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Performance Analysis & Enhancement of Cooling Tower in cement plant

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ABSTRACT - Every cement Plant must have a cooling tower. Cooling towers are essentially heat rejection devices that move heat from hot water to the air. An experimental analysis of a cooling tower used in actual industry operations is part of the investigation. The performance of a counter-flow induced draught cooling tower is primarily influenced by the temperature of the inlet water and the mass flow rates of water and air. By optimising the cooling tower's liquid to gas ratio (L/G), the effectiveness of the cooling tower can be raised by up to 20%. Similar to how tower characteristic ratio and other factors can be greatly enhanced,

KEYWORDS: cooling tower with induced counter flow draught, Liquid to gas (L/G) ratio, range, effectiveness of cooling tower, and tower characteristic ratio

I. INTRODUCTION

The cooling tower (CT) is the most significant piece of industrial machinery, and its main function is to remove heat while using the least amount of water possible. In a cooling tower, water is made to trickle down in little drops or to build up a thin layer over a flat surface where it will come into touch with air travelling in the opposite direction and upward. The air is discharged into the atmosphere once the heat transfer from the water to the steam elevates the air's temperature and relative humidity to 100%. This causes some water to evaporate and separate from the main body of water, which cools as a result. Thus, cooling towers use evaporative cooling as a method of cooling. Natural airflow and mechanical draught are the two primary types of cooling towers. The following airflow configurations for mechanical draught towers are available: Counterflow forced draught, or induced draught from the opposite direction. draught caused by cross flow. Hot water arrives at the top of the counterflow induced draught design, as opposed to the air, which enters at the bottom and leaves at the top. It uses both forced and induced draught fans. Water enters at the top of cross flow induced draught towers and flows over the fill. However, the air is injected at the side, either on one side (single-flow tower) or on opposite sides (double-flow tower). Through the top of the structure, an induced draught fan pulls air across the wetted fill. the impact of different input factors in the current investigation. The cooling tower used for the study is one from a cement factory. An industry standard cooling tower is a counter flow induced draught cooling tower. By altering the fan pitch angle, we take into account the impact of the air mass flow rate in this study. By mounting the VFD in a drive and adjusting the fan's pitch. The effects of additional cooling tower input parameters are investigated using this model.

II. COOLING TOWER CALCULATIONS

Heat removal and water conservation are the main purpose of cooling towers. Two mechanisms are used to transport heat. Latent heat is lost in this phase as a portion of the cooling water, usually 1 to 3%, actually evaporates as it readily interacts with air. Heat exchanged without a phase shift makes up the balance in sensible heat transfer. The amount of heat transferred depends significantly on the relative humidity of the incoming air.

According to thermodynamics

Heat removed from water = heat absorbed by surrounding air

$$L(T_1 - T_2) = G(h_2 - h_1)$$



$$L/G=(h_2-h_1)/ (T_1-T_2)$$

Where, L = Mass flow rate of water entering the tower,

G = Mass flow rate of air through the tower,

T1 = hot water temperature ,

T2 = cold water temperature,

Temperature of air water vapor mixture at the inlet wet bulb temperature = 32.7°c

Temperature of air water vapor mixture at the exhaust wet bulb temperature =35°c

h₂= enthalpy of air water vapor mixture at the exhaust wet-bulb temperature = 98.4 kj/kg

h₁ = enthalpy of air – water vapor mixture at the inlet wet bulb temperature = 97.8Kj/kg

Relative humidity = 90%

The values of h₁ and h₂ are obtained from psychometric chart at 95% relative humidity corresponding to inlet and exhaust wet – bulb temperature of air-water vapor mixture.

L = 600 cubic meter/hr.

The flow of water is regulated by using 2 pumps whose combined efficiency is 85% and each pump has capacity to regulate 300 cubic meter/hr.

Therefore L= 300*2 = 600 cubic meter/hr. the pumps are 85% efficient .

Therefore L= 600*(85/100) =510 cubic meter/hr.

