JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

A REVIEW ON HEAT TRANSFER AND FLUID FLOW CHARACTERISTICS THROUGH U-TUBE HEAT EXCHANGER

[1]Sonu Kumar Kushwaha, [2]Nitin Tenguriya, [3]D.K. Mudaiya

[1]Research scholar, Department of Mechanical engineering, Sagar Institute of research & technology Bhopal
[2]Professor, Department of Mechanical engineering, Sagar Institute of research & technology Bhopal
[3]Professor, 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 tube with twisted tape inserts systems 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. The purpose of this paper is to provide an overview of research works carried out to improve the thermal performance of a heat exchanger by using different parameters like type of fins, orientation, shapes and locations. This review is to help understand how every mentioned parameters influences on improvement of thermal performance.

***Keywords* – Heat exchanger, twisted tape insert, Nano Material, Heat transfer mechanism**

I. INTRODUCTION

[1]. A heat exchanger is a device built for efficient heat transfer from one medium to another. The media may be separated by a solid wall to prevent mixing or they may be in direct contact [2]. They are widely used in space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, aerospace industry and sewage treatment [3]. The classic example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air [4].

A heat exchanger consists of heat transfer elements such as a core or matrix containing the heat transfer surface, and fluid distribution elements such as headers, manifolds, tanks, inlet and outlet nozzles or pipes, or seals [5]. Usually, there are no moving parts in a heat exchanger; however, there are exceptions, such as a rotary regenerative exchanger (in which the matrix is mechanically driven to rotate at some design speed) or a scraped surface heat exchanger [6].

The double-pipe heat exchanger is one of the simplest types of heat exchangers. It is called a double-pipe exchanger because one fluid flows inside a pipe and the other fluid flows between that pipe and another pipe that surrounds the first. Flow in a double-pipe heat exchanger can be co-current or counter-current [7] [8].

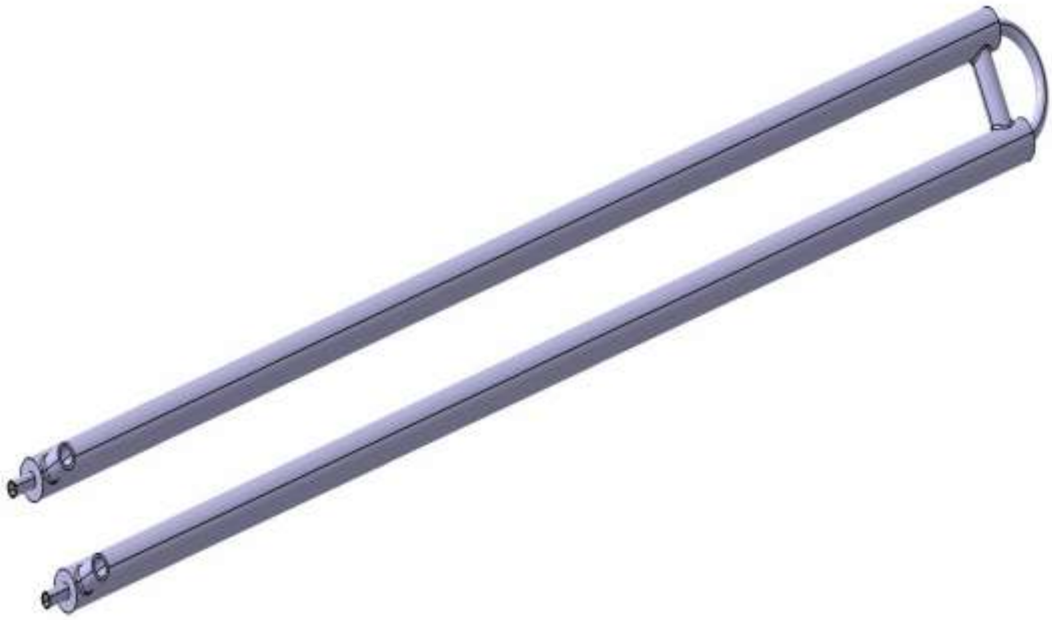

Figure 1 U tube heat exchanger

THEORY

Heat exchangers are devices that transfer or exchange heat between two fluids without mixing and include various types depending on the design, application, required space, and the fluid flows in the system. All the heat exchangers have a barrier that separates the fluids and allows the heat transfer simultaneously [9]. The double pipe heat exchanger is one of the basic kinds of exchangers with a very flexible configuration [10], [11]. There are two types of counterflow or parallel flow for this type that are the basis of design and calculation for determining pipe size, length, and a number of bends [12].

