Calculating Water Evaporation Rate from Vertical Wet Fabrics

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Problems dealing with liquid evaporation often fall into the category of coupled heat and mass transfer problems and are generally hard to solve. Fortunately, heat transfer is analogous to mass transfer in formulation. Analogies among heat and mass transfer have their origin either in mathematical description of the effects or in the physical parameters used for quantitative description. This analogy can help in constructing correlations for mass (heat) transfer problems based on available correlations obtained for analogous heat (mass) transfer problems. In this work we use the well-known Chilton-Colburn analogy to derive a correlation for the free convective mass transfer from a wet fabric. We derive this correlation from the well-known Churchill and Chu correlation obtained for the free convection heat transfer from a vertical isothermal plate. For the sake of brevity only a final expression is presented. Evaporation rate of water vapor from a vertical wet fabric in the free convection regime, N_1 [kg/m^{2}s], can be calculated using the following expression.

$$N_1 = \frac{\tilde{M}_w k y_{1w}(1-j)}{L\tilde{C}_p}\left(0.825+0.324 Ra_L^{1/6}\right)^2$$

where $\tilde{M}_w = 18\ kg/kmole$ is the molecular weight of water. k, $\hat{C}_p$, and j are thermal conductivity [kW/mK], specific heat [kJ/kgK], and relative humidity of the laboratory, respectively. L is the length of the fabric [m], $Ra_L = g(T_w - T_\infty) b L^3 / na$ is the Rayleigh number, and y_{1w} is the mole fraction of the water-vapor at the fabric surface. $b = 2/(T_w + T_\infty)$, where T_w and T_∞ are the fabric and laboratory temperatures [K]. Having the thermal condition of the vapor-air mixture (humidity ratio, air density and molecular weight), it is easy to calculate y_{1w}.

To compare predictions of the above correlation with experiment, we prepared four square nonwoven fabrics with a length of 0.30 m. Fabrics were wetted and the excess water contents were removed completely so that no water drop formation or dripping could take place during the experiment. Fabrics were hung in a laboratory with a relative humidity and drybulb temperature of j = 57% and T_∞ = 23°C, respectively (see Fig.1). Attention was paid to conduct the experiment far from any air stream in the lab. The wetbulb temperature at this thermodynamics condition is found to be T_w = 17.2°C. The fabrics weight loss was measured every 5 minutes.

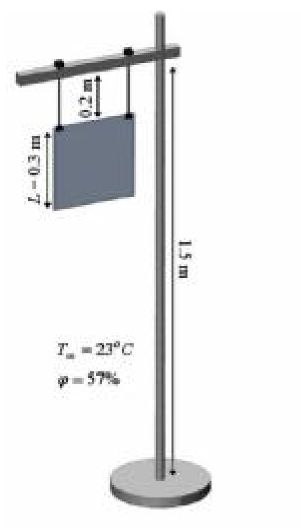

Figure 1: Schematic of the experimental setup

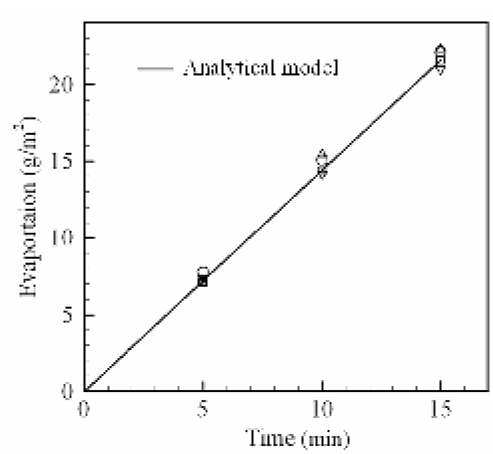

Figure 2: Comparison between the experimental data (symbols) and analytical model (solid line).

From Fig.2 it can be seen that our expression can successfully predict the rate of water evaporation and is in perfect agreement with the experiment.

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