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Numerical Investigation of Forced Convection Heat Transfer on a Circular Finned tube with AL2O3-Water Nano Fluid

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Abstract

This paper presents a three-dimensional numerical analysis to study the laminar forced convection heat transfer and flow characteristics of AL_2O_3–water Nano fluid with Solid particles less than 100 nm through a tube with 1m Length and 25 mm inner diameter and 30mm outer diameter contains circular fins with 30mm inner diameter and 50mm outer diameter with thickness of 2mm , investigated numerically by using finite volume method, models using ANSYS 14.5 Based on the single-phase approach, The flow of fluid is assumed to be incompressible, steady and laminar with various thermo physical properties according to volume concentration of Nano particles The Navies Stokes equations along with the energy equation have been solved by using SIMPLE algorithm Technique. The effects of different parameters such as nanoparticle volume concentration (1%, 3% and 5%), and Reynolds number are varied from (500 - 2100) for various axial locations of tube with AL2O3–water fluids and the effect of different values of velocity at the tube inlet will be studied during this paper. Where the results showed that the coefficient of heat transfer increases when the concentration of Nano fluid increase.

Keywords- forced convection-circular finned tube-AL2O3 Nanofluid - Navier Stokes

Nomenclature

The following symbols are used generally throughout the text. Others are defined as and when used.

Symbols	Meaning	Units
Cp	Specific heat at constant pressure	J/kg.K
K	Thermal conductivity	W/m.K
Nu	Nusselt number	-
P	Pressure	Pa
Re	Reynolds number	-
T	Temperature	K
V	Velocity vector	m/s
X	Distance along axis	m

Greek letters

α	Thermal diffusivity	m2/s
ϕ	Volume fraction	-

ρ	Density	kg/m3
μ	Molecular dynamic viscosity	N.s/m2

Subscripts

bf	Base fluid
f	Fluid
nf	Nanofluid
s	Solid of particle

Introduction

Heat exchangers are usually used devices that transfer heat from one fluid (gas or liquid) to another without those two fluids mixing. Heat transfer enhancement is the process of enhancing the performance of a heat transfer unit. It is used in heating , air conditioning systems in a household, chemical processing, power production in large plants, There are different methods used to increase the heat transfer rate in compact heat exchangers One of these methods is the use of Extended surfaces "finned tube" Achieving higher heat transfer rate by increasing heat transfer area and increasing flow mixing in the boundary layer is the main goal for these methods and The other method is to increase the thermal conductivity of fluid by used Nano fluid. Proposed the use of Nano fluids which are having extremely impressive and attractive thermal properties [1]

This study aims to enhance the heat transfer characteristics for heat exchanger with use of Nano fluid and finned tube.

Zamzamian (2011) [2], studied numerically the effect of forced convective heat transfer of nanofluids of aluminum oxide and copper oxide prepared in ethylene glycol in turbulent flow. They discover vast enhancement in convective heat transfer coefficient of the nanofluids in contrast to the base fluid. Furthermore, their outcomes show that with expanding nanoparticles concentration and nanofluid temperature, the convective heat transfer coefficient of nanofluid will increases.

Naik (2013) [3], analyzed turbulent convective flow of CuO nanofluids of propylene glycol–water as the base fluid and flow through a circular tube, subjected to a regular and uniform heat flux at the wall. They found that nanofluids containing extra concentrations have proven higher heat transfer coefficient. They compared their numerical results with the experimental data and affordable appropriate agreement is performed.

Sheikholeslami (2014) [4] , observed numerically the impact of natural convection heat transfer in a nano fluid (CuO) crammed enclosure with elliptic internal cylinder. They observed that Nusselt number increments with an increment each of nanoparticles volume fraction, Rayleigh numbers and inclination angle. .Likewise, they found that expanding Rayleigh number prompts a lessening in heat transfer enhancement. For high Rayleigh number the minimum heat transfer enhancement ratio occurs at slanted elliptic cylinder is 90.

