CFD Analysis of Shell and Tube heat Exchanger by Different Nano Fluids

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Abstract

In this paper, CFD analysis is conducted on the shell and tube heat exchanger, using forced convective heat transfer to determine flow characteristics of nanofluids by varying volume fractions and mixed with water, the nanofluids used in the analysis are Titanium Nitride and Zinc Oxide with constant volume concentrations of 0.02 % flowing under turbulent flow conditions. CFD analysis is done on the heat exchanger by applying the properties of the nanofluid with different volume fractions to obtain temperature distribution, heat transfer coefficient and heat transfer rate. 2D model of the shell and tube heat exchanger will be done in Pro/Engineer and analysis will be done in Ansys. The results revealed that as volume fraction and Reynolds number increased Nusselt number increased, and friction factor decreased.

Keyword:Nusselt number, Numerical analysis, heat exchanger, heat transfer, friction factor, enhancement.

Introduction: The thermal conductivity of heating or cooling of fluids is very important property for the development of energy efficient heat transfer equipment. Meanwhile, all the processes involving heat transfer, the thermal conductivity of the fluid is one of the basic and most important parameter taken into account in designing and controlling the processes. Nanofluids are engineered colloids which are made of a base fluid and nanoparticles of (1-100) nm. It has been found by many researchers that the nanofluids provide higher thermal conductivity compared to base fluids. Its value increases with the increase in particle concentration, temperature, particle size, dispersion and stability. Nevertheless, it is expected that other factors like density, viscosity, and specific heat are also responsible for the convective heat transfer enhancement of nanofluids. Nanofluids are having high thermal conductivity and high heat transfer coefficient compared to single phase fluids.

Heat transfer and separation of fluid flow in annular channel occurred due to change in pressure gradient caused by an increase or decrease of cross-sectional area of annular channel. Fluid flow in annular channels can be found in several heat exchange devices, such as heat exchangers, nuclear reactors, evaporators, condensers, etc. Generally, many experimental and numerical studies are concerned with the phenomena of separation and reattachment flow.

A nanofluid is prepared by dispersing particles of metal or metal oxide with sizes ranges from 0-70 nm, in a base liquid such as water. The purpose of using nanofluids is to achieve higher values of heat transfer coefficient compared with that of the base liquid. This is achieved by the dispersion of solid particles, which have higher thermal conductivity than the base liquid. There are many engineering applications that can benefit from the use of nanofluids, for example absorption refrigeration, micro electromechanical systems, lubrication of automotive systems, coolant in machining, automobile radiator cooling, solar water heating, heat exchangers, several medical applications, nuclear reactors, and in several aerospace applications. Recent advances in material technology have made it possible to produce innovative heat transfer fluids by suspending nanometer-sized particles in base fluids, which could change the transport and thermal properties of the liquids. Nanofluids represent solid-liquid composite materials consisting of solid nanoparticles with sizes no larger than 100 nm suspended in liquid. This study presents the work undertaken by various investigators and the possible impact of nanofluids on the enhancement of heat transfer in the near future.

Large volume of studies devoted to characterization of individual thermo-physical properties of nanofluids, such as thermal conductivity, viscosity, and agglomeration of nanoparticles, has been summarized in a number of review articles.

Evaluation of cooling efficiency, i.e., ability to remove heat from the heat source, includes assessing flow regime-dependent contributions from thermal conductivity, viscosity, specific heat, and density of the fluid and also depends on the applied flow regime. The studies devoted to evaluation of the heat transfer performance of nanofluids are scarce and inconclusive compared to the studies on the thermo-physical properties of various nanofluids indicating a significant gap between fundamental research and practical applications of nanofluids for thermal management.

II. Computational Fluid Dynamics

CFD is useful for studying fluid flow, heat transfer; chemical reactions etc. by solving mathematical equations with the help of numerical analysis. CFD resolve the entire system in small cells and apply governing equations on these discrete elements to find numerical solutions regarding pressure distribution, temperature gradients. This software can also build a virtual prototype of the system or device before can be apply to real-world physics to the model, and the software will provide with images and data, which predict the performance of that design. More recently the methods have been applied to the design of internal combustion engine, combustion chambers of gas turbine and furnaces, also fluid flows and heat transfer in heat exchanger. The development in the CFD field provides a capability comparable to other Computer Aided Engineering (CAE) tools such as stress analysis codes.

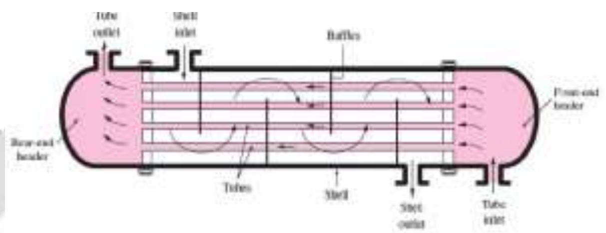

Fig 1.Schematic diagram of heat exchanger

The analysis is performed on a shell and tube heat exchanger with the specifications as mentioned below.

