Heat transfer Enhancement using Nano fluids in a Wavy Heat Exchanger

Devath Ashok, P. N. Reddy, B. Shirish, T. Ch. Siva Reddy

***Abstract:** The Nano liquids have higher estimations of thermal conductivity than those of the unadulterated fluids and more prominent potential for heat transfer upgrade, in this exploration, a solitary - stage invention approach is utilized to investigate the effect of nanoadditive shape on the liquid stream and heat transfer parts of γ-AlOOH (boehmite alumina), nano liquid streaming however a 3D wavy blade, The γ-AlOOH (boehmite alumina) nanoadditives of shape (platelet) are spread in half water 50%ethylene glycol mix as the base liquid. The effect of the Reynolds number and nano added substance of volume portion on the Nusselt number is numerically considered for platelet molded nanoadditive. It is shows that, among the considered Reynolds number (100,400,700) with the platelet shape. At Reynolds number=700 speaks to the most elevated Average Nusselt Number, heat transfer execution and pressure drop, while the at Reynolds number=100 execution is low. What's more, in addition, the computing shows that for all conditions improvement the Reynolds number raises the Nusselt number and weight drop of the γ-AlOOH nano-liquid. What's more that, it is discovered that builds the nanoadditive portion prompts an improvement in the Nusselt number of the assessed nano-fluids.in platelet shape at all states of pressure drop increments with expansion of nano particles with base liquid.*

***Keywords:** Nusselt number; Nano fluids; Reynolds Number, Heat transfer rate, pressure drop, γ-AlOOH (boehmite alumina).*

I. INTRODUCTION

The spreading of a nano-fluid driblet is increased by the solid-like ordering structure of nano particles assembled close to the contact line by diffusion, which provides rise to a structural disjoining pressure within the locality of the contact line. However, such improvement isn't determined for little droplets with diameter of nanometer scale; as a result of the wetting continuance is far smaller than the diffusion continuance. Throughout this work, a two-phase mixture approach is employed to seem at the influence of nano additive type on the fluid flow and heat transfer aspects of γ- AlOOH nano-fluid flowing through a twisted oval tube.

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The γ-AlOOH (boehmite alumina) nano additives of assorted shapes (i.e. cylindrical, brick, blade, and platelet) unit distributed in water as a result of the bottom fluid. The influence of the nusslent number selection and nano additive volume fraction on the nusselt selection, pressure drop is numerically studied for numerous nano additive shapes. It's disclosed that, among the thought of nano additive shapes, the living substance type represents the simplest heat transfer performance, whereas the worst performance belongs to the brick type nano additives. To boot, the findings reveal that for all states, enhancing the Reynolds number selection intensifies the nusselt selection, pressure drop, and of the γ-AlOOH nano fluid. Moreover, it's found that boosting the nano additive fraction lands up in associate improvement at intervals the nusselt selection and of the examined nano-fluids. Moreover, the pressure drop of all the thought of nano-fluids enhances with augmenting the Reynolds number completely different of conditions

GOVERNING EQUATIONS

1. Continuity Equation

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0$$

2. Momentum Equation (Navier-stokes Equation)

X-Momentum equation

$$\rho\left(u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}\right)=-\frac{\partial p}{\partial x}+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right)$$

Y -Momentum equation:

$$\rho\left(u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}\right)=-\frac{\partial p}{\partial y}+\mu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right)$$

Z- Momentum equation:

$$\rho\left(u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}\right)=-\frac{\partial p}{\partial z}+\mu\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right)$$

3. Energy Equation

$$\left(u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}+w\frac{\partial T}{\partial z}\right)=\frac{1}{\alpha}\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}\right)$$

4. Boundary conditions

In this boundary conditions base fluid and nano additive (volume fraction nano particles), is used those are 0%, 0.5%,1%, 1.5%, 2% is used. The inlet temperature of fluids is considered to be 293 K. The Different Reynolds number is 100, 400, and 700. At the inlet. The velocity is given as inlet. The top and bottom wall given temperature is 303k and left and right walls are adiabatic

a) Inlet

In this boundary condition given as velocity inlet. Different velocities taken as different conditions. And Inlet temperature taken as 293 k.

