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OPTIMIZATION AND CFD ANALYSIS OF INDUCED DRAFT COUNTER FLOW WET COOLING TOWER

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Abstract — *Cooling towers are one of the biggest heat and mass transfer devices used to transfer process waste heat to the atmosphere. Cooling towers make use of evaporation whereby some of the water is evaporated into a moving air stream and subsequently discharged into the atmosphere. As a result, the remainder of the water is cooled down significantly.*
The process parameters such as inlet air rate, water flow rate and fills porosity have more influence on Thermal performance of cooling tower. The Temperature of outlet water is maintained nearest to inlet air wet bulb temperature to obtain the best Thermal Performance of cooling tower. So current work is to obtain and maintaining outlet water Temperature nearest to inlet air wet bulb temperature.
Three different models are made in Creo software and CFX analysis is carried out in ANSYS 12.1.Portable Minitab 16.1 software is used for Taguchi analysis. Result obtained from the taguchi analysis shows that which combination of design parameter gives the minimum temperature of outlet hot water. The exercise has been carried out at Hariom Metal cast pvt. At Kathwada GIDC, Ahmedabad.

Keywords*- Induced draft tube, wet cooling tower, optimization of flow, counter flow study, CFD of cooling tower.*

I. INTRODUCTION

A foundry is a factory that produces metal castings. Metals are cast into shapes by melting them into a liquid, pouring the metal in a mould, and removing the mold material or casting after the metal has solidified as it cools. The most common metals processed are aluminium and cast iron. However, other metals, such as bronze, brass, steel, magnesium, and zinc are also used to produce castings in foundries. In this process, parts of desired shapes and sizes can be formed.

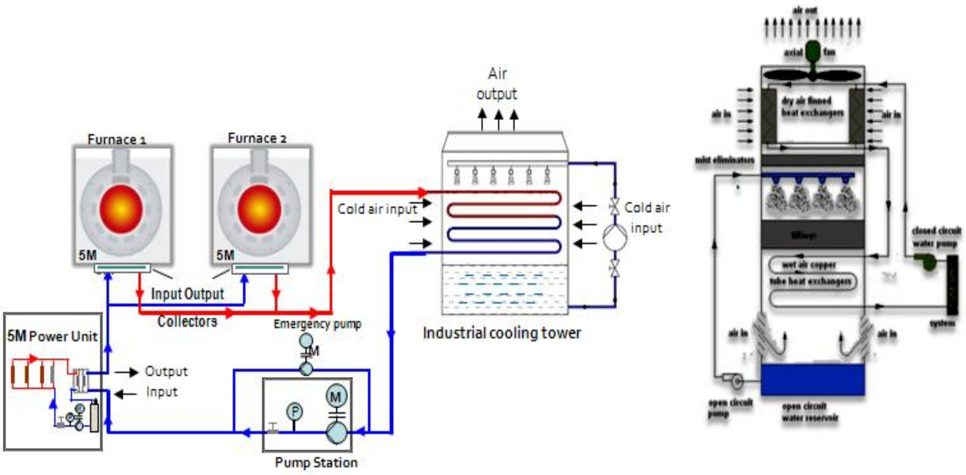

Figure 1. Closed Type Water Cooling System

Cooling Tower Types With respect to drawing air through the tower, there are two types of cooling Towers: (1) Natural draft and (2) Mechanical draft.

Induced Draft An induced draft mechanical draft tower is a draw-through arrangement, where a fan located at the discharge end pulls air through the tower. The fan induces hot moist air out the discharge. This produces low entering and high exiting air velocities, reducing the possibility of recirculation in which discharged air flows back into the air intake. When compared to Forced draft cooling towers, induced draft towers have the following advantages:

1. Recirculation tendency is less of a problem. The air that is thrown out from the top of the Cooling Tower has no chance of getting back into the Cooling Tower. The push of the fan adds to the upward thrust of the warm air.

2. The induced draught can be square as well as round. The distribution system is that of a sprinkler which is c considered to be the most efficient water distribution System.
3. Noise level is very low, because the fan and motor are placed on the top of the Cooling Tower. They are not level with the observer.
4. A forced draft Cooling Tower cannot be a cross flow type model. An induced draft can be either cross flow or counter flow.

Cross-Flow Cooling Tower In cross flow induced draft cooling towers, air enters one or more vertical faces of the cooling tower and moves horizontally through the fill material. Water drops by gravity and the air passes through the water flow into an open plenum area. A shallow pan type elevated basin is used to distribute hot water over the tower fill by means of orifices in the basin floor. The application relying on gravity distribution is normally limited to cross-flow towers.