Table 1. Shell and Tube heat exchanger specifications

Specification	**Dimensions (mm)**
Length of heat exchanger	1500
No of tubes	09
Diameter of inner shell	136
Diameter of outer shell	142
Diameter of inner tube	17
Diameter of outer tube	23
No of baffles	05

Grid Independence is the term used to designate the enhancement of results by using successively smaller cell sizes for the calculations. A calculation should reach the correct result so the mesh becomessmaller; hence the term is known as grid Independence. The ordinary CFD technique is, to start from coarse mesh and gradually improve it until the changes detected in the values are smaller than a pre-defined acceptable error. There are 2 problems with this. Firstly, it can be quite difficult with other CFD software to gain even in a single coarse mesh resulting for some problems. Secondly, refining a mesh by a factor two or above can lead to take more time. This is clearly offensive for software intended to be used as an engineering tool design operating to constricted production limits. In addition to that the other issues have added significantly to the perception of CFD as an extremely difficult, time consuming and hence costly methodology. Finally grid independence test has been conducted at a flow rate of 8 LPM hot water, 10LPM cold water flow rates in ANSYS-FLUENT, by decreasing and increasing the size of the elements. The gained results are tabulated in Table 1, for outlet temperatures of cold water and hot water of 2-pass double pipe heat exchanger.

III. RESULTS AND DISCUSSION

Temperature contours the temperature contours of inside pipe of Shell and Tube heat exchanger are shown in Fig. 2. From the figure it was observed that temperature of inside fluid i.eTiN nano fluid gradually increased from inlet to the outlet of pipe. Fig. 4 shows the temperature contours of annulus pipe of Shell and Tube heat exchanger. From the figure it was observed that temperature of annulus fluid i.e., pure water gradually decreased from inlet to the outlet of annulus pipe.

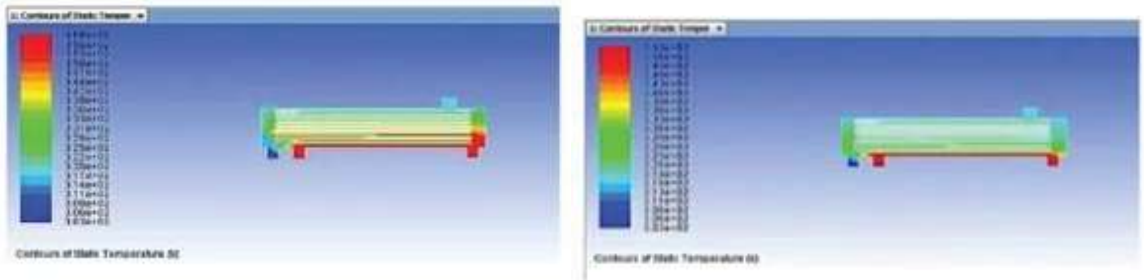

Fig 2. Temperature distribution at 0.02 volume concentration

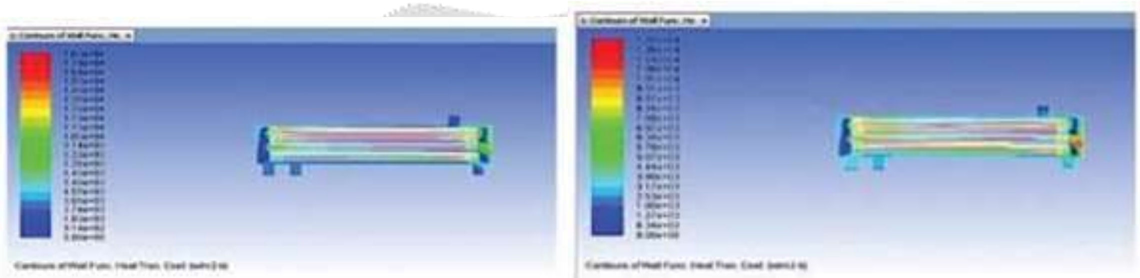

Fig 3. Heat Transfer Coefficient

Conclusion:

A steady state computational fluid dynamics (CFD) models were simulated by ANSYS FLUENT 16.0 and the effect of Reynolds number and Nusselt number on the flow behaviour of the nanofluid in the pipe were studied and the variations in the properties are presented. The heat transfer enhancement is observed to be better in the turbulent region compared to that of laminar region for all volume fractions considered in the analysis. The maximum error was found that 10.56%. It is observed that according to simulation results there is a 18% enhancement in heat transfer coefficient at 0.2% volume concentration of TiN nanofluid when compared to water at Reynolds number range of 22000. The friction factor is increased with the increase of volume concentration but it is observed that the friction factor enhancement is less compared to the enhancement to the heat transfer for volume fraction considered in the analysis.

References:

(1) T. Hussein, G. Ahmadi, TuqaAbdulrazzaq, Ahmed JassimShkarah, S.N. Kazi, A. Badarudin, et al., Thermal performance of nanofluid in ducts with double forward-facing steps, J. Taiwan Inst. Chem. Eng. 47 (2015) 28–42.

(2) H. Togun, A. Tuqa, S.N. Kazi, A. Badarudin, M.K.A. Ariffin, H. Togun, A. Tuqa, S.N. Kazi, A. Badarudin, M.K.A. Ariffin, Heat transfer to laminar flow over a double backward-facing step, Int. J. Mech. Aerosp. Manuf. Ind. Sci. Eng. World Acad. Sci. Eng. Technol. 80 (2013) 117–139.