Hsien-Hung and Shuhn-Shyurng(2014)[5], numerically research the convective heat transfer of water-based Al2O3 nanofluids flowing through a square cross section duct with a fixed heat flux under laminar flow conditions. They investigated the influences of nanoparticle concentration and Peclet number on the heat transfer attributes of Al2O3-water nanofluids. The nanoparticle diameter is 25 nm and six particle concentrations (0.2, 0.5, 1, 1.5, 2, and 2.5 vol. %) are taken into consideration. They confirmed that the heat transfer coefficients and Nusselt number of Al2O3-water nanofluids increment with expansions within the Peclet number and similarly particle volume concentration. The heat transfer coefficient of nanofluids is elevated via 25.5% at a particle volume concentration of 2.5% and a Peclet quantity of 7500 as contrasted with that of the base fluid (pure Water).

Bouhalleba and Abbassi (2016) [6], analyzed numerically heat transfer and fluid flow of natural convection in inclined cavity full of Cu-water Nano fluid and partially heated. . The Prandtl number is kept constant at 7.02 corresponding to water. Aspect ratio and solid volume fraction are changed from 0.5 to 4 and from 0% to 4% respectively, and the inclination angel is varied from 0°to 90. They found that the efficiency of heat transfer is enhanced by the increment of nanoparticles ratio into base liquid; but there is an optimum solid volume fraction which promotes the heat transfer rate. Additionally they found that the diameter of solid particle is an imperative parameter that influences the heat transfer efficiency, its effect is more critical than the concentration itself.

Mathematical Model and numerical analysis:

The basic flow configuration, under study, is shown in Fig. 1. A three dimensional pipe have 1 m length and 25 mm inner diameter and 30mm outer diameter contains circular fins with 30mm inner diameter and 50mm outer diameter and thickness of fins is 2mm and The distance between each fin and the second fin is 48mm was spotted in the simulation. The continuity, momentum and energy equations for a three dimensional incompressible laminar flow has been solved using appropriate boundary conditions by mean computational fluid dynamics technique. Following assumptions have been made: three-dimensional problem, there is no viscous dissipation, no gravity acts, the fluid properties are various according to volume concentration of Nano particles and radiation heat exchange was assumed negligible.

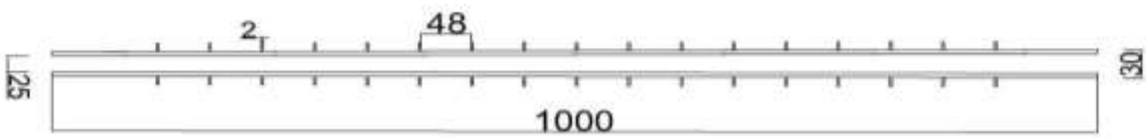

Figure (1): Schematic diagram of the physical system

The three-dimensional governing equations for the conservation of mass, momentum and energy and for the single phase are solved using a finite volume approach. The spatial discretization is achieved through a second-order upwind scheme. The SIMPLEC algorithm is selected to overcome the pressure-velocity coupling. All calculations are steady state and three-dimensional.

At steady state conditions using above assumption, the governing equations as given below [7]:

Continuity equation:

$$\nabla.(\rho_{nf}\mathbf{V}) = 0 \qquad (1)$$

Momentum equation:

$$\nabla.(\rho_{nf}\mathbf{V}\mathbf{V}) = -\nabla P + \nabla.(\mu_{nf}\mathbf{V}) \qquad (2)$$

Energy equation:

$$\nabla.(\rho_{nf}C\,\mathbf{V}T) = \nabla.(k_{nf}\nabla T) \qquad (3)$$

The effective physical properties of the nanofluids in the above equations are:

1- **Density:**

The density (□*nf*) in kg/m³is determined by the following equation:

$$\rho_{nf} = (1-\phi)\rho_f + \phi\rho_s \qquad (4)$$

2-**Dynamic viscosity:**

The viscosity ratio of the Nano fluid is calculated by the following equation:

$$\mu_{nf} = \frac{\mu_f}{(1-\phi)^{2.5}} \qquad (5)$$

3-**Thermal Diffusivity**

The thermal diffusivity of the Nano fluid is determined by the following equation:

$$\alpha_{nf} = \frac{k_{nf}}{(\rho C_p)_{nf}} \qquad (6)$$

4-Heat Capacity

The heat capacity of the Nano fluid is calculated by the following equation:

$$(\rho C_p)_{nf} = (1-\phi)(\rho C_p)_f + \phi(\rho C_p)_s \qquad (7)$$

5-**Thermal conductivity**

The thermal Conductivity of Nano fluid is determined by the following equation:

Where:

F: Fluid

nf :Nanofluid

s: Solid of particle

Table (1): Thermo physical Properties of nano fluid .

