CFD ANALYSIS OF NANO FLUID ACROSS IN LINE TUBE BANKS OF HEAT EXCHANGER

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Abstract: In the present work, laminar cross flow forced convective heat transfer of nano fluid over tube banks with Circular geometry under constant wall temperature condition is investigated numerically. In this study nanofluid instead of pure fluid, as external cross flow, because of its potential to increase heat transfer rate of the system. The effect of the nanofluid on the compact heat exchanger performance was studied and compared to that of a conventional fluid. The two dimensional steady state Navier-Stokes equations and the energy equation governing laminar incompressible flow are solved using a finite volume method for the case of flow across an in-line bundle of tube banks as commercial compact heat exchanger. The nanofluid used was copper water 1% and the performance was compared with water. In this paper, the effect of parameters such as tube shape circular and heat transfer comparison between nanofluid and pure fluid is studied. Temperature profile, heat transfer coefficient and pressure profile, Nusselt Number were obtained from the simulations and the performance was discussed in terms of heat transfer rate and performance index. The increase in Reynolds number caused an increase in the heat transfer rate and a decrease in the overall bulk temperature of the cold fluid.

Keywords: Nano fluid, CFD; heat transfer, circular tube

I Introduction

Flow past tube banks with Circular configurations have wide ranging practical applications, such as in heat exchangers, cooling and heating equipments. There are two important phenomena happening in a heat exchanger: fluid flow in channels and heat transfer between fluids and channel walls. Thus, improvements to heat exchangers can be achieved by improving the processes occurring during those phenomena. Firstly, the rate of heat transfer depends on the surface area to volume ratio, which means the smaller channel dimensions provide the better heat transfer coefficient. Secondly, improving the properties of the heat transfer fluids (nanofluids) can yield higher heat transfer coefficient in a heat exchanger. Nanofluids are colloidal dilute dispersion of nanoparticles (generally less than 5% in volume) such as metals, oxides, carbides, or carbon nanotubes in conventional coolants or base fluids such as water, ethylene glycol, and oil. Miniaturization of electronic components has led to the demand for development of new compact heat exchangers and also cooling fluids with higher heat transfer performance. Modification of thermo physical properties for liquid coolants by adding some solid particles is the main subject of nanofluids. The idea of using metallic particles to increase the thermal conductivity of fluids is not a new concept. By knowing the fact that metals in solid form have much higher thermal conductivity than fluids, Maxwell (1873) who was the one originally proposed the idea of using metallic particles to increase the thermal properties of fluids.

II Literature Review

Jaafar1 et al. studied an experimental work on the forced convective heat transfer and flow characteristics of a nanofluid consisting of water and different volume concentrations of Al_2O_3 nanofluid (0.3–2) % flowing in a horizontal shell and tube heat exchanger counter flow under turbulent flow conditions are investigated. The Al_2O_3 nanoparticles of about 30 mm diameter are used in the present study. The results show that the convective heat transfer coefficient of nanofluid is slightly higher than that of the base liquid at same mass flow rate and at same inlet temperature. The heat transfer coefficient of the nanofluid increases with an increase in the mass flow rate, also the heat transfer coefficient increases with the increase of the volume concentration of the Al2O3 nanofluid, however increasing the volume concentration cause increase in the viscosity of the nanofluid leading to increase in friction factor.

V. L. Bhimanil2 et al. studied forced convective heat transfer in a water based nanofluid has experimentally been compared to that of pure water in an automobile radiator. Five different concentrations of nanofluids in the range of 0.1-1 vol. % have been prepared by the addition of TiO2 nanoparticles into the water. The test liquid flows through the radiator consisted of 34 vertical tubes with elliptical cross section and air makes a cross flow inside the tube bank with constant speed. Liquid flow rate has been changed in the range of 90-120 l/min to have the fully turbulent regime. Results demonstrate that increasing the fluid circulating rate can improve the heat transfer performance. Meanwhile, application of nanofluid with low concentrations can enhance heat transfer efficiency up to 45% in comparison with pure water.

