Performance Analysis of Helical Tube Heat Exchanger

Anand Patel[1]

[1]Mechanical Engineer
[1]Department of Mechanical Engineering,
[1]LDRP- Institute of Technology and Research, Gandhinagar, India

Abstract - A heat exchanger is a device that is used to transfer thermal energy between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperatures and in thermal contact. Heat exchangers are one of the most important Typical applications involve heating or cooling of a fluid stream of concern and evaporation or condensation of single or multi component fluid streams heat transfer apparatus that find its use in industries like oil refining, chemical engineering, electric power generation etc. The objective of present work is thermal performance evaluation of helical heat exchanger.

Index Terms – Helical Tube Heat Exchanger, Asbestos Insulator, Thermocouple, Heat Transfer.

I. INTRODUCTION

Heat exchangers (HE) are units that transfer of heat between fluids at distinctive temperatures through warmth transfer. Heat exchangers may additionally be categorized in accordance to extraordinary criteria. The classification separates warmth exchangers (HE) in recuperates and regenerators, in accordance to development is being used. In recuperators, warmth is transferred without delay between the two fluids and by way of opposition, in the regenerators there is no instant warmth trade between the fluids. Rather this is finished through an intermediate step involving thermal power storage. Recuperators can be categorized in accordance to switch manner in direct contact and oblique contact types. In oblique contact HE, there is a wall (physical separation) between the fluids. The recuperators are referred to as a direct switch type. In contrast, the regenerators are units in which there is intermittent warmness trade between the warm and bloodless fluids via thermal strength storage and launch via the warmness exchanger floor or matrix. Regenerators are essentially categorized into rotary and constant matrix models. The regenerators are referred to as an oblique switch type.

