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Heat Transfer of Pin Finned Heat Exchanger Using Nano Fluids

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Abstract: The heat transfer characteristics of heat exchanger can be augmented by changing fluids or by changing geometry of heat exchanger. The nanofluids encompasses nanoparticles which aid in enhancing heat transfer characteristics without increasing pumping power requirement. The current research investigates the application ZnO/water nanofluid for compact heat exchanger application using techniques of Computational Fluid Dynamics. The CFD analysis is conducted for different volume fractions of ZnO/water i.e. .02, .04 and .07 and turbulence model used for analysis is RNG k-epsilon. The results have shown significant increase in heat transfer coefficient with the use of nanofluids as compared to water.

***Key Words**: Heat exchanger, nanofluid, CFD*

1. INTRODUCTION:

The heat exchangers are used to transfer heat from hot fluid to cold fluid. The compact heat exchanger finds its application in various HVAC applications. One of the types of compact heat exchanger is finned tube. The finned side of finned tube heat exchanger has higher thermal resistance and is therefore used in air side. This results in overall improvement of thermal performance of heat exchanger. These finned surfaces include “crimped spiral fin, plain fin, slit fin and fin with delta-wing longitudinal vortex generator and so on” [6].

2. LITERATURE REVIEW

L.H. Tang, M. Zeng, Q.W. Wang [1] have conducted numerical investigation on different types of heat exchangers. The investigation carried out with 12 rows and 18mm tube diameter has shown that crimpled fin (figure 1) has highest effectiveness as compared to other type of fins.

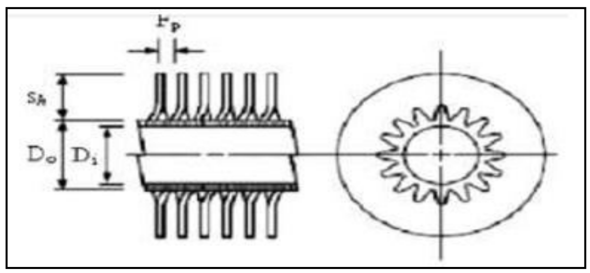

Fig 1: Crimped spiral fin [1]

Mao-Yu Wen, Ching-Yen Ho [2] have conducted experimental investigation of wavy fin, plate fin using wind tunnel. The investigation was carried out for Reynolds number ranging from 2000 to 6000 and the various parameters like “heat transfer coefficient, the pressure drops of the air side, the Colburn factor (j), and fanning friction factor (f) against air velocity are evaluated” [2]. The findings have shown that average HTC and pressure drop of wavy fin was higher than flat fin.

Parinya Pongsoi, Patcharapit Promoppatum, Santi Pikulkajorn, Somchai Wong wises[3] has conducted experimental investigation on finned tube heat exchanger to investigate effect of fin pitches on frictional and heat transfer characteristics. The results have shown that fin pitch doesn't have any significant effect on both the characteristics.

Thirapat Kuvannarat, Chi-Chuan Wang, Somchai Wongwises [4] has conducted numerical investigation of finned tube heat exchanger under dehumidifying conditions. The results have shown that "for a heat exchanger with two rows and fin pitch of 1.41 mm, the heat transfer coefficients is about 5–50% and pressure drop 5-20% higher for fin thickness of 0.25 mm than those for fin thickness of 0.115 mm" [4].

Chi-Chuan Wang, Jane-Sunn Liaw, Bing-Chwen Yang [5] have conducted numerical investigation of herringbone finned tube heat exchanger to determine the performance of airside. The results have shown that performance decreased for tube diameter larger than 16.59mm.

3. OBJECTIVE

The objective of current research is to investigate the effect of ZnO/water nanofluid on heat transfer characteristics of compact heat exchanger. The volume fraction of ZnO/water considered for analysis is .01, .02 and .04. The CAD model of heat exchanger is developed in Creo design software and CFD analysis is conducted using ANSYS CFX.

4. METHODOLOGY

The computational domain taken for analysis is shown in figure 2 below. The section of finned tube heat exchanger highlighted in red color is considered for analysis. The symmetric boundary conditions is used for the analysis.

