ISSN: 0974-5823 Vol. 6 (Special Issue, Nov.-Dec. 2021)

International Journal of Mechanical Engineering

Effect of fan speed and ambient temperature on the performance of Air cooled condenser at vacuum pressure conditions- A Numerical study

Neeraj p. Badola[1], Dilip M.Patel[2]

[1]Research scholart, Rai University, Ahmedabad-380009, India

[2]Principal, Applied science and engineering, Rai University, Ahmedabad-3800009, India

Abstract

Presently in all thermal power plants and petrochemical industries the use of Air cooled condensers is getting in application because of several benefits, due to reduced number of components, and low cost. The use of vacuum controlled air cooled condensers is getting importance as it can be run at minimum steam temperature. The only problem is control of the temperature of the steam that goes into the condenser as that creates a fluctuation in vacuum conditions which in turn creates back pressure in the turbine and reduces the power output of the plant.. In this paper focus is given to understand he effect of Fan speed and ambient temperature on the effective performance of Air cooled Condensers at vacuum conditions. Geometry of the tubes and fins is constructed using CATIA V 5. Numerical simulation using CFD ANSYS Fluent is done to see the effects at various velocities of air coming from the fan and various ambient conditions. Eulerian model is used with Realizable k – epsilon model. A 6.5 MW power plant is chosen for study where the focus is on Air cooled Condenser [ACC]. A single tube is chosen for study, the first tube in the bundles of ACC. A sample simulation is shown, and finally results in form of tables are shown. The objective is to guide the manufacturers to take these things into consideration before getting the right thing installed.

Keywords: *Air cooled heat exchangers [ACHE]; Air cooled condensers [ACC]*

1, Introduction

An Air Cooled condenser (ACc) is a heat exchanger in which air from the fan is used to cool the fluid for Condensation which is in contrast to other types of heat exchanger. The main advantage of these exchanger is that it requires less amount of water amount of water though the plant requires large cooling capacity. The cooling is provided by using Axial-flow fan which provides high velocity air to cool the hot fluid. It can be as small as an automobile radiator or large like big ACHEs in power plant industry or Petrochemical industry. Due to several problems like water shortage and its cost with water pollution, the use of air cooled heat exchangers has increased especially for process cooling in refineries and chemical plants. There is an increased use of Air Cooled Condensers for power stations. The basic Condensers are normally configured as an A-frame or "roof type". .Though ACHE looks simple the design of an ACHE is more complex than for a Shell and Tube Heat Exchanger, as there are many more components which affect its performance. Air-cooled heat exchangers are mainly used in the oil and gas industry, from upstream production to refineries and petrochemical plants, under extreme conditions like high pressure and high temperature conditions, as well as corrosive fluids and environments. The most used is Air cooled Condenser which is of high use in power plant industry. These Condensers run in Vacuum operated conditions. Though lot of research has taken place, the industries dealing with manufacturing of Air cooled Condensers are still looking for a practical solution to problem of condensation in extreme conditions.

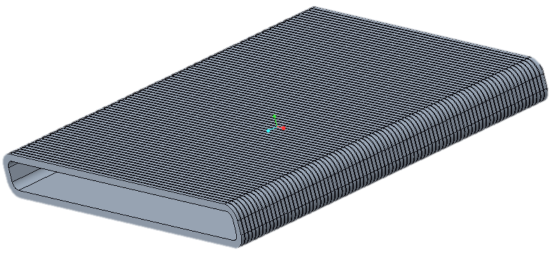
1.1. Literature Survey

Effect of off axis flow on the performance of axial flow fans in the installation is studied. Actuator model is developed for CFD Fluent, and validated against experimental data for off axis angle of 45 degrees. Experimental data confirmed numerically. Found that fan static pressure and fan static efficiency were adversely affected. [1]. Study is focussed to understand how to weaken the negative effects of wind effects. A novel vertical arrangement of ACC is proposed to weaken the adverse wind effects and utilise wind power to improve the cooling efficiency of ACC. By means of CFD simulation and experimental validation the temperature flow fields for vertical arrangement is obtained. Found that the air flow rate for vertical arrangement was increased [2]. Increased inlet flow losses through numerical resolution of flow fields associated with system comprising single and two banks of ACC. Found that for 2 banks inlet flow losses at periphery fan is dominated by flow separation occurring around the inlet tip of fan inlet section. [3]. Focus id given to determine as to what extent the performance characteristic of axial flow fan affects the aerodynamic behaviour of forced draft ACC. Axial flow fan and heat exchanger model is employed with CFD. Found that the angles in which the blades are set in the hub as well as the volume flow rate at which the fan operates affect he plenum chamber aerodynamic behaviour. [4]. In this work essential design parameters are identified for optimal configuration of ACC. Minimum frontal area, maximum heat transfer area, maximum cycle efficiency with respect to condenser temperature and cooling air velocity is derived. Presented in dimensionless form so that they can be used for any other plant.[5].Based on study of wind break wall to weaken the flow distortions and hot air recirculation. Physical and mathematical models are established for air side flow and heat flow with 3 different configurations of wind break wall. Found that thermo flow performance of ACC are improved by extension of inner and outer walk ways and elevation of wind break wall. [6]]. Physical and mathematical models of air side flow and heat flow at various ambient wind speeds and directions are set up. Velocity and temperature fields are presented. Volumetric air flow rate, inlet air temperature and heat rejection are obtained by CFD. Found that reversed flow happened in upward condenser cells leading to high temperature, worsening the cooling capacity at high ambient wind speeds.[7]. In a dry cooling power plant the physical and mathematical models on air side and heat flow side in ACC at various wind speeds and directions are set up using Radiator model. Found that the thermo flow performance is superior in downstream rather than in upstream.[8] Study is focussed on use of chilled water thermal energy storage system [TES] which is used to pre cool the inflow air in ACC whenever the ambient temperature increases above the design temperature for that particular ACC. Analysis showed that tank volume of 4500 cubic metre will be required to maintain the inlet temperature at 20 deg C throughout the year. [9]. This paper investigates effects of various incident winds and its direction on hot air recirculation which in turn helps to avoid undesirable work conditions. A comparison is done between cross and self HAR. Different methods to minimise hot air recirculation were presented. [10].

