CFD Analysis of Natural Convection In Annular Elliptical Cylinder

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Abstract- *Natural convection heat transfer from a vertical cylinder with elliptical fins has been studied using CFD analysis by varying the Rayleigh number (Ra) in both laminar ($10^4 \leq Ra \leq 10^8$) and turbulent ($10^{10} \leq Ra \leq 10^{12}$) regimes. The computations were carried out by varying the fin spacing to tube diameter ratio (S/d). With the addition of fins to the heated isothermal tube surface, heat transfer goes on increasing for laminar flow and for turbulent flow, heat transfer first increases and gets a maximum value, then starts to decrease. The effect of parameters like S/d ratio and Rayleigh number (Ra) on Nusselt number (Nu) are analyzed, and correlations for average Nusselt number has been developed for both laminar and turbulent regimes. The analysis is carried out using the ANSYS FLUENT. The model and the geometric designing is carried out in the solidworks. The different configuration of S/d ratios (where s is the distance between two fins and the d is the cylinder diameter) are considered in the analysis.*

Keywords- s/d ratio, Annular Heat transfer , Rayleigh Number

I. INTRODUCTION

Heat exchangers are widely used in various, transportation, industrial, or domestic applications such as thermal power plants, means of heating, transporting and air conditioning systems, electronic equipment and space vehicles. In all these applications improvement in the efficiency of the heat exchangers can lead to substantial cost, space and material savings. Hence considerable research work has been done in the past to seek effective ways to improve the efficiency of heat exchangers. The referred investigation includes the selection of fluid with high effective heat transfer surfaces made out of high conductivity materials, high thermal conductivity and selection of their flow arrangements. For both single and two phase heat transfer effective heat transfer enhancement techniques have been reported. However in the present work only SINGLE PHASE STEADY STATE NATURAL CONVECTION technique has been considered. The heat transfer enhancement methods reported in publications be summarized in many forms but primarily they may be grouped as active enhancement methods. The basis of any heat transfer enhancement technique lies in the utilization of some external power in order to permit the mixing of working fluids, the rotation of heat transfer surfaces, the vibration of heat transfer surfaces or of the working fluids also the generation of electrostatic fields. The major heat transfer enhancement techniques that have found widely spread commercial application are those which possess heat transfer enhancement elements. All passive techniques aim for the same, namely to achieve higher values of product of the heat transfer coefficient and heat transfer surface area. A distinguish between the way how the heat transfer enhancement is achieved, is common in the heat transfer community. Here in the present work, a terminology similar to the literature is followed although for practical applications are irrelevant how the heat transfer enhancement is achieved.

II. LITERATURE

Bejan[1] and Kreith et al. [2]. Use of fins is one of the simplest ways of overcoming this shortcoming of low heat transfer rates while keeping the system noise-free and maintenance-free. Use of fins to enhance heat transfer was extensively studied by Guvenc and Yuncu[3] and Yazicioglu and Yuncu[4].

The shape of the fin is an important consideration for heat transfer enhancement since the entire surface of the fin may not be equally effective. Hence, the basic job of the designers is to improve the rate of heat transfer by effectively designing the fins. One has to consider factors such as the shape of the primary surface, application of the system and location of the system to design efficient fins. Use of natural convection systems with fins are quite large in number which includes heat exchangers, cooling of electronic components, internal and external combustion engines, annular finned heat sinks, utilization of natural circulation for energy storage systems for space heating (e.g. baseboard heating), air cooling systems for air conditioning and refrigeration. For a cylindrically shaped primary surface, one of the most popular choices among shape of fins to enhance the rate of heat transfer are annular fins because of their inherent ease of manufacturing and also simplicity in the analysis due to radial symmetry. There is plenty of existing literature in the field of natural convection heat transfer which includes Churchill and Chu [5] and Churchill [6], where the authors experimentally developed a cor-relation for average Nusselt number as a function of Rayleigh number and Prandtl number for natural convection from the horizontal cylinder and vertical flat plate respectively. Relevance of the study of natural convection over a vertical flat plate while considering natural convection over vertical cylinder comes due to the fact that a vertical cylinder (at least for thick cylinder) may betreated as a vertical flat plate due to similarity in correlation of Nusselt number as investigated by Gebhart et al. [7] and has been explained in Ozisik[8] and Holman [9]. However, for the slender vertical cylinder, the curvature effect cannot be neglected, and the correlation will be different as explained by Popiel et al. [10]. LeFevre and Ede [11] proposed an integral heat transfer solution that accounts for the effect of wall curvature in the laminar range.