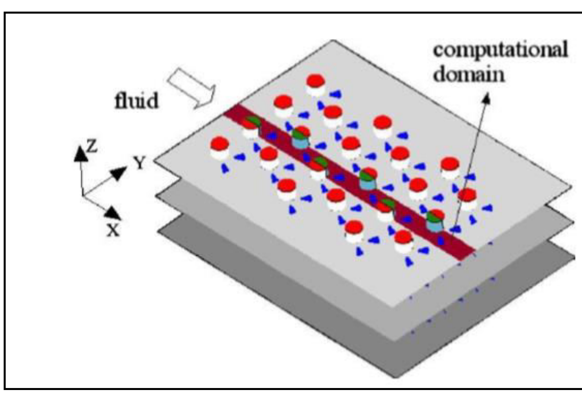

Figure 2: Computational domain

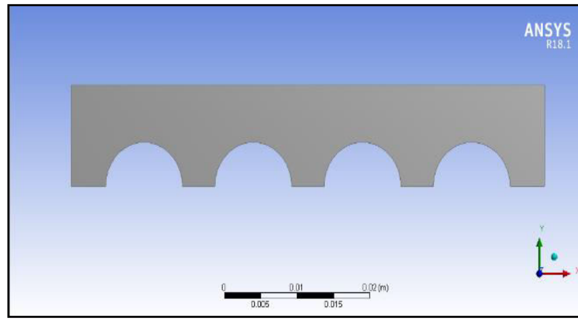

Fig.3 Imported CAD model in ANSYS

The CAD model developed in creo design software is converted in .iges file format which makes it compatible to exchange the file in other software. The CAD model of finned tube heat exchanger is imported in ANSYS design modeler as shown in figure 3 where is checked for hard edges.

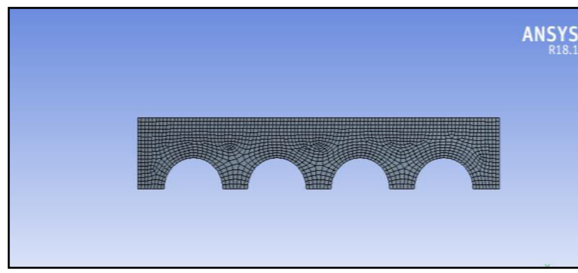

Fig.4. Meshed model in ANSYS and parameter setting

A hexahedral mesh is generated at different regions using fine sizing. The mesh type is different for different zones. The inlet boundary condition, outlet boundary condition and symmetric boundary conditions are defined. The fluid flow analysis is conducted for different fluid velocities of .2m/s, .4m/s, .6m/s, .8m/s and 1m/sec are applied. The RNG k-epsilon turbulence model is employed in this study to simulate the turbulent flow due to its suitability for a wide range of wall-bounded and free-shear flows. The RNG k-epsilon is a "semi-empirical model with several constants which were obtained from experiments and RNG k-ε model based on model transport equations for the turbulence kinetic energy (k) and its dissipation rate (ε)" [7] .

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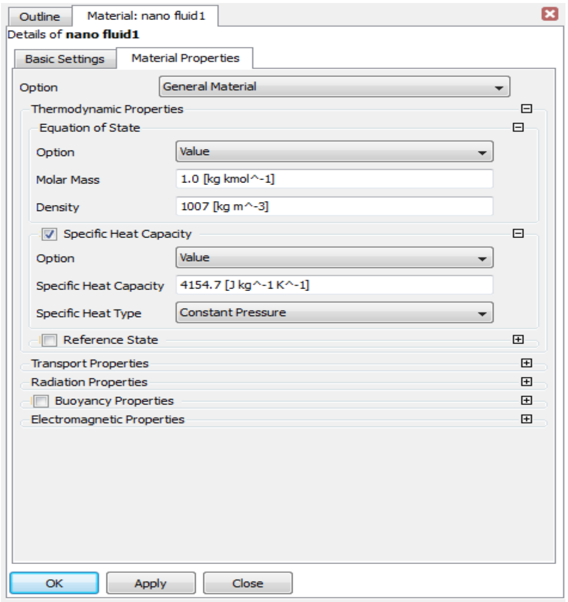

Fig.5. Setting domain parameters and assigning fluid properties

The material properties of nanofluids are defined for ZnO/water as shown in figure 5 above.

5. RESULTS AND DISCUSSION

From temperature contour plotted below in fig 6 shows that fluid in contact with tube shows higher temperature as compared to fluid away from tube. There is non-uniformity in temperature distribution of fluid due to flow across tube banks. The heat transfer is due to turbulence and above tube banks uniform temperature with blue colored contours.

