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CFD Analysis of a Finned Vertical Tube with Different Cross Sections to Improve the Heat Transfer Rate

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ABSTRACT: The heat transfer rate to a fluid flowing in pipe can be enhanced by the use of internal fins. This work concerned with simulation analysis of vertical tube with helical fins used to enhance their heat transfer performance subjected to natural convection heat transfer. All the main parameters which can significantly influence the heat transfer performance of finned tube has been analyzed. Natural convection in a vertical tube without fins was taken as the reference the and different fin patterns such as a single fin with large no. of turns like coiled shape and large no. of fins with single turn is compared with reference tube on the basis of different parameters such as heat transfer rate, surface Nusselt number, heat transfer coefficient, fin effectiveness etc. There are some dimensionless numbers which affect the natural convection such as nusselt number which is the function of Reynolds number, grashof number and prandtl number, Rayleigh number which is the product of grashoff and Prandtl number. After getting best fin configuration compared it with different fin profile such as rectangular cross section, tapered fin with trapezoidal cross section and hyperbolic cross section. All the computer simulation analysis has been done on the ANSYS. The Navier-stokes equations were used to solve for the fluid flow inside the tube and the Boussinesq approximation was used to get the buoyancy effect. Aluminum is used for the fin material and air is taken as the fluid flowing inside the tube and the flow is taken as laminar. It was found that the large number of fins with single turn is more efficient than other fin patterns, as there is less flow resistance, high heat transfer rate.

Key words: CFD, FVT, HTR, ANSYS, Nusselt, Grashoff, Prandtl

I. INTRODUCTION

Convection is a process which involves mass movement of fluids. Natural convection occurs due to temperature difference which produces the density difference which results in mass movement, this process is called natural or free convection. For example, assume a plate which is maintained isothermal at temperature T_w and the surrounding temperature is T_∞. On getting heated, the fluid near the wall moves up due to the effect of buoyancy and this hot fluid is replaced by cold fluid moving towards the wall. Hence a circular current is set up due to density difference. There is a boundary layer adjacent to the plate where the velocity and temperature and velocity vary from plate to free stream. Initially the velocity increase with increasing distance from the surface and reaches a maximum and then decrease to approach zero value. This is because of action of viscosity diminishes rapidly with distance from plate, while density difference decreases more slowly.

The used of heat transfer enhancement has become widespread during the last so many years. The need of heat transfer enhancement is to reduce the size and cost of heat exchanger equipment, or increase the heat duty for a give size heat exchanger. This goal can be done in two ways active and passive enhancement. The active enhancement is less common because it requires addition of external power (e.g., an electromagnetic field) to cause a desired flow modification. In the passive enhancement, it consists of alteration to the heat transfer surface or incorporation of a device whose presence results in a flow field modification. The most popular enhancement is the fin.

Fins are the extended surfaces which are used to enhance the rate of heat transfer dissipation from heated surfaces to air. Fins can be placed on plane surfaces, tubes, or other geometries. These surfaces have been used to increase heat transfer rate by adding additional surface area and encouraging mixing. When number of fins are used to enhance heat transfer under natural convection conditions the optimum geometry of fins (corresponding to a maximum rate of heat transfer) should be used, provided this is compatible with available space and financial limitations. The common fins used extensively to increase the rates of natural convection heat transfer from systems are rectangular fins because such fins are simple and cheap,

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to manufacture. The heat transfer to the fluid flowing through a cylindrical pipe by the heat dissipating surfaces can be obtained mainly by using the mechanisms of heat transfer by forced convection, natural convection and by radiation heat transfer. This paper mainly concerned with those issues related to the heat transfer obtained mainly by natural convection. A great number of experimental and analytical work has been done on vertical and horizontal finned tube subjected to natural convection. Kayansayan [2] studied the thermal characteristic of fin and tube heat exchanger, Rao [3] studied the heat transfer from horizontal fin array, Yang [4] conducted an experiment on mixed convective cooling of a fin in a channel, Sharif and Bergman [5] worked on enhancement of PCM melting in enclosure with horizontal finned internal surface. Myhren [6] worked on improving thermal performance of ventilation radiators using internal fins. Baek [7] studied on heat transfer enhancement using straight and twisted internal fins.

II. LITERATURE SURVEY

Munoz et al. [8] done analytical work on internal helically finned tubes for parabolic trough design by CFD tools. The application of finned tubes to the design of parabolic trough collectors has some losses as the pressure losses, thermal losses and thermo-mechanical stress and thermal fatigue. The result shows an improvement potential in parabolic trough solar plants efficiency by the application of internal finned tubes.