2. Challenges and Simulation

A 6.5 MW power plant working on Rankine cycle is taken for analysis. The most important feature of this plan is that right from the exit of the turbine to the entire Condensing unit the plant works under Vacuum conditions, the maximum pressure maintained is -0.85 kg/cm^2 which is done by a Vacuum controlling section. It is found that under extreme conditions like very high ambient temperature, Condensation is a problem which affects the working of the entire plant and the plant runs on lower load capacity. To take a step towards achieving solution to it Numerical Simulation is done to show the effect of various parameters like Fan velocity and Ambient temperature. An effort is done towards by taking data from a running unit in one of the installations where the objective is to give a solution to the problem of complete Condensation. A single tube is taken for simulation of Condensation at various ambient conditions and various velocities of Air coming from the Fan. For this Eulerian model is chosen under which Realizable k- epsilon model is chosen for simulation.

The Eulerian model focuses on specific locations of the flow in the flow field. Eulerian simulation model generally employs a fixed mass for the fluid. The field is represented as a function of position x and time t, $u = f\{x,t\}$, where u is the flow field. The governing equations used are Navirer stokes equation. Further Realizable k- epsilon model is used to simulate further analysis.



;

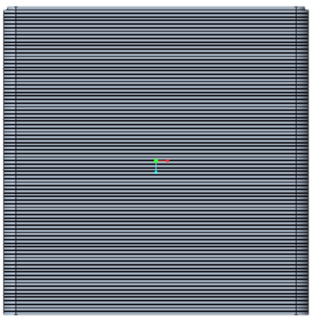
Fig 1- 3 D view of single tube

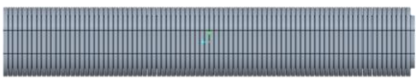
Table 1-Tube specifications

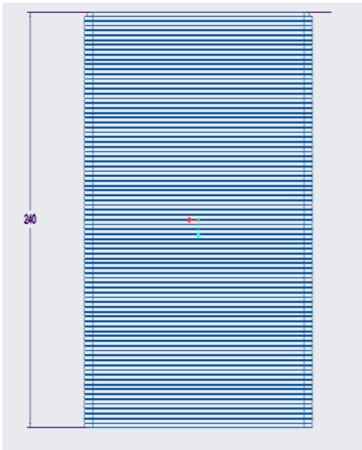
Tube Dimensions in mm	219 x 19 x 1.5
Tube Length in mm	9600 mm
Tube material	Aluminium

Table 2- Fin specifications

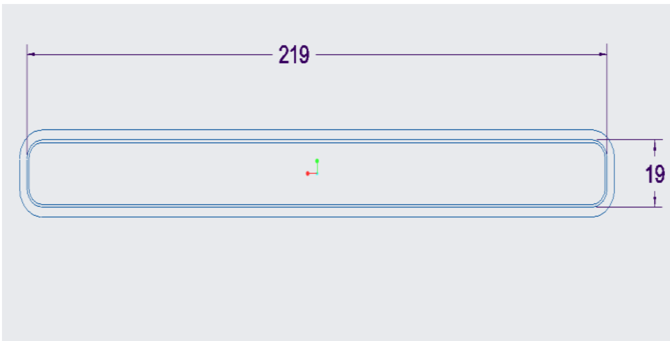
Fin Dimensions in mm	200 x 0.25
Fin Pitch in mm	2.3
Fin material	Aluminium







[a] [b] [c]



[d]

Fig 2--a-Top view of finned tube , b-left side view of finned tube, c-tube for simulation, d-tube dimensions

