International Journal of Innovative Science and Modern Engineering (IJISME)
ISSN: 2319-6386, Volume-3 Issue-6, May 2015

Numerical Investigation of Performance of Double Tube Heat Exchanger using Nano Fluid

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Abstract*— *The current research aims at analyzing the heat transfer rate of the nano particles with double tube heat exchanger. Graphene, the nano particle under consideration, can be prepared using Hummers and Offeman method. The analysis has been done with the help of Ansys14 Fluent software. The physical properties (density, thermal conductivity, specific heat, viscosity) of the nano particles are taken from a standard journal and analyzed in a double tube heat exchanger. The simulation is done using the Ansys fluent for a particular concentration of graphene and the results are found to be almost similar. Hence the result obtained is standardized. The analysis is done for various concentration of graphene i.e. graphene 1(0.07% by weight) and graphene 2(0.080% by weight) with corresponding properties and analysis has been continued by making grooves on the outer surface of the inner tube in case of double tube heat exchanger. It has been found that the performance and heat transfer rate of double tube heat exchanger with grooving is better than that of without grooving.

Index Terms*—. *Nanofluids, Convective heat transfer, Laminar flow, Graphene

I. INTRODUCTION

Nanfluids are suspensions that can be obtained by dispersing different nanoparticles in host fluids with the aim of enhanced thermal properties [1]. Over the past few years, it has been shown that nanofluids are able to remarkably improve the thermal conductivity, stability and heat transfer coefficient and reduce the consumed power and the costs [2–5]. These advantages made a growing tendency in the use of nanofluids in different types of heat exchangers, due to the optimized energy consumption. Hence, discovering suitable nanofluids with improved heat transfer properties and high thermal conductivity became a serious challenge. More specifically graphene water-based nanofluids reveal great improvements, which is owing to the high thermal conductivity of graphene [6]. The experimental studies have reported significant enhancement on the thermal conductivity and heat transfer coefficient of nanofluids. Many studies evaluated the convective heat transfer of nanofluids [7–10]. For example it has been shown that alumina–water nanofluids at 6 vol% can increase the heat transfer coefficient in the entrance and fully developed regions by 17% and 27%, respectively, when compared with pure water. Here we performed simulation using water as working fluid, graphene 1 solution (0.07% by weight),graphene 2 solution (0.080% by weight) in a tubular heat exchanger and comparing it with the results obtained in experiment. Also we performed simulation using graphene 1 solution (0.07% by weight) in a tubular heat exchanger by providing grooves and compared it with the results obtained with that of without groove.

II. FLOW MODELING AND SIMULATION

The computational model and its dimensions used is similar to that used by Ahmad Ghozatloo, Alimorad Rashidi, Mojtaba Shariaty-Niassar for their research work. All the 3D models are generated using ICEM-CFD and computational analysis are done by using ANSYS 14-Fluent software. Boundary Conditions are same as experimental work that is taken from Ahmad Ghozatloo, Alimorad Rashidi, Mojtaba Shariaty-Niassar (Convective heat transfer enhancement of graphene nanofluids in shell and tube heat exchanger). Three types of boundaries are applied: inflow, outflow and fixed walls and the fluid flow is considered to be laminar. Also no slip condition is applied on fixed walls.

III. COMPUTATIONAL CONFIGURATION OF HEAT EXCHANGER

The dimensions of these geometries are the same to the dimensions of experimental set-up.

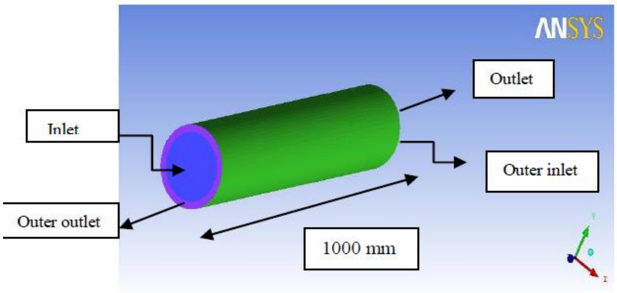

Figure 1: Configuration of the outer face

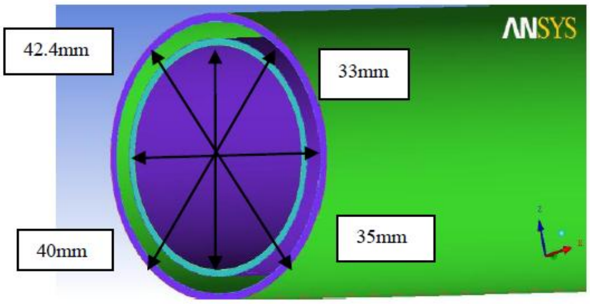

Figure 2: Dimensions of the heat exchanger

Manuscript Received on May13, 2015.

