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CFD Analysis of Finned Tube Heat Exchanger Using Nano Fluid

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***Abstract*-Nanofluids consist of nanoparticles suspended in a liquid medium and the particle size is smaller than 100 nm. Nanofluids have great thermo-physical properties such as thermal conductivity, thermal diffusivity, viscosity and heat transfer coefficient as compared to their base fluids. The current research investigates the application of ZnO/water nanofluid on compact heat exchanger with circular tubes using techniques of Computational Fluid Dynamics (CFD). The CAD model is developed in Creo design software and CFD analysis is conducted using ANSYS CFX. The volume concentration of nanoparticles used for analysis are .02,.04 and .07. The CFD analysis is conducted for both laminar and turbulent flow regime using k-epsilon turbulence model. The temperature distribution, Nusselt number and pressure plots are generated to determine heat transfer characteristics. The results are encouraging and significant enhancement of heat transfer is achieved using ZnO/water nanofluid. However, the pumping power requirement also increased with increase in nanoparticle concentration.**

***Keywords*-EGR cooler, CFD, NOx Emission.**

I.INTRODUCTION

In finned tube heat exchange, the liquid side has higher heat transfer coefficient as compared to gas side. The fins are used on gas side to increase surface area A. The condensing liquid is on one side and gas on other side. The geometry of finned tube heat exchanger has mostly circular tubes, rectangular tubes but sometimes elliptical tubes are also used. The fins are placed on outside and are attached using tension winding or mechanical fits.

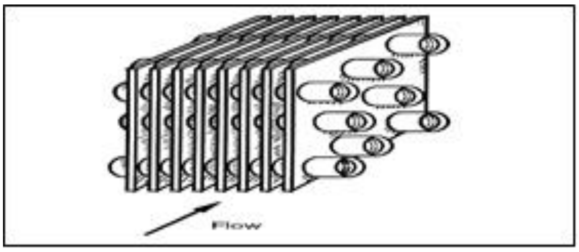

Figure 1. Finned tube heat exchanger.

II. LITERATURE REVIEW

Mao-Yu Wen, Ching-Yen Ho [1] has investigated compounded fin, wavy fin and plate fin for Re number ranging from 2000 to 6000 and air velocity ranging from 1m/s to 3m/s. The colburn factor and fanning factor along with heat transfer coefficient and pressure drop are determined and compounded fin has shown best results among all other types.

ParinyaPongsoi, PatcharapitPromoppatum, Santi Pikulkajorn, Somchai Wong wises [2] conducted investigation on spiral fin and tube heat exchanger (L footed) with varying fin pitches. The HTC of air side and friction factor was determined for Re number ranging from 4000 to 15000. The hot water was used as fluid and findings have shown significance of fin pitch on average HTC.

A. Nuntaphan, T. Kiatsiriroat, C.C. Wang [3] conducted investigation on 23 heat exchangers having crimpled spiral configurations with varying tube diameter, fin spacing. The findings have shown that increasing tube diameter causes increase of pressure drop and average HTC and both of the variables reduces with increased fin height. These results hold for inline arrangement. In case of staggered arrangement, the effect of fin height on pressure drop is quite low (as compared to inline arrangement). The transverse tube pitch has significant on pressure drop and HTC.

ParinyaPongsoi, Santi Pikulkajorn, Chi-Chuan Wang, Somchai Wongwises [4] investigates the crimpled finned tube heat exchanger having multipass parallel configuration for Re number ranging from 4000 to 13000. The effect of fin materials i.e. copper and aluminium and fin pitches on performance of air side performance is evaluated. The experimental findings have shown that fin pitch doesn't have any significant effect on Colburn j factor. The increase in friction factor is however observed at fin pitch of 6.2mm.

III. PROPOSED WORK

The application of nanofluids in heat exchanger can improve its effectiveness as it possesses higher heat transfer rate as compared to base fluids. Therefore, it is essential to investigate the effect of ZnO water nano fluid in finned tube exchanger to determine its efficacy and compare it with base fluid (water). In the current study ZnO water nanofluid is analyzed in finned tube heat exchanger using techniques of computational fluid dynamics. The turbulence model considered for analysis is shear stress transport and CFD analysis is conducted using ANSYS CFX software.

