Comparative Thermal Performance Analysis of Helical Coil Heat Exchanger with Nanofluid Using ANSYS

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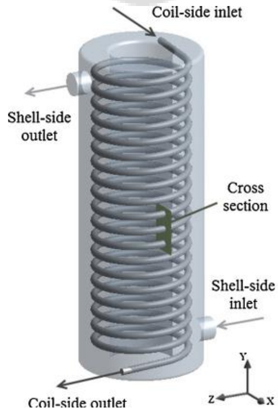
ABSTRACT

In cooling system of heat exchanger, the water is evaporated at high temperature, so it will need to add water and also water is low capacity of absorb heat. By using nanofluids in heat exchanger instead of water, it can improve the thermal efficiency of heat exchanger. So, the effect of the heat exchanger is improved and the overall efficiency of heat exchanger will have increased. A Nanofluid is a fluid containing nanometer-sized particles, called nanoparticles. Nanofluid is mixed with the fluid like water. Conventional heat transfer fluids such as Water, mineral oil, and ethylene glycol play an important role in many industries including power generation chemical production, air conditioning, transportation, and microelectronics etc. In particular, tube containing nanofluids provide several advantages over conventional fluids, including thermal conductivities far above those of traditional solid/liquid suspensions, a nonlinear relationship between thermal conductivity and concentration, strongly temperature-dependent thermal conductivity, and a significant increase in critical heat characteristics. In present work, Computational Fluid Dynamics Analysis is performed for different mass flow rates at coil side and constant rate of shell side under steady state conditions. Also, the volume fraction of Nano particles can be varying. Further a computational work has been accomplished to determine the effect of heat transfer in the helical coil heat exchanger by considering the parameters like pitch, coil diameter, total height of coil etc. In this work, evaluated the results from ANSYS CFD software with different coil flow and compared to each for finding better one. It was found that the characteristics of heat transfer were found better at the $Al_2O_3+H_2O$ *with 5% and it is well desired to be maintained in the coil.*

Keywords: *Helical Coil Heat Exchanger (HCHE), Nanofluid, Aluminum oxide, ANSYS CFD*

I. INTRODUCTION

It has been widely reported in literature that heat transfer rates in helical coils are higher as compared to those in straight tubes. Due to the compact structure and high heat transfer coefficient, helical coil heat exchangers find extensive use in industrial applications such as power generation, nuclear industry, process plants, heat recovery systems, refrigeration, food industry, etc. [1]. Heat exchanger with helical coils is used for residual heat removal systems in islanded or barge mounted nuclear reactor systems,wherein nuclear energy is utilized for desalination of seawater. The performance of the residual heat removal system, which uses a helically coiled heat exchanger, for various process parameters was investigated by [1].



II. PROBLEM IDENTIFICATION

Most of the previous works on helically coiled tube have employed water as the heat transfer fluid. Recently, much work has been carried out on heat transfer by replacing the conventional heat transfer fluids with nanofluid in a circular tube and helical type heat exchangers. In particular, the work on heat transfer in helically coiled tube by using Al2O3+H2O nanofluid is very limited with varying their volume of concentration. Moreover, the effect of coiled tube pitch and flow direction on Al2O3+H2O nanofluid heat transfer were reported. Further, the coiled tube with Al2O3+H2O nanofluid correlations for heat transfer rate, overall heat transfer coefficient and effectiveness have been developed. Therefore, in the present investigation the Al2O3+H2O nanofluid is employed as coiled tube side fluid in a shell and helically coiled tube heat exchanger to analyse the thermal and flow behavior at particle volume concentration. The results are compared with the traditional fluid i.e. water and with the different volume of concentration and flow rateresults.