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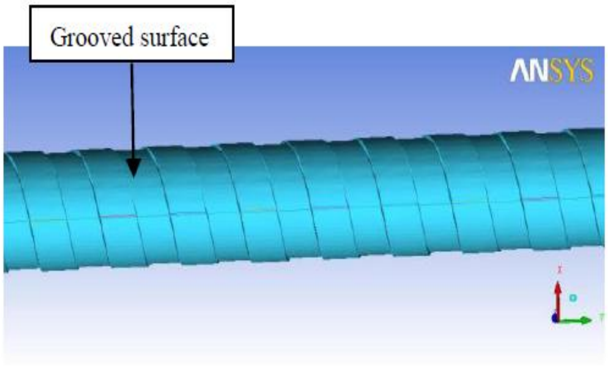

Figure 3: Configuration showing the grooved surface

IV. MESHING AND GRID GENERATION

As Computational Fluid Dynamic (CFD) has developed, better algorithms and more computational power have become available to CFD analysts, resulting in diverse solver techniques. One of the direct results of this development has been the expansion of available mesh elements and mesh connectivity (how cells are connected to one another). Grid generation is done using mesh type: tetra-mixed and mesh method- robust (octree).

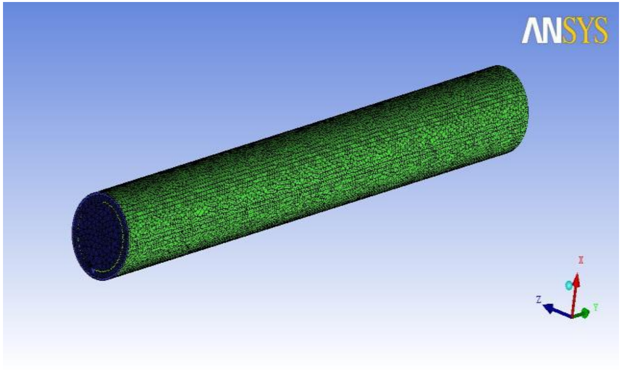

Figure 4: **Meshing of double tube heat exchanger**

V. GRID INDEPENDENT TEST

Grid convergence is the term used to describe minimization of the error and improvement of results by using successively smaller cell sizes for calculations. A calculation should approach the correct answer as the mesh becomes finer; hence the term grid convergence comes to picture. Here Grid independence Test is carried out here to analyze the effect of grid number on the maximum static temperature of the flow field.

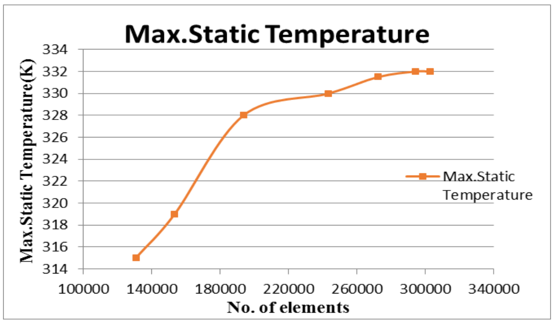

Figure 5: Variation of temperature with number of elements

From the graph it is evident that grid independence test was successful and the variation in maximum static temperature value dies out as the number of meshing elements increases and the stable value is achieved for a minimum value of number of elements equal to 2,80,000 and onwards. The graph (figure 5) shows that after attaining certain value of number of elements, the physical properties almost become stationary i.e. the maximum number of elements has been reached.

VI. GOVERNING EQUATIONS

The physical aspects of any fluid flow are governed by three fundamental principles: mass is conserved; Newton's second law and energy is conserved. These fundamental principles can be expressed in terms of mathematical equations, which in their most general form are usually partial differential equations.