Dr. Zena K.3 et al. Investigations have been carried out in this paper to study the enhancement of heat transfer characteristics for cross flow low integral finned tube heat exchanger with using of (MgO) nanofluid. The study includes designing and manufacturing of test section from Pyrex glass with dimensions 1200) mm width, height and length, respectively. Has a single×500×(250 copper tube with eight passes. The low integral finned tube with (19 mm) inner diameter, (21 mm) root diameter and (24 mm) outer diameter. The fin height is (1.5 mm), thickness (1 mm) and the pitch is (2 mm). Air was used as a cooling fluid passing across the test tube with a range of velocities (1, 2, 3 and 4) m/sec. The inner side flow rates with a range of (2, 3, 4, 5 and 6) L/min. for water and for nanofluid. The fluid temperatures at the inlet of test tube were (50, 60, 70, 80) °C. Magnesium Oxide (MgO) nanoparticle powder with (40 nm) diameter was dispersed in distilled water with different volume concentrations (0.15, 0.35, 0.55, and 0.75) % by volume is used to prepare the nanofluid. The results showed increasing of thermal conductivity and density of fluid when using nanofluid, the results also showed enhancement of heat transfer characteristics when using the nanofluid.

S. Eiamsa-ard[4] et al. presented Titanium dioxide (TiO2) in water as nanofluid was employed for heat transfer enhancement together with overlapped dual twisted tapes (O-DTs). The study encompassed Reynolds numbers from 5400 to 15,200, O-DTs with overlapped twist ratios (yo/y) of 1.5, 2.0 and 2.5 and nanofluids with TiO2 volume concentrations (ϕ) of 0.07%, 0.14% and 0.21%. The experimental and numerical results indicated that O-DTs with smaller overlapped twisted ratio delivered a stronger swirl intensity and higher turbulent kinetic energy (TKE). The use of O-DTs at the smallest overlapped twist ratio of 1.5 enhanced heat transfer rates up to 89%, friction factor by 5.43 times and thermal performance up to 1.13 times as compared to those of plain tube. In addition, heat transfer increased as TiO2 volume concentration of nanofluid increased, owing to the increases of contact surface and thermal conductivity. The simultaneous use of the O-DTs having twist ratios 1.5 with the nanofluid with TiO2 volume concentration of 0.21% resulted in heat transfer enhancement around 9.9–11.2% and thermal performance improvement up to 4.5% as compared to the use of O-DTs alone. The empirical correlations of heat transfer rate (Nu), friction factor (f) and thermal performance (η) in a constant wall heat flux tube equipped O-DTs at different overlapped twist ratios (yo/y) and volume concentrations of TiO2 nanoparticles (ϕ) are also reported for heat transfer applications.

Tun-Ping Teng 5 et al. study analyzes the characteristics of alumina (Al2O3)/water nanofluid to determine the feasibility of its application in an air-cooled heat exchanger for heat dissipation for PEMFC or electronic chip cooling. The experimental sample was Al2O3/water nanofluid produced by the direct synthesis method at three different concentrations (0.5, 1.0, and 1.5 wt.%). The experiments in this study measured the thermal conductivity and viscosity of nanofluid with weight fractions and sample temperatures (20-60°C), and then used the nanofluid in an actual air-cooled heat exchanger to assess its heat exchange capacity and pressure drop under laminar flow. Experimental results show that the nanofluid has a higher heat exchange capacity than water, and a higher concentration of nanoparticles provides an even better ratio of the heat exchange. The maximum enhanced ratio of heat exchange and pressure drop for all the experimental parameters in this study was about 39% and 5.6%, respectively. In addition to nanoparticle concentration, the temperature and mass flow rates of the working fluid can affect the enhanced ratio of heat exchange and pressure drop of nanofluid. The cross-section aspect ratio of tube in the heat exchanger is another important factor to be taken into consideration.

III Cad Model and Computational Domain

A section of the problem is shown in Fig.1.0 Because of the symmetry of the tube banks geometry; only a part of the domain needs to be modeled. Fig.2.0 shows the CAD model of four tube heat exchanger the computational meshed model is shown in Fig. 3.0 the CFD domain consists of four tubes with circular geometry. The hydraulic diameter Dh of computational domain is 10.55 mm for circle tube shapes.