b) Inlet wall

Inlet wall is a smooth wall and this taken as adiabatic condition.

c) Outlet

In this outlet temperature and outlet pressure

d) Outlet wall

Outlet wall is a smooth wall and this taken as adiabatic condition.

e) Wall

In this constant heat flux taken. And wall temperature is considered as 303k.In this top wall is considered.

f) Symmetric

Both side same dimensions. That taken as axis symmetric. Due to symmetry taken symmetry.

g) Calculation Procedure and Formulae

Calculating procedure for Reynolds number and average Nusslent number for those following equations

Flow Reynolds number is defined by:

- $\boldsymbol{Re} \frac{UD_h}{v}$
- Where, U = velocity
- D_h = hydraulic diameter
- The Nusselt number equation is given by Nu :
- **Nu=** $\frac{hD}{k}$
- where,
- h=coefficient of heat transfer, W/m2K
- D= Characteristics length, m
- k=thermal conductivity of the fluid, W/m K

Table I: Thermo physical base fluid and volume fraction of nano particles those properties.

Properties	γ-AlOOH (boehmite alumina)	50%Water 50% Ethylene Glycol blend
Density(kg/m^3)	3050	1067.5
Specific heat (J/kg K)	618.3	3300
Thermal conductivity(K)(W/m K)	30	0.3799
Viscosity (kg/ms)	-	0.003399

Above properties explains thermal physical properties of γ-AlOOH (boehmite alumina) is nano additive 50%water50% Ethylene Glycol blend as base fulid.adding nano particles to base fluids it improves to thermal properties

II. MODELING AND MESHING

A. 3D Modeling

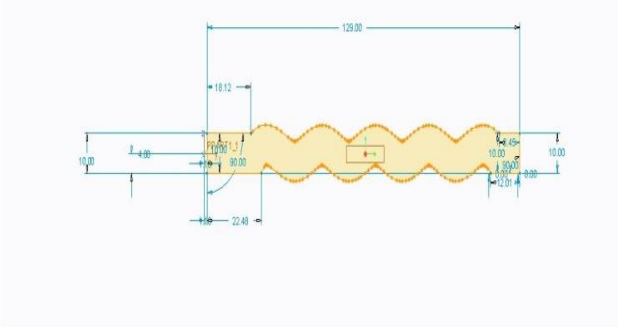


Fig. 1: Geometry of physical model.

Above geometry explains in details, in this fin pitch is 2mm, fin height is 8mm, wave length is 10.8mm,fin thickness is 0.2mm fin length 65 mm, twice of wave fin amplitude is (2A) is 1.5 mm and upstream length is 10mm and finally downstream length is 20mm.simulation is 3D.

B. 3D Meshing

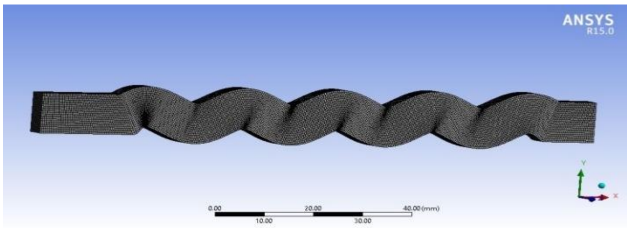


Fig. 2: 3D Geometry Meshing model

In this 3D wavy channel is taken with different dimensions, and mesh rectangular structured mesh. and in This inlet and outlet lengths' are different because of an outlet back flow taken place if length is short. Since outlet length is more than inlet. In this same boundary condition given but in this bottom wall boundary condition is taken.

And top and bottom wall given 303k temperature. in fin pitch taken 2mm and fin height taken 8mm.in this also inlet temperature taken is 293k.In this rectangular structured mesh is mesh and near wall, inflation is given to wall for accurate results. If fine mesh is present that temperature is high at the walls. In this top wall and bottom wall are considered.