An extensive review of recent progress in improving heat transfer using longitudinal vortex generation was made by Jacobi et al. [1]. Fiebig et al. [2] noted that longitudinal vortices exhibit lower flow loss and better heat transfer properties than transverse vortices. Shambhu Kumar Rai et al. [3] reviewed studies conducted by various researchers in the field of heat exchangers. G.E. Kondhalkar et al. [4] analyzes the performance of spiral tube heat exchangers compared to shell and tube heat exchangers. P. Nafon [5] proposed that the heat exchanger consists of a spirally wound block of two pipes of different diameters, the body and coil. Ashish Agarwal et al. [6] experimentally investigated the role of phase change materials in the case of shell-and-tube heat storage in solar dryers. Lavinia Gabriela et al. [7] discussed various thermal energy storage systems and their importance in thermal systems. Sukri Himran et al [8] studied thermal energy storage in paraffin using a tube array in a shell and tube heat exchanger. Thirugnanam. S. et al. [9] studied waste heat recovery using phase change materials. In this study, a concentric tubular heat exchanger using a phase change material was used. Ganesh Patil et al. [10] developed a heat exchanger based on phase change materials using organic and inorganic materials. Jorge A.V. et al.[11]: developed an algorithm for stationary modeling of gasketed plate heat exchangers with generalized configurations. Amey Shirodkar et al. [12] addressed the thermodynamic problem of thermal expansion of pipe heads due to high temperatures. Manoj Kumar Pandita et al. [13] studied the characteristics of shell-and-tube heat exchangers. The performance of the heat exchanger was evaluated using the CFD Fluent package for different baffle angles. Patel Dharmik A. et al.[14] performed a CFD analysis of a triple concentric tube heat exchanger using mathematical models, experimental models and correlations from previous studies. G.W.N. Santosh et al. [15] focused on hot liquid cooling with seawater using a shell-and-tube heat exchanger. Anil Kumar Samal et al [16] studied the design of shell and tube heat exchanger with helical baffle and study the flow and temperature field inside the shell using ANSYS software tools. Thundil Karuppa Raj R et al [17] attempted was made to investigate the impacts of various baffle inclination angles on fluid flow and the heat transfer characteristics of a shell-and-tube heat exchanger for three different baffle inclination angles namely 0°, 10° and 20°.Vindhya Vasiny Prasad Dubey et al [18] focused on extensive thermal analysis of the effects of severe loading conditions on the performance of the heat exchanger. Che´rif Bougriou, et al [19] concerned a new type of heat exchangers, which is that of shell-and-double concentric tube heat exchangers. Andre´ L.H. Costa a et al [20] presented a study about the design optimization of shell-and-tube heat exchangers. O. García-Valladares [21] developed detailed one-dimensional steady-state and transient numerical simulations of the thermal and hydrodynamic behavior of triple concentric tube heat exchangers. Abdalla Gomaa et al. [22] studied experimental and numerical studies on triple concentric tube heat exchangers, paying particular attention to double tube heat exchangers. Hinge [23] investigated the design and performance of a single-segment shell-and-tube heat exchanger considering vertical and parallel baffle plates. Girish et al [24] used Fluent software to study the pressure drop inside a shell and tube heat exchanger considering various baffles. Haran, etc. [25] studied thermal analysis in case of shell and tube heat exchangers considering both water and oil type which is most used in refrigeration and air conditioning industries. Pranita et al. [26] studied shell and tube exchangers by considering the effect of types of baffles considering thermal performance and pressure drop. Petinin et al [27] studied the shell and tube heat exchangers considering different tube patterns variation like triangular, rotated triangular and the combined shell and tube heat exchangers. Kaushik [28] have studied the optimal design in shell and tube heat exchangers considering various parameters such as outer diameter, pitch, length, baffle spacing and cut etc. Yang et al [29] studied the properties of the heat exchanger by changing the fluid flow in the shell in the case of a shell and tube heat exchanger by considering a spiral baffle plate. Kahya et al. [30] studied a shell-and-tube heat exchanger comparing simulation results with analytical calculations using heat transfer studies. Amirtaraj et al [31] investigated a shell-and-tube heat exchanger with an inclined baffle to achieve higher heat transfer efficiency and lower pressure drop. Oguz et al. [32] studied the thermal design of a shell and tube heat exchanger using an intelligent coordination harmony algorithm. Yanzhong [33] investigated the improvement of heat transfer by installing a seal on an annulus. They closed the gap between the baffle and the hull with sealant. Tsjuwang et al. [34] investigated a coupled multi-pass shell-and-tube heat exchanger with spiral baffles to improve heat transfer properties and simplify the manufacturing process. Thermal Performance enhancement study was performed in heat exchanger devices such as [35-38] Patel, Anand et al. [39] HD Chaudhary et al. [40-48] Anand Patel et al. for solar air & water heater or solar cooker, [49-50] Patel Anand Patel et al. for heat spreader by varying geometries of heat collector. The studies involving effect of helical diameter of shell and helical tube heat exchanger [51-60]. The [61-65] research articles include studies to enhance heat transfer rate in a shell and coiled heat exchanger experimentally by varying design parameters such as shell side flow rate, coil diameter, tube side flow rate and coil pitch.