IV. METHODOLOGY

The CAD model is developed in Creo design software using sketch and extrude tools. The first step involves importing CAD model in ANSYS workbench using import tool and geometry cleanup is performed using various tools.

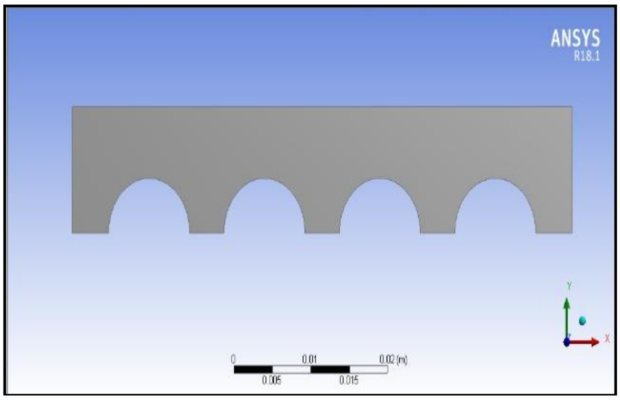

Fig 2. Imported CAD model in ANSYS.

The model is meshed using brick elements and with given parameters and appropriate mesh density. The mesh size is set to fine and inflation to normal with relevance set to 100. Transition is set to slow and smoothing medium and span angle fine as shown in figure 3 below.

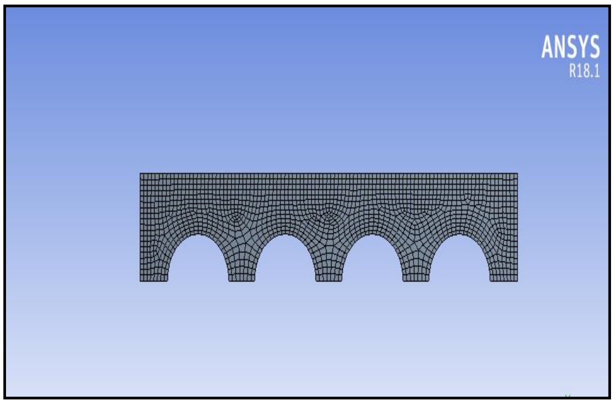

Fig 3. Meshed model in ANSYS and parameter setting.

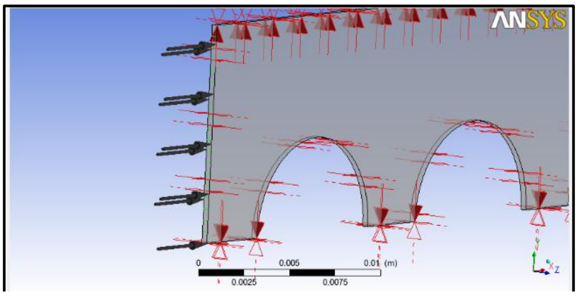

Fig 4. Inlet boundary conditions.

The inlet boundary conditions are defined on left surface with varying velocities as shown in fig 4 and turbulence intensity is medium to 5% whereas for outlet right surface is selected and relative pressure is set to zero.

V. RESULTS AND DISCUSSION

For this case we have used water as fluid without incorporating aluminum oxide nano particles and results are shown below. From temperature contour plotted below in fig 5 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.

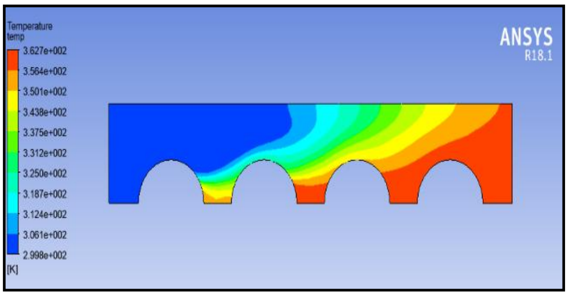

Fig 5. Temperature Contour.