Continuity:

$$\frac{\partial \rho}{\partial t}+\frac{\partial(\rho u)}{\partial x}+\frac{\partial(\rho v)}{\partial y}+\frac{\partial(\rho w)}{\partial z}=0 \qquad 1$$

X momentum:

$$\frac{\partial(\rho u)}{\partial t}+\frac{\partial(\rho uu)}{\partial x}+\frac{\partial(\rho vu)}{\partial y}+\frac{\partial(\rho wu)}{\partial z}=\frac{\partial \sigma_{xx}}{\partial x}+\frac{\partial \tau_{yx}}{\partial y}+\frac{\partial \tau_{zx}}{\partial z} \qquad 2$$

Y momentum:

$$\frac{\partial(\rho v)}{\partial t}+\frac{\partial(\rho uv)}{\partial x}+\frac{\partial(\rho vv)}{\partial y}+\frac{\partial(\rho wv)}{\partial z}=\frac{\partial \sigma_{yy}}{\partial y}+\frac{\partial \tau_{xy}}{\partial x}+\frac{\partial \tau_{zy}}{\partial z} \qquad 3$$

Z momentum:

$$\frac{\partial(\rho w)}{\partial t}+\frac{\partial(\rho uw)}{\partial x}+\frac{\partial(\rho vw)}{\partial y}+\frac{\partial(\rho ww)}{\partial z}=\frac{\partial \sigma_{zz}}{\partial z}+\frac{\partial \tau_{xz}}{\partial x}+\frac{\partial \tau_{yz}}{\partial y} \qquad 4$$

Energy:

$$\frac{\partial(\rho E)}{\partial t}+\frac{\partial(\rho uE)}{\partial x}+\frac{\partial(\rho vE)}{\partial y}+\frac{\partial(\rho wE)}{\partial z}=$$

$$\frac{\partial(u\sigma_{xx}+v\tau_{xy}+w\tau_{xz})}{\partial x}+\frac{\partial(u\tau_{yx}+v\sigma_{yy}+w\tau_{yz})}{\partial y}$$

$$\frac{\partial(u\tau_{zx}+v\tau_{zy}+w\sigma_{zz})}{\partial z}+\frac{\partial(\mathrm{k}\frac{\partial T}{\partial X})}{\partial X}+\frac{\partial(\mathrm{k}\frac{\partial T}{\partial Y})}{\partial Y}+$$

$$\frac{\partial(\mathrm{k}\frac{\partial T}{\partial Z})}{\partial Z} \qquad 5$$

Table 1: Boundary Conditions

Inlet temperature of cold fluid (^{o}C)	25
Inlet temperature of hot fluid (^{o}C)	55
Velocity of cold fluid at inlet (m/s)	15.5
Velocity of hot fluid at inlet (m/s)	20
Heat flux at outer wall (W/m^{2})	5429
Heat flux at inner wall (W/m^{2})	2142.32

VII. RESULTS AND DISCUSSION

Here we describe the results obtained from simulation work.

Validation of CFD Work

The results that were obtained by Ahmad Ghozatloo, Alimorad Rashidi, Mojtaba Shariaty-Niassar in their experimental practice was verified with the help of ANSYS fluent' 14 software, and the computational results were in quite a good agreement with the experimental results.

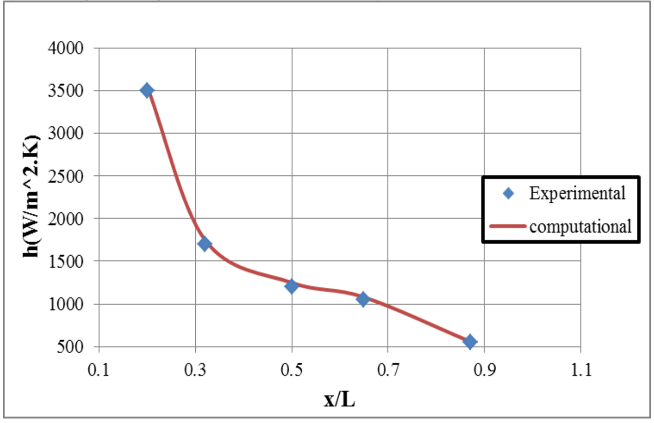

Figure 6: Heat transfer coefficient h (W/m^2.K) with (x/L) for water.

The graph figure 6 shows the variation of heat transfer coefficient h (W/m^2.K) with (x/L) for water along the length of the tube based on experimental as well as computational results.