II. EXPERIMENTAL SETUP

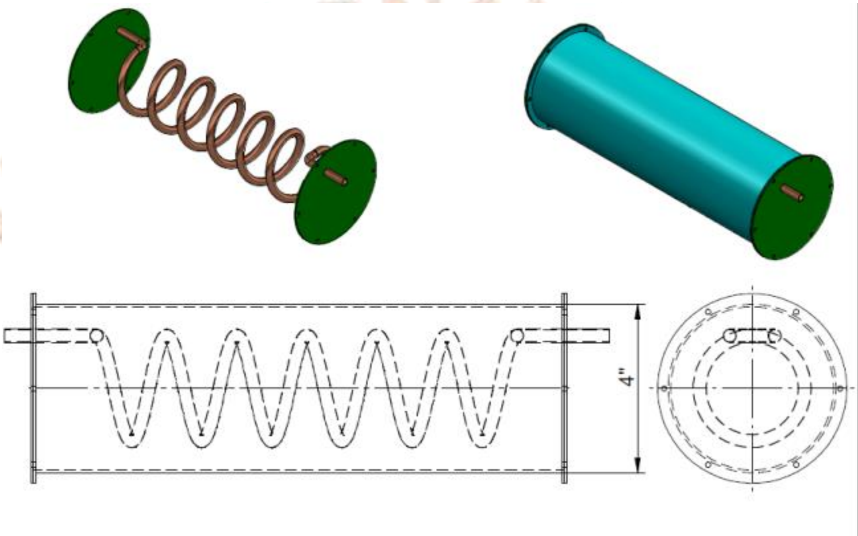

Figure 1 CAD Model of Experimental Set up

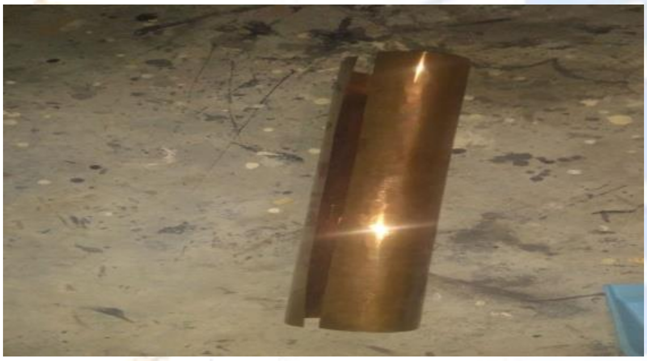

Plate 1 4” Cylindrical pipe

Plate 2 Helical Heat exchanger pipe

Plate 3 Helical Tube Heat exchanger

Plate 4 Asbestos Insulator

Plate 5 Thermocouple and Measuring Flask

In the present work first of all from copper sheet of 20 gauges the 4” cylindrical pipe of 0.23 m length is rolled and fabricated using brazing process. Inside the cylindrical pipe copper helical shaped pipe is inserted which is made of ½” diameter copper The inlets and outlets are provided on 4”copper cylindrical pipe and 2” diameter helical shaped pipe made of ½” copper pipe. The K type thermocouples are used for temperature measurement purpose and 20 liter tank with tape is used to supply cold and hot water in the heat exchanger. The electric heater is used for heating of water.

III. RESULT AND DISCUSSION

Table 1 Result Table

Counter Flow				
Hot		**Cold**		**€ counter flow**
Tin	**Tout**	**Tin**	**Tout**	
65	52.5	33	44.5	0.39
55	45.1	33	41.4	0.45
parallel				
Hot		**Cold**		**€ parallel**
Tin	Tout	Tin	Tout	
65	55.7	33	43.7	0.29
55	47.8	33	42.2	0.33

From result Table 1 it is clear that in case of counter flow the effectiveness values are than parallel flow because of more retention time and uniform heat transfer between hot and cold fluid also due to helical shape in the hot fluid the rate of heat transfer is better which enhances the rate of heat transfer. This heat exchanger is compact in size and better thermal performance can be obtained.

IV. CONCLUSION

The major conclusion is that using such compact heat exchanger the locations where less space availability such heat exchangers can be used.

V. REFERENCES

[1] A.M. Jacobi, R.K. Shah, Heat transfer surface enhancement through the use of longitudinal vortices: a review of recent progress, Experimental Thermal and Fluid Science Volume 11 1995.

[2] M. Fiebig, Embedded vortices in internal flow: heat transfer and pressure loss enhancement, International Journal of Heat and Fluid Flow Volume 16 1995.

[3] Shambhu Kumar Rai, Parmeshwar Dubey, A REVIEW ON HEAT EXCHANGER, IJARIIE, Volume 3, 2017

[4] G. E. Kondhalkar& V. N. Kapatkat, Performance Analysis of Spiral tube heat exchanger used in oil extraction system. International Journal of Modern Engineering Research, Volume 2, 2012.