Property	Fluid Phase (Water)	Nanoparticle (AL2O3)
ρ (kg/m^3)	998.2	3880
Cp (J/kg K)	4182	729
k (W/m K	0.6	42
μ(kg/m.s)	0.001003	___

Table (2) : Thermo physical Properties of nano fluid with different volume concentration

Nano fluid Water /AL2O3)	□□□	□□□	□=1
ρ (kg/m^3)	1142.2	1084.6	1027
Cp (J/kg K)	3595	3811	4051
k (W/m K	0.69	0.65	0.61
μ(kg/m.s)	0.001140	0.001082	0.001028

The boundary conditions are specified as follows:

· At the tube inlet: u(y) = 0.12 m/s and T = Ti =350 ºK

· At the tube outlet: pressure outlet boundary P = 0

· At the wall: convection heat transfer on the extended surface with heat transfer coefficient =20 to the environment, T=300K

Result and discussion

Through numerical analysis by ANSYS 14.5 on two types of tubes, one of which is smooth tube and the other is finned tube and two types of fluid one of which is pure water and the other is Nano fluid and for the purpose of comparing them, the results showed that The presence of nanoparticles with fluid at work occupies the interstellar distances between the working fluid molecules and will therefore increase the heat transfer as shown in table (3) and Fig.2 and Fig3 , compared to the results of fluid without fins and without nano, When the speed changes in a given concentration and a particular model exists, the heat transfer will increase as shown in Fig.4 and Fig.5 and The results from the Temperature contours showed that the process of cooling through the finned tubes is better than the tube that does not contain fins as shown in Fig.6.

Table (3): The Results of the case study

Type of tube	Number of node	Number of element	Velocity value m/s	Type of fluid	Volume concentration	Heat transfer coefficient W/m^2.k
Smooth tube	26029	18957	0.08	Pure water	0%	148
				Nano fluid	1%	151
					3%	156
					5%	161
			0.12	Pure water	0%	171
				Nano fluid	1%	173
					3%	180
					5%	186
Finned tube	28592	53714	0.08	Pure water	0%	149
				Nano fluid	1%	151.5
					3%	157
					5%	162.5
			0.12	Pure water	0%	172
				Nano fluid	1%	174
					3%	181
					5%	187