In double pipe heat exchangers, we have a large pipe with a small pipe inside it concentrically, and all the heat transfer process occurs inside the larger pipe [13]. One fluid flows through the inner of a small pipe, and another fluid is between the two pipes, and that is how the inner pipe acts as a conductive barrier. The outside or shell side includes fluid flow passing on the inner side or tube side [14].

Trapezoidal-Cut Twisted Tapes

The trapezoidal-cut twisted tapes are made of 1.00 mm thick aluminium strips, the width of the strip being 1 mm less than the inside diameter of the test section tube. The strips are twisted on a lathe by manual rotation of the chuck. The twist ratio (y) for this strip is defined as the ratio between one length of twist (or) pitch length to diameter. The full-length twisted tape has its trapezoidal–cut dimensions as 6 mm deep, 6 mm at its base and 10 mm wide at its top. The trapezoidal-cut is taken alternately on both top and bottom of the tape to improve the fluid mixing near the inner walls of the pipe. The schematic of this trapezoidal cut test section is shown in Fig. 2

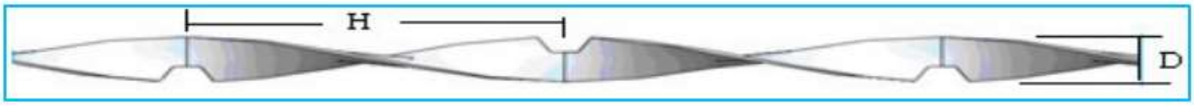

Figure 2 Schematic representation of trapezoidal-cut twisted tape [15]

II. Literature Review

(Calviño et al. 2021) [16] thermal properties of graphene have proved to be exceptional and are partly maintained in its multi-layered form, graphene nanoplatelets (GnP). Since these carbon-based nanostructures are hydrophobic, functionalization is needed in order to assess their long-term stability in aqueous suspensions. In this study, the convective heat transfer performance of a polycarboxylate chemically modified GnP dispersion in water at 0.50 wt% is experimentally analyzed. After designing the nanofluid, dynamic viscosity, thermal conductivity, isobaric heat capacity and density are measured using rotational rheometry, the transient hot-wire technique, differential scanning calorimetry and vibrating U-tube methods, respectively, in a wide temperature range. The whole analysis of thermophysical and rheological properties is validated by two laboratories.

(Abdulrahman, Ibrahim, and Faisel 2020) [17] The heat exchanger (HX) plays a key role for several industries, to reduce the energy consumption by rising heat transfer rate through heat exchanger. In this study, numerical simulation of shell and double tube heat exchanger without and with baffles is analyzed to evaluate the heat transfer and exergy analysis. A numerical simulation of 3D model with turbulent flow at the range (4000-12000) is performed with commercial computational fluid dynamics (CFD) software ANSYS (Fluent). The circular vents baffles model is used at the side of the shell. The simulation results show that the circular vents on the baffles of the heat exchanger have a significant impact on thermal- hydraulic performance and exergy analysis. Also, the results show that the heat exchanger effectiveness with baffles increases by 17% at high Reynolds number comparing with heat exchanger without baffles. Besides, the highest value of exergy loss reached to 42W with baffles presence. Finally, it is concluded that the heat exchanger with baffles gives better hydraulic and thermal performance than that of heat exchanger without baffles.

(Gharibi et al. 2018) [1] three-dimensional numerical model of a U-tube heat exchanger is simulated based upon the real field data of an abandoned oil well located in southern Iran. To assess and optimize the performance of the heat exchanger, the influences of mass flow rate, fluid inlet temperature, insulation length, and pipe diameter are analyzed. The simulation results indicate that the retrofitted well can be utilized for both electricity generation and direct applications. The great advantage of the proposed heat exchanger is that it can work steadily as a long-term geothermal production system.