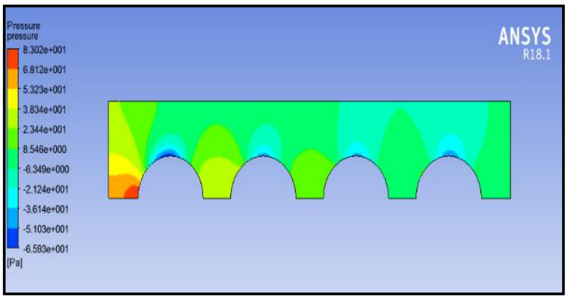

Fig. 6. Pressure Contour.

The pressure contour as shown in fig 6 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.

In the second sub case the maximum temperature developed is near tube and of magnitude 299K as shown in fig 7 while the distribution pattern is same as described in first sub case.

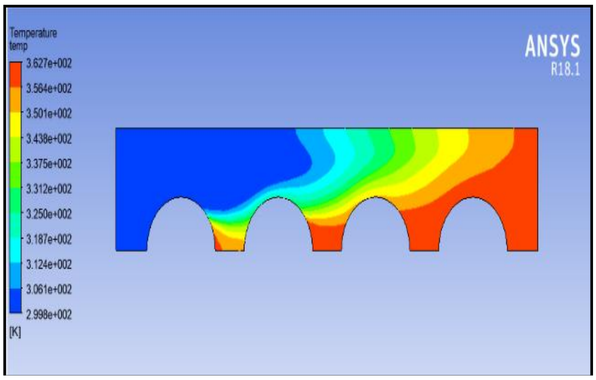

Fig 7. Temperature Contour for water.

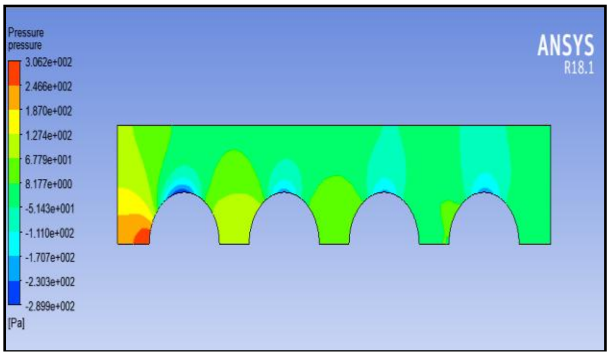

Fig 8. Pressure Contour for water.

The pressure contour as shown in fig 8 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 colour. For other points negative pressure is developed and ranges from -289.9 Pa to 306.2 Pa max value. From temperature contour plotted 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. Maximum temperature obtained is 311.9K as shown in fig 9.

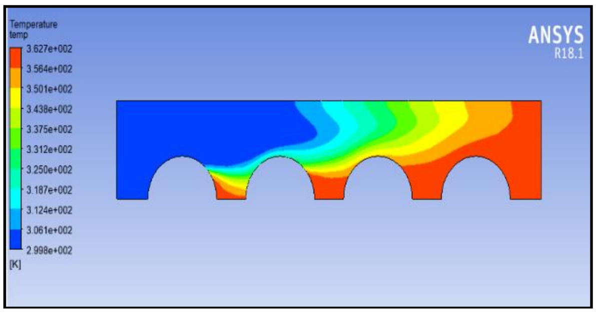

Fig. 9. Temperature Contour for water.

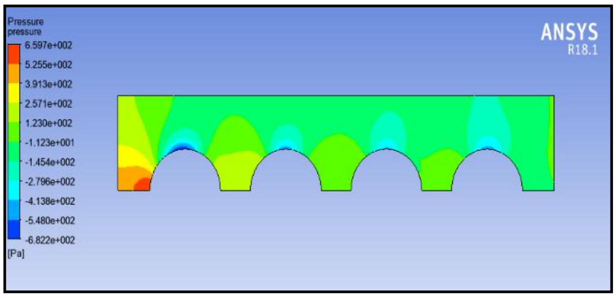

Fig 10. Pressure Contour for water.