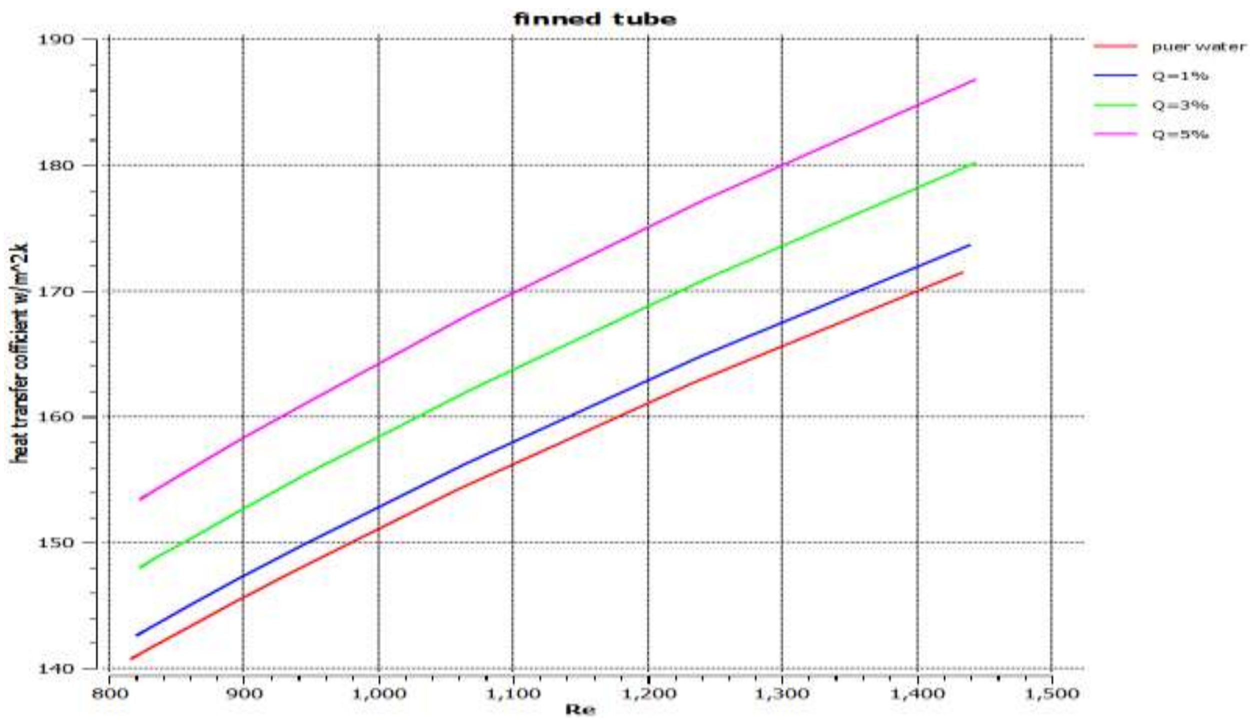

Figure (2): Heat Transfer coefficient Variation with Reynolds Number for the finned tube with volume concentration (0%,1%,3%,5%)