III. RESULTS AND DISCUSSION

In this consideration of results for Average Nusslent number. Base fluid and nano additive γ-AlOOH (boehmite alumina).

Table 1: Average Nusselt number of 3D Geometry results

	0%	0.5%	1%	1.5%	2%

Re 100	24.28	26.54	27.36	28.35	30.24
Re 400	33.99	36.25	38.24	40.24	42.65
Re 700	38.24	40.34	42.54	44.35	49.26

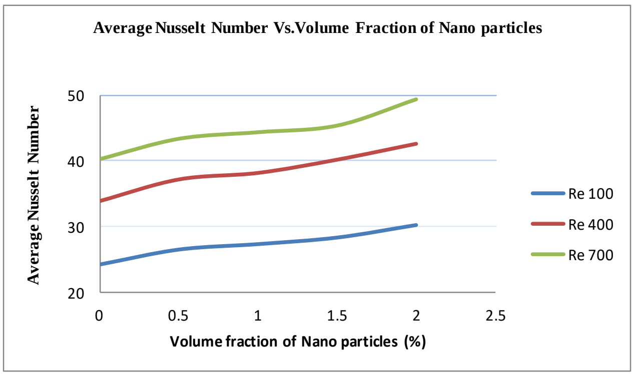


Fig. 1: Graph for 3D Average Nusselt number Vs Volume fraction of Nano particles (%)

Table 2: Heat transfers rate results for 3D geometry

	0%	0.5%	1%	1.5%	2%
Re 100	1.56	2.95	5.52	7.41	9.85
Re 400	3.85	7.32	11.39	15.411	19.23
Re 700	5.47	9.606	13.52	19.92	24.15

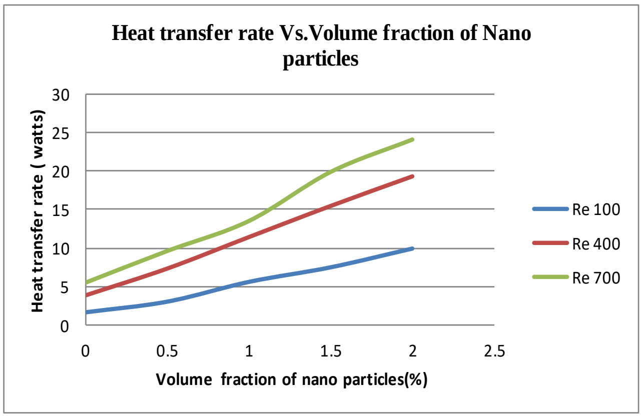


Fig. 2: Graph for Heat transfers rate vs. Volume fraction of Nano particles

Table 3: Heat flux results for 3D geometry

Different Reynolds number	0%	0.5%	1%	1.5%	2%
Re 100	3.523	6.67	12.46	16.738	22.24
Re 400	8.696	16.534	25.72	34.811	43.43
Re 700	12.355	21.698	30.539	44.996	54.551

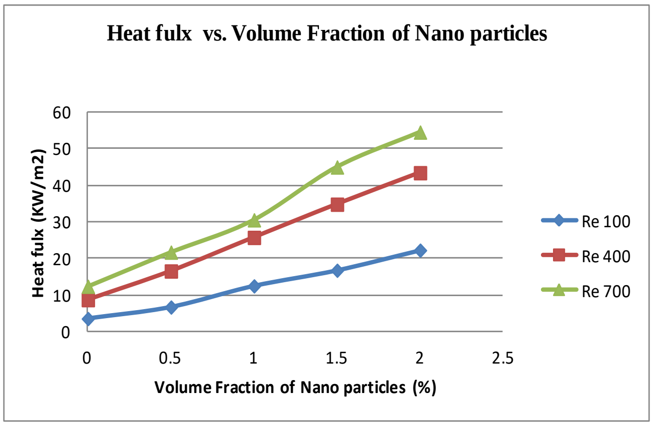


Fig-3 Graph for Heat flux vs. Volume fraction of Nano particles.