[5] PaisarnNaphon,Thermal performance and pressure drop of the helical-coil heat exchangers with and without helically crimped fins, International Communications in Heat and Mass Transfer Volume 34, 2007.

[6] Ashish Agarwal, R.M. Sarviya, An experimental investigation of shell and tube latent heat storage for solar dryer using paraffin wax as heat storage material, Engineering Science and Technology, an International Journal Volume 19 2016.

[7] Lavinia Gabriela SOCACIU, Thermal Energy Storage with Phase Change Material, Leonardo Electronic Journal of Practices and Technologies Issue 20, January-June 2012

[8] SyukriHimran, RustanTaraka, Anto Duma, An Analysis on Thermal Energy Storage in Paraffin-Wax Using Tube Array on a Shell and Tube Heat Exchanger, International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering Volume 9, 2015.

[9] Thirugnanam.C, Marimuthu.P, Experimental Analysis of Latent Heat Thermal Energy Storage using Paraffin Wax as Phase Change Material, International Journal of Engineering and Innovative Technology (IJEIT) Volume 3, 2013

[10] Ganesh Patil, Prof. (Dr.) C.H.Bhosale, Prof. N.N.Shinde, Prof.M.M.Wagh,Analysis of Various Phase Change Materials and its Application for Solar Water Thermal Storage System, International Research Journal of Engineering and Technology (IRJET) Volume 02. 2015

[11] Jorge A.W. Gut, Jos_e M. Pinto Modeling of plate heat exchangers with generalized configurations, International Journal of Heat and Mass Transfer Volume 46, 2003.

[12] Amey Shirodkar and Sangita Bansode Optimization of Tubesheet Thickness of Shell and Tube Heat Exchanger, IJISET - International Journal of Innovative Science, Engineering & Technology, Volume 1 2014.

[13] Manoj Kumar Pandita, Prof. Ashok Kumar Gupta, Kailash Kumar Lahadotiya "CFD analysis of a single shell and single tube heat exchanger and determining the effect of baffle angle on heat transfer" International journal of engineering sciences & research technology Volume 4 2015.

[14] Patel Dharmik A, V. D. Dhiman, Jignesh J. Patel, Ravi Engineer, CFD analysis of triple concentric tube heat exchanger, University Journal of Research ISSN (Online) 0000–0000, ISSN (Print) 0000–0000.

[15] G.V.N.Santhosh, Y.V.RamanaMurty, S.SwethaRadha, Performance Analysis of Shell and Tube Heat Exchanger, International Journal of Mechanical Engineering and Computer Applications, Volume 2, 2014.

[16] Anil Kumar Samal, Shell and tube heat exchanger design using CFD tools,

[17] Thundil Karuppa Raj R, Srikanth Ganne , Shell side numerical analysis of a shell and tube heat exchanger considering the effects of baffle inclination angle on fluid flow using CFD.

[18] Vindhya Vasiny Prasad Dubey, Raj Rajat Verma, Piyush Shanker Verma, A.K.Srivastava Performance Analysis of Shell & Tube Type Heat Exchanger under the Effect of Varied Operating Conditions IOSR Journal of Mechanical and Civil Engineering, Volume 11, 2014.

[19] Che´rif Bougriou, Khireddine Baadache Shell-and-double concentric-tube heat exchangers Heat Mass Transfer. 2010.

[20] Andre´ L.H. Costa, Eduardo M. Queiroz Design optimization of shell-and-tube heat exchangers, Applied Thermal Engineering Volume 28, 2008.

[21] O. García-Valladares, Numerical simulation of triple concentric-tube heat exchangers International Journal of Thermal Sciences Volume 43 2004.

[22] Abdalla Gomaa, M.A. Halim, Ashraf Mimi Elsaid , Experimental and numerical investigations of a triple concentric-tube heat exchanger Volume 15, 2015

[23] S.S. Deshpande, S.A. Hinge, Design and performance study of shell and tube heat exchanger with single segmental baffle having perpendicular & parallel-cut orientation, Int. J. Eng. Res. Technol. Volume 3, 2014.