Geometry

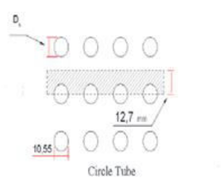

Fig. 1. Schematic diagram of a tube bank as a 2D model of compact heat exchanger with circular tube geometry.

IV Boundary Conditions

The fluid is assumed to be incompressible with constant property and the flow is laminar and in steady state condition. A mass flow rate of 0.05 to 1.58 kg/s is applied to the inlet boundary of the periodic module. The fluid enters with uniform temperature of 300 K and different inlet uniform velocities V in are applied. At the outlet of the computational Model a relative average pressure equalling zero was defined. A constant temperature Tw = 340 K is specified for the wall (tube).

V Numerical Method

The modeled cases were solved using ANSYS software. A Segregated, implicit solver option was used to solve the governing equations. The first order upwind discrimination scheme was employed for the terms in energy, momentum, and laminar flow parameters. A standard pressure interpolation scheme and SIMPLER pressure velocity coupling were implemented.

VI Properties of Nanofluids

The selection process and determination ofnanofluid thermo physical properties are important area in nanofluid applications. The single-phasemethod is chosen to calculate the thermo physical properties of nanofluids. In the current study the considered nano fluid is a mixture of water and containing mainly Cu. The thermo physical properties of the cu as nano particle and water-based nanofluid are presented at temperature 293 K in Table 1.

Table 1.0 **Properties of nano fluid**

Material	ρ Kg/m^3	Cp J/Kg·K	k W/m·K	μ Kg/m·s
Pure water $c = 0\%$	981.3	4189	0.643	0.000598
cupper (Cu)	8930	383.1	386	-
Cu-water $c = 1\%$	1061	4150.9	0.662	0.000612
Cu-water $c = 2\%$	1140.7	4112.8	0.682	0.000627
Cu-water $c = 3\%$	1220.4	4074.8	0.702	0.000642
Cu-water $c = 4\%$	1300.2	4036.7	0.723	0.000657
Cu-water $c = 5\%$	1378	3998	0.744	0.000672

VII Results and Discussion

The purpose of this paper is to present results of an investigation into the overall variation of heatTransfer coefficient around the in-line array with circular tube shapes. The numerical study consider the effect of nanofluid such as Cu on the flow and heat transfer characteristics of tube banks in a physical domain for different Reynolds number. Table 2.0 and Table 3.0 shows the results of water and Nano fluid at different velocities respectively.

VIII Pressure Contours and Temperature contours.

The evolution of numerical simulation such as pressure contours and temperature contours for flow across a four row of tube bank with two different nanoparticle volume concentrations (water, Cu) is shown in Fig. 5. To Fig.12 the tube shape influence on the flow pattern and streamlines path. Fig. 13 shows the Average Nu comparison graph for two fluids.

