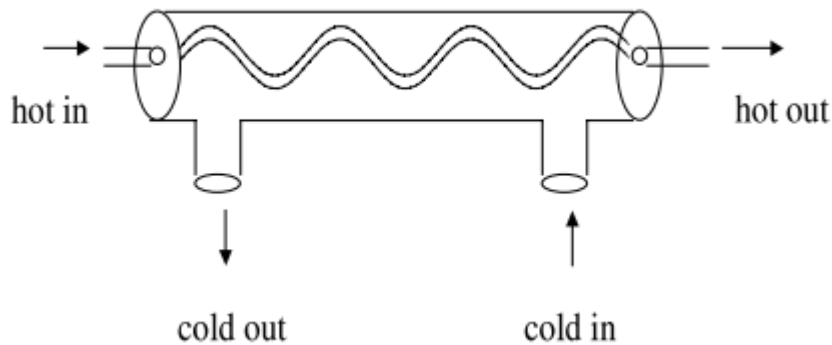

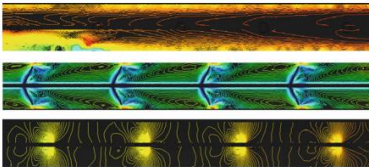
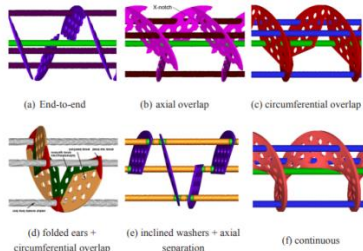
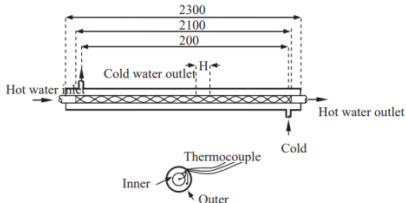
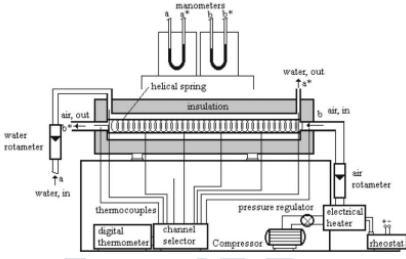
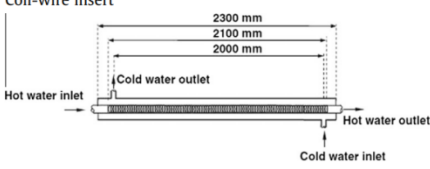
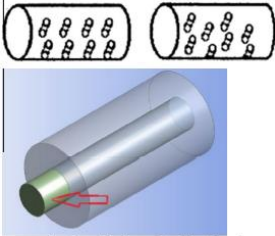


Figure 1 Schematic of test section. (Yang and Chiang et al)

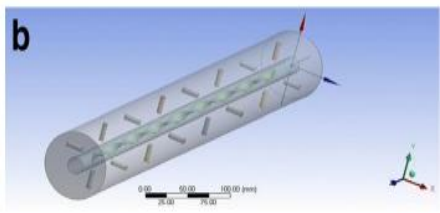
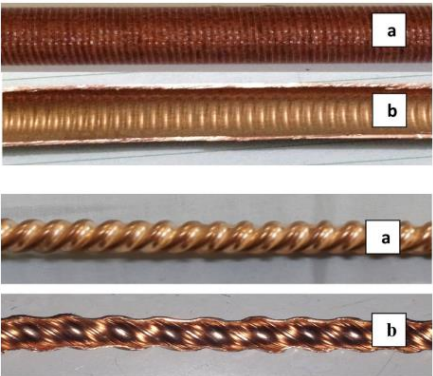
The different geometrical changes adopted by previous researchers are as

| Authors                                 | Configurations  | Findings  |
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| K. V. Jithin and Arjunan Pradeep et al. |  <p>Helical wire turbulator inserting inside of the inner pipe</p> | <ul style="list-style-type: none"> <li>• The double-pipe heat exchanger has been experimentally studied by inserting a helical wire as turbulator.</li> <li>• Hot and cold water is taken as working fluid in the inner pipe and outer pipe of a heat exchanger.</li> <li>• The mass flow rate in both tubes is varied, and the experiment is carried out in two modes without using turbulator and using turbulator.</li> <li>• The overall heat transfer coefficient is increased up to 40% by using turbulator.</li> <li>• Similarly, effectiveness and NTU also increased depending on the mass flow rate of cold and hot water.</li> <li>• The dimensionless exergy loss for the present system is calculated, and one important observation from the same is that dimensionless exergy loss by using turbulator is lower in the laminar flow region compared to the turbulent flow.</li> <li>• Considering the cost, flexibility, and simplicity of the turbulator, it is advisable to use turbulator inside the</li> </ul> |

