Academic Guru Publication House

Technological Advancements : Research & Reviews
Volume 1
Year: 2021

AG PH Books

A Review on Heat Transfer and Fluid Flow Characteristics through Double-Pipe U-Tube Heat Exchanger

Sonu Kumar Kushwaha[1*]

[1]Research scholar, Department of Mechanical engineering, Sagar Institute of research & technology Bhopal

Abstract

In the current context more and more efficient heat transfer system are required. The solution based on turbulent flow through heat exchangers has proven successful in terms of high heat transfer rate. All past studies on this topic was experimental based. The present approach is based on CFD (Computational Fluid Dynamics) technique. As a starting point, this study examines how various characteristics, such as the kind of fins, orientation, forms, and positions, might be used to optimise heat exchanger thermal performance. The purpose of this review is to explain how each of the parameters listed affects thermal performance.

Keywords: Heat exchanger, Twisted tube insert, Nano Material, Heat transfer mechanism.

1. INTRODUCTION

It is commonplace across a wide range of industries to make use of various kinds of heat exchangers. Heat exchangers composed of metals, such as copper, aluminium, and steel, are common. Plastics, on the other hand, were selected as a practical material for heat exchangers because they are resistant to chemicals and corrosion. Chemically resistant and lighter than corrosion-resistant alloys, they are less expensive. [1] Plastic heat exchangers aren't only for corrosive environments; they're also

* ISBN No. 978-81-953278-8-1

employed in the food processing sector, biotechnology, and the automobile and aerospace industries. Because metal heat exchangers have a long history of use, well-designed manufacturing systems, and established procedures, enterprises are reluctant to modify their methods. No matter how much progress has been made in the world of material science and technology, we still believe that the potential for plastic heat exchangers to be used must be reexamined.[2]

There are three basic kinds of heat transfer augmentation methods: active, passive, and compound. DPHE was thoroughly reviewed by Mohamad et al., who covered in depth the aforementioned heat transfer augmentation strategies [3]. An external force is used to boost heat transmission when using active techniques, the authors noted. The use of reciprocating plungers, a magnetic field, surface or flow vibration, and electromagnetic fields are a few examples. There are no external forces employed to increase heat transmission in passive techniques. For heat transmission, surface or geometric modifications are used. Because of their simplicity, cheap cost, and ease of installation and maintenance, modifications such as twisted tape inserts or fins are quite popular. However, surface alterations may improve the heat transfer coefficient and hence the rate of heat transfer, but they can also cause an increase in pressure drop.[4]

1.1. Double-Pipe Heat Exchangers

The inner pipe of this exchanger is generally plain or finned, as seen in Figure. To get the best possible performance for the given surface area, one fluid runs through the inner pipe while the other flows through the annulus between the pipes. It is possible for fluids to flow in a parallel flow direction if the application demands a nearly constant temperature on the wall. The simplest heat exchanger is this one. By disassembly, cleaning is a breeze, and flow distribution isn't an issue. If one or both of the fluids is at a high pressure, this design is also a good choice. [5]

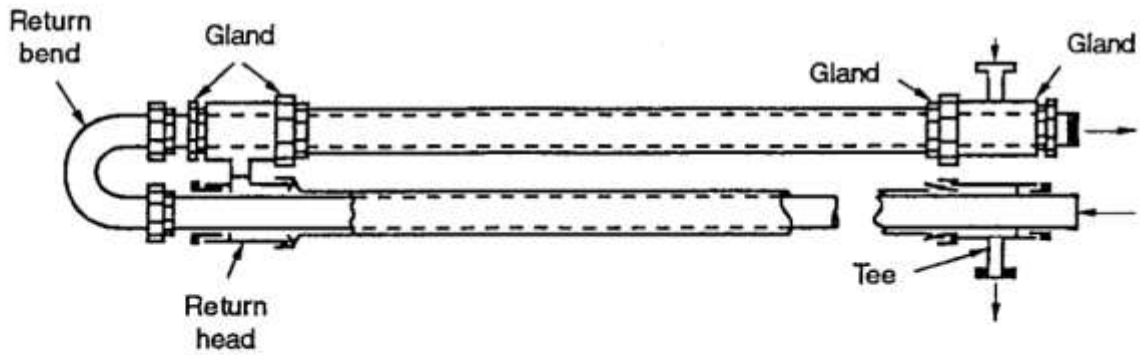

Figure 1: Double pipe heat exchanger[6]