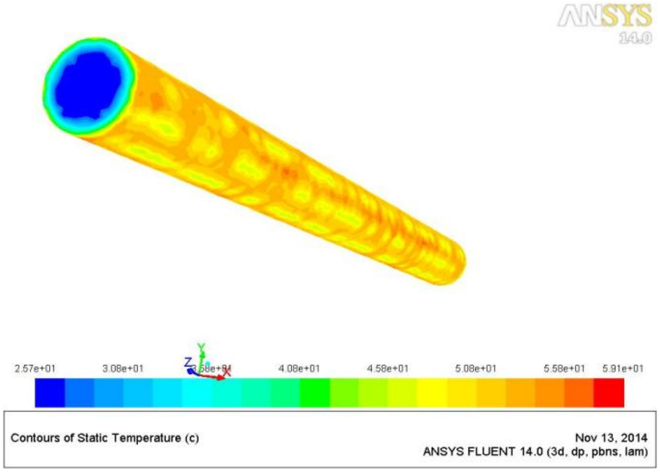

Figure 7: Contours of static temperature

The figure 7 shows the variation of static temperature along the length of the tube for graphene1. The static temperature varies from 25°C to 59.1°C.

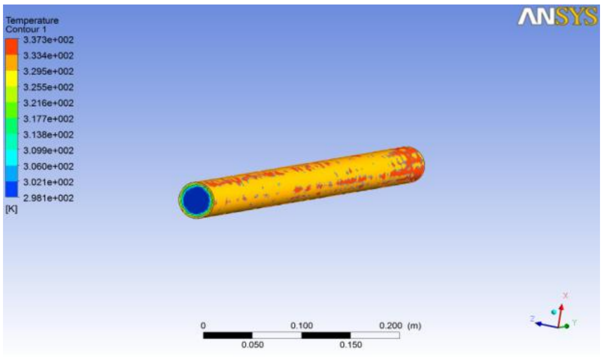

Figure 8: Temperature variation for graphene1 with grooving

The figure 8 shows the variation of static temperature along the length of double tube heat exchanger when grooving was incorporated on the outer surface of the inner tube and graphene 1 was used as a cold fluid.

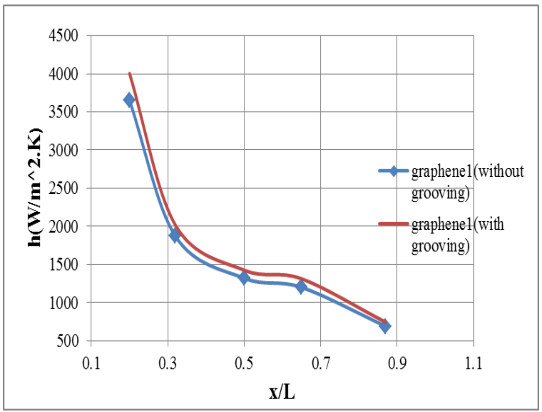

Figure 9: Heat transfer coefficient h (W/m^2.K) with (x/L) for graphene1

From the figure 9 it can be easily inferred that the incorporation of grooving in the heat exchanger has significant effect on heat transfer coefficient and an average of 9.48% increment in heat transfer coefficient value has been observed.

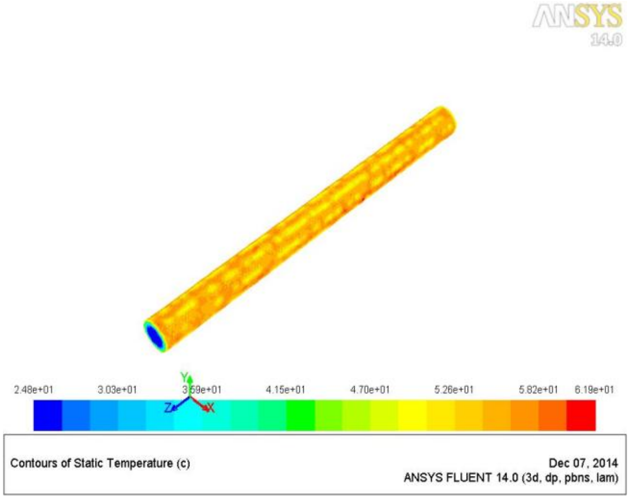

Figure10: Contour Variation for Graphene2 without grooving

The figure 10 shows the variation of static temperature for a double tube heat exchanger without grooving and when graphene 2 was used as a cold fluid.