[24] D. Gireesh, J.B. Rao, Design and analysis of heat exchanger with different baffles, Int. J. Mag. Eng. Technol. Manag. Res. Volume 4, 2017.

[25] V. Hari Haran, G. Ravindra Reddy, B. Sreehari, Thermal analysis of shell and tube heat ex-changer using C and Ansys, Int. J. Computer Trends Technol. Volume 4, 2013.

[26] P. Bichkar, O. Dandgaval, P. Dalvi, R. Godase, T. Dey, Proc. Manufacture Volume 20, 2018

[27] M.O. Petinin, A.A. Dare, Performance of shell and tube heat exchangers with varying tube layouts, Br. J. Shell Tube Heat Exchangers Varying Tube Layouts Volume 12, 2016.

[28] A.K. Prasad, K. Anand, Design and analysis of shell and tube type heat exchanger, Int. J. Eng. Res. Technol. Volume 9, 2020

[29] Y.-S. Son, J.-Y. Shin, Performance of a shell-and-tube heat exchanger with spiral baffle plates, KSME Int. J. Volume 15, 2001.

[30] A.H. Cahya, R. Permatasari, Design of shell and tube heat exchanger for waste water using heat transfer research inc, Int. J. Adv. Sci. Technol. Volume 29, 2020.

[31] P.S.P. Amirtharaj, S. Allaudinbasha, M. Janagan, R. Karthikeyan, S. Muthukumar, Design and analysis of shell and tube heat exchanger with inclined baffles, Int. J. Sci. Eng. Dev. Res. Volume 1, 2016.

[32] O.E. Turgut, M.S. Turgut, M.T. Coban, Design and economic investigation of shell and tube heat exchangers using improved intelligent tuned harmony search algorithm, Ain Shams Eng. J. Volume 5, 2014.

[33] S.W. Wen, Y. Li, An experimental investigation of heat transfer enhancement for a shell-and-tube heat exchanger, Appl. Thermal Eng. Volume 29, 2009.

[34] Chen G., Zeng M., Wang Q. and Qi S., (2010), Numerical studies and experimental validation on combined parallel multiple shell-pass shell-and-tube heat exchangers with continuous helical baffles, Chemical Engineering Transactions, 21, 229-234 DOI: 10.3303/CET1021039 Numerical studies on combined parallel multiple shell-pass shell-and-tube heat exchangers with continuous helical baffles.

[35] Anand Patel and Sadanand Namjoshi, "Phase change material based solar water heater," International Journal of Engineering Science Invention., vol. 5, no. 8, August 2016.

[36] Anand Patel, Divyesh Patel, Sadanand Namjoshi (2018); Thermal Performance Evaluation of Spiral Solar Air Heater; Int J Sci Res Publ 5(9) (ISSN: 2250-3153). http://www.ijsrp.org/research-paper-0915.php?rp=P454598

[37] Patel A, Parmar H, Namjoshi S 2016 Comparative thermal performance studies of serpentine tube solar water heater with straight tube solar water heater. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) 13 79–83.

[38] Patel, Anand et al."Thermal Performance Analysis of Fin Covered Solar Air Heater", "International Journal of Engineering Science and Futuristic Technology" (2017).

[39] HD Chaudhary, SA Namjoshi, A Patel, Effect of Strip Insertion on Thermal Performance Evaluation in Evacuated Tube Solar Water Heater with Different Inner Tube Diameter REVISTA GEINTEC-GESTAO INOVACAO E TECNOLOGIAS, Volume 11, Issue 3, Page- 1842-1847.

[40] Anand Patel. "Effect of Inclination on the Performance of Solar Water Heater." International Journal for Scientific Research and Development 11.3 (2023): 413-416.