SAZALI [9] experimental study of a vertical internally finned tube subjected to natural convection heat transfer. The length of tube was 100mm. the tube taken for the experiment has inner diameter 80mm and the outer diameter 90mm. The tube contains four radial, straight, and equally spaced around the circumference of the tube. Other dimensions like height of the fins are 100mm and the length of the fins are 25mm. Air was used as a working fluid in the experiment. The result shows that the value of Nu for vertical cylinder under variables time varies with the temperature is increasing.

Myhren et al. [6] studied heat output optimization of a ventilation radiator by varying the distribution of vertical, longitudinal convection fins. The investigation was made using Computational Fluid Dynamics simulations while analytical calculations were used for different flow and heat transfer mechanisms. The results showed that heat transfer can be increased in the section where ventilation air is brought into the room by slightly changing the geometry of the fins like decreasing the fin-to-fin distance. The small change in internal design could mean considerable increase in thermal efficiency for the ventilation radiator as a whole. Wang et al. [10] studied heat transfer performance of internally finned tubes with blocked core- tube was numerically investigated by the realizable k–e turbulence model With method using FLUENT. By using 3 kinds of lateral fin profiles, S-shape, Z-shape and V-shape, were studied and compared. The corresponding correlations of Nusselt number and friction factor were obtained for different-shape internally finned tubes. The result showed that tubes with S-shape fins and Z-shape fins were best profile as compared with V-shape fins, and moreover, tube with Z-shape fins had the best performance.

Giri et al. [11] worked on the role of natural convection in many applications like ice-storage air-conditioning. A mathematical formulation of natural convection heat and mass transfer over a shrouded vertical fin array is developed. The base plate was kept at a temperature below the dew point of the surrounding moist air due to this, occurrence of condensation of moisture on the base plate, while the fins may be partially or fully wet. The results showed that beyond a certain stream wise distance, further fin length does not improve the sensible and latent heat transfer performance, and that if dry fin analysis is used under moisture condensation conditions, the overall heat transfer will be lowballed by about 50% even at low buoyancy ratios. Papadopoulos et al. [12] done the Numerical study of laminar fluid flow in a curved elliptic duct with internal fins. The study of the fully developed laminar incompressible flow inside a curved duct of elliptical cross-section with four thin and internal longitudinal fins is done using the improved CVP method. Results showed that the friction factor increases for large fins and for high Dean numbers and in some cases, it has dependent on the cross-sectional aspect ratio. The thermal results show that the heat transfer rate is increased by the internal fins and that it depends on the aspect ratio.

Foong et al. [13] conducted the numerical study to investigate the fluid flow and heat transfer characteristics of a square micro channel with four longitudinal internal fins. 3-D numerical simulations were performed on the micro channel with variable fin height ratio in the presence of a developed laminar flow. Constant heat flux boundary conditions were assumed on the external walls of the square micro channel. Results obtained of the average local Nusselt number distribution along the channel length as a function of the fin height ratio. The analytical study was carried out for different fin heights and flow parameters. Aziz [14] et al. measured the heat transfer rate for different fin profile such as rectangular, trapezoidal, and concave parabolic (finite tip thickness). Results obtained from the comparison based on the relationship between the dimensionless heat flux, the fin parameter, and dimensionless tip temperature for all three geometries.

III. RESULTS AND DISCUSSION

Analysis has been done on five tubes of same dimensions but having different fin configurationorfin profile with same fin height.

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Description of the tubes:

1. Tube 1 : This tube is the plane vertical tube without fins.

2. Tube 2: This tube is a vertical tube having a single helical fin of rectangular fin profile with large number of turns along the length.

3. Tube 3: This tube is a vertical tube having ten helical fins of rectangular cross-sectional area with single turn along the length.

4. Tube 4: This tube is a vertical tube having ten helical fins of trapezoidal cross-sectional area with single turn along the length.

5. Tube 5: This tube is a vertical tube having ten helical fins of concave parabolic cross-sectional area with single turn along the length.

Problem data:

Tube no.	Inner Diameter (mm)	Outer Diameter (mm)	Fin Profile	Fin Height (mm)	Fin Thickness (mm)
1.	50	53	Without fin	5	2
2.	50	53	One rectangular fin	5	2
3.	50	53	arfin	5	2
4.	50	53	oidalfin	5	Varying from 2 to 4 mm
5.	50	53	10 concave parabolic fin	5	Varying from 2 to 4 mm

Table 1 Problem data for different fin configuration and fin profile.

