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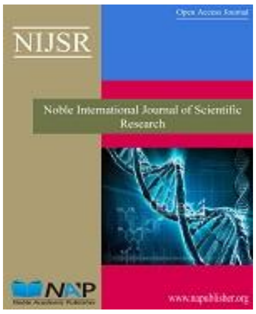

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PARAMETRIC BASED EXERGY ANALYSIS OF INDUCED DRAUGHT COOLING TOWERS OF THE THERMAL AND THE LAKHRA POWER PLANTS JAMSHORO

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ABSTRACT: With the help of energy and exergy analyses of induced draught counterflow wet cooling tower of the thermal power plant Jamshoro and the lakhra coal power plant is demonstrated through employing EES (engineering equation solver) in this paper. First the model was made and then the simulation and the validation, with the help of very rudimentary and basic equations, were performed successfully by utilizing given operating parameters in order to evaluate and calculate the cooling tower performance and other required parameters. The inlet air wet bulb temperature plays tremendous role in causing the change in water and air outlet temperature, cooling tower effectiveness and exergy efficiency and destruction. With the increasing of wet bulb temperature there is direct effects on effectiveness and exergy efficiency of the cooling tower. The mass flow rate of water to air ratio is in the range of 2.47 for the thermal power plant and 2.09 for the lakhra power plant and the ratio is changed with the variation of wet bulb temperature of inlet air. The evaporation loss was very negligible as compared to the flow rate of water.

Keywords: Counterflow, Energy, Exergy, Parameters, Simulation, Validation.

1. INTRODUCTION

Basically, the cooling tower is a type of heat exchanger which takes out heat from the warm water that enters in it from height to be cooled and then this cool water again goes back to serve its purpose effectively and properly. The warm water that is to be cooled is being discharged from condenser another important heat exchanger that condenses the saturated steam fallen into it from last stage of turbine and this cool water is fed back into the condenser. This whole process is aimed at saving scant resource of water and capital cost. However, with the aid of recuperative heat exchanger an important part of the plant, the cooling tower achieves its purpose of lowering warm water temperature targeting at higher efficiency and cost effectiveness. Laid the foundation for introducing the rudimentary and rogue concept of energy and heat transfer role in cooling tower [1]. The equations related to mass and heat transfer in cooling by evaporative in wet cooling towers were formed by him [2]. The changing of dead state conditions don't have specific effect on the wet cooling towers and however, wet bulb temperature of inlet air has huge impact and influence than inlet water temperature as per evidenced by energy and exergy analysis [3]. Carried out the investigative study by varying the environmental conditions and they also studied the behavior with respect to thermal of the type of counter flow wet cooling tower besides conducting the exergetic analysis to witness the performance by magnitude and location wise [4]. Investigated Khuzestan steel Co cooling towers in perspective of energy and exergy analysis by showing the mathematical model with respect to rule of heat and mass transfer between air and water [5]. Conducted the fabulous study by coming to the conclusion that as the water descends its exergy decreases constantly from the upper part of the tower to the lower meanwhile as the air goes from bottom to the upper its exergy increases constantly along the tower so one is losing exergy while other is gaining exergy on the way to their respective path [6]. Demonstrated a model for counter flow cooling tower regarding its height perspective [7]. Made a new model of a mechanical draft cooling tower [8]. Performed optimized performance thermo-hydraulic analysis getting basic algebraic equations for calculating the maximum performance stage of counter current mechanical draught cooling towers utilizing e-NTU technique [9]. Executed the study with respective to thermodynamic point of view by employing energy and exergy analysis for the evaporative heat exchangers and counter flow wet cooling towers [10]. Conducted the parametric based study with the help of exergy analysis technique by witnessing the effects of inlet temperature and inlet relative humidity on the performance parameters [11]. Gave the rudimentary theory relative to operation of cooling tower [12]. Carried out the energy and exergy analyses of the boiler and its parts furnace, economizer and superheaters [13].

However, this study demonstrates at carrying out energy and exergy analyses of induced draught counter flow rectangular cooling tower (IDRCT) through EES software which has many thermodynamic point of view features and properties by employing very simple equations to come to know about the behavior of the performance and efficiency of cooling tower and to know the effect of one parameter on the other the parametric study has also been performed especially of inlet temperature, wet bulb temperature and water to air (LG) ratio on performance parameters.