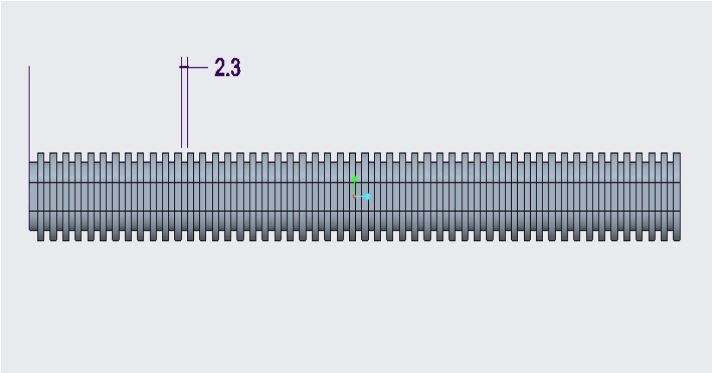


Fig 3- geometry showing dimensions of Fin

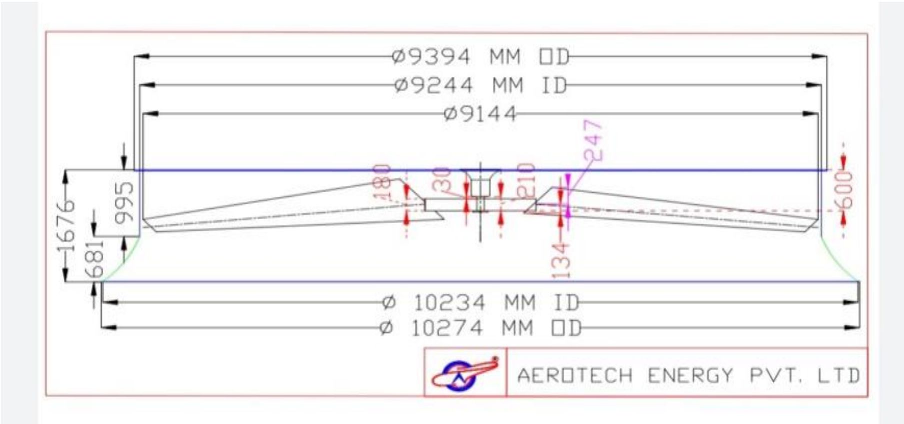


Fig 4 Fan geometry [17]