III. METHODOLOGY

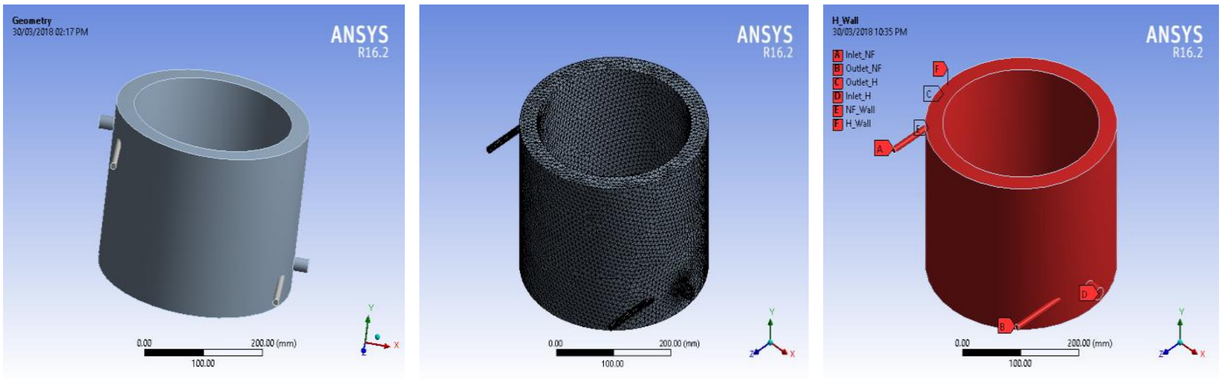
In this work a Computational Fluid Dynamic (CFD/CFX) analysis has been performed in the helical coil heat exchanger (HCHE). Some parameters/inputs of heat exchanger have been referred from the literature of [1] [20]. In this work also, Response surface optimization in ANSYS has been done for optimized heat exchanger parameters. Obtained results from the present and previous work have been compared.The properties of coolant (Al2O3+H2O) with different concentration (1%-5%) and base fluid flow Hydrogen are as shown in Table 1.

Table 1. Fluid and Material Properties of cold fluid (Al2O3+H2O) with different concentration (1%-5%) and hot fluid (Hydrogen) [19]

Properties of Fluids					
Materials	**Volume of Concentration**	**Density**	**Specific Heat Capacity**	**Thermal Conductivity**	**Viscosity**
	c%	**ρ**	**Cp**	**k**	**μ**
Hydrogen	-	71.0	14310	0.182	0.009
Pure Water	0%	981.3	4189	0.643	0.000598
$Al_2O_3+H_2O$	1%	1007.4	4154.7	0.661	0.000612
$Al_2O_3+H_2O$	2%	1033.6	4120.5	0.68	0.000627
$Al_2O_3+H_2O$	3%	1059.8	4086.2	0.699	0.000642
$Al_2O_3+H_2O$	4%	1086	4052	0.719	0.000657
$Al_2O_3+H_2O$	5%	1112.2	4017.8	0.739	0.000672

3.1 COMPUTATIONAL FLUID DYNAMICS (CFD)

The invention of high speed computers, combined with the accurate numerical methods for solving physical problems, has revolutionized the way we study and practice fluid dynamics and heat transfer problems. This is called Computational Fluid Dynamics (CFD/CFX), and it has made it possible to analyzed complex flow geometries with the same ease as that faced while solving idealized problems using conventional methods. CFD may thus be regarded as a zone of study combining fluid dynamics and numerical analysis.



(a) (b) (c)

Fig 2. Helical coil heat exchanger (a) 3D modeling of HCHE, (b) Meshed view of HCHE and (c) Different boundary conditions in HCHE

The following steps are follow by CFD Analysis:

(a) Modeling of domain
(b) Meshing of domain
(c) Apply Boundary conditions and
(d) CFD Analysis.

IV. RESULTS AND DISCUSSIONS

In this section are discussing about the various results obtained from analysis and optimizations. The present work used the nanofluid and water. In this work show the replacing fluid from cold side as traditional coolant. This result compared with traditional type (water) results with nanofluids (different % concentration) and improve the overall efficiency of the heat exchanger with helical type.

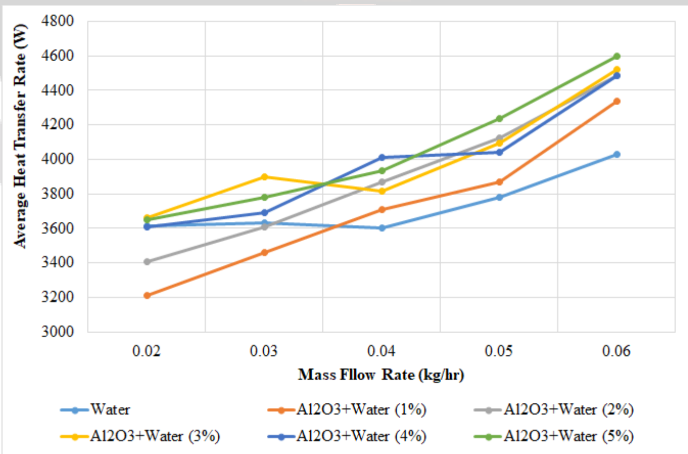


Fig 3. Graph of average heat transfer rate between water, Al2O3+H2O as a coolant used in HCHE obtained from ANSYS 16.2