(3) M.R. Safaei, T. Hussein, K. Vafai, S.N. Kazi, A. Badarudin, Investigation of heat transfer enhancement in a forward-facing contracting channel using FMWCNT nanofluids, Numer. Heat Transfer, Part A Appl. 66 (2014) 1321–1361.

(4) T. Hussein, A. Tuqa, S.N. Kazi, H.K. Abdul Amir, B. Ahmed, M.K.A. A, et al., Numerical study of turbulent heat transfer in separated flow: review, Int. Rev. Mech. Eng. 7 (2013) 337–349.

(5) T. Hussein, A.J. Shkarah, S.N. Kazi, A. Badarudin, CFD simulation of heat transfer and turbulent fluid flow over a double forward-facing step, Math. Probl. Eng. 2013 (2013) 1–10.

(6) T. Hussein, T. Abdulrazzaq, S.N. Kazi, A. Badarudin, A.A.H. Kadhum, E. Sadeghinezhad, A review of studies on forced, natural and mixed heat transfer to fluid and nanofluid flow in an annular passage, Renew. Sust.Energ. Rev. 39 (2014) 835–856.

(7) L. Boelter, G. Young, H.W. Iversen, An Investigation of Aircraft Heaters XXVII—Distribution of Heat Transfer Rate in the Entrance Section of a Circular Tub. NACA-TN-1451, 1948.

(8) L. Khezzar, S.R.N. De Zilwa, J.H. Whitelaw, Combustion of premixed fuel and air downstream of a plane sudden-expansion, Exp. Fluids 27 (1999) 296–309.
(9) S. De Zilwa SR, J.H. Whitelaw Sivasegaram, Active control of isothermal and combusting flows in plane sudden-expansions, Proc. Transp. Phenom. Thermal Sci. Process Eng. (1997) 325–330.
(10) S.K. Park, T. Ota, An experimental approach to turbulent heat transfer using a symmetric expanded plane channel, J. Mech. Sci. Technol. 24 (2010) 857–863.
(11) C.C. Chieng, B.E. Launder, On the calculation of turbulent heat transport downstream from an abrupt pipe expansion, Numer. Heat Transfer 3 (1980) 189–207.
(12) B.T.F. Chung, S. Jia, A turbulent near-wall model on convective heat transfer from an abrupt expansion tube, Heat Mass Transf. 31 (1995) 33–40.
(13) W.D. Hsieh, K.C. Chang, Calculation of wall heat transfer in pipeexpansion turbulent flows, Int. J. Heat Mass Transf. 39 (1996) 3813–3822.
(14) D. Lee, J. Lee, H. Park, M. Kim, Experimental and numerical study of heat transfer downstream of an axisymmetric abrupt expansion and in a cavity of a circular tube, J. Mech. Sci. Technol. 25 (2011) 395–401.
(15) E. Abu-Nada, Application of nanofluids for heat transfer enhancement of separated flows encountered in a backward facing step, Int. J. Heat Fluid Flow 29 (2008) 242–249
(16) A.S. Kherbeet, H.A. Mohammed, B.H. Salman, The effect of nanofluids flow on mixed convection heat transfer over microscale backward-facing step, Int. J. Heat Mass Transf. 55 (2012) 5870–5881.
(17) H. Togun, M.R. Safaei, R. Sadri, S.N. Kazi, A. Badarudin, K. Hooman, et al., Numerical simulation of laminar to turbulent nanofluid flow and heat transfer over a backward-facing step, Appl. Math. Comput. 239 (2014) 153–170.
(18) B.C. Pak, Y.I. Cho, Hydrodynamic and heat transfer study of dispersed fluids with submicron metallic oxide nanoparticles, Experimental Heat transfer, 11 (1998) 150-170.
(19) R.L. Hamilton, O.K. Crosser, Thermal conductivity of heterogeneous two-component systems, I & EC Fundamentals, 1 (1962) 187-191.
(20) H.C. Brinkman, The viscosity of concentrated suspensions and solutions, International Journal of Chemical and Physics, 20 (1952) 571-581.
(21) Y. Xuan, Q. Li, Investigation on convective heat transfer and flow features of nanofluids, Journal of Heat Transfer, 125 (2003) 151-155.
(22) V. Gnielinski, New equations for heat and mass transfer in turbulent pipe and channel flow, International Chemical Engineering. 16 (1976) 359-368.
(23) R.H. Notter, M.W. Rouse, A solution to the Graetz problem – III. Fully developed region heat transfer rates, Chemical Engineering Science 27 (1972) 2073–2093.
(24) H.Blasius, Grenzschichten in FlussigkeitenmitkleinerReibung (German), Z. Math. Phys., 56 (1908) 1-37.
(25) B.S. Petukhov, Heat transfer and friction in turbulent pipe flow with variable physical properties, J. P. Hartnett and T. F.Irvine, (eds), Advances in Heat Transfer, Academic Press, New York, (1970) 504-564.