The pressure contour as shown in fig 10 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 -682.1 Pa to 659.7 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 11.

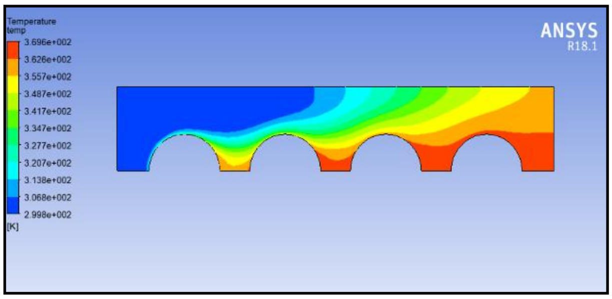

Fig 11. Temperature Contour for ZnO / water .02.

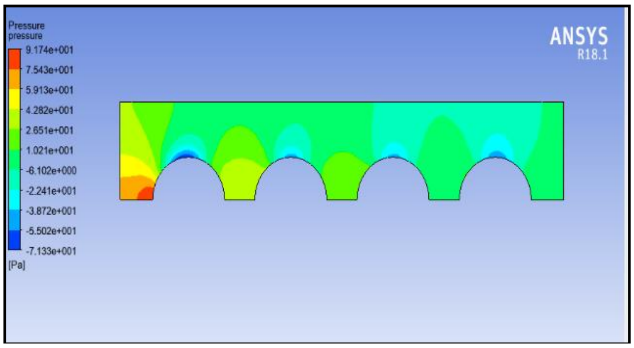

Fig 12. Pressure Contour for ZnO / water .02.

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.

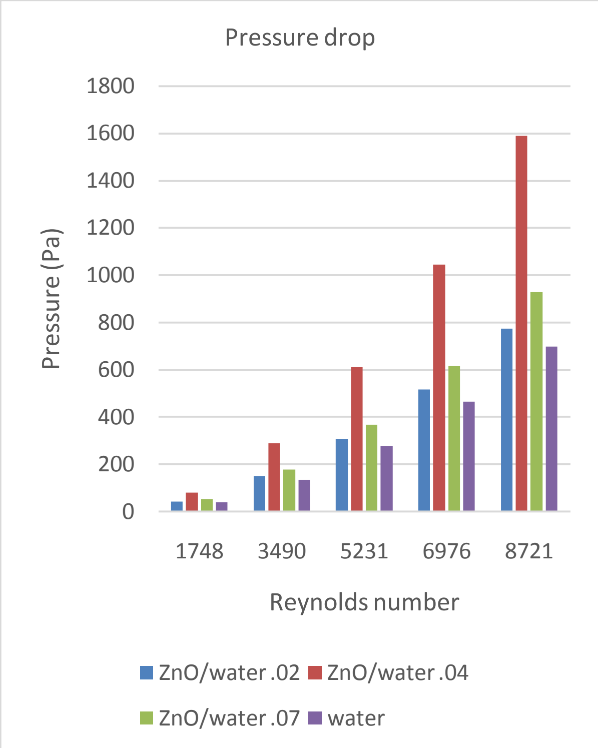

Fig 13. Nusselt number comparison for different volume fraction of ZnO.

The Nusselt number comparison between different volume fractions of nanofluids is shown in figure 13 above. The minimum Nusselt number is observed using water as base fluid which increased with increase in volume fraction of nano fluids. The increase in concentration of nanoparticles helps to achieve higher heat transfer rate.

VI. CONCLUSION

Numerical simulation has been investigated on heat transfer characteristics and pressure drop of ZnO/water nanofluid in compact heat exchanger with circular tube shapes and an in-line Arrangement of tubes under steady state laminar fluid flow. Heat transfer enhancement is increasing with the nanoparticle and using circular tube geometry. An significant increase of heat transfer is found with .02 volume fraction of nanofluid compared to base fluid (water) at lower Reynolds number.

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