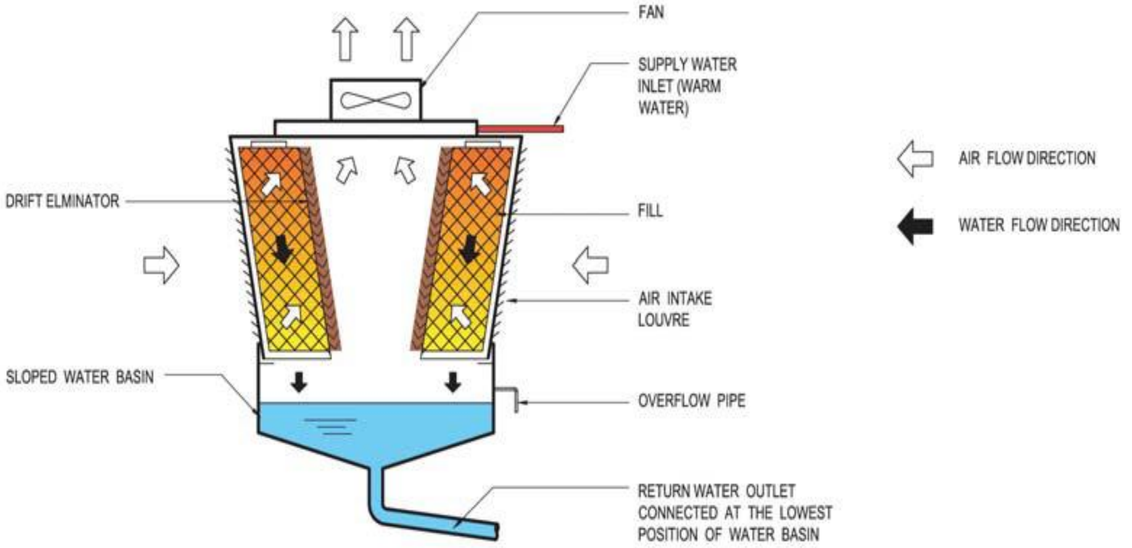

Figure 2. Cross Flow Cooling Tower

Components of Cooling Tower The basic components of an evaporative tower are: Frame and casing, fill, cold water basin, drift eliminators, air inlet, louvers, nozzles and fans.

Cooling Tower Performance The important parameters, from the point of determining the performance of cooling towers, are:

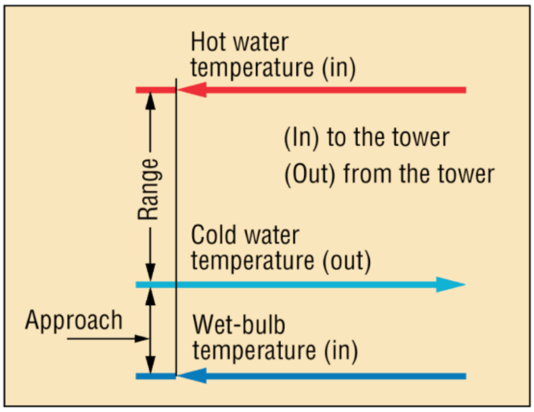

Figure 3. Cooling Tower Performance

1. "Range" is the difference between the cooling tower water inlet and outlet temperature.
2. "Approach" is the difference between the cooling tower outlet cold water temperature and ambient wet bulb temperature.
3. Cooling tower effectiveness (in percentage) is the ratio of range, to the ideal range, i.e., difference between cooling water inlet temperature and ambient wet bulb temperature, or in other words it is = Range / (Range + Approach).
4. Cooling capacity is the heat rejected in kCal/hr or TR, given as product of mass flow rate of water, specific heat and temperature difference.
5. Evaporation loss is the water quantity evaporated for cooling duty.

*Evaporation Loss (m3/hr) = 0.00085 x 1.8 x circulation rate (m3/hr) x (T1-T2)
T1-T2 = Temp. Difference between inlet and outlet water.

6. Cycles of concentration (C.O.C) is the ratio of dissolved solids in circulating water to the dissolved solids in makeup water.