Fujji and Uehara [13] compared the heat transfer rates by laminar natural convection along the outer surface of a vertical cylinder with the same along a vertical flat plate.
Kuiken[14] investigated the radial curvature effects on axisymmetric free convection boundary-layer flow for vertical cylinders and cones with non-uniform temperature differences between the surface and the ambient fluid. Bejan and Lageinvestigated the Prandtl number effect on the transition in natural convection along a vertical surface. Day et al. [16] revisited the topic of laminar natural convection from isothermal vertical cylinders.

III. PROBLEM DESCRIPTION

A vertical cylinder of diameter (d) 25 mm with fins of uniform thickness (t) 1 mm having a constant inter-fin spacing (S) is taken for the analysis as shown in Fig. 1. The material for the fin is chosen to be aluminum because of its high thermal conductivity. Although the results are reported mostly in non-dimensional form, some of the important dimensional values are given here can help the prospective researchers in reproducing the results of the present study.
The simulation of natural convection on a vertical cylinder with annular fins can be modeled by a two-dimensional axisymmetric geometry as it is clear from Fig.1. Fig.1(a) shows the isometric view of a vertical cylinder fitted with annular fins, while Fig. 1(b) shows the schematic diagram of the computational domain with annular fins on a vertical cylinder in cross sectional view (two-dimensional axisymmetric geometry) along with the boundary conditions. The surface of the cylinder is maintained at a constant temperature (T_w) which is usually the case in industrial practice (at least for a short distance). However, the varying surface temperature could have been solved quickly but it would have added a further dimension to the analysis, which has been avoided at the first level. The principal objective is to compute the natural convection heat transfer for this finned vertical cylinder and visualize the fluid flow pattern around the cylinder and the fin.

IV. MATHEMATICAL MODELLING

The flow is assumed to be steady, laminar or turbulent depending on the Rayleigh number and the fluid is assumed to be incompressible. The surrounding fluid i.e. air is considered to be incompressible ideal gas. The other thermo-physical properties are deemed to be constant. Viscous dissipation is assumed to be negligible. Reynolds averaged Navier-Stokes (RANS) equations are used for predicting the turbulent flow. The two equation eddy viscosity based k - ε model is used for calculating the turbulent viscosity (m_t). Boussinesq turbulent viscosity hypothesis is used to link the Reynolds stresses to the velocity gradients. The fundamental conservation equations governing the fluid flow and heat transfer by assuming the above conditions for the present problem are given below in their compact Cartesian form. Continuity equation

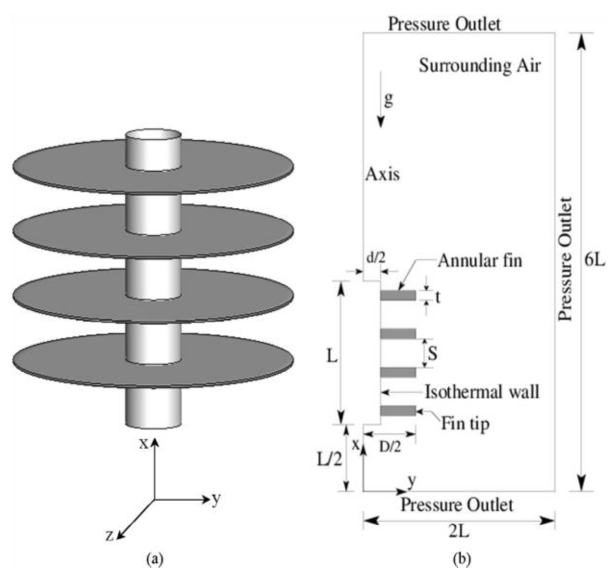

Figure 1 Schematic diagram of the Cylinder with Fins

Boundary conditions

The boundary conditions used in the problem is Temperature of the cylinder at 350K the Fluent allows us to shange the properties of the fluid where we can select bosenniq model to allow the system to solve the problem as a natural convection The natural convection is given at the wall conditions.

Interfacial conditions.

As we all know fluent uses the volumes method to distinguish the solids and volumes the interfacial method uses the algorithm to define the solid regions as the wass where the heated region is present and the heat is generated the heat transfer occurs from the thermal expansion coefficient has been occurred to transfer the heat to the solid to the fluid.

The initial conditions

The initial conditions have to be taken as the environmental conditions especially in the case of the temperature and the pressure.

