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Energy and Second Law Analysis of Shower Cooling Tower Used for Air Cooling Application for Human Comfort with Variation in Water to Air Mass Flow Ratio

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***Abstract:** The present study deals with heat and mass transfer analysis of a downward parallel flow of air and water droplet interaction. For this purpose a two dimension MATLAB mathematical model has been developed to solve simultaneous governing differential equations to predict the exit condition of air and droplets. The result indicated a potential for significant air temperature reduction along shower cooling tower (SCT) height. The results also show thermal efficiency of SCT decrease with increasing the water to air mass flow ratio (RLG). Exergy analysis has also been carried out to indicate variation of exergy of water spray and total exergy of air flowing through the SCT. The second law efficiency (SLE) of SCT increases by increasing the RLG because exergy destruction increases with increasing the RLG.*

***Keywords:** SCT; Heat and mass transfer analysis; RLG; DBT; Exergy analysis.*

NOMENCLATURE			
A	cross section area of test section, (m^2)	A_n	outlet orifice area of nozzle, (m^2)
A_s	surface area of droplet, (m^2)	C	specific heat, (kJ/kg K)
C_d	coefficient of drag	D	droplet diameter, (m)
D_c	cross-sectional diameter of SCT, (m)	DBT	dry bulb temperature, (°C)
dm_d	change in mass flow rate of water vapor, (kg/s)	d_n	outlet orifice diameter of nozzle, (m)
E	internal energy, (kJ/kg)	g	gravitational acceleration, (m/s^2)
H	height of SCT, (m)	h	specific enthalpy, (kJ/kg)
h_f	specific enthalpy of saturated water, (kJ/kg)	h_{fg}	specific enthalpy of evaporation, (kJ/kg)
$h_{fg,0}$	specific enthalpy of evaporation at 0°C, (kJ/kg)	h_g	specific enthalpy of saturated vapor, (kJ/kg)
h_m	mass transfer coefficient, (kg/m^2 s)	I	exergy destruction of system, (W)
Le_f	Lewis factor	m_a	mass flow rate of air, (kg/s)
m_d	mass flow rate of water from the nozzle, (kg/s)	M_d	mass of a drop, (kg)
N	number of droplets	q	heat transfer, (kJ/kg)
R	drag force, (N)	R_a	gas constant for per unit molecular weight of dry air, (J/kg K)
R_v	gas constant per unit molecular weight of water vapor, (J/kg K)	RLG	Water to air mass flow ratio
S_f	specific entropy of saturated water, (kJ/kg K)	S_g	specific entropy of saturated vapor, (kJ/kg K)

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SCT	shower cooling tower	SLE	Second law efficiency
T_a	temperature of air, (°C)	u_a	air velocity, (m/s)
U	drop velocity, (m/s)	W	relative velocity of drop w.r.t. air, (m/s)
X	exergy, (W)		
Greek letters			
ρ	density (kg/m^3)	ω	specific humidity, (kg_w/kg_a)
ϕ	relative humidity of air, (%)	ϕ_0	ambient humidity
θ	inclination of water droplet from horizontal	η_{th}	thermal efficiency, (%)
Subscripts			
00	environment	0	restricted dead state
a	air	*av*	average condition
c	convective	*d*	droplet
e	evaporative	*in*	inlet
l	evaporative loss	*m*	mean
out	outlet	*p*	constant pressure
t	total	*s*	saturated
v	vapor	*w*	water
x	horizontal coordinate	*y*	vertical coordinate

