Thermal Performance Evolution of 2-D CFD Model of Natural Draft Wet Cooling Tower

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Abstract :- A 2-D computational fluid dynamics simulation of heat and mass transfer inside a natural draft wet cooling has been conducted to investigate the thermal performance of tower under the range of design parameter. The simulation of multi phase steady state flow inside a natural draft cooling tower has been found in various positions inside cooling tower along the diameter. Air temperature varies fluently above and below the fill because maximum heat transfer take place in fill zone as compare to spray zone and rain zone. At outlet air temperature changes around 3- 5%. Random change of pressure occurs below the fill, near wall its value almost zero. Enthalpy and entropy having descending values towards wall from axis.

Index Terms:- Wet cooling tower, thermal performance, cfd .

1 INTRODUCTION

Cooling towers are heat rejection devices used to transfer waste heat to the atmosphere. Cooling towers are an integral part of many industrial process. They are often used in power generation plants to cool the condenser feed-water. In cooling tower the ambient air is used to cool warm water coming from the condenser. There are many cooling tower designs or configurations. In dry cooling towers the water is passed through finned tubes forming a heat exchanger so only sensible heat is transfered to the air. In wet cooling towers the water is sprayed directly into the air so evaporation occurs and both latent heat and sensible heat are exchanged. Cooling towers can further be categorised into forced or natural draft towers. Forced units tend to be relatively small structures where the air flow is driven by fan.

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In a natural draft cooling tower the air flow is generated by natural convection only.

The draft is established by the density difference between the warm air inside the tower and the cool dense ambient air outside the tower. In a wet cooling tower, the water vapour inside the tower contributes to the buoyancy and tower draft. A further classification is between counter-flow and cross-flow cooling towers. In cross-flow configuration, the air flows at some angle to water flow whereas in counter-flow the air flows in the opposite direction to water flow.

2 NATURAL DRAFT WET COOLING TOWER

This study is concerned with natural draft wet cooling towers (NDWCT) in counter-flow configuration. These structures are most commonly found in power generation plants.

In a NDWCT in counter flow configuration.
There are three heat and mass transfer zones,

1. spray zone
2. fill zone
3. rain zone

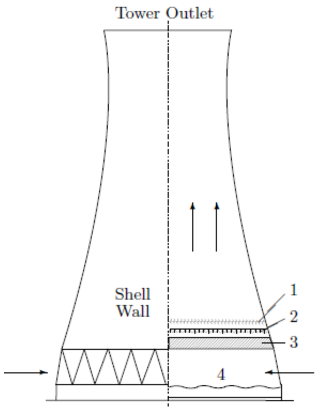


Figure 1. Natural draft wet cooling tower 1. Drift eliminator 2. Nozzle 3. Fill 4. Water basin

The water is introduced into the tower through spray nozzles approximately 8-12m above the basin. The primary function of the spray zone is simply to distribute the water evenly across the tower. The water passes through a small spray zone as small fast moving droplets before entering the fill. There are a range of fill types. Generally they tend to be either a splash bar fill type or film fill type. The splash bar type acts to break up water flow into smaller droplets with splash bars or other means. A film fill is a more modern design which forces the water to flow in film over closely packed parallel plates. This significantly increases the surface area for heat and mass transfer.

3 MODELING OF COOLING TOWER

Computation Fluid Dynamic Modeling: In order to analysis different conception of cooling tower behavior in wind first the computational fluid dynamic modeling of cooling tower is developed. The CFD (Anysis) code" FLUENT 12" is used for modeling. This package has been employed in this study to develop a two dimensional steady state simulation of NDWCT.

4 GEOMETRY

In the first step geometry is created in 2 D using reference data providing different parts of cooling tower considering important details. The structure of whole model imagined in advance, because the possibilities in the subsequent steps depended on the composition of different geometrical shapes .Assumptions were made to take into account the main features of real construction.