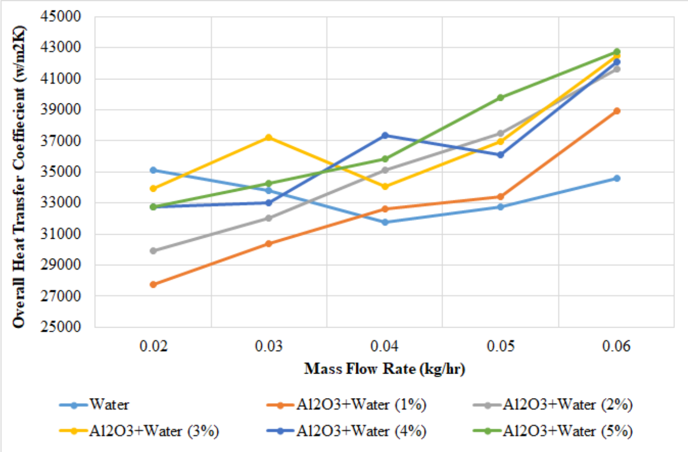


Fig 4. of overall heat transfer coefficient between water, Al2O3+H2O as a coolant used in HCHE obtained from ANSYS 16.2

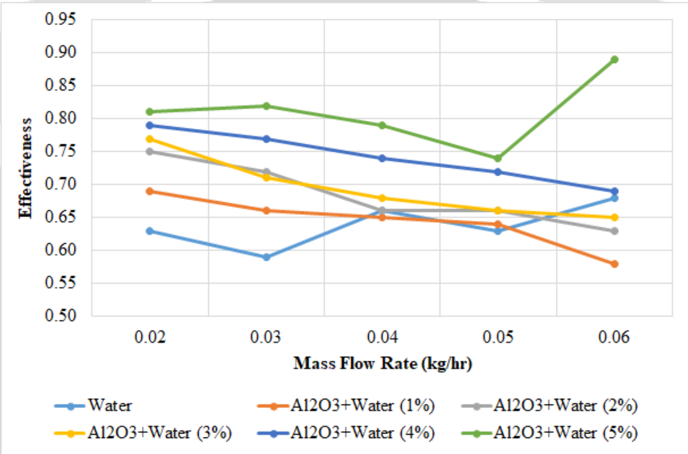


Fig 5. Graph of effectiveness between water, Al2O3+H2O as a coolant used in HCHE obtained from ANSYS 16.2

Table 5. Average heat transfer comparison and improvement between traditional cold fluid and nanofluid cold fluid (present)

Average Heat Transfer (W)			
Mass Flow Rate	**Water**	**Al2O3+Water (5%)**	**% Improvement**
0.02	3612.98	3651.32	**1%**
0.03	3630.04	3779.54	**4%**
0.04	3602.60	3932.28	**9%**
0.05	3782.14	4238.94	**12%**
0.06	4028.89	4596.46	**14%**

Table 5. Overall heat transfer coefficient comparison and improvement between traditional cold fluid and nanofluid cold fluid (present)

Overall Heat Transfer Coefficient (W/m2K)			
Mass Flow Rate	**Water**	**Al2O3+Water (5%)**	**% Improvement**
0.02	35083.17	32754.05	**-7%**
0.03	33783.18	34268.83	**1%**
0.04	31789.41	35825.10	**13%**
0.05	32749.11	39768.46	**21%**
0.06	34620.65	42734.79	**23%**

Table 5. Effectiveness comparison and improvement between traditional cold fluid and nanofluid cold fluid (present)

Effectiveness			
Mass Flow Rate	**Water**	**Al2O3+Water (5%)**	**% Improvement**
0.02	0.63	0.81	**29%**
0.03	0.59	0.82	**39%**
0.04	0.66	0.79	**20%**
0.05	0.63	0.74	**17%**
0.06	0.68	0.89	**31%**