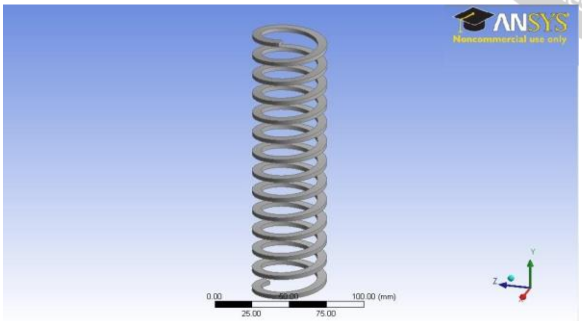


Fig 1 One helical fin with large number of turns

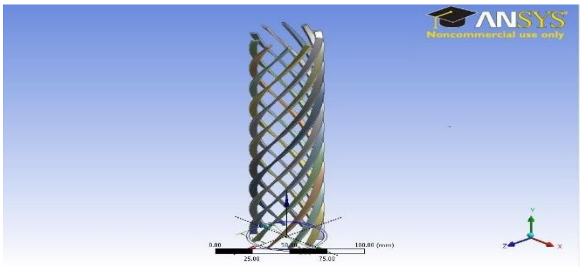


Fig. 2 Ten helical fins with single turn

Temperature contours for different tubes:Tube1:

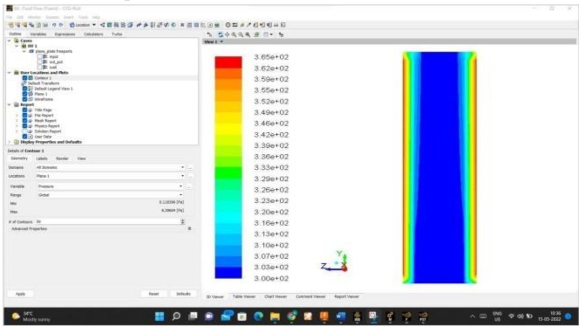


Fig. 3 Temp. contour of vertical tube without fin

Tube2:

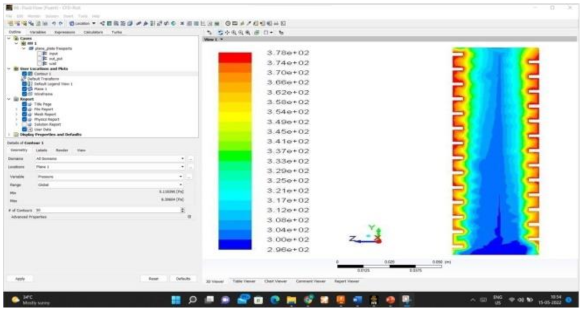


Fig 4 Temp. contours of vertical tube with rectangular fin profile

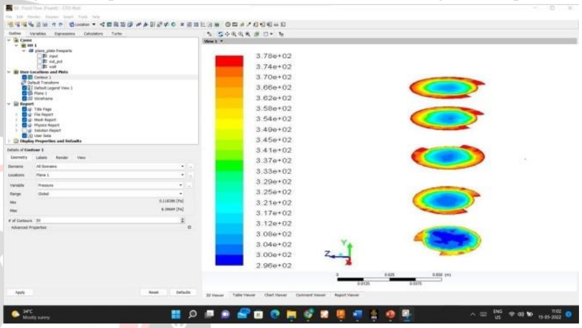


Fig 5 Temp. contours of tube2 in different horizontal plane

TUBE:3

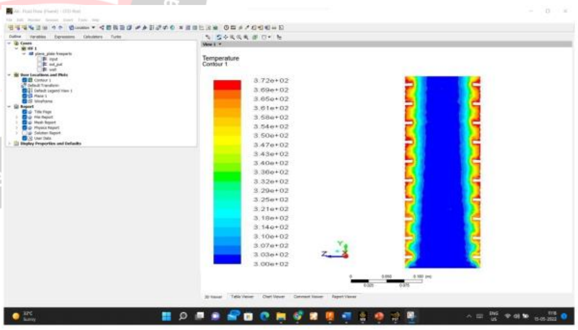
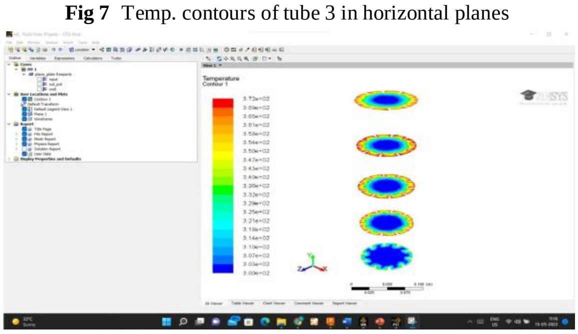