I. INTRODUCTION

In hot season in India and other parts of the world, evaporative cooling of air is an attractive energy efficient technique for producing a comfortable indoor environment in residential and commercial buildings. The general disadvantage of the conventional cooling tower is fouling due to salt decomposition on the fills and it is a major source of cooling tower performance deterioration (Xiaoni et al. 2007 and Bilal et al. 2006). Replacement and cleaning of fills is very difficult. Therefore, to overcome these disadvantages, SCT has been developed where fills are removed completely and small water droplets replace the fill as the mode of simultaneous heat and mass transfer. The easiness and ostensible dependability of operation of the basic mechanisms of this system suggest that for suitable environmental conditions, i.e. the climate is hot and dry, application of evaporative cooling is an attractive option with high cooling efficiency, low cost, and low maintenance. Muangnoi et al. (2014) examined water-jet cooling tower using experiments and numerical simulations. They found that evaporation share of the total energy transfer and total exergy supplied effect the performance. Terblanche et al. (2009) measured drop size distribution photographically below three different counter-flow wet-cooling tower fills. It was observed that an increase in water mass velocity generally results in slightly larger Sauter mean drop diameters. Nuyttens et al. (2007) developed a test rig and protocol for the characterization of spray nozzles using a phase doppler particle analyser (PDPA). This test rig was able to measure droplet sizes and velocities based on light-scattering principles. It has been observed that nozzle type as well as nozzle size have an important effect on droplet size as well as on velocity spectra. The inlet air and inlet water temperatures were 23 ˚C, and 30-40 ˚C respectively. Kloppers and Kroger (2005) gave a detailed procedure to solve the governing equations with its unique requirements for heat and mass transfer equations of evaporative cooling in wet-cooling towers. Xiaoni et al. (2007) conducted study on cooling tower without fill packing and found that small sauter mean droplet diameter is desirable for high performance of SCT. Qi et al. (2008) design towers with no tower packing and observed that equivalent diameter of inlet water droplets and the initial air velocity affect the outlet water temperature. Qi and Liu (2008) developed a model to solve mass, momentum and energy equations used for analysis of SCT. They compare these results with its previous model and found that new model predicts the results very accurately compared to previous model. Givoni (1997) developed SCT and compares its performance under three different climatic conditions: Los Angeles in California, USA, Riyadh (Saudi Arabia) and Yokohama (Japan) found that system provide effective cooling even in an extreme desert climate. Pearlmutter et al. (1996) develop and monitor small-scale down draft evaporative cool tower in arid Negev Highlands of southern Israel. The result shows a scope for substantial temperature reduction in the order of 10 °C under summer daytime conditions. Kachhwaha et al. (1998) develop two dimensional simple and efficient numerical model and observed that DBT decrease of up to 9°C by employing evaporative cooling during dry summer months. Sureshkumar et al. (2008) Study evaporative cooling of air by water sprays for two ambient conditions, viz., hot-dry and hot-humid, covering DBT from 35 to 47 ˚C, and relative humidity 10 - 60%. Rotar et al. (2005) presents experimental and numerical analyses of the natural-draft cooling tower they find fill system mainly reduce the air mass flow rate, which results in a lower heat and mass-transfer from the water to the air. Sirok et al. (2003) examined that efficiency of cooling tower decreases with increase the water to air mass flow ratio. Sureshkumar et al. (2007) develop 1-D parallel flow heat and mass transfer model to solve air and water spray interaction for different combinations of drop diameter, air velocities, DBT and specific humidity. By using an optimum number of categories and velocity sub-classes, reasonably accurate predictions are obtainable with savings in computation time. Qureshi and Zubair (2006) investigated complete cooling tower which consists of three zones; namely, spray zone, packing and rain zones. In cooling towers, a significant portion of the total heat rejected may occur in the spray and rain zones and fouling is a major source of cooling tower performance deterioration. Cui et al. (2016) concluded that the droplet diameter had large impact on the droplet temperature distribution and thermal performance of cooling tower. Bejan (1997) expressed total exergy air is the sum of convective and evaporative exergy of air. Muangnoi et al. (2007) developed a mathematical model based on heat and mass transfer principle to find the properties of water and air. The results show that water exergy decreases continuously from top to bottom. Qureshi and Zubair (2003) carried out numerical study using engineering equation solver (EES) to determine the variation of second-law efficiency as a function of mass flow rate, relative humidity and temperature. It has been observed that an increase in the relative humidity of the incoming air stream increases second-law efficiency. Qi et al. (2013) developed mathematical model of energy and exergy for a counter flow SCT. The destruction of the exergy of water is high at the bottom and gradually decreases moving up to the top of the tower. Murtaza et al. (2012) found that the air enhances the break-up of the liquid sheet from an atomizer; air also disperses droplets and prevents its collision. Zunaid et al. (2017a & 2017b) show the total exergy of the system destroyed at the top of SCT. Zunaid et al. (2011, 2013, 2018) reported evaporative exergy is the main component in total exergy of air, they also reported that few ampunt of exergy release by water is absorbed by air. In the present work heat and mass transfer model for mono droplets and air interaction in downward vertical parallel flow configuration of SCT has been developed in MATLAB. A parametric study has been performed to determine the effect of variation in inlet water to air mass flow ratio along SCT height. The spray air model is represented by differential equation of mass, momentum and energy of multi droplets.

II. EXPERIMENTAL FACILITY

Diagram of forced draft parallel flow SCT used for experimental work is shown in Fig. 1. The hot atmospheric air enters at the top of SCT with the help of a fan. The water from the storage tank supplied to the impaction pin nozzle with the help of reciprocating pump. Nozzle breaks the water into the small droplets for maximizing the surface area so as to increase the heat transfer between the droplets and the air. The Malvern spraytec laser diffraction system is used for measure droplets sizes at the different pressure. The Sauter mean diameter of droplets used for analysis. The hot air is cooled down by convection and evaporation heat transfer and leaves the tower from the bottom. The exit air goes to the space where cooling is required.