Average hot water temperature to the tower and average cold water temperature from the tower checked in each hour a day for last 4 days is given

Day	Cold water temprature	Hot water temprature
05/01/2020	32	39
06/01/2020	31	41
07/01/2020	33	42
08/01/2020	34	40

Table- 1 - Temperature reading (RCCPL CT)

Thermodynamics also dictate that the heat removed from the water must be equal to the heat absorbed by the surrounding air: $L (T_1 - T_2) = G (h_2 - h_1)$

Where L, G are the mass flow rate of water and air respectively,

Average cold water temperature (T₁) = 32.50°C,

Average hot water temperature (T₂) = 40.50°C

Inlet wet bulb temperature of air Twb₁ = 28°C,

Exit wet bulb temperature of air Twb₂ = 34°C

Corresponding to inlet and exit wet bub temperatures the enthalpies are taken from psychometric chart



h_2 = enthalpy of air-water vapor mixture at exhaust wet-bulb temperature = 120KJ/KG

h_1 = enthalpy of air-water vapor mixture at inlet wet-bulb temperature = 94KJ/KG

$$510(40.50 - 32.50) = G (120 - 94)$$

$$G = 156.93 \text{ Kg/s}$$

V = volume of air entering = 7559 cubic meter/minute,

Calculation of Makeup water required:

Total loss = Drift losses + Evaporative losses + Blow down losses + Supply of hot water to Cement plant

$$D = \text{drift losses} = 0.15\% \text{ of water supply} = (0.15/100) * 510 = .765 \text{ cubic meter/hr.}$$

$$E = \text{evaporative losses} = 0.00085 * \text{water flow rate} * (T_1 - T_2) = 0.00085 * 510 * (40.83 - 32.33) = 3.468 \text{ cubic meter/hr.}$$

The amount of total dissolved solids in the remaining water rises when the cooling tower portion of the water evaporates during circulation. blow down is applied in order to control the cycle of concentration. The cycle of concentration's function is to blow down. From the following formula, blow down can be calculated:

$$B = E / (\text{COC} - 1)$$

$$B = \text{Blow Down (m}^3/\text{hr)}$$

$$E = \text{Evaporation Loss (m}^3/\text{hr)}$$

COC = Cycle of Concentration. Varies from 3.0 to 7.0 depending upon Manufactures Guidelines

$$\text{Therefore Blow down losses} = E / (\text{COC} - 1) = 3.468 / (3 - 1) = 1.734 \text{ cubic meter/hr}$$

Day	Water Supplied
5/01/2020	96 cubic meter/day
6/01/2020	93 cubic meter/day
7/01/2020	94 cubic meter/day
8/01/2020	89 cubic meter/day

Table-2

Average water supplied to Cement plant = 93 cubic meter/day.
= 3.875 cubic meter/hr.

Therefore make up water required = .765 + 3.468 + 1.734 + 3.875 = 9.842 cubic meter/hr.

$$\text{Efficiency (E)} = [(\text{hot water temperature} - \text{cold water temperature}) / (\text{hot water temperature} - \text{wet bulb temperature})] * 100$$

$$= [(40.50 - 32.50) / (40.50 - 28)] * 100$$

$$= 64\%$$

The fan blades of the cooling tower were initially switched from aluminium alloy to FRP in order to improve performance. The airflow through the fan is primarily influenced by the blade pitch angle, the air gap between the blade tip and the casing, etc. The FRP blade's pitch has been properly raised to improve the air gap and maximise system airflow while reducing air leakage. The efficiency of FRP fans is greatly enhanced by their higher lift to drag ratio, wider chord along the blade twist, and lower drag losses. The increased fan efficiency and reduced weight of fan blades, reduce the electrical power input to the fan motor.



Performance results of replacement of aluminium alloy fans by FRP fans

(I) Analysis of air flow through existing aluminum alloy fan:

Calculation of air velocity and flow rate through the cooling tower

Pitch angle (θ) = 11°

Pitch distance = $r \tan \theta = 6 \tan 11 = 1.166$,

Pitch distance and velocity are connected by the following relation,
 $1.166 = [12 * V] / [S * RPM]$

V = air velocity (foot/minute)

RPM (Rotations per minute) = 315,

S (fan series) = 70

$1.166 = [12 * V] / [70 * 315]$

Air Velocity = 2142 ft /minute = 10.8 m/sec.