Fig 6 Temp. contours of tube3 in vertical plane

Fig 7 Temp. contours of tube 3 in horizontal planes



Tube4 :

Fig 8 Temp. contours of tube 4 in vertical plane

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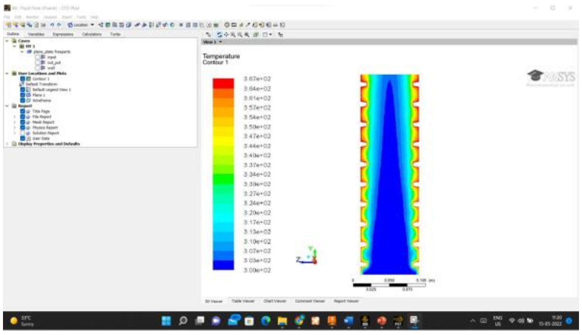

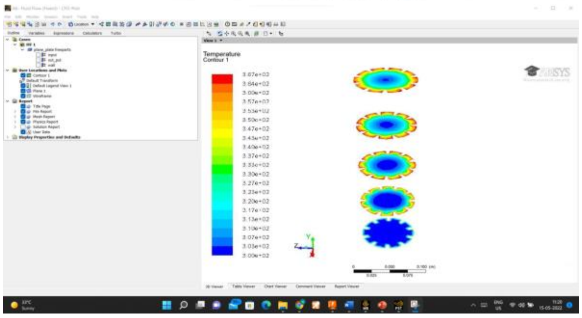

Tube5 :

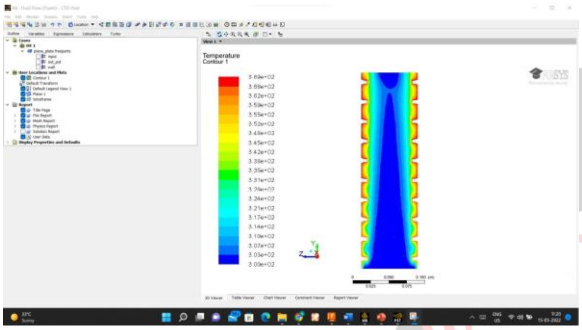

Fig 5.10 Temp. contours of tube5 in vertical plane plane

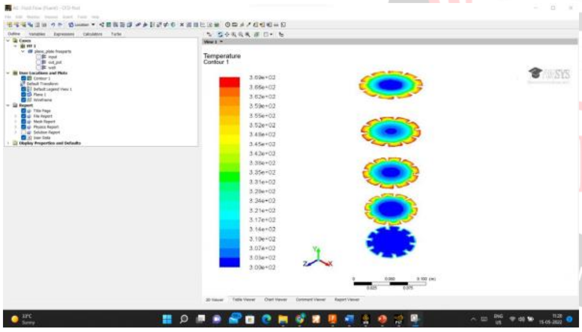

Fig 11 Temp. contours of tube5 in horizontal planes

Heat transfer rate

Tube no.	Heat transfer from fin (W)	Heat transfer from innerwall (w)
1.	---------	11.054466
2.	7.0425867	5.6044407
3.	9.6723562	7.1381139
4.	11.977043	6.2673212
5.	11.243548	5.7177154