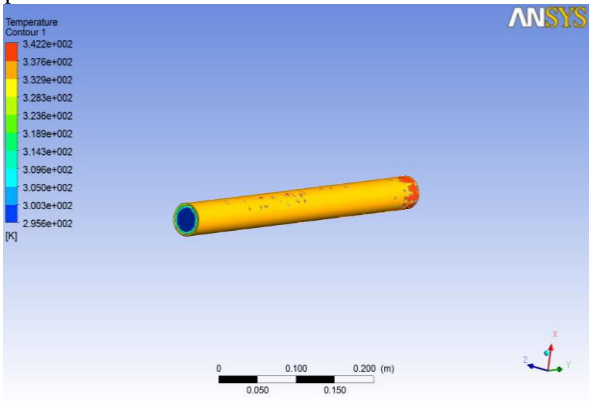

Figure.11: Contour variation for graphene2 with grooving

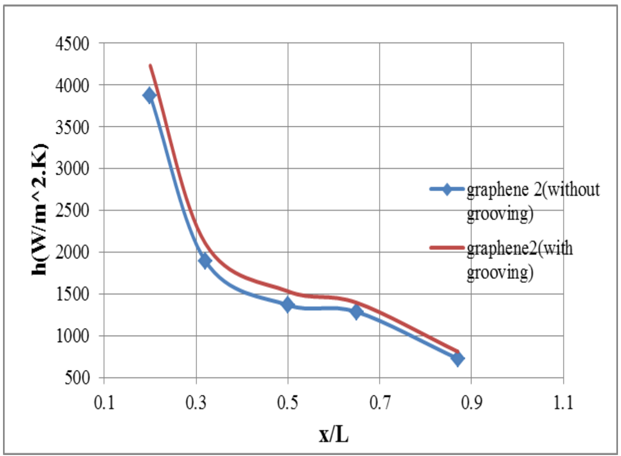

Figure 12: Heat transfer coefficient h ($W/m^2.K$) with (x/L) for graphene2

From the graph it can be easily inferred that with the provision for grooving on the outer surface of heat exchanger the heat transfer coefficient also increases and this increment is on an average 10.51%.

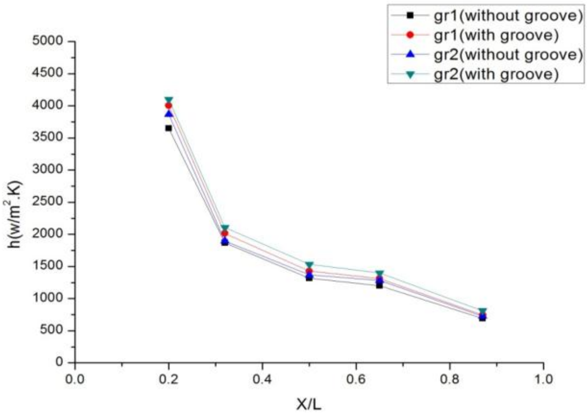

Figure.13 Heat transfer coefficient h ($W/m^2.K$) with (x/L) for graphene1 and graphene2

The Figure 13 shows the variation of heat transfer coefficient h ($W/m^2.K$) with (x/L) for graphene1 and graphene2 with and without grooving. The maximum heat transfer coefficient has been obtained for graphene2 when grooving was incorporated on the outer surface of the inner tube.

VIII. CONCLUSION

The computational work has verified the results obtained by Ahmad Ghozatloo, Alimorad Rashidi, and Mojtaba Shariaty-Niassar for their research work. The increment in heat transfer coefficient values with the increment in the concentration of graphene in water based nanofluid solution are the findings of the research work. Provision for grooving on the outer surface of the inner tube of the heat exchanger is also made in this research work and it has been found that grooving helps in enhancing the heat transfer coefficient value significantly. When graphene1 and graphene2 were compared an increment of **5.67%** (average value) was observed. When grooving was incorporated the increment in heat transfer coefficient value for graphene1 was **9.48%** (average value) and for graphene2 it was **12.51%** (average value).So an overall increment in heat transfer coefficient for graphene 2 with grooving is observed.

ACKNOWLEDGMENT

The author would like to thank the Mechanical Engineering Department of National Institute of Technology (NIT Silchar) for providing Computational Fluid Mechanics Lab of NIT Silchar to carry out the research work.

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