Solution Procedure

The diffusive terms of the momentum and energy equations were discretized so that they are at least second order accurate in space (Central difference scheme was used). SIMPLE algorithm was used for coupling the pressure and the velocity terms for the pressure correction equation. Normally a first order upwind scheme is initially adopted to get a converged solution, and after that the scheme is switched over to second order upwind which is believed to be more accurate due to the second order accuracy it uses. However, with a SIMPLE algorithm for pressure correction the second order upwind scheme may not converge from the beginning for natural convection where mass conservation becomes a difficult task. That is why, we had to adopt initially the first order upwind, and then switched over to second order upwind. Normally SIMPLE algorithm is more stable, and takes little less time compared to all other schemes. Hence, SIMPLE algorithm was used for present computation. The relative convergence criterion for the energy equation was set to 10^6 and for all other equations, it was set to 10^4. If a stricter criterion could be used, like 10^5 or 10^6 for the momentum and mass continuity equations it was observed that there were convergence problems. So, adopting the residuals to 10^4 for all the cases could result in smoother convergence and lesser computational time.

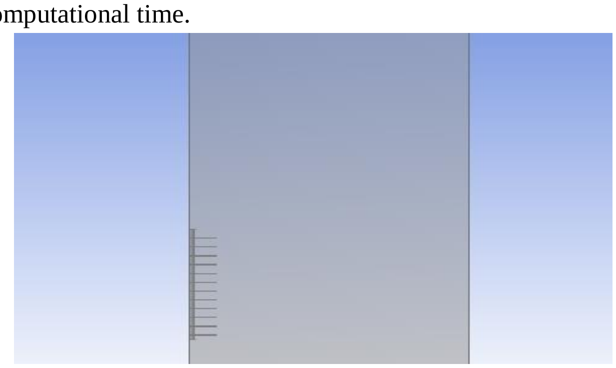

Fig 2 Design Ansys Fluid Domain With Isothermal Wall

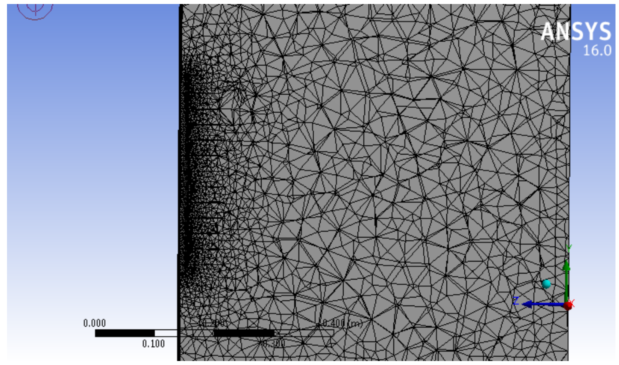

Fig 3 Discretized model of the Computational domain

V. RESULTS AND DISCUSSION

In the present study, the numerical simulation of full Navier stokes equation along with energy equation has been solved for a vertical tube fitted with annular fins of constant thickness for both laminar and turbulent flow (10^4 Ra 10^8) and In this section, visualization of temperature plume and flow field over a vertical cylinder with annular fins has been provided for many different fin configurations which may be helpful for the readers to have a complete physical understanding of the flow around the fin tube array. In the result and discussion section, we would explain the effect of various parameters such as S/d, and Ra on heat transfer and Nusselt number. For Rectangular circular and Elliptical out of the three Models Elliptical is said to be the most better model Below is the results of the Elliptical fin with variant Rayleigh number and s/d ratio.

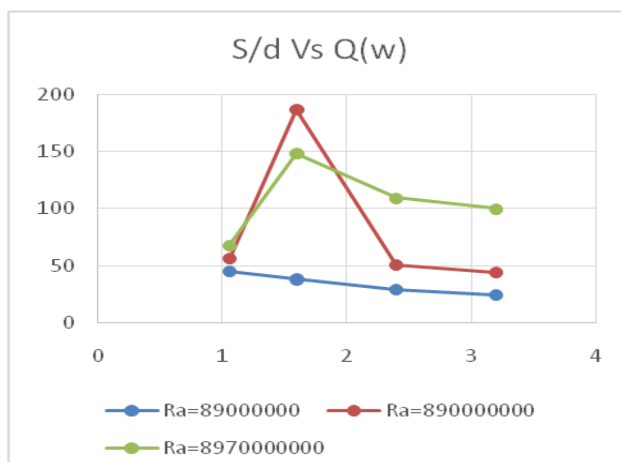

Fig 4 Variation of heat transfer rate with non-dimensional fin spacing for different values of diameter and Ra in laminar flow

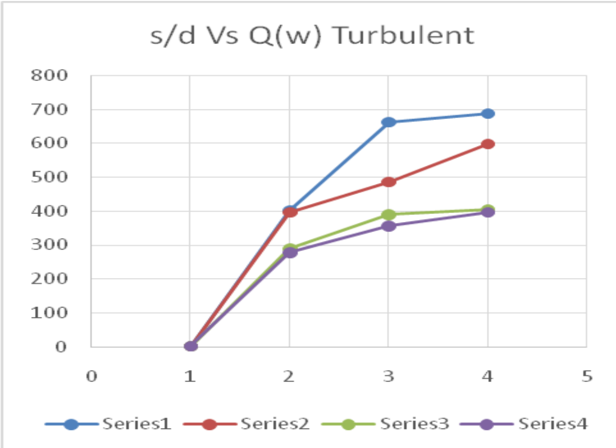

Fig 4 Variation of Nusselt Number with non-dimensional fin spacing for different values of diameter and Ra in Turbulent flow.

