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1 Cooling tower model description:

This script aimed to model a cooling tower using a python custom model in DWSIM environment. In this model, the inputs are the properties of the air, makeup, and water streams, dry and wet bulb temperature, and mass transfer correlation coefficients (c and n).[1]

1.1 Mass and heat balances:

$$m_{a,i} + m_e = m_{a,o} \quad (1\text{-}1)$$

$$m_{a,i}h_{a,i} + Q_{rej} - Q_e = m_{a,o}h_{a,o} \quad (1\text{-}2)$$

$$m_{w,i} - m_e + m_m = m_{w,o} \quad (1\text{-}3)$$

$$m_{w,i}T_{w,i}C_{pw} - Q_{rej} + m_m T_m C_{pw} = m_{w,o}T_{w,o}C_{pw} \quad (1\text{-}4)$$

1.2 Additional equations:

$$Q_{rej} = \epsilon_a m_a (h_{s,w,i} - h_{a,i}) \quad (1\text{-}5)$$

$$\epsilon_a = \frac{1 - e^{-NTU(1-m^*)}}{1 - m^* e^{-NTU(1-m^*)}} \quad (1\text{-}6)$$

$$NTU = c\left(\frac{m_a}{m_w}\right)^{-(1+n)} \quad (1\text{-}7)$$

$$m^* = \frac{m_a}{m_w} \times \frac{C_s}{C_{pw}} \quad (1\text{-}8)$$

$$C_s = \frac{h_{s,w,i} - h_{s,w,o}}{T_{w,i} - T_{w,o}} \quad (1\text{-}9)$$

1.3 Psychometric equation:

$$P_s = 10^{p_1+p_2+p_3+p_4} \quad (1\text{-}10)$$

Where:

$$p_1 = -7.90298 \times (z - 1) \quad (1\text{-}11)$$

$$p_2 = 5.02808 \times \log(z) \quad (1\text{-}12)$$

$$p_3 = -1.3816 \times 10^{-7} \times \left(10^{11.344\times\left(1-\frac{1}{z}\right)} - 1\right) \quad (1\text{-}13)$$

$$p_4 = 8.1328 \times 10^{-3} \times \left(10^{-3.49149\times(z-1)} - 1\right) \quad (1\text{-}14)$$

$$z = 373.16/(T(k)) \quad (1\text{-}15)$$

1.4 Saturation enthalpy:

$$h_s = (T(C) - 25) \times C_{air} + x_{sat} \times (2501 + 1.859 \times (T(C) - 25)) \quad (1\text{-}16)$$

$$x_s = 0.62198 \times \frac{P_s}{P_{atm} - P_s} \tag{1-17}$$

1.5 Outlet air enthalpy:

$$h_{a,o} = h_{a,i} + \epsilon_a (h_{s,w,i} - h_{a,i}) \tag{1-18}$$

1.6 Error formula:

$$error = (T_j - T_{(j-1)})^2 + \left(m_{e\,j} - m_{e\,j-1}\right)^2 \times 10^5 \tag{1-19}$$