(Kushwaha et al. 2020) [18] heat transfer and fluid flow characteristics for both Newtonian and non-Newtonian fluids in tube-in-tube helical coil (TTHC) heat exchangers have been investigated numerically. The various TTHC heat exchanger configurations studied are (1) parallel and (2) counter flow, with and without baffles. The power law index (n) and Dean number (NDe) are varied from 0.5 to 1.25 and 50 to 500, respectively. Further, two different models have been proposed to predict the friction factor (f) and Nusselt number (Nu) in TTHC. It is observed that fand Nu in the TTHC heat exchanger with baffles in the annulus is higher as compared to without baffles. Furthermore, at low Prandtl number the baffles have significant influence on heat transfer, while at high Prandtl number flow configuration has high significance.

(Serageldin et al. 2020) [14] maintain the space between the upward and downward U-tube legs of a single U-tube with an oval cross-section. Therefore, short-term and long-term transient numerical simulations were performed to compare the thermal and energy performance of the ground source heat pump system with both a single U-tube with an oval cross-section coupled with a novel spacer, and a conventional single U-tube with a circular cross-section. The impact of using different spacer cross-sections (circular cross-section, oval cross-section, and an oval cross-section with fins, double spacers with circular cross- section), materials, and length on the thermal performance was examined. Finally, a straightforward economic study was implemented to examine the feasibility of utilizing the proposed spacer.

(Mohapatra et al. 2019) [19] paper presents numerical investigations of a three fluid heat exchanger (TFHE), which is an improvement on the double pipe heat exchanger, where a helical tube is inserted in the annular space between two straight pipes. The helical tube side fluid, that is, hot water continuously transfers heat to the outer annulus side fluid and innermost tube side fluid. The heat transfer and pressure drop characteristics of the TFHE are assessed for different flow rates and inlet temperatures. With an increment in the volumetric flow rate of the helical tube side fluid and outer annulus side fluid, the overall heat transfer coefficient increases, and the effectiveness decreases for heat transfer from the helical tube side fluid to outer annulus side fluid in both parallel flow and counter flow configurations.

(Kim et al. 2019) [7] Describes a compound porous media model approach for numerical analysis to investigate the aero-thermal performance and characteristics of a flat top U-tube heat exchanger. The heat exchanger was considered as a combination of three sections; vertically straight tube section, bent tube section, and horizontally straight tube section. The porous media coefficients were obtained by using empirical correlations for the pressure drop and heat transfer for each section. The numerical results of the compound porous media model were compared to those of a conjugate heat transfer (CHT) CFD analysis, considering real tube geometry and experiments in order to validate the proposed compound porous media approach.

(Kumar et al. 2018) [20] Inserts are used to enhance the heat transfer rates between the two fluids in heat exchanger tubes. A variety of tube inserts such as twisted tape, wire coil, swirl flow generator have been investigated for their effect on heat transfer rates and fluid friction. This paper reviews the works pertaining to the application of different class of tube inserts in order to comprehend the prevailing mechanism of fluid flow and heat transfer. An attempt has been made to elucidate the fluid flow behaviour sustained by the particular class of insert that controls the heat transfer rates across the thermal boundary layer attached to the tube wall.

(Khoshvaght-Aliabadi, Davoudi, and Dibaei 2018) [21] Experimental study is performed to investigate hydrothermal characteristics of agitated-vessel U tube heat exchanger. In order to augment the rate of heat transfer in the tube side, two passive enhancement techniques, namely spiky twisted tapes and water based metallic nanofluids, are used. Three twist ratios ($\alpha = 0.33, 0.67$, and 1) with different values of width/depth for peripheral cuts ($\beta = 0.33, 0.5, 0.67, 1, 1.5, 2$, and 3) and three metallic nanofluids (Cu/water, Fe/water, and Ag/water) are tested.