Table .4: 3D wavy fin of Pressure Drop

	0%	0.5%	1%	1.5%	2%
Re 100	2.528	3.612	5.084	7.055	9.587
Re 400	10.06	14.45	20.278	28.0150	38.50
Re 700	17.68	25.289	35.612	49.352	67.379

In this 3D wavy plate wave length is taken as 10.8mm and twice of wave fin amplitude is (2A) is 1.5mm and with respect to velocity it is calculated.

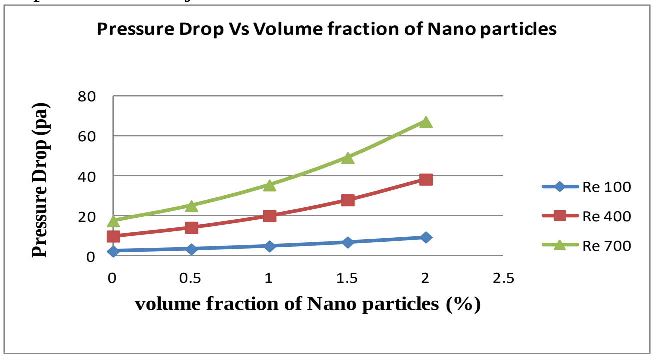
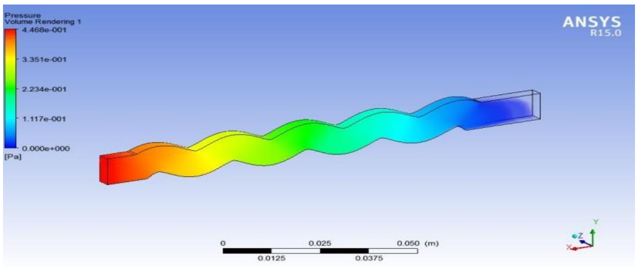
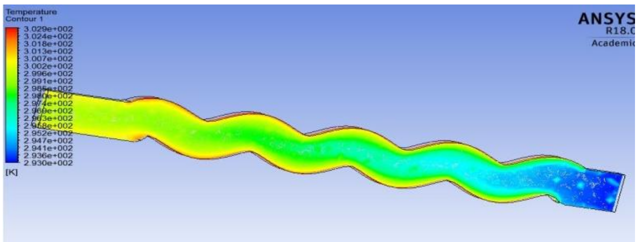


Fig-4: Graph for pressure drop vs. Volume fraction of Nano particles.