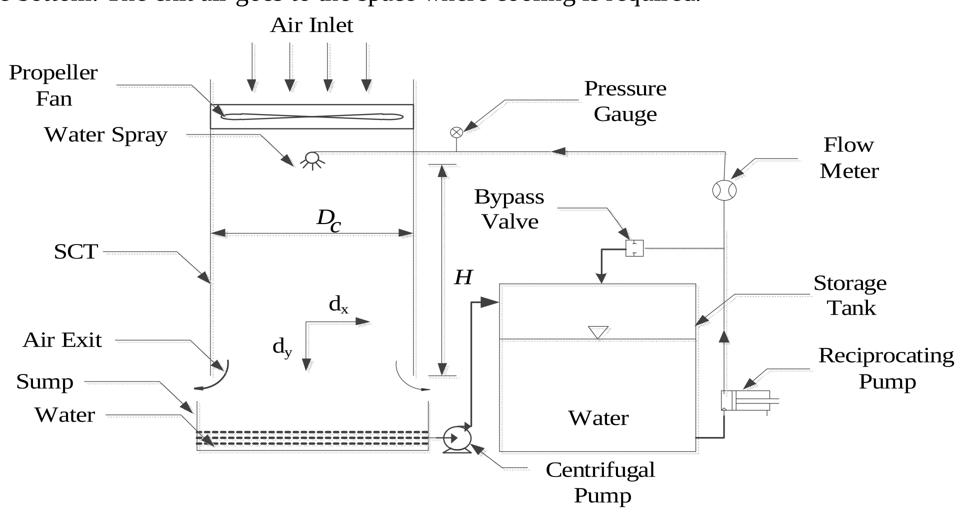

Fig. 1. Parallel flow downdraft evaporative SCT

III. MATHEMATICAL MODEL

In order to describe the motion characteristics of the water droplet in mathematical model some critical simplifying assumptions concerning the water droplet are made. The water droplet is spherical in shape and droplet temperatures are uniform. The possibility of collision or scattering of the water droplet during the motion process is ignored. Equilibrium is reached when the drop is cooled by circumgyration. Liberation, non-uniformity of internal flow and temperature distribution are ignored. The mass momentum and energy conservation equations for varying diameter of water droplets and air are derived by the help of Xiaoni and Zhenyan (2008) and Kloppers and Kroger (2005). The following analysis considers the property variations in the vertical direction. The SCT height is divided into n sections of finite thickness $'dy'$ and finite volume $'dV'$. The water is assumed to be distributed evenly in the form of water droplets with average diameter. The positive direction is taken from top to bottom of the tower.

A. Conservation of mass for water droplet

A control volume for air-water droplet,

$$(m_d)_{in} = (m_d)_{out} + \frac{dm_d}{dy}dy \tag{1}$$

Where mass flow rate of water $'m_d' = N.M_d$

The water evaporation rate of single droplet associated with mass transfer with height given as:

$$\frac{dM_d}{dt} = -h_m(\omega_s - \omega_a)A_s \tag{2}$$

Where $A_s = \pi D^2$ and $'\omega_s'$ = specific humidity of water vapour at the drop surface.

$$\frac{dM_d}{dy} = -\frac{h_m}{U_y}(\omega_s - \omega_a)A_s \tag{3}$$

Where, $U_y = \frac{dy}{dt}$

Since, $M_d = \frac{1}{6}\pi D^3 \rho_w$, then ,

$$\frac{1}{6}\pi\rho_w \frac{d}{dy}(D^3) = -\frac{h_m}{U_y}(\omega_s - \omega_a)\pi D^2 \tag{4}$$

Here variation in density of water is neglected with respect to height of SCT and the variation of droplet diameter with tower height can be written as:

$$\frac{d(D)}{dy} = -\frac{2h_m}{U_y \rho_w}(\omega_s - \omega_a) \tag{5}$$

B. Conservation of momentum for water droplet

The gravity forces, buoyancy forces and aerodynamic drag forces acting on the droplet moving in downward direction with a velocity $'U'$. The forces can be expressed as:

Gravity, $$G = M_d g = \frac{\pi D^3 \rho_w g}{6} \tag{6}$$

Buoyancy force, $$F = \frac{\pi D^3 \rho_a g}{6} \tag{7}$$

Resistance force, $R = \dfrac{\pi C_d \rho_a W^2 D^2}{8}$ (8)

Velocity of droplet in x and y directions are given as:

$$U_x = U\cos\theta \quad (9)$$

$$U_y = U\sin\theta \quad (10)$$

Resultant velocity of droplet and its inclination angle 'θ' from horizontal is shown in Figure 6 and it is given as:

$$W = \sqrt{(U_y - u_a)^2 + U_x^2} \quad (11)$$

$$\theta = \tan^{-1}(\frac{U_y}{U_x}) \quad (12)$$

Now the resistive force (drag force) acts in the opposite direction of the relative velocity of the droplet w.r.t. air is shown in Figure 5. Resolving the drag forces in the x and y directions respectively we get

$$R_x = R\frac{U_x}{U} = \frac{1}{8}\pi\rho_a C_d W D^2 U_x \quad (13)$$

$$R_y = R(\frac{U_y - u_a}{U}) = \frac{1}{8}\pi\rho_a C_d W D^2 (U_y - u_a) \quad (14)$$