(Li, Guan, and Wang 2018) [22] scientific prediction of insulation depth of the outlet section of vertical deep-buried U-bend tube heat exchanger (THE) in geothermal heating, in this study, a full-scale numerical calculation model combining the heat transfer processes inside and outside the tube was established. This model was further validated through in-situ experiment for a vertical deep-buried U-bend THE system with a depth of 2505 m in Xi'an. Four constant heat conditions with different magnitudes were selected and the highest average outlet temperature of the circulating water within the tube in the entire heating season corresponded to the optimum insulation depth. Furthermore, the effect of insulation depth at the outlet section of the buried tube on the heat transfer performance was analyzed by numerical calculation.

(FAHAD and ALSHARA 2017) [23] numerical model of cylindrical coordinates, three dimensional of a laminar heat transfer and fluid flow inside shell and tube heat exchanger is examined. The thermo-hydraulic performance of heat exchangers is predicted with finite volume method by CFD simulations using ANSYS 15.0 code. Shell-and-tube heat exchanger is consisted of one pass of warm water laminar flow at the shell side and two passes single tube of laminar cold water. The annular baffles are inserted on shell side, and on the facing distances of the length of tube from the outer surface. Baffles are inserted with staggered position on the shell and tube to achieve good fluid circulation. Also baffles on the tube side are varied with angle inclination, number and diameter while only number and length on the shell side.

(Prasad, Gupta, and Deepak 2015) [15] enhance the rate of heat transfer in heat exchangers using Al_2O_3 nanofluid. In this work an experimental analysis on trapezoidal-cut twisted tape insert in a double pipe U-tube heat exchanger using Al_2O_3 water based nanofluid is presented. The heat transfer coefficients and the corresponding friction factors required for performance analysis are determined taking into account the typical operating conditions of the heat exchangers in turbulent flow regimes with particle volume concentration of 0.01% and 0.03% and twist ratios ranging between 5 and 20. Experimental data is generated at flow rates ranging from 0.0333 kg/s to 0.2667 kg/s. Experimental data is generated with water and nanofluid for Reynolds number in the range $3000<Re<30000$, the Nusselt number of entire pipe for 0.03% concentrations of nanofluid with trapezoidal-cut twisted tape inserts of $H/D = 5$ is enhanced by 34.24% as compared to water. The friction factor of entire pipes for 0.03% concentration of nanofluid with trapezoidal-cut twisted tape inserts of $H/D=5$ is enhanced by 1.29 times as compared to water. The results of the investigation indicate an enhancement in the performance parameters of the heat exchanger namely heat transfer coefficient and friction factor with an increase in volume concentration of the nanoparticle.

(Zarrella, Capozza, and De Carli 2013) [24] two borehole heat exchangers were analyzed over both long- and short-term periods; the thermal properties of the ground, energy loads and the axial effects of weather conditions were also taken into account. Finally, a reduction in the borehole length for the helical-shaped pipe was also assessed and compared with the performance of the double U-tube.

(Çakmak 2013) [6] Several measures and applications that can be performed in order to enhance energy efficiency, one of which is the evaluation of disposed energy. One of the most widely used processes for recycling the disposed energy is the employment of the heat exchanger systems which ensure heat exchange between two or more fluids at different temperatures. In this paper a U-tube heat exchanger has been designed and waste heat has been stored by using phase change material in the system. Calcium chloride hexahydrate with 29 °C melting temperature was used as phase change material and water was used as heat transfer fluid. It has been determined that 588 kJ and 417 kJ heat energy can be stored at two different water inlet temperatures of 65 °C and 45 °C, respectively.

III. Conclusion

To enhance the heat transfer various types of heat exchanger were used in this review paper. Different heat exchanger geometries like tube in tube, shell and tube, triple tube are used. Different geometry inside the tubes like twisted tape, twisted tape with trapezoidal cuts are also used in order to making turbulent flow. Many types of nanofluids like Aluminum oxide (Al_2O_3,), Silicon dioxide (SiO_2), and Ethylene Glycol are used. The effects of the presence of trapezoidal-cut twisted tape inserts on thermal performance factor are also principally governed by the influence of heat transfer improvement. Evidently, nanofluids with higher concentration of Al_2O_3 nanoparticles yield higher thermal performance factors. Therefore, it can be stated that for the range investigated the benefits from the heat transfer improvement as a positive effect over that from the increase of friction loss as a negative effect.

