CFD Analysis on Finned Tube Heat Exchanger using Alumina Nanofluid As Coolant

Edwin Cyriac
PG Scholar
Department of Mechanical Engineering
Mar Athanasius College of Engineering

Reji Mathew
Professor
Department of Mechanical Engineering
Mar Athanasius College of Engineering

Aneesh K Johny
PG Scholar
Department of Mechanical Engineering
Mar Athanasius College of Engineering

Sunny K George
Professor
Department of Mechanical Engineering,
Mar Athanasius College of Engineering

Issac Thamban
Professor
Department of Mechanical Engineering
Mar Athanasius College of Engineering

Abstract

Finned tube heat exchanger are used for heat transfer between air, gas and liquids or steam. Heat exchanger with finned heating surfaces, so-called finned tube heat exchanger, offer the possibility of heat transfer between gases and liquids significantly space-saving and is more efficient to implement than it is possible with straight tubes. Finned tube heat exchangers are designed to transfer heat from clean air and gases with high efficiency on liquids or vapors, and vice versa. In this way the media can be heated, cooled or condensed, in a closely space. Finned tube heat exchangers can be used for different applications and in a variety of designs. In this work a model of finned tube heat exchanger was made and by using ANSYS fluent and used Al2O3 nanofluid as cooant for heat transfer enhancement and the analysis was carried out. CFD simulations are done for different concentration of Al2O3 at different flow speed. Temperature contours in all the cases can be plotted by using CFD.by this we can clearly understand the heat transfer enhancement role of small concentration of nano particle on base fluid.
Keywords- Nanofluid, CFD, Al2O3, Finned Tube Heat Exchanger, Industrial Chiller

I. INTRODUCTION

Finned tube heat exchanger are mainly used for heat transfer between liguid and gasius working medium, for example, between air and water, steam and water etc. Heat exchanger with finned heating surfaces, so-called finned tube heat exchanger, offer the possibility of heat transfer between gases and liquids significantly space-saving and is more efficient to implement than it is possible with straight tubes. Finned tube heat exchangers are designed to transfer heat from clean air and gases with high efficiency on liquids or vapors, and vice versa. In this way the media can be heated, cooled or condensed, in a closely space. Finned tube heat exchangers can be used for different applications and in a variety of designs. The problem of non-Newtonian fluid flow has been under a lot of attention in recent years because of its various applications in different fields of engineering specially the interest in heat transfer problems of non-Newtonian fluid flow, such as hot rolling, lubrication, cooling problems and drag reduction.

II. LITERATURE BACKGROUND

Madrood, M. R. K., Etemad S. G., Bagheri R**.** [1] Natural convection heat transfer of non-Newtonian nanofluids(dispersion of Al_2O_3 and TiO_2) in 0.5 wt% aqueous solution of carboxy methyl cellulose) in a vertical cylinder uniformly heated from below and cooled from top was investigated experimentally. They showed that the heat transfer performance of nanofluids is significantly enhanced at low particle concentrations and that increasing nanoparticle concentration has a contrary effect on the heat transfer of nanofluids.

Cheng (2012). [2] studied the free convection heat transfer over a truncated cone embedded in a porous medium saturated by a non-Newtonian power-law nanofluid with constant wall temperature and constant wall nanoparticle volume fraction and reported that increasing the thermophoresis parameter or the Brownian parameter tends to decrease the reduced Nusselt number. Moraveji et al. [3] numnerically investigated forced convective heat transfer effect on the non-Newtonian nanofluid containing Al2O3 and xanthan aqueous solution as a liquid single phase in the horizontal tube with constant heat flux. M. Hojjat, S. et al. [4] investigated the forced convective heat transfer of these nano-fluids through a uniformly heated circular tube under turbulent flow conditions. Results reveal that the local and average heat transfer coefficients of nanofluids are larger than that of the base fluid. Heat transfer enhancement of nanofluids increases with an increase in nanoparticle concentration. Similar trend are demonstrated for Nusselt number of nano fluids. For a given nanop article concentration and Peclet numb er, the local heat transfer coefficient of the base fluid and that of the nanofluids decreases with the axial distance from the tube inlet.

Mohammad Hojjat et al.[5] Forced convection heat transfer of non-Newtonian nanofluids in a circular tube with constant wall temperature under turbulent flow conditions was investigated experimentally Al2O3,TiO2and CuO nanoparticles into the base fluid(CMC) Results indicate that the convectiveheat transfer coefficient of nanofluids is higher than that of the base fluid. The enhancement of the convective heat transfer coefficient increases with an increase in the Peclet number and the nanoparticle concentration. The increase in the convective heat transfer coefficient of nanofluids is greater than the increase that would be observed considering strictly the increase in the effective thermal conductivity of nanofluids. Mahmoud Reza et al. [6] Al2O3, TiO2 nanoparticles in a 0.5 wt. % CMC. Natural convection heat transfer of non-Newtonian nanofluids in a vertical cylinder uniformly heated from below and cooled from top was investigated experimentally. Results show that the heat transfer performance of nano fluids is significantly enhanced at low particle concentrations. Increasing nanoparticle concentration has a contrary effect on the heat transfer of nanofluids, so at concentrations greater than 1 vol. % of nanoparticles the heat transfer coefficient of nano fluids is less than that of the base fluid