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|  |   | <p>.double-pipe heat exchanger for getting more heat transfer performance with the same setup.</p> <ul style="list-style-type: none"> <li>• The turbulator yields better performance in the laminar flow region.</li> </ul>   |
| <p>J. BalaBhaskara Rao, B. Murali Krishna and K. Narendra et al.</p> |  | <ul style="list-style-type: none"> <li>• Double pipe heat exchanger with adjusted inclined elliptical leaf angle strips.</li> <li>• The strip having a circular rod and three elliptical shaped leaves is attached with a gap of 50 mm.</li> <li>• The heat transfer rate increases from 0° elliptical leaf angles to 60° elliptical leaf angle and declines from 60° elliptical leaf angle to 180°.</li> <li>• The heat transfer rate and pressure drop move with increase of Reynolds number.</li> <li>• Better results at 60° angle.</li> <li>• The overall heat transfer rate increase when Reynolds number increases from 5000 to 20000, at 60-degree elliptical leaf angle it is 21% higher than the existing double pipe heat exchanger</li> </ul> |
| <p>Yaping Chen et al.</p>  |  | <ul style="list-style-type: none"> <li>• The results show that similar shell side heat transfer coefficient can be obtained and the deviations of <math>h_o</math> are within +5% to -10%, but the results of pressure drop are quite deviant with two approaches.</li> </ul>   |

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| <p>PaisarnNaphon et al.</p> |                            | <ul style="list-style-type: none"> <li>• Effects of relevant parameter on the heat transfer and pressure drop are considered.</li> <li>• The twisted tape insert has significant effect on enhancing heat transfer rate.</li> <li>• The pressure drop also increases.</li> <li>• New proposed correlations for the heat transfer coefficient and friction factor based on the present experimental data are given for practical uses.</li> <li>• The agreement between the results obtained from the experiment and those obtained from the proposed correlations is reasonable.</li> </ul>                                   |
| <p>E.K. Akpınar et al.</p>  |                            | <ul style="list-style-type: none"> <li>• An augmentation of up to 2.64 times in Nusselt number was observed compared to the empty pipe</li> <li>• An increase of up to 2.74 times in friction factor compared to the smooth tube was observed in the experiments</li> <li>• The helical wires retard the development of boundary layers in the pipe, and the velocity and temperature profiles approach those in plug flow. Correlations are presented in details</li> </ul>  |
| <p>Naphon et al.</p>        | <p>Coil-wire insert</p>  | <ul style="list-style-type: none"> <li>• Coil-wire insert is more significant in laminar flow</li> <li>• Effect of coil-wire insert on the enhancement of heat transfer tends to decrease as Reynolds number increases</li> </ul>   |
| <p>Akpınar et al.</p>       |                          | <ul style="list-style-type: none"> <li>• Heat transfer rates increased with decreasing diameters and also increasing number of holes. Outer tube: cold water</li> <li>• The highest heat transfer rate was 130% compared to the smooth tube. This increase was for a swirl element which has 5 holes of 3mm diameter for the zigzag configuration</li> <li>• The most important role in pressure loss is played by swirl elements due to form drag, sudden contraction and enlargement losses in the entrance section of the tube. Correlations are presented in details which are based on dimensionless numbers.</li> </ul> |

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| <p>Eiamsa-ard et al.</p>         |    | <ul style="list-style-type: none"> <li>• The use of the louvered strip with backward arrangement leads to better overall enhancement ratio than that with forward arrangement around 9–24%</li> <li>• The Nusselt number increases with the increase of the inclined angle. This can be explained by a strong turbulence intensity generated by louvered strips, leading to rapid mixing of the flow especially at higher inclined angles</li> <li>• The Nusselt number increases with the increase of the inclined angle. This can be explained by a strong turbulence intensity generated by louvered strips, leading to rapid mixing of the flow especially at higher inclined angles</li> </ul>  |
| <p>Sheikhol-eslami et al.</p>    |   | <ul style="list-style-type: none"> <li>• Friction factor and Nusselt number decrease with the increase of open area ratio and pitch ratio</li> <li>• Thermal performance increases with the increase of open area ratio but it decreases with the increase of pitch ratio</li> <li>• The presence of holes is a good method for reducing pressure losses The correlations are widely studied in details</li> </ul>   |
|                                  |  | <ul style="list-style-type: none"> <li>• The finned design demonstrates a slightly higher fouling, and thus lower cleanliness factor, compared to the bare case.</li> <li>• The number of tubes is lower in the finned design which results in a lower pressure drop as compared to the bare design.</li> <li>• For the bare case, the cleanliness factor does not affect the costs significantly, whereas for the finned case, the fouling increases all the types of costs.</li> <li>• There is an optimal velocity value regarding the operating and investment costs for the abovementioned investigated pure fluids and their nanoblends, flowing in the annulus side of the heat exchanger at a constant heat load (80 kW).</li> </ul> |
| <p>Naphon and mohanty et al.</p> |  | <ul style="list-style-type: none"> <li>• Use of annular insert causes slightly in increasing the heat transfer coefficient.</li> <li>• Highest effectiveness was obtained for middle turn twisted tape up to 50 % when compared with plain case. The middle turn twisted tape gives the</li> </ul>   |