References

[1] S. Gharibi, E. Mortezazadeh, S. J. Hashemi Aghcheh Bodi, and A. Vatani, "Feasibility study of geothermal heat extraction from abandoned oil wells using a U-tube heat exchanger," *Energy*, vol. 153, pp. 554–567, 2018, doi: 10.1016/j.energy.2018.04.003.

[2] 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.

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

[4] S. Basavarajappa, G. Manavendra, and S. B. Prakash, "A review on performance study of finned tube heat exchanger," *J. Phys. Conf. Ser.*, vol. 1473, no. 1, 2020, doi: 10.1088/1742-6596/1473/1/012030.

[5] 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.

[6] G. Çakmak, "Experimental investigation of thermal storage in U-tube heat exchanger," *Int. Commun. Heat Mass Transf.*, vol. 44, pp. 83–86, 2013, doi: 10.1016/j.icheatmasstransfer.2013.03.012.

[7] 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.

[8] 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.

[9] L. H. Dai, Y. Shang, X. L. Li, and S. F. Li, "Analysis on the transient heat transfer process inside and outside the borehole for a vertical U-tube ground heat exchanger under short-term heat storage," *Renew. Energy*, vol. 87, pp. 1121–1129, 2016, doi: 10.1016/j.renene.2015.08.034.

[10] E. Zanchini and A. Jahanbin, "Correlations to determine the mean fluid temperature of double U-tube borehole heat exchangers with a typical geometry," *Appl. Energy*, vol. 206, no. May, pp. 1406–1415, 2017, doi: 10.1016/j.apenergy.2017.09.120.

[11] 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. September, pp. 320–330, 2018, doi: 10.1016/j.apenergy.2018.09.094.

[12] 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.

[13] 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.

[14] 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. August, p. 100805, 2020, doi: 10.1016/j.seta.2020.100805.

[15] 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.

[16] 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.

[17] R. S. Abdulrahman, F. A. Ibrahim, and S. H. Faisel, "Numerical study of heat transfer and exergy analysis of shell and double tube heat exchanger," *Int. J. Heat Technol.*, vol. 38, no. 4, pp. 925–932, 2020, doi: 10.18280/ijht.380419.

[18] N. Kushwaha, T. C. Kumawat, K. D. P. Nigam, and V. Kumar, "Heat Transfer and Fluid Flow Characteristics for Newtonian and Non-Newtonian Fluids in a Tube-in-Tube Helical Coil Heat Exchanger," *Ind. Eng. Chem. Res.*,

vol. 59, no. 9, pp. 3972–3984, 2020, doi: 10.1021/acs.iecr.9b07044.

[19] 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.

[20] B. Kumar, G. P. Srivastava, M. Kumar, and A. K. Patil, "A review of heat transfer and fluid flow mechanism in heat exchanger tube with inserts," *Chem. Eng. Process. Process Intensif.*, vol. 123, pp. 126–137, 2018, doi: 10.1016/j.cep.2017.11.007.

[21] M. Khoshvaght-Aliabadi, S. Davoudi, and M. H. Dibaei, "Performance of agitated-vessel U tube heat exchanger using spiky twisted tapes and water based metallic nanofluids," *Chem. Eng. Res. Des.*, vol. 133, pp. 26–39, 2018, doi: 10.1016/j.cherd.2018.02.030.

[22] 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.

[23] S. FAHAD and A. K. ALSHARA, "Numerical Investigation of Heat Transfer and Flow Characteristics in Shell-and U-Tube Heat Exchanger With Baffles," *J. Univ. Duhok*, vol. 20, no. 1, pp. 404–415, 2017, doi: 10.26682/sjuod.2017.20.1.37.

[24] A. Zarrella, A. Capozza, and M. De Carli, "Analysis of short helical and double U-tube borehole heat exchangers: A simulation-based comparison," *Appl. Energy*, vol. 112, pp. 358–370, 2013, doi: 10.1016/j.apenergy.2013.06.032.