R. Kamali , A.R. Binesh[7] numerically investigated convective heat transfer of multi-wall carbon nanotube (MWCNT)-based nano fluids in a straight tube under constant wall heat flux condition. The objectives of this research are to provide detailed information of non-Newtonian behavior of CNT nanofluids, comparison of the numerical simulation predictions to the experimental measurements and investigation of non-Newtonian effects on the local heat trans fer of the CNT nano fluid and compare the thermal performance of the CNT nanofluids and convent ional fluids. Putra et al.[8] presented a study of the natural convection of nanofluids (Al2O3–water, CuO–water with w = 1–4%) using a horizontal cylinder test section with one end heated and the other cooled. The time to reach the steady state was much lesser even at relatively high particle concentrations, due to the non-agglomera-tive and mono-dispersive nature of the nanofluids. The heat transfer coefficient was found to be higher at the hot wall than at the cold wall. The natural convective heat transfer is higher for the CuO–water than the Al2O3–water nanofluid.

Wen and Ding [9] conducted experiments on nanofluids (TiO2–water with w =0–1%) using two horizontally positioned aluminum discs separated by a 10 mm gap filled with nanofluid. The lower disc was heated at the bottom surface and the upper surface was open to the atmosphere.The temperature rose smoothly without any initial temperature oscillations as compared to micro-sized particles. The time to reach the steady state was also shorter and the heating surface temperature was found to increase with nanoparticle concentra-tions. The temperature difference between the walls increased with the volume fraction and reached 2.3 K for a w = 0.57% compared to 1.5 K for pure liquid. Hwang et al.[10] theoretically presented the effects of the volume fraction, the size of nanofluids (Al2O3–water),and the average temperature of nanofluids on natural convective heat transfer characteristics in a rectangular cavity heated from the bottom.

III. METHODOLOGY

A. *Designing of Finned Tube Heat Exchanger*

The figure 1 shows the finned tube heat exchanger made in solidworks software and finnes are arranged in the tubes. There is one inlet and one outlet. The inlet is where the hot fluid comes in and out let is where the hot fluid goes out. The air is the cooling medium in these kinds of heat exchangers and heat will transfer from hot fluid to air through fluid convection. Finned tube heat exchanger offer the possibility of heat transfer between gases and liquids. Heat exchanger with finned heating surfaces used for heat transfer between air, gas and liquids or steam. It is space-saving and is more efficient to implement than it is possible with straight tubes. The effectiveness of the heat transfer will be improved by using finns.Finned tube heat exchangers are designed to transfer heat from clean air and gases with high efficiency on liquids or vapours, and vice versa. In this way the media can be heated, cooled or condensed, in a closely space. Finned tube heat exchangers can be used for different applications and in a variety of designs.

Table 1: Geometric details

Part ID	*Dimensions*
Overall dimensions (LxBxH)	*850 x 520 x 620*
Tube dia	*OD – 20 mm ID – 15 mm*
Fin dia	*40 mm*
Fin thickness	*1.5 mm*
Pitch	*15 mm*
No. of tubes per system	*144 nos.*