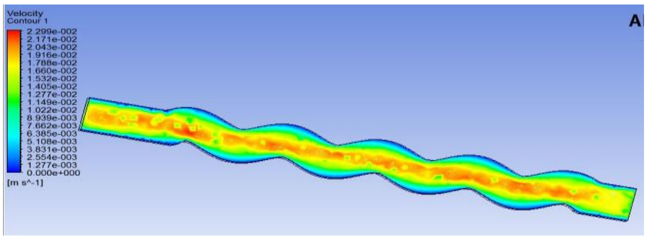
A. Counters for 3 D Geometry



Pressure

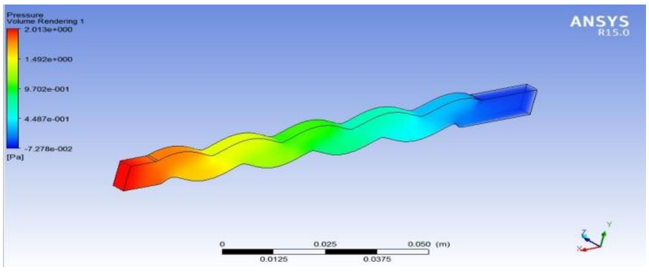


Temperature

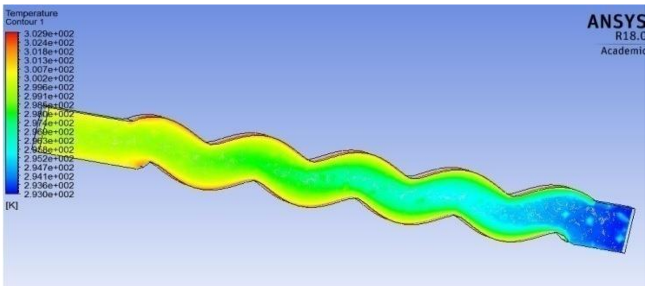


Velocity

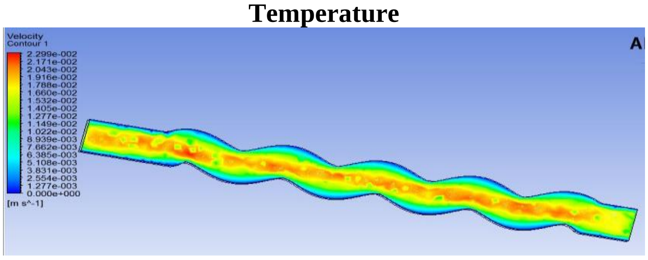
Fig-5: Contours of pressure, temperature, velocity at 0% particles for Re 100



Pressure

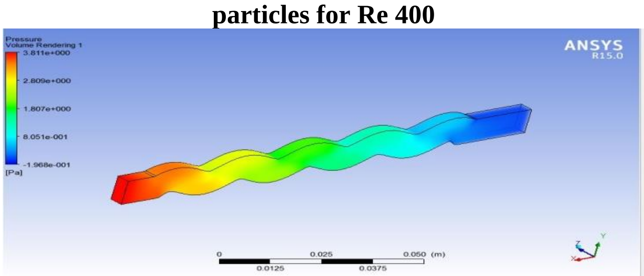


Temperature

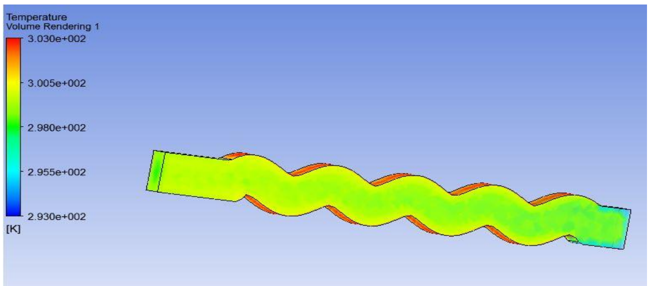


Velocity

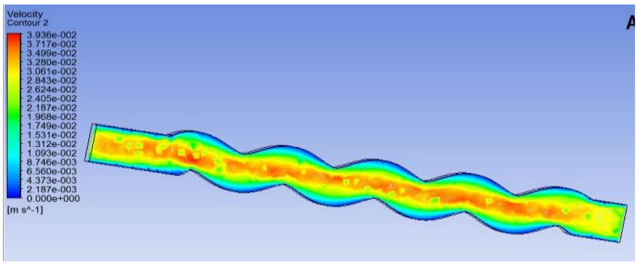
Fig-6: Contours of pressure, temperature, velocity 0% particles for Re 400