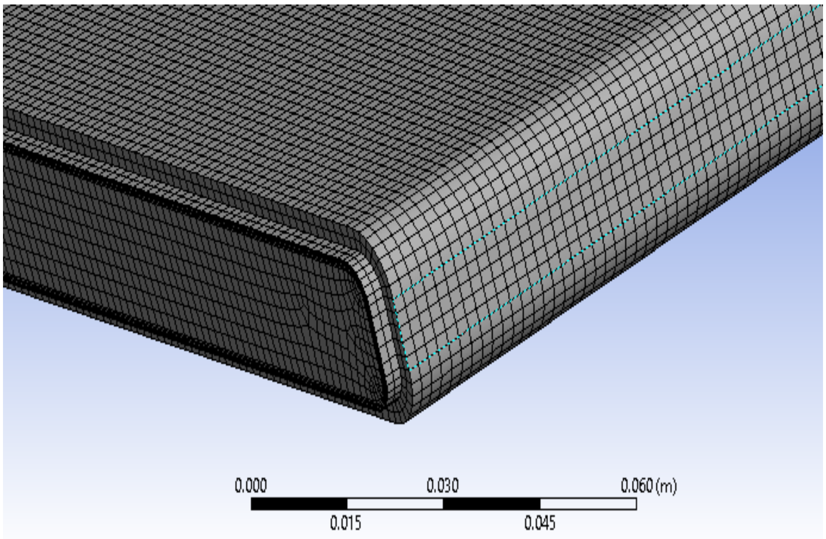


Fig 5- Meshing

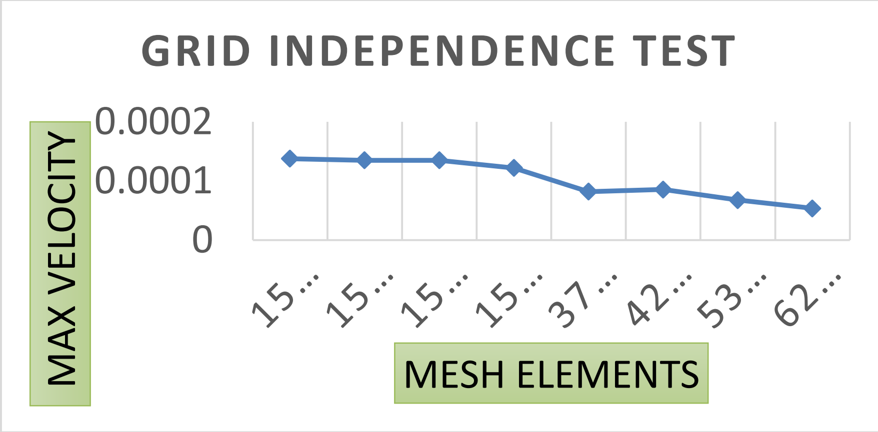


Fig 6-Graph showing Grid independence test

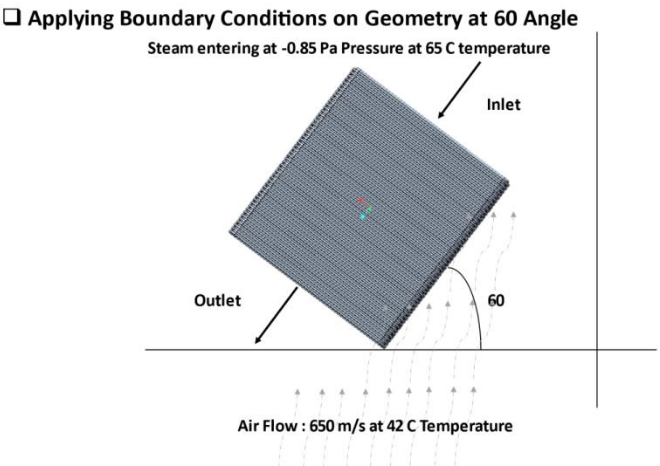


Fig 7- -View showing the inclination of the tube at 6o deg

Table 3 – Heat transfer coefficient values of Air on the outside wall of the tube on Fan side

Ambient temperature in deg K	Velocity of the Air from the Fan in m/sec	Heat transfer coefficient on the outer wall of the finned tube on the fan side in W/ m^2 deg K
315	650	580
315	700	614
315	750	630
316.5	650	574.5
316.5	700	608
316.5	750	639
318	650	571
318	700	602
318	750	648

2.1- Calculations

The value of heat transfer coefficient on the wall of the tube on the fan side is calculated by using the formula,

Nu = [h{a} x La] / k{a}