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|                        |    | <p>better effectiveness about 21 to 29 % as compared to other cases.</p> <ul style="list-style-type: none"> <li>• The enhancement of heat transfer coefficient with twisted tape inserts as compared to plain pipe varied from 13.12 to 16.13 %.</li> </ul>   |
| Osama A. Mohsen et al. |  | <ul style="list-style-type: none"> <li>• Under turbulent flow, extending the heat transfer surface using different fin geometries leads to different values of heat transfer depending on the geometry and on the fluid flow rate (or Reynolds number).</li> <li>• The investigated fin geometries in the current work exhibited different heat transfer enhancements as well as different pressure drop values.</li> <li>• The rectangular fin provides the largest heat transfer enhancement, from 68 to 168% when compared to a smooth tube and depending on the flow conditions.</li> <li>• The associated pressure drop is high when using this type of fin.</li> <li>• The helical rib tube gives lower heat transfer enhancement (from 22 to 97% compared to the smooth tube) with a lower pressure drop than for the rectangular fin.</li> <li>• The circular finned tubes do provide the heat transfer benefit expected with only 3–47% improvement in heat transfer, but causes the lowest pressure drop</li> </ul> |

### ***Heat transfer enhancement using different heat transfer medium***

Nanofluid is a two-phase fluid, basically a colloidal suspension of nanoparticles in base fluids like oil and water. Hybrid nanofluids are engineered fluids of two different nanoparticles dispersed into base fluid. A hybrid material combines the properties (physical and chemical) and exhibits them homogeneously. The thermo-physical properties of hybrid nanofluid are comparatively higher than single-particle nanofluid and base fluid. An instrument devised to make the exchange of heat between two fluids at different temperature without mixing them is known as a heat exchanger. From the analysis of various research papers, it has been inferred that a material does not inherit all the properties needed for a specific purpose. Hybrid nanofluids have a wide application in the field of electro-mechanical, HVAC, automotive cooling, etc.

Chopkar et al. analysed that the thermal conductivity was enhanced by using  $\text{Al}_2\text{O}_3\text{-Cu}$ /water hybrid nanofluid in electronics cooling through a heat sink by comparing the results obtained with base fluid and single-particle nanofluid.

An experiment was conducted by Dhinesh Kumar D et al. using a tubular heat exchanger for  $\text{Cu/TiO}_2$  hybrid water-based nanofluid, and it was observed that the overall heat transfer has increased to 30.4% at a volume concentration of 0.7% .

Suresh et al. conducted an experiment for  $\text{Al}_2\text{O}_3\text{-Cu}$ /water hybrid nanofluid in a tube and suggests that at Reynolds number of 1730, Nusselt number enhanced by 13.56%.

Madhesh et al. conducted an experiment in a tube-type counter flow heat exchanger using Cu–TiO<sub>2</sub> deionized double-distilled water hybrid nanofluid and observed that thermal conductivity enhanced as compared to base fluid.

The numerical studies associated with the nanoparticle addition concluded that magnetic nanofluids improved the heat transfer coefficient, and that Cu performed better than CuO and CNT (Saeedan M. et al), and that aluminium oxide performed better than titanium carbide (Alhusseny A et al). In an experimental study by Khan et al., the heat transfer characteristics of a car radiator were investigated for ZnO nanoparticles in a 50:50 water–ethylene glycol mixture for increasing volumetric concentrations. They reported that the heat transfer performance improved for higher concentrations of nanoparticles. Basically, nanofluid exhibit higher thermal conductivity and enhance the heat exchanger's effectiveness. The reason behind such enhancement may be the increase in surface area and heat capacity of the fluid by suspending particles.

## Conclusion

The goal of this paper was to provide a complete review of studies in the subject of geometrical augmentation and nanofluid use in heat exchangers. A large number of studies have been conducted to evaluate the performance of nanofluids in heat exchangers due to their suitable features. In practice, the cost of nanofluid synthesis and the stability of nanoparticles are two major aspects to consider when developing the usage of nanofluids in heat exchangers. One of the most significant issues identified in research on the use of nanofluids in heat exchangers is the lack of standardisation among diverse evaluations. Despite the fact that the two-pipe heat exchanger is the most basic of all the heat exchangers, it is the most efficient, its optimal design is difficult, various geometrical factors affect the heat transfer enhancement.

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