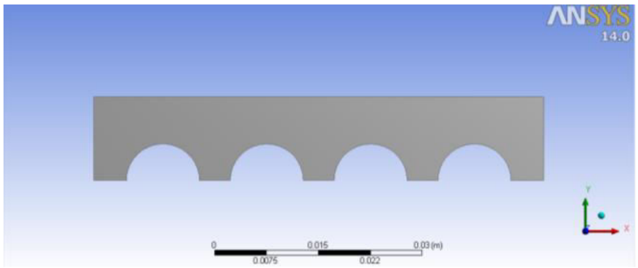

Fig. 2. Cad model of four tube bank

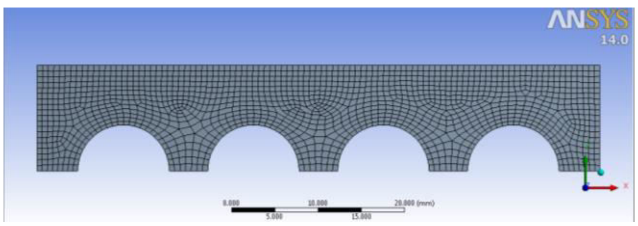

Fig.3. Meshed model of four tube bank

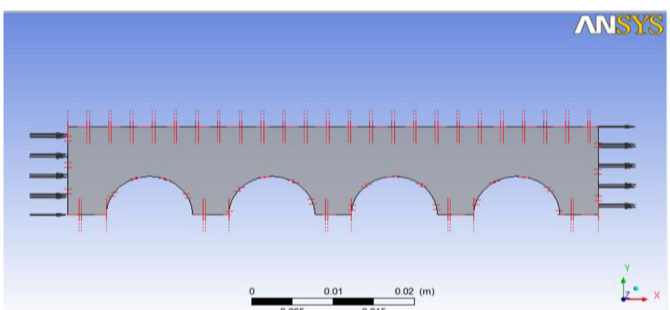

Fig.4. Boundary Conditions

Fluid – Water

CASE 1 u= .2m/s

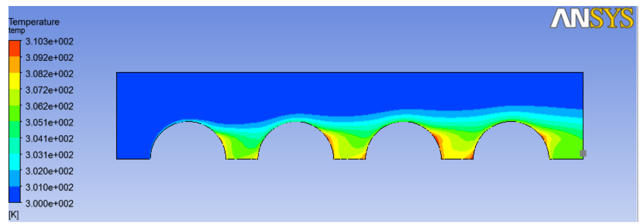

Fig. 5. Temperature Contour

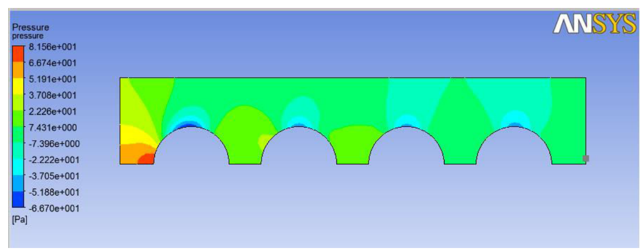

Fig. 6. Pressure Contour

CASE 2 u= .4m/s

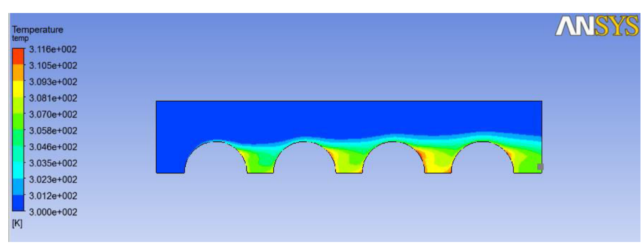

Fig. 7. Temperature Contour

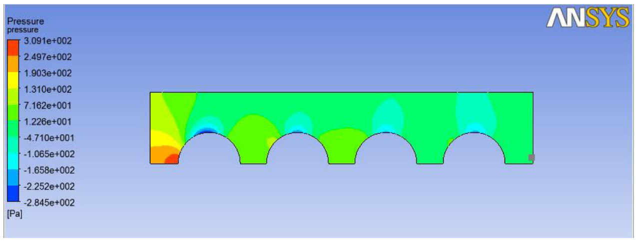

Fig. 8 Pressure Contour

Material: Nano Fluid Cu-1%

CASE 1 u= .2m/s

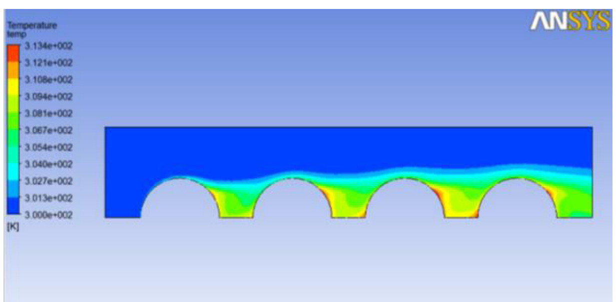

Fig.9. Temperature Contour

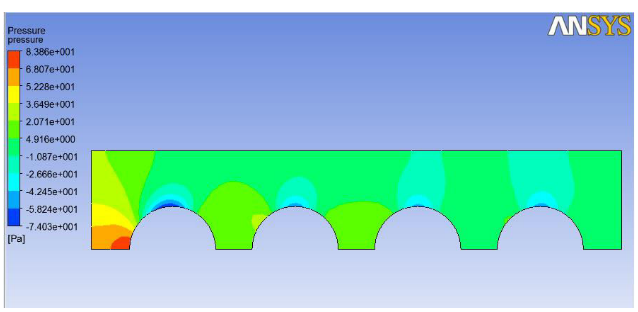

Fig. 10 Pressure Contour

CASE 2 u= .4m/s

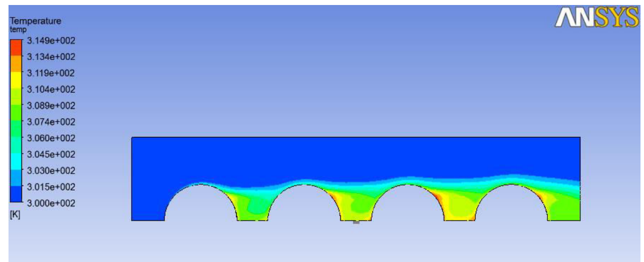

Fig.11. Temperature Contour

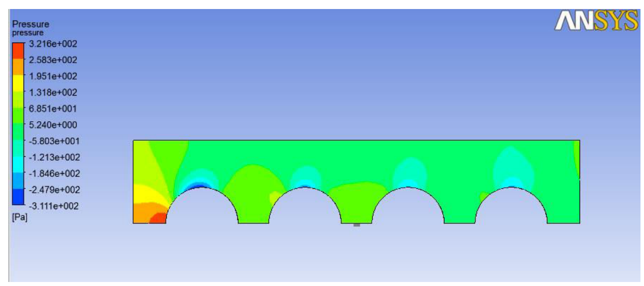

Fig. 12 Pressure Contour

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Table 2.0 **Results of Water fluid**

u	u_{max}	Re_d	Pressure Drop (Pa)	Nusselt Number	T_{out}-T_{in}	Wall Heat transfer coeff.
.2 m/s	.35456	2194	57.25	375.9	9.47	3469.87
.4 m/s	.70912	4388	205.2	737.6	6.52	6809.26
