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DESIGN OF COOLING TOWER BY VARYING AIR INLET ANGLE OF BLOWER FAN PIPE

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ABSTRACT

This project will give idea about how we have did study and design of cooling tower by varying air inlet angle of blower fan pipe on inlet parameters of cooling tower. A cooling tower is a type of heat exchanger used to reduce the temperature of a water stream by extracting heat from water and emitting it to the atmosphere. Cooling towers use the evaporation of water to remove process heat and cool the working fluid to near the wet-bulb air temperature. Cooling towers are able to lower the water temperatures more than devices that use only air to reject heat, like the radiator in a car, and are therefore more cost-effective and energy efficient. They are generally used in HVAC applications. There are many types of cooling towers available. The effectiveness of cooling of water is depend on various process parameters like DBT, WBT of Air, fill material and sits size, inlet air flow rate, air inlet angle of blower fan, water flow rate and temperature etc. This paper will give idea about design cooling tower. We have done theoretical calculation to design cooling tower. Then by considering outlet temperature of water find out effectiveness of cooling tower. We design the model of cooling tower on solidwork 2019. The forced draft cross flow and counter flow cooling tower are the most common ones used in HVAC applications. Forced draft cooling tower is a type of mechanical draft tower which has a blower type fan at the air intake. With the fan on the air intake, the fan is more susceptible to complications due to freezing conditions. The benefit of the forced draft design is its ability to work with high static pressure. Such setups can be installed in more-confined spaces and even in some indoor situations. This fan geometry is also known as blow-through. The fan forces air into the tower, creating high entering and low exiting air velocities. The low exiting velocity is much more susceptible to recirculation.

Keywords— *Air inlet parameters, forced draft cooling tower, HVAC, Blower.*

1. INTRODUCTION

A cooling tower is a specialized heat exchanger in which air and water are brought into direct contact with each other in order to reduce the water's temperature. As this occurs, a small volume of water is evaporated, reducing the temperature of water being circulated through the tower. Water, which has been heated by an industrial process or in an air-conditioning condenser, is pumped to the cooling tower through pipes. The water sprays through nozzles onto banks of material called "fill," which slows the flow of water through the cooling tower, and exposes as much water surface area as possible for maximum air-water contact. As the water flows through the cooling tower, it is exposed to air, which is being pulled through the tower by the electric motor- driven fan. When the water and air meet, a small amount of water is evaporated, creating a cooling action. The cooled water is then pumped back to the condenser or process equipment where it absorbs heat. It will then be pumped back to the cooling tower to be cooled once again.

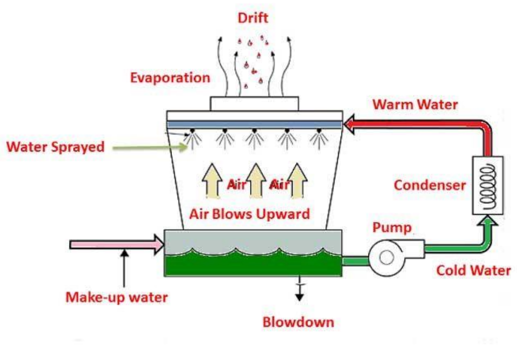


Fig.1 Cooling Tower with specification

There are several important factors that govern the operation of cooling tower:

- The dry-bulb and wet-bulb temperatures of the air
- The temperature of warm water
- The efficiency of contact between air and water in terms of the volumetric mass transfer coefficient and the contact time between the air and the water
- The uniformity of distribution of the phases within the tower
- The air pressure drops
- The desired temperature of the cooled water.

Air might enter the tower driven by a density gradient (natural draft), might be pushed into the tower (forced draft) at the base or drawn into the tower (induced draft) assisted by a fan.