1.2. Nanofluids

An entirely new kind of heat transfer fluid, nanofluids, is a product of nanotechnology and is made by dispersing and suspending nanoparticles with typical diameters of 10 nm or less. It was Choi (1995) who developed the name "Nanofluids" to characterise this novel class of heat transfer fluids based on nanotechnology that have enhanced thermal characteristics, which are superior to those of their own hosting liquids as well as traditional particle fluid suspensions.[7]

Nanofluids aim to disperse and suspend nanoparticles (ideally 10 nm in size) in host fluids in a homogeneous and stable manner to attain the greatest possible thermal characteristics at the lowest possible concentrations (preferably 1% by volume). Because nanoparticles promote energy transmission in liquids, it is essential to understand how they work.[8]

Procedures for preparing Nanofluids:

There are two ways to prepare Nanofluids and that is mentioned below:

Two step Method

Two-step approach is most common: dry powders or other nanomaterials are first created using chemical or physical methods to create the nanoparticles, fibre or tube. It is then distributed into the host fluid in the second stage using one of the following methods: vigorous magnetic force agitation, ultrasonic and high-shear mixing and homogenizing. As Nano powder synthesis methods have already been scaled up to industrial production levels, this is the most cost-effective way to create nanofluids on a wide scale. Nanoparticles prefer to agglomerate because of their large surface area and strong surface activity. The one-step approach was designed to circumvent the challenge of making stable nanofluids using the technology that was previously used.[9]

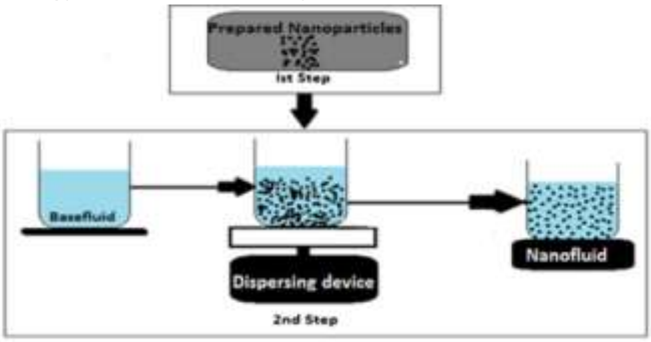

Figure 2: Two-step Nanofluids Preparation

One step Method

Particles are made and dispersed in the fluid simultaneously in a one-step process. There are less agglomerations of nanoparticles using this approach, which avoids operations such as drying, transporting, and dispersion of the nanoparticles. It is possible to make nanoparticles that are perfectly disseminated in the base fluid using one-step methods.[10]

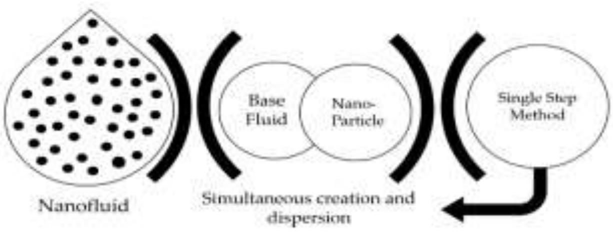

Figure 3: One-step Nanofluids Preparation

1.3. THEORY

The “double-pipe heat exchanger” is one of the most straightforward forms of heat exchangers. When two pipes are connected, one fluid runs within the first while the other flows between and around the first. This is known as a “double-pipe exchanger”. Co-current or counter-current flow is possible in a heat exchanger with two pipes.

Double-pipe heat exchanger theory is discussed in “Incropera and Dewitt (1996)”. Using the same textbook, we can figure out how to handle transient behaviour in terms of heat transfer.

1.4. Trapezoidal-Cut Twisted Tapes

Using 1.00 mm thick aluminium strips, the trapezoidal-cut twisted tapes have a 1 mm smaller width than the test section tube's interior diameter. On a lathe, the strips are manually twisted by rotating the chuck. The twist ratio (y) for this strip may be calculated by dividing the diameter by the length of one twist (or pitch). The trapezoidal-cut measurements of the full-length twisted tape are 6 mm deep, 6 mm at the base, and 10 mm wide at the top. For better fluid mixing along the pipe's inner walls, a trapezoidal-cut is made on both the tape's top and bottom surfaces. Figure shown below depicts the trapezoidal cut test portion.