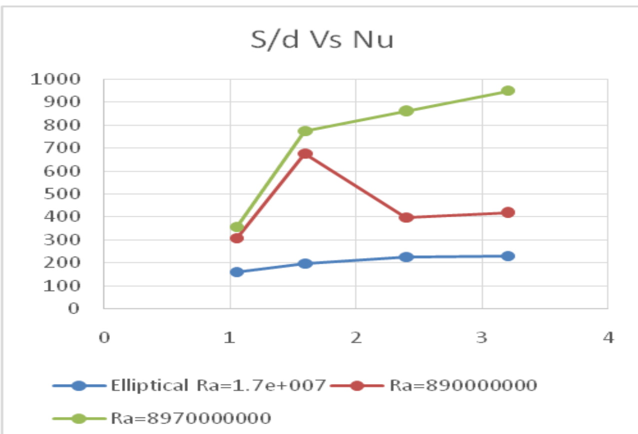

Fig 5 Variation of Nusselt number with non-dimensional fin spacing, S/d and NU for laminar flow.

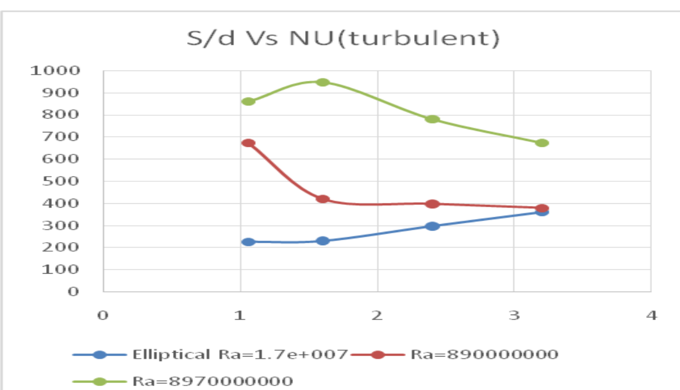

Figure 6 Variation of Nusselt number with non-dimensional fin spacing, S/d and NU for laminar flow.