- 2-D symmetry model is developed, fix the fill corresponding to real arrangement.
- Inlet and outlet space is created at bottom and top of the tower
- Cooling tower shell is considered as a wall with zero thickness and its profile is formed by curve by three point including throat.
- Assuming symmetrical thermal and flow field in the model, only one half of the cooling tower is modeled with a symmetry boundary condition.

Tower height	130 m
Air inlet height	9 m
Fill depth	1 m
Tower basin diameter	98 m
Fill base diameter	94 m
Tower top diameter	68 m
Spray zone height	12 m
Water flow rate	15000 kg/s
Water inlet temperature	318 K
Ambient air temperature	298 K
Ambient air humidity	55 %
Ambient pressure	101 kPa
Inlet turbulence intensity	1 %

Design parameters for reference tower

5 MESH

After geometry mesh is generated. During mesh generation much attention to be paid with mesh quality requirement recommendation in FLUENT . In order to have an appropriate resolution of the flow field inside the cooling tower the computational domain is discretised into a large number of finite volume cells.

- Different parts is meshed with different element sizing .
- Fill zone must be fine meshed.
- By using mapped face meshing mesh the model with appropriate element sizing.
- After mesh generation create name of different parts of cooling tower.
- The inner and outer surface of the wall inside the model have identical shapes but are disconnected, so the mesh sizes on the two sides of the walls can be different.

6 CELL ZONE CONDITION

In cell zone surface body is considered as fluid. The operating pressure is 101325 Pa in upstream from the centerline of the cooling tower. The gravitational acceleration is 9.81 m/s^2. Operating temperature is 288.16 K and operating density is 1.22 kg/m^3 entered.

7 Boundary Conditions

Velocity inlet boundary condition is used to define the inlet velocity and other properties of air. Velocity magnitude of air takes normal to the boundary of inlet. Turbulence is taken as intensity and length scale. Thermal condition and species in mole fraction is defined.
Pressure out let is defined at out let of air. Other zone also define likewise.

8 Governing Equations

The governing equations for incompressible steady fluid flow can be written
in general form as:

$$\nabla \cdot (\rho u \phi - T\phi \nabla \phi) = S\phi$$

where ρ is the air density (kg/m3), u is the fluid velocity (m/s), ϕ is the flow variable (u, v, w, k, ε, T, ω) and T_ϕ is the diffusion coefficient for ϕ and S_ϕ the source term. These equations can be expanded into the individual momentum and transport equations which, together with the continuity equation give the Navier-Stokes Equations. These equations can be solved numerically enabling fluid flow to be simulated forming the basis for CFD.
For all flows, FLUENT solves conservation equation for mass and momentum. For flows involving heat transfer and compressibility an additional equation energy conservation is solved. For flows involving species mixin ,a species conservation equation is solved.
The continuity equation for conservation of mass in Cartesian coordinates for transient flow can be given as,

$$\partial \rho / \partial t + \nabla \cdot (\rho \vec{v}) = S_m$$

where S_m is the mass source term. The steady equation is obtained by simply neglecting the transient terms, $\partial/\partial t$, from the left hand side.
The equation for conservation of momentum can be written as,

$$\partial/\partial t\,(\rho u_i) + \partial/\partial x_j\,(\rho u_i u_j) = -\,\partial p/\partial x_i + \partial/\partial x_j\,[\,\mu\,(\partial u_i/\partial x_j + \partial u_j/\partial x_i)] + S$$

where S is now a source term for momentum. The source term for buoyancy
can be written as,

$$S_b = (\rho - \rho_{ref})\,g$$

The transport equation for a scalar ϕ can be written as:

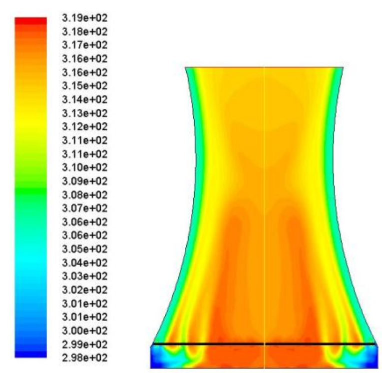
$$\partial/\partial t(\rho\phi) + \partial/\partial x_j(\rho\phi u_j) = \partial/\partial x_j\,[\rho T\,(\partial\phi/\partial x_j)] + S_\phi$$