2. TYPES OF COOLING TOWER

1.1 Types of cooling Tower:

There are two main types of cooling tower:

- Natural Draft Cooling Tower
- Mechanical Draft Cooling Tower

In natural draft cooling towers, air flow is obtained by pressure difference obtained from its structure i.e. chimney effect. Warm and moist air (less dense) after heat transfer will go out of the cooling tower to the atmosphere, creating to flow in fresh air (denser). The flow of air occurs due to the density difference between the warm (less dense) air inside the cooling tower and relatively cool (denser) ambient air outside the cooling tower.

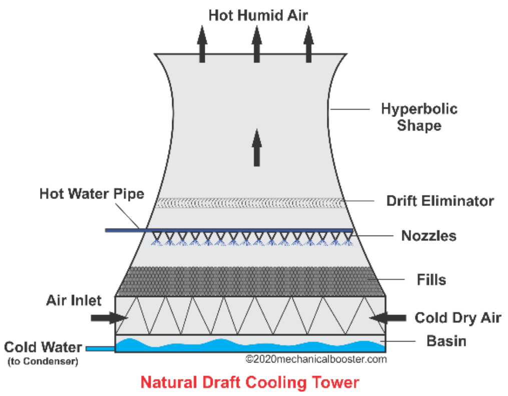


Fig.2 Natural Draft Cooling Tower

In Mechanical Draft Cooling Tower, fan is used to circulate the air. When power plant runs on peak load, it requires a very high rate of cooling water. To rotate fan, it uses motor with speed around 1000 rpm. Working principle is same as natural draft cooling tower, only difference is that here fan is mounted on the cooling tower. If fan is mounted on the top of the tower is called as induced draught cooling tower which is most popular for very large capacity installation and requires large capacity of fan. So, forced draught cooling tower contains horizontal shaft for the fan and it is placed at bottom of the tower and induced draught cooling tower contains vertical shaft and it is placed at top of the cooling tower.

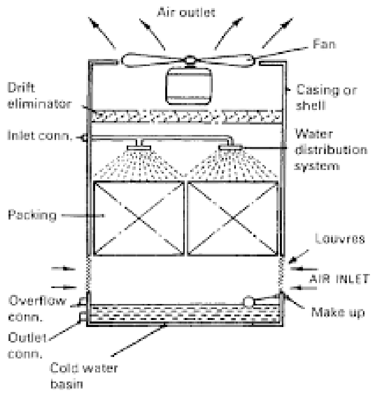


Fig.3 Mechanical Draft Cooling Tower

Types of Mechanical Draft Cooling Tower:

- Induced or Forced Draft Counter Flow
- Induced or Forced Draft Cross Flow

1.2 Components of Cooling Tower

The basic components of Cooling Towers are packing, Louvers, Water Inlet, Nozzles, Cooling Tower Basin, Fans, Drift eliminators, frame and casing.

1.3 Terminology

- Dry Bulb Temperature: Temperature of air measured under atmospheric conditions
- Wet Bulb Temperature: The temperature in degree celsius to which air can be cooled, making it adiabatic to Saturation By The Addition Of Water Vapour.
- Cooling tower approach: The Difference In Temperature (Degree Celsius) Of The Cold Water Leaving The Tower And Wet Bulb Temperature Of Ambient Air.
- Cooling tower range: range is the difference between the temperature of water entering the cooling tower and leaving the cooling tower.
- Recirculation: The discharge recirculation occurring in cooling towers increases the tower entering air wet bulb temperature, thereby reducing the tower heat rejection capacity.
- Air flow: Total Quantity of Air Along With Water Vapour Flowing Through The Tower.
- Cooling load: Rate Of Heat Removal From The Water Flowing Through The Tower Expressed In KW.
- Basin: The Area At The Bottom Of The Tower For Collecting Cold Water. Cross Flow Towers Have A Hot Water Distribution Basin At The Top And In Some Cases, A Water Basin Between The Top And Bottom Basin.
- Cooling tower effectiveness: It is the ratio of Range, to ideal range.
- Cycle of concentration: It is ratio of dissolved solids in circulating Water To The Dissolved Solids In Makeup Water.

3. LITERATURE REVIEW

Parimala murugaveni, P Mohamed Shameer [1]in their research they carried out cooling tower performance has been analyzed by varying air inlet parameters with different air inlet angles and by attaching a nozzle in air inlet. The cooling tower analyzed here is used specifically for small scale industries, which is a forced draft counterflow cooling tower with single module capacities from 10 to 100 cooling tons. In this paper, they made their body of cooling tower in solidwork and they done analysis of inlet and outlet parameter using ANSYS software Air Inlet Pipe Angles 0^o, 30^o about horizontal axis,30^o about vertical axis, 30^o about both horizontal and vertical axis (that is along z axis). Conclusion: by varying angle of inlet air pipe, we are able to slightly increase effectiveness.

Priyanka G.M.R. Nagraj[2] in their research they carried out with a view to predicting the performance of a shell and finned tube heat exchanger in the light of waste heat recovery application. The performance of the heat exchanger has been evaluated by using the CFD package ANSYS13.0. They made an attempt to predict the performance of the heat exchanger by considering different heat transfer fluid and the result so obtained have been compared. The analysis is carried out and pressure drop and temperature rise along the tube surfaces has been investigated. They found that energy extraction rate is quite significant, that means the effectiveness of exchanger is higher by increasing the contact surface area of hot and cold fluid by using the finned tube heat exchanger.

Mohd Amir, Fithry, Yusoff, MohdZamri [3] in their paper explored the area in the cross-flow cooling tower where the focus on where the porous media or the fill / packing are located and the area in the vicinity for a single-phase flow. The behavior of the air intake flow into the cooling tower from the side part through the fill was observed and how it affects the distribution of the air flow inside the fill will be analyzed. The solution of the related governing equation for the basic flow and for flow involving porous media was presented. It was revealed that the porosity introduced a high pressure drop inside the cooling tower. The pressure inside the cooling tower generally is lower that before the porous media was introduced. The results also revealed that if the heat transfer inside the porous media is to be improved, higher dynamic pressure inside the cooling tower is required which would result in higher fan power output.

Dr. Jalal M. Jalil, Dr. Talib K. Murtadha, Dr. Qasim S. Mehdi [4] conducted numerical and experimental studies for open type forced draft water cooling tower. The numerical part includes a three-dimensional computational solution of air and water simultaneous equations which represents the fluid flow, heat transfer and mass transfer.

Dr. D. Al. D.H. Alwan Dr. I. W. Maid A. H. Soheel [5] in their article, presents an experimental and numerical investigation of the performance of a forced draft counter flow cooling tower with two kinds of wire mesh packing.

Nader Pourmahmoud, Amir Hassan Zadeh, Omid Moutaby, And Abdolreza Bramoperformed [6] research on the energy separation and flow field behavior of a vortex tube by utilizing both straight and helical nozzles. They mentioned that higher swirl velocity is obtained at 450 in divergent nozzle and at 300 in convergent nozzle. Higher swirl velocity due to appropriately nozzle shapes can effectively influence the exit gold gas temperature. Three kinds of nozzles set include of 3 and 6 straight and 3 helical nozzles have been investigated and their principal effects as cold temperature difference was compared by using CFD software.

Santosh Kumar, Chandrasekhar prasad, Tajo Pawan, gobinath N, shyam kumar, feroskhan [7]in their research experiments are conducted to examine the performance of a cooling tower used for a stationary IC engine, with different bed materials at three different flow rates. From the experiments, it is evident that at higher flow rates jute carpets with mesh show better cooling, while coming to lower flow rates polystyrene balls perform better.

Sunil Vikas Kesare, Prof.Swami [8] in their research they did Analysis and optimization of Centrifugal Blower impeller by using FEA. To reduce the corrosion problem of the blower SS204L material is used. By corrosion test Stainless steel is more corrosion resistant than M.S.

Pooja Magar, Mahesh Shinde, Prof. Kshirsagar [9] in their research they did Design analysis and optimization of centrifugal Blower. Property of Blower increased without changing material, Stress directly proportional to displacement, FOS is large for 3mm thickness material.

Pushkar R. Chitale, Rohan K. Gamare,Shubham K. Chavan, Suresh R. Chavan,Amar S. Yekane [10] in their research they design of cooling tower is closely related to cooling tower characteristics which is unique for a particular tower and loading factor which depends on hot water temperature.

4. DESIGN OF COOLING TOWER

Table 1 Technical Specifications

Volume of circulating water (V)	400 M^3/hr
Inlet temperature of water (T_1)	32^0 C
Outlet temperature of water(T_2)	26^o C
Wet bulb temperature (WBT)	24^0 C
Inlet temperature of air (T_{a1})	24^0 C

Outlet temperature of air (T_{a2})	28^0 C
Design relative humidity	80%
Allowable evaporating losses	1.44%

Table 2: Data from Steam Table and psychometric chart

Enthalpy of air at inlet temperature (Ha1)	62.5 KJ/Kg
Enthalpy of air at outlet temperature (Ha2)	77.5 KJ/Kg
Specific humidity of air inlet temperature (W1)	0.015 KJ/Kg of dry air
Specific humidity of air outlet temperature (W2)	0.0193 KJ/Kg of dry air
Specific volume of air at inlet temperature (Vs1)	0.87 m^3/Kg
Specific volume of air at outlet temperature (Vs2)	0.88 m^3/Kg
Enthalpy of water at inlet temperature (Hs1)	125.7 KJ/Kg
Enthalpy of water at outlet temperature (Hs2)	83.9 KJ/Kg

4.1 Thermal Design Calculations

Cooling Tower Approach (CTA)

CTA = T_2– WBT

= 26-24

= 2^0 C

Cooling Tower Range (CTR)

CTR = T1– T2

= 32 - 26

= 6℃

Mass Of Water Circulated In Cooling Tower

Mw1= Volume Of Circulating Water X Mass Density Of Water,

= 400 X 1000

Mw1= 400000 Kg/Hr=111.11 Kg/sec

Heat Loss by water (HL)

HL= Mw1X CpwX (T1– T2)

= 400000 X 4.186 X (32 - 65)

HL= 10046400 Kj /Hr

Volume Of Air Required (V)

V= (HL X Vs1) / [(Ha2– Ha1) - (W2– W1) X CpwXt2]

= (10046400 X 0.87) / [(77.5-62.5) – (0.0193 – 0.015) X 4.186 X 26]

V= 601456.43 M^3 / Hr

Mass Of Air Required (Ma)

Ma= Volume of Air Required / Specific Volume Of Air At Inlet Temperature

= V / Vs1

= 601456.43/0.87

=691329.23 Kg/hr

Ma= 192.03 Kg/sec

Quantity Of Make-Up Water (Mmake-Up)

Mmake-Up = (V X (W2-W1)) / Vs2

= (601456.43 X (0.0193 – 0.015)) / 0.88

Taking Evaporative Loss In Consideration,

Mmake-Up = 2938.93 X [1 + (1.44 / 100)] = 2981.25 Kg/Hr Mmake-Up= 49.68 Kg/Min

Effectiveness Of Cooling Tower (€)

€= $range\ range + approach$

= 6/8 = 0.75

€= 75 %

4.1.1 Estimation of Different Types Of Losses In Cooling Tower

Drift Losses (DL):

Taking Drift Losses As0.20% Of Circulating Water,

DL = 0.20 X Mw1/ 100

= 0.20 X 400000 / 100

DL = 800 Kg /Hr

Windage Losses (WL)

Taking Windage Losses As 0.5% Of Circulating Water,

WL = 0.005 X Mw1

= 0.005 X 400000

= 2000 Kg /Hr

Evaporation Losses (EL)

Taking Evaporation Losses As 1% Of Circulating Water Per 10°FOf Cooling Range.

EL= (0.01 X Mw1X Range)/10

= (0.001 X 400000 X 42.8)/10

EL= 17120 Kg /Hr

Blow Down Losses (BL)

Number Of Cycles Required Is Given By,

Cycles Of Concentration (C.O.C) = XC / XM

XC = Concentration of Solids In Circulating Water,

XM = Concentration Of Solids In Make-Up Water

Water Balance Equation For Cooling Tower Is,

M = WL + EL + DL

=2000+ 17120+ 800

M = 19920 Kg /Hr

XC / XM = M / (M - EL)

= 19920 / (19920 -17120)

C.O.C. = 7.11

So, Blow Down Loss (BL)

BL= EL / (C.O.C - 1)

= 17120 / (7.11 - 1)

BL= 2801/96 Kg /Hr

4.2 Structural Design Calculations

Outlet Air Temperature (Assumed) = 27.5℃ = 28 ℃

Relative Humidity = Ø = 80%

Hsa= Enthalpy of Saturated Air at Water Temperature.

Ha = Enthalpy of Moist Air at that Temperature And Humidity

Table 3: Calculation for (Has - $H_{a)}$)$^{-1}$

T 0C	Has (KJ/Kg)	Ha (KJ/Kg)	Has - Ha	(Has - Ha)-1
26	81	69.5	11.5	0.08698
27	85	73	12	0.08333
28	90	77.5	12.5	0.08
29	95	80	15	0.0667
30	99.5	85	14.5	0.06897
31	106	89.5	16.5	0.0606
32	111	94.5	16.4	0.06097

Cooling Tower Characteristic Equation Can Be Given As,

$[(Ka * V)/ L]$calc= R * [1 / (Hsa– Ha)]Avg

Where,

K= Mass Transfer Coefficient ($Kg\ hr/m^2$)

A = Constant Area (M^2)

V Active Cooling Volume (M3)

L = Loading Factor (Kgwater / Sec-M 2 water)

$(Hsa– Ha)^{-1}avg$ = 0.0725

$[(Ka * V)/L]_{calc}$ = 6 X 0.0725

$[(Ka \text{ X } V)/L]_{calc}$= 0.435 $Kgair/ Kgwater$

4.4.2 Determination Of Loading Factor (L)

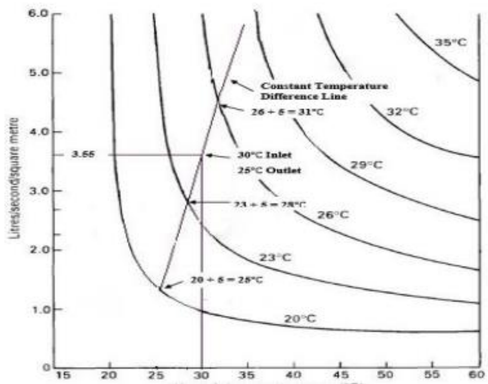


Fig.4 Loading Factor Vs Water Inlet Temperature

From Graph,

L = 4.20 Litres / Seconds / M^2

4.2.3. Determination of Tower Dimension

Z = $[(Ka *V)/\ ]_{calc}$ X L/Ka

Where, Z = Height Of Tower (M)

B = Base Area (M^2)

V_f= Fill Volume (M^3)

Considering, Ka as 100 Pound Air/Hr X Ft_{fill}

Ka = 0.47 Kgair / Sec-M^3

L = 4.20 Litres / Sec-M^2

= 4.20 X 10^{-3} M^3 water / Sec – M^2_b

L = 4.20 Kgwater / Sec-M^2_{water}

So,

Z = (0.435 X 4.20) / 0.47

= 3.88 M …. (Fill Height)

Now,

Volume Of Fill = Base X Z

$$B = \frac{L}{L}$$

= 111.11/4.20 ($Kgwater/sec$)/(Kgwater/sec-m^2)

= 26.45 M^2

fill Volume =B*Z

=21.16*3.88

V_f =102.625 M^3

5. COOLING TOWER MODEL

5.1 Modelling of Cooling Tower

Based on the obtained specifications (Size & Dimensions), the cooling tower model has been prepared in solidworks 2019 3D Modelling software.

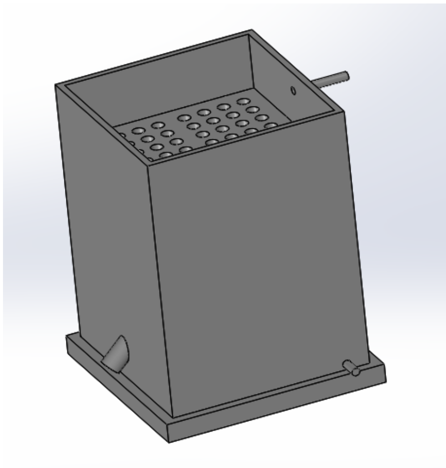


Fig.5 Isometric View of Cooling Tower Model

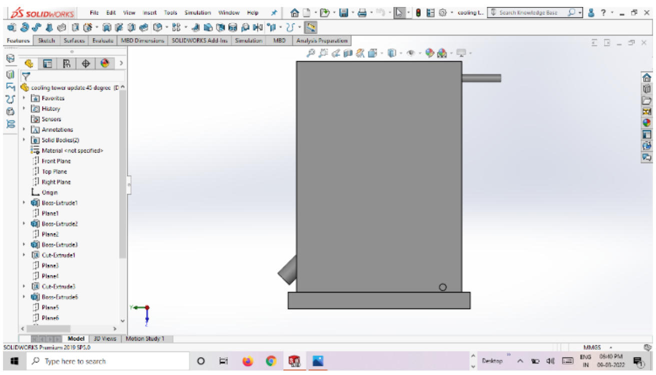


Fig.6(i)Air inlet Pipe at 45^0 Inclined Horizontally – Cooling Tower Model

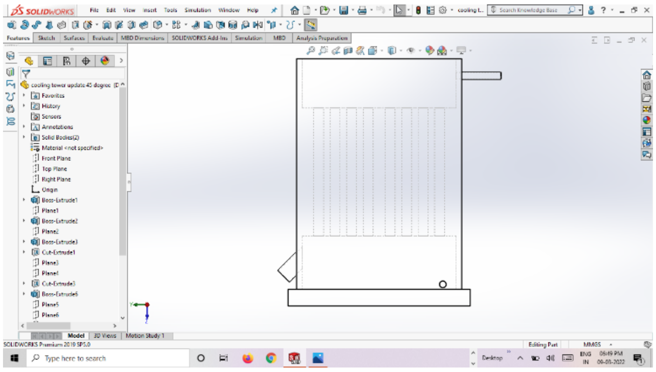


Fig6(ii) Air inlet Pipe at 45^{0} Inclined Horizontally (Hidden line Visibility)

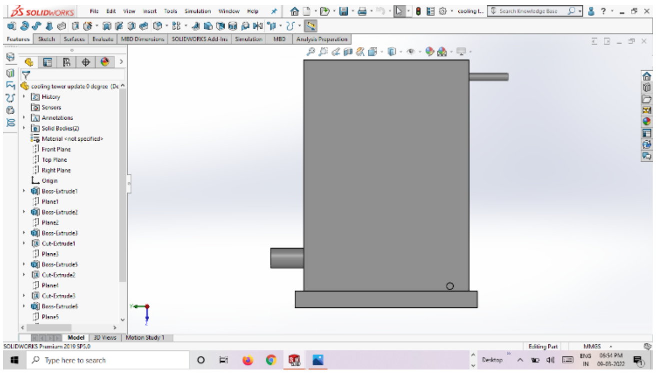


Fig.7(i)Air inlet Pipe at 0^{0}– Cooling Tower Model

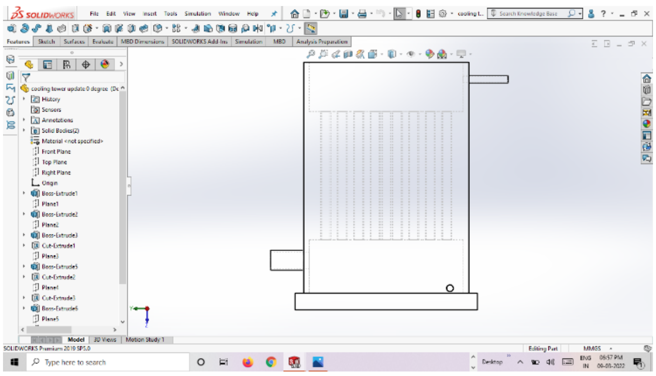


Fig.7(ii)Air inlet Pipe at 0^{0}(Hidden line Visibility)

5.2 CFD Pre-Processing

The cooling tower models have been imported as the geometries into IGES format. Then these models are meshed and CFD analysis is carried out using ANSYS 2022. By applying the appropriate boundary conditions.

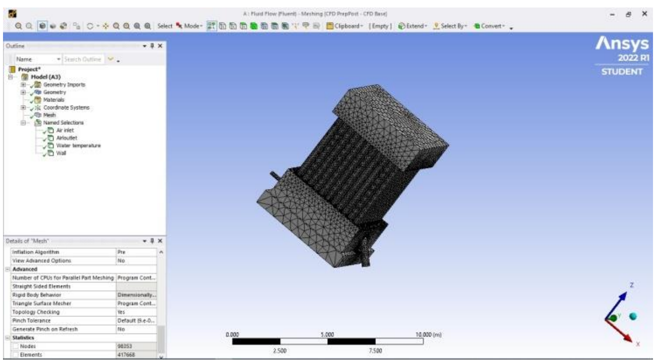


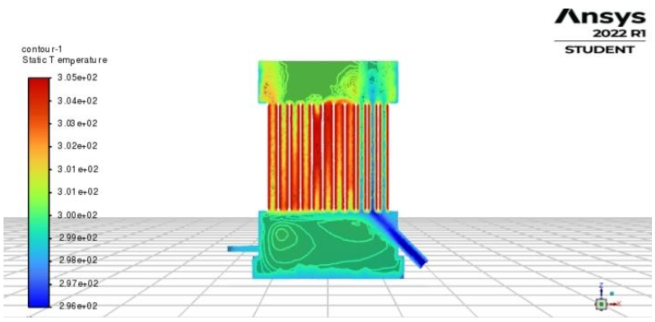
Fig 8 Meshed Model of Cooling Tower

Boundary conditions applied,

- Inlet temperature of hot water=305K
- Mass flow rate of water=111Kg/sec
- Inlet mass flow rate of air=192.03 Kg/sec
- Inlet air pressure= 1.013 Bar
- Inlet WBT of air=297 K
- Fills Porosity=50%

5.3 Analysed Cooling Tower Model

The imported cooling tower models are solved by applying boundary conditions, the solutions have been obtained. The analysed cooling tower models are shown:



Air Inlet Temperature	305 K
Water Inlet Temperature	297 K
Water Outlet Temperature	300K

6. RESULTS AND CALCULATIONS

From the analysis, the outlet water temperature has been obtained on the basis of which the effectiveness of all cooling tower models have been estimated by the below formula,

Effectiveness = Range/ [Range + Approach]

Table 4: Effectiveness of cooling tower for T_2

T_2	Range	Approach	Effectiveness
300 K	5K	3K	62.5%

7. CONCLUSION

Based on our theoretical calculation and design model made using solid work,

1) The design of cooling tower is closely related to cooling tower charactistics which is unique for a particular tower and loading factor which depends on hot water temperature.

2) Rate of heat gain by air is always not equal to rate of heat loss by water due to different types of heat losses.

3) It is almost possible to use CFD to carry about performance analysis of cooling tower in terms of effectiveness.

4) Results clearly demonsrates that with increase in air inlet angle at 45^0 we get slight change in effectiveness.

FUTURE SCOPE

- CFD provide alternative to cost effectiveness speedy solution to cooling tower design and optimization.
- Theoretical calculation we done to find out to design cooling tower model.
- By referring boundary condition from theoretical calculation, we can do further CFD analysis which is more important.

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