Re = [ρ{ax} x v{a} D] / μ{a}

$Nu = 0.023 [Re]^{0.8} [Pr]^{0.6}$

The values of thermal conductivity, specific heat, dynamic viscosity, density and Prandtl number for air at a particular temperature can be obtained from the table showing properties of ait.

2.2- Simulation sample

Table 4 -Conditions taken for simulation

Temperature at the inlet of he Condenser tube	321 deg K
Pressure at the inlet of the Condenser tube	-83300 Pascal
Mass flow rate of the steam at the tube inlet of Condenser	4.76 kg/dec
Ambient temperature	315 deg K
Heat transfer coefficient on the wall on the air side or fan side	630 W/m^2 deg K
Velocity of air on the fan side	750 m/sec

Results of simulation

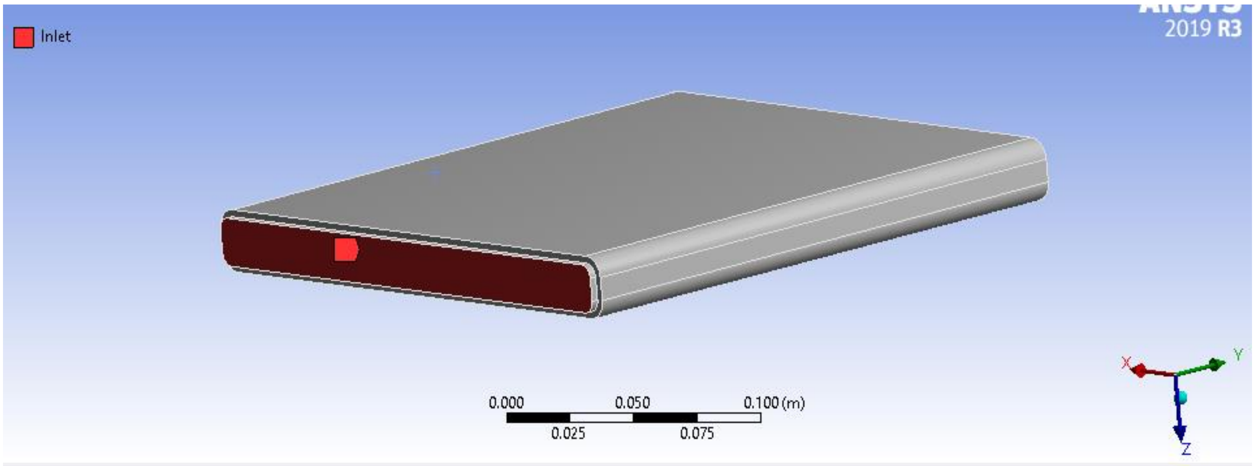
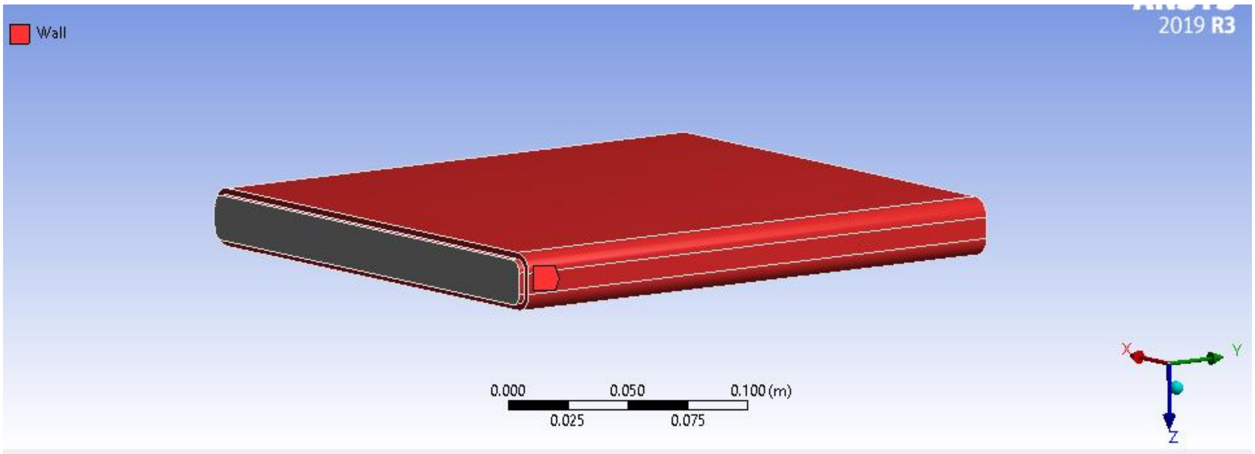