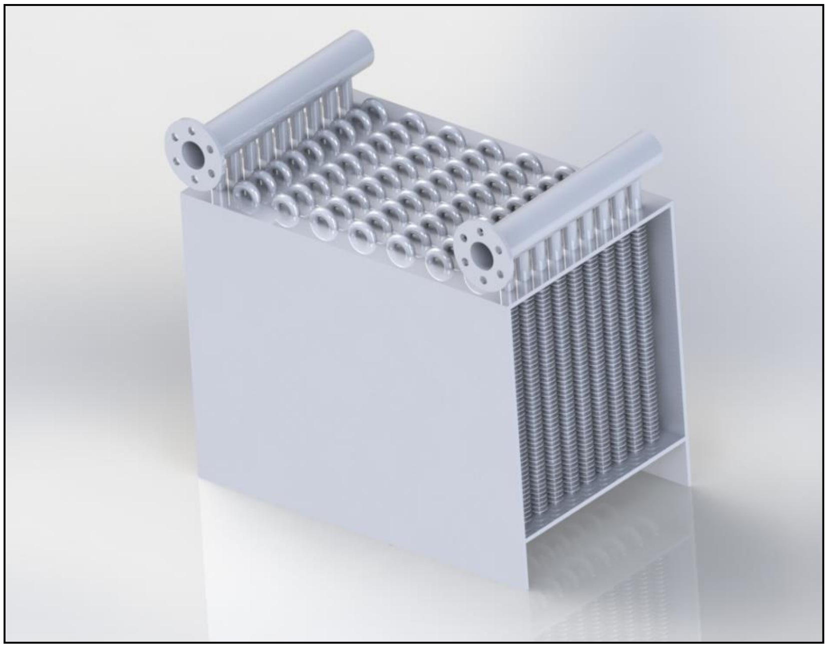

Fig. 1: The CAD drawing of the heat exchanger

B. CFD Analysis of Finned Tube Heat Exchanger

Geometric model is generated in 'SOLIDWORKS' which is very popular modeling software. The generated model is exported to the further process in the form of .IGES as it is a third party format which can be taken in to any other tools. Extracting the fluid region is the next step in which all the surfaces which are in the contact of fluid are taken alone and all other surfaces are removed completely. To keep the domain air /water tight some extra surfaces are created. This clean up is done in ANSA meshing tool which is very robust meshing **.**After cleaning up the geometry surface mesh is generated in ANSA tool itself. All the surfaces are discritized using tri surface mesh element .

1) Meshing Details

Table 2: Meshing Details

Mesh	*Count*	*Quality*
SURFACE MESH	*1625780*	*0.6*
VOLUME MESH	*9254845*	*0.81*

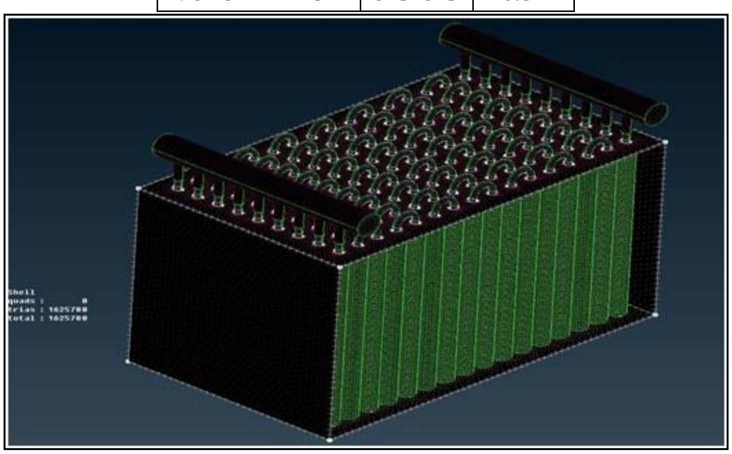

Fig. 2: Meshed Model

2) Solver Setup and Cell Zone Conditions

Ansys-fluent is used as the solver for this case. Fluid is assumed to be 3-D, turbulent Turbulence model is by K-ε Realizable model with Energy ON and Simple algorithm is used to solve the problem Segregated solver is used for pressure-velocity coupling Fin side fluid is air ,Tube side fluid is water, water + 0.1% Al_2O_3 and water + 0.05% Al_2O_3.Heat exchanger material Aluminum

3) Property of Fluid

Table 3: Properties of Fluid

Parameter	Water	Water + 0.05% Al_2O_3	Water + 0.1% Al_2O_3
Desnsity (ρ) Kg/m^3	998.2	992.25	1038
Specific Heat (C_p)j/kg-k	4182	4157	4182
Thermal conductivity (w/m.K)	0.6	0.651	0.72
Viscosity (μ)kg/m.s	0.001003	0.000786	0.000950

4) Boundary Conditions

Table 4: Boundary Conditions

Part ID	Parameter
Tube side fluid	
Mass flow rate	0.25, 0.5 and 0.75 Kg/s
Inlet Temperature	360 K
Air	
Velocity	5 m/s
Inlet Temeprature	300 K

IV. Result and Discussion

The performance of the heat exchanger is determined by the effectiveness of heat transfer process. The performance of the heat exchanger relies on the fin profiles, type of coolant used and arrangement of pipes etc. In the present work, the working fluid is mixed nanoparticles based additives to enhance the heat transfer process. Numerical analysis is carried out to examine the effect of different volume fraction of additives added with the hot liquid. In the below section CFD results are plotted for different flow rates are tabulated.

Table 5: The tabulation of results from CFD analysis

Mass flow rate of hot fluid	Velocity of cold fluid (Air)	Cold fluid		Hot fluid	
		Inlet	Outlet	Inlet	Outlet
Kg/s	m/s	K		K	
WATER SYSTEM					
0.25	5	300	305.1	360	357.92
0.5	5	300	305.33	360	358.94
0.75	5	300	305.2	360	359.28
0.05% Al_2O_3-WATER SYSTEM					
0.25	5	300	305.28	360	356
0.5	5	300	305.1	360	357.5
0.75	5	300	304.2	360	358.05
0.1% Al_2O_3-WATER SYSTEM					
0.25	5	300	305.22	360	355
0.5	5	300	305.26	360	356.5
0.75	5	300	305.3	360	357.37

V. Conclusions

The CFD analysis was conducted on a finned tube heat exchanger for different flow rates by using three different fluids First water is used as hot fluid and then 0.05 Volume fraction of Al_2O_3 water solution and after that the analysis with 0.1Volume fraction of Al_2O_3-water solution is done And found that the heat transfer rate will increase when we substitute water with a Al_2O_3 –water nanofluid And also when the concentration of nanoparticle increases the total heat transfer rate also increases.

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