7. Blow down losses depends upon cycles of concentration and the evaporation losses and is given by relation:
Blow Down = Evaporation Loss / (C.O.C. – 1)

8. Liquid/Gas (L/G) ratio, of a cooling tower is the ratio between the water and the air mass flow rates. Against design values, seasonal variations require adjustment and tuning of water and air flow rates to get the best cooling tower effectiveness through measures like water box loading changes, blade angle adjustments. Thermodynamics also dictate that the heat removed from the water must be equal to the heat absorbed by the surrounding air:

II. PROBLEM FORMULATION

The cooling tower finds a variety of applications in the field of a process industries, power plant and heating ventilation and air conditioning where high heat transfer performance and high effectiveness are mostly required. There are many factors which affect the performance of counter flow cooling tower like water flow rate, air flow rate, fill porosity, water to air ratio, fouling, heat leakage in the atmosphere. There are many investigators who have worked on cooling tower by using Merkel equation and poppe's equation to calculate effectiveness of cooling tower by considering the effect of water and air flow rate, ambient wet bulb temperature, tower characteristics. But no one have considered the effect of fill porosity.

Experimentally used to validate the result obtained by use of Ansys. We have used three different fill porosity models in Ansys to find out outlet temperature of hot water. Also we use taguchi method for optimization of cooling tower performance affected parameters with the help of portable Minitab software. The taguchi method reduces number of experiments to be performed and hence save time.

The work to be conducted is stated as "PERFORMANCE ENHANCEMENT OF INDUCED DRAFT COUNTER FLOW WET COOLING TOWER OF BLOW MOULDING MACHINE". It involves the following main objectives.

OBJECTIVES

1) To observe the effects of process variables on the outlet temperature of the water. Such as
   1. Inlet water flow
   2. Inlet air velocity
   3. Fill porosity (packing density).

   For this following step needs to be perform

   (a) Modeling of cooling tower
   (b) Effectiveness calculation
   (c) CFD analysis in ansys
   (d) Experimental reading for validation of ansys result
   (e) Optimization of effectiveness by Taguchi method.

2) The effects of range and approach temperatures will be established from CFD analysis.
3) To identify the conditions that make alternative capacity control methods for cooling towers cost effective.
4) The optimization of tower based free cooling systems for energy consumption.

III. METHODOLOGY

In this thesis, Production drawing of cooling tower obtained from DOLPHIN PLAST PVT LTD. From available production drawing solid model of FRP Cooling tower is prepared in Creo software. Software use calculation for effectiveness & heat transfer rate along with taguchi method for optimization of different parameters at different conditions in counter flow FRP cooling tower has been done. We are varying process parameters such as inlet water flow rate, inlet air rate, fill porosity at different condition of counter flow FRP cooling tower and we are getting different results of heat transfer rate & effectiveness. The analysis has been carried out using formula and supported by softwares.

INTRODUCTION TO CFD Application of the CFD to analyze a fluid problem requires the following steps. First, the mathematical equations describing the fluid flow are written. These are usually a set of partial differential equations. These equations are then discretized to produce a numerical analogue of the equations. The domain is then divided into small grids or elements. Finally, the initial conditions and the boundary conditions of the specific problem are used to solve these equations. The solution method can be direct or iterative. In addition, certain control parameters are used to control the convergence, stability, and accuracy of the method. All CFD codes contain three main elements: (1) A preprocessor, which is used to input the problem geometry, generate the grid, and define the flow parameter and the boundary conditions to the code. (2) A flow solver, which is used to solve the governing equations of the flow subject to the conditions provided. There are four different methods used as a flow solver: (i) finite difference method; (ii) finite element method, (iii) finite volume method, and (iv) spectral method. (3) A post-processor, which is used to massage the data and show the results in graphical and easy to read format.