Fig 8-Tube taking boundary conditions



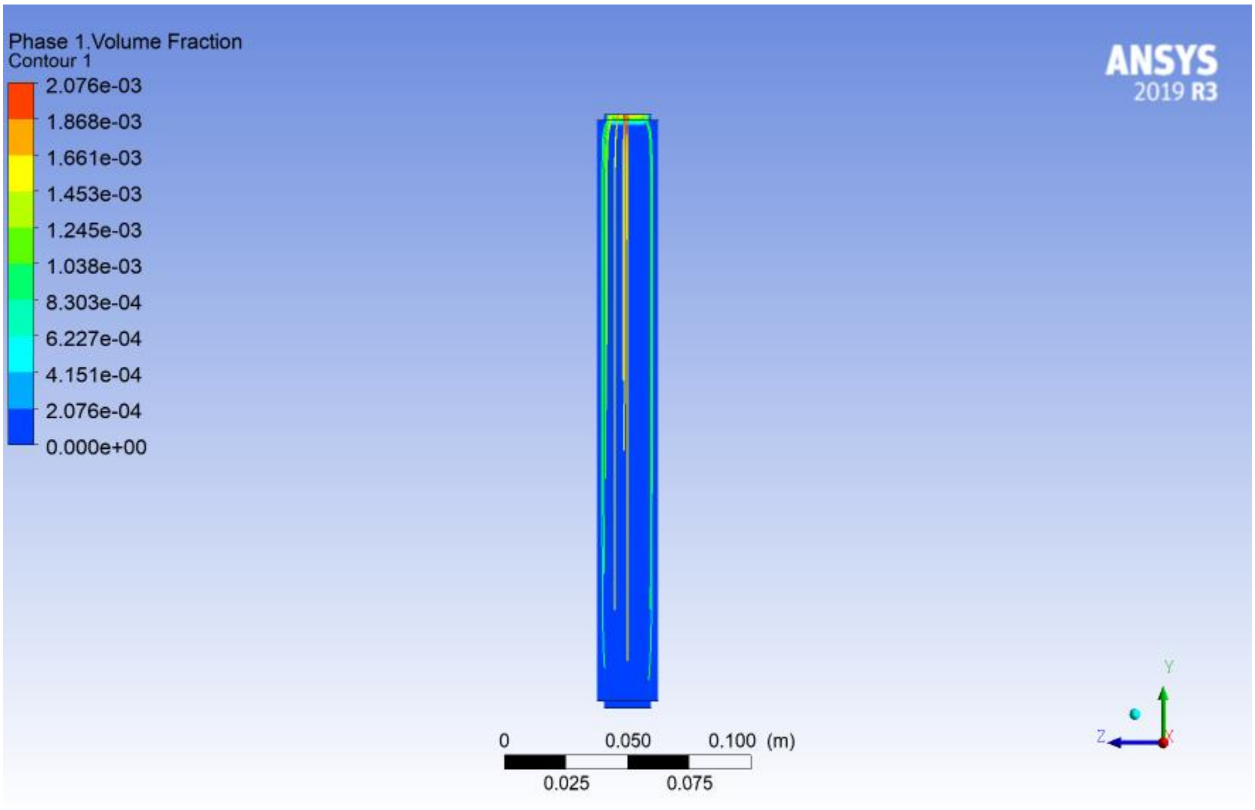
Wall

Applying Convection

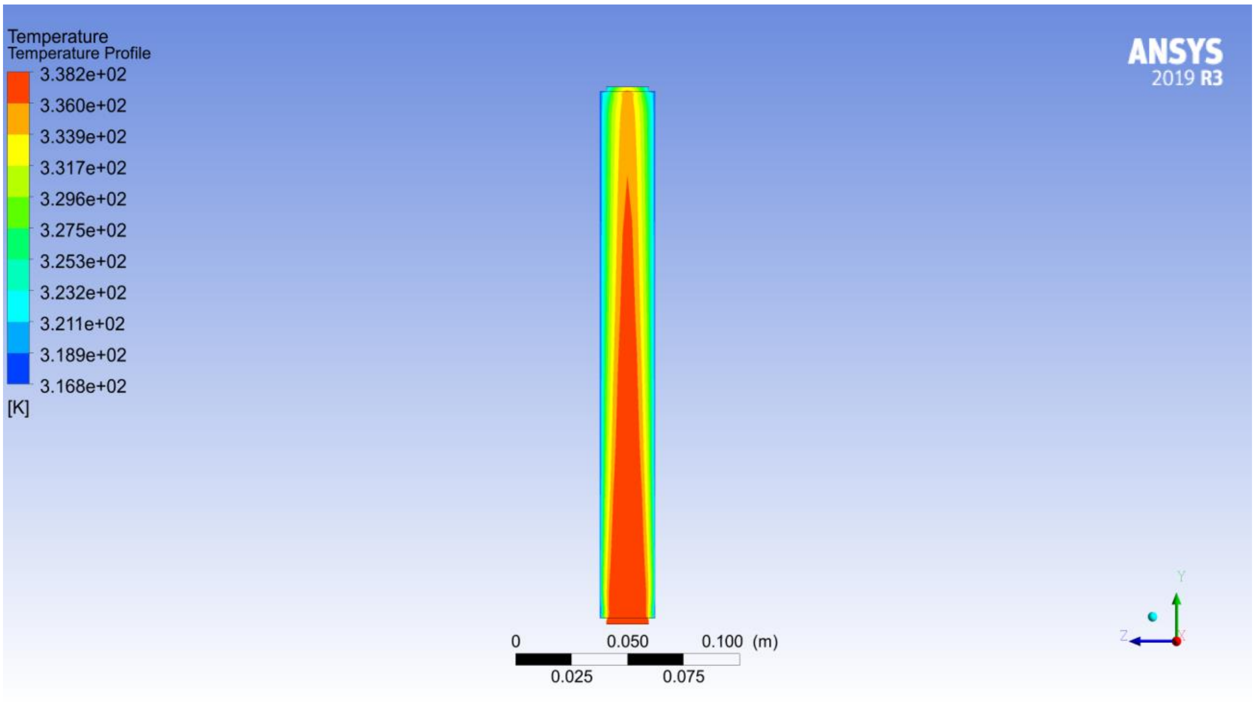
Heat Transfer Coefficient : 580 w/m2 K

Free Stream(Wall Surface/Surrounding) temperature : 315 K

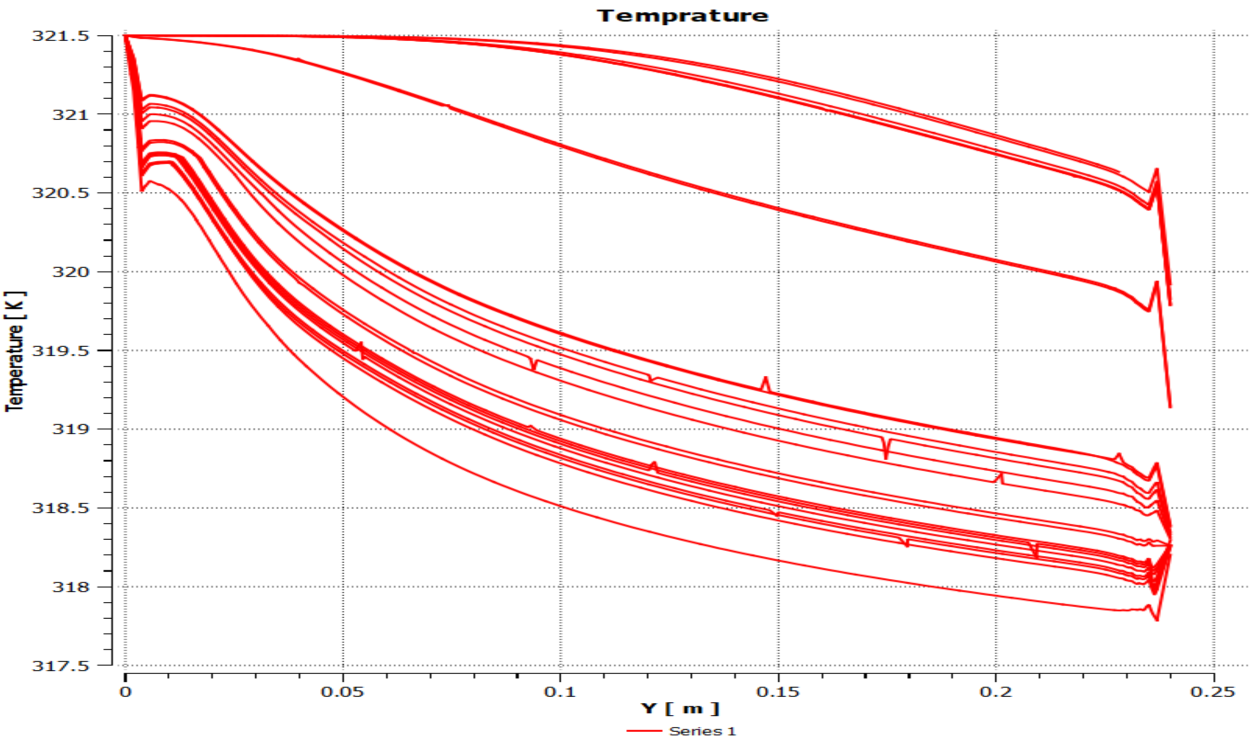
Wall Thickness : 1.5 mm

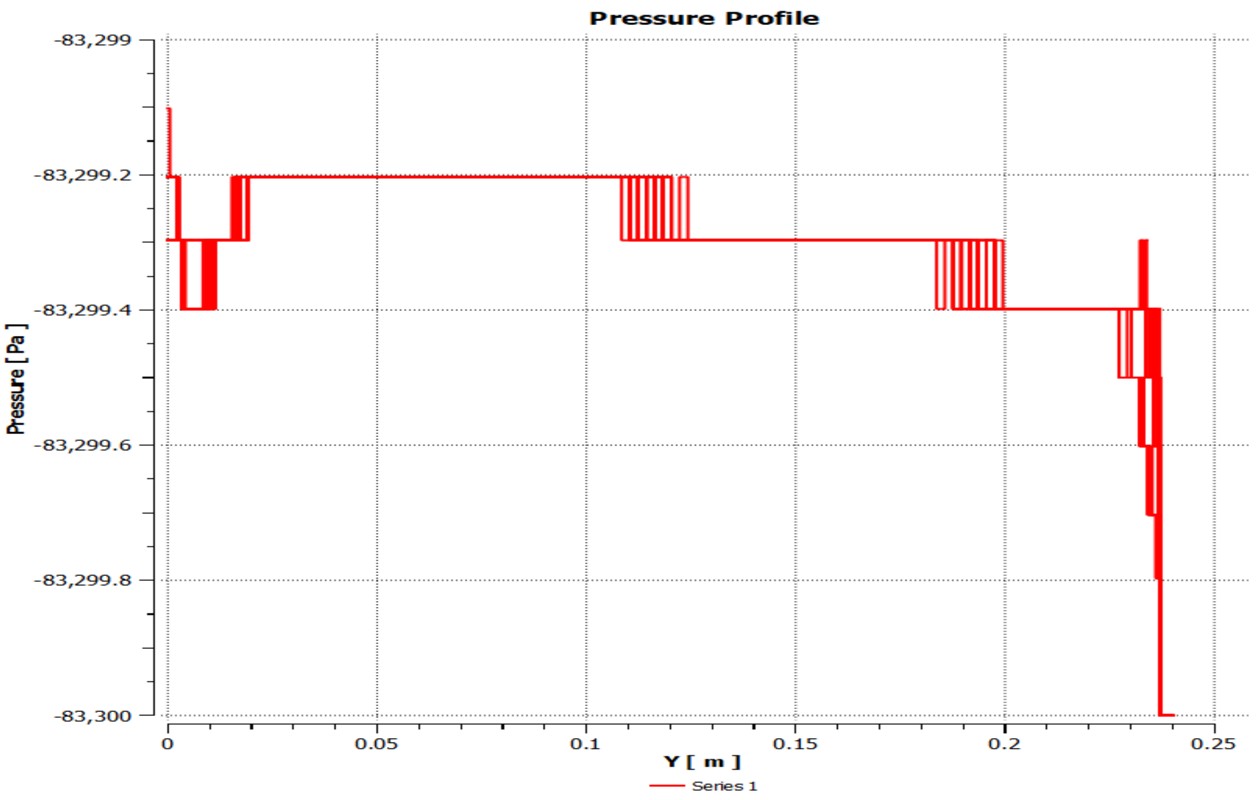


Condensation profile



Temperature profile





- ***Modal : Eulerian Multiphase***

  Phase 1 : Water liquid

  Phase 2 : Mixture template (steam and Air)

- ***Mass Transfer***

Condensation from Phase 2 to Phase 1 with Water Liquid Species at Saturation temperature : 373.16 K

- ***Viscous Model***

  K-epsilon (2 Equations)