To calculate ACFM (Actual cubic flow per minute),

$V = [1.27 * (ACFM)] / [DR^2 - (S/12)^2]$

DR – diameter of fan ring in feet = 14ft

$2142 = [1.27 (ACFM)] / [196 - (70/12)^2]$

ACFM = 273231.5 Cubic feet per minute

= 7749 meter cube per min

(II) Analysis of air flow rate by variable pitch FRP fan:

FRP fan used are variable pitch axial fan. And as the pitch angle increases the volume of air drawn by the axial fan also increases. As the mass flow of air increases the amount available to water molecules also increases, as a result the heat transfer rate also increases .

Pitch angle (θ) = 14°

Pitch distance = $r \tan \theta = 6 \tan 14 = 1.495$

$1.495 = [12 * V] / [S * RPM]$

V = Velocity

RPM = 315

S = 70

$1.495 = [12 * V] / [70 * 315]$

Air Velocity = 2747.06 ft./minute = 13.850 m/sec.

To calculate ACFM (Actual cubic flow per minute),

$V = [1.27 * (ACFM)] / [DR^2 - (S/12)^2]$

DR – diameter of fan ring in feet = 14ft



$$2747 = [1.27 (ACFM)] / [196 - (70/12)^2]$$

ACFM = 350412.8 Cubic feet per minute

= 9937.9 meter cube per min

Percentage increase in volume flow rate of air = $[(9937.9 - 7749) / 7749] * 100 = 28.24\%$

Particulars	Present Motor With Aluminium alloy blades	Present Motor With FRP blades	Present Motor With FRP blades And VSD drive
Motor rating, (kW)	45	45	45
Average motor load factor,(%)	86.7	78.7	74.3
Motor efficiency, (%)	89	75	89
Motor input, (kW)	39.01	35.41	33.45
Power factor	0.9	0.88	0.92
Energy savings, (kWh/day)		86.4	135.84
Energy savings, (KWh/month)		2592	4075
Savings, (Rs/month) (energy cost @7/Kwh		18144	28526
Investment for FRP fan blades& VSD , (RS)		378000	550000
Pay back period, (months)		21	19

Table-3

The adoption FRP fan blades leads to energy saving of 2592 KWh/month. The payback period for an initial investment is 21 months. The replacement of both the fan blades and motor with VSD will enhance the energy savings by 4075 KWh/month. The anticipated capital investment is 550000 and the payback period is 19 months. The latter is more attractive, The fan blades of the cooling tower were initially switched from aluminium alloy to FRP in order to improve performance. The airflow through the fan is primarily influenced by the blade pitch angle, the air gap between the blade tip and the casing, etc. The FRP blade's pitch has been properly raised to improve the air gap and maximise system airflow while reducing air leakage. The efficiency of FRP fans is greatly enhanced by their higher lift to drag ratio, wider chord along the blade twist, and lower drag losses.

The increased fan efficiency and reduced weight of fan blades, reduce the electrical power input to the fan motor.

Proposal :-OPERATIONAL OPTIMIZATION

Presently CT fans in a cement plant are being operated 8 months in Summer & Rainy Season in a year. During the winter when the wet bulb temperature is lower, The operation of CT can be reduced based on the wet bulb temperature and CW temperature at CT outlet.

The performance test is conducted by switching-off the CT fan Auto logic when the wet bulb temperature was low (i.e., varying between 14.1 – 14.6 oC) and the energy consumption was reduced by fans in service with marginal variation in range and effectiveness.

III. CONCLUSION

The replacement of Aluminium bladed fan by modern technology FRP bladed fans reduced the power consumption by 15 – 25 %, the effectiveness had increased by 7 – 8 %, the SEC had decreased by 31 – 40 % and the overall fan efficiency had improved by 30 – 32 %. The replacement of these fans releases an additional energy of about 3.0 MW per year for one 4MTPA Cement plant. The operational optimization will also reduce the auxiliary power and is help in reducing the condensate sub-cooling problem.



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