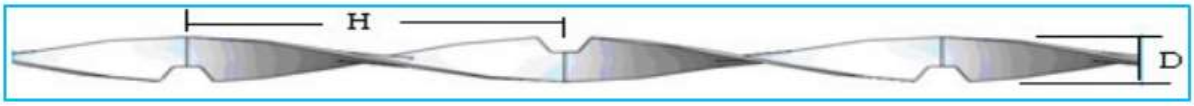

Figure 4: Schematic representation of trapezoidal-cut twisted tape [11]

2. LITERATURE REVIEW

(Ngo et al., 2021) [12] A two-dimensional (2D) gas-solid Eulerian “computational fluid dynamics (CFD) model” is used to analyse the hydrodynamic and heat transport properties of a BFB reactor with “immersed heat exchange tubes for CO2 methanation”. The CFD model was combined with a reaction kinetics model for a Ni-based catalyst. For the bed growth of Geldart B particles, the 2D-CFD model with Huilin and Gidaspow drag was verified using experimental data.

(Bahiraei, Naseri and monavari, 2021) [13] A two-dimensional (2D) “gas-solid Eulerian computational fluid dynamics (CFD) model” is used to analyse the hydrodynamic and heat transport properties of a BFB reactor with immersed heat exchange tubes for CO2 methanation. The CFD model was combined with a reaction kinetics model for a Ni-based catalyst. For the bed growth of Geldart B particles, the 2D-CFD model with Huilin and Gidaspow drag was verified using experimental data. The heat of reaction was efficiently eliminated in the BFB reactor with a 25% heat exchange area, and the reactor maintained isothermal conditions, according to the results.

(Calvino et al., 2021) [14] This material's thermal characteristics have been well documented and are enhanced by the fact that graphene nanoplatelets are multi-layered (GnP). A functionalization of these hydrophobic carbon nanostructures is necessary to determine their long-term stability in aqueous solutions. “Polycarboxylate chemically modified GnP dispersion” in water at 0.50 wt % is tested for convective heat transfer performance in this work. To test the nanofluids thermal conductivity, density, isobaric heat capacity, and isothermal viscosity across a broad temperature range, researchers use rotational rheometry, the transient hot-wire method, differential scanning calorimetry, and the vibrating U-tube method. The thermo physical and rheological characteristics of the material have been verified by two separate labs.

(Dube kerme and Fung, 2020) [15] Modeling the transient heat transfer in “a twin U-tube borehole heat exchanger (BHE)” with either varying or equal mass flow rate and intake fluid temperature has been proposed in this study. Using previously available data, we were able to test the suggested model. As part of the vertical BHE optimization and efficiency testing as well as a rapid assessment of how borehole characteristics and thermal properties affect overall performance, the modelling, simulation, and analysis are critical. In the design, optimization, and performance analysis of ground source heat pump and borehole thermal energy storage systems, the model is essential.

(Pandey, Prajapati and singh, 2020) [16] The current study's goal is to see whether a Y-shaped insert within a circular tube heat exchanger may improve heat transmission and fluid flow. With four different values of Perforation Index (PI) ranging from zero to 30 percent, air is employed as the working fluid in the “RNG K- Turbulence model”. The Reynolds number (Re) varies from 3000 to 21000. Larger PI results in a higher friction factor, whereas lower PI results in a lower friction factor and a higher heat transfer. At Re = 3000, the non-perforated insert case has the maximum heat transfer and “Thermal Performance Factor (TPF)” of 5.05 times and 2.88 times, respectively, above the smooth tube.

(Jahanbin, 2020) [17] Building climate control and residential hot water generation may benefit from the use of “Ground-Coupled Heat Pumps (GCHPs)”. Drilling and installation costs are the primary impediment to their use in urban settings. “Ground-source heat pump (GCHP)” systems may benefit from an innovative and simple design of the GHE, particularly the vertical GHE with an elliptical U-tube. Elongated U-tubes may significantly increase heat transmission and reduce borehole thermal resistance compared to single U-tubes, according to the findings. When the form factor is greater, heat transmission is enhanced more effectively. In this study, it was shown that “elliptical U-tubes” have the ability to reduce borehole thermal resistance and increase GCHP system COP.

(Serageldin et al., 2020) [18] Spacers that may be used to maintain the distance between the legs of a single U-tube with an oval cross section have been developed in this research. The ground source heat pump system was subjected to short-term and long-term transient numerical simulations in order to assess its thermal and energy performance using a single oval-section U-tube linked with a new spacer and a “traditional circular-section single U-tube system”. Different spacer cross-sections (circular, oval, and oval with fins, double circular cross-section spacers), materials, and length were evaluated for their effect on thermal performance.