Navier-Stokes equations represent all the scales of fluid motion. Many flows in engineering are
highly turbulent and so resolving all the scales explicitly using direct numerical simulation is too computationally intensive, requiring very fine discretisation of the above equations. Turbulence models are employed to reduce the computational work load by introducing simplifying assumptions and representing some of the scales of motion with additional equations.
The transport equations for the turbulence kinetic energy, k, and the rate
of dissipation, ε, are given as

$$\partial/\partial t(\rho k) + \partial/\partial x_i(\rho k u_i) = \partial/\partial x_j\,[(\alpha_k \mu_{eff})\,\partial k/\partial x_j\,] + G_k + G_b - \rho\,\varepsilon + S_k$$

$$\partial/\partial t\,(\rho\varepsilon) + \partial/\partial x_i\,(\rho\varepsilon u_i) = \partial/\partial x_j\,[(\alpha_\varepsilon \mu_{eff})\partial\varepsilon/\partial x_j] + C_{1\varepsilon}.\varepsilon/k\,(G_k + C_{3\varepsilon}G_b) - C_{2\varepsilon}\rho\,\varepsilon 2/k\ - R\varepsilon + S_\varepsilon$$

9 Results



Contours of Static Temperature (k)

The air entering in to cooling tower suddenly changes temperature due to contact of hot water coming out from nozzle. Highest temperature zone is near the axis of cooling tower. As the air flows up the temperature goes

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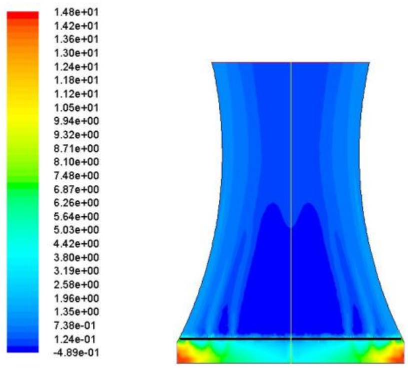
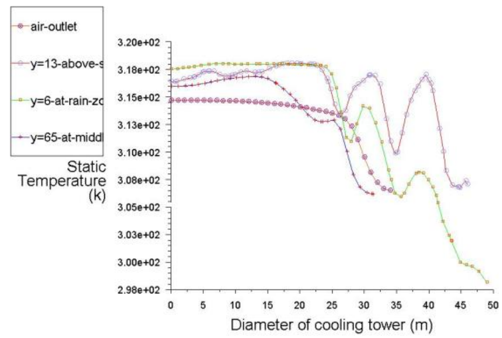
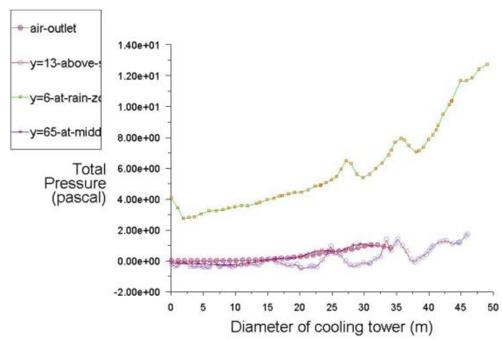
down. Near wall of cooling tower the air temperature is comparatively low.