Pressure

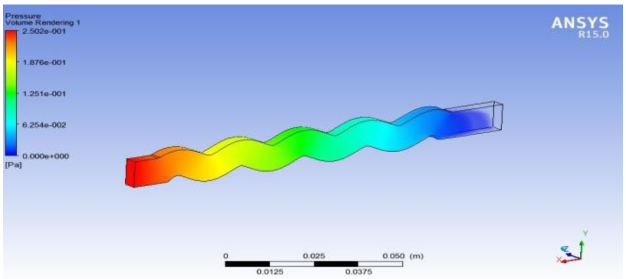


Temperature

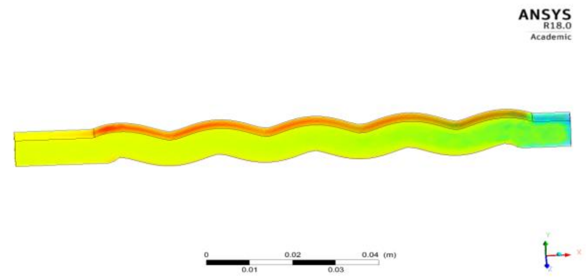


Velocity

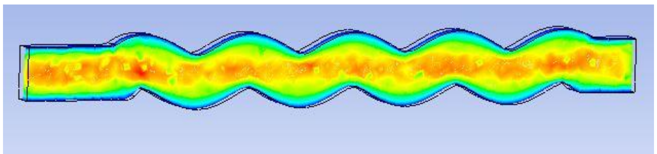
Fig-7: Contours of pressure, temperature, velocity 0% particles for Re 700



Pressure



Temperature



Velocity

Fig-8: Contours of pressure, temperature, velocity 1% particles for Re 100

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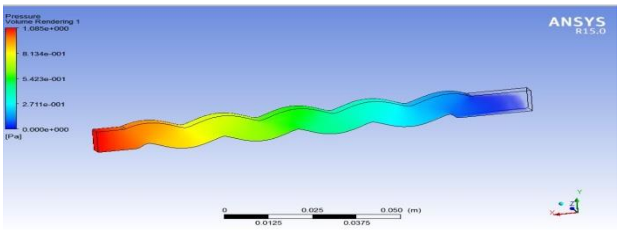
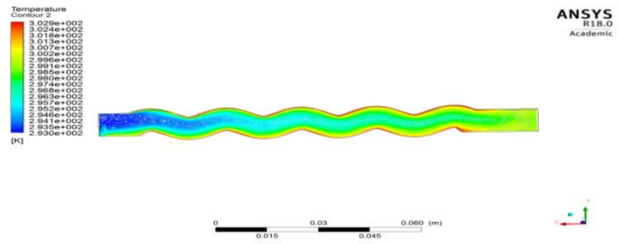
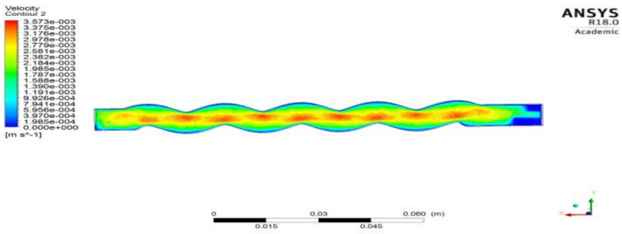


Pressure

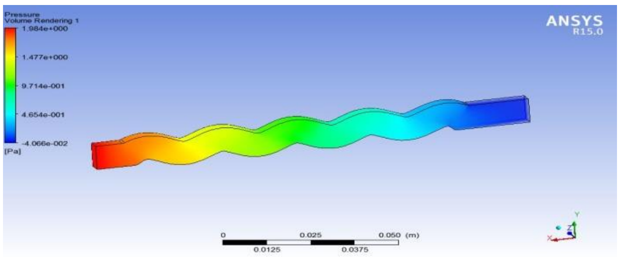


Temperature

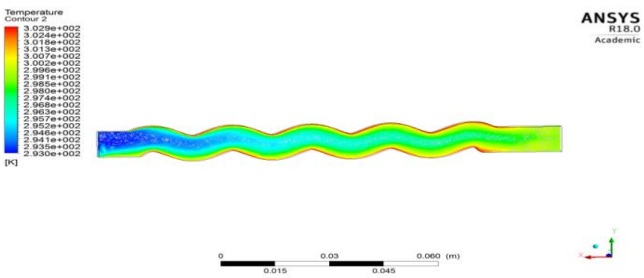


Velocity

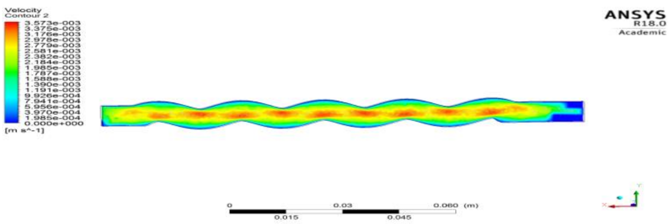
Fig-9: Contours of pressure, temperature, velocity 1% particles for Re 400