Momentum of droplet in vertical direction yield the variation of vertical component of droplet velocity in y direction with height is expressed as:

$$\frac{dU_x}{dy} = -\left[\frac{3(C_d \rho_a W U_x)}{4D\rho_w U_y}\right] - \frac{3U_x}{D}\frac{dD}{dy} \quad (15)$$

Similarly momentum of droplet in x direction with variation of height is expressed as:

$$\frac{dU_y}{dy} = \left[g(\rho_w - \rho_a) - \frac{3(C_d \rho_a W (U_y - u_a))}{4D}\right]\frac{1}{\rho_w U_y} - \frac{3U_y}{D}\frac{dD}{dy} \quad (16)$$

C. *Conservation of energy for water droplet*

The water droplets lose its sensible heat 'q_c' and latent heat 'q_e' to the air at expense of the internal energy. Energy balance on control surface surrounding the water droplet yields following equations.

$$\frac{dE}{dt} = -(q_c + q_e) \quad (17)$$

Where $E = M_d c_{pd} T_d$ (18)

$$q_c = hA_s(T_d - T_a) \quad (19)$$

$$q_e = h_m A_s(\omega_s - \omega_a)h_{fg} \quad (20)$$

Where $h_{fg} = h_{fg0} + c_{pv}T_d$ (21)

Then $M_d c_{pd}\dfrac{dT_d}{dt} = -[h(T_d - T_a) + h_m(\omega_s - \omega_a)h_{fg}]A_s$ (22)

$$\frac{dT_d}{dt} = -\frac{6h_m}{\rho_w c_{pd} D}\left[\frac{h}{h_m}(T_d - T_a) + (\omega_s - \omega_a)h_{fg}\right] \tag{23}$$

Where $T_d - T_a = \dfrac{(h_s - h_{av}) - (\omega_s - \omega_a)h_{fg}]}{c_{pav}}$ (24)

$$Le_f = \frac{h}{h_m c_{pav}} \tag{25}$$

And $c_{pav} = c_{pa} + \omega_a c_{pv}$ (26)

Then, $\dfrac{dT_d}{dt} = -\dfrac{6h_m[Le_f(h_s - h_{av}) + (1 - Le_f)(\omega_s - \omega_a)h_{fg}]}{c_{pd} D \rho_w} - \dfrac{3T_d}{D}\dfrac{dD}{dt}$ (27)

$$\frac{dT_d}{dt} = \frac{dT_d}{dy}\frac{dy}{dt} = U_y\left[\frac{dT_d}{dy}\right] = -\frac{6h_m[Le_f(h_s - h_{av}) + (1 - Le_f)(\omega_s - \omega_a)h_{fg}]}{c_{pd} D \rho_w} - \frac{3T_d}{D}\frac{dD}{dt} \tag{28}$$

Therefore energy balance of drops is represented by

$$\frac{dT_d}{dy} = -\frac{6h_m[Le_f(h_s - h_{av}) + (1 - Le_f)(\omega_s - \omega_a)h_{fg}]}{U_y c_{pd} D \rho_w} - \frac{3T_d}{D}\frac{dD}{dy} \tag{29}$$

D. Thermal balance equations in the SCT

The total enthalpy transfer at air-water interface consists of an enthalpy transfer associated with the mass transfer due to the difference in vapor concentration between the saturated air and main stream air. Sensible heat transfer between air and water droplets occur due to the difference in temperature of water droplets and DBT of air. A mass balance in the control volume is given as:

$$dm_d = m_a d\omega_a \tag{30}$$

The energy balance in the control volume of the SCT

$$m_a dh_{av} = m_d dh_d + h_d dm_d \tag{31}$$

Rearranging using above two equations

$$dT_d = \frac{m_a}{m_d}\left(\frac{dh_{av}}{c_{pd}} - T_d d\omega_a\right) \tag{32}$$

Energy balance at the water and air interface yields

$$dq = dq_c + dq_e \tag{33}$$

$$dq = \left[h(T_d - T_a) + h_m h_{fg}(\omega_s - \omega_a)\right]dA \tag{34}$$

$$dq = \left[\frac{h}{C_{pav}}(h_s - h_{av}) + \left(h_m - \frac{h}{c_{pav}}\right)h_{fg}(\omega_s - \omega_a)\right]dA \tag{35}$$

The enthalpy transfer to the air stream is $dh_{av} = \dfrac{dq}{m_a}$

$$dh_{av} = \frac{dq}{m_a} = \frac{h_m}{m_a}\left[Le_f(h_s - h_{av}) + (1 - Le_f)h_{fg}(\omega_s - \omega_a)\right]dA \tag{36}$$

Where, $dA = \dfrac{m_d dy \pi D^2}{M_d U_y} = \dfrac{6 m_d dy}{\rho_w D U_y}$

Now change in air temperature due to mass and heat transfer interaction can be expressed as:

$$\frac{dh_{av}}{dy} = \left(\frac{m_d}{m_a}\right)\frac{6h_m}{\rho_w D U_y}\left[Le_f\left(h_s - h_{av}\right) + \left(1 - Le_f\right)h_{fg}\left(\omega_s - \omega_a\right)\right] \tag{37}$$