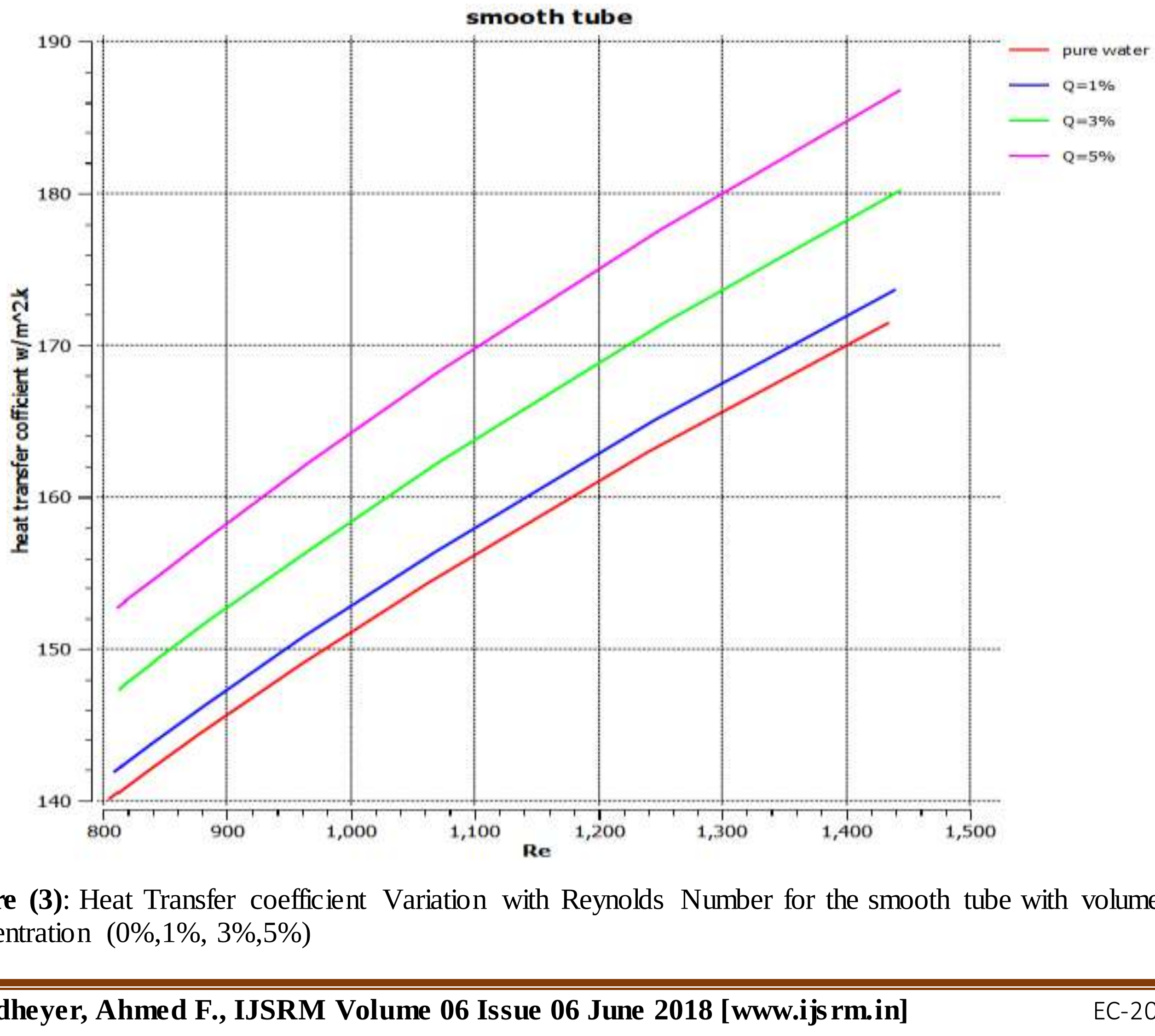

Figure (3): Heat Transfer coefficient Variation with Reynolds Number for the smooth tube with volume concentration (0%,1%, 3%,5%)