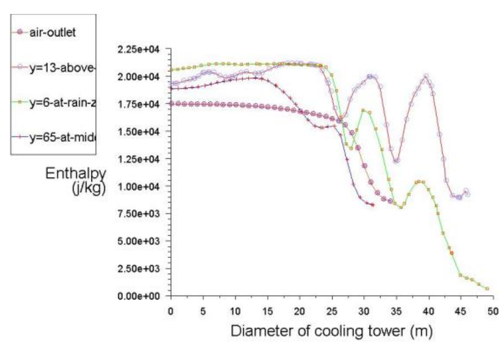
Contours of Total Pressure (pascal)



At inlet the pressure of air is maximum and gradually decreases as the air flows up. Above the spray zone and around the axis up to some extent the pressure having very less some, time it is negative also. Some distance from wall the value of pressure is like constant through- out the wall. Below the fill it is always higher than above the fill. Dynamic pressure is having higher value near the wall and lesser near the axis thorough-out the cooling tower height. Static pressure decreases up to fill and than decreases up to air outlet. Value of pressure coefficient is high at inlet and low at outlet.

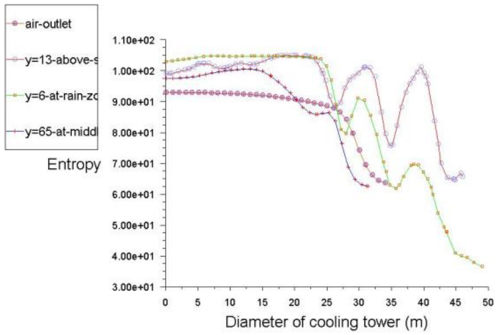


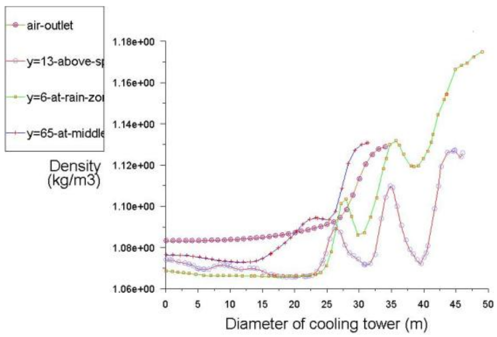
To find out the various properites of cooling tower there must be some line horizontzl with refrence to axis and ground level.

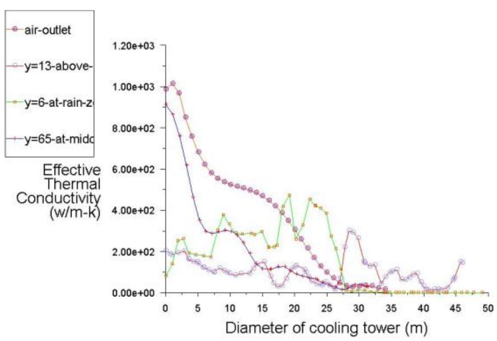


S. NO.	Wind speed	Horizontal line coordinate (Diameter of cooling tower)		Line name
		(X_1, Y_1)	(X_2, Y_2)	
1	2 m/s	(0, 6)	(49, 6)	Y=6 , at rain zone
2	2 m/s	(0, 13)	(46, 13)	Y=13, above spray zone
3	2 m/s	(0, 65)	(36, 65)	Y=65, at middle

Three line drawn horizontally at rain zone, above spray zone and at middle of the cooling tower to find out the various thermal properties of cooling tower.







Conclusion

The simulation of multi phase steady state flow inside a natural draft cooling tower has been conducted using CFD code "FLUENT 12". Thermal parameter has been find out in various positions inside cooling tower along the diameter. Air temperature varies fluently above and below the fill because maximum heat transfer take place in fill zone as compare to spray zone and rain zone. At outlet air temperature changes around 5% near axis, where at its change near the wall is only 3%. Random change of pressure occurs below the fill, near wall its value almost zero. Enthalpy and entropy having descending values towards wall from axis.

Nomenclature C_p specific heat (j/kg K) g gravitational acceleration (m/s^2) G mass flow rate per unit area (kg/s/m^2) k turbulence kinetic energy (m^2/s^2) R universal gas constant (N.m/kmol.K)

S source term U, v velocity component (m/s)

Greek letters ε turbulence kinetic energy dissipation rate (m^2/s^3) Τ diffusion coefficient (kg/ms) μ viscosity (kg/ms) ρ air density (kg/m^3) α kinetic energy coefficient

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