E. Mass balance equation in the SCT

Mass balance equation for the control volume

$$dm_d = m_a d\omega_a = N\frac{dM_d}{dt} \tag{38}$$

Substituting, $N = \dfrac{m_d dy}{M_d U_y}$ and $M_d = \dfrac{1}{6}\pi D^3 \rho_w$,

$$dw_a = \left(\frac{m_d}{m_a}\right)\frac{6h_m}{\rho_w U_y D}\left(\omega_s - \omega_a\right)dy \tag{39}$$

The mass transfer associated with the control volume expressed as:

$$\frac{dw_a}{dy} = \frac{m_d h_m A_s}{m_a M_d U_y}\left(\omega_s - \omega_a\right) \tag{40}$$

F. Drop trajectory equation

Drop trajectory expressed in terms of horizontal and vertical components of velocity.

$$\frac{dx}{dy} = \frac{U_x}{U_y} \tag{41}$$

G. Exergy Formulation

Total exergy of air and water vapour mixture is sum of exergy of water (X_d) and total exergy of air (X_{air}). The total air exergy is sum of convective exergy of air (X_a) and evaporative exergy of air (X_e).

$$X_d = m_d\left((h_{fd} - h_{g0}) - T_0(s_{fd} - s_{g0}) - R_v \ln(\phi_0)\right) \tag{42}$$

Exergy of air due to convective heat transfer

$$X_c = m_a\begin{bmatrix} c_{pa}\left(T_a - T_0\right) - T_0\, c_{pa}\ln\left(\dfrac{T_a}{T_0}\right) + \\ \omega_a\left\{c_{pv}\left(T_a - T_0\right) - T_0\, c_{pv}\ln\left(\dfrac{T_a}{T_0}\right)\right\}\end{bmatrix} \tag{43}$$

Exergy of air due to evaporative heat transfer

$$X_e = m_a\begin{bmatrix} R_a T_0 \ln\left(\dfrac{1+1.608\omega_{a0}}{1+1.608\omega_a}\right) + \\ \omega_a R_v T_0 \ln\left(\dfrac{\omega_a(1+1.608\omega_{a0})}{\omega_{a0}(1+1.608\omega_a)}\right)\end{bmatrix} \tag{44}$$

Total exergy of water and air is given as:

$$X_{total} = X_d + X_c + X_e \tag{45}$$

The total exergy destruction $'I'$ per unit time for discrete height of tower will be:

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$$\underbrace{I}_{\substack{total\,exergy/unit\ time\\ destroyed}} = \underbrace{X_{total,y(j)}}_{\substack{total\,exergy/unit\ time\\ entering\,at\,height\ y(j)}} - \underbrace{X_{total,y(j+1)}}_{\substack{total\,exergy/unit\ time\\ leaving\,at\,height\ y(j+1)}} \tag{46}$$

Where, $y(j+1) - y(j) = dy$

H. Boundary conditions

The boundary conditions required for solution of above formulation include tower geometry, spray characteristics and initial air and water conditions. Tower geometry includes height, cross section area and shape of the tower. Spray characteristics are droplet velocity, temperature, angle of projection, mean droplet diameter. The initial parameters required for air condition are air velocity, flow rate, dry bulb temperature and relative humidity at inlet.

IV. RESULT AND DISCUSSION

A. Model validation

The experimental data of a parallel flow down draft SCT has been used for model validation. Comparison of outlet air DBT obtained from the experiment and those obtained from the computational work are shown in Fig. 2. It can be seen that the majority of the data fall within ±10% of the model.

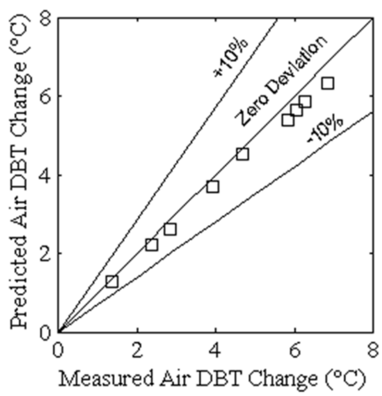

Fig. 1. Comparison of predicted and measured air DBT.

B. Parametric Study

After validation, a parametric study has been performed computationally to determine the effect of variation in inlet RLG. Initial conditions used for computer simulation are, inlet DBT of air 40 ˚C; relative humidity 20%, inlet air volume flow rate 400 m^3/h, inlet water temperature 34 ˚C, ratio of mass flow rate of water to air 0.5, The distance between spray water inlet to bottom of tower (tower height) 1.25 m (along the direction of y-coordinate) and tower diameter 0.61 m. Droplet diameter was 200 µm, droplet velocity from 10 m/s and droplet angle of projection at inlet is 45^0. The reference temperature and relative humidity are same as inlet condition and acceleration due to gravity is 9.81 m/s^2.