V. CONCLUSION

- In this numerical simulation has been workout on heat transfer characteristics pure water and Al_2O_3+H_2O nanofluid in helical coil heat exchanger (HCHE).
- These numerical results reveal the enhancement in heat transfer, with respect to the base fluid, identified to characterize of nanofluid with different concentration percentage.
- Heat transfer enhancement is increasing with the nanoparticle and using helical coil tube geometry.
- The Heat transfer rate increases1%, 4%, 9%, 12% and 14% as compared to traditional fluid flow (water) with increase in flow rate at coil side, because at higher flow rates, the dispersion effects and chaotic movement of the Nano-particles intensifies the mixing fluctuations and causes increase in overall heat transfer coefficient. Hence the Al_2O_3+H_2O 5% volume of concentration has been selected for best improvement in this work.
- The overall heat transfer coefficient increases-7%, 1%, 13%, 21% and 23% with increase in flow rate at coil side. At 0.06 kg/hr mass flow rate, the deviation occurred which indicates the optimal flow rate in the coil.
- The heat exchanger effectiveness is increased 29%, 39%, 20%, 17% and 31% considerably with increase in coil side flow rate and Nano particle percentage.
- Nanofluid containing small number of nanoparticles have substantially higher overall heat transfer coefficient than those of base fluids. And it increases with increase in the particle volume fraction (Al_2O_3+H_2O 5%), because the increase in the nanoparticle volume fractions, intensifies the interaction and collision of nanoparticles.

Reference

[1] Kishor Kumar Sahu, Dr. N. K. Saikhedkar, "Computational Fluid Dynamic Analysis for Optimization of Helical Coil Heat Exchanger", International Journal of Engineering Research & Technology, Vol. 5, Issue 4, 2016.

[2] Yimin Xuan, Qiang Li, "Heat transfer enhancement of nanofluids", International Journal of Heat and Fluid Flow 21, Vol. 58, Issue 64, 2000.

[3] P. Sivashanmugam, "Application of Nanofluids in Heat Transfer", An Overview of Heat Transfer Phenomena, Chapter 14, 2012.

[4] WisutChamsa-ard, Sridevi Brundavanam, Chun Che Fung, Derek Fawcett and Gerrard Poinern, "Nanofluid Types, Their Synthesis, Properties and Incorporation in Direct Solar Thermal Collectors: A Review", Nanomaterials, Vol. 7, Issue 131, 2017.

[5] GolakiyaSatyamkumar, SarvaiyaBrijrajsinh, Makwana Sulay, Thumar Ankur, Rathwa Manoj, "Analysis of Radiator with Different Types of Nano Fluids", Journal of Engineering Research and Studies, Vol. VI, Issue I, 2015.

[6] V. Ajaykumar, T. Sudhakar, R. Titusjames, U. Sathishkumar, "Investigation of Shell and Tube Heat Exchanger with Nano Fluid using ANSYS", International Journal of Science Technology & Engineering, Vol. 2, Issue 06, 2015.

[7] Raman Chouda, "Analysis of Heat Exchanger with Nanofluids", International Journal of Core Engineering & Management, Vol. 1, Issue 6, 2014.

[8] Dr. M. Thirumarimurugan, Dr. T. Kannadasan, A. Sivalingam, T.S. Krushnathej, Prof. S. Gopalakrishnan, "Experimental and Simulation Studies on Spiral Heat Exchanger for Miscible System Using Matlab" International Journal of Advanced Engineering Technology, Vol.II, Issue IV, pp 269-277, 2011.

[9] PaisarnNaphon, Somchai Wongwises, "A study of the heat transfer characteristics of a compact spiral coil heat exchanger under wet-surface conditions" Experimental Thermal and Fluid Science", Vol. 29, pp 511–521, 2005.
[10] Dr M A. Hossain, M I. Islam, S A. Ratul, MT U R. Erin, "Comprehensive Study on Heat Transfer Co-efficient and Effectiveness for Water Using Spiral Coil Heat Exchanger" Proceedings of the Global Engineering, Science and Technology Conference 2012, Dhaka, Bangladesh, pp 28-29, 2012.