Pressure

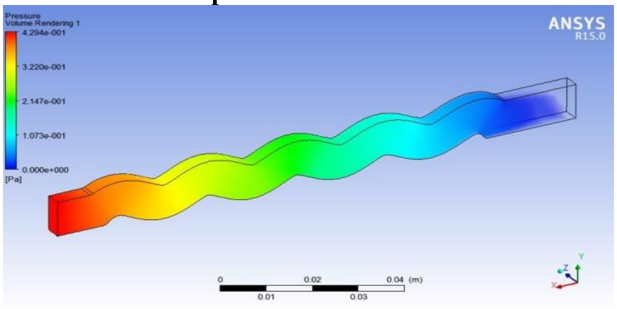


Temperature



Velocity

Fig-10: Contours of pressure, temperature, velocity 1% particles for Re 700



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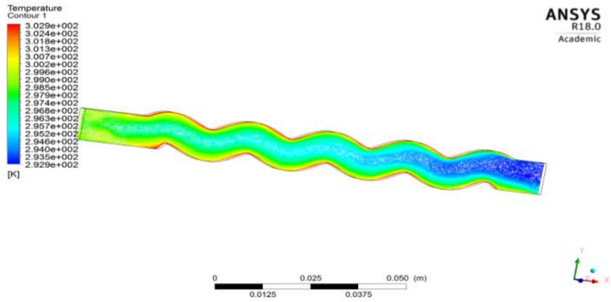

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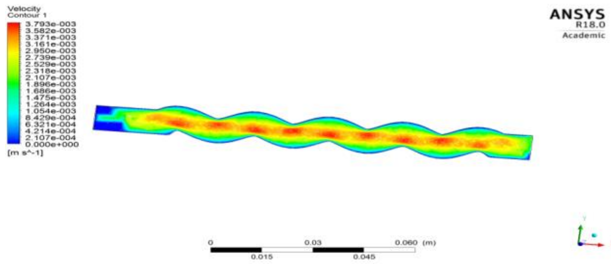
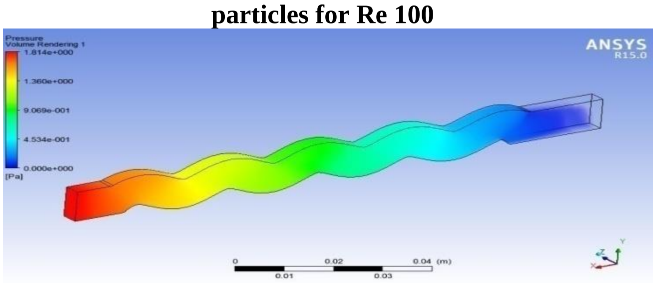
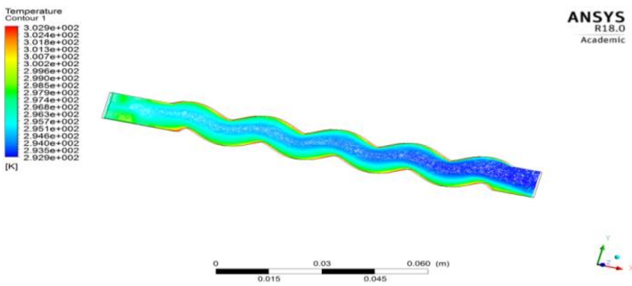


Velocity

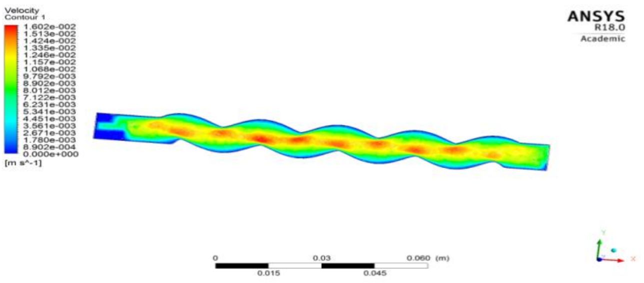
Fig-11: Contours of pressure, temperature, velocity 2% particles for Re 100