(Kerme and Fung, 2020) [19] The heat transfer in a “single U-tube borehole heat exchanger” is the subject of this paper's investigation, modelling, and performance evaluation. The heat transmission mechanism within and outside the borehole was studied using an unsteady heat transfer approach. Based on energy balance equations, coupled with thermal resistance model, implicit numerical technique was utilised to find solution. It was determined how the temperatures of the fluid, the wall of the hole, the grouts, and the ground around the hole changed with time and depth. It was also necessary to do a dynamic simulation in order to determine the effect of various factors.

(Naldi and Zanchini, 2020) [20] For both short-term and long-term fluid-to-ground thermal response factors, a novel cylindrical model is provided, which may be used to calculate both (BHE). It is possible to simulate a BHE using a cylinder with the same radius and heat capacity as a real-world comparable cylinder. There is a “heat-generating cylindrical surface with an equivalent radius (req)” that has been tuned by repeated 2D finite-element simulations of the cylinder's homogenous material. There is a layer between req and BHE radius, and its thermal resistance is equal to BHE's thermal resistance. A correlation is shown that yields the optimal values of req.

(Luo, Yan and Yu, 2020) [21] For geothermal energy usage, seasonal energy storage, etc., ground heat exchanger (GHE) is essential. U-tube GHE's asymmetric form and complicated heat interaction between fluid, grout, and soil make the “transient heat transfer analytical model” a problem. A new analytical model for “U-tube GHE” was developed in this work using a composite media technique. The novel modelling is aided by inspiration from the heat transmission of GHE in multilayer soil. A novel analytical model for U-tube GHE has been developed by combining the methodologies of tackling non-uniform pipe wall temperature/heat flux and the influence of ground surface flux. Models are verified using both experimental and other simulation data. With the use of visualization, we've been able to examine how the temperature changes in longitudinal and cross sections of GHE. Some novel findings were discovered during the investigation of grout material selection and borehole depth design.

3. CONCLUSION

In this review study, a variety of fins were employed to improve heat transmission. To analyse the “heat transfer rate and pressure drop” of different fin shapes such as rectangular (rectangular), triangular (triangular), trapezoidal (trapezoidal), wavy (wavy), offset strip (offset strip), louvred (louvred), and perforated (perforated) are employed. “Trapezoidal-cut twisted tape” inserts have a significant impact on the thermal performance factor because they promote heat transmission. Because of their high thermal conductivity, Al2O3 nanoparticles seem to have a significant impact on nanofluids' thermal performance. Therefore, it can be concluded that the good effects of improved heat transmission outweigh the negative effects of increased friction loss in the range studied.

References

[1] L. Zhu, S. Chen, Y. Yang, and Y. Sun, "Transient heat transfer performance of a vertical double U-tube borehole heat exchanger under different operation conditions," *Renew. Energy*, vol. 131, pp. 494–505, 2019, doi: 10.1016/j.renene.2018.07.073.

[2] J. Kim, T. Sibilli, M. Y. Ha, K. Kim, and S. Y. Yoon, "Compound porous media model for simulation of flat top U-tube compact heat exchanger," *Int. J. Heat Mass Transf.*, vol. 138, pp. 1029–1041, 2019, doi: 10.1016/j.ijheatmasstransfer.2019.04.116.

[3] M. Omidi, M. Farhadi, and M. Jafari, "A comprehensive review on double pipe heat exchangers," *Appl. Therm. Eng.*, vol. 110, pp. 1075–1090, 2017, doi: 10.1016/j.applthermaleng.2016.09.027.

[4] T. Mohapatra, S. Ray, S. S. Sahoo, and B. N. Padhi, "Numerical study on heat transfer and pressure drop characteristics of fluid flow in an inserted coiled tube type three fluid heat exchanger," *Heat Transf. - Asian Res.*, vol. 48, no. 4, pp. 1440–1465, 2019, doi: 10.1002/htj.21440.

[5] C. K. Mangrulkar, A. S. Dhoble, S. Chamoli, A. Gupta, and V. B. Gawande, "Recent advancement in heat transfer and fluid flow characteristics in cross flow heat exchangers," *Renew. Sustain. Energy Rev.*, vol. 113, no. September 2017, p. 109220, 2019, doi: 10.1016/j.rser.2019.06.027.

[6] R. K. Shah and D. P. Sekuli, *Selection of Heat Exchangers and Their Components*. 2007.

[7] E. Zanchini and A. Jahanbin, "Effects of the temperature distribution on the thermal resistance of double u-tube borehole heat exchangers," *Geothermics*, vol. 71, no. February 2017, pp. 46–54, 2018, doi: 10.1016/j.geothermics.2017.07.009.