1.1. Process Description and Assumptions Made

Here for the investigation two induced draught of cooling towers of the thermal power plant and the lakhra coal power plant Jamshoro are examined. Their working and function is almost similar and identical. Just the difference between the two is that former is of a highest capacity and while latter is of low capacity cooling towers as per the required capacity of generation of electricity. First and foremost the warm water that carries the great potential of heat and thus energy is made to enter from the height of the cooling tower and then this is showered into the bottom and this will step by step comes to bottom by releasing its heat when coming in contact with the air that comes from bottom with high velocity by the help of induced draught fan to carry away the heat released by the showering water. Because of this the cooling effect takes place which renders the cool water to be employed in the cycle in order to avoid the loss of scarce water and huge capital loss the cooling water is recycled. In this way the precious water is used again and again. The water vapors that are evaporated are being compensated in the form of makeup water which balances the entering and exiting water flow rate.

The following assumptions have been taken into consideration:

1. All the potential, chemical, thermal, kinetic energy and exergy have been neglected as these are very small to be considered and to produce any specific impact.
2. Blowdown and drift effect have been neglected.
3. The steady state flow conditions prevail thorough out the fluid streams.
4. The dead-state condition is at 101.32 kPa and 25^{o} C.
5. The effect in terms of energy and exergy associated with makeup water is too small to be considered so it has been altogether neglected.
6. Relative humidity of outlet/saturated air is presupposed to be 1.
7. The evaporation loss of water is being compensated in the form of makeup water through the raw water induction from river.

1.2. Thermodynamics Model Equations and Schematic Diagram

The thermodynamic equations of cooling tower demonstrated in terms of energy and exergy analysis along with the relevant diagram.

Energy balance:

$$\sum_i \dot{m} = \sum_o \dot{m} \quad (1)$$

$$\dot{m}_{a1} \times h_{ai} + \dot{m}_{w3} \times h_{w3} = \dot{m}_{a2} \times h_{a2} + \dot{m}_{w4} \times h_{w4} \quad (2)$$

Dry air mass balance:

$$\dot{m}_{a1} = \dot{m}_{a2} \quad (3)$$

Water mass balance:

$$\dot{m}_{w3} + \dot{m}_{a1} \times \omega_1 = \dot{m}_{w4} + \dot{m}_{a2} \times \omega_2 \quad (4)$$

Makeup water:

$$\dot{m}_{mw} = \dot{m}_{a1}(\omega_2 - \omega_1) \quad (5)$$

Volumetric rate of air into cooling tower:

$$V = \dot{m}_{a1}\, v_{ai} \quad (6)$$

Water to air ratio:

$$LG = \dot{m}_{w3}/\dot{m}_{a1} \quad (7)$$

$\dot{Q}$ out cooling tower:

$$Q_{out\ ct} = \dot{m}_{w3} \times cp_w\,(T_{w3} - T_{w4}) \quad (8)$$

Range of Cooling tower:

$$R = (T_{w3} - T_{w4}) \quad (9)$$

Approach of cooling tower:

$$Approach = (T_{w4} - T_{wet\ bulb}) \quad (10)$$

Cooling tower effectiveness:

$$\text{Cooling tower effectiveness} = R/(R + Approach) \quad (11)$$

Exergy of Air in:

$$E\dot{x}_{air\ in} = \dot{m}_{a1}(h_{a1} - h_0) - T_0(s_{a1} - s_0) \quad (12)$$

Exergy of air out:

$$E\dot{x}_{air\ out} = \dot{m}_{a2}(h_{a2} - h_0) - T_0(s_{a2} - s_0) \quad (14)$$

Exergy of water in:

$$E\dot{x}_{water\ in} = \dot{m}_{w3}(h_{w3} - h_0) - T_0(s_{w3} - s_0) \quad (15)$$

Exergy of water out:

$$E\dot{x}_{water\ out} = \dot{m}_{w4}(h_{w4} - h_0) - T_0(s_{w4} - s_0) \quad (16)$$

Net exergy in:

$$E\dot{x}_{net\ in} = E\dot{x}_{air\ in} + E\dot{x}_{water\ in} \quad (17)$$

Net exergy out:

$$E\dot{x}_{net\ out} = E\dot{x}_{air\ out} + E\dot{x}_{water\ out} \quad (18)$$

Exergy destruction rate:

$$E\dot{x}_{destruction} = E\dot{x}_{net\ in} - E\dot{x}_{net\ out} \quad (19)$$

Exergy efficiency:

$$Ex_{efficiency} = (1 - E\dot{x}_{destruction}/E\dot{x}_{net\ in}) \times 100 \quad (20)$$