[41] Patel, Anand. "The Performance Investigation of Square Tube Solar Water Heater", International Journal of Science & Engineering Development Research (www.ijsdr.org), ISSN:2455-2631, Vol.8, Issue 6, page no.872 - 878, June-2023, Available :http://www.ijsdr.org/papers/IJSDR2306123.pdf

[42] "Anand Patel. ""Comparative Thermal Performance Investigation of Box Typed Solar Air heater with V Trough Solar Air Heater"". International Journal of Engineering Science Invention (IJESI), Vol. 12(6), 2023, PP 45-51. Journal DOI- 10.35629/6734".
[43] Patel, Anand, et al. "Comparative Thermal Performance Evaluation of U Tube and Straight Tube Solar Water Heater." International Journal of Research in Engineering and Science (IJRES), vol. 11, no. 6, June 2023, pp. 346–52. www.ijres.org/index.html.
[44] Patel, A., Namjoshi, Dr. S., & Singh, S. K. (2023). Comparative Experimental Investigation of Simple and V-Shaped Rib Solar Air Heater. International Journal of All Research Education and Scientific Methods (IJARESM), 11(6), 2455–6211. http://www.ijaresm.com/uploaded_files/document_file/Anand_PatelYHv7.pdf
[45] Anand Patel, "Comparative Thermal Performance Analysis of Circular and Triangular Embossed Trapezium Solar Cooker with and without Heat Storage Medium", International Journal of Science and Research (IJSR), Volume 12 Issue 7, July 2023, pp. 376-380, https://www.ijsr.net/getabstract.php?paperid=SR23612004356.
[46] Patel, Anand. "Experimental Investigation of Oval Tube Solar Water Heater With Fin Cover Absorber Plate." International Journal of Enhanced Research in Science, Technology & Engineering, vol. 12, issue no. 7, July 2023, pp. 19–26, doi:10.55948/IJERSTE.2023.0704.
[47] Patel, Anand. "Comparative Thermal Performance Evaluation of V-shaped Rib and WShape Rib Solar Air Heater." International Journal of Research Publication and Reviews, vol. 14, issue no. 7, July 2023, pp. 1033–39.
[48] Patel, Anand.""Comparative Thermal Performance Analysis of Box Type and Hexagonal Solar Cooker"", International Journal of Science & Engineering Development Research (www.ijsdr.org), ISSN:2455-2631, Vol.8, Issue 7, page no.610 - 615, July-2023, Available :http://www.ijsdr.org/papers/IJSDR2307089.pdf".
[49] Patel, AK, & Zhao, W. "Heat Transfer Analysis of Graphite Foam Embedded Vapor Chamber for Cooling of Power Electronics in Electric Vehicles." Proceedings of the ASME 2017 Heat Transfer Summer Conference. Volume 1: Aerospace Heat Transfer; Computational Heat Transfer; Education; Environmental Heat Transfer; Fire and Combustion Systems; Gas Turbine Heat Transfer; Heat Transfer in Electronic Equipment; Heat Transfer in Energy Systems. Bellevue, Washington, USA. July 9–12, 2017. V001T09A003. ASME. https://doi.org/10.1115/HT2017-4731.
[50] Anand Patel, "Thermal Performance Investigation of Twisted Tube Heat Exchanger", International Journal of Science and Research (IJSR), Volume 12 Issue 6, June 2023, pp. 350-353, https://www.ijsr.net/getabstract.php?paperid=SR23524161312, DOI: 10.21275/SR23524161312.
[51] M. Rahimi, M.J. Hosseini, M. Gorzin, Effect of helical diameter on the performance of shell and helical tube heat exchanger: An experimental approach, Sustainable Cities and Society, Volume 44, 2019, Pages 691-701, ISSN 2210-6707, https://doi.org/10.1016/j.scs.2018.11.002. (https://www.sciencedirect.com/science/article/pii/S2210670718314434).
