ICSolar Model

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1 Steady Model

Consider the model of air and water interaction consisting of an initial inlet region (denoted by 0) and a pair of regions, an open region with pipe followed by a module, denoted by (1,2) satisfying

$$W_1: \quad \dot{m}_w C_{p,w}(T_{w,1} - T_{w,0}) - h_{wa}(T_{a,1} - T_{w,1}) = 0 \tag{1}$$
$$A_1: \quad \dot{m}_a C_{p,a}(T_{a,1} - T_{a,0}) - h_{wa}(T_{w,1} - T_{a,1}) - h_e(T_e - T_{a,1}) - h_i(T_i - T_{a,1}) = 0 \tag{2}$$
$$W_2: \quad \dot{m}_w C_{p,w}(T_{w,2} - T_{w,1}) - Q_w = 0 \tag{3}$$
$$A_2: \quad \dot{m}_a C_{p,a}(T_{a,2} - T_{a,1}) - Q_a = 0 \tag{4}$$

Where i and e are interior and exterior contributions. Each pair of these forms a 'module'. In this work, we use

$$C_{p,w} = 4.218 kJ/(kgK) \tag{5}$$
$$\dot{m}_w = 0.0008483 kg/s \tag{6}$$
$$C_{p,a} = 1.005 kJ/(kgK) \tag{7}$$
$$\dot{m}_a = 0.384 kg/s \tag{8}$$
$$h_{wa} = 4.823 \times 10^{-5} kW/(Km) \tag{9}$$
$$h_i = 1.572 \times 10^{-4} kW/(Km) \tag{10}$$
$$h_e = 4.837 \times 10^{-4} kW/(Km) \tag{11}$$
$$\tag{12}$$

With Initial and Boundary Conditions of $T_{a,0} = 20C, T_i = 25.0C, T_e = 22.5C$. At this point, we set $Q_a = 0$ as the surrounding air acts like a reservoir and its effect is currently minimal. Our inputs are $T_{w,0}$ and $Q_{w,i}$ from experimental data. We also occasionally have access to $T_{a,0}$, the ambient air temperature.

2 Unsteady Model

Consider the steady model in 4 and introduce the time derivative, $mC_p\frac{\partial T}{\partial t}$ and rearrange to get

$$W_1: \quad m_{w,1}C_{p,w}\frac{\partial T}{\partial t} + \dot{m}_w C_{p,w}(T_{w,1} - T_{w,0}) - h_{wa}(T_{a,1} - T_{w,1}) = 0 \tag{13}$$

$$W_2: \quad m_{w,2}C_{p,w}\frac{\partial T}{\partial t} + \dot{m}_w C_{p,w}(T_{w,2} - T_{w,1}) - Q_w(t) = 0 \tag{14}$$

$$A_1: \quad m_{a,1}C_{p,a}\frac{\partial T}{\partial t} + \dot{m}_a C_{p,a}(T_{a,1} - T_{a,0}) - h_{wa}(T_{w,1} - T_{a,1}) - h_e(T_e - T_{a,1}) - h_i(T_i - T_{a,1}) = 0 \tag{15}$$

$$A_2: \quad m_{a,2}C_{p,a}\frac{\partial T}{\partial t} + \dot{m}_a C_{p,a}(T_{a,2} - T_{a,1}) - Q_a = 0 \tag{16}$$

To handle the mass term, we need the volume. We have a length of the first tube as $L_1 = 0.15m$ and $L_{3,5,...} = 0.3m$. The cross sectional area of the tube is based on inner diameter, $d = 0.003m$ and outer diameter of $d = 0.0142m$. The volume of the surrounding air we are interested in has a cross section of $0.4m \times 0.4m$. Using the density and the specific heat, we get that $m_a = 0.0576kg$, $m_w = 2.12 \times 10^{-3}kg$.

For regions with modules, we can create a small volume, $m_{a,2,4,6,...} \approx Cm_a$ and $m_{w,2,4,6,...}Cm_w$.