C. Effect of variation in inlet RLG

This study based on variation of water to air mass flow ratio from 0.1 to 1.5 kg/kg. Table 1 shows exit air DBT, specific humidity, water temperature and makeup water required are increase with increasing the. Fig. 3 (a) shows maximum drop in DBT of air obtain at 0.5 kg/kg of RLG because amount of water increase in air-water mixture by increasing the RLG. Fig. 3 (b) shows maximum specific humidity achieve by 1.5 kg/kg RLG because volume of water increase in air-water mixture by increasing the RLG. Fig. 3 (c) shows variation in convective, evaporative and total exergy of air by varying the RLG. Fig. 3(c) and Table 1 indicate total exergy of air is the sum convective and evaporative exergy of air. Fig. 3 (d) and Table 1 show exergy of water is increase by increasing the RLG. Fig. 3 (e) shows thermal efficiency of SCT decrease by increasing the RLG, because quantity of water surge in air-water mixture by increasing the RLG. Fig. 3 (f) shows SLE of SCT increase by increasing the RLG, because SCT exergy destruction increases (Table 1) by increasing the RLG.

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Table 1 Effect of variation in inlet air RLG

RLG_{in}	$T_{a,out}$ (˚C)	$\omega_{a,out}$ (kg_w/kg_a)	$T_{d,out}$ (˚C)	$m_{d,l}$ (kg/s)	η_{th} (%)	$X_{c,out}$ (W)	$X_{e,out}$ (W)	$X_{a,out}$ (W)	$X_{d,out}$ (W)	$X_{t,out}$ (W)	I_t (W)	η_{II} (%)
0.5	27.47	0.0235	27.46	0.0017	56.57	31.54	125.38	156.92	13708.07	13864.99	424.38	97.03
0.75	28.40	0.0249	28.39	0.0018	48.53	26.87	148.02	174.89	20742.24	20917.13	516.94	97.59
1	29.10	0.0260	29.09	0.0019	42.47	23.69	165.99	189.68	27794.58	27984.26	594.49	97.92
1.25	29.62	0.0268	29.61	0.0020	37.98	21.41	180.64	202.05	34859.36	35061.41	662.02	98.15
1.5	30.03	0.0275	30.02	0.0021	34.43	19.69	192.82	212.51	41933.05	42145.56	722.56	98.31