1.7 Procedure:

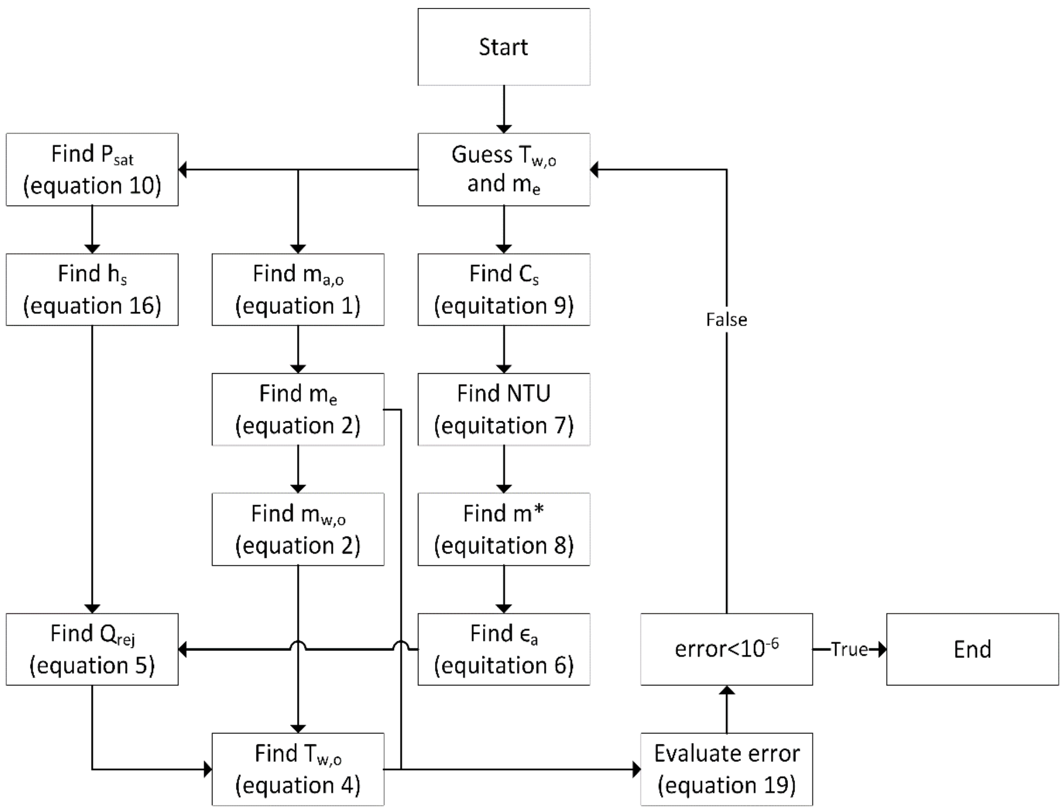

Figure 1 Modeling procedure

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2 Validation:

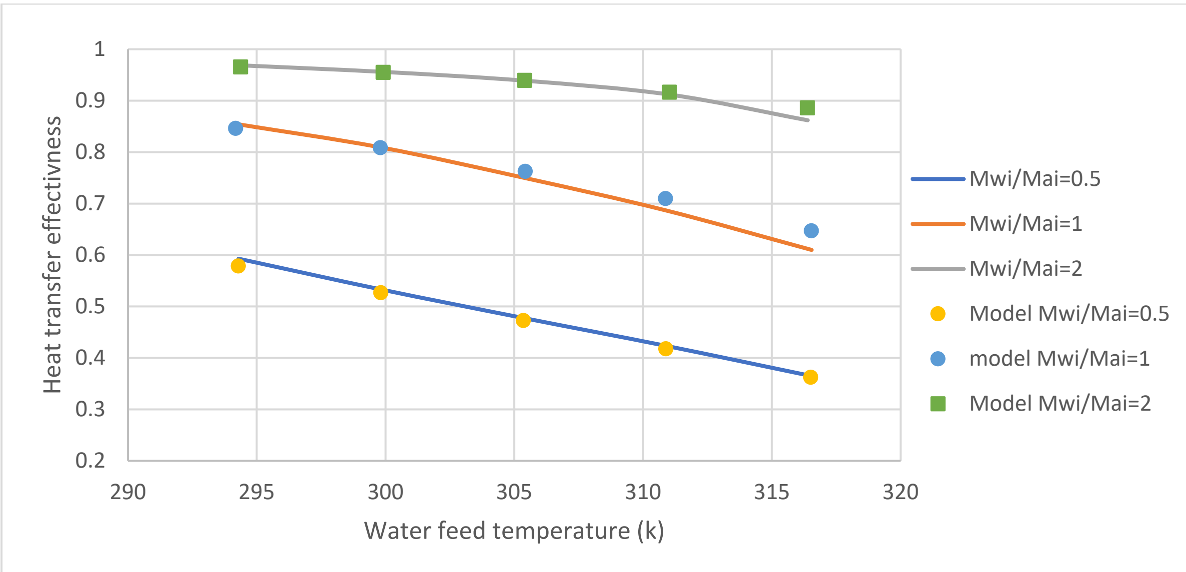

Figure 2 Model and the literature comparison[2]

3 Nomenclature

m: mass flow rate
h: enthalpy
Q: energy
NTU: number of transfer unit
P: pressure

T: temperature
C_p: specific heat capacity
ϵ: heat transfer effectiveness
m^*: ratio of air to water effective capacitance rate
x: mass fraction of water in air

3.1 Subscript

a: Air
i: inlet
j: step number
rej: rejection
n, c: mass transfer correlation coefficients

w: water
o: outlet
s: saturated
atm: atmosphere

4 References

[1] L. Lu and W. Cai, “A Universal Engineering Model For Cooling Towers,” 2002.
[2] J. E. Braun, “Methodologies for the Design and Control of Central Cooling Plants,” 1988.