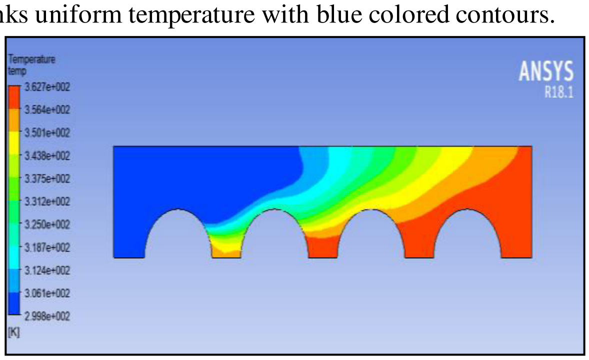

Fig 6 Temperature Contour

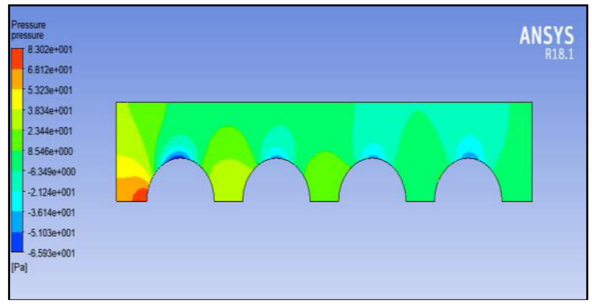

Fig. 7 Pressure Contour

The pressure contour as shown in fig 7 shows that maximum pressure is developed at regions near inlet and as we move towards the pressure generated decreases and is minimum at second quadrant point of tube shown by dark blue color. For other points negative pressure is developed and ranges from -65.3 Pa to 83.5 Pa max value. The temperature plot obtained is very different as that of using water as fluid. Here maximum temperature shown by red colour is developed across entire fluid exit. This is due to presence of ZnO particles in water and minimum temperature is obtained at region near inlet and lasts to quarter length of exchanger thereafter temperature increases. The maximum temperature obtained is 369K which is much higher as compared to water as fluid as shown in fig. 8.

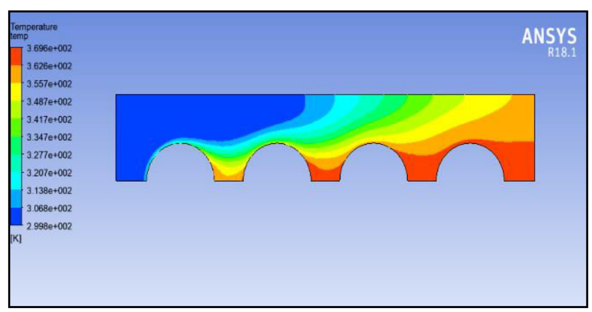

Fig. 8 Temperature Contour for ZnO / water .02

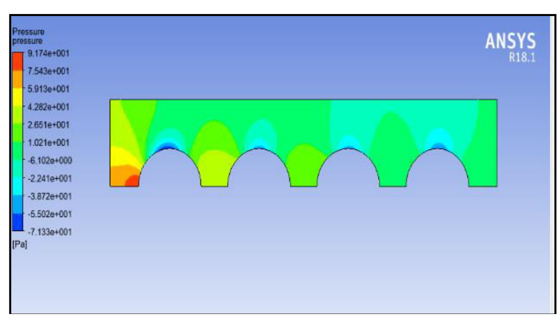

Fig.9 Pressure Contour for ZnO / water .02

The pressure contour obtained here is similar as that of water but difference lies in maximum and minimum values. The maximum value of pressure is 91.74Pa near inlet and first tube while minimum (tensile) is 71.33Pa developed at vicinity of tubes on upper portion.

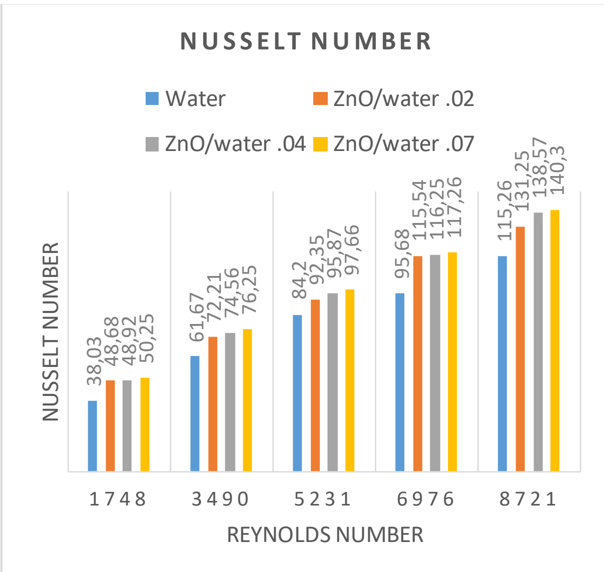

Fig. 10 Nusselt number comparison for different volume fraction of ZnO

6. CONCLUSION

The CFD analysis conducted on finned tube heat exchanger using ZnO/water nanofluid has shown significant improvement in heat transfer characteristics as compared to water. The augmentation of heat transfer for .02 volume fraction of ZnO/water nanofluid is 28.5% at low Reynolds number. Similarly, for .04 volume fraction of ZnO/water nanofluid 29% augmentation of heat transfer is observed. The RNG k-epsilon turbulence model gave good prediction of swirl generated on various zones and these vortices enhanced heat transfer rate by inducing turbulence.