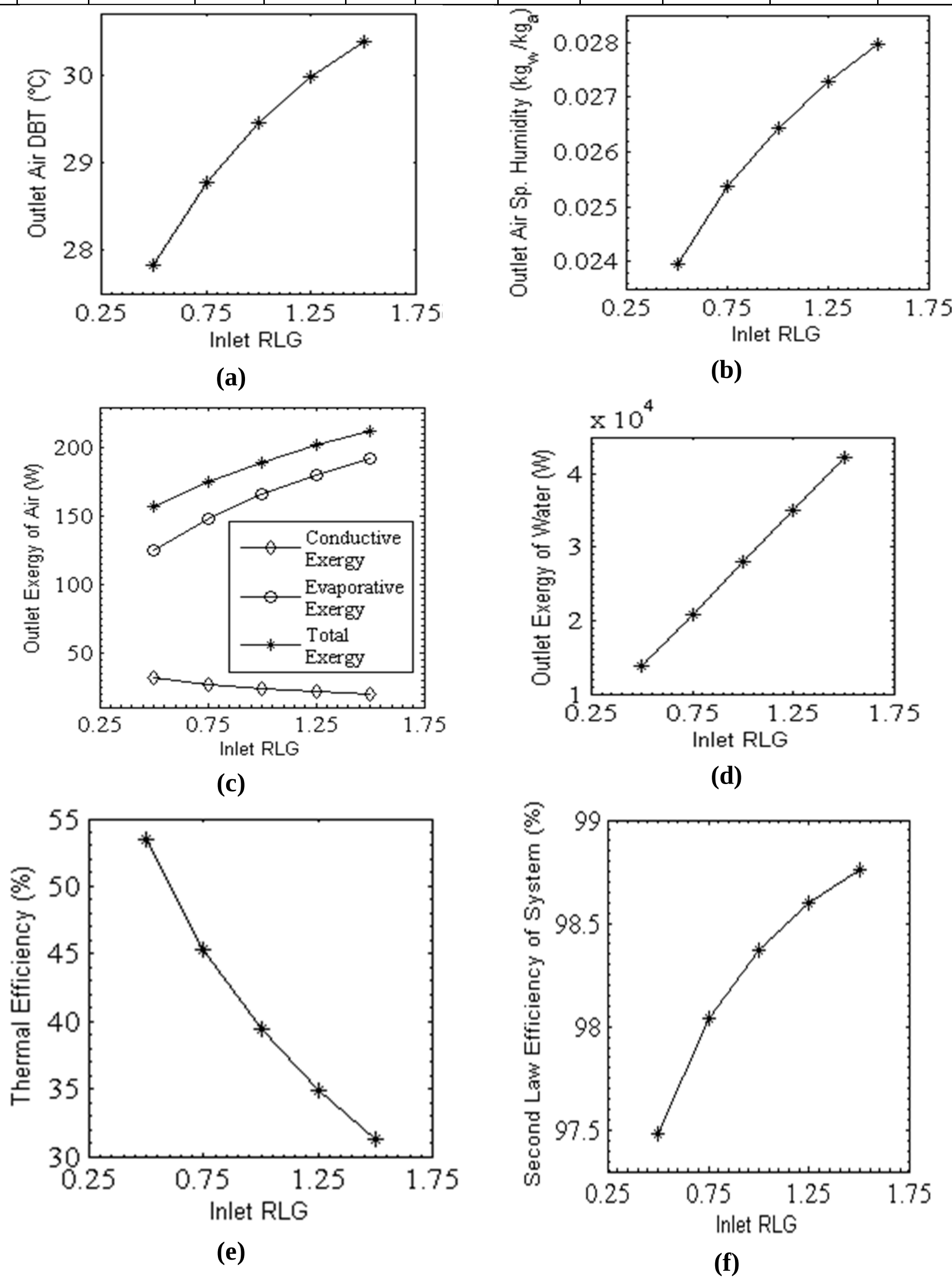


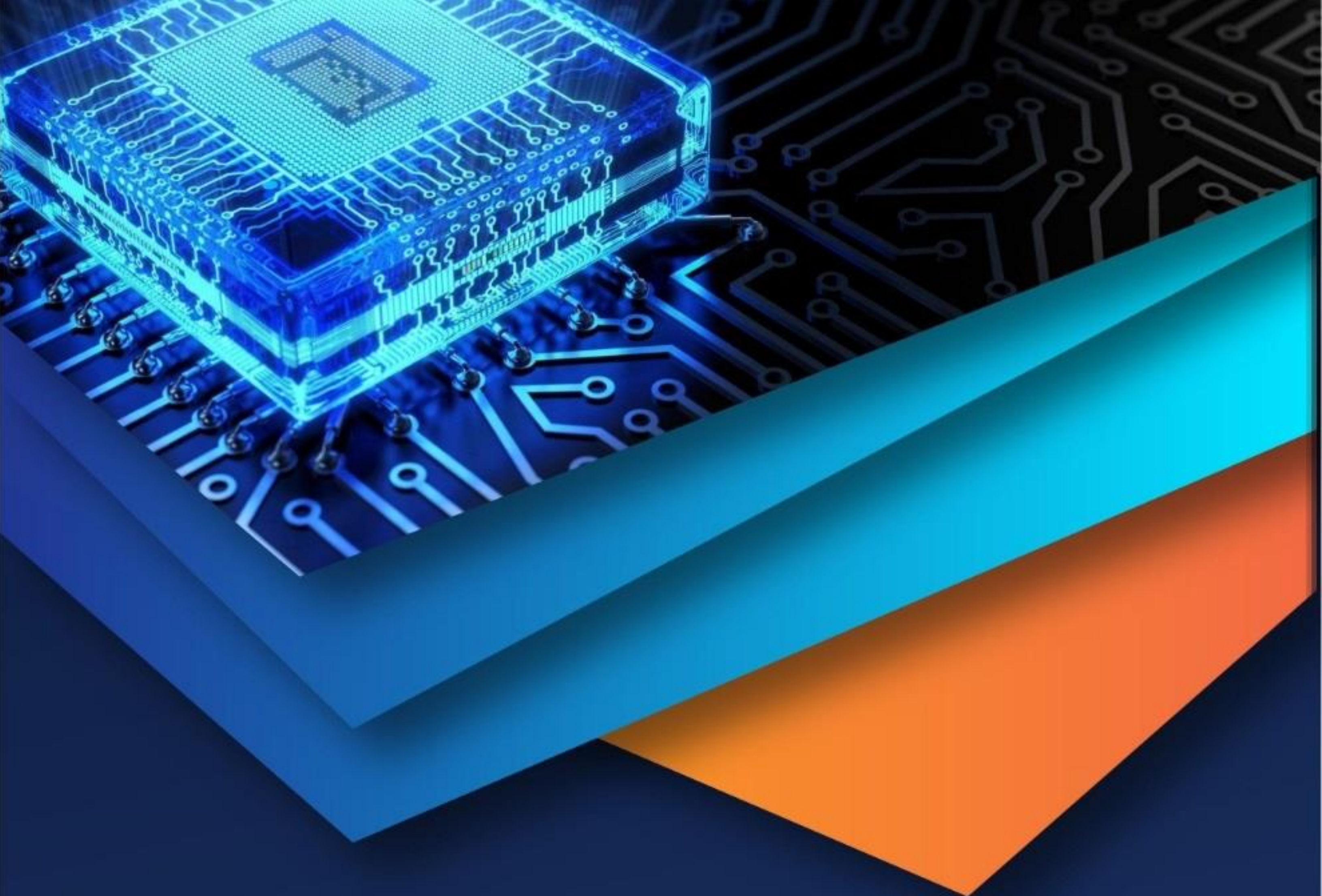
Fig. 3. Variation of different parameters by varying the inlet RLG (a) air DBT, (b) specific humidity of air, (c) exergy of air, (d) exergy of water, (e) thermal exergy, (f) SLE of system.