.6 m/s	1.06	6559	442.2	1103.34	6.43	10184.7
.8 m/s	1.4182	8776	808.25	1425.53	6.65	13158.8
1 m/s	1.7728	10970	1244.7	1720.91	6.529	15885.4

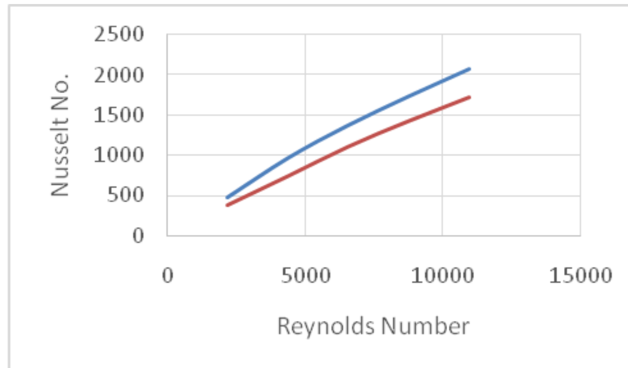

Fig. 13. Comparison of Average Nu no. for Two fluids

Table 3.0 **Results of Nanofluid**

u	u_{max}	Re_d	Pressure Drop (Pa)	Nusselt Number	T_{out}-T_{in}	Wall Heat transfer coeff.
.2 m/s	.35456	2194	57.25	481.14	13.57	4900.31
.4 m/s	.70912	4388	210.41	968.64	9.894	9865.3
.6 m/s	1.06	6559	456	1372.56	9.156	13979
.8 m/s	1.4182	8776	797	1733.79	8.854	17658
1 m/s	1.7728	10970	1209.56	2071.75	8.678	21100

IX Conclusions

Numerical simulation has been investigated on heat transfer characteristics and pressure drop of Cu/water nanofluid in compact heat exchanger with circular tube shapes and an in-line Arrangement of tubes under steady state laminar fluid flow. The numerical results reveal the Enhancement in heat transfer, with respect to the base fluid, identified to characterize nanofluid. Heat transfer enhancement is increasing with the nanoparticle and using circular tube geometry.

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