  <u>Model Constants</u>

  C2-Epsilon : 1.9

  TKE Pradtl Number : 1

  TDR Pradtl Number : 1.2

  Desperation Pradtl Number : 0.75

  Energy Pradtl Number : 0.85

  Wall Pradtl Number : 0.85

  Turbulent Schmidt Number : 0.7

2.Results

Table 5- Effect of change in velocity of air from the fan at a particular temperature

Ambient temperature , deg K	Velocity of air from the Fan, m/sec	Wall heat transfer coefficient on steam side,W/m^{2}K	Pressure at the steam side in Pascal	Reynolds number	Prandtl number
315	650	719.93	-83298.5	152.15	1.2726
315	700	719.4	-83298.5	152.145	1.2727
315	750	718.9	-83298.5	152.14	1.2728
316.5	650	714.85	-83297.5	152.23	1.2056
316.5	700	714.2	-83297.5	152.24	1.2057
316.5	750	713.74	-83297.5	152.23	1.2058
318	650	709.45	-83296.5	152.31	1.1191
318	700	708.92	-83296.5	152.31	1.1193
318	750	708-69	-83296.5	152.31	1.1196.

Table 6- Effect of change in ambient temperature at a particular velocity of air from the fan

Velocity of air coming from Fan, m/sec	Ambient temperature, deg K	Wall side heat transfer coefficient on steam side, W/m^2 deg K	Pressure on the stea	Reynolds number	Prandtl number
650	315	719.93	-83298.5	152.15	1.2726
650	316.5	714.85	-83297.5	152.23	1.2056
650	318	709.45	-83296.5	152.31	1.1191
700	315	719.4	-83298.5	152.145	1.2727
700	316.5	714.2	-83297.5	152.24	1.2057
700	318	708.92	-83296.5	152.31	1.1193
750	315	718.9	-83298.5	152.14	1.2728
750	316.5	713.74	-83297.5	152.23	1.2058
750	318	708.69	-83296.5	152.31	1.1196

4. Conclusion

1. At a particular temperature with increase in velocity of air from the fan the wall heat transfer coefficient is decreasing, the temperature at which condensation takes place is decreasing,- Reynolds number is decreasing but Prandtl number is increasing

2. With increase in ambient temperature at a particular velocity of air- On the steam side the Wall heat transfer coefficient is decreasing, the temperature at which condensation takes place is increasing, Reynolds number is increasing and Prandtl number is decreasing

Appendix

Re = Reynolds number

Pr = Prandtl number

Nu = Nusselt number

h{a} = heat transfer coefficient on the outside of the tube on the fan side = W/[m^2 K]

la = effective length of the tube , m

D = Hydraulic diameter of the fan. m

k{a} = thermal conductivity of air , W/[m K]

ρ {a}= Density of air, kg/m^3

μ{a} = Dynamic viscosity of air . kg/[m sec

References

1. P.J.Hoichkies, C.J.Meyer,T.W.Van Backstorms, Numerical investigation into the effect of cross flow on the performance by axial flow fan in forced draft air cooled heat exchanger, Article in Applied thermal energy, 2009
2. Xiaoze Du, Li Un Yang, Lu Chan, Yongping Yang, A novel layout of air cooled condenser to improve the thermo flow performance, Journal of applied thermal energy, September 2016
3. C.J.Meyer, Numerical investigation of the effect of inlet flow distortion on forced draft air cooled heat exchangers, Applied thermal energy, August 2005
4. C.J.Meyer, D.G.Kroger, Numerical investigation of the effect of fan performance on forced draft air cooled heat exchanger plenum chamber aerodynamic behavior, Applied thermal energy, August 2004
5. S.C.Lau, K.Annamalai, S.V.Shelton, Optimization of air cooled condensers, Journal of energy resource technology, August 2014
6. L.J.Yang, X,Z,Diu, Y.P.Yang, Influence of wind break wall configurations upon flow and heat transfer characteristics of air cooled condenser In a power plant, International journal of thermal science, August 2011
7. L.J.Yang, X.Z.Diu, Y.P.Yang, Wind effect on the thermo flow performance and its decay characteristics for air cooled condenser in a power plant, International journal of thermal science, August 2011
8. L.J.Yang, X.Z.Diu, Y.P.Yang, Space characteristics of thermal performance for air cooled condensers at ambient winds, International journal of thermal science, August 2011
9. V.Godhian Shetty, N.Nirmalakhandan, M.Myint, C.Ricketts, Improved air cooled condenser performance in combined cycle power plant, Journal of energy engineering, August 2016
10. Saud Ghani, Seifilislam Mahmoud Ahmad Gamaladin, Fotemi Bakochristou, Esmail El Baily, Mohamad Mustafa Mohamad, Radina Mohamad El Hassan Elsau, Numerical and wind tunnel investigation of hot air recirculation Across LNG plant in ACHE, Applied thermal engineering, August 2004
11. D.G. Kroger, Air cooled condensers and cooling towers