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Experimental study and predictions of an induced draft ceramic tile packing cooling tower

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Abstract

Deterioration of the filling material in traditional cooling towers is of serious concern. In this study, long life burned clay is used as the filling material. It guards against common cooling tower problems resulting from chemical water treatment and deterioration. The size of the ceramic packing material and outlet conditions predictions by theoretical modeling require heat and mass transfer correlations. An experimental study to evaluate the heat and mass transfer coefficients is conducted. The previous correlations found in the literature could not predict the mass transfer coefficient for the tested tower. A mass transfer coefficient correlation is developed, and new variables are defined. This correlation can predict the mass transfer coefficient within an error of ±10%. The developed correlation is used along with theoretical modeling to predict the cooling tower outlet conditions within an error of ±5%.

Keywords: Cooling tower; Ceramic packing; Correlation

1. Introduction

The cooling tower is a steady flow device that uses a combination of mass and energy transfer to cool water by exposing it as an extended surface to the atmosphere. The water surface is extended by filling, which presents a film surface or creates droplets. The air flow may be cross flow or counter flow and caused by mechanical means, convection currents or by natural wind. In mechanical draft towers, air is moved by one or more mechanically driven fans to provide a constant air flow. The function of the fill is to increase the available surface in the tower, either by spreading the liquid over a greater surface or by retarding the rate of fall of the droplet surface through the apparatus. The fill should be strong, light and deterioration resistant. In this study, long life burned clay bricks were used as the filling material. Its hardness, strength and composition guard against common cooling tower problems resulting from fire, chemical water treatment and deterioration.

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Nomenclature

a	area of heat and mass transfer (m^2/m^3)
C_p	specific heat (kJ/kg K)
D_v	diffusion coefficient (m^2/s)
d_{eq}	equivalent diameter for structured packing (m)
E	efficiency (%)
h	enthalpy (kJ/kg)
h_c	heat transfer coefficient (kW/m^2 K)
K	thermal conductivity (W/m K)
K_x	mass transfer coefficient (kW/m^2 K)
Le	Lewis number
m	flow rate (kg/s)
m'	superficial flow rate (mass velocity) (kg/m^2 s)
M	molecular weight (kg/kmol)
q	heat flux (kJ/kg)
t	temperature (°C)
Z	tower height (m)

Greeks

μ	viscosity (Ns/m^2)
ρ	density (kg/m^3)
ω	humidity ratio (kg water/kg dry air)

Subscripts

a	air
db	dry bulb
i	inlet or interface
m	mean
o	outlet
t	total
v	vapor
wb	wet bulb
w	water

Several studies on cooling tower analysis were developed with different points of view. Webb and Villacres [1] described three computer algorithms that have been developed to perform rating calculations of three evaporatively cooled heat exchangers. The heat and mass transfer characteristic equation of one of the heat exchangers is derived from the manufacturer's rating data at the design point. Jaber and Webb [2] produced the effectiveness-NTU (number of transfer unit) design method for counter flow towers using Merkel's simplification theory [3]. Braun et al. [4] presented effectiveness models for cooling towers and cooling coils. The results of the models were compared with those of more detailed numerical solutions to the basic heat and mass transfer coefficients and experimental data. Osterle [5] pointed out that the Merkel assumptions underestimated the required NTU. Soylemez and Unsal [6] presented an interactive computer code for sizing forced draft, counter flow cooling towers using a closed formula offered by Unsal and Varol [7]. El-Dessouky et al. [8] modified the analysis done by Jaber and Webb. They presented a solution for the steady state counter flow wet cooling tower with new definitions of tower effectiveness and number of transfer units. Bernier [9] presented an analysis of the basic heat and mass transfer processes occurring around a droplet in transient cooling of a spray counter flow tower. The influence of fill height, water retention time and water–air flow ratio on the tower performance was represented.