[52] Al-Abidi et al., 2014 A.A. Al-Abidi, S. Mat, K. Sopian, M.Y. Sulaiman, A.T. Mohammad, Experimental study of melting and solidification of PCM in a triplex tube heat exchanger with fins, Energy and Buildings, 68 (Part A) (2014), pp. 33-41.
[53] Alkilani et al., 2011 M.M. Alkilani, K. Sopian, M.A. Alghoul, M. Sohif, M.H. Ruslan Review of solar air collectors with thermal storage units Renewable and Sustainable Energy Reviews, 15 (3) (2011), pp. 1476-1490.
[54] Cao et al., 2018 X. Cao, Y. Yuan, B. Xiang, F. Haghighat Effect of natural convection on melting performance of eccentric horizontal shell and tube latent heat storage unit Sustainable Cities and Society, 38 (2018), pp. 571-581.
[55] Chen et al., 2017 X. Chen, Q. Zhang, Z.J. Zhai, D. Wu, S. Liao Experimental study on operation characteristics of a novel refrigeration system using phase change material Energy and Buildings, 150 (2017), pp. 516-526.
[56] Dhaidan et al., 2015 N.S. Dhaidan, J.M. Khodadadi Melting and convection of phase change materials in different shape containers: A review Renewable and Sustainable Energy Reviews, 43 (2015), pp. 449-477.
[57] Gorzin et al., 2018 M. Gorzin, M.J. Hosseini, A.A. Ranjbar, R. Bahrampoury Investigation of PCM charging for the energy saving of domestic hot water system Applied Thermal Engineering, 137 (2018), pp. 659-668.
[58] Joybari et al., 2017 M.M. Joybari, F. Haghighat, S. Seddegh, A.A. Al-Abidi Heat transfer enhancement of phase change materials by fins under simultaneous charging and discharging Energy Conversion and Management, 152 (2017), pp. 136-156.
[59] Kousha et al., 2017 N. Kousha, M.J. Hosseini, M.R. Aligoodarz, R. Pakrouh, R. Bahrampoury Effect of inclination angle on the performance of a shell and tube heat storage unit – An experimental study, Applied Thermal Engineering, 112 (2017), pp. 1497-1509.
[60] Nkwetta and Haghighat, 2014 D.N. Nkwetta, F. Haghighat Thermal energy storage with phase change material – A state-of-the art review Sustainable Cities and Society, 10 (2014), pp. 87-100.
[61] N. Jamshidi, M. Farhadi, D.D. Ganji, K. Sedighi, Experimental analysis of heat transfer enhancement in shell and helical tube heat exchangers, Applied Thermal Engineering, Volume 51, Issues 1–2, 2013, Pages 644-652, ISSN 1359-4311, https://doi.org/10.1016/j.applthermaleng.2012.10.008. (https://www.sciencedirect.com/science/article/pii/S1359431112006643).
[62] N. Jamshidi, M. Farhadi, K. Sedighi, D.D. Ganji Optimization of design parameters for nanofluids flowing inside helical coils International Communications in Heat and Mass Transfer, 39 (2012), pp. 311-317.
[63] H. Shokouhmand, M.R. Salimpour, M.A. Akhavan-Behabadi Experimental investigation of shell and coiled tube heat exchangers using Wilson plots International Communications in Heat and Mass Transfer, 35 (2008), pp. 84-92.
[64] S. Gunes, E. Manay, E. Senyigit, V. Ozceyhan A Taguchi approach for optimization of design parameters in a tube with coiled wire inserts Applied Thermal Engineering, 31 (2011), pp. 2568-2577.
[65] S. Chingulpitak, S. Wongwises A comparison of flow characteristics of refrigerants flowing through adiabatic straight and helical capillary tubes International Journal of Heat and Mass Transfer, 38 (2011), pp. 398-404.
[66] Patel, Anand. "Experimental Evaluation of Twisted Tube Solar Water Heater." International Journal of Engineering Research & Technology (IJERT), vol. 12, issue no. 7, IJERTV12IS070041, July 2023, pp. 30–34, https://www.ijert.org/research/experimental-evaluation-of-twisted-tube-solar-water-heater-IJERTV12IS070041.pdf.