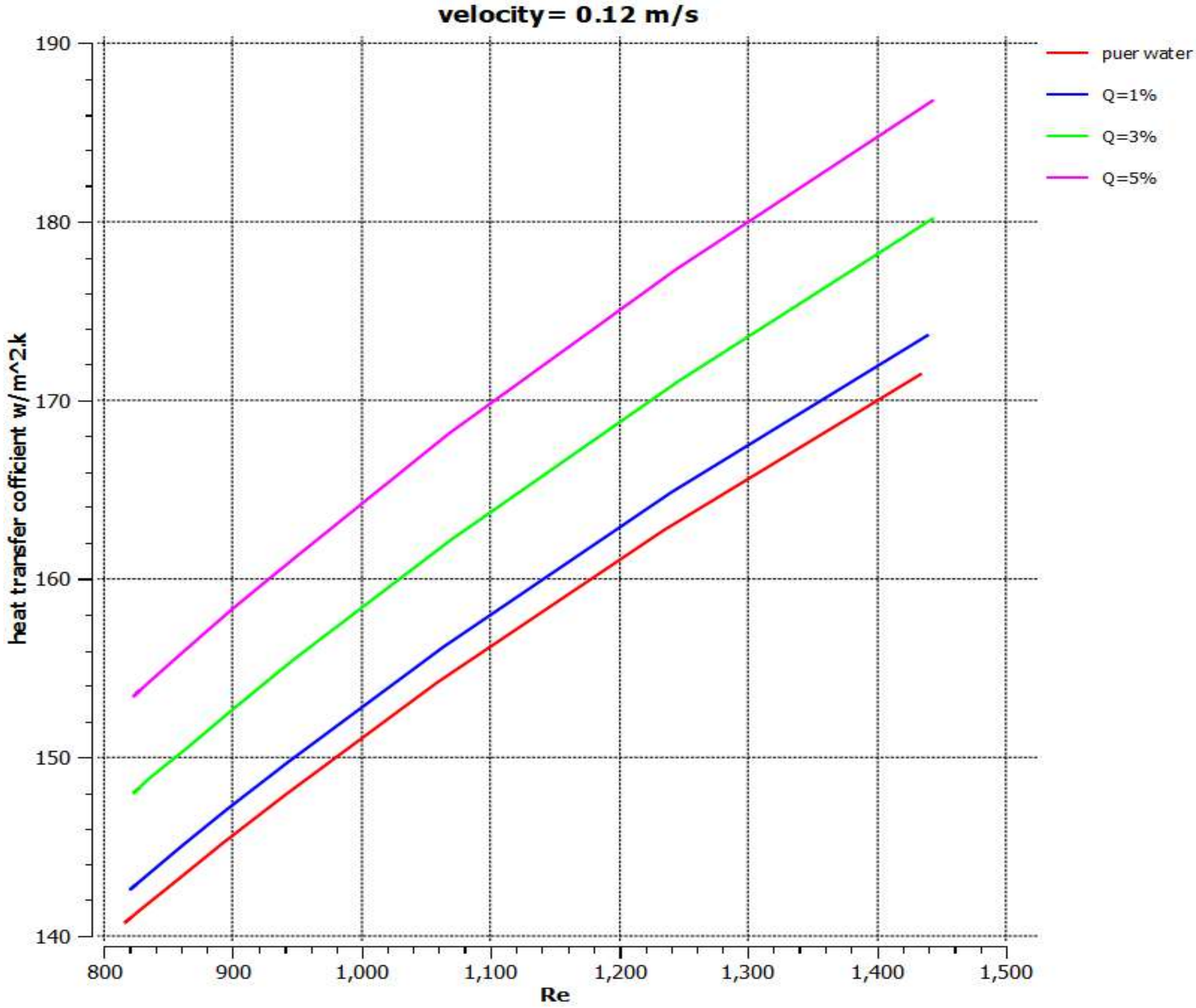

Figure (4): Heat Transfer coefficient Variation with Reynolds Number for the finned tube with velocity = 0.12 m/s and volume concentration (0%, 1%,3%,5%)