Figure 1. schematic diagram of induced draught wet cooling tower

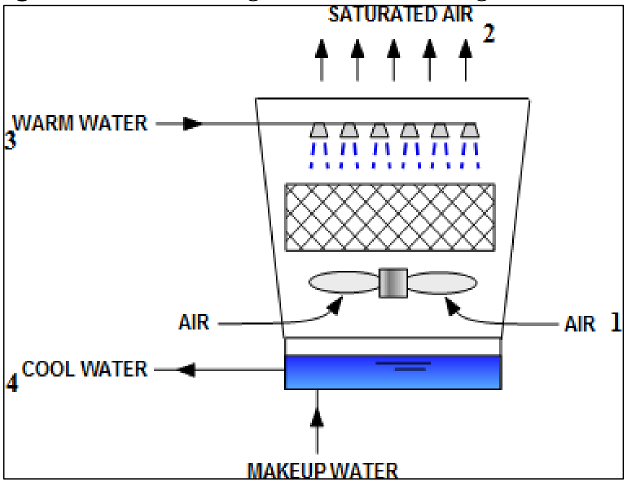

Table 1. Baseline data of induced draught wet cooling tower of the lakhra power plant

NAME	VALUE
Atmospheric temperature	101.3259 kPa
Atmospheric pressure	25 °C
Dry bulb temperature of air	31.5 °C
Inlet temperature of water	40 °C
Wet bulb temperature of air	26 °C
Outlet/Saturated temperature of air	38 °C
Outlet temperature of water	32 °C
Water mass flow rate	2736 kg/s
Relative humidity of inlet air (rh1)	0.6496
Cp of water	4.183 kj/kg.K
Cp of inlet air	1.042 kj/kg.K
Cp of outlet air	1.088 kj/kg.K

Table 2. Baseline data of induced draught wet cooling tower of thermal power plant Jamshoro

NAME	VALUE
Atmospheric temperature	101.3259 kPa
Atmospheric pressure	25 °C
Dry bulb temperature of air	31 °C
Inlet temperature of water	45 °C
Wet bulb temperature of air	26 °C
Outlet/Saturated temperature of air	42 °C
Outlet temperature of water	35 °C
Water mass flow rate	8000 kg/s
Relative humidity of inlet air (rh1)	0.6755
Cp of water	4.183 kj/kg.K
Cp of inlet air	1.042 kj/kg.K
Cp of outlet air	1.088 kj/kg.K

2. RESULTS AND DISCUSSION

Table 3. Outcome of induced draught wet cooling tower of the Lakhra power plant Jamshoro

NAME	VALUE
Exergy efficiency	100 %
Cooling tower effectiveness	57.14 %
Exergy in	255109 KW
Exergy out	255106 KW
Exergy destruction rate	3.02 KW
$\dot{Q}_{\text{out by cooling tower}}$	91540 kj/s
Mass flow rate of air	1309.8 kg/s
Makeup water flow rate	32.09 kg/s

Humidity ratio of inlet air (wi)	0.01901
Humidity ratio of outlet air (wo)	0.04351
Volumetric rate of flow of air	1165 m^3/s
Water to air ratio (LG)	2.09

Table 4. Outcome of induced draught wet cooling tower of the thermal power plant Jamshoro

NAME	VALUE
Exergy efficiency	100 %
Cooling tower effectiveness	52.63 %
Exergy in	910654 KW
Exergy out	910649 KW
Exergy destruction rate	5.056 KW
$\dot{Q}_{\text{out by cooling tower}}$	334536 kj/s
Mass flow rate of air	3239 kg/s
Makeup water flow rate	115.1 kg/s
Humidity ratio of inlet air (wi)	0.01992
Humidity ratio of outlet air (wo)	0.05477
Volumetric rate of flow of air	2877 m^3/s
Water to air ratio (LG)	2.47

As can be seen from above table 3 & 4 the outcomes have been achieved by performing energy and exergy analyses through the help of Engineering Equation Solver (EES) software.

2.1. Parametric Study

In this section the effect of different operating parameters or independent variables on the performance parameters or dependent variables is studied and examined of thermal power plant Jamshoro. The figure 1 depicts the increasing of exergy efficiency and cooling tower effectiveness at expense of increasing wet bulb temperature as it nears to the inlet water temperature that will render minimum difference thus maximum effectiveness. From figure 1 too it can be deduced that the LG (water to air ratio) is decreased at the cost of increasing wet bulb temperature. From figure 2 it can be seen that as the warm temperature/inlet water temperature is increased the effectiveness of cooling tower is raised because by raising warm water temperature the range is increases correspondingly and then range is directly proportional to cooling tower effectiveness.