V. CONCLUSION

Simple and efficient mathematical model for predicting the exit condition of air along the downdraft parallel flow SCT have been developed. Tower operates in different inlet RLG. The maximum cooling (12.53 ˚C) of air achieved at 0.5 kg/kg of RLG, maximum thermal efficiency (56.57%) also obtained at 0.5 kg/kg RLG. The energy concept alone is not sufficient to describe some important view points on energy utilization. The present model predicts the exergy of air and water along SCT height through the fundamental balance law. An exergy analysis also used to indicate exergy destruction of air and water flowing through the cooling tower to explain the performance of cooling tower. Exergy destruction of system is high at the top and low at the bottom of tower because water droplets reduce its exergy faster when it comes in contact of air at the top of tower.

REFERENCES

[1] Bejan, A. (1997) 'Advanced Engineering Thermodynamics', 3 ed. Wiley.
[2] Cui, H., Li, N., Peng, J., Cheng, J., & Li, S. (2016) 'Study on the dynamic and thermal performances of a reversibly used cooling tower with upward spraying', Energy, Vol. 96, pp.268-277
[3] Kachhwaha, S. S., Dhar, P. L., and Kale, S. R. (1998) 'Experimental studies and numerical simulation of evaporative cooling of air with a water spray—I. Horizontal parallel flow', International Journal of Heat and Mass Transfer, Vol. 41, No. 2, pp.447-464..
[4] Kloppers, J. C., & Kröger, D. G. (2005) 'A critical investigation into the heat and mass transfer analysis of counterflow wet-cooling towers', International Journal of Heat and Mass Transfer, Vol. 48, No. 3, pp.765-777.
[5] Qi, X., Liu, Y., & Liu, Z. (2013) 'Exergy based performance analysis of a shower cooling tower', Strojniški vestnik-Journal of Mechanical Engineering, Vol. 59, No. 4, pp.251-259.
[6] Muangnoi, T., Asvapoositkul, W., & Hungspreugs, P. (2014) 'Performance characteristics of a downward spray water-jet cooling tower', Applied Thermal Engineering, Vol. 69, No.1, pp.165-176.
[7] Muangnoi, T., Asvapoositkul, W., & Wongwises, S. (2007) 'An exergy analysis on the performance of a counterflow wet cooling tower', Applied thermal engineering, Vol. 27, No. 5, pp.910-917.
[8] Nuyttens, D., Baetens, K., De Schampheleire, M., & Sonck, B. (2007) 'Effect of nozzle type, size and pressure on spray droplet characteristics', Biosystems Engineering, Vol. 97, No. 3, pp.333-345.
[9] Qureshi, B. A., & Zubair, S. M. (2003) 'Application of exergy analysis to various psychrometric processes', International Journal of Energy Research, Vol. 27, No. 12, pp.1079-1094.
[10] Qureshi, B. A., & Zubair, S. M. (2003) 'Application of exergy analysis to various psychrometric processes', International Journal of Energy Research, Vol. 27, No. 12, pp.1079-1094.
[11] Qureshi, B. A., & Zubair, S. M. (2003) 'Application of exergy analysis to various psychrometric processes', International Journal of Energy Research, Vol. 27, No. 12, pp.1079-1094.
[12] Zunaid, M., Murtaza, Q., & Gautam, S. (2017a) 'Energy and performance analysis of multi droplets shower cooling tower at different inlet water temperature for air cooling application', Applied Thermal Engineering, 121, 1070-1079
[13] Zunaid, M., Murtaza, Q., & Kachhwaha, S. S., (2011) 'Performance Analysis of Down Draft Parallel Flow Shower cooling Tower', in 21st National and 10th ISHMT-ASME Heat and Mass Transfer Conference 28-31 Dec. 2011 in IIT Madras Chennai India.
[14] Zunaid, M., Murtaza, Q., Samsher, & Kachhwaha, S. S., (2013) 'Exergy and Performance Analysis of Parallel Flow Shower Cooling Tower', in International Conference Smart Technologies for Mechanical Engineering 25-26 October, 2013, DTU, Delhi, India
[15] Zunaid, M., (2018) 'Energy and Exergy Analysis of Shower Cooling Tower with Variation in Inlet Air Dry Bulb Temperature for Industrial Application', International Journal for Research in Applied Science & Engineering Technology, 6 (3), 583-588.



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