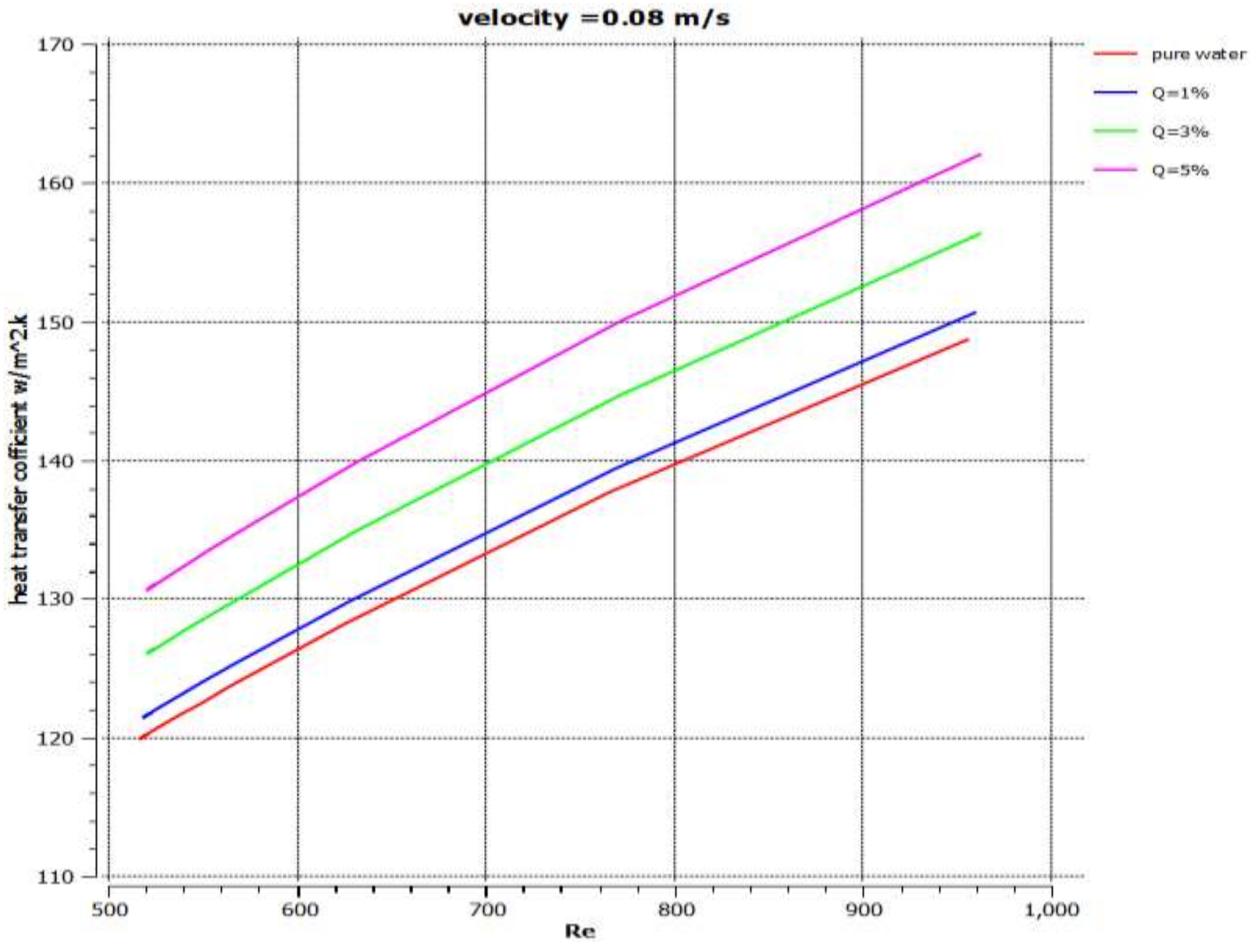

Figure (5): Heat Transfer coefficient Variation with Reynolds Number for the finned tube with velocity = 0.08 m/s and volume concentration (0%, 1%, 3%, 5%)

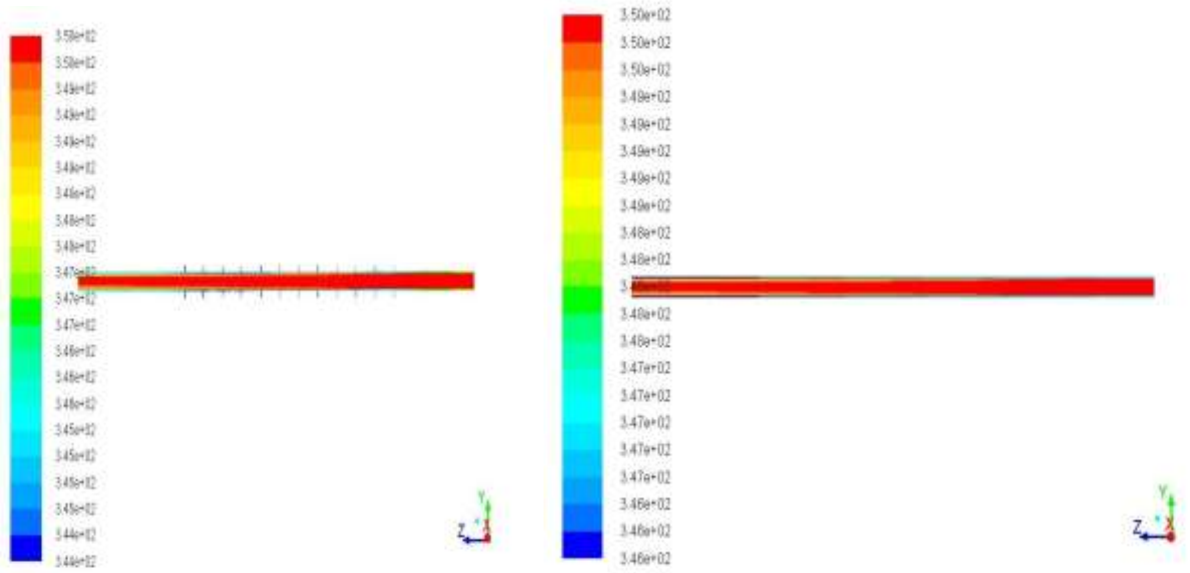

Figure (6): Temperature contours map for AL2O3-Water Nano-fluid (Q=5%) for finned and smooth tube.

Conclusions:

As the results show, heat transfer through finned tube is better than heat transfer through tubes without fins, as well as the use of nano fluid is better than using pure water.

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