[8] C. Li, Y. Guan, and X. Wang, "Study on reasonable selection of insulation depth of the outlet section of vertical deep-buried U-bend tube heat exchanger," *Energy Build.*, vol. 167, pp. 231–239, 2018, doi: 10.1016/j.enbuild.2018.02.047.

[9] E. Zanchini and A. Jahanbin, "Simple equations to evaluate the mean fluid temperature of double-U-tube borehole heat exchangers," *Appl. Energy*, vol. 231, no. June, pp. 320–330, 2018, doi: 10.1016/j.apenergy.2018.09.094.

[10] A. A. Serageldin, Y. Sakata, T. Katsura, and K. Nagano, "Thermo-hydraulic performance of the U-tube borehole heat exchanger with a novel oval cross-section: Numerical approach," *Energy Convers. Manag.*, vol. 177, no. August, pp. 406–415, 2018, doi: 10.1016/j.enconman.2018.09.081.

[11] P. V. D. Prasad, A. V. S. S. K. S. Gupta, and K. Deepak, "Investigation of Trapezoidal-Cut Twisted Tape Insert in a Double Pipe U-Tube Heat Exchanger using Al2O3/Water Nanofluid," *Procedia Mater. Sci.*, vol. 10, no. Cnt 2014, pp. 50–63, 2015, doi: 10.1016/j.mspro.2015.06.025.

[12] S. I. Ngo, Y. Il Lim, D. Lee, and M. W. Seo, "Flow behavior and heat transfer in bubbling fluidized-bed with immersed heat exchange tubes for CO2 methanation," *Powder Technol.*, vol. 380, pp. 462–474, 2021, doi: 10.1016/j.powtec.2020.11.027.

[13] M. Bahiraei, M. Naseri, and A. Monavari, “A CFD study on thermohydraulic characteristics of a nanofluid in a shell-and-tube heat exchanger fitted with new unilateral ladder type helical baffles,” *Int. Commun. Heat Mass Transf.*, vol. 124, p. 105248, 2021, doi: https://doi.org/10.1016/j.icheatmasstransfer.2021.105248.

[14] U. Calviño, J. P. Vallejo, M. H. Buschmann, J. Fernández-seara, and L. Lugo, “Analysis of heat transfer characteristics of a GnP aqueous nanofluid through a double-tube heat exchanger,” *Nanomaterials*, vol. 11, no. 4, 2021, doi: 10.3390/nano11040844.

[15] E. Dube Kerme and A. S. Fung, “Transient heat transfer simulation, analysis and thermal performance study of double U-tube borehole heat exchanger based on numerical heat transfer model,” *Appl. Therm. Eng.*, vol. 173, p. 115189, 2020, doi: 10.1016/j.applthermaleng.2020.115189.

[16] L. Pandey, H. Prajapati, and S. Singh, “CFD study for enhancement of heat transfer and flow characteristics of circular tube heat exchanger using Y-shaped insert,” *Mater. Today Proc.*, no. xxxx, 2020, doi: 10.1016/j.matpr.2020.10.890.

[17] A. Jahanbin, “Thermal performance of the vertical ground heat exchanger with a novel elliptical single U-tube,” *Geothermics*, vol. 86, no. August 2019, p. 101804, 2020, doi: 10.1016/j.geothermics.2020.101804.

[18] A. A. Serageldin, Y. Sakata, T. Katsura, and K. Nagano, “Performance enhancement of borehole ground source heat pump using single U-tube heat exchanger with a novel oval cross-section (SUO) and a novel spacer,” *Sustain. Energy Technol. Assessments*, vol. 42, no. October 2019, p. 100805, 2020, doi: 10.1016/j.seta.2020.100805.

[19] E. D. Kerme and A. S. Fung, “Heat transfer simulation, analysis and performance study of single U-tube borehole heat exchanger,” *Renew. Energy*, vol. 145, pp. 1430–1448, 2020, doi: 10.1016/j.renene.2019.06.004.

[20] C. Naldi and E. Zanchini, “A one-material cylindrical model to determine short- and long-term fluid-to-ground response factors of single U-tube borehole heat exchangers,” *Geothermics*, vol. 86, no. January, p. 101811, 2020, doi: 10.1016/j.geothermics.2020.101811.

[21] Y. Luo, T. Yan, and J. Yu, “Integrated analytical modeling of transient heat transfer inside and outside U-tube ground heat exchanger: A new angle from composite-medium method,” *Int. J. Heat Mass Transf.*, vol. 162, p. 120373, 2020, doi: 10.1016/j.ijheatmasstransfer.2020.120373.