Figure 2a. Effect of wet bulb temperature on the cooling tower effectiveness, exergy efficiency and LG ratio.

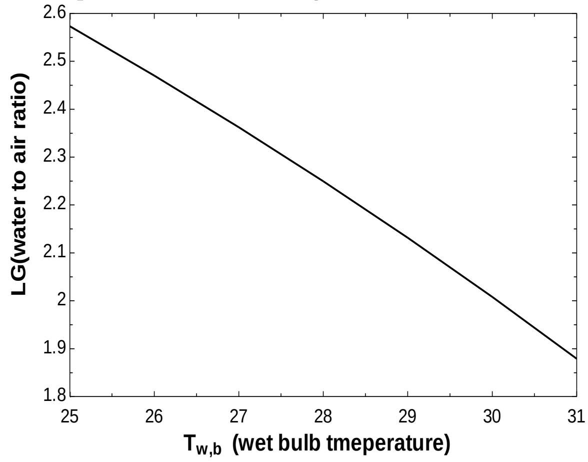

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Figure.2b Effect of wet bulb temperature on the cooling tower effectiveness, exergy efficiency and LG ratio

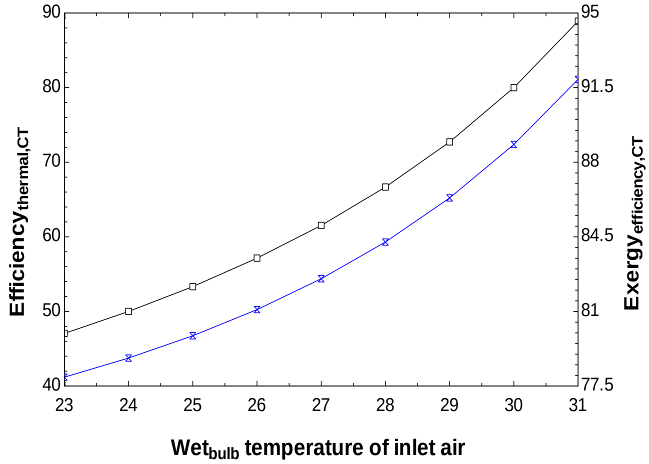
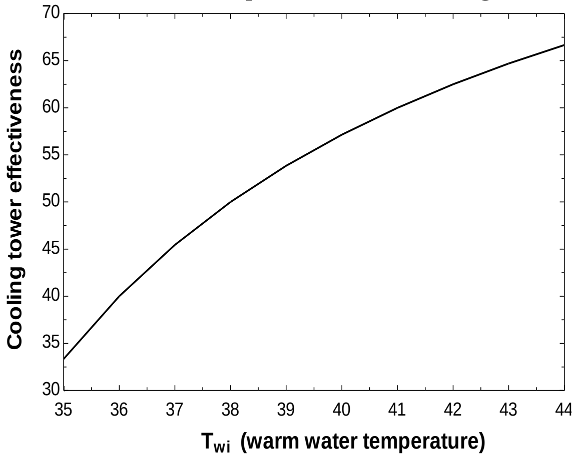


Figure 3. effect of warm water temperature on the cooling tower effectiveness



3. CONCLUSION

It is come to the conclusion that by investigation and examination through energy and exergy analyses along with performing parametric based study is very helpful in evaluating and assessing the performance and efficiency of the cooling tower and then effects of operating parameters on performance parameters. The exergy efficiency of the cooling tower is 100% of both plants .The wet bulb of inlet air temperature plays a significant role along with inlet water temperature and it was deduced that drier the area the higher will be the efficiency of the cooling towers because of the low moisture content in the air and thus low relative humidity. With the raising of inlet water temperature and wet bulb temperature the effectiveness is raised simultaneously. With the increasing of wet bulb temperature there is direct effects on effectiveness and exergy efficiency of the cooling tower

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NOMENCLATURE

$\dot{h}$	Specific enthalpy (kJ/kg)
i	In
$\dot{m}$	Mass flow rate (kg/s)
o	Out
P	Pressure (kPa)
S	Specific entropy (kJ/kg.K)
T	Temperature (c)

Tw, b	Wet bulb temperature ()
Twi	Inlet water temperature (c)
$\dot{Q}$	Heat load (kj/s)
V	Volumetric rate of flow ($\boldsymbol{m^3/s}$)
ABBREVIATIONS	
R	Range
LG	liquid (water) to Gas (air)

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