Pressure

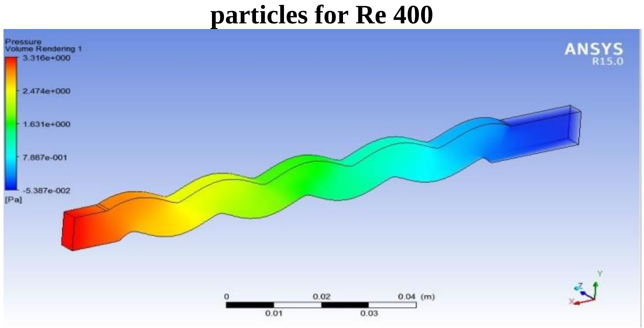


Temperature

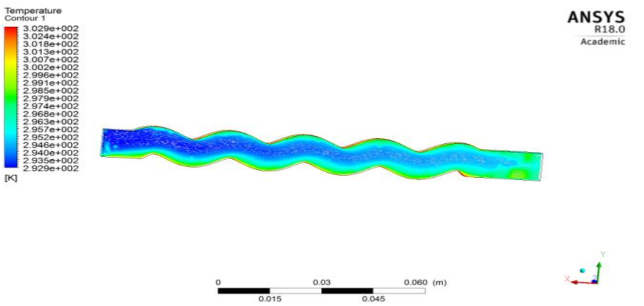


Velocity

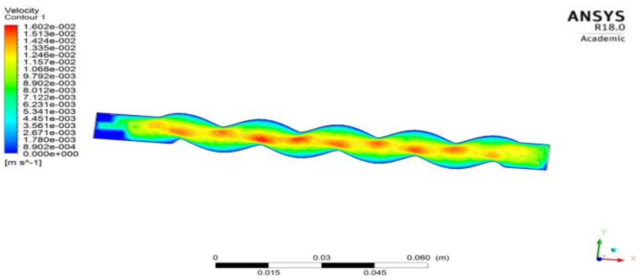
Fig-12: Contours of pressure, temperature, velocity 2% particles for Re 400



Pressure



Temperature



Velocity

Fig-13: Contours of pressure, temperature, velocity 2% particles for Re 700

IV. CONCLUSION

In this thesis CFD analysis is performed, the hydro thermal aspects of water based γ-AlOOH (boehmite alumina) nano-fluid are numerically calculated in 3D wavy heat exchanger for platelet shape of nanoadditive. The influence of the nanoadditive fraction (0.5% to 2%) and Reynolds number (100,400,700) is studied.

1. Considering volume fraction of nano particle at 2%, at Reynolds number 700 resulted in high average Nusselt number. Percentage increasing in average Nusselt number is 28.81422%, 25.501%, 24.539%, for Reynolds of 700, 400, 100 respectively with increase in volume fraction from 0% to 2%.
2. Heat transfer increment from 0.5% to 2% of volume fraction of nano particles is 6.9W, 11.91W, 14.544W, for Reynolds number 100,400,700 respectively. From the results heat transfer rate was increased while increasing the Reynolds number in 3d wavy channel. And 3d wavy channel has got higher average Nusselt number than rectangular duct.
3. Increment in the Reynolds number increases the average Nusselt number at different proportions with addition of volume fraction of nano particles.
4. Augmenting the particle volume fraction enhances the thermal conductivity and viscosity. Percentage increase in conductivity and viscosity are observed to be 5.22%, 98.7% respectively.
5. Pressure drop found high at Reynolds number 700 and low at Reynolds number 100; it is same for 2D and 3D geometry conditions. With addition nano particles, pressure drop increased at all Reynolds number.

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