Table 3 Heat transfer rate for different tube

IV. CONCLUSION

The tube1, tube2 and tube3 have been compared on the basis of different graphs governed from the CFD analysis and it has seen that from fig. 5.3, 5.4 and fig. 5.5, fin configuration in tube3 is more effective than other two tubes. The geometry of fins used in Tube2 has more restricted path for the air flow which increases the flow resistance and decreases the air flow rate and that downs the heat transfer rate. From fig. 5.12, fig. 5.13 and fig. 5.14, it can be seen that value of surface nusselt number has maximum value for tube3 as compared to tube1 and tube2. For tube3, near the bottom point of the tube, it is more than 300 which is greater than the tube2 which has nearly equal to 250. The surface heat transfer coefficient is compared at different position on the tube, and has more value for tube3, nearly equal to 9W/m^2-k at the lowest position of the tube, as compared to 5.5W/m^2-k and 4.5W/m^2-k for the tube1 and tube2 respectively. Heat transfer rate is 11.05 W, 12.647 W and 16.81 W respectively for the tube1, tube2 and tube3. Tube3 has maximum heat transfer rate. Hence the results showed that, for tubes having different fin configurations, the tube having ten equally spaced internal helical fins is more effective as compared to the tube without fin and tube2 which has one helical fin with large number of turns. Tube3, tube4, tube5 having same fin configuration, which already had been concluded, have been compared for best fin profile. Tube3, tube4 and tube5 have rectangular, trapezoidal and concave parabolic fin profiles respectively. From fig. 5.14, fig. 5.15 and fig. 5.16, it has seen that at the position of 20mm from the bottom point of the tube the value of surface nusselt number is 450 for tube3, for tube4 it is more than 600 which is greater than tube5 which has less than 600. The value of surface heat transfer coefficient has approximately equal values for tube4 and tube5 of approximately equal to 14W/m^2-k as compared to tube3 of approximately equal to 10W/m^2-k. Heat transfer rate from tube4 is 18.244 W which is more than 17.061 W and 16.81 W for tube5 and tube3 respectively. Hence the overall performance of the fins and heat transfer rate from different fin profile has maximum value for trapezoidal fins for natural convection through internal fins for the given case.

REFERENCE

[1] Nag P.K., Heat and mass transfer, New Delhi, TMH, 2010

[2] Kayansayan N., Thermal characteristics of fin and tube heat exchanger, Experimental thermal and fluid science, 1993, Vol. 7, pg. 177-188

[3] Rao V.D., Naidu S.V., Rao B.G., Sharma K.V., Heat transfer from a horizontal fin array by natural convection and radiation, international journal of heat and mass transfer, 2006, Vol. 49, pg. 3379-3391

[4] Yang M.H., Yeh R.H., Hwang J.J., Mixed convective cooling of a fin in a channel, international journal of heat and mass transfer, 2009, vol. 53, 760-771

 DOI : 10.35291/2454-9150.2022.0240

[5] Sharif N., Bergman T.L., Faghri A., Enhancement of PCM melting in enclosure with horizontally fixed internal surfaces, international journal of heat and mass transfer, 2011, vol. 54, pg. 4182-4192

[6] Myhren J.A., Holmberg S., Improving the thermal performance of ventilation radiator- the role of internal convective fins, international journal of heat and mass transfer, 2010, vol. 50, pg. 115-123

[7] Tijing L.D., Baek B.J., A study on heat transfer enhancement using straight and twisted internal fins inserts, international journal of heat and mass transfer, 2006, vol.33, pg. 719-726

[8] Munoz J., Abanader A., Analysis of helical finned tubes for parabolic through designed by CFD tools, Applied energy, 2011, vol. 88, pg. 4139-4149

[9] Sazali N., Experimental study of natural convection heat transfer in a vertical internally finned tube, 2009

[10] Wang Q., Zeng M., Lin M., Effect of lateral fin profiles on turbulent flow and heat transfer performance of internally finned tubes, Applied thermal energy, 2009, vol.29, pg. 3006-3

[11] Giri A., Narasimhan G., Murthy M., Combined natural convection heat and mass transfer from vertical fin arrays, international journal of heat and mass transfer, 2003, vol. 24, pg. 100-113

[12] Papadopoulous P.K., Hatzikonstantinou P.M., Numerical study of laminar fluid flow in a curved elliptical duct with internal fins, international journal of heat and fluid flow, vol. 29, April 2009, pg. 540-544

[13] Andrew J.L., Ramesh N., Chandratilleke T.T., Laminar convective heat transfer rate in a micro channel with internal longitudinal fins, international journal of thermal sciences, October 2009, vol. 48, pg. 1908-1913

[14] Aziz A., Fang T., Alternative solution for longitudinal fins of rectangular, trapezoidal and concave parabolic profiles, Energy conversion and management, 2010, vol. 51, pg. 2188- 2194

[15] Donalson I.G., Free convection in a vertical tube with linear wall temperature gradient, 1961

[16] Stokes G.G., On the effect of the internal friction of fluids or the motion of pendulums, Transactions of Cambridge Philosophical Society, 1851, vol. 9, page 8

[17] Reynolds, Osbrone(1883), An experimental investigation of circumstances which determine whether the motion of water shall be direct or sinuous and law of resistance in parallel channels, philosophical transaction of royal society, vol. 174, pg. 935-982

[18] Rathore M. M., Kapuno R., Engineering heat transfer, Jones & Bartlett publishers (2012)

[19] Venketashan S. P., Heat transfer, Ane books India.

 DOI : 10.35291/2454-9150.2022.0240