Contours of temperature

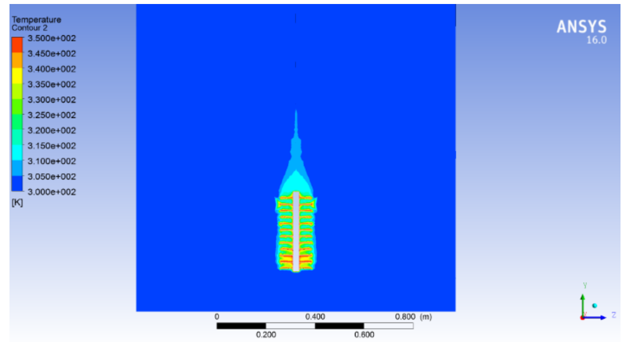

Figure 7 Temperature Contour of Elliptical Fin With the s/d ratio of 1.06

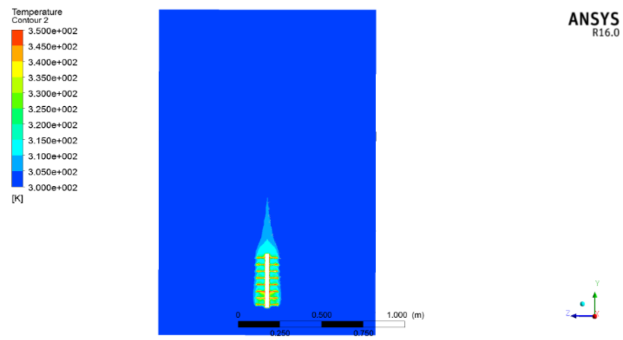

Figure 8 Temperature Contour of Elliptical Fin With the s/d ratio of 1.6

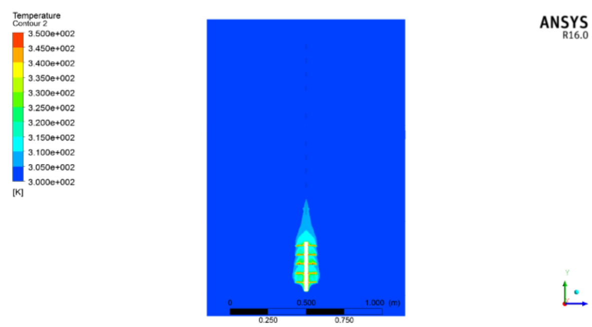

Figure 9 Temperature Contour of Elliptical Fin With the s/d ratio of 2.4

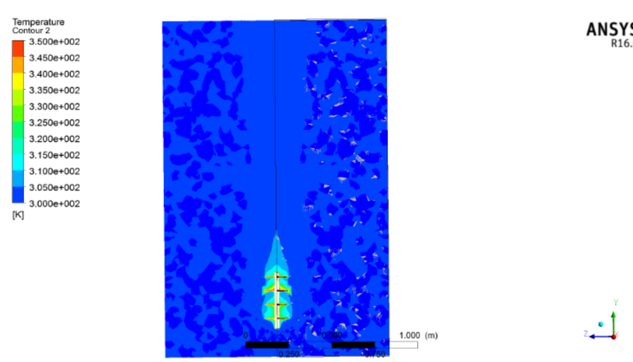

Figure 10 Temperature Contour of Elliptical Fin With the s/d ratio of 1.06 3.2

VI. CONCLUSION

The analysis Carried out from the Ansys fluent has show the significant improvement in the field of the natural convection using vertical cylinder out all the 3 models designed from the solidworks the analysis done and from the obtained results are presented above from the results plots and contours we can say that the non dimensional spacing ratio of 1.02 in elliptical has showing the improved heat transfer efficiency out of all the analysis the heat transfer is higher in the 1.02 configuration with elliptical region

1. With the addition of fins to the isothermal cylindrical wall, the heat transfer increases monotonously for laminar flow, and for turbulent flow, the heat transfer increases to a maximum value and then decreases with the further addition of fins.

REFERENCES

[1] Bejan A. Convection Heat Transfer. third ed. India: Wiley; 2004.

[2] Kreith F, Manglik RM, Bohn MS. Principles of Heat Transfer. seventh ed.Cengage Learning; 2011.

[3] Güvenç A, Yüncü H. An experimental investigation on performance of fins ona horizontal base in free convection heat transfer. Heat Mass Transf. 2001;37:409e16.

[4] Yazicioğlu B, Yüncü H. Optimum fin spacing of rectangular fins on a verticalbase in free convection heat transfer. Heat Mass Transf. Stoffuebertrag.2007;44:11e21.

[5] Churchill SW, Chu HHS. Correlating equations for laminar and turbulent freeconvection from a horizontal cylinder. Int. J. Heat Mass Transf. 1975;18:1049e53.

[6] Churchill SW. A comprehensive correlating equation for laminar, assisting,forced and free convection. AIChE J. 1977;23:10e6.

[7] Gebhart B, Jaluria Y, Mahajan RL, Sammakia B. Buoyancy-Induced Flows andTransport. New York: Hemisphere Publishing Corporation; 1988.
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[8] Oz ̧s k MN. Heat Transfer a Basic Approach. Singapore: McGraw-Hill BookCompany; 1985.

[9] Holman JP. Heat Transfer. tenth ed. New York: McGraw-Hill Higher Education;2010.

[10] Popiel CO, Wojtkowiak J, Bober K. Laminar free convective heat transfer fromisothermal vertical slender cylinder. Exp. Therm. Fluid Sci. 2007;32:607e13.

[11] LeFevre EJ, Ede AJ. Laminar free convection from the outer surface of a verticalcircular cylinder. In: Proc. 9th Int. Congr. Appl. Mech.; 1956. p. 175e83.

[12] Minkowycz W, Sparrow E. Local non similar solutions for natural convectionon a vertical cylinder. J. Heat Transf. 1974;96:178e83.

[13] Fujii T, Uehara H. Laminar natural convection heat transfer from the outersurface of a vertical cylinder. Int. J. Heat Mass Transf. 1970;13:607e15.

[14] Kuiken HK. Axisymmetric free convection boundary-layer bodies. Analysis1968;11:1141e53.

[15] Bejan A, Lage JL. The Prandtl number effect on the transition in natural con-vection along a vertical surface. J. Heat Transf. 1990;112:787e90.

[16] Day JC, Zemler MK, Traum MJ, Boetcher SKS. Laminar natural convection fromisothermal vertical cylinders: revisiting a classical subject. J. Heat Transf.2013;135:022505.