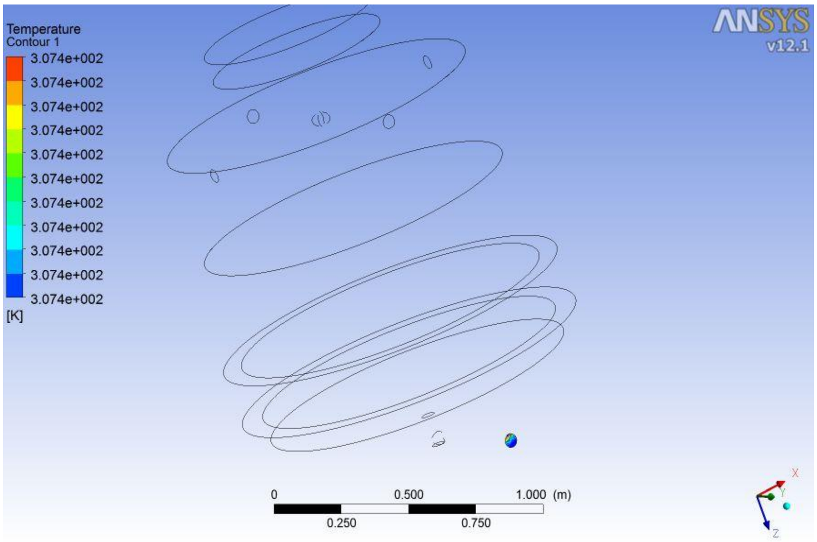

Figure 4. Temperature distributions in cooling tower

COMPARISON BETWEEN PRACTICAL READING AND ANSYS-CFD ANALYSIS

The practical value of Inlet and Outlet Hot Water Temperature are showing below.

Table 1. Comparison between practical and Ansys reading (CFD)

	Inlet Hot Water Temperature	Outlet Hot Water Temperature
Practical Reading	315 k	308K
Ansys Result	315 k	307.4K

This value is taken by temperature probe at Specified locations.From Ansys result and practical reading we can conclude that ansys result is in good agreement with the practical reading. This solid model reflects the practical set up and can be used further for different analysis.

SELECTION OF EXPERIMENT SET UP BY TAGUCHI METHOD

The Taguchi method involves reducing the variation in a process through robust design of experiments. The overall objective of the method is to produce high quality product at low cost to the manufacturer. The Taguchi method was developed by Dr. Genichi Taguchi of Japan who maintained that variation. He developed a method for designing experiments to investigate how different parameters affect the mean and variance of a process performance characteristic that defines how well the process is functioning. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varied; it allows for the collection of the necessary data to determine which factor, most affect product quality with a minimum amount of experimentation, thus saving time and resources.

IV. TAGUCHI EXPERIMENTATION AND ANALYSYS

Once the experimental design has been determined and the trials have been carried out, the measured performance characteristic from each trial can be used to analyze the relative effect of the different parameters. To demonstrate the data analysis procedure, the following L9 array will be used, but the principles can be transferred to any type of array. In this array, it can be seen that any number of repeated observations (trials) may be used. Ti,j represents the different trials with i = experiment number and j = trial number.

To determine the effect each variable has on the output, the signal-to-noise ratio, or the SN number, needs to be calculated for each experiment conducted. The calculation of the SN for the first experiment in the array above is shown below for the case of a specific target value of the performance characteristic. In the equations below, yi is the mean value and s_i is the variance. y_i is the value of the performance characteristic for a given experiment.

$$SN_i = 10\log\frac{y_i^{\,2}}{s_i^{\,2}} \tag{4.1}$$

where

$$\overline{y_i} = \frac{1}{N_i}\sum_{u=1}^{N_i} y_{i,u}$$

$$s_i^{\,2} = \frac{1}{N_i - 1}\sum_{u=1}^{N_i} (y_{i,u} - \overline{y_i})$$

i = Experiment number
u= Trial number
N_i = Number of trial for experiment i

For the case of minimizing the performance characteristic, the following definition of the SN ratio should be calculated:

$$SN_i = -10\log\left(\sum_{u=1}^{N_i}\frac{y^2_{\;u}}{N_i}\right) \tag{4.2}$$

For the case of maximizing the performance characteristic, the following definition of the SN ratio should be calculated:

$$SN_i = -10\log\left(\frac{1}{N_i}\left[\sum_{u=1}^{N_i}\frac{1}{y^2_{\;u}}\right]\right) \tag{4.3}$$

After calculating the SN ratio for each experiment, the average SN value is calculated for each factor and level. This is done as shown below for Parameter 3 (P3) in the array.

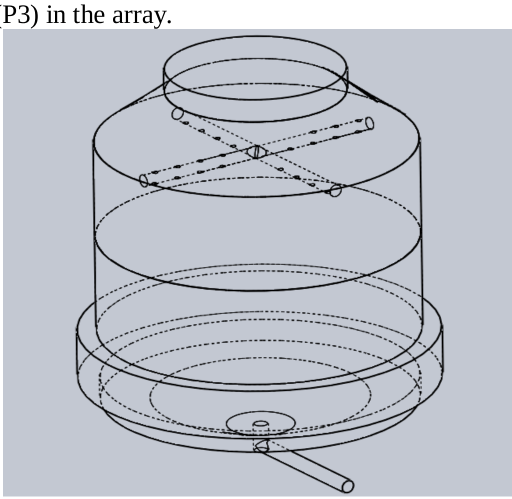

Figure 5. Model 1

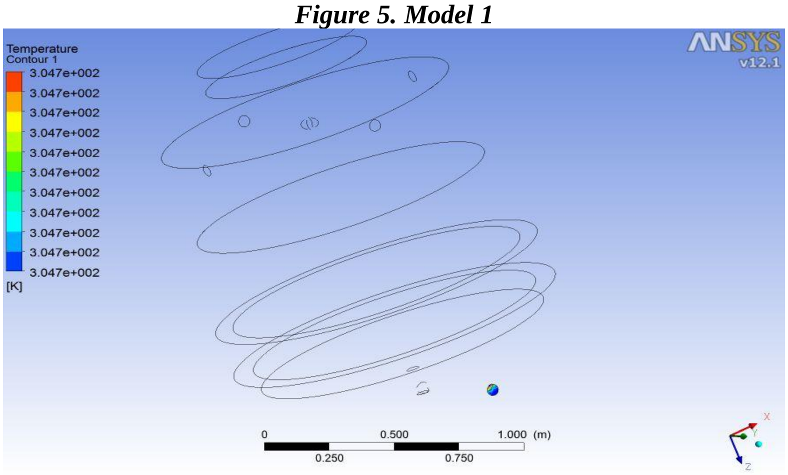

Figure 6. Temperature distribution for case 1

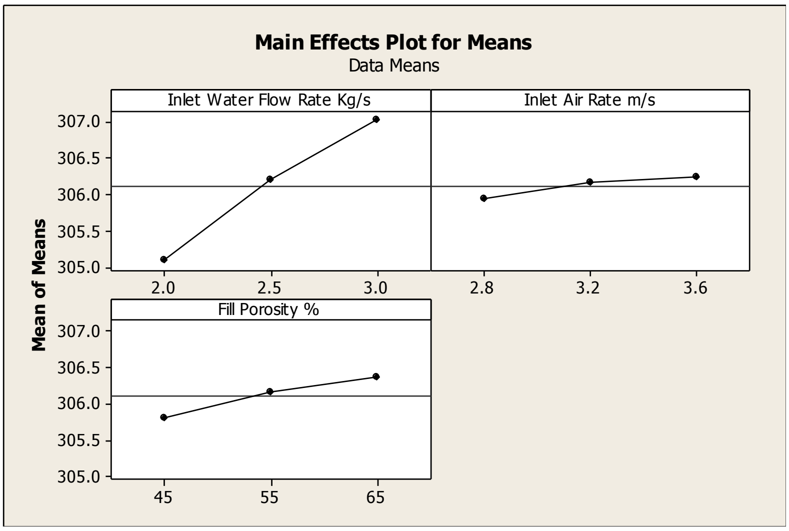

Figure 7. Main Effect Plot for Means

V. CONCLUSION

The below mentioned conclusion has been made as under:

- The optimum condition which gives the maximum effectiveness in counter flow FRP cooling tower was obtained with inlet water flow rate kept at level (2 kg/s), air flow rate kept at (2.8 m/s) and fill porosity at level (45%).
- The value of delta is 0.05, 0.02 and 0.01 for inlet water flow rate, fill porosity and inlet air rate respectively. Hence, the most dominant effect regarding SN ratio is in case of inlet water flow rate.
- ANSYS12.1 and MINITAB 16.1 software gives the output as Hot water outlet temperature contour for different parameters at different conditions. It reduces time for calculations.
- Improvement in Effectiveness of counter flow FRP cooling tower is 0.22 after taking inlet water flow rate 2.0 kg/s, inlet air rate 2.8 m/s and fills porosity 45%.
- Cooling tower Variable Frequency Drives typically control the fan motor based on an analog input signal from either a temperature sensor, which senses the outlet water temperature. Variable Frequency Drives reduce energy use by reducing the fan speed to match the rejected heat load requirement. For example, VFDs can reduce fan energy consumption by about 80% when operating at half speed.
- The results clearly demonstrate that with an increase in inlet water mass flow rate for the same fill porosity, the surface area required both for convection and evaporation is reduced, resulting in higher water outlet temperatures and reduced heat transfer rates.
- The exercise has been carried out at Hariom Metal cast pvt ltd. .at Kathwada GIDC, Ahmedabad. In addition it analytical approach